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To the Graduate Council:

I am submitting herewith a thesis written by Robert D. Freeland entitled "The production and marketing of greenhouse tomatoes in the Knoxville, Tennessee, area." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Plant Sciences.

Bill Pickett, Major Professor

We have read this thesis and recommend its acceptance:

M. B. Badenhop, Homer D. Swingle

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

August 8, 1957

To the Graduate Council:

I am submitting herewith a thesis written by Robert D. Freeland entitled "The Production and Marketing of Greenhouse Tomatoes in the Knoxville, Tennessee, Area." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Horticulture.

Major Professor

We have read this thesis
and recommend its acceptance:

Accepted for the Council:

Dean of the Graduate School

THE PRODUCTION AND MARKETING OF GREENHOUSE TOMATOES IN THE KNOXVILLE, TENNESSEE, AREA

A THESIS

Submitted to
The Graduate Council
of
The University of Tennessee
in
Partial Fulfillment of the Requirements
for the degree of
Master of Science

by

Robert D. Freeland

August 1957

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33

ACKNOWLEDGEMENT

The writer is greatly indebted to the Department members of Agricultural Economics, Botany and Horticulture for their assistance and is especially grateful to Professor Homer D. Swingle under whose guidance this study has been conducted.

R. D. F.

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CHAPTER I

INTRODUCTION

General

The demand for greenhouse tomatoes in this nation has resulted in a gradual expansion of the greenhouse tomato industry since 1900. The largest area of production is in Ohio, due largely to the accessibility of markets for this perishable product. The accessibility of markets, combined with the concentration of skilled labor for greenhouse tomato production, led to the expansion of the industry even into areas least suitable for production because of long, cloudy periods during the fall and winter months. The industry has expanded until approximately sixteen million square feet of greenhouse space is devoted to the fall and spring production of greenhouse tomatoes (1). This compares to 111,499 square feet of greenhouse space available for all plant and vegetable production in Tennessee (28).

The expansion of the greenhouse tomato production industry into areas more favorable for the production of warm season crops has been restricted because of one or more of these factors:

1. High initial cost required for greenhouse construction.

2. Lack of information regarding demand for a higher priced, higher quality product.

3. Lack of production information available for use by unskilled labor.

There is no information available pertaining to the specific production and marketing of greenhouse tomatoes in the Tennessee area. Tomatoes sold in this area after regular season production have been tomatoes that were grown in milder climates, picked green mature, and then shipped to packing houses where they were held for ripening. After ripening, they were marketed through normal wholesale and retail outlets. In contrast, greenhouse tomatoes are vine ripened and marketed with the calyx attached, which serves as an indication of recent picking and as a trademark of greenhouse tomatoes. Vine ripening results in higher quality tomatoes which command a higher price than tomatoes ripened in packing houses.

The relatively low cost of greenhouse construction, resulting from the introduction of polyethylene film as a substitute covering for greenhouses instead of glass, was the reason for initiating this study.

Objective of the Study

The objective of this study was to explore the profitability of producing tomatoes for the fresh market in a greenhouse covered with polyethylene in the Knoxville, Tennessee area.

Opinions of competent observers on the desirability of producing greenhouse tomatoes for sale in the local market differed widely at the beginning of the experiment. Some felt that the annual replacement cost of the polyethylene and the fuel costs of producing a warm season crop in such a structure would make the endeavor unprofitable; others felt the demand for this high quality product would not be sufficient to justify the high costs of production. Procedures which have furnished data for this report were designed in an attempt to find more conclusive evidence to answer these questions. These procedures are outlined in Chapter III.

CHAPTER II

REVIEW OF LITERATURE

The profitable production of greenhouse tomatoes requires the manipulation of climatic factors combined with tested favorable cultural practices. The more important controllable climatic factors in greenhouse tomato production are water, temperature, and light.

Controllable Climatic Factors

Water

Water is important in many ways to the physiological processes of plants. The general role water plays in the physiology of plants is summarized by Daubenmire (4) as follows:

> As the closest approximation of a universal solvent it dissolves all minerals contained in the soil. It is the medium by which solutes enter the plant and move about through the tissues. By permitting solution and ionization within the plant it greatly enhances the chemical reactivity of both simple and elaborate compounds. It is the raw material in photosynthesis. It is essential for the maintenance of turgidity without which cells cannot function actively, and indeed is necessary for the mere passive existence of protoplasm for very few tissues survive if their water content is reduced as low as 10%. The fact that water can to a remarkable degree absorb much heat from warm surroundings with relatively little change in temperature tends to slow the rate of temperature changes in protoplasm and thus make uniform the temperature conditions affecting the rate of biochemical reactions.
>
> The water in the soil is continuous with that in the plant, and the entire system is in constant upward movement since the shoot loses water to the atmosphere at practically all times. Nearly all this water moving upward in the plant is lost in transpiration, only about 0.1-0.3% of it being tied up in chemical compounds.

It is necessary to control the water supply in the production of greenhouse tomatoes to obtain optimum root distribution. Root distribution depends to a very important extent on soil moisture and the correlated factor, aeration. Roots do not grow and branch freely in a very dry soil, or in a soil that is in a water-logged condition. Gardner (7) states that the water-logged condition probably inhibits root growth and activity through a lack of aeration.

