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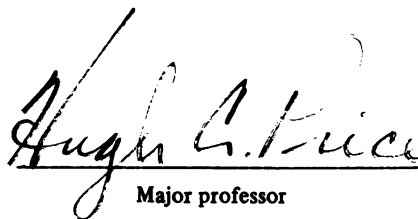
EFFECT OF NITROGEN, PLANT POPULATION
AND CHLORFLURENOL ON GYNOECIOUS, PARTHENO-
CARPIC PICKLING CUCUMBERS (CUCUMIS
SATIVUS L.)

presented by

Rishi Raj Adhikari

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EFFECT OF NITROGEN, PLANT POPULATION
AND CHLORFLURENOL ON GYNOECIOUS,
PARTHENOCAPIK PICKLING CUCUMBER
(Cucumis sativus L.)

By

Rishi Raj Adhikari

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ABSTRACT

EFFECT OF NITROGEN, PLANT POPULATION AND CHLORFLURENOL ON GYNOECIOUS, PARTHENOCARPCIC PICKLING CUCUMBERS (Cucumis sativus L.)

By

Rishi Raj Adhikari

The effect of different nitrogen rates (0, 50, 100, and 200 Kg/ha) and plant population (75,000, 150,000, and 300,000/ha) on chlorflurenol (2.4L/ha) treated gynoecious, parthenocarpic pickling cucumber, cv. MSU 41x 581, was investigated. Dollar value, yield of the fruits, and total vine or biomass weight of cucumber increased with increased plant population. There was no effect on firmness or L:D ratio of the fruits. Nitrogen had no effect on fruit yield or quality.

The nutrient composition of the leaves was affected by the rate of nitrogen application, plant population and stages of plant development.

Chlorflurenol at 100 ppm induced 7 to 8 fruits to develop per plant while untreated plants in the greenhouse produced practically none.

Ovaries induced to develop by chlorflurenol treatment accumulated less Ca and K than ovaries under exogenous NAA. It is hypothesized that this restricted cation accumulation is the cause of misshapen fruits in size grade greater than 5 cm diameter.

To my Mother, Mrs. Naina Adhikari,
in her loving memory

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INTRODUCTION

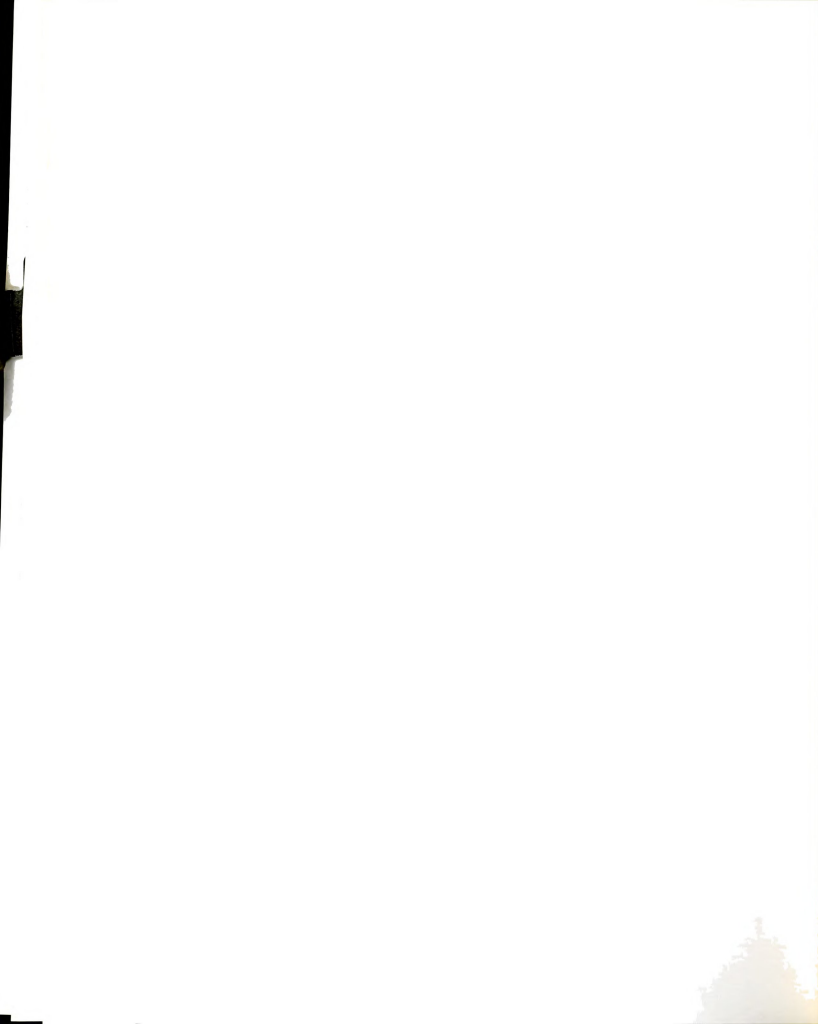
Michigan is the leading state in pickling cucumber production, The acreage of this crop in 1979 was about 11,000 hectares. The total production of pickling cucumbers in the United States was 0.68 million tons and that in Michigan was 0.12 million tons which is 17.6% of the country's total. Pickling cucumber production in Michigan was valued at 15.5 million dollars in 1979. Mechanical harvesting of pickling cucumbers was initiated in 1958 and today nearly 90% of the crop is harvested in this manner in Michigan. The advent of mechanized harvest has necessitated the development of a new "system" of production.

The traditional monoecious cultivars used to be hand harvested 12-15 times during the season because the crown fruit inhibited the development of subsequent fruits on the vine. This phenomena is attributed to the hormone Auxin (indole acetic acid) being produced by the seeds in the fruits and transported to the other parts of the plant. Hand harvesting required much labor and time. Labor has become increasingly costly and unavailable, thus necessitating the mechanical harvesting of the fruits. But the prerequisite for mechanical harvesting is the concentration of many fruits of the valuable grade size at one time, as machine harvesting is a once over destructive harvest. For this type of cucumber, dominance is the limiting factor in producing many fruits on one vine at the same time. So far the average number of fruits



per plant in the United States is only 1.6. Thus, cucumber breeders have strived to develop parthenocarpic cultivars which would eliminate this seed induced dominance. Parthenocarpic, all female cultivars were developed, however, fruit setting was inconsistent and often was completely lacking. Researchers found however that auxin transport inhibitors applied when the ovaries are fully formed would induce them to proceed to develop normally.

Synthetic auxin transport inhibitors such as TIBA (2, 3, 5 - triiodo benzoic acid), chlorflurenol (methyl - 2 - chloro - 9 - hydroxy fluorene - 9 - carboxylic acid) when applied to monoecious cultivars have produced several parthenocarpic fruits on the vine (Beyer and Quebedeaux, 1974; Cantliffe, 1972; Cantliffe, et al., 1972; Cantliffe, 1974 A, B). The presence of male flowers, however, results in early seeded fruits, which inhibit further fruiting and drastically reduce yields. To overcome this problem, scientists have developed hybrids of gynoeceous sex expression with parthenocarpic fruit set capability. The procedure is to cross gynoeceous and hermaphroditic parent lines out doors using bees for pollination. The seeds, so produced, and planted produce numerous, female flowers with parthenocarpic fruits. These ovaries do not set fruit in the absence of pollen and generally abscise after 48 to 72 hours. The application of chlorflurenol, when the ovaries are fully formed, inhibits the transport of auxin out of the ovary, thus the accumulation of auxin triggers the development of the ovary, assuring the consistency of fruit production by developing all ovaries to fruits at the same time. The manipulation of harvest dates makes it possible to obtain more fruits of the smaller, more valuable size grades. Chlorflurenol stops



the growth of the plant immediately after application, which facilitates fruit recovery from high density plantings.

Nitrogen is essential for maximum fruit production. A high nitrogen dose has been reported to produce more but less firm fruits with poor fruit shape.

The present study was initiated to investigate the yield and yield parameters of gynoeocious parthenocarpic cucumber plants treated with chlorflurenol. The influence of nitrogen and plant population on the fruit yield and quality such as fruit firmness, length-diameter ratio and cause of nubs and crooks were investigated. The nutrient percent in the vine leaves was determined for all treatments.



LITERATURE REVIEW

General Nutrient Requirement

As early as 1795, McPhail realized the importance of nutrition for cucumber growth and yield. Cow dung, horse manure and animal and vegetable moulds were considered very useful (72). Increased yield from the application of manure has been reported by many workers (16, 64, 98, 106, 122). Magruder (1923) obtained increased yields by the application of ground limestone and manure. Numerous studies have been done to determine the optimal dose of N:P:K for pickling cucumber under varying conditions which resulted in varying response for yield and growth of cucumber (34, 40, 64, 65, 70, 98, 106, 113, 120, 122). Dearborn (1936) and Anderson (1941) stressed the need for more nitrogen for better yield. Other workers (9, 93, 119), however, observed reduced yield of cucumber at higher rates of nitrogen by injurious effect on the plants. Phillips (1955) found 16 kg/ha N to be adequate under high temperature and low soil moisture conditions. Similar response was observed by other workers (107).

Mechanical once-over harvesters started coming out of assembly lines in the early 1960s. This initiated a whole new method of cultural practices. Bishop et al. (1969) found 50:100:50 kg/ha, N:P:K to be adequate for cucumber. Nicklow (1966), working with once-over harvesting cucumbers under high plant populations found the highest yield with the application of 120:120:240 kg/ha N:P:K. This finding is supported by K.



Miecik (1976). Johnson et al. (1973) pointed out that fertilizer requirements of cucumber depended on soil type and rainfall. Downes and Lucas (1966) found no consistent response to nitrogen by pickling cucumber. There was good response of cucumber to the application of 60 kg/ha N (75, 19). Motes (1977) observed that the early maturing (50-60 days) hybrids require less nitrogen than monoecious varieties. He recommended 40-50 kg/ha N in soils with <2% O.M. and 25-40 kg/ha N for the soils with >2% O.M. Ermokhin and Naumenkho (1976) found the application of mineral fertilizers ineffective for cucumber when the soil had 15-25 mg $\text{NO}_3 - \text{N}$, 60-70 mg P_2O_5 and 60 mg K_2O per 100 gm of soil at planting.

Mode of Application

The effects of different modes of application of fertilizers have been investigated. Side dressing 30-40 kg/ha N on cucumber had no effect (9, 25, 57). Split application of N has been reported better for cucumber (67, 98, 120). Side placed application of 400 kg/ha 5:20:20, N:P:K, was better than placing it 2" below the seed which decreased plant stand and yield (Miller, 1957). Bushnell (1941) reported side dressing at the first true leaf stage increased the yield but side dressing did not when applied later. He recommended 40 kg N/ha as side dressing on top of 80:80:80 kg/ha N:P:K preplant. Broadcast half of 12:12:12 @ 300-420 kg/ha and half side dressed 2" to the side and 2" below gave 10.7 ton/ha of cucumber fruits. However, lowest yields were recorded by broadcasting after plowing the land (McCall et al. 1958). Ries (1957) reported no increase of early yield by supplemental fertilizer. However, in nutrient



leaching conditions it is useful. Under high plant populations (more than 300,000/ha) 66 kg/ha supplemental nitrogen is recommended (78). Fertilizer spray for better yield of cucumber has been recommended by Hoglund (1958).

Phosphorus and Potash: Critical Factors

Phosphorus was found to be more important than nitrogen (12, 60, 64, 114). This has been disputed by others who found nitrogen to be the most limiting factor (33, 74). Phosphorus had very little relationship with yield. Deficiency of P and especially K had an adverse effect on fruit chemical composition and decreased fruit processing quality. Bushnell (1941) recommended the application of potash along with manure. The potash application rate was the most potent independent variable affecting early and total marketable yield. Again, this was disputed by Miller (1957). Any recommendation on phosphorus and potash rates should be based on the soil test.

