HORTICULTURAL ASPECTS CONCERNED WITH THE PRODUCTION OF PICKLING CUCUMBERS FOR ONCE-OVER HARVEST

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OF PICKLING CUCUMBERS FOR ONCE-OVER HARVEST

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AN ABSTRACT

Submitted to
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The survival of the pickling cucumber industry in Michigan may depend 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.

This study explored the possibilities of growing and harvesting cucumbers in a once-over manner similar to the present systems used for peas and beans.

The flowering and fruiting characteristics of a monoecious and a gynoecious variety were observed for 2 growing seasons. These varieties produced large indeterminant vines and developed only 1-4 marketable fruit at one time.

Two successive crops of cucumbers were grown and harvested on the same land in 1961 and 1962. Spring plantings yielded much higher than plantings made after June 20 because of unfavorable environmental conditions in late summer.

Several plant population and spacing experiments were conducted during both growing seasons. High plant populations of up to 43,560 plants per acre resulted in higher once-over harvest yields. Plants spaced 1 foot apart in the row yielded higher than those spaced 6 inches apart reguardless of the plant population.

Inhibition of further fruit development exerted by the fruit previously set was a major factor limiting concentrated cucumber fruit production. Growth measurements indicated that normally developing fruit increase in size rapidly from the third to the seventh day after pollination. Inhibited fruit develop similarly until the third day after pollination, when the inhibition is manifested. No further increase in size results until the previously set fruit are removed.

Another phase of this study involved the evaluation of growth regulator sprays as a means of increasing the number of fruit per plant. Several types of growth regulator sprays were applied to plants at various stages of growth, both in the field and greenhouse. It was concluded that these chemicals were not consistently effective in increasing once-over harvest yields of pickling cucumbers.

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INTRODUCTION

Michigan is the leading state in production of pickling cucumbers. In 1962, approxiamately 22,500 acres with a farm value of nearly 6 million dollars were harvested. This compares with a 10 year average (1951-1960) of 34,920 acres with a farm value of about 5 million dollars. Harvested acreage for the entire United States in 1962 was about 102,000 acres with a farm value of 21.7 million dollars (2).

At the present time, pickling cucumbers are harvested by hand. In Michigan the majority of the harvesting is done by migrant laborers, 65% of whom are Mexican Nationals (58). In the past, laborers have been paid on a crop share basis, but in 1962 a new government regulation was established setting a $1 per hour minimum wage for Mexican Nationals. This action resulted in labor costs to farmers as high as 75% of the value of the crop, compared to a cost of about 50% of the value under the previous system (57). The unfavorable economics of harvesting, along with an uncertain supply of labor and problems of recruiting, transporting, and housing, has resulted in a search for mechanical means of harvesting cucumbers.

All successful mechanical harvesters used for horticultural crops operate on a once-over or destructive harvest basis. The cucumber, unlike many other crops, does not develop a large number of marketable fruit at one time. In a once-over harvest operation, concentrated fruit set is necessary to produce profitable yields.

In the past 10 years, several investigators have carried on research with mechanical cucumber harvesters and harvesting aids using a multiple-harvest approach. A research program to study mechanical harvesters was initiated at Michigan State University in 1957. Stout and Ries, and Bingley (5, 56) evaluated several machines and built an experimental harvester using several promising components. In 1961, after several years of disappointing performances, these researchers decided to evaluate the possibilities of a once-over harvest system for cucumbers.

This study explored the problems concerned with the once-over harvest system.

REVIEW OF LITERATURE

TAXONOMY AND MORPHOLOGY

The cucumber, Cucumis sativus L. is a member of the family Cucurbitaceae which contains about 90 genera and 700 species. Members of this family are frost susceptible herbs with a tropical or sub-tropical origin. The genus Cucumis contains about 30 species of trailing or climbing annuals and perennials which are generally monoecious (3). Species of the genus Cucumis that are grown commercially as annuals are: C. sativus L., the cucumber; C. melo L., the muskmelon; and C. anguria L., the gherkin.

Cucumis sativus L. is characterized by an extensive prostrate vine with several lateral branches. The root system is also extensive and consists of a long tap root which may extend several feet into the soil with widely spread branch roots. The leaves are usually three-lobed, the middle lobe being large and pointed. Tendrils, which are defined as "an outgrowth of the bud axis", may occur at each node. The flowers are borne in the axil of each leaf, the staminate flowers often occurring in clusters and the pistillate flowers usually appearing singularly. Hermaphroditic flowers may occur in some cultivars. The fruits are triloculate pepoes, quite varible in shape with numerous spines or hairs (3, 19).

Cucumber varieties for pickling purposes have been selected for several characteristics. Among these are: High yielding plants, disease resistant plants, firm fruit, black spined fruit, and fruit with desirable shape and color for processing.

FLOWERING BEHAVIOR OF CUCUMIS SATIVUS L.

Most of the cultivars of Cucumis sativus L. are monoecious. Shifriss (50) has summarized the various types of sex expression as follows:

monoecious- plants bearing both staminate and pistillate flowers on the same individual.

gynoecious- individuals bearing exclusively pistillate flowers.

heraphroditic- individuals bearing exclusively perfect flowers.

andromonoecious- individuals bearing staminate and perfect flowers on the same individual.

An androecious or all-staminate category was included by C. and H. Yampolsky (71) but Shifriss denied the existence of a true genetically male cucumber plant. Cultivars grown commercially are of the monoecious or gynoecious type.

Many investigators have studied the flowering behavior of monoecious cucumbers. Heimlich (26) reported that the first staminate inflorescence is likely to occur in the first or second leaf axil, and may continue to develop in many leaf axils throughout the life of the plant. Several primordia may be laid down in each leaf axil so that the flowers are borne in clusters. Judson (34), in a morphological study of pistillate flower formation, observed that the first primordia occurred several nodes from the cotyledonary node.

Emerson (18) noted a sequence of phases in monoecious plants which became increasingly pistillate. Currence (13) later observed that as the distance from the base of the stem increased, the percentage of female flowers increased. He stated that the cucumber, during development, changed from a strongly staminate condition to a strongly pistillate condition. He also noted that the laterals were more pistillate than the main axis. Nitsh et. al. (43) reported essentially the same phenomonen in Cucurbita pepo L.. However, the first flowers formed were underdeveloped staminate, followed by several progressive stages ending in the formation of pistillate flowers which develop parthenocarpically. These observations indicate that the typical monoecious plant goes through 3 phases; a staminate phase, a monoecious phase, and a pistillate phase.

Edmund (17) discussed the possible effect of staminate-pistillate ratios on yield. He concluded that excessive production of either flower type could result in losses to growers.

FACTORS AFFECTING SEX EXPRESSION

Tiedjens (61) and Emerson (18) both concluded from their observations that sex expression is a result of genetics and environment. In 1961, Wittwer and Bukovac (8) stated "flower sex expression in the cucumber is subject to genetic, environmental, and chemical control."

Genetic factors

Extensive studies have been and are being conducted concerning the genetics of sex expression in Cucumis sativus L.. It is generally agreed that several hereditary factors are involved, however, there is still much to be learned. Evidence has been presented which indicates that two major genes and a complex of polygenes are present (21). Shifriss (52) stated at least 3 groups of factors are involved. "A few qualitative genes determine the type of flowers which can be differentiated; polygenes govern the formation of a substrate which channels the expression of the genes for different kinds of flowers; an accelerator gene speeds up the rate of physiological processes controlled by the polygenes." Non-genetic factors may also affect the substrate which channels the action of the genes.

Gynoecious plants have been discovered in several Japanese and Korean races of cucumbers (37). Tkachenko (62) reported that "femaleness" and "maleness" are controlled by a pair of genes, and that "femaleness" is dominant. In 1960, Peterson (44) described a technique for breeding F_1 hybrid gynoecious cucumbers. A homozygous gynoecious line (MSU 713-5) was produced by crossing a gynoecious segrate found in the Korean race Shogoin and the pickling variety Wisconsin SMR-18, described by Walker (63). Gynoecious varieties have shown promise for increased yields and earlier and more concentrated fruit set.

Environmental factors

In 1884, Heyer (28) noted that the staminate to pistillate ratio could be altered by environmental factors. Many investigators have studied the effects of temperature and photoperiod using both variables in the same experiment.

Edmund (16) grew several varieties in 3 different seasons and concluded that the number of pistillate flowers increased with a decreasing length of day. During the short days of winter, pistillate flowers often occurred in clusters at each node. Nitsch *et. al.* (43) reported that high temperatures and long days tend to keep the vines in a staminate phase, whereas low temperatures and short days speed up the pistillate phase. They were able to induce parthenocarpic pistillate flowers in some varieties by exposure to short days and cool nights, and indicated that perhaps the night temperature was the more important. Shifriss and Galun (53) using several continuous plantings found a continuous increase in the number of staminate nodes preceding pistillate nodes from May to August. May plantings had 7 staminate nodes preceding pistillate nodes and August plantings had 16. Researchers in India also confirmed these results (11). Japanese workers obtained similar responses by altering temperatures and photoperiod and indicated that the period from 10-30 days following germination was the most critical in determining sex exression (32). It was concluded that environmental factors change physiological conditions of the plant before flower differentiation. Under a given set of environmental conditions, the number of nodes from the cotyledonary leaves to the first pistillate flower was found to be quite constant within a variety (53).

Nitrogen levels have been found to alter sex expression in the cucubits. Dearborn (15) reported that plants with a high nitrogen supply produced more pistillate and fewer staminate flowers than those with low nitrogen. Hall (25) confirmed these results using Cucumis anguris L. and obtained the response regardless of photoperiod. Miller (38) reported that both pistillate and staminate flower production was increased but the staminate to pistillate ratio was decreased when high nitrogen levels were maintained.