Limited applications of water are desirable during early stages of growth to insure a low level of nitrogen uptake relative to the carbohydrates produced. Kraus and Kraybill (17) report such a condition is conducive to reproductive growth. Early reproductive growth is desirable in greenhouse tomato production, not only because of early yield from the first cluster, but also because the indeterminate tomato plant commonly forms fruit clusters after every third leaf after the first fruit cluster has been formed. The height to which greenhouse tomato plants can grow is limited by the greenhouse structure. Early setting of fruit is necessary for greater total yields because of the above mentioned factors.

There can be no precise schedule prescribed for watering. Considerations must be given to the nitrogen requirement of the plant as indicated by plant color, and the moisture content of the soil as indicated by "feel" or measuring instruments. Hoffman (12) has given a general watering schedule for a spring crop of greenhouse tomatoes. In addition to the recommendations of small applications of water during early growth, he suggests the following watering schedule:

March -- three-fourths to one inch per week

April -- one and one-fourth to one and one-half inches per week

Summer -- one and one-half to two and one-half inches per week

The hose and overhead sprinkler system are two chief ways to water tomatoes under glass according to Hoffman (13). The first waterings in the spring are done by hose, with small amounts being applied at the base of the plants. Overhead sprinklers are used when one or more clusters are well set with fruit.

Emmert suggests tying the hose on to a broom or mop handle for watering around the base of individual plants (5).

Temperature

The majority of tomato producers in the Temperate Zone have been more concerned with ways to compensate for insufficient heat than in ways to lower the temperature. Greenhouses are the result of the need to maintain temperature control.

Porte and Smith (24) listed the regulation of greenhouse temperature second only in importance to providing optimum amounts of water for the plants. These writers recommend that while the crop is growing the temperature should be held between 60°F. to 65°F. during the night and between 70°F. to 75°F. during sunshiny days. On cloudy days the temperature should be kept around 65°F. to 68°F. If night temperatures were held below 58°F. during fruit bud development, blossoms aborted or fruits that set were misshapen and of poor quality.

Alban (1) obtained highest total yeild but lowest early yield by maintaining a 50°F. night temperature for five weeks during poorest light periods, and then maintaining a night temperature of 62°F. until the crop was removed. The day temperature was held constant at 70°F.

Calvert's (3) findings agreed with Went's (35) that variations in soil temperatures above 57°F. have little effect on the cropping of greenhouse tomatoes. Raising soil temperature above 57°F. did not increase yield in Calvert's experiments, but lowering air temperature below 60°F. produced sharp decreases in early yield. When air temperatures were maintained above 60°F. there was no instance in which the soil temperature fell below 57°F.

Light

Daubenmire (4) states that light is rivaled only by water in its influence upon the morphology and anatomy of plants, and that light has less evident but important effects on the physiological processes and chemical composition of plants.

The presence of light is necessary for the production of carbohydrates. Experiments indicate light markedly influences the quality of many greenhouse crops, and a highly significant correlation has been found between quality and hours of sunlight in the period in which the tomato fruits made the major portion of their growth.

Porter (23) found a decrease in light resulted in increased vegetative growth, decreased fruit production, and decreased amounts of photosynthate produced by the plant.

Experiments designed to produce a consistent increase in ascorbic acid concentration of greenhouse grown fruit by supplemental lighting were unsuccessful (6).

Howlett's (14) experiments indicated that a reduction in carbohydrates produced by tomato plants resulted in poor anther development, microspore degeneration, and pollen sterility.

Verkerk (33) states that supplemental light will aid the production of normal flowers if light conditions are poor.

In the production of greenhouse tomatoes, light is controlled by plant spacing, training, pruning, and location of greenhouse as well as the cover itself.

Cultural Practices

The determination of most favorable cultural practices in the production of greenhouse tomatoes has been the object of much research. A review of the results of research pertaining to the production of greenhouse tomatoes follows this listing of cultural practices:

1. Variety selection
2. Production of plants
3. Soil selection
4. Fertilization
5. Cultivation
6. Mulching
7. Pollination
8. Ventilation

9. Pruning and training

10. Pest control

11. Harvesting

Variety Selection

The majority of F_1 hybrids developed for field use are poorly adapted to the low light and high fertility conditions generally prevalent in greenhouses. In addition, the susceptibility of F_1 hybrids developed for field use to the common greenhouse diseases of wilt (*Fusarium oxysporum* f. *Lycopersici*) and leaf mold (*Cladosporium fulvum*) have made them unacceptable for greenhouse production, according to Lambeth (18).

Market preference is an important consideration in the choice of varieties. The small three to four ounce red English forcing varieties are still most popular in the East. The larger fruited varieties weighing six to eight ounces are preferred in Indiana and Ohio. Ohio greenhouse tomato growers prefer pink tomatoes except in the southern part of the State. Indiana growers prefer the red-fruited tomatoes except in the Terre Haute area (24).