Nutrient Uptake and Concentration

Miller (1957) reported that there was marked increase in soluble magnesium during the season and petiole samples at tip over, midseason and at the last harvest indicated an inverse relationship between soluble nitrogen and phosphorus and between potassium and calcium. Campbell (1953) found potassium and calcium application increased the sodium concentration in cucumber. Large sodium and low potassium accumulation in cucumber was associated with lower yields, Carpena, et al. (1978) found more nutrient uptake by plants at sparser than at denser



populations. Dearborn (1936) and Bishop, et al. (1969) observed increased N, Ca, Mg and decreased phosphorus and potassium by increased application of nitrogen. Increased K application increased tissue K content (60). Less magnesium was observed when the application of potassium was increased (12). Cantliffe (1977, D) found similar results. However, he observed increased potash with increased nitrogen and concentration of $\text{NO}_3 - \text{N}$ in leaf blades and tissue rapidly decreased during the last 2 to 3 weeks before harvest (fruit sizing period). The petiole tissue concentration of $\text{NO}_3 - \text{N}$ outside .5 to .8%, reflected reduced yields. He further observed that optimum yields generally occurred when plants contained 4-5% total N and the source of N (NH_4NO_3 or urea) and sidedressing had little influence on tissue concentration of $\text{NO}_3 - \text{N}$ and total N. Hansen (1978) reported that NO_3 content in cucumber plants was not influenced by increased N application from 0 to 400 kg/ha N. El-Shiekh et al. (1970) reported that the critical $\text{NO}_3 - \text{N}$ concentration for cucumber on dry weight basis was 2000 ppm; a higher rate decreased the growth of cucumber plants significantly. $\text{NO}_3 - \text{N}$ was a better criteria than total N for determining critical nitrogen concentration for maximum growth and the total N content in cucumber plant was reported to be 2% (46). Ammonium fertilization suppresses cation accumulation in cucumber and the difference in cation accumulation in the shoots is attributed to the form in which N is translocated from root to shoot (8). Ingestad (1973) estimated that if $\text{N} \approx 100 \text{ mg}/100 \text{ gm}$ weight, K:P:Ca:mg would be 75:13:9:9. He also reported that cucumbers prefer nitrate and were sensitive to high ammonium concentrations and that cucumbers were obligate calcicoles due to high tolerance to calcium



and deficiency symptoms manifested in young leaves in spite of abundance in old leaves. Perez, et al. (1978) reported that in the early stage of cucumber growth, requirement for K was greater than that for Ca and Mg. The requirement for Ca increased from flowering onward, whereas Mg uptake was relatively uniform. Calcium accumulated mainly in the leaves. Although K uptake from the nutrient solution did not increase with plant age, K accumulation in the fruit was attributed to translocation from the leaves. Mavrodii (1978) calculated that a cucumber crop utilized 34.2 - 64.2% N from ammonium nitrate applied before planting or as top dressing. A heavy crop of fruits takes more nitrogen at the expense of leaves or other vegetative parts (38). Wilkins (1917) found very high concentration of Ca in cucumber plants. He also found CaO up to 5% which increased progressively as the plant reached maturity. In the fruit Ca was low, never more than 1%. The seeds had even lower Ca content, i.e., 1/4 of that of the fruit. He envisioned the relationship of calcium with other nutrients as follows; as Ca increased in the vine, the other nutrients decreased. The opposite was the case in fruit, as the plant progressively matured (calcium decreased, other nutrients increased). McCollum and Miller (1971) found the maximum rate of growth and nutrient accumulation at about 50 days after seeding cucumbers. They further reported when 80:42:80 kg/ha N:P:K was applied in the cucumber field the total uptake by the plant was 90:12:145 kg/ha N:P:K and by the fruit it was 40:6:55 kg/ha. This was supported by other workers (17, 111, 112). In once-over mechanical harvesting system, Motes (1977) found 25 kg/ha N removed by 15-20 ton cucumbers/ha. In addition, 25-35 kg/ha is removed by vines. Laske (1979) observed that



cucumber cultivar, Uniflora D, removed 500 kg/ha N and when $N \approx 1$, the removal of $P_2O_5:K_2O:CaO:MgO$ was 0.4:2.0:1.6:0.24. He further reported that nitrogen and zinc uptake was greater and K, Ca and Mg uptake was smaller in high temperature as compared to low temperature.

Nutrient Effect on Plant and Fruit Quality

Symptoms of nitrogen deficiency are first evident on the tops of plants concomitant with a reduction in rate of growth. Stems and leaves remain small, giving a stunted appearance. Fruits may be pale yellow in color and are often pointed at the blossom end (Morrison, 1966). Deficiency of P and especially of K had an adverse effect on fruit chemical composition and decreased fruit processing quality (122). Copper deficiency increased the proportion of poorly developed fruits (1). A high application of sodium nitrate or animal manure had no injurious effects on firmness or on other brining qualities of cucumber (38, 113). However, Cantliffe (25) and Flocker (50) reported more off-shaped fruit at high nitrogen rates. K. Mieck (1976) reported that it was not nitrogen level that determined the quality of canned cucumber but the freshness of the fruit before processing. There are some reports (67, 75) of increased fruits per plant by higher nitrogen rates. However, Morrison (1966) reported a slight decrease in the number of plants at high nitrogen rate. Nicklow (1966) found smaller size fruits with the addition of 120 kg N and 240 kg K_2O /ha than more or less. However, Flocker (50) observed a yield increase with bigger size fruits



by increased nitrogen dose and Dearborn (1936) found smaller sized fruits with low nitrogen application. The addition of nitrogen has been reported to decrease the percent of cull fruits and the curtailment of the food supply (lack of fertilizer) to the fruits results in misshapen fruit of various sizes (38, 64, 108). Seaton et al. (1939) observed misshapened fruit in heavier and very poor soil than sandy soil. However, Wittwer and Tyson (1950) found no significance in the nubs and crooks compared with fertilizer treatments (300, 500 and 800 kg/ha of 3:12:12). Miller (1957) found increased length:diameter ratio with high nitrogen application whereas Cantliffe (1977,C) found no such relationship. Low nitrogen supply slowed the growth of the vine (38) whereas, early vegetative growth was retarded in cucumber plants with high N levels (67). Barnes (1941) reports that excess nitrogen may produce excessive vegetative growth and delay fruit setting. However, nitrogen had no relation with earliness of the crop in other studies (42, 61, 64). Lloyd and McCollum (1940) found that an early crop resulted from more phosphorus application. Nitrogen had no influence on sex expression in cucumber and there were abortive female flowers around the 18th node on the vine (Matsuzaki and Hayase, 1963). They suggested this response was due to utilization of all available nutrients by the older developing fruits. However, Cantliffe (1977, C) found increased pistillate flowers/plant by nitrogen application up to 134 kg/ha.

Plant Population

The need for higher plant population of cucumber was expressed by Putnam (1963). He stressed that the survival of the pickling cucumber industry in Michigan depended on the development of a successful mechanical



harvesting system. Research conducted from 1957 to 1960 indicated that mechanical harvesters based on a multiple harvest approach were not successful. He explored the possibility of growing and harvesting cucumbers in a once-over manner. High plant population up to 104,544/ha resulted in higher once-over harvest yields. Ries (1957); Bradley et al. (1975); Cantliffe (1977, D) and Mehwald (1977) found increased yield of cucumber by closer spacing especially in high fertility soils. Statens (1963) observed declined yield by wider spacing and increased yield per square meter in the first four weeks of cropping. Martin, et al. (1976) found highest yield (31.7 ton/ha) by plants grown at 1.40 X .4 m. Gomen and Wricke (1977) found greatest yield of cucumber from plots with 16 plants/m² than with 4, 8, or 32 plants/m², whereas Perez, et al. (1977) observed higher yield of cv. Sporu and Bit Spot by 1.9 plants/m² than 2.9 plants/m². El-Aidy and Moustafa (1978) found slight but not significant increase in the yield of Beta Alpha cv. by denser planting (20 cm). Reaves and Raymond (1979) found better yield by 7.5 cm spacing than 15, 30 cm in multiple harvesting cucumber and 12.5 cm gave higher yield than 25 or 50 cm in once-over harvest of the cucumber fruits. High plant population has increased the dollar value of cucumber (Morrison and Ries (1967) and Reaves and Campbell (1979)). Morrison (1966) reported highest dollar/ha by plants at closest spacing (9 X 9 cm²). He found the value per hectare doubled as the number of square feet per plant was reduced by one-half. Cantliffe and Phatak (30) found increased dollar/ha by increased plant population of 50,000 to 500,000 plants/ha. However, Nicklow and Fernandez (79) have reported decreased dollar returns by exceeding plant populations beyond 360,000 plants/ha.

High density planting of cucumber did not reduce the length of main stem but decreased the number of axillary shoots to 0.3 to 2.1/plant in hybrid cv. Parifin Witto and Koravo (Lesic, 1976). El-Aidy and Moustafa found better vegetative growth with 40 cm than 20 cm plant-to-plant spacing. Plant population has some effect on fruit development and number of fruits per plant. Staten (1963); Putnam (1963); Morrison (1966); Morrison and Ries (1967); Cantliffe and Phatak (1975A) observed increased number of fruits/plant by wider spacing and decreased fruits by closer spacing. The last three groups of scientists also found a decreased rate of fruit growth in high plant populations. Ries (1957) reported earlier maturity of pickling cucumber by close spacing. Mehwald (1977) found it was possible to harvest gherkins earlier when there were 100,000 plants/ha than 50,000 plants/ha. However, delayed harvesting of cucumber plants by a few days with close spacing has been reported (42). High plant population has been reported to reduce the female flower with marked effect in varieties with mainly female flowers and slight effect or absent in varieties with higher proportion of male flowers (Edelstejn and Paponov, 1964). Lesic (1976) reported most pistillate flowers appeared on the main stem in high plant population. Cantliffe and Phatak (1975A) reported lowest L:D ratio of cv. Premier at 50,000 plants/ha whereas cv. Bounty did not show any response. Morrisson (1966) reported no change in L:D ratio in cv. Spartan Dawn by plant population. Good quality fruits of grade 1 were produced by closer spacing (Statens, 1963). Ware, et al. (1953) reported increased culls at 30 cm than 60 cm or 90 cm spacing. Similar results were observed by Mehwald (1977) in gherkins. Nicklow and



Fernandez (1969) observed a high percent of misshapen fruits at high plant population. They reported a pronounced sharp dip in gross photo-synthesis at high plant population to be the possible cause of misshapen fruits. However, Cantliffe and Phatak found no effect of varying plant population on the percent of (1975, A) off-shape fruit or fruit color. Putnam (1963) reported less dry matter per plant at higher plant population. He speculated that a decrease in dry matter decreased the capacity of the plants to support developing fruits by insufficient CO₂, light, water or nutrients. This was supported by Hopen (1962).

Recommendations

Anderson (1941) recommended 180 X 5 to 7.5 cm planting for more yield and easy harvesting by hand for multiple harvest. Phillips (1955) reported that a space of more than 90 cm²/plant was apparently unnecessary for cucumber plants. Ries (1957) recommended that pickling cucumbers should be planted 2-4 seeds/30 cm of the row, resulting in 10 to 12 cm apart in the row. Cantliffe (1974B) proposed that yields of pickling cucumber harvested once-over could be improved by increasing plant populations and applying chlorflurenol. Motes (1977) has recommended 96-120,000 plants/ha with no irrigation and 168-240,000 plants/ha with irrigation. Eindhoven (1978) found best results by planting cucumbers at a distance of 42.5 cm rather than 37.5 or 50 cm.

Morphactins

Chlorflurenol is a member of a group of chemicals known as "morphactin." Its trade and the technical names are curbiset and



2-chloro-9-hydronylfluorene-9-carboxylic acid, respectively. Schneider (1970) has described the morphactins as having a wide growth regulating concentration range and high tolerance with a favourable therapeutic index. These chemicals have prolonged action by over-dosing, subsistence of action and recovery capability of the plants. Morphactins also have a broad spectrum of action and vary within wide limits including weeds, grasses as well as woody species. Their action is systemic. A high concentration results in dwarfism whereas low concentration has a transient effect on shoot growth, branching, and the morphogenesis of new growth subsequent to the treatment. It was due to such effects on plant morphology that they have been named "morphactins."

Criley (1972) found chlorflurenol abscising the coconut fruits of 4 to 8 cm and up to 20 cm diameter when applied at 5000 ppm with 2 chloro-ethylphosphonic acid (ethephon) at the time when pistillate flowers were most receptive. Chlorflurenol can be transferred by volatilization (Gaither, 1974). When untreated beans (Phaseolus vulgaris) were grown along with treated beans in an enclosed chamber both types showed reduced leaf surface, dark greening of leaves and inhibition of second internode elongation. Hield and Hemstreet (1974) found the reduction of ice plant (Carpobrotus edule L. Bolus) growth when chlorflurenol was applied at 300 ppm. Its effect was enhanced with X-77 adjuvant. They suggested a continuous spray program to control ice plant growth on the highways. Purohit (1972) while working with potatoes observed that chlorflurenol affected the polarity of the sprouts by adversely affecting the excessive elongation and hook formation of the sprouts.