Chemical factors

In recent years much work has been accomplished on altering the flowering of cucurbits with growth regulating chemicals. The chemicals studied have been of two types, those which favor the development of pistillate flowers and those which favor the development of staminate flowers. Several researchers have reported the effects of indole-3-acetic acid and related compounds on flowering of cucumbers under greenhouse conditions (11,31,33,46). Papers were published in the early 1950's stating that Indoleacetic acid (IAA) and Napthaleneacetic acid (NAA) applied to the foliage as a spray or in lanolin paste would favor the formation of pistillate flowers (31). Researchers in India were able to obtain the same response by spraying IAA and NAA in the field (11,46). Wittwer and Hillyer (29) found that foliar sprays of 2,3,5-TIBA at 25ppm increased the number of pistillate flowers and decreased the number of staminate flowers. Yield increases of up to 30% were later reported when .0025% 2,3,5-TIBA was sprayed on greenhouse cucumbers (47). In 1957, Heslop-Harrison (27) concluded that sex expression is regulated by the level of growth substances present during flower development, and that the higher level favors pistillate flower formation. Galun (20) conducted extraction studies and could not find this difference in auxin levels, however, a higher concentration of growth inhibitor was extracted from the old leaves of strongly male plants.

Other chemicals have been shown to speed up the pistillate phase. In experiments with Cucurbita pepo L. variety Acorn, maleic hydrazide applied as a foliar spray completely suppressed staminate flower formation (66). In 1960, the quarternary ammonium compounds, 2-chloroethyltrimethyl ammonium chloride and others were shown to exhibit several effects on plants (68). Mitchell (41) studied the effects of several quartenary ammonium compounds on flowering. Many of the chemicals, when applied to aerated solution cultures, exhibited the ability to induce the pistillate condition more rapidly. Allytrimethylammonium bromide at 5 x 10^{-4}M proved most effective in increasing pistillate flower formation on several varieties of Cucumis sativus L., but also resulted in a marked suppression of vegetative growth.

Galun (20) was able to neutralize the effects of NAA by using it in combination with Gibberellin A_3. During the past 15 years, several papers have been published concerning the effects of Gibberellins on Cucurbits. Wittwer and Bukovac (67) reported that Gibberellin increased the number of staminate flowers preceding the first pistillate flower in two monoecious varieties of cucumbers. Gibberellin A_3 at 10^{-3} molar applied to the root media was found to cause reversion from pistillate to staminate up to the tenth nodes in gynoecious cucumbers (41). In a breeding program involving the selfing of gynoecious plants, staminate flowers were induced by Gibberellin A_3 at 1500ppm applied as a foliar spray (44,45). Two or 3 weekly applications were made beginning when the plants were in the second true-leaf stage. In 1962, the order of activity of the most active Gibberellins on staminate flower induction on gynoecious cucumbers was reported as $A_7 > A_4 - A_2 > A_9$ (69).

Other factors affecting flowering

Tiedjens (61) in 1928 observed that the presence of developing fruit exerted an inhibitory effect on further vegetative development and production of pistillate flowers. An increase in pistillate flower formation has been obtained by defloration and by preventing pollination of flowers (36). It was later reported from experience with several plant species, that flower buds often abscise before anthesis on plants which have produced fruit heavily (42). The number of flowers produced was greatly enhanced by disbudding, defloration, and defruiting, the greater effect being derived by disbudding.

Galun (22), in a defoliation experiment, observed that the removal of young leaves diminished the female tendancy, and the removal of mature leaves diminished the staminate tendancy. He reasoned that this response was obtained because young leaves are active in producing growth substances, whereas mature leaves are acting in destroying them or counteracting their effect.

FACTORS AFFECTING FRUIT DEVELOPMENT

Environmental factors

Temperature is a critical factor determining fruit set as it has been shown to affect anthesis, anther dehiscence, nectar secretion, and pollen germination (50,51). Temperatures of about 60°F. are required for anthesis to occur. If the day before anthesis would normally occur is below 60°F., the maturity of the blossom is delayed and a higher temperature following is necessary for both anthesis and dehiscence (51). Dehiscence and nectar secretion have been reported to start at about 62°-63°F. and to reach an optimum at temperatures between 65° and 70°F.. Germination of pollen will not occur at temperatures below 70°F. and the optimum has been reported as 80°-85°F. (50). Miller (38) reported that night temperatures of 60°F. produced fruits with a higher length to diameter ratio than those grown at a night temperature of 70°F.. It is generally agreed that high temperatures are favorable for rapid growth, which results in higher quality fruits.

Pollination is necessary for fruit set and development of high quality fruit, except in a few unique varieties which naturally set fruit parthenocarpically. It has been reported that when flowers were not pollinated, 94% aborted and that poor pollination results in many "crooks" and "nubbin" fruit (50). Since pollen of cucumbers is rather sticky, natural pollination must be accomplished by insects (4). The most important insect responsible for pollination is the honey bee (*Apis mellifera* L.) which collects nectar from pistillate flowers. A higher percentage of fruit set has been obtained with the use of bees than has been obtained with hand pollination.

Chemical factors

Several investigatiors have attempted to set cucumber fruit parthenocarpically with growth regulators. Wong (70) reported that napthaleneacetic acid at 1% applied to the cut style cap or as a .01% aqueous solution applied to the stigma was effective in setting fruit parthenocarpically, Gustafson (23) tried several chemicals and failed to obtain fruit set in cucumbers with all except NAA. However, only 3% of the NAA treated buds were set. Some other Cucurbits responded more favorably (9,12,23). Researchers in India applied two foliar sprays of gibberellin at 10ppm during the 1-2 leaf stage and during the 3-4 leaf stage. The first pistillate flowers formed had giant ovaries and developed parthenocarpically at a more rapid rate than normally fertilized fruits on the control plants (11). In general, inducements of parthenocarpy in *Cucumis sativus* L. by chemicals has not been successful, although success has been reported with other many-seeded fruits (23).

Other factors

Several other factors, because of their effect on growth and development of the cucumber plant have an indirect bearing on fruit production. Kotowski (35) conducted extensive experiments on seed germination and observed that cucumber seed seldom germinates at soil temperatures below 52°F.. The optimum was found to be 75°-85°F.. Seaton and Kremer (50) planted cucumbers in two different soil temperature environments with the air temperature identical. After 30 days, plants in soil at 60°F. were only 5 inches high whereas plants in soil at 85°F. were 30 inches high.

Optimum temperature for plant growth has been reported as 65°-75°F. (4). High temperatures and high humidity are favorable conditions for the development of many foliage diseases. Since these conditions persist in the south, the more susceptible black-spined pickling cucumbers cannot be grown successfully there.

Sunlight has been shown to be a limiting factor in the growth of greenhouse cucumbers during the winter months (60). When light intensity is low (100-1500 foot candles), the rate of photosynthesis is almost directly proportional to light intensity providing no other factors are limiting (54). A plant may remain alive for long periods of time if enough photosynthesis occurs to balance the 24 hour respiratory loss, but no growth will occur (7). Most plants which thrive in the sun require a minimum of 400-500 foot candles for maintenance and grow increasingly better at intensities up to 2500 foot candles. Higher intensities have no increased benefit.

Improved plant growth has been reported from additional carbon dioxide added to the atmosphere. Bolas (6) reported increases in the growth of cucumbers in small enclosures by addition of carbon dioxide. Increases in fresh and dry weights and number of fruits developed were obtained by Hopen (29) when the atmospheric carbon dioxide level was increased.

Adequate soil moisture is necessary for maximum growth and yields. Excessive moisture at time of germination may expedite damping off (50). The rate of water absorption by roots in soils at 60°F. is about one-fifth that by roots in soils at 85°F. when the air temperature are equal.

Tiedjens (60) reported that although there is adequate water in the soil, cucumber plants may wilt because of improper soil structure or poor soil-root relationship. During dry periods, water may become a limiting factor in growth, therefore irrigation may be beneficial.

Miller et. al. (39) reported that pickling cucumbers are quite responsive to small application of fertilizer but may be easily injured by it. Many researchers have studied fertilizer requirements for different soil types under several environmental conditions. Specific needs vary considerably from soil to soil. Ries and Carolus (49) were able to obtain yields of over 400 bushels per acre on above average fields when 20 pounds of nitrogen, 160 pounds of phosphate and 80 pounds of potash were added. Side dressings of nitrogen have proven effective on low fertility soils (1,65). Most researchers agree that well drained sandy loam soils of 5.5-6.5 are best for pickling cucumber production (4).

Generally it is agreed that nitrogen is most often the important limiting nutrient factor in the growth of cucumbers. Dearborn (15) reported that plants receiving low nitrogen grew more slowly and produced fewer and smaller fruits than those getting liberal nitrogen applications. It has also been reported that conditions which prevent plants from absorbing nitrogen from the soil result in the production of poorly shaped fruits (60). The effect of nitrogen on flowering has been discussed.

Several researchers have reported the apparent inhibition of growth of cucumber plants by the developing fruit. Tiedjens (61) noted that varieties differ in their capacity to develop a number of fruits at one time. He theorized that simultaneously fertilized flowers developed equally well, but that less advanced ones were arrested in their development. The inhibition phenomonen was also reported in Citrullis (12) and in Cucumis melo L. (9) to the extent that after the "crown set" the next series of flowers to appear absissed until finally another cycle of fruit setting occurred.

Fertilization (gametic union) has been shown to exert a stimulatory effect on vegetative growth for a short period of time. Inhibition continues until the seed coats of the developing seeds begin to mature (64). Most researchers believe that the developing fertilized ovaries produce a growth regulating substance which has a dominating influence on growth and further development of the plant (15,36,64).

Several experiments using varying plant population have been conducted. Mississippi workers have found that higher yields were obtained when plants were spaced 7.5 or 15 inches apart compared to 30 or 45 inches (1). It was also noted that more fertilizer was required to supply the larger number of plants. Ries (48) obtained increased early yields with close spacings in a 4 year study. It is generally agreed that crop plants should be distributed in such a manner so that the maximum area per plant leaf is exposed to sunlight, and that roots do not compete for moisture and nutrients (54).

Many other factors may affect the growth and subsequent fruit development of pickling cucumbers. Among these are insect and disease damage, damage from the wind, lightning and hail, and weed competition. High yields are dependent upon vigorous growth throughout the season.

THE EVOLUTION OF CUCUMBER HARVESTERS

California researchers (24) reported in 1956 that a harvesting aid which was constructed by a grower was effective in reducing harvesting time by one-half over regular hand picking. The device consisted of a motor driven vehicle with platforms extended on either side. The pickers lay prone on the platforms and harvested onto a conveyer as the vehicle moved slowly through the field. Harvesting aids have been used with only varying degrees of success and still involve a large labor force.