Since its introduction in 1948, Ohio W-R Globe has largely replaced other large, pink-fruited varieties in Ohio because of its wilt resistance and higher yields. Popular red-fruited varieties in the southern portion of Ohio are Marglobe and Master Marglobe (15). Michigan State Forcing is the most popular greenhouse tomato variety grown in Michigan. Red, firm, globe shaped fruits which average four ounces per fruit are characteristics of this variety which was developed from a cross of Marglobe and Ailsa Craig. Plants of Michigan State Forcing variety are very susceptible to leaf mold, and only moderately resistant to fusarium wilt (24). Potentate is a small fruited variety very popular in Minnesota because of its productivity in dark, cloudy weather. Waltham Forcing and Improved Bay State varieties have replaced the small fruited English forcing varieties in the New England States and parts of New York (24).

The earliness, uniformity, and productivity advantages offered by F_1 hybrids have resulted in experiments conducted by Lambeth (18) to incorporate these advantages with resistance to wilt and leaf mold. Trucker's Forcing X Ohio W-R 3 is a F_1 hybrid that has shown satisfactory resistance to leaf mold organisms and to race 1 of wilt. This hybrid also produced the highest average total yield in pounds of fruit per plant of twenty-four lines, varieties, and hybrids tested in 1956. This hybrid has large, red, uniform fruit and vigorous foliage.

Production of Plants

Seeds should be sown in sterilized soil, after being coated with a chemical dust such as Semesan for control of fungi and bacteria that cause dampening-off and seed decay (16). Kirby (16) states that the most effective soil sterilization is the use of steam to heat the soil until all parts of the soil reach at least 160°F., and held at this temperature for thirty minutes.

An ideal soil for seeding tomatoes is a mixture of two parts field soil, one part sand, and one part compost. Emmert (5) states that three times as many seeds should be sown as the number of plants required.

Lewis (19) found that the critical period influencing the first fruit bud formation is between the eighth and twelfth day after cotyledon expansion. Wittwer (36) obtained highest yields on four varieties tested by maintaining night temperatures of 50°F. and day temperatures of 65°F. during the two week period immediately following cotyledon expansion.

The seedlings are to be transplanted into containers as soon as the seedlings can be conveniently handled. The shock of transplanting is less with small seedlings than with large seedlings. Four inch pots filled with two parts field soil and one part sand is most popular with Ohio greenhouse tomato growers (15).

The plants should be eight to ten inches high with large root systems and fruit buds partially developed eight to ten weeks after seed germination. The plants should be somewhat deficient in nitrogen as indicated by light yellow-green color of leaves at this stage. A complete all soluble fertilizer should be added to the pots one or two days before the plants are to be transplanted to greenhouse beds. The starter fertilizer will hasten the first harvest by reducing the shock of transplanting (5).

The spring crop is transplanted in the greenhouse about January

10 in Ohio (24). The greenhouse soil should have been warmed to at least 57°F. according to Calvert's (3) findings, but not more than 80°F. (24).

Plants are removed from pots with a minimum of damage to roots and tops. The ball of roots, as well as the stem up to the cotyledon leaves, should be completely covered with soil and firmed to eliminate large air spaces (24).

Light restriction results in poor fruit set on plants spaced close together. Hoffman (10) found that a spacing permitting three and one-half to four square feet per plant produced highest yield. Ohio greenhouse tomato growers commonly space to allow five square feet per plant (12) (15).

Soil Selection

Porte and Smith (24) described favorable soil for greenhouse tomato production as being loams to silt loams. Heavier soils require more preparatory labor and hold soil water tenaciously. This results in water-logged, poorly aerated soil. Less labor is required for sandy or gravelly soils, but this advantage is offset by their inability to hold moisture and mineral fertilizing elements. Silt loams retain moisture well, yet water drains enough to permit aeration (24).

The wide range of soils in which greenhouse tomatoes are successfully produced in Ohio points out that proper soil management of a given soil type is more important than the soil type itself (15).

Soil testing for the determination of pH, potassium, and phosphorous levels is a requirement for proper soil management.

Porte and Smith (24) state that a slightly acid soil within a pH range of 6.0 to 6.5 is desirable.

Fertilization

Rate and time of application of fertilizer is dependent upon the level of fertility of the soil, type of soil, intensity of light, and the stage of plant growth. The majority of fertilizer recommendations are based on a given set of conditions, and may not be applicable except for conditions similar to those upon which the recommendations were based.

The ideal rate of application is that amount necessary to produce optimum yields. Tomato plants remove more minerals than necessary for the production of the fruit crop on heavily fertilized soils. Excessive applications of fertilizer are not only wasteful, but may also cause a soluble salt problem. When the concentration of soluble salts exceed 2,000 parts per million, injury to the plants occurs in the form of root burning. Another problem resulting from excessive applications of fertilizer is the one of excess of one mineral preventing another ion from moving into the plant. Excessive potassium reduces magnesium entrance; and excessive applications of phosphorous may be a factor in causing deficiencies of manganese, boron, and iron (15).

The total pounds of fertilizer materials removed from one acre of greenhouse soil by 9,000 plants which produced 96,000 pounds of fruit is as follows: (15)

Nitrogen ------- 379

Phosphorous ---- 101

Potassium --------616

Calcium ----------516

Magnesium --------123

The amounts listed above as being removed are equivalent to the following amounts of fertilizer (15):

Nitrogen ---------1,895 pounds of ammonium sulfate (20 per cent nitrogen)

Phosphorous ------1,443 pounds of super phosphate (16 per cent P_2O_5)

Potassium --------1,484 pounds of muriate of potash (50 per cent K_2O)

Calcium ----------723 pounds of burned lime (CaO)

Magnesium --------750 pounds of dolomitic limestone (MgO)

Potassium and phosphorous are applied during soil preparation in order that it be at depths available to the roots. Porte and Smith (24) recommend 25 to thirty pounds of 20 per cent super phosphate and twenty to 25 pounds of muriate of potash per 1,000 square feet of soil bed, for growers unfamiliar with the soil's level of fertility and expected yield.