Parthenocarpic Fruit Development:
An Action of Chemicals: Chlorflurenol
in Particular

As early as 1939 Gustafson showed that the auxin level in ovaries of parthenocarpic oranges, lemons and grapes were higher than in non-parthenocarpic fruits. Elassar et al. (1974) found that synthetic auxin and Benzyladenine (BA) effectively induced parthenocarpy when applied in the whole cucumber plant. Direct application of β -naphthoxyacetic acid (β -NOA), gibberellin (GA), parachlorophenoxyacetic acid (4-CPA) and BA had effect when directly applied on flowers at anthesis, while ethephon and abscissic acid (ABA) were ineffective. 4-CPA was most effective as determined by shape and numbers of fruits. GA, when applied to whole plant, increased vegetative growth and inhibited the fruit growth even after natural pollination. The mechanism of action of the chemicals producing parthenocarpic fruits has been under intense investigation. Shulamit and Rudich (1979) report from Israel that the parthenocarpic fruit development in cucumber is controlled by sink strength and that the hormones act to assimilate mobilization of transport enhancing factors. Patrick (1979) further investigated the proposal that indole-acetic acid (IAA) enhanced acropetal transport in stems by acting along the transport channel in decapitated seedlings of Phaseolus vulgaris L. Hay (1955) has shown that pretreatment with 2, 4-D or TIBA inhibits subsequent translocation of IAA. Cantliffe (1972), while working with nine growth regulating chemicals, found that chlorflurenol and TIBA were most effective in parthenocarpic fruit set and development in seeded cucumber. He reported to have produced 6 to 7 fruits per plant, as opposed to 1.6 fruit per plant in the

United States. Also, a new growth regulator CCDP (3-carboxy-1-(p-chlorophenyl)-4-6-dimethyl-2-pyridone) significantly increased the number of female flowers and fruits. Parthenocarpy has been induced in unfertilized pistillate flowers of cucumber by the foliar application at early flowering of 10 to 1000 ppm of DPX 1840 [3, 3a-dihydro-2-(p-methoxyphenyl)-8H pyrazolo [5, 1-a isoindol-8-one]], a new auxin transport inhibitor (Quebedeaux and Beyer, 1972). They found increased pistillate flowers by ethephon application and increased number of fruits which developed parthenocarpically by subsequent application of DPX 1840. Beyer and Quebedeaux (1974) tried different inhibitors of auxin transport [DPX 1840, chlorflurenol, N-1-Naphthylphthalamic acid (Naptalam) and TIBA] and found that the results were compatible with the hypothesis that auxin transport inhibitors induce parthenocarpy in cucumber by rapidly blocking the natural flow of auxin from the ovary thereby resulting in an accumulation of auxin within the ovary sufficient to trigger parthenocarpy. Watkins and Cantliffe (1979) supported the above mentioned mechanism of parthenocarpy when they found more build-up of applied NAA in ovaries of cucumbers after the application of chlorflurenol to the peduncle. Wiebosch and Berghoef (1974) applied 40-60 ppm of the methylester of chlorflurenol once between 1 and 3 weeks after the start of flowering and found that it induced 7 to 11 parthenocarpic fruits in seeded cucumber. They have stressed the use of chlorflurenol for once-over harvesting of cucumber. Schneider et al. (1977) reported an increased number of fruits in cucumber plants by the application of chlorflurenol which reduced the fruit size and period of development.

Gynoeceous cultivars were induced to fruit without pollination by using chlorflurenol at 100 ppm. Cantliffe (1974, A) reported that fruit development from pollinated flowers of cucumber on the early nodes inhibited the fruit set on the later nodes. Chlorflurenol overcame this inhibition and produced many parthenocarpic fruits in non-pollinated flowers. It also reduced the seed number in non-parthenocarpic fruits. Pollination was shown to improve the effect of chlorflurenol in increasing fruit set (Cantliffe, 1977, B). However, Wells (1978) found variable effects of chlorflurenol on the yield of gherkin. Also, Putnam (1963) found inconsistent results by spraying growth regulators such as Benzothiazole, 2-chloroethyl ammonium chloride and maleic hydrazide on pickling cucumber yield for once-over harvest. Cantliffe (1974, B) proposed that the yields of seeded cultivars of pickling cucumber harvested once over could be improved by increasing plant population and applying chlorflurenol in the fourth leaf stage to limit growth and promote fruit set. He found more male flowers produced by a lower concentration (.1 and 1.0 ppm) of chlorflurenol; and fewer male flowers at 10 or 100 ppm. Plant growth was terminated by chlorflurenol at 100 ppm. Rudich and Rabinowitch (1974), while working with tomato found increased fruit set under high temperature conditions. Chlorflurenol increased fruit malformation and inhibited vegetative growth. Chlorflurenol increased yield of smaller sized fruits and reduced the percentage of off-shaped fruits, only on plants previously treated with ethephon, implying that chlorflurenol is more effective in plants with more female flowers as ethephon increases femaleness in



cucumbers (24, 27, 28, 29). Cantliffe and Phatak (1975, B) applied chlorflurenol and ethephon to pickling cucumbers and reported 68% more yield by increased number of fruits per plant. Similar results were observed in gherkins (102). The chemicals, when applied separately, increased the dollar value by 14% over the control. Chlorflurenol also reduced the length and diameter ratio of the fruits (also, Soenoedji, 1977, and Pike et al. 1979). They suggested applying ethephon twice, one week apart commencing at the fourth true leaf stage followed by a 50 to 100 ppm chlorflurenol spray when 6-8 female flowers have reached anthesis. Alanap (Naptalam) and chlorflurenol when applied to pickling cucumbers, increased total and smaller fruit yield by hand or mechanical harvesting (Palevitch and Menagem, 1977; Shannon and Robinson, 1976; Soenoedji, 1977). Pike et al. (1979) and Soenoedji (1977) observed misshapen fruits after using chlorflurenol. Dean and Baker (1979) applied 50 or 100 ppm chlorflurenol on gynoecious parthenocarpic cucumber and reported that it stimulated parthenocarpic fruit development. They suggest that the response to chlorflurenol is more by parthenocarpic plants than weak or non-parthenocarpic ones (5, 36). The temperature seemed to modify the action of this growth regulator, low night temperature being more favorable. Baker (1979) found 5.4 to 12.6 ton/ha of 1 and 2 size grade fruits in 1978 grower trials in Michigan when he used parthenocarpic gynoecious cucumber with chlorflurenol. However, in 1979 the yield was 2.8 to 8.4 ton/ha.

Calcium: A Factor Affecting Nubbin
and Crooking of Fruits

There are various factors affecting the production of cull-fruits in cucumber. Bangerth (1972) found an increasing number of fruit disorders caused by Ca deficiency in cucumbers. He observed that blossom end rot and cracking in tomato, and bitterpit, lenticel spots, internal breakdown and water core in apples and fruit cracking in several stone fruits could be reduced by Ca treatments. Ingestad (1973) reported low calcium uptake causing deficiency in the young parts, despite relatively high content in the old leaves. Requirement of Ca by cucumber plant increases from flowering onwards and its accumulation is mainly in the leaves (Wilkins, 1917; Ingestad, 1973; and Perez et al. 1978). Calcium has been reported to be in ionic condition in the phloem sap of plants (Vangoor and Wiersma, 1974). Calcium requires metabolic maintenance for besipetal transport. Acropetal movement is slight, probably non-metabolic and essentially constant (Evans, 1964, and Dela Fuente and Leopold, 1973). The latter reported that besipetal transport of the auxin, IAA in sunflower stem sections was markedly suppressed by washing the tissue in ethylene diamine tetraacetate (EDTA) and the transport was restored by subsequent application of calcium solutions. The above chemical treatment was shown to result in the removal of substantial amounts of calcium from the tissue. Lesser effects were observed for magnesium and lanthanum. They suggested that Ca was an important component of the membrane system on which the auxin transport site was presumed to exist.

Many workers have tried to explain the mechanism of misshapen fruits in cucumber. Percent fruit set in muskmelon plants



treated with 1% IAA on the stigma was increased (Burrell and Wtaker (18)). Wong (1939) reported some success in producing parthenocarpic fruits in cucumber by applying NAA in lanolin to the cut styles. Booth et al. (1962) suggested that apical dominance and correlative inhibition of lateral buds might involve the diversion of nutrients toward actively growing regions (young leaves and fruits) and that the role of auxin in correlative inhibition may be to stimulate the movement of nutrients towards meristematic regions which are known to be centers of high auxin production. This was supported by Seth and Wareing (1966) and Bowen and Wareing (1971). They found that IAA-directed transport was demonstrated by the movement of ^{14}C -labelled photosynthates from the leaves to the peduncles. They suggested that hormone directed transport may play an important role in directing the movements of nutrients toward developing seeds which are rich sources of endogenous hormones. Barrett and Amling (1978) found more ^{14}C labelled assimilates in fruiting plants than non-fruiting plants after they pulsed the leaves of cucumber with $^{14}\text{CO}_2$. Shulamit and Rudich (1979) reported that parthenocarpy could be induced in non-parthenocarpic cultivars by changing sink strength with plant growth regulators to the ovary. The hormones act to assimilate the mobilization of transport enhancing factors. Patrick (1979) observed that the concentrations of two inhibitors of auxin transport, which did not interfere with IAA-promoted besipetal transport, were found to decrease the IAA-promoted component of acropetal metabolite movement. The later inhibition was relieved by treating the stems with a supplementary supply of IAA below the point of inhibitor application. Hay (1955) reported that the mechanism which was responsible for the transport of IAA through excised sections of bean stems was disrupted



when 2, 4-D or TIBA was applied to the foliage, subsequently inhibiting the translocation of IAA. Similar results were obtained with chlomechimid (94). Watkins and Cantliffe (1979) found enhanced fruit set of unpollinated cucumber ovaries by the application of NAA and chlomechimid. More ^{14}C NAA was accumulated in the ovary by chlomechimid application by inhibiting NAA movement out of the ovary. They suggested that fruit development might be regulated by the chlomechimid by restricting auxin movement out of the ovary through the peduncle, causing an increase in auxin accumulation in the ovary which triggers fruit growth. Bangerth (1976) observed that artificially induced parthenocarpic fruits of apples, pears and tomatoes, as well as seeded fruits treated with TIBA, frequently show symptoms of Ca deficiency and a low Ca content. He concluded that auxins, probably produced by the seeds, play a significant role in Ca translocation into fruits. Exogenous IAA application could replace the effect of seeds in this respect. Auxin transport rather than auxin accumulation seems to be necessary for Ca transport as can be concluded from the auxin transport inhibitors.



MATERIALS AND METHODS

1. Field Experiment

A field of sandy loam soil type at the Horticultural Research Center, Michigan State University was selected for this experiment. Soil testing of the composite sample was done at planting and the results are as follows:

O.M. (%)	(meq/100 gm)	pH	P	K	Ca	Mg	Zn	Mn	Cu	Fe
			(kg/ha)					(ppm)		
2.53	8.02	6.1	196	190	1231	110	2	3	1	32

Nitrogen as ammonium nitrate at the rates of 0, 50, 100, 200 kg/ha was applied by a gandy spreader. The field was then disked and nitrogen was worked into the soil. A fine seed bed was prepared by running a drag twice through the field followed by a cultipacker.

The gynoecious parthenocarpic pickling cucumber, MSU 41X581, was planted on June 22, 1979. No other seeded cucumber variety was planted in the vicinity during the entire period of this trial to avoid pollination of this line. The seeding was done using a Swedish precision planter, Nibex. The row to row distance was maintained at 33 cm. and as many as 20 seeds were dropped per meter of row to maintain about 5 cm.



within the row spacing. The herbicide Alanap:Prefar at the rate of 4.47:6.72 kg/ha was applied immediately after seeding for pre-emergence control of weeds. Following emergence the plants were thinned to maintain three plant populations; 75,000; 150,000; 300,000/hectare. Additional hand weedings were done to make the field as weed free as possible. Depending upon natural rainfall 25.4 mm, water was maintained after every 5 days by sprinkler system throughout the growing season. There was no significant attack of any insects or diseases. Therefore, no pesticide was applied throughout the experiment. As many as 10 leaves were taken from randomly selected plants at three stages: vine tipover, 24 hours after chlorflurenol spray and at harvest. The leaves were washed in tap water and dried in the oven at 40.5° C for 4 days and ground in a wiley mill to pass a 20 mesh screen. The samples were sent to OARDC, Wooster, Ohio for analysis of twelve different nutrients including N, P, K, Ca, Mg, Na, Mn, Fe, B, Cu, Zn and Al.