Stout and Ries (56) initiated a study of multiple-pick cucumber harvesters in 1957. At that time, several patents for harvesters had been issued and several machines had been developed. Extensive tests were conducted using the existing machines and an experimental harvester built at Michigan State University (5). The performance of all machines tested was not consistant enough to label any one unit successful. Problems encountered with multiple-pick harvesters as listed by Stout et. al. (57) are as follows:

a. Accumulative damage to plants with resultant decrease in yields.

b. Inadequate mechanical components for removing fruit set near the base of the plant.

c. Inability to remove and retrieve all the marketable fruit from certain commerical varieties.

d. Lower yields because of wide row spacing required by machine.

e. Pulling of plants from the soil when vine growth is luxuriant or anchorage poor.

f. Small acreage capacity for a machine because of the necessity of repeatedly harvesting the same plants.

In 1961, studies began on the development of a once-over harvester. Delong (16) tested several mechanisms for removal of fruit from the vine. A component consisting of two flat rubber belts arranged on parallel rollers was successful in removing a high percentage of fruit.

Feasibility studies based on production costs of $50 per acre and predicted costs of 3 different types of once-over harvesters show that it will be necessary to harvest at least 100 acres of cucumbers per season with a machine costing no more than $6,000 (57). Once-over yields of at least 70-80 bushels of high grade fruit will be necessary to make once-over harvesting feasible.

STATEMENT OF THE PROBLEM

Since all successful harvesters for horticultural crops operate on a once-over harvest basis, and since a multiple harvest approach has not proven feasible, a study of once-over harvesting of cucumbers was initiated.

The objectives of this research were to study the basic horticultural problems encountered in once-over harvesting, to evaluate methods of increasing yields, and to determine the feasibility of this system with the present varieties. The following factors were studied:

a. The flowering and fruiting characteristics of a monoecious and a gynoecious variety.

b. Successive plantings throughout the growing season and the possibility of 2 crops in the same year.

c. Plant populations and spacings as they affect yields.

d. Fruit inhibition as a major factor limiting yields.

e. An evaluation of growth regulators as a means of increasing fruit set and yield.

MATERIALS AND METHODS

During the 1961 season, the experimental plots were located at the Michigan State University Horticulture Farm on a Wauseon fine sandy loam soil. In 1962, the plots were located at the Michigan State University Forestry Nursery on a Hillsdale sandy loam soil.

Prior to planting, 500 pounds per acre of 12-12-12 analysis fertilizer was broadcast and disked into the soil. On plots where successive plantings were made, an additional 300 pounds per acre of 12-12-12 was broadcast and disked in prior to planting the second crop. Late plantings also received a side dressing of 200 pounds per acre of ammonium nitrate applied when the plants were at the 2-3 true leaf stage. Irrigation was applied as needed during both growing seasons.

Each plot was 25 feet in length with guard plants at both ends of the row. All harvests were destructive or once-over harvests. The plants were pulled from the soil by hand and all of the marketable and cull fruit removed. The fruit were weighed and counted and then graded on a portable grader with openings corresponding to the various grade sizes. Yield data were converted to bushels and dollars per acre and fruit per plant. The fruit grades and values for both years were as follows:

Grade		Size (inches)	Value per 100 pounds (dollars)	
1961	1962		1961	1962
1	1	up to $1\frac{1}{16}$	5.00	6.00

Grade		Size (inches)	Value per 100 pounds (dollars)	
1961	1962		1961	1962
2	2	$1\frac{1}{16}$ - $1\frac{1}{2}$	2.00	2.50
3	3	$1\frac{1}{2}$ - 2	1.00	1.25
oversize	4	greater than 2	----	.50
culls	culls	crooked, nubbin or yellow fruit	----	----

Seed of the gynoecious hybrid variety Spartan Dawn, which was used in all experiments, contained 10 percent monoecious pollen parent to assure an ample supply of pollen. These plants were included in the yield records but were not observed for flowering and fruiting characteristics.

Data were statistically evaluated by analysis of variance and mean differences were compared by the least-significant difference and Duncan's multiple range tests.

I. <u>Successive planting studies</u>

Six successive plantings were made in 1961 in which several factors were studied. The plots were seeded on May 24, June 5, June 26, July 24, August 2, and August 10. The 3 later plantings followed earlier plantings on the same plot. After harvest, vines from the preceding crop were allowed to dry out for 2 days and fertilizer was then broadcast and disked in with the vines.

The plots were arranged in a split plot design, the order of randomization being varieties, spacings, and harvests. Each treatment was replicated 3 times. The varieties Spartan Dawn and Wisconsin SMR-18 were planted in 3 harvest rows spaced 5 feet and $2\frac{1}{2}$ feet apart. Guard rows were planted between each block and bordered the entire plot. After emergence the plants were thinned to 6 inches apart in the 5 foot rows and 1 foot apart in the $2\frac{1}{2}$ foot rows to give equal plant populations Four plants from each replicate were selected and the flowering sequence was observed at 2-3 day intervals until harvest.

The first harvest was conducted when a few fruit were $1\frac{1}{2}$ inches in diameter. The second and third harvest rows were taken at 2-3 day intervals following the first harvest.

In 1962, 7 successive plantings were made to establish a sequence of harvests throughout the entire season. The criteria used to determine the time of planting was the time when the first true leaf of plants from the preceding planting had begun to enlarge. The plots were seeded on May 17, May 25, June 8, June 19, June s9, July 10, and July 20. The 2 later plantings followed earlier plantings on the same plot.

A split plot design was employed with the order of randomization being varieties, spacings, and harvests. Each treatment was replicated 4 times in the first 3 plantings and 2 times in the last 4 plantings. The varieties Spartan Dawn and Wisconsin SMR-18 were planted in 2 harvest rows spaced 4 and 2 feet apart. After emergence the plants were thinned to 6 inches and 1 foot apart in the row to give equal plant populations with each spacing.

The June 8 planting was employed to determine if higher yields could be obtained from the second picking than were obtained from the first picking. Marketable fruit were removed from the intact vines instead of employing a destructive harvest. Four days later the second harvest was made by pulling the vines in the usual manner.

Plants from the guard rows of each variety were harvested and the node position of the fruit was recorded. The percent of fruit occurring at each node was calculated.

II. Plant population studies

In 1961, 3 spacing trials were planted on June 5, July 26, and August 7. The plot design was a split plot with the order of randomization being variety, spacing, and harvest date. Each spacing was replicated 2 times within each variety. The plots were seeded in rows 4, 2, and 1 foot apart with a V-belt seeder using the varieties Spartan Dawn and Wisconsin SMR-15. Three harvest rows were included in each spacing block with guard rows planted between blocks as shown in Figure 1. After emergence the plants were thinned to give spacings of $4 \times \frac{1}{2}$, $2 \times \frac{1}{2}$, 2×1, and 1×1 feet.

Four plants in each replicate were selected at random for flowering observations. The number of pistillate flowers produced on plants at each spacing was recorded at 3-4 day intervals. The time of harvest was determined as described in the preceding study.

In 1962, a spacing trial was planted on May 28 using the varieties Spartan Dawn and Wisconsin SMR-18. The plot design was similar to that used in 1961. The spacings used were 3×1, $3 \times \frac{1}{2}$, 2×1, $2 \times \frac{1}{2}$, 1×1, and $1 \times \frac{1}{2}$ feet.

III. Inhibition and pollination studies

In 1961, the guard rows of the spacing trials were used as a source of plants for other studies. A study of the inhibition of further fruit enlargement by the fruit previously set was initiated with the May 24 planting. Six plants from each of 4 guard rows were selected at random and observed as follows. On July 19, the number of marketable fruit on each plant was recorded and the plants were divided into 2 groups. The marketable fruit were removed from 1 group of plants and no fruit were removed from the other group. After 7 days, the number of marketable