The rate and time of nitrogen applications should be governed by the needs of the developing tomato plants. A relatively high nitrogen application during periods of low light intensities results in excessive vegetative growth and non-setting of lower clusters (24).

Howlett (14) found that nitrogen deficiency affected microsporogenesis and the development of the male gametophyte relatively little.

Mack (20) found repeated applications totaling far more than the usual requirements of a given tomato crop did not induce great vegetation growth in greenhouse tomato plants grown in composted soil in ground beds. An increase in yield, size and grade of fruit in the spring crop resulted.

Further experiments by Mack and Thomas (26) indicated that higher yielding plots of greenhouse and field grown tomatoes had a higher nitrogen analysis in the fifth leaf from the base than those from lower yielding plots.

Cultivation

Cultivation should always be shallow. Deep cultivation damages the root system of the tomato plant. Cultivation should be designed to break up the surface crust when the soil has become packed, and to destroy weeds. Breaking the crust enables water to penetrate the soil evenly, and destruction of weeds removes competition for nutrients and water. Cultivation is usually unnecessary when the soil has been sterilized or when mulches are used.

Hand cultivation is satisfactory for small operations. Large operations require especially designed garden tractors to cultivate the closely spaced plants. The shading effects of the closely spaced plants generally decreases the number of weeds.

Mulching

Mulching prevents soil surface packing and favors an even supply of water by preventing evaporation (24). The most commonly used mulching material is wheat straw. This is applied to a depth of two to three inches over the entire area. A mulch reduces soil compaction, conserves moisture, reduces cultivation, and prevents the surface from becoming muddy following irrigation (15). Even with these advantages, Hoffman (12) does not consider mulches necessary for the successful production of greenhouse tomatoes.

Pollination

Hand pollination of greenhouse tomatoes is necessary to insure ample fruit set. This is accomplished by tapping each flower cluster. Daily tapping of each cluster is required, since all flowers in a cluster do not open at once (24).

Pollen is not readily transferred during dark, cloudy days. Brief periods of sunshine should be used advantageously for the pollination during a period of cloudy weather, and it may be desirable to tap twice on sunshiny days to insure ample pollination (15).

Since there are many seeds in each fruit and fertilization of each is requisite for smooth fruit, a large number of pollen grains must reach the stigma (11).

Verkerk (33) states the more frequent the pollination the more seeds per fruit. He found a highly significant correlation between the size of the fruit and the number of seeds in the fruit. He concludes that if conditions for tomato growing are poor, the greater is the emphasis to be placed on insuring successful pollination.

Spraying plants or flowers with certain hormones results in large, seedless fruit. The shape of the fruit is affected and the corolla usually remains under the sepals, serving as a mark of identification by buyers, according to Hoffman (11). Hoffman (11) further states that hormone treated fruits soften rapidly and cannot be shipped for any great distance.

Murneck and Wittwer (22) state that hormone sprays should be used only to supplement pollination during adverse conditions, and not as a substitute for pollination.

The most efficient method of insuring pollination of greenhouse tomatoes is with the electric vibrator, which operates on an ordinary dry cell battery. Electrical impulses vibrate a wire several times per second. As the device is moved from one cluster to another, each flower is shaken several times (24).

Tomato fruits usually set without difficulty on the first flower of the fall crop and the later flower of the spring crop (15). This differential set is due to more favorable light conditions resulting in more available carbohydrates. This substantiates the previously mentioned work of Howlett (14), whose experiments indicated that the suppression of male organs and the production of microspore degeneration and pollen sterility in tomatoes were the results of carbohydrate deficiency.

During periods of adequate carbohydrate formation, resulting in the production of fertile pollen, methods of pollination other than with an electric vibrator may be used. A commonly used method is that of having an operator walk between plant rows, tapping each overhead wire sharply with a stick. The vibrations travel along the wire shaking the plant and dislodging the pollen. Some growers prefer to jar each plant, but there is danger of bruising the plant or growing fruits when using this method (24).

Satisfactory crops of self pollinating tomato varieties also grow in greenhouses without any assistance to natural pollination (24). Burk and Roberts (2) state that the most satisfactory self pollinating varieties are those with characteristically short pistils.

Ventilation

Ventilation is a means by which proper air temperatures in greenhouses may be maintained. Another important feature of ventilation is the removal of excess moisture. Moisture constantly evaporating from the soil surface and transpiring from the tomato foliage results in increased humidity unless moist air is removed. Ventilation should be regulated to prevent the relative humidity from exceeding 90 per cent, as an aid in controlling leaf mold (24) (15).

Ventilation requires exacting operation particularly during mild weather in the fall and spring when proper night temperatures may be maintained by keeping the ventilators closed. This is likely to create conditions inside the house that will start an epidemic of leaf mold. No grower should be tempted at such times to conserve fuel needed to provide adequate heat by reducing ventilation (24).