Chlorflurenol (Methyl - 2 - chloro - 9 - hydroxyfluorene - 9 - carboxylic acid) was applied as a single full coverage spray at the rate of 2.4 litre/ha with a CO₂ pressurized (knapsack) backpack sprayer at 445 litre/ha volume when the plants attained 5-7 open flowers. The spray solution was prepared immediately before application.

The harvesting was done once-over by hand 54 days after seeding when the diameter of 4 percent of fruits by weight were judged to be grade 3 (3.75 to 5 cm). The grades of the fruits have been determined by employing PCIC (Pickling Cucumber Improvement Committee) standard of measuring the fruit diameter as follows:



Grade Size	Diameter
1	less than 2.65 cm.
2	2.65 to 3.75 cm.
3	3.75 to 5 cm.
Oversize	more than 5 cm.

The dollar value was calculated by PCIC method and by the data provided by the Aunt Jane Pickling Company which is as follows:

Grade Size	Dollar/Ton	
	PCIC	Local
1	143	243
2	72	154
3	48	72

The fresh vine weight was recorded and the fruits were graded, counted and weighed. Five fruits each from grade 2A and 2B were taken for determining length: diameter ratio and fruit firmness. The Magnus Taylor fruit pressure tester was used to measure the firmness by taking one reading at the middle of each fruit. The total biomass yield was also recorded. The experiment was laid out in a split plot design with nitrogen as main plot and plant population as sub-plot. The plots were 8 x 3 meters and sub-plots 2 x 3 meters. The experiment was replicated 3 times.



II. Greenhouse Experiment

A. Use of Chlorflurenol for Fruit Production in Gynoecious Parthenocarpic Cucumber

MSU 41X581, gynoecious, parthenocarpic hybrid seeds were used for this experiment. Three seeds were sown in each peat pot in a flat on October 6, 1978. On October 18, 1978, the seedlings were thinned leaving one in each pot. The seedlings were transplanted into 9 inch pots and transferred to three different temperatures in the greenhouse. All the plants were staked for support. Plants were watered every other day. The fertilizer (Peters (9-45-15) @ 25 gm/4.5 liter water) was given twice during the growing season with irrigation water. Ambush insecticide was given two times at the rate of 0.5 ml/liters for the control of whitefly. There was some mild evidence of powdery mildew towards the end of the experiment.

There were two different treatments given to the plants at about the 5 to 7 open flower stage (November 27, 1978):

- (a) chlorflurenol drench-spray at the rate of 100 ppm.
- (b) control-sprayed with water only.

There were three average night temperatures (16, 21 and 27° C) used as blocks. The fruits were harvested on December 7, 1978 (10 days after treatment), counted and weighed. The experiment was conducted in a randomized block design with 3 blocks (temperatures), 3 plants per block per treatment.



B. Cation Uptake

The seeds of MSU 41X581 were pregerminated in aerated water in a cheesecloth on November 8, 1979 under room temperature. After 4 days, 3 to 4 germinated seeds were planted in each pot filled with a peatlite mixture. The greenhouse temperature was maintained at $23 \pm 3^{\circ}$ C. The seedlings were removed leaving one in each pot depending upon uniformity and vigor. All the seedlings were staked for support. Water was given every other day to full soaking. Fertilizer (Peters (9-45-15) @ 25 gm/4.5 liter water) was applied with water twice during the experiment. The insecticide, Ambush, was sprayed once at the rate of .5 ml/liter for the control of whitefly. The fungicide, Bravo, was sprayed at the rate of 4 ml/liter for the control of soft rot when the symptoms were seen in some lower leaves. The following three treatments were given 63 days after seeding when many flowers on the plants had opened within about 12 hours.

1. α - NAA (0.5%) in lanolin paste was applied to the distal end of the ovary after excising the corolla.
2. The plants were drench sprayed with 100 ppm chlorflurenol.
3. A droplet of 100 ppm chlorflurenol was applied on the pedicel of the flower.

Fruits were harvested twice, 14 and 21 days after treatment. The fresh weight was recorded and the fruits were oven dried at 40.5° C for 6 days following which dry weight was taken. The dried fruits were then ground in a wiley mill and dry ashed at 282° C for 10 hours. The dry ash sample was analyzed for Ca^{++} , K^{+} and Mg^{++} by atomic absorption spectrophotometry.

The experiment was conducted in a randomized design with 3 replications. As many as 3 plants were used per replication per treatment.



RESULTS

Effect of Plant Population

In the field study the dollar value of the crop increased significantly as the plant population increased (Figure 1). The increase of plant population from low, medium to high (75,000 to 300,000 plants/ha) increased the dollars from 410 to 792 per hectare using the PCIC method of evaluation. However, using a local method of evaluation supplied by Aunt Jane Pickling Company, the value per hectare increased from 836 to 1613 dollars.

The marketable fruit yield was significantly higher at higher plant population (Figure 2). At low plant population, the yield per hectare was 5.5 tons which increased to 10.4 tons at high plant population. The amount of fruits by size grade was also significantly more at higher plant population. The numbers of size grades 1A, 1B, 2A and 2B were significantly greater at the highest plant population. However, there was no significant difference in the amount of grade 3, oversize (0.S.) and cull fruits under different plant populations.

Increased plant population had no significant effect on the production of the percent fruit by size grade (Table 1). The only exception was in the case of 1B, which was significantly higher at medium and high plant population than at low plant population. The percent culls ranged from 1.4 to 1.7 and percent marketable fruits 97.9 to 98.5. It is also clear from the table that most of the fruits (94%) produced are of a valuable size grade (i.e., 1 and 2).



Figure 1.

Effect of 3 plant populations on dollar value of cucumber fruit
by two methods.

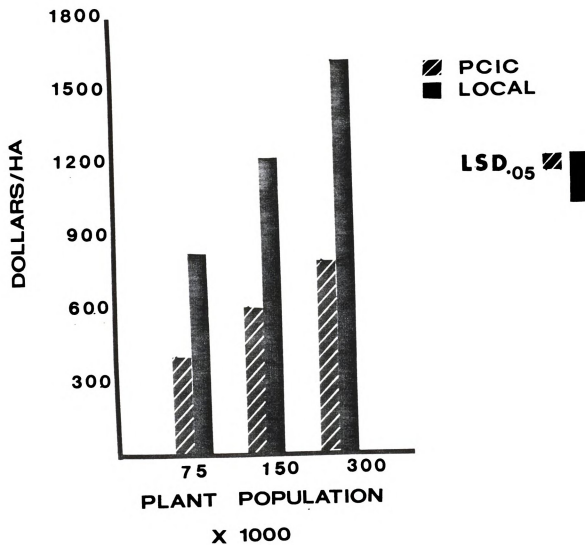
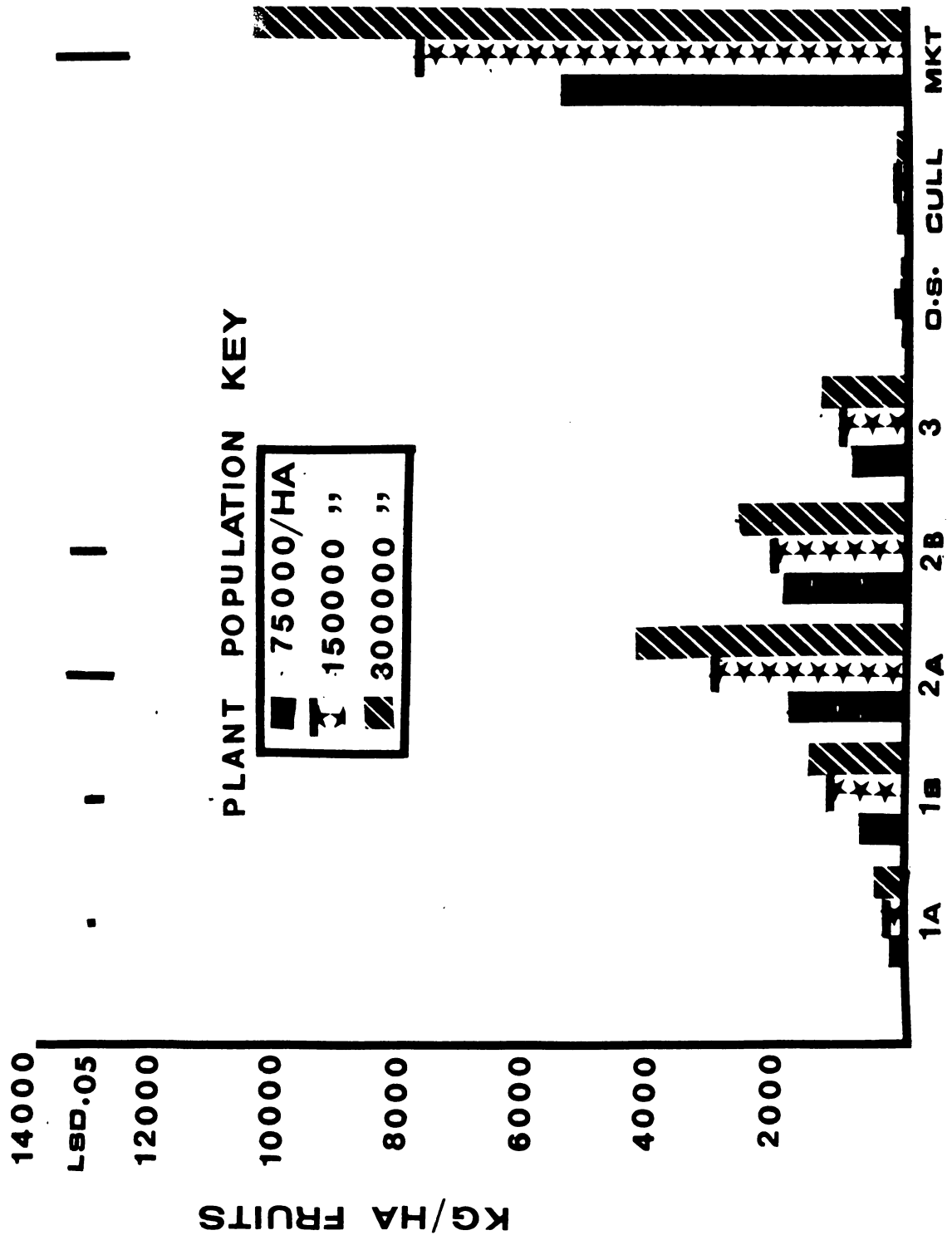




Figure 2.

Effect of 3 plant populations on cucumber fruit yield (kg/ha)
by size grade.





The number of fruits per plant decreased significantly as the plant population increased (Figure 3). There was a slight decrease of fruit number per plant when plant population was increased. The number of fruits per plant at low plant population was 2.5 and at high plant population it was only 1.7 per plant. The number of marketable fruits under different size grades showed no significant difference by different plant population except 2B's which had the same trend as the marketable fruits, i.e., it decreased significantly with increased plant population.

The yield of vine and biomass increased significantly with the increase of plant population (Table 2). The vine increased from 13.2 to 28 ton/ha and biomass increased from 18.8 to 38.6 ton/ha by increasing the plant population.

Increased plant population had no significant effect on the fruit pressure of cucumber fruits (Appendix 1). The fruit pressure of cucumber was generally high ranging from 22.1 to 23.7 lbs. Similarly, the effect of plant population on the fruit length:diameter ratio was not significant. The length:diameter ratio of size 2A was 2.5 and that of 2B size grade was 1.8 to 1.9. (Appendix 2.)

The nutrient content in cucumber leaf tissue at 3 different stages of development (tipover, 24 hours after chlorflurenol spray and at harvest at 3 plant populations) is presented in Table 3. The nitrogen composition of the leaves was affected very little by plant population but did generally increase with increased rates of nitrogen application (Table 4). The decrease in N composition of the leaves, however, was



Table 1.

The Effect of Plant Population on Percent

Cucumber by Size Grade

Plant Population (1000/ha)	Percent Fruit by Size Grade							
	1A	1B	2A	2B	3	0.S.	Culls	Marketable
75	28.2	22.2 ^{b1/}	26.6	16.6	4.7	.1	1.40	98.5
150	22.3	27.8 ^a	29.1	14.3	4.3	.3	1.70	97.9
300	24.2	26.3 ^a	31.7	11.9	4.0	.1	1.40	98.4

^{1/} Means followed by same letters are not significantly different by LSD at 5% level



Figure 3.