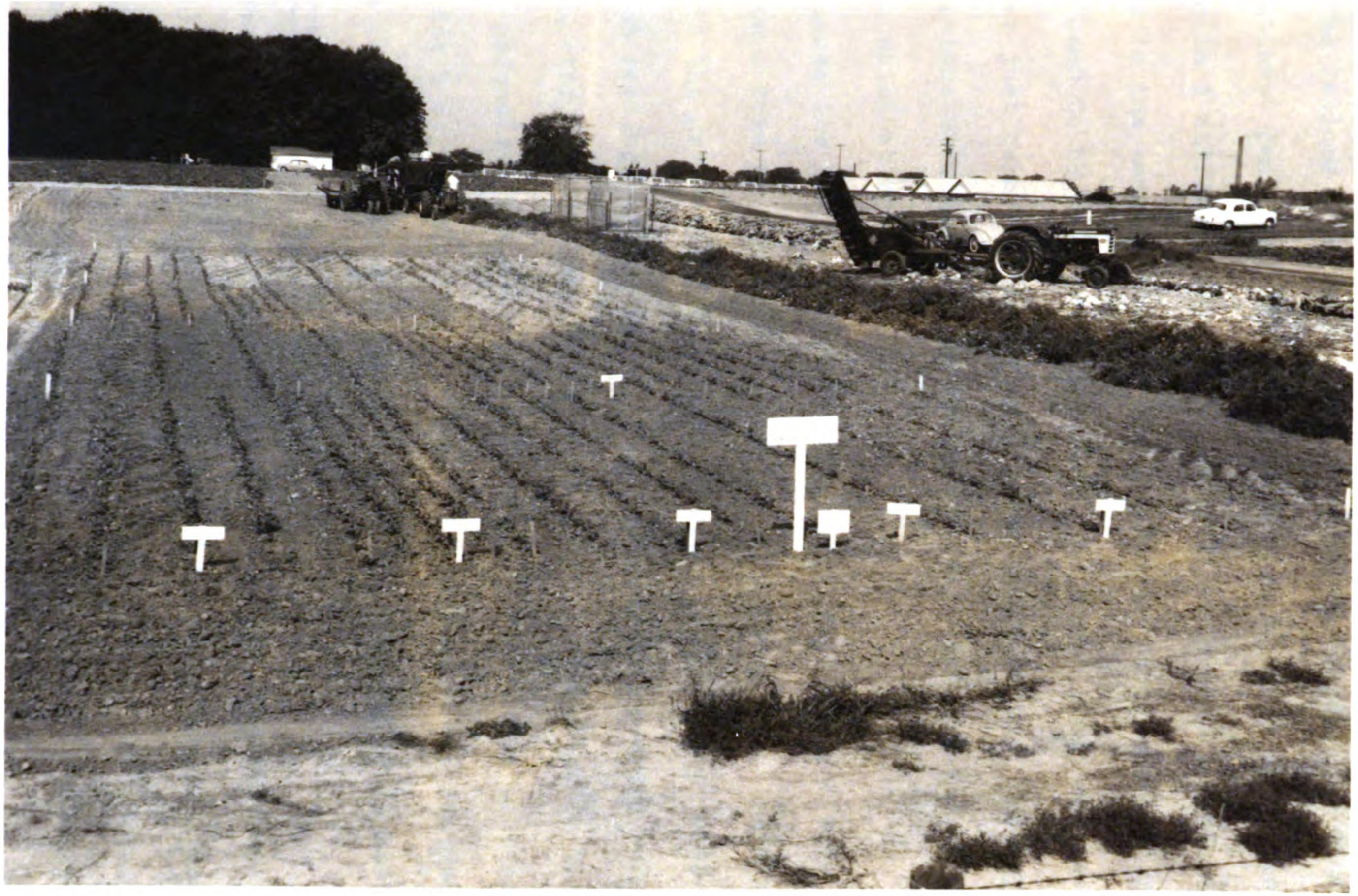

Figure 1. 1961 spacing trial for once-over harvest showing the plot design and the spacings used. From left to right; 2 x 1, 1 x 1, 2 x $\frac{1}{2}$, and 4 x $\frac{1}{2}$ feet.

fruit on both sets of plants was recorded.

Plants in the guard rows of the June 5 planting were used in an attempt to determine if a real inhibition from the enlarging fruit existed, or if the failure of more fruit to develop was merely due to a lack of pollination. Ten pistillate flowers from each of 3 replicates were treated in 3 different ways. The control group was allowed to be pollinated in the usual manner by bees. Another group was hand pollinated and allowed to be pollinated by bees. The third group was covered with capsules just before anthesis to prevent pollination. Ten days later observations were made on the number of fruit set and the number of ovaries which aborted.

Plants for the fruit growth study conducted in 1962 were selected from guard rows of the June 8 planting of Spartan Dawn. Ovary measurements to the nearest tenth mm were made on 10 flowers at anthesis with a direct reading caliper gage.[1/] The measurements recorded were the greatest diameter, and the length from the base of the calyx to the junction of the peduncle. The ovaries of 25 pollinated flowers were measured daily for 7 days after pollination. The data were transformed into volume (cm^3) assuming a cylinder as the approximate fruit shape.

IV. Evaluation of growth regulators

Two replicated experiments and a non-replicated test were conducted in 1961. On May 17, 2 variety blocks of Spartan Dawn and Wisconsin SMR-18 were planted in rows 5 feet apart. After emergence, the plants were thinned to approximately 6 inches apart in the row. Treatments were laid out in a randomized complete block design with 3 replicates for

1/ Federal Products Co., Providence, Rhode Island.

Wisconsin SMR-18 and none for Spartan Dawn. Treatments were applied as foliar sprays when the plants were at the 2-3 true leaf stage. The chemicals were applied with a small plot sprayer using quart bottles as containers and carbon dioxide cylinders as a source of pressure. Tween-20 (.05%) was used as a wetting agent in all treatments and the leaves were sprayed to the point of run-off.

Three plants from each replicate were selected at random for observation. The number and position of pistillate flowers was recorded at 2-4 day intervals. Five plants were harvested from each plot when the first grade 3 fruit were observed.

The second planting was seeded in rows 4 feet apart on July 24, using the variety Wisconsin SMR-18. The plots were randomized as before with 3 replications, and the chemical treatments were applied on August 11, when the plants had 3 true leaves.

Since inconsistent results were obtained in 1961, another growth regulator test was conducted in 1962. Variety blocks of Spartan Dawn and Wisconsin SMR-18 were seeded in rows 4 feet apart on June 12. After emergence, the plants were thinned to 6 inches apart in the row. The treatments were arranged in a randomized complete block design with 3 replications. The chemicals were applied on July 2, when the plants were at the 2-3 true leaf stage. Three plants from each replfcate were chosen for pistillate flower observations. Yield records were obtained from 10 plants in each plot.

Another experiment was conducted in an attempt to increase fruit production. Six plots, 25 feet in length, were selected at random in a field of Spartan Dawn. Three replicates were sprayed with potassium gibberellate at 1000 ppm using Tween-20 (.05%) as a wetting agent, when the first flowers were opening (August 7). The remaining plots were designated as controls. Fifteen days later the fruit were harvested.

In the fall of 1962, a greenhouse study was initiated to determine if gibberellin applications might induce the development of parthenocarpic fruits. Seeds of the variety Spartan Dawn were sown in 50 6-inch pots on October 2. Five pots were also planted to the variety Minnesota Dwarf XII to assure an adequate pollen supply. The plants were maintained at a 65°F. night temperature with no supplemental light. Shortly after emergence, the plants were thinned to 1 plant per pot. Soluble fertilizer was applied weekly after the appearance of the first true leaf. The plants were staked and grown to the flowering stage. Forty uniform plants were selected and the first 2 pistillate flowers on each plant were treated. The treatments were arranged in a split plot design, the main plots being pollination vs. no pollination. A check and 3 gibberellin treatments were included in each pollination treatment, and each was replicated 5 times. Hand pollination was accomplished by detaching the staminate flowers, tearing back the petals, and rubbing the anthers over the stigma of the pistillate flowers. The non-pollinated flowers were covered with capsules at anthesis. The gibberellin treatments were executed the same day as the pollination treatments. Potassium gibberellate was applied by three different methods as follows:

a. Applied to the ovary in a ring of lanolin paste. (1 ml of 100 ppm solution in 10 ml lanolin)

b. Sprayed on the ovary with a hand atomizer (100 ppm).

c. Injected .05 cc into the ovary with a hypodermic needle (100 ppm).

Fruit set observations were made 7 days later.

RESULTS AND DISCUSSION

I. Successive planting studies

The flowering sequence data recorded from 12 plants of each variety in 1961, were summarized and from this an "average" plant was drawn for each observation date. Spartan Dawn produces only 1 or 2 staminate flowers under normal field conditions. The first pistillate flower may occur at the cotyledonary node and usually is not set. Pistillate flowers may occur at each succeeding node throughout the life of the plant (Figure 2). The variety Wisconsin SMR-18 goes through a staminate phase for the first 8 to 9 nodes, after which it becomes monoecious and remains so until harvest. The laterals produce chiefly pistillate flowers, the first of which usually become marketable fruit (Figure 3).

Two varieties showed distinctive differences in fruiting habit. The variety Spartan Dawn set a high percentage (80%) of its fruit along the main stem. The most concentrated region was from node 2 to 8. A large number of fruit also occurred on node 1 of the lateral branches. Wisconsin SMR-18 developed 69% of its fruit on laterals, 61% on node 1 of the laterals (Table 1). Fruit occurred on the main stem of this variety in the region of node 6 to 11, and this was rarely more than 1 fruit per plant.

In 1961, late season plantings produced dollar yields much lower than the earlier plantings (Table 2). This may be accounted for at least in part by the severe damage to the later plantings by angular leaf spot (10).

Two crops were grown to maturity on the same plot during 1 growing season. The latest planting to mature was made on August 2. A planting made on August 10 was destroyed by frost on September 29 about 5 days before maturity.

An average of 51 days was required from planting to the maxium harvest with a range of 47-57 days for the variety Spartan Dawn. Wisconsin SMR-18 produced its maximum yield on an average of 52 days from planting with a range of 48-60 days. The maximum yield usually occurred at the second harvest or about 2 days following the appearance of grade 3 fruit.

Plants spaced 1 foot apart in the row yielded consistently higher dollar per acre and fruit per plant yields than those spaced 6 inches apart at the same plant population (Table 3). There was no difference between varieties in the dollar yield per acre produced, although Spartan Dawn consistently produced more fruit per plant.

Bushels per acre was found to be an unreliable estimate of the actual yield especially when comparing a sequence of harvests in the same planting. High bushel yields are often misleading because of the prescence of many low grade fruit. The bushel yield, dollar yield, and grade changes in 3 successive once-over harvests of the same planting indicate dollar yield was a much more reliable figure because it considers not only the weight of the fruit, but also the grade and corresponding value (Table 4).

Seven plantings of cucumbers were successfully harvested in 1962. No statistical comparison of plantings could be made, but it was observed that the early plantings (May 17-June 19) yielded higher than the later plantings (Table 5). The average number of days from planting to the optimum harvest date with Spartan Dawn was 49 days, with a range of 46-

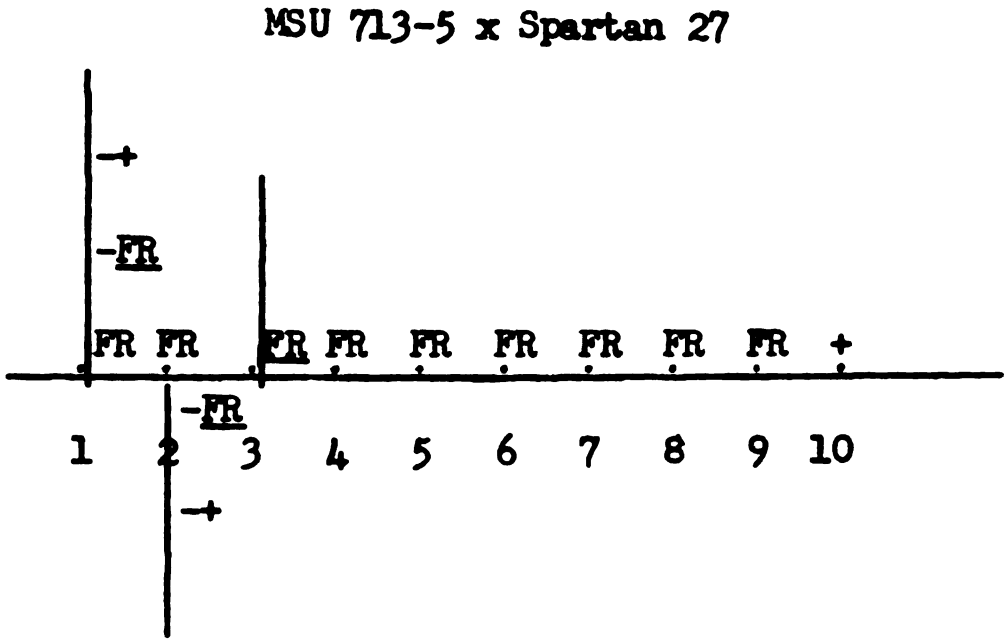

Figure 2. Flowering sequence and position of marketable fruit on a typical plant of the variety Spartan Dawn.