Pruning and Training

The single stem system of pruning is universally used by greenhouse growers of tomatoes (15). This involves the removal of all lateral branches. Lateral branches should be removed when small to keep plant injury to a minimum. They are grasped between thumb and fore-finger and removed by a quick snap (24). Hoffman (11) states the correct method of removing lateral branches that have been permitted to grow too long is to bend the branch to one side until bark and under tissues break, and then in the opposite direction, preventing bark being ripped from the main stem. Pinching or cutting lateral branches enhances spread of virus diseases from plant sap that may be present on the nail or blade.

The terminal bud is usually removed on plants of the spring crop. This prevents the formation of additional flowers and subsequent fruit set. It also enhances development of fruits already on the plant. The terminal bud is removed a few weeks before the end of harvest (15).

Removal of the lower leaves which touch the ground after the plant is three to four feet high is a practice of some growers (38). The practice is to reduce leaf mold damage by removing leaves in contact with the innoculum, and provides ventilation at the ground level. However, Hoffman (9) states that pruning of lower leaves before dying and drying in order to prevent leaf mold which is favored by high humidity, is not recommended because humidity remains fairly constant whether the leaves are pruned or not pruned. In experiments designed to test this statement, plants not pruned until leaves died and dried showed a higher yield per plant.

A discussion by Porte and Smith (24) regarding training of greenhouse tomato plants follows:

Most greenhouse tomato plants are supported by stout wires running parallel to the soil surface six or more feet above it. These wires are directly over the plants and are attached to the greenhouse frame. The most commonly used support for each plant is a strong string or sisal twine tied to the wire directly above the plant with the other end tied loosely around the stem of the plant near the ground. After allowing the plant to grow for some distance above the tie it is wound loosely around the string, always in the same direction. While this is being done, the string should be kept under the point of leaf attachment to the main stem. In this way the leaves will not be broken and the plant will be supported at the bases of the leaf petioles and will not slip down the string. The tender growing tops with developing leaves are left to grow free for awhile, as they are likely to snap off if wound around the string all the way to the top of the plant. Sometimes the lower end of the string is tied to a coil wire anchor or to a peg driven in the soil near the base of each plant. When the plants are laden with exceptionally heavy yields of fruit it may be advisable to support the upper portion of such plants with extra string attached to the overhead wire to prevent breakage of supporting string and consequent loss of productive plants.

Light stakes may sometimes be used to support tomato plants. They are pushed into the soil near the base of each plant and tied at the top to small wires overhead. In supporting the plant on the stake, the best practice is to tie raffia or soft twine tightly around the stake two to three inches above a leaf petiole or fruit cluster, then loop the raffia under the base of petiole or fruit cluster, take up most of the slack, and tie a square knot.

Pest Control

Plant pest is a broad term which includes insects, fungi, bacteria, viruses, and nematodes. Environmental factors such as soil conditions, water supply, temperature, sunlight, and atmospheric humidity may also have a detrimental affect on the yield and quality of the crop. A complete discussion of these factors and recommendations for control can be found in the U. S. Department of Agriculture Farmers' Bulletin No. 1934 (31), and Ohio Extension Service Bulletin SB-10 (15). Adequate control of pests is obtained by the proper application of proven chemicals and practices in optimum amounts and degrees for a given place and time.

Emmert (5) states that most insects and diseases detrimental to the production of greenhouse tomatoes can be controlled by dusting or spraying with parathion or malathion and manazate every week to ten days.

Harvesting

Harvesting of spring greenhouse tomatoes set about January 10, usually begins around April 1. Usually the fruits are harvested two to three times a week as they approach a full-ripe color and are still firm. The nearer tomatoes approach full ripeness before harvesting, the heavier and more flavorful they will become. Therefore, growers should carefully adjust time of harvest in accord with the length of time required to place the fruit on the retail market (24).

Practically all greenhouse grown tomatoes are clipped from the vine with the calyx attached. This distinquishes them from field grown tomatoes. The stems are clipped as close as possible to the calyx to prevent protruding stems from damaging other fruits when packed (15).

The tomatoes are wiped, sorted, graded and packed before marketing. The tomatoes are graded by standards devised for fresh tomatoes by the United States Department of Agriculture (32).

The yield of greenhouse tomatoes vary considerably. A good average yield for the spring crop is 10,000 eight pound baskets per acre.

Five thousand eight pound baskets per acre is considered a good average yield for the fall crop (15).

Production of Tomatoes in Plastic Greenhouses

Practices concerning production of tomatoes in polyethylene greenhouses are similar to glasshouse production in many respects. Exceptions are those which need modifying due to lower light intensity or those dealing with control of atmospheric humidity.

The air tight construction of polyethylene greenhouses results in a higher relative humidity than in glasshouse structures unless attention is given to ventilation.

There is more condensation of moisture on the surface of polyethylene houses than in glasshouses. The air tight construction is partially responsible. The property of polyethylene surfaces to hold droplets of water until evaporation results, rather than allowing the water to drain to the soil surface, is another factor responsible for higher humidities developing in these houses.

Glass is transparent as opposed to polyethylene being translucent. This is an important factor on days of marginal sunshine necessary for the process of photosynthesis. A Cornell report states that 83 per cent of light intensity is admitted through the polyethylene on days when light intensity measured 8,400 foot candles (25). The condensation of moisture inside polyethylene greenhouses also reduces light intensities. Two layers of polyethylene have been recommended as a measure to reduce condensation (25).