Effect of 3 plant populations on number of fruits per plant
of cucumber.

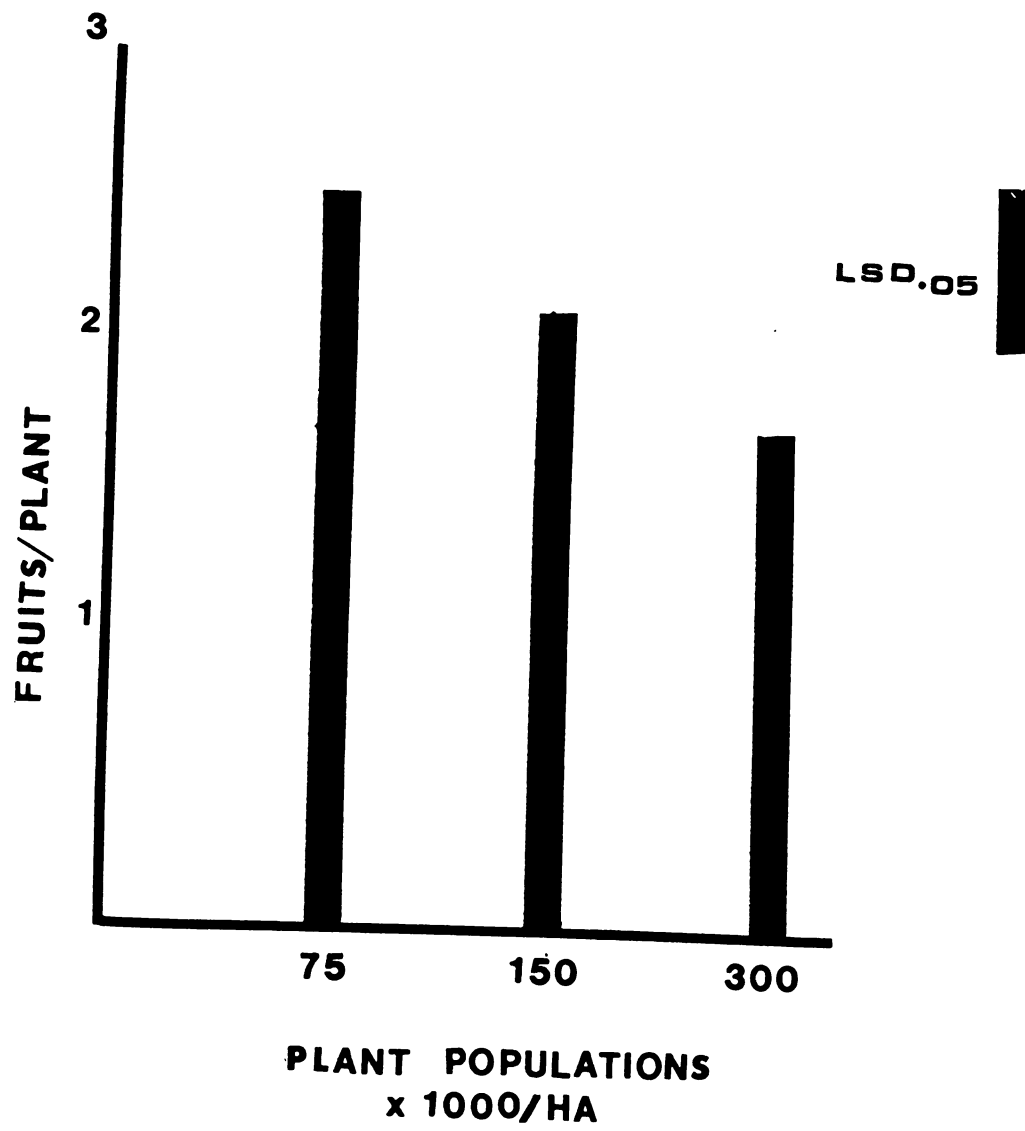




Table 2.
The Effect of Plant Population
on Vine and Biomass Yield of Cucumber

Plant Population (1000/ha)	Vine (kg/ha)	Biomass (kg/ha)
75	13,248.6 ^{c1/}	18,899.5 ^c
150	19,579.9 ^b	27,731.9 ^b
300	28,065.8 ^a	38,674.8 ^a

^{1/}Means followed by same letter are not significantly different by LSD at 5% level.



Table 3.

The Cucumber Leaf Tissue Concentration of Different Nutrients at Different Stage of Plant Under Different Plant Populations,

	N ^{1/} %	P (PPM)	K (PPM)	Ca (PPM)	Mg (PPM)	Na (PPM)	Mn (PPM)	Fe (PPM)	B (PPM)	Cu (PPM)	Zn (PPM)	Al (PPM)
<u>1st Stage</u> <u>Plants</u> (1000/ha)												
75	4.86 ^{x/}	3,092.3	33,509.7 ^a	37,192.1	7,934.4 ^b	48.1	21.9	420.1 ^a	32.1	6.1	43.9	667.3 ^a
150	4.97	3,104.9	32,721.4 ^{ab}	38,145.5	8,566.7 ^a	45.8	25.4	354.0 ^b	32.6	6.2	40.3	511.3 ^b
300	4.88	3,098.7	31,735.7 ^a	35,908.2	8,318.7 ^{ab}	43.5	26.3	303.1 ^c	32.3	5.9	40.7	386.6 ^c
<u>2nd Stage</u> <u>Plants</u> (1000/ha)												
75	4.23 ^a	2,940.0	34,525.0 ^a	43,344.1 ^a	8,634.6	55.6	20.1	221.9	34.3	5.8 ^{y/}	57.0	371.4 ^a
150	4.19 ^a	2,941.6	33,241.2 ^a	39,317.0 ^b	8,600.3	54.5	19.9	171.9	33.4	5.8	59.1	244.7 ^b
300	3.93 ^b	2,908.7	31,743.6 ^b	36,826.8 ^b	8,343.2	55.2	20.0	200.7	33.4	5.5	58.8	196.0 ^c
<u>3rd Stage</u> <u>Plants</u> (1000/ha)												
75	3.69	2,874.4	30,803.7 ^a	52,595.1 ^a	9,966.9 ^a	61.6	24.4	234.2 ^a	47.6 ^a	7.2	49.5 ^a	374.2 ^a
150	3.66	2,802.8	29,457.4 ^b	50,928.1 ^a	10,113.5 ^a	59.9	24.5	204.7 ^b	48.1 ^a	7.2	47.6 ^a	301.9 ^b
300	3.52	2,689.3	27,401.1 ^c	45,448.8 ^b	9,269.1 ^b	62.9	24.1	169.7 ^c	45.2 ^b	6.7	45.3 ^b	230.8 ^c

^{x/} Interaction of plant population and nitrogen.

^{y/} Interaction of plant population and nitrogen.

^{1/} Means followed by same letter are not significantly different by LSD at 5% level.



very significant from the tipover stage to the time of harvest (Figure 4). The plant population X nitrogen rate interaction was significant only at tipover stage (Table 4). When zero nitrogen was added, the percent N in the leaves decreased as plant population increased, however, this relationship was not evident at the other nitrogen rates.

The phosphorus, manganese and sodium content in the leaves at all stages and boron at tipover and at chlorflurenol spray stage and copper at tipover and maturity were not affected by varying plant populations (Table 3). Boron at harvest decreased significantly at high population. Plant population X nitrogen interaction was significant at the 2nd sampling for copper composition in the leaves. However, no clear trend was observed (Appendix 4).

The potassium decreased significantly with higher plant population. Calcium, magnesium, iron, zinc and aluminum reacted similarly (Figures 6, 7, 8, 10, 14, 15).

Effect of Nitrogen

In general nitrogen had no pronounced effect on fruit and plant of cucumber in this study. The L:D ratio of sizes 2A and 2B was not significantly affected by nitrogen rates (9, 50, 100, 200 kg/ha) (Appendix 3). The pressure of 2A size fruit seems to be greater with no nitrogen (23 lbs.) (Table 5). However, the trend is not clear. There was no significant difference in fruit pressure of size 2B fruit by nitrogen rates.

An interaction occurred between nitrogen and plant population on cucumber plant height (Appendix 5). However, no clear trend is evident except at 100 kg N/ha where plant height was increased significantly more at high plant population.

Table 4.

The Effect of Nitrogen X Plant Population on Percent
Nitrogen Content in Cucumber Leaves at Tipover
(1st Stage of Sampling)

Nitrogen (kg/ha)	Plant Populations ^{1/} (1000/ha)		
	75	150	300
0	4.86	4.83	4.57
50	4.72	4.85	4.98
100	5.02	5.08	5.04
200	4.90	5.11	4.88

The LSD_{.05} for comparing means in the same column is .25 and in the same row is .22.

^{1/}Means of ten random leaves/plot. Sample analyzed in triplicates.



Table 5.

The Effect of Nitrogen Fertilization on the
Cucumber Fruit Pressure by Size Grade

Nitrogen (kg/ha)	Fruit Pressure <u>A/</u> (lbs. force)	
	2A ^{1/}	2B
0	23.0 ^a	23.4 ^a
50	21.3 ^b	22.8 ^a
100	22.3 ^{ab}	23.0 ^a
200	21.5 ^b	23.4 ^a

^{1/} Means followed by same letter are not significantly different by LSD at 5%.

A/ Means of 5 fruits in each size grade.

Nitrogen content in the cucumber leaf increased with added nitrogen rates (Table 6). There was significantly more N content at 200 kg N/ha than at 0 or 50 kg N/ha in the 2nd and 3rd sampling. The interaction of nitrogen X plant population has already been explained for nitrogen and copper content.

Nitrogen had no effect on potassium, magnesium, iron, boron, zinc and aluminum content in cucumber leaves (Figures 6, 8, 10, 12, 14, 15). Phosphorus at tipover decreased with increased nitrogen (Figure 5). There was no effect at the later stage of plant growth. However, calcium, sodium and manganese increased significantly with nitrogen application (Figures 7, 9, 10). The composition of different nutrients in the leaves varied through the season. Nitrogen, phosphorus, potash, iron and aluminum decreased through the season as their uptake was noticed reduced towards harvest (Figures 4, 5, 6, 10, 15). Calcium, magnesium, sodium, boron and zinc is increased through the season as their content was higher in the leaves at harvest than at the tipover stage. (Figures 7, 8, 9, 12, 14.)



Table 6.
The Cucumber Leaf Tissue Concentration of Different Nutrients at Different Sampling Stages under Different Nitrogen Rates.

1st Sample (N kg/ha)	N ₁ / %	P (PPM)	K (PPM)	Ca (PPM)	Mg (PPM)	Na (PPM)	Mn (PPM)	Fe (PPM)	B (PPM)	Cu (PPM)	Zn (PPM)	Al (PPM)
0	4.75 ^{x/}	3,401.3 ^a	33,905.7	35,264.7	8,432.1	44.0	22.7 ^b	356.5	33.9	6.1	40.6	514.6
50	4.85	3,147.0 ^b	32,366.7	36,648.8	8,295.7	42.1	20.3 ^b	338.2	32.3	6.4	41.9	463.9
100	5.00	3,094.2 ^b	33,090.8	38,833.3	8,523.9	52.1	24.6 ^b	355.3	31.9	5.6	42.8	513.8
200	4.99	2,751.8 ^c	31,259.2	37,581.1	7,841.5	44.9	30.3 ^a	386.2	31.1	6.1	41.3	594.6
2nd Sample (N kg/ha)												
0	3.76 ^b	3,068.7	33,402.6	37,371.7	8,380.2	53.3	15.9 ^c	207.4	34.7	5.5 ^{y/}	60.7	329.4
50	3.90 ^b	3,895.6	33,058.4	38,919.4	8,574.5	51.9	17.1 ^{bc}	234.3	34.2	6.0	56.1	242.8
100	4.25 ^{ab}	3,009.6	33,184.2	41,438.4	8,804.7	62.7	19.6 ^b	172.0	33.0	5.5	57.2	240.3
200	4.55 ^c	2,746.9	33,033.7	41,587.8	8,344.9	52.5	27.4 ^a	178.9	33.0	5.8	59.3	270.2
3rd Sample (N kg/ha)												
0	3.11 ^c	2,847.3	29,720.5	45,956.1	9,448.4	52.1 ^b	17.3 ^b	200.3	47.9	6.1 ^b	47.2	314.4
50	3.44 ^{bc}	2,674.8	29,226.5	48,949.4	9,664.7	53.3 ^b	19.8 ^b	199.7	46.9	7.1 ^a	47.3	297.0
100	3.82 ^{ab}	2,945.0	29,275.1	51,987.4	10,266.1	70.0 ^a	23.9 ^b	209.9	46.7	7.4 ^a	49.8	300.3
200	4.04 ^a	2,688.1	28,661.0	51,736.5	9,736.5	68.6 ^a	36.3 ^a	201.6	46.5	7.6 ^a	45.5	296.9

^{x/} The interaction of plant population and nitrogen is presented in Table 9.