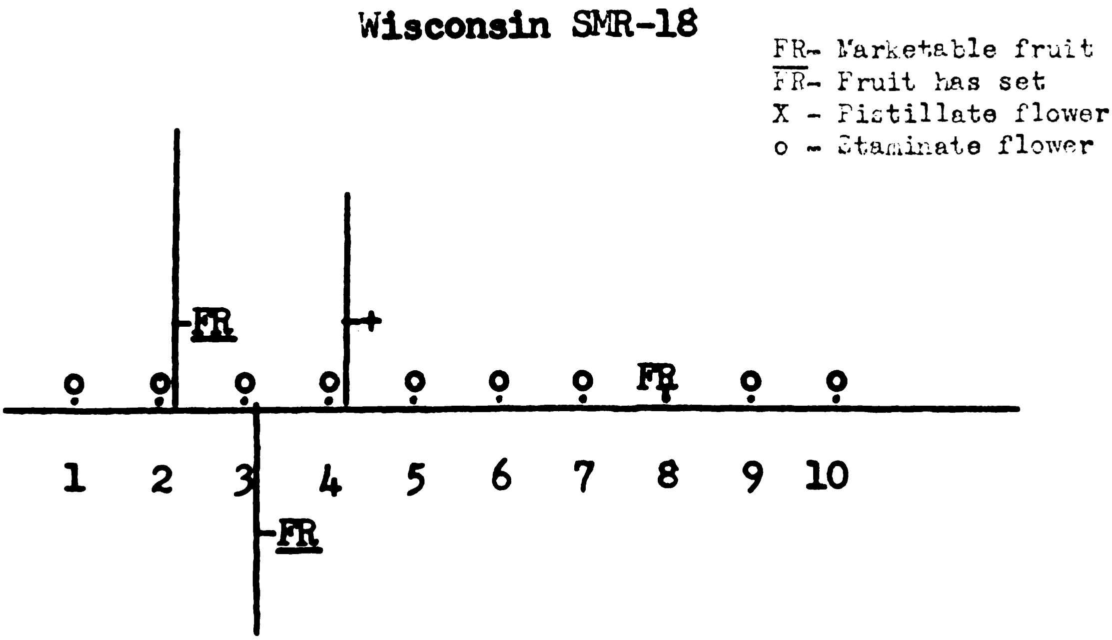

Figure 3. Flowering sequence and position of marketable fruit on a typical plant of the variety Wisconsin SMR-18.

Table 1. The position on the vine and percent of fruit occurring at each node of 2 varieties.[1/]

Main Stem	Spartan Dawn	Wisconsin SMR-18
Node		
1	0.6	0.2
2	7.7	0.6
3	12.5	0.2
4	11.9	0.4
5	13.7	0.6
6	15.4	2.2
7	8.1	5.7
8	5.9	8.3
9	2.4	6.9
10	1.8	3.2
11	0.2	2.8
Main Stem Total	80.2	31.1
Laterals		
Node		
1	16.0	60.7
2	3.0	6.5
3	0.4	1.6
4	0.4	0.1
Lateral Total	19.8	68.9

1/ Calculated from 1011 fruit harvested from 180 plants of each variety.

Table 2. Dollar yield per acre and number of days from planting to optimum harvest for 5 successive plantings (1961).

Crop	Date Planted	Variety	Harvested	Number of days	Dollar Yield 1/
IA	May 24	Spartan Dawn	July 21	57	131
		SMR-18	July 24	60	94
IIA	June 5	Spartan Dawn	July 28	52	104
		SMR-18	July 28	52	79
III	June 28	Spartan Dawn	August 18	50	70
		SMR-18	August 21	53	143
IB 2/	July 24	Spartan Dawn	September 11	48	59
		SMR-18	September 11	48	45
IIB 2/	August 2	Spartan Dawn	September 18	47	44
		SMR-18	September 20	49	38
Average		Spartan Dawn		51	82
		SMR-18		52	80

1/ This is with a spacing of $2\frac{1}{2}$ x 1 feet.

2/ Planted on the same plot after a preceding cucumber crop was removed.

Table 3. Dollar yield per acre and fruit per plant produced by 2 varieties grown at 2 different spacings (plant population 17,420). 1/

Varieties	Spacings (feet) $2\frac{1}{2} \times 1$	$5 \times \frac{1}{2}$	Average 2/
	Dollars per acre		
Spartan Dawn	63.8	43.0	53.4
Wisconsin SMR-18	63.3	32.8	48.1
Average	63.6	37.9	
	Fruit per plant		
Spartan Dawn	2.6	1.7	2.2
Wisconsin SMR-18	1.8	1.1	1.5
Average 3/	2.2	1.4	

1/ Average of all harvests.
2/ F value for varieties not significant.
3/ F value for difference between spacings significant at odds of 99:1.

Table 4. A typical harvesting sequence showing changes in bushels, dollars and grades (Spartan Dawn planted May 24).

Harvest	Bushels per acre	Dollars per acre	Grade (% by weight) 1	2	3	Oversize, culls
I (7/19)	37	46	23	61	16	-
II (7/21)	130	83	5	21	63	11
III (7/24)	254	67	2	10	30	58

Table 5. Dollar yield per acre and number of days from planting to optimum harvest for 7 successive plantings (1962).

Crop	Date planted	Variety	Harvested	Number of days	Dollar yield 1/
IA	May 17	Spartan Dawn	July 7	50	160
		SMR-18	July 9	52	141
IIA	May 25	Spartan Dawn	July 12	48	124
		SMR-18	July 16	52	169
III	June 8	Spartan Dawn	July 25	46	154
		SMR-18	July 30	51	154
IV	June 19	Spartan Dawn	August 6	48	172
		SMR-18	August 9	51	140
V 2/	June 29	Spartan Dawn	August 20	51	53
		SMR-18	August 22	53	56
IB 3/	July 10	Spartan Dawn	August 29	49	63
		SMR-18	September 1	52	72
IIB 3/	July 20	Spartan Dawn	September 13	53	35
		SMR-18	September 13	53	40
Average		Spartan Dawn		49	109
		SMR-18		52	110

1/ This is with a spacing of 2 x 1 feet.

2/ Hail on August 10 severely injured this and succeeding plantings.

3/ Planted on the same plot after a preceding cucumber crop was removed.

53 days. Wisconsin SMR-18 reached the optimum harvest stage on an average of 52 days after planting and the range was only 51-53 days. The criteria used for determining the time of planting gave a satisfactory sequence of harvest throughout the season.

A hail storm on August 10 severely injured the June 29 and all later plantings. Several cool nights occurred in August and September as shown in the table of temperature data (Table 16). These temperatures were unfavorable for cucumber growth and development, hence the percentage of cull fruit produced in the last 3 plantings was in the magnitude of 35-58%. Two crops of cucumber were successfully grown in 1 season on the same plot, although the second crop yields were very low.

In a study involving the comparison of yields obtained from the first and second pickings, no difference between pickings was found at either spacing or variety (Table 6).

The plants spaced 1 foot apart in the row again produced more fruit per plant and higher dollar yields. No difference was found between the two varieties (Table 7).

II. Plant population studies

The total of pistillate flowers produced per plant and the flowering sequence were not affected by plant population in 1961. However, the number of marketable fruit per plant and dollar per acre yield was influenced by different spacings as shown in Table 8. The number of fruit per plant was consistently greater when the plants were spaced 1 foot apart in the row compared to those spaced 6 inches apart. Plant populations of 43,560 plants per acre resulted in higher dollar yields than populations of 21,780 plants per acre.

Data for 3 plantings indicate that spring plantings yield higher

Table 6. A comparison of the first and second harvests of Spartan Dawn and Wisconsin SMR-18.

Harvest	Dollar yield per acre Plant spacing (feet) 2 x 1	4 x ½	Average 1/
1	177	123	150
2	163	127	145
Average	170	125	

1/ F value for difference between harvests not significant.
2/ F value for difference between spacings significant at odds 99:1.

Table 7. Dollar yield per acre and fruit per plant produced by 2 varieties grown at 2 different spacings (plant population 21,780). 1/

Varieties	Dollars per acre Plant spacing (feet) 2 x 1	4 x ½	Average 2/
Spartan Dawn	110.3	88.7	99.5
Wisconsin SMR-18	112.1	82.6	97.4
Average 3/	111.2	85.7	
	Fruit per plant		
Spartan Dawn	3.7	2.9	3.3
Wisconsin SMR-18	3.0	2.0	2.5
Average 3/	3.4	2.5	

1/ Averages of the highest yielding harvests.
2/ F value for difference between varieties not significant.
3/ F value for difference between spacings significant at odds of 99:1.

than mid-summer plantings (Table 9). The late plantings were severely infested with angular leaf spot which resulted in reduced fruit production.

The increase in once-over harvest yields with high plant populations was in agreement with reports by Anderson (1) and Ries (48) for increased early yields on multiple harvest varieties. The spacings had no apparent effect on flowering but did affect the plant growth. Since plants spaced 1 foot apart in the row yielded higher than those spaced 6 inches apart in the row, regardless of the distance between rows, it appears that root and vine distribution may be important factors. Plants spaced in this manner may be more favorably situated to obtain the maximum amount of light, water, and nutrients.

The problem of deteriorated fruit at close spacings as reported by Hopen (30) did not appear in 1961. Plants grown for once-over harvest do not remain in the field to the point where such a thick mat of vegetation is formed as would be the case for multiple harvest.

In 1962, plant populations of 43,560 and 87,120 produced higher dollar per acre yields than the lower plant populations, however, no increased yield was obtained at plant populations over 43,560 (Table 10). Plants at each row spacing produced more fruit per plant when spaced 1 foot apart in the row rather then 6 inches. This was not reflected in higher dollar yields because of a 2-fold difference in plant population. Both varieties responded similarly to the spacings used.