Marketing

The successful development of a market for an out of season fruit of superior quality is dependent upon the consumer's willingness to buy the product at a price which will allow producers an adequate return on their investment. The demonstration of this willingness by consumers has resulted in the expansion of the fruit and vegetable forcing industry in this nation.

An appraisal of long-run demand prospects for farm products has been provided by economists and statisticians of the Agricultural Marketing Service. Based on the assumptions that current population trends will continue, that a high level of employment and fairly stable prices will be maintained, and that there is peace in the world, the projected trend for agricultural products in 1975 is a 40-45 per cent larger market than in 1953 (29). The increase in consumer dollars and the matter of expected changes in consumer tastes has an important bearing on increased consumption of specific farm products. The increase in consumer dollars may increase per capita consumption of farm products about a tenth from 1953 levels (29). The demand for food in general, is not very responsive to changes in prices and consumer incomes within a nation. The stability of food expenditures in relation to income is discussed by Thomsen and Foote (27). These writers conclude that an increase in price does not reduce consumption very much, nor does a rise in income increase per capita consumption to any great extent. However, the increase in post war consumer income resulted in a modification in the kinds of commodities desired. The increases in per capita consumption were largely in livestock products, fruits, and vegetables (27). Daly (29) predicts these trends will continue, and that these increases are likely to be offset by a reduction in per capita consumption of cereals and potatoes, resulting in a fairly constant number of pounds of food consumed per person even though the price-weighted consumption index would rise as consumers shift to the higher cost foods.

In a discussion of the projected 1975 farm product market, Daly (29), of the Agricultural Marketing Service, states as follows:

> Consumption of fruit may increase nearly a fifth per person. Citrus fruits would show the largest gains.
> Vegetable consumption, excluding potatoes, would be about a sixth larger per person. The largest relative gain is projected for tomatoes, although consumption of most leafy, green, and yellow vegetables may increase as much or more than tomatoes.

Assuming that consumption of greenhouse tomatoes will increase, the problem of market development for greenhouse tomatoes exists in areas where this product has not been sold. Waugh (34) states that the measurement of market potentials is still far from being an exact science. The problems of estimating the costs involved in developing the potential market, the required promotional campaigns, and the determination of how much of a product could be sold at various price levels involve many difference considerations.

Some of these involved in the development of markets for new products are expressed by McDowell (21) as follows:

> Technological progress in one field or in one direction often requires and must wait upon progress in other fields or directions in order to contribute its maximum benefit. Heavier production, in itself, may have an adverse effect on

price more than offsetting lower unit costs of production. The development of a new product, no matter how great its merit and consumer acceptance, is of little value unless it can be produced and marketed at a profit.

Hansen (8) presents an excerpted check list for the introduction of new consumer products from the U. S. Bureau of Foreign and Domestic Commerce. The check list may be used on problems involving appraisal of consumer acceptance, production possibilities, and market potentials for new products.

Markets for new products, such as cereals, have been developed by General Mills (34). Studies for the development of new markets for products, such as a new concentrated apple juice, have been completed by Bayton, Dwoskin, and Robert (34). Studies for the development of new markets for new peanut butter spreads in Georgia have been reported by the U. S. Department of Agriculture (30).

The development of markets for food products which consumers have used in one form or another is understandably less difficult than the development of markets for food products which consumers have never used or even seen. An example of the difficulty expected in market development when the product introduced is entirely new is the contrast in consumer knowledge of "Cherrios" (34) and greenhouse tomatoes when their respective markets were being developed.

The quality of greenhouse tomatoes can be compared by consumers with the remembered quality of in season field tomatoes, or with the quality of tomatoes ripened in ripening houses and available for consumption during winter months. The greenhouse ripened tomato may be substituted for the house ripened tomato, or an entirely new market may be developed for the greenhouse tomatoes.

CHAPTER III

METHODS OF PROCEDURE

Construction of Greenhouse

The greenhouse employed for this study was constructed somewhat similar to plans developed at the University of Kentucky. It had overall dimensions of 18' X 88' which allowed a 15'8" X 85'8" area for production. The loss of area was due to the 8" foundation and 6" heating pipes along each wall.

The location available for the construction of the greenhouse necessitated the excavation of soil to obtain a level ground bed. The bed foundation was graded with a slight slope to permit drainage. Eight inches of cinders were leveled over the ground bed to further promote drainage. Eighty-eight cubic yards of soil were used to fill the bed to a depth of about eighteen inches.

A continuous foundation made of 8" X 16" concrete blocks was used to support the bottom sill. The height from the ground to the eaves was six feet and to the ridgepole ten feet. Five ventilators each 2½' X 8' were spaced evenly along each side of the house. Framework was 2" X 4" pine except the rafters which were 2" X 2" fir spaced 24" on center.

The high quality material used for framing and the permanent foundation justifies the assumption that the structure will last for ten years. The 5 per cent depreciation of the cost of construction charged to the spring crop was derived by assuming that two crops per year could be grown in the structure for the next ten years. Other depreciation percentages were derived in the same general manner.