^{y/} The interaction of plant population and nitrogen is presented in Table 10.

^{1/} Means followed by same letters are not significantly different by LSD at 5% level.

Figure 4.

Effect of 4 nitrogen and 3 plant population rates on the composition of nitrogen in the leaf tissue of cucumber at 3 stages of development.

1st sample = At tipover.
2nd sample = At 5-7 flowering stage.
3rd sample = At harvest.

Figure 5.

Effect of 4 nitrogen and 3 plant population rates on the composition of phosphorus in the leaf tissue of cucumber at 3 stages of development.

1st sample = At tipover.
2nd sample = At 5-7 flowering stage.
3rd sample = At harvest.

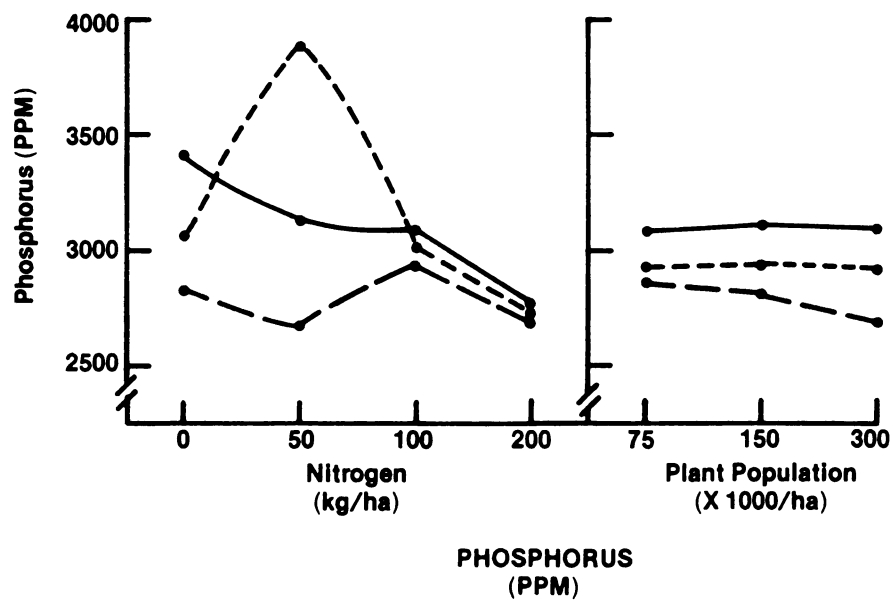
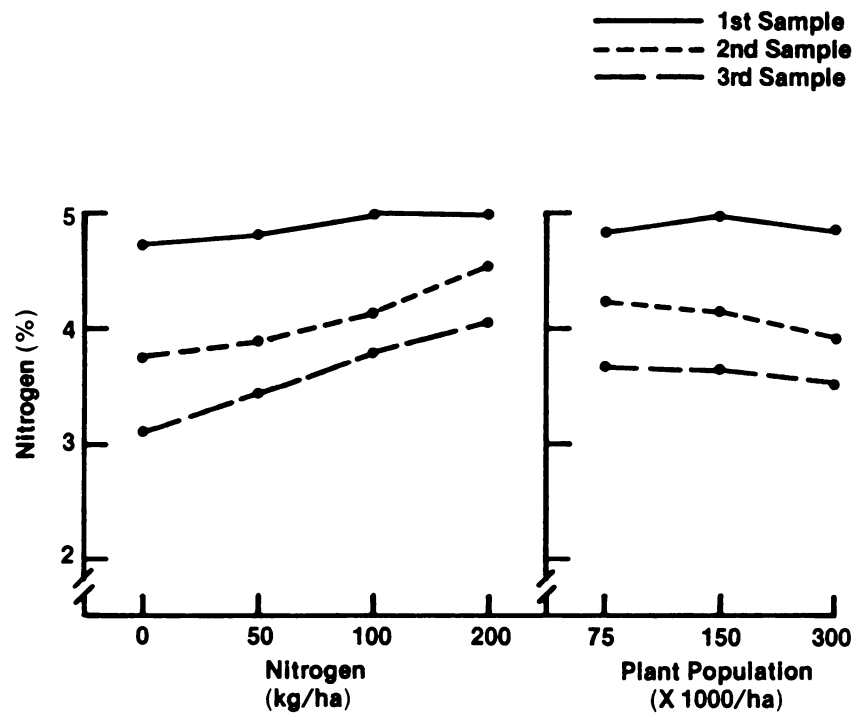
NITROGEN
(%)



Figure 6.

Effect of 4 nitrogen and 3 plant population rates on the composition of potassium in the leaf tissue of cucumber at 3 stages of development.

1st sample = At tipover.

2nd sample = At 5-7 flowering stage.

3rd sample = At harvest.

Figure 7.

Effect of 4 nitrogen and 3 plant population rates on the composition of calcium in the leaf tissue of cucumber at 3 stages of development

1st sample = At tipover.

2nd sample = At 5-7 flowering stage.

3rd sample = At harvest.

POTASSIUM (PPM)

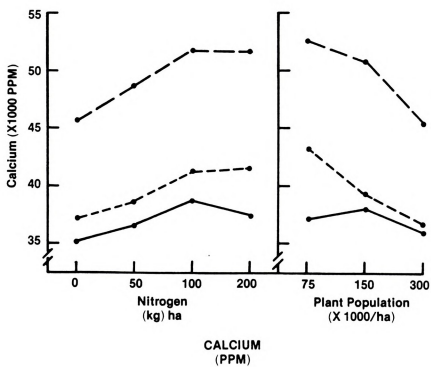
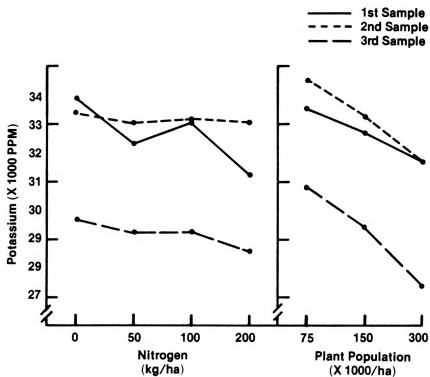




Figure 8.

Effect of 4 nitrogen and 3 plant population rates on the composition of magnesium in the leaf tissue of cucumber at 3 stages of development.

1st sample = At tipover.

2nd sample = At 5-7 flowering stage.

3rd sample = At harvest.

Figure 9.

Effect of 4 nitrogen and 3 plant population rates on the composition of sodium in the leaf tissue of cucumber at 3 stages of development.

1st sample = At tipover.

2nd sample = At 5-7 flowering stage.

3rd sample = At harvest.

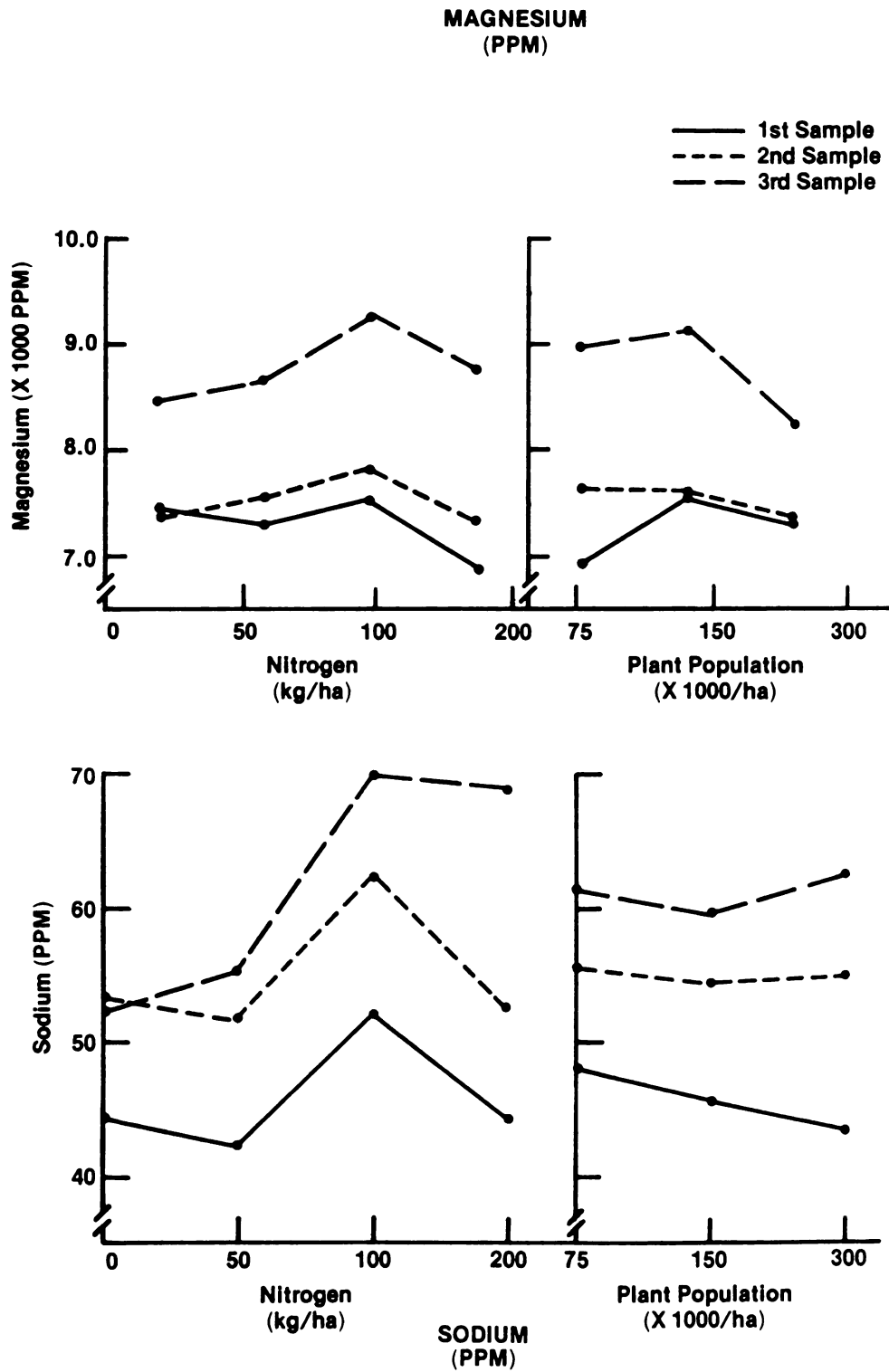


Figure 10.

Effect of 4 nitrogen and 3 plant population rates on the composition of manganese in the leaf tissue of cucumber at 3 stages of development.

1st sample = At tipover.

2nd sample = At 5-7 flowering stage.

3rd sample = At harvest.