The results of the spacing studies were in agreement with those obtained in 1961. With the present indeterminant varieties, there was no increased benefit obtained by increasing the plant population over 43,560. Advantages may be obtained by the development of determinant, dwarf-type plants which may be grown successfully at higher plant populations.

Table 8. The effect of plant spacings on yield of Spartan Dawn and Wisconsin SMR-15.

Spacing Between rows (feet)	Spacing In rows (feet)	Plant population	Fruit per plant 1/	Stat. signif. 2/	Yield (dollars per acre) 1/	Stat. signif. 2/
4	½	21,780	1.7	a	39	a
2	½	43,560	1.8	a	59	bc
2	1	21,780	2.7	b	51	a c
1	1	43,560	2.5	b	70	b

1/ Average of 8 different harvest dates of both varieties.

2/ Means with unlike letters are significantly different, odds 99:1.

Table 9. Dollar yields for different plantings and spacings of Spartan Dawn and Wisconsin SMR-15. 1/

Planting	Plant spacing (feet) 4 x ½	2 x ½	2 x 1	1 x 1	Average
I. June 5	86	96	103	94	95
II. July 26	37	76	61	94	67
III. August 2	28	62	41	64	49
Average 2/	50 a	78 b	68 b	84 b	

1/ Average of the highest harvests of each plantings.

2/ Means with unlike letters are significantly different, odds 19:1.

Table 10. The effect of several plant spacings on yield of Spartan Dawn and Wisconsin SMR-18 (Average of 4 harvest dates).

Spacings (feet) Between Rows	In Rows	Plant population	Fruit per plant	Stat. signif. 1/	Yield (dollars per acre)	Stat. signif. 2/
3	1	14,520	3.5	a	93	a
3	½	29,040	2.0	b	101	a
2	1	21,780	2.7	a	108	a
2	½	43,560	1.6	b	124	a b
1	1	43,560	1.9	b	162	b
1	½	87,120	1.1	c	125	a b

1/ Means with unlike letters are significantly different, odds 99:1.

2/ Means with unlike letters are significantly different, odds 19:1.

III. Inhibition and pollination studies.

Studies conducted in 1961 indicated that further fruit development was arrested on plants when the marketable fruit were not removed. After a period of 7 days no appreciable fruit development occurred when the original fruit were left on the plant. However, when the marketable fruit were harvested, other inhibited fruit continued to develop into marketable size (Table 11).

Data from the pollination study indicated in an indirect manner that a true inhibition existed, and that the lack of further fruit development was not due to a lack of pollination. When flowers were not pollinated, 97% aborted within 10 days (Table 12). Inhibited fruit do not abort to a great extent, but may remain on the plant in an arrested condition for at least 2 weeks. A large percentage of the unfertilized ovaries had shriveled and undergone abscission in this period of time. Natural pollination by bees resulted in 83% fruit set, and no significant increase was achieved by additional hand pollination.

It was noted in 1961 that many fruit are set and make an initial burst of growth and then are inhibited from further development. A study of fruit growth was conducted in 1962.

Of the 25 flowers selected for measurements, 14 developed into marketable fruit, 8 became inhibited after about 3 days growth, and 3 shriveled and later abscised. Ovaries at full bloom inhibited fruit after 7 days, and non-pollinated ovaries after 7 days are shown in Figure 4. At the third day after pollination, the inhibition effect was first observed in the data. No increase in size of the inhibited fruit occurred from the third to the seventh day after pollination as shown in Figure 5. The fruit which became marketable continued to grow at a rapid

Table 11. The inhibitory effect of developing fruit on subsequent fruit development.

Date	Number of marketable fruit per plant 1/ Treatments Harvested	Not harvested
July 12 (before harvest)	2.9	3.1
July 19 (harvested)	4.3	3.3
Total fruit produced 2/	7.2	3.3

1/ Average of 12 plants.

2/ F value for difference between treatments significant at odds 99:1.

Table 12. The effects of various pollination treatments on abortion of cucumber ovaries.

Treatments	% ovary abortion 1/	Stat. signif. 2/
Field pollinated	17	a
Field and hand pollinated	13	a
No pollination	97	b

1/ Average of 30 flowers per treatment.

2/ Means with unlike letters are significantly different, odds 99:1.

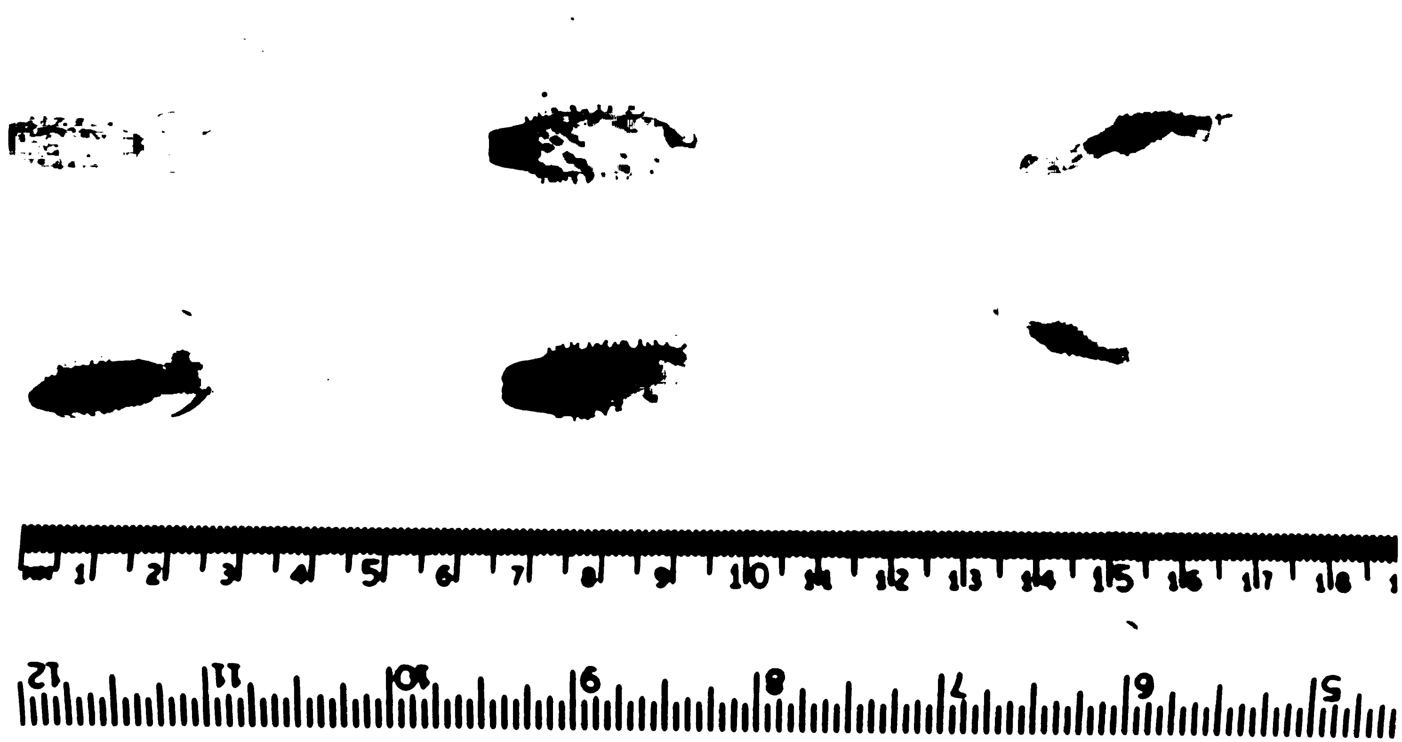

Figure 4. A comparison of pistillate flowers at full bloom with inhibited fruit after 7 days, and non-pollinated ovaries after 7 days.

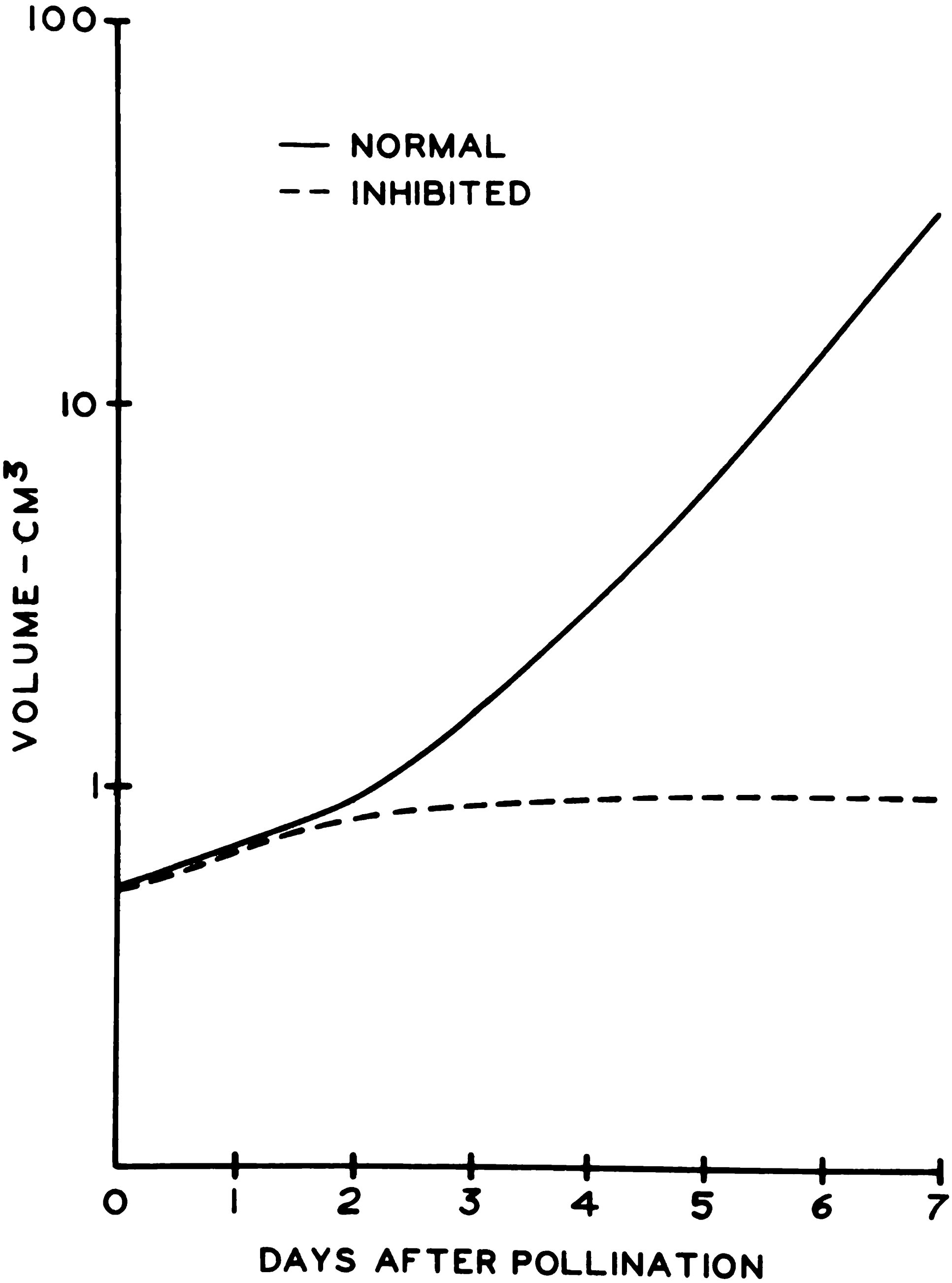

Figure 5. Growth of cucumber fruit after pollination.