The outside of the greenhouse was covered with 3,150 square feet of 0.002" polyethylene. A layer of 0.0015" polyethylene was placed along the roof and walls inside the greenhouse for insulation purposes. Two layers of polyethylene instead of one reportedly reduces fuel costs by 40 per cent. Another reported advantage of using two layers of polyethylene is the reduction of condensation, which would increase light intensities inside the greenhouse. The structure was completed in November, 1956, and the first observation of polyethylene deterioration was approximately June 15, 1957.

The house was heated with a 160,000 BTU butane burning heater manufactured by L. B. White Company, Onalaska, Wisconsin. The heater was placed inside the greenhouse near the door which was the lowest part of the greenhouse. Six inch stove pipes conducted the heat around the perimeter of the house. The pipes were buried at the heater and emerged approximately one-third the distance of the greenhouse from the burner and lay on top of the ground for the distance remaining to fan. When the temperature in the greenhouse reached the point at which the thermostat was set, electrical contact started the fan in motion. The vacuum created in the joint-sealed pipes initiated opening of gas valves which were located near the burner's pilot light. The gas was ignited and the heat produced was drawn through the pipes from the suction created by the fan at the opposite end of the greenhouse. The exhaust fumes were pulled through the fan and blown outside the greenhouse. When the desired temperature had been reached, electrical contact to the fan was broken by the thermostat, the vacuum no longer existed, and the gas valves closed. The thermostat connected with the operations of the heater was located one-third of the length of the greenhouse from the heater and at a height of four feet.

Butane gas was stored in a 500 gallon tank outside the greenhouse. Two meters were installed; one recorded the cubic feet of gas used, and the other recorded the number of hours the heater burned. Daily readings of these meters were taken.

A six inch open-end pipe from outside the greenhouse to a position by the burner provided oxygen necessary for the combustion of the gas.

Production of Plants

The tomato variety Ohio W R 3 Globe was selected because of its large, pink fruits, and its resistance to fusarium wilt. The seeds were sown November 1, 1956, and had germinated by November 10, 1956. During the two weeks after emergence temperature control of near 50°F. was attempted in an effort to duplicate favorable results obtained by Lewis (19) and Wittwer (36). The unseasonably warm day and night temperatures nullified this attempt.

One half of the seedlings were transplanted November 23, 1956, and the others were transplanted November 27, 1956. Four inch clay pots were used as plant containers.

Night temperatures were maintained as near 60°F. as possible, and day temperatures were maintained as nearly as possible within a range of 65°F. to 70°F.

Seven and one-half ounces of a 10-25-30 analysis soluble fertilizer was dissolved in fifteen gallons of water, and applied at the rate of 100 ml. per potted plant on January 2, 1957.

Production of Fruits

Soil Selection

A mixture of Huntington silty clay loam and Cumberland silty clay loam soils was used in the plastic house in which the plants were set. Two soil samples were taken from each half of the ground bed, and were tested for pH, and potassium and phosphorous levels. Results indicated the need of 0-20-20 fertilizer.

Fertilization and Planting

One week before planting a 0-20-20 analysis fertilizer was applied at a rate of 1,500 pounds per acre. The fertilizer was broadcast and worked into the soil as the soil bed was being roto-tilled in preparation for planting. Liming was not considered necessary since the pH was 6.0-6.1.

Heating of the plastic greenhouse began January 3, 1957, to insure optimum soil and air temperatures for the setting of the plants.

Furrows two feet apart were dug six to eight inches deep crossways of the house. A 20 per cent super phosphate fertilizer was applied at the rate of 275 pounds per acre in the furrows before the plants were set. This was not stirred with the soil.

Planting was done January 5, and January 7, 1957, spacing plants eighteen inches apart in the rows with a two foot walkway down the center of the house. The plants were spaced two feet from each wall. This allowed a planting of 368 plants with individual spacing of 18" X 24". Roots and stems up to the cotyledon leaves of the plant were covered with soil. A 10-25-30 analysis fertilizer from a one ounce per gallon mixture was then applied as a drench at the rate of 0.6 pint per plant.

When the third cluster of fruits set, 1,800 pounds per acre of a 6-12-12 analysis fertilizer was broadcast between rows and watered into the soil. This was done April 16, 1957.

Watering

The soil was watered evenly using an open hose, before planting. The water was applied at the base of the plants and between the rows until the soil surface became saturated and the water began to puddle.

Cultivation

Practically no cultivation was required due to the relatively weed free soil that was used. Some cultivation was required to break the soil crust that resulted from workers walking over the unmulched soil for staking, tying, pruning and pollinating.

Pollination

During the flowering period, blooms were tapped daily by the use of an electric vibrator. A period of thirty minutes each day was required to pollinate all flower clusters when each plant had developed approximately four flower clusters. When conditions permitted the opening of ventilators, pollination from wind movement was used.

Temperature Control

Night temperatures were maintained between 55°F. and 64°F., except for two nights when the heater failed to operate. A low of 34°F. and 36°F. was recorded inside the greenhouse these two nights. These low temperatures occurred January 16, and January 18, when the plants were developing the first flower buds.

Day temperatures were maintained between 64°F. and 80°F. from January through March by correlating ventilation and heating practices. Ventilation was provided by five 2½' X 8' ventilators along each side of the greenhouse, and by a 3' X 5'8" door on the southern end of the greenhouse.