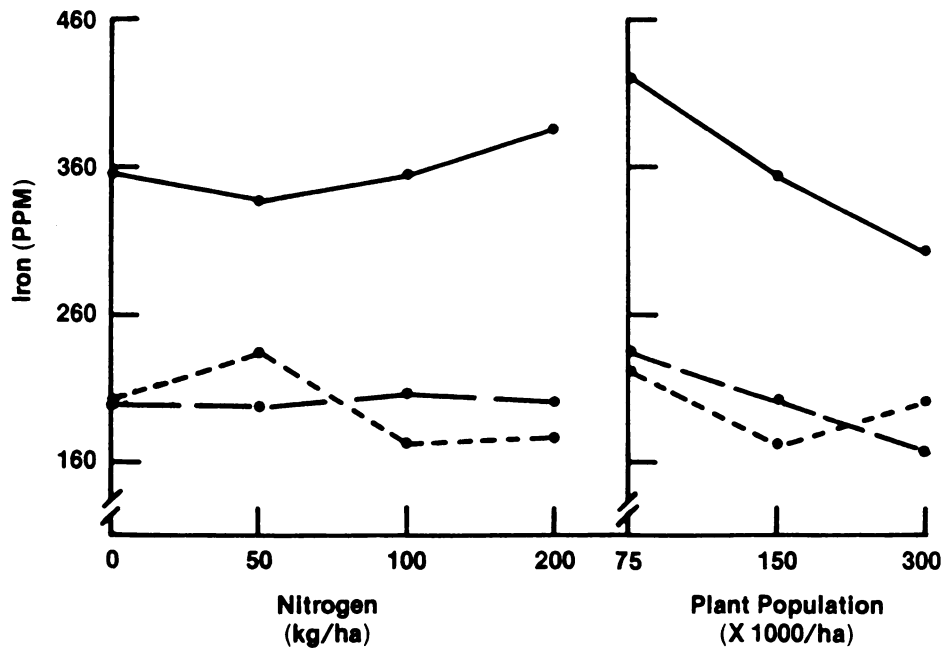
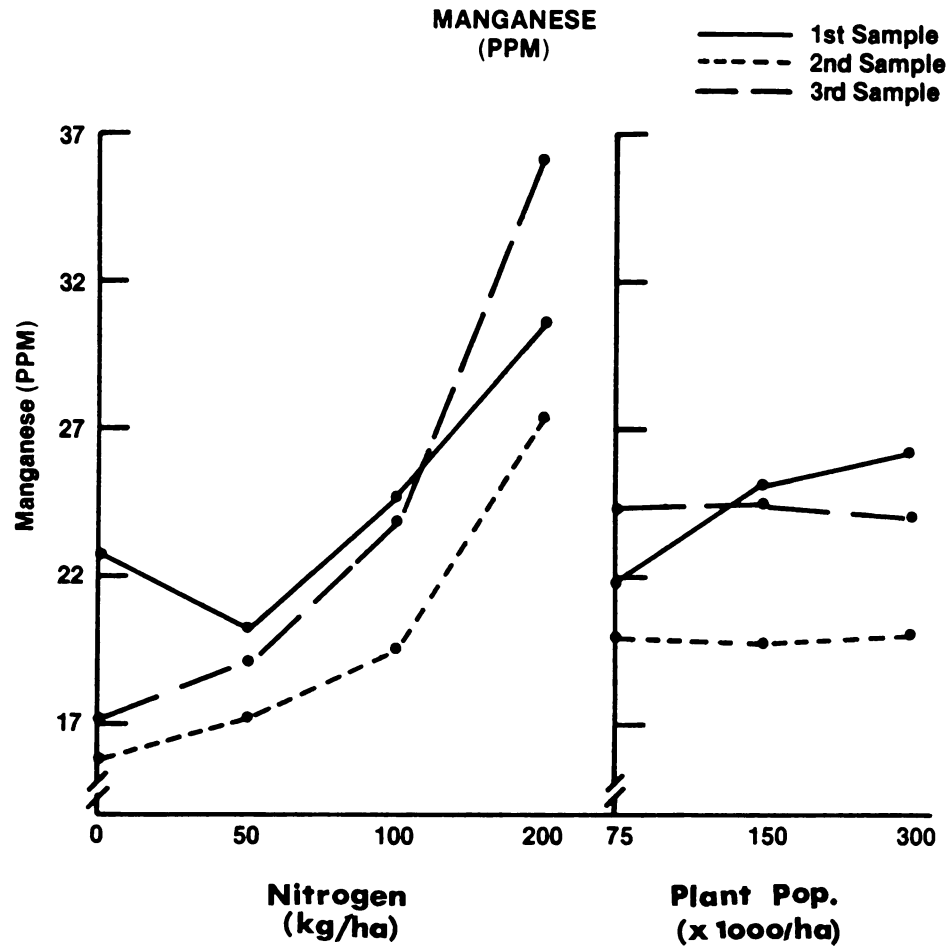
Figure 11.

Effect of 4 nitrogen and 3 plant population rates on the composition of iron in the leaf tissue of cucumber at 3 stages of development.

1st sample = At tipover.

2nd sample = At 5-7 flowering stage.

3rd sample = At harvest.



IRON (PPM)



Figure 12.

Effect of 4 nitrogen and 3 plant population rates on the composition of boron in the leaf tissue of cucumber at 3 stages of development.

1st sample = At tipover.

2nd sample = At 5-7 flowering stage.

3rd sample = At harvest.

Figure 13.

Effect of 4 nitrogen and 3 plant population rates on the composition of copper in the leaf tissue of cucumber at 3 stages of development.

1st sample = At tipover.

2nd sample = At 5-7 flowering stage.

3rd sample = At harvest.

**BORON
(PPM)**

— 1st Sample
- - - 2nd Sample
- · - 3rd Sample

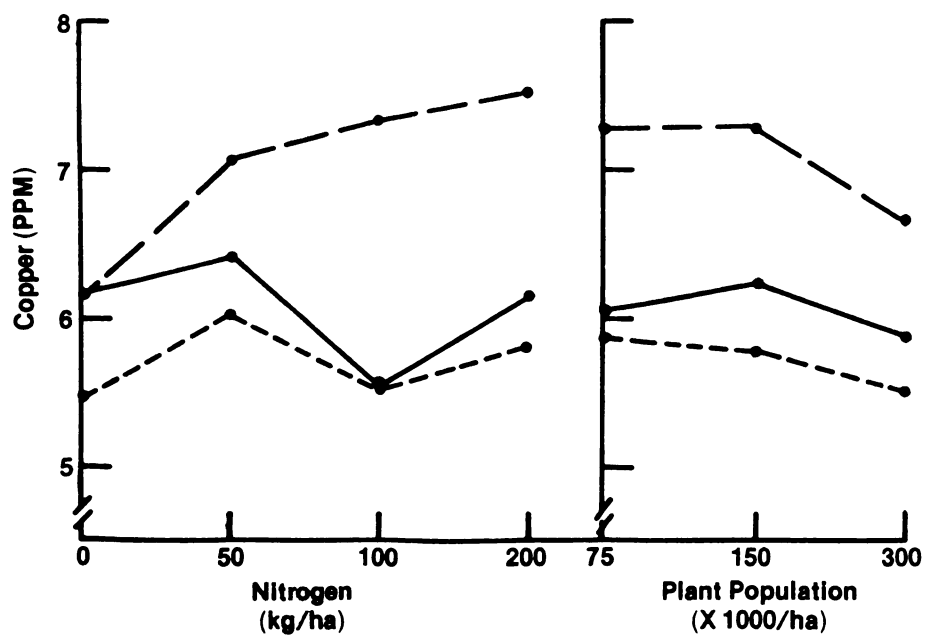
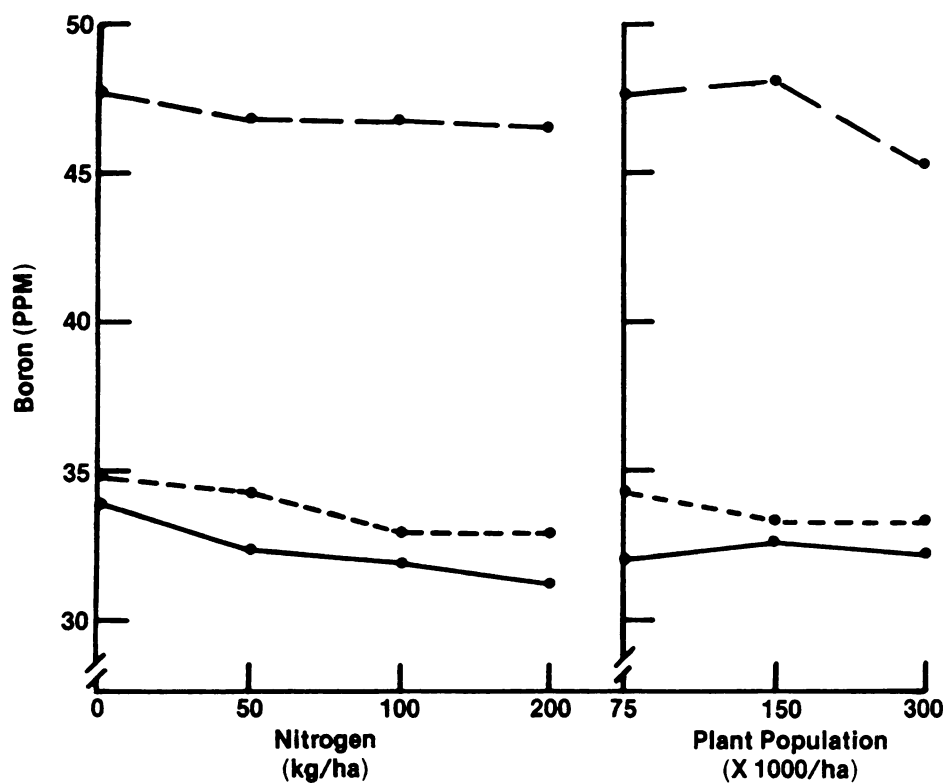
**COPPER
(PPM)**

Figure 14.

Effect of 4 nitrogen and 3 plant population rates on the composition of zinc in the leaf tissue of cucumber at 3 stages of development.

1st sample = At tipover.

2nd sample = At 5-7 flowering stage.

3rd sample = At harvest.

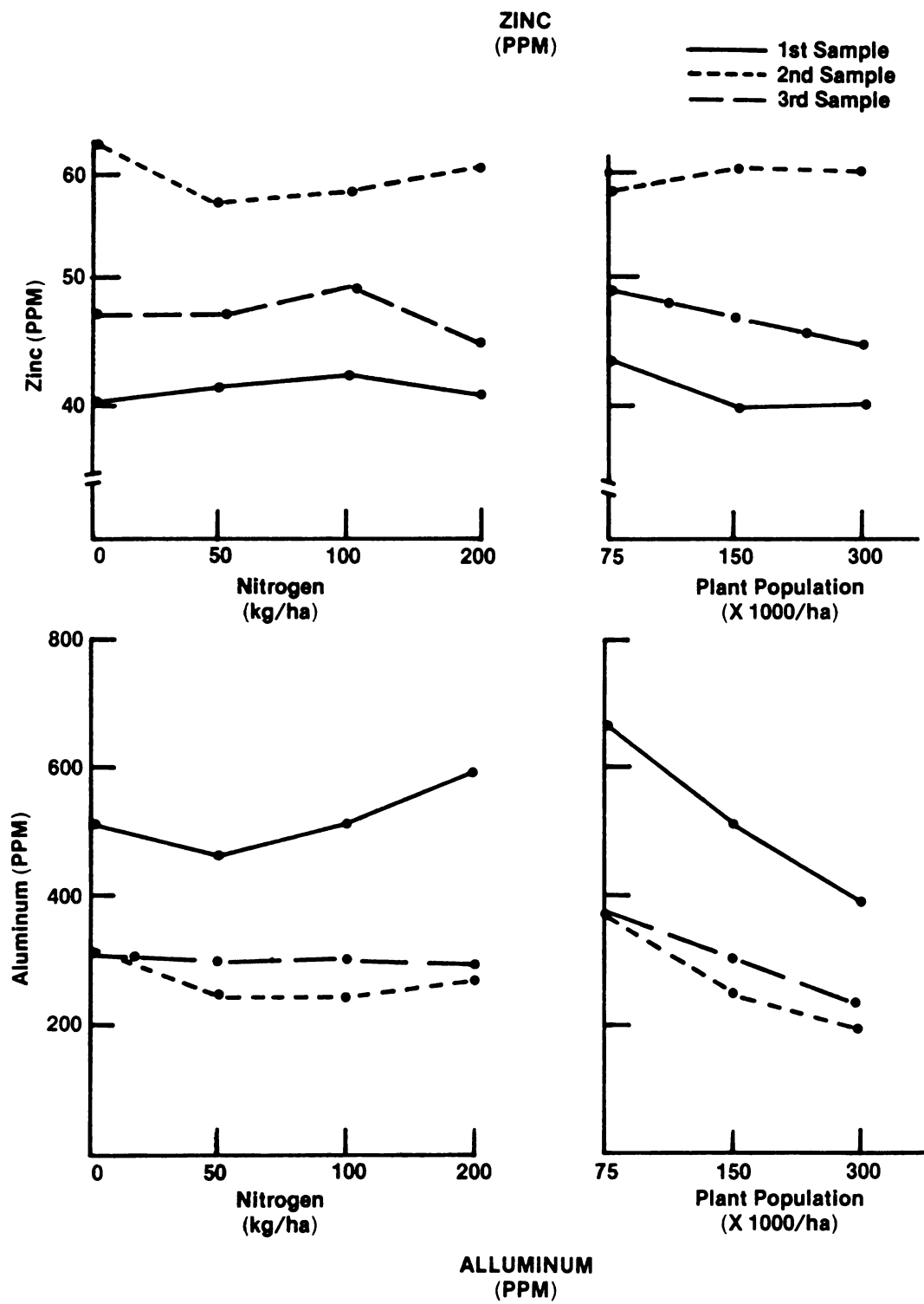
Figure 15.