rate until the seventh day. The growth curve obtained was similar to that reported by Sinnott (55) for other cucurbit fruits.

IV. Evaluation of growth regulators

The results obtained with chemical sprays in 1961 were inconsistent in 2 different plantings with 2 different sets of environmental conditions. Non-replicated treatments on the May 17 planting of Spartan Dawn resulted in 2 apparent responses. Plants treated with ethylene glycol monobutyl ether gibberellate formed staminate flowers up to node 5 of the main stem. The vines were also more extensive in growth. Plants treated with 2-chloroethyltrimethylammonium chloride (CCC) at 2000 ppm appeared to yield more fruit per plant than any of the other treatments (Figure 6).

The monoecious variety Wisconsin SMR-18 exhibited several responses as shown in Table 13. CCC at 2000 ppm hastened the appearance of pistillate flowers, increased the number of pistillate flowers formed, and increased the yield over that of the control plants. The number of pistillate flowers and yield was also increased with the 500 ppm treatment (Figure 7). The plants treated with ethylene glycol monobutyl ether gibberellate at 1000 ppm remained in the staminate phase longer and produced fewer fruit per plant, although the bushel yield was not different from the control. Naphthalene acetamide and benzothiazole-2-oxyacetic acid at both rates used increased the number of pistillate flowers, fruit per plant, and bushel yield per acre. Although maleic hydrazide at 500 ppm and (2-chlorophenylthio) propionic acid at 100 ppm exhibited no effect on the number or position of pistillate flowers, it did result in increased yields compared to the control plants. No injurious effects were observed from any of the treatments.

No difference existed between any treatments applied August 11

Table 13. The effects of growth regulator sprays on flowering and yields of Wisconsin SMR-18.

Treatment: Chemical	Rate (ppm)	Node first pistillate flower occurred 1/	Number pistillate flowers 1/	Fruit per plant 2/	Yield (bushels per acre) 2/
Naphthalene acetamide	100	8.6	3.7	3.5	56
Naphthalene acetamide	50	8.7	3.8	3.8	67
Benzothiazole-2-oxyacetic acid	50	7.8	4.8	4.7	88
Benzothiazole-2-oxyacetic acid	20	7.9	4.2	4.6	131
(2-chlorophenylthio)propionic acid	500	8.8	2.7	3.8	31
(2-chlorophenylthio)propionic acid	100	9.5	3.4	3.7	58
2-chloroethyltrimethylammonium chloride	2000	6.9	4.2	4.1	62
2-chloroethyltrimethylammonium chloride	500	9.2	5.0	5.5	101
ethylene glycol monobutyl ether gibb-erellate	1000	13.7	1.3	2.3	26
ethylene glycol monobutyl ether gibb-erellate	200	11.3	2.8	3.5	41
Maleic hydrazide	500	8.4	2.6	3.7	68
None (Tween-20, .05%)	-	8.7	3.0	3.1	33
LSD at odds 99:1		1.9	0.8	0.5	20

1/ Average of 9 plants.
2/ Average of 15 plants spaced 5 x ½ feet.

Figure 6. A plant of the variety Spartan Dawn treated with CCC at 2000 ppm. In comparison, control plants produced 3.4 fruit per plant.

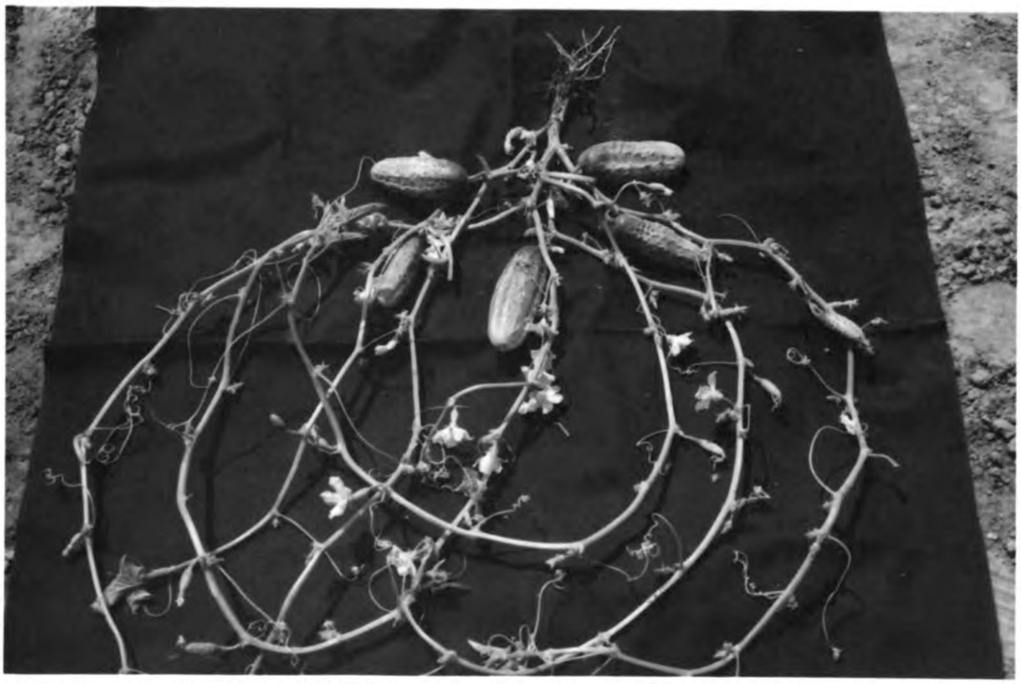

Figure 7. A plant of the variety Wisconsin SMR-18 treated with CCC at 500 ppm. In comparison, control plants produced 3.1 fruit per plant.

(Table 14).

Staminate flower induction with gibberellin in an early planting was in accord with reports by Mitchell (41) for greenhouse applications and by Peterson (45) for applications in the field. The effects of CCC on flower expression were also similar to that reported by Mitchell. The flower responses obtained with the auxin-like compounds were similar to those reported in the literature. Since maleic hydrazide and (2-chlorophenylthio) propionic acid did not affect pistillate flower formation, their effect on increasing yield is difficult to explain. It is possible that several of these compounds may have had an effect on the inhibition mechanism in the cucumber.

Inconsistency in the results from 2 experiments indicated that perhaps environmental and physiological factors at the time of application had an important effect on the absorption, translocation, and effectiveness of these compounds. Other factors may overcome any effect that the chemicals might have had. This is typical of the problems encountered with growth regulators under field conditions.

In 1962, growth regulators applied as foliar sprays at the 2-3 true leaf stage had no effect on the fruit per plant or bushel yield. (Table 15). Gibberellin induced staminate flower formation on the first few nodes of Spartan Dawn but did not reduce the total number of pistillate flowers produced. More variability in flowering occurred among plants in the same treatment than was observed in 1961. Failure to obtain favorable responses from chemical sprays under another set of environmental conditions' indicated that these treatments were not a reliable means of increasing yields in the field.

A gibberellin spray of 1000 ppm applied at anthesis did not increase

Table 14. The effect of growth regulator sprays on flowering and yield of Wisconsin SMR-18 cucumbers.

Treatment Chemical	Rate (ppm)	Number pistillate flowers 1/	Fruit per plant 2/	Bushels per acre 2/
None (Tween-20, .05%)	-	3.9	3.2	55
Benzothiazole-2-oxyacetic acid	100	3.2	2.3	40
Benzothiazole-2-oxyacetic acid	20	4.0	3.1	66
Benzothiazole-2-oxyacetic acid	5	3.0	2.4	36
2-chloroethyltrimethylammonium chloride	2000	4.6	2.9	62
2-chloroethyltrimethylammonium chloride	500	3.8	2.7	65
2-chloroethyltrimethylammonium chloride	100	4.2	2.7	39
Maleic hydrazide	1000	2.8	2.8	46
Maleic hydrazide	500	3.2	2.9	76
Maleic hydrazide	250	3.8	3.1	60
LSD at odds 19:1		NS	NS	NS

1/ Average of 9 plants observed 5 days before harvest.

2/ Calculated from yields of 30 plants spaced 4 x 1 feet.

Table 15. The effect of growth regulator sprays on flowering and fruiting of two varieties.

		Spartan Dawn			Wisconsin SMR-18		
Chemical	Rate (ppm)	Number pistillate flowers 1/	Fruit per plant 2/	Bushels per acre 2/	Number pistillate flowers 1/	Fruit per plant 2/	Bushels per acre 2/
None (Tween-20, .05%)	-	9.4	3.1	74	2.5	3.0	67
Maleic hydrazide	200	9.2	2.9	57	3.2	3.2	80
Maleic hydrazide	20	9.7	3.4	60	2.1	3.7	87
2-chloroethyltrimethylam-monium chloride	500	10.8	3.3	69	3.2	2.9	97
2-chloroethyltrimethylam-monium chloride	50	11.1	2.5	62	3.0	3.7	89
Benzothiazole-2-oxyacetic acid	50	8.8	2.9	45	3.2	3.1	88
Gibberellic acid (K salt)	100	7.3	2.9	50	2.0	2.9	66
Gibberellic acid (K salt)	10	8.1	2.4	49	2.2	1.9	64
LSD at odds 19:1		NS	NS	NS	NS	NS	NS

1/ Average of 9 plants.