Effect of 4 nitrogen and 3 plant population rates on the composition of aluminum in the leaf tissue of cucumber at 3 stages of development.

1st sample = At tipover.

2nd sample = At 5-7 flowering stage.

3rd sample = At harvest.





Effect of Chlorflurenol on Fruit Yield

The effect of chlorflurenol on the gynoecious parthenocarpic cucumber was remarkable in the greenhouse study. The use of 100 ppm chlorflurenol yielded significantly more fruits per plant than the controls (Table 7). The weight of fruits per plant and the weight per fruit was also significantly higher with chlorflurenol than the controls (Tables 8 and 9). The unreplicated temperatures (16, 21 and 27° C) showed a significant increase in weight per fruit and weight per plant under chlorflurenol at 21 and 27° C than at 16°C. However, there was no difference in the number of fruits per plant. No fruits were produced at higher temperatures (21 and 27° C) with control plants. There was some fruit production by controls in low temperatures (16° C).

Cation Uptake

The percent dry weight of cucumber fruits was higher at 77 days after seeding (DAS) than at 84 DAS under all treatments (Table 10). Auxin (NAA) treatment resulted in higher percent dry weight than chlorflurenol spray by both methods (pedicel application and drench spray on the whole plant) at 77 and 84 DAS.

Calcium uptake by fruits under .5% NAA was significantly higher than by chlorflurenol spray on the whole plant or its application on the pedicel in both the samples (77 and 84 DAS). Potassium was significantly higher under NAA than under chlorflurenol treatments at 77 DAS, but was not significant at 84 DAS. Magnesium uptake was not significantly affected by the treatments on both the samples, but was more at 77 DAS



than 84 DAS. All the cations (Ca^{++} , Mg^{++} and K^+) were higher in the fruits by chlorflurenol treatments applied at the pedicel than sprayed on the whole plant.

Table 7.

The Effect of Chlorflurenol @ 100 PPM on Fruit Number
per Plant of Cucumber under Different Temperatures

Temperature	Treated	Control
27°C	7.33	0.00
21°C	6.66	0.00
16°C	7.66	1.66

LSD_{.05} for comparing means for both column and rows
is 4.22.

Table 8.

The Effect of Chlorflurenol @ 100 PPM on the
Fruit Weight of Cucumber under Different Temperatures

Temperature	Fruit Weight (gm) per Plant	
	Treated	Control
27°C	195.77	0.00
21°C	176.17	0.00
16°C	117.55	4.93

LSD_{.05} for comparing means for both column and rows = 45.82.



Table 9.

The Effect of Chlorflurenol @ 100 PPM on the Weight
per Fruit of Cucumber under Different Temperatures

Temperature	Weight per Fruit (Gm)	
	Treated	Control
27°C	26.93	0.00
21°C	27.11	0.00
16°C	17.73	0.98

LSD_{.05} for comparing means for both column and
row is 9.02.

Table 10.

The Effect of Chlorflurenol and NAA on the Development
and Cation Uptake of Parthenocarpic Fruits

Treatments	77 Days after Seeding					84 Days after Seeding				
	Dry Wt		Percent			Dry Wt		Percent		
	gm/fruit	Percent	Ca	K	Mg	gm/fruit	Percent	Ca	K	Mg
NAA (.5%) ¹	1.20	4.71	.350 ^{a1/}	5.743 ^a	.371 ^a	7.27	4.29	.331 ^a	4.547 ^a	.331 ^a
Chlorflurenol (pedicel) ²	1.50	4.68	.300 ^b	5.298 ^b	.382 ^a	9.50	3.34	.301 ^b	4.754 ^a	.347 ^a
Chlorflurenol (spray) ³	2.10	4.20	.287 ^b	4.667 ^b	.380 ^a	4.70	3.89	.289 ^b	4.410 ^a	.324 ^a

¹Lanolin paste to distal end of ovary after corolla excision.

²Droplet of 100 ppm chlorflurenol solution on pedicel.

³Spray of 100 ppm chlorflurenol to the entire plant.

^{1/}Means followed by the same letters are not significantly different by LSD at 10% level.



DISCUSSION

Plant Population Effect

The influence of plant population on the yield of the parthenocarpic cucumber cultivar was in agreement with other reports on seeded cucumbers (30, 75). There was a direct relationship between plant population and yield. This was primarily because of the occurrence of more tonnage of smaller size fruits under high plant populations. This is in agreement with Cantliffe and Phatak (1975, A), who found increased dollar value and fruit yield with increased plant populations at densities of 50,000 to 100,000 and 250,000 to 500,000 plants/ha. This yield increase with increased plant population is probably due to the increased number of fruit producing plants per hectare. The foliar application of chlorflurenol stops vegetative growth of the vine immediately by inhibiting meristems. All the ovaries that are fully developed are induced to develop simultaneously. This facilitates the growing of a high density crop for once over harvesting with very high recovery of small size fruits.

The number of fruits per plant varied from 1.7 to 2.5 and was inversely related to plant population. This is again in agreement with other workers for seeded cultivars (30, 75, 76). Dry weight of the plant under high plant population has been reported to be lower than under low plant population, making the plant lose its capability to support developing fruits as plant population increases (88).



This decreased capability is most likely due to competition for light, water, carbon dioxide and nutrients at higher populations (58).

Total vine weight and biomass yield were positively correlated with plant population. This is due to increased total photosynthetic area and increased total water and nutrient uptake under high plant population.

Nutrient accumulation in the leaves as affected by plant population, nitrogen nutrition and age of the leaves was mostly in agreement with the findings of other workers (26, 90) with seeded cucumbers.

Nitrogen Effect

Nitrogen had no dramatic effect on fruit yield and quality. Seeded cucumbers have been reported to have a low nitrogen requirement in general (9, 12, 41, 93) depending upon soil fertility. The residual N content in the soil seemed to be high as shown by N content in the leaves under no nitrogen application. The additional N application increased N content in the leaves without any influence on yield or quality of the crop. Therefore, increasing the N above 50 kg/ha seems to be ineffective and wasteful.

Chlorflurenol Effect

Chlorflurenol is essential for fruit set of the parthenocarpic cultivar MSU 41X581 in either the greenhouse or the field. Few fruits are expected from the controls unless this auxin transport inhibitor is applied to the entire plant or the pedicel. However, under low temperature (16° C) few very small fruits were observed probably due to

low auxin transport out of those ovaries under low temperature or due to reduced inactivation of auxin at low than at higher temperatures. This is in agreement with the findings of Ponti (1978) who found that parthenocarpy was influenced unfavorably by high temperature which could be compensated by low night temperature. The mechanism of action of chlorflurenol in producing many fruits at the same time is hypothesized to be that of inhibiting auxin transport out of the ovaries. The accumulation of auxin within the ovary appears to be necessary to induce further ovary development. In seeded cucumbers auxin synthesis occurs concomitantly with fertilization of the ovary.

Cation Uptake

The field trial was harvested when a small percentage of size grade 3 fruits were observed. This early harvest was initiated because a delay in harvest results in an increased percent of nubbs and crooks as fruits achieve size 3(103). This abnormal development is probably due to a lack of growth factors as the ovary develops and matures. Since the cull fruit induced by chlorflurenol application have the appearance of nutritional deficiency, it was hypothesized that it was due to restricted cation accumulation in the fruits that induce the poor fruit development. Auxins have been reported being assimilate mobilizers (14, 99, 101). Chlorflurenol blocks the transport of certain metabolites into the ovary concomitant with inhibiting the auxin transport out of the ovary. Cations such as calcium, potassium and magnesium are important constituent of the fruit (109) whose transport into a fruit may be dependent upon the movement of auxin out of the organ or site of accumulation. Since



the application of chlorflurenol most likely inhibits the auxin transport out of the ovary, the movement of nutrients especially Ca^{++} is prevented from moving into the fruit. Naphthalene acetic acid application resulted in significantly higher Ca^{++} and K^+ accumulation in the fruit than by chlorflurenol, thus supporting the hypothesis. Bangerth (1976) also observed low calcium content and calcium deficiency in artificially induced parthenocarpic fruits treated with auxin transport inhibitor. As the fruit auxin content was not analyzed for its quantity under different treatments transport of auxin seems to play more important role in restricting Ca^{++} and K^+ uptake by chlorflurenol as inhibitor of auxin transport rather than the amount of auxin in the fruit.

SUMMARY

Effects of different nitrogen and plant population rates on gynoecious, parthenocarpic pickling cucumber, MSU 41X581, were studied in a factorial field trial. Four nitrogen rates (0, 50, 100 and 200 kg/ha) were applied as main plots. Three plant populations (75,000; 150,000; and 300,000/ha) were maintained as subplots by thinning after emergence.

Plant population had a significant influence on the yield of cucumber by producing a large number of small size, more valuable fruits. However, fruits/plant were decreased by increased plant population. There was no effect of plant population on fruit quality such as, firmness, L:D ratio and percent cull fruits. High plant population decreased the composition of K, Ca, Mg, Fe, Zn and Al in the leaves and had no effect on N, P, Na, Mn, B and Cu content.

Nitrogen rates had no effect on fruit yield and quality. The content of N, Ca, Na, and Mn was increased by increased N application, whereas, P content was decreased with no effect on K, Fe, F, Cu, Zn and Al content. Nutrients like N, P, K, Fe and Al decreased through the season, whereas, Ca, Mg, Na, B and Zn increased in the leaves of cucumber. There was no effect of developmental stage of the plant for Mn and Cu content in the leaves. Dry weight, Ca^{++} and K^+ in the fruits were more when treated with NAA rather than chlorflurenol. There was no effect on Mg^{++} content.

In the conclusion, the gynoecian parthenocarpic pickling cucumber responded similar to the seeded cultivars. Plant population had positive response over the yield, making it possible to go for even higher plant population. Nitrogen had very little effect on this type of cucumber as



was the case with seeded ones. Chlorflurenol seemed to increase misshapen fruits by blocking the nutrient uptake by the ovary.



APPENDICES



Appendix 1.

The effect of plant population on cucumber fruit pressure by size grade.

Plant Population (1000/ha)	Fruit Pressure ^{1/} (lbs. force)	
	2A	2B
75	22.13	23.75
150	22.22	23.07
300	22.13	22.79

^{1/}Mean values of 5 fruits in each size grade.



Appendix 2.

The effect of plant population on length and diameter ratio of cucumber fruits by size grade.

Plant Population (1000/ha)	Length:Diameter Ratio ^{1/}	
	2A	2B
75	2.53	1.88
150	2.50	1.92
300	2.50	1.94

^{1/} Mean values of 5 fruits in each size grade.

Appendix 3.

The effect of nitrogen fertilization on the length:diameter ratio of cucumber fruits by size grade.

Nitrogen Rate (kg/ha)	Length:Diameter Ratio ^{1/}	
	2A	2B
0	2.5	1.9
50	2.5	1.9
100	2.4	1.9
200	2.5	1.9

^{1/} Mean values of 5 fruits in each size grade.



Appendix 4.

The effect of nitrogen X plant population on the content of copper (PPM) in cucumber leaf tissue at 5-7 flowering stage (2nd stage of sampling).

Nitrogen (kg/ha)	Plant Population ^{A/} (1000/ha)		
	75	150	300
0	6.30 ^{1/}	5.55	4.58
50	5.78	6.22	6.06
100	5.28	5.92	5.86
200	6.04	5.79	5.51

^{1/}The LSD_{.05} for comparing means in the same column is .95 and in the same row is .85.

^{A/}Means of 10 random leaves/plot. Sample analyzed in triplicates.



Appendix 5.

The effect of nitrogen X plant population on the height of the cucumber plant (cm).

Nitrogen (kg/ha)	Plant Populations ^{A/} (1000/ha)		
	75	150	300
0	82.2 ^{1/}	74.6	73.9
50	80.9	102.5	94.7
100	77.0	81.2	101.3
200	84.4	76.7	78.2

^{1/}The LSD_{.05} for comparing means in the same column is 27.4 and in the same row is 16.0.

^{A/}Mean values are average of 5 random plants per plot.

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