2/ Average of 30 plants spaced 4 x ½ feet.

the fruit per plant or dollar yield per acre over that produced by the untreated plants. The control and gibberellin treated plants yielded an average of 3.1 and 3.3 fruit per plant and 106 and 117 dollars per acre respectively.

The 1962 greenhouse study indicated that gibberellin treatments under the conditions used, were not effective in the inducement of parthenocarpic fruit development. When pollination was prevented, no flowers were set regardless of the gibberellin treatment. All of the non-pollinated flowers had aborted after a period of 7 days. Forty percent of the hand pollinated flowers were set and no increase was obtained with the gibberellin treatments. Flowers at later node positions might respond more favorably to these treatments, as the first flowers formed often show a natural tendancy to undergo abcission.

SUMMARY

The horticultural aspects concerned with the production of pickling cucumbers for once-over harvesting have been studied for 2 growing seasons.

The flowering and fruiting characteristics of a gynoecious and a monoecious variety of pickling cucumbers were studied in relation to a once-over harvest. The varieties used produced large indeterminant vines typical of those now grown for multiple harvesting, and did not develop a large number of fruit at one time.

Successive planting studies were conducted in which plantings were made from mid-May until mid-August. During both growing seasons, the earlier spring plantings yielded much higher than the later plantings, because of unfavorable environmental conditions in late summer. With the varieties used, once-over harvesting was accomplished in approximately 50 days after planting. Because of the shortened growing season, 2 crops of cucumbers were successfully grown on the same soil in one year.

The data obtained from the successive harvests indicated that the time of harvest is a very important factor in obtaining the maximum yields. The grade and value of fruit declined rapidly in a period of 2 days. Bushels per acre was found to be an unreliable indication of the true yield.

Several plant population and spacing studies were conducted. High plant populations of up to 43,560 plants per acre resulted in higher once-over harvest yields. Plants spaced 1 foot apart in the row were

found to produce more fruit than those spaced closer together. Fruit deterioration was not a problem at the close spacings.

Pollination was found to be essential for fruit set in both varieties as no pollination resulted in ovary abortion and abscission. Fruit inhibition by the fruit previously set was found to be a major factor limiting concentrated fruit production by the cucumber. No increase in the number of fruit on plants occurred for a period of 1 week when the marketable fruit were not removed. Growth measurements of normally developing fruit and inhibition fruit showed similar growth for the first 2 days after pollination. After the second days, the rate of growth of inhibited fruit was decreased, and after the third day no increase in size was made. Fruit inhibition appears to be phenomenon which the cucumber has developed throughout its evolutionary processes which assures that at least 1 fruit will develop at the expense of others.

Several types of growth regulating chemicals were applied to plants in the field and the greenhouse at various stages of growth. The objective of these treatments was to alter the flowering and fruit setting capabilities of the plants in a favorable manner. Inconsistent results were obtained under varying environmental conditions with all the compounds tested except the gibberellins, which did not produce a beneficial effect. It was concluded that chemical applications were not an adequate means of increasing once-over yields of pickling cucumbers.

These studies indicated that the varieties used could be successfully once-over harvested only if a low cost machine was available as reported by Stout _et. al._ (57) and if a large acreage could be grown keeping production costs at a minimum. High fertility levels and irrigation will probably be required. The ultimate success of once-over harvesting may depend upon the production of determinant varieties with concentrated fruit setting ability, which are adapted to high plant populations.

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APPENDIX

Table 16. Daily temperature data recorded from the Michigan State University Horticulture Farm.

Date	1961			1962		
	Max.	Min.	Mean	Max.	Min.	Mean
May 15	76	60	68.0	-	-	-
16	63	42	52.5	94	61	77.5
17	64	38	54.0	95	59	77.0
18	55	47	51.0	94	64	79.0
19	63	38	50.5	93	59	76.0
20	63	44	53.5	83	68	75.5
21	62	45	53.5	73	53	63.0
22	59	35	47.0	81	45	63.0
23	68	38	53.0	88	62	75.0
24	75	38	56.5	67	55	66.0
25	70	51	60.5	80	45	62.5
26	41	33	37.0	69	45	57.0
27	62	31	46.5	74	37	55.5
28	70	48	59.0	84	47	65.5
29	64	48	56.0	93	60	76.5
30	71	35	53.0	81	65	73.0
31	69	48	58.5	84	66	75.0
June 1	71	56	63.5	68	50	59.0
2	77	62	69.5	68	44	56.0
3	70	49	59.5	78	39	58.5
4	80	51	65.5	85	55	70.0
5	88	50	69.0	80	64	72.0
6	78	50	64.0	76	57	66.5
7	79	52	65.5	80	46	63.0
8	77	63	70.0	85	46	65.5
9	80	58	69.0	79	60	69.5
10	86	60	73.0	78	65	71.5
11	91	60	75.5	81	60	70.5
12	93	68	80.5	69	52	60.5
13	90	69	79.5	74	49	61.5
14	71	52	61.5	82	54	68.0
15	70	44	57.0	86	50	68.0
16	77	43	60.0	88	51	69.5
17	83	45	64.0	92	62	77.0
18	84	49	66.5	88	64	76.0
19	82	56	69.0	80	58	69.0
20	68	46	57.0	75	51	63.0
21	77	43	60.0	79	51	65.0
22	75	50	62.5	83	61	72.0
23	62	51	56.5	81	61	71.0

Temperature data continued

	1961			1962		
Date	Max.	Min.	Mean	Max.	Min.	Mean
24	70	44	57.0	81	59	70.0
25	71	50	60.5	83	56	69.5
26	82	45	63.5	80	56	68.0
27	87	51	69.0	85	47	66.0
28	93	64	78.5	90	51	70.5
29	95	67	81.0	91	60	75.5
30	96	67	81.5	90	67	78.5
July 1	92	63	77.5	83	59	71.0
2	83	69	76.0	77	58	67.5
3	75	57	66.0	76	57	66.5
4	77	48	62.5	80	54	67.0
5	84	51	67.5	85	60	72.5
6	87	54	70.5	93	57	75.0
7	77	54	65.5	91	61	76.0
8	77	63	65.0	89	67	78.0
9	80	48	64.0	78	58	68.0
10	80	51	65.5	82	50	66.0
11	88	59	73.5	94	63	78.0
12	89	59	74.0	84	61	72.5
13	75	57	66.0	81	53	67.0
14	80	59	69.5	82	63	72.5
15	87	63	75.0	80	52	66.0
16	80	60	70.0	85	55	70.0
17	83	55	69.0	85	56	70.5
18	88	59	73.5	88	52	70.0
19	86	62	74.0	84	55	69.5
20	87	64	75.5	76	64	70.0
21	88	60	74.0	79	61	70.0
22	86	69	77.5	72	56	64.0
23	86	64	75.0	73	59	66.0
24	87	64	75.5	80	50	65.0
25	77	62	69.5	80	58	69.0
26	90	59	74.5	76	49	62.5
27	88	60	74.0	81	45	63.0
28	82	62	72.0	68	52	60.0
29	87	65	76.0	78	61	69.5
30	88	64	76.0	82	62	72.0
31	81	64	72.5	79	59	69.0
August						
1	67	61	64.0	84	54	69.0
2	81	63	72.0	84	47	65.5
3	86	58	72.0	87	56	71.5
4	82	61	71.5	89	63	76.0
5	71	61	66.0	88	62	75.0
6	76	62	69.0	72	61	66.5
7	81	53	67.0	89	59	74.0
8	85	60	72.5	83	65	74.0
9	88	67	72.5	78	53	65.5
10	86	65	75.5	82	45	63.5

Temperature data continued

Date	1961 Max.	1961 Min.	1961 Mean	1962 Max.	1962 Min.	1962 Mean
11	85	68	76.5	83	47	65.0
12	80	57	68.5	79	60	69.5
13	71	44	57.5	66	58	62.0
14	86	50	68.0	78	56	67.0
15	85	60	72.5	81	43	62.0
16	84	56	70.0	83	60	71.5
17	84	51	67.5	76	47	61.5
18	88	52	70.0	83	44	63.5
19	85	58	71.5	90	56	73.0
20	70	54	62.0	81	64	72.5
21	72	49	60.5	84	59	71.5
22	81	47	64.0	82	53	67.5
23	63	59	61.0	90	52	71.0
24	73	60	66.5	94	58	76.0
25	76	62	69.0	78	65	71.5
26	77	60	68.5	70	63	66.5
27	83	61	72.0	80	53	66.5
28	88	68	78.0	90	56	73.0
29	86	64	75.0	89	60	74.5
30	90	62	76.0	90	58	74.0
31	89	60	74.5	84	68	76.0
September						
1	81	68	74.5	81	62	71.5
2	82	69	70.5	85	48	66.5
3	87	71	79.0	83	66	74.5
4	86	68	77.0	84	65	74.5
5	85	70	77.5	81	45	63.0
6	85	64	74.5	73	31	52.0
7	86	61	73.5	77	35	56.0
8	87	59	73.0	78	45	61.5
9	89	60	74.5	76	61	68.5
10	91	68	79.9	77	60	68.5
11	89	71	80.0	73	45	59.0
12	73	63	68.0	87	49	68.0
13	86	66	76.0	87	62	74.5
14	75	60	67.5	78	58	68.0
15	64	47	55.5	76	51	63.5
16	73	46	59.5	78	50	64.0
17	75	46	60.5	76	59	67.5
18	76	45	60.5	69	47	58.0
19	78	43	60.5	63	42	52.5
20	75	55	65.0	56	33	44.5
21	82	61	71.5	66	29	47.5
22	86	64	75.0			
23	73	59	66.0			
24	76	59	66.5			
25	65	50	57.5			
26	64	46	55.0			
27	69	42	55.5			
28	54	39	46.3			
29	61	30	45.5			