A meter was installed to measure the cubic feet of gas used. Another meter was installed which recorded the number of hours the heater operated. The gallons of gas required per month was calculated by dividing the total number of gallons consumed by the total hours operated per month.

Pruning and Training

The one stem system of plant pruning was used.

Three types of training methods were used. The plants in the row by the East wall were trained to string which was loosely tied at the bottom of each plant and tied securely to the overhead wire. Fifty plants were trained in this method.

One inch square stakes were driven into the ground beside fifty plants, and the stakes were tied to overhead cross wires. The plants were tied to the stakes in a manner similar to field culture.

Wire stakes were used for the remaining plants. These were made of two strands of No. 9 gauge wire twisted together and the tops of the stakes were tied to cross wires.

Pest Control

The chemical sprays used were malathion at the rate of one and one-half pints per one hundred gallons, and captan at the rate of two pounds per one hundred gallons. The spraying was started one week after planting and continued every week to ten days. Malathion was omitted from the spray program when evidence of insects failed to appear. Captan was included in each spray for the prevention and control of fungus diseases.

Harvesting

The tomato fruits were harvested by cutting the fruit stem as near the calyx as possible with pruning shears. The short stems were a measure to prevent fruit puncturing when packed.

The fruits were sorted, graded, wiped, and weighed before marketing. Grades were based on those of the U. S. Standard.

Marketing

Two markets were chosen as possible retail outlets for the field grown tomatoes. The retail price of the U. S. Combination grade was 40 per cent higher than the wholesale price.

Advertisement concerning availability of greenhouse tomatoes in the area by the producer was restricted to a local agricultural information program. The retailer placed two advertisements concerning greenhouse tomatoes in the local evening paper during the harvest period.

The tomatoes were displayed in bulk lots. A sign along the bin identified them as being greenhouse tomatoes. The green calyx also served as identification.

CHAPTER IV

RESULTS

Construction Costs

The total cost of construction was $1,268.04, of which $894.04 (70.5 per cent) was expended for materials and $374.00 (29.5 per cent) was expended for labor. The amount charged to the production of the spring crop of tomatoes was $161.89, of which $78.59 (48.5 per cent) was charged for materials and $83.30 (51.5 per cent) was charged for labor.

The construction costs and the amount charged to the spring crop of tomatoes are listed in Table I.

Production Costs and Labor

The labor used in the production of the tomatoes was experienced farm labor. Little supervision was necessary after a procedure was explained. The going wage scale in the area of $0.75 per hour was paid for labor.

The hours of labor required per month for the major time consuming production practices and the total cost of labor for production are shown in Table II. The hours of labor required per month ranged from 24.75 hours (January) to 48.75 hours (May). The average number of hours required per month was 34.42 hours.

Miscellaneous production and marketing costs resulted in a

TABLE I

CONSTRUCTION COSTS OF POLYETHYLENE GREENHOUSE

Item	Cost	Per Cent Charged to Spring Crop	Amount Charged to Spring Crop
Materials			
Plastic	$ 54.65	50	$ 27.32
Heating pipes	51.55	25	12.89
Movable water hose	5.00	10	.50
Heater, thermostat, and fan	225.00	5	11.25
Foundation blocks	83.95	5	4.20
Masonry materials	61.25	5	3.06
Framing	290.67	5	14.52
Structural hardware	39.00	5	1.95
Permanent water pipes	32.97	5	1.65
Fuel tank	50.00	2.5	1.25
Labor			
Applying plastic	132.00	50	66.00
Installing heating pipes	6.00	25	1.50
Hauling soil	100.00	10	10.00
Construction	96.00	5	4.80
Excavation	40.00	2.5	1.00
TOTALS	$1,268.04		$161.89

TABLE II

HOURS OF LABOR REQUIRED PER MONTH FOR PRODUCTION OF 0.03 ACRE OF GREENHOUSE TOMATOES

	Production Practices							
Month	Setting	Spraying	Tying and Pruning	Ventilation	Pollination	Watering	Picking	Total
Jan.	20.00	1.50	0.25	3.00				24.75
Feb.		4.50	17.25	5.00	2.00			28.75
Mar.		4.50	14.00	3.00	11.25	0.25		33.00
Apr.		3.75	9.25		5.25	10.00	8.75	37.00
May		4.00	6.50		1.50	21.50	15.25	48.75
June		4.00	1.00			13.00	16.25	34.25
TOTALS	20.00	22.25	48.25	11.00	20.00	44.75	40.25	206.50
	TOTAL COST OF LABOR FOR PRODUCTION AT $0.75 PER HOUR: $154.88							

total cost of $108.75, of which $80.97 (74.5 per cent) was expended for production costs and $27.88 (25.5 per cent) was expended for marketing costs. These costs are listed in Table III.

Temperature Control

The monthly hours of heater operation, and the volume and costs of gas consumed are shown in Table IV.

A monthly rental charge of $2.00 for the 500 gallon gas storage tank results in a rental charge of $12.00 for the spring crop. The total charge for gas and rental fee was $218.89.

Yields

An average yield of 5.87 pounds of salable fruit per plant was obtained. The average total yield of 7.46 pounds of fruit per plant was produced. Harvest began April 8, 1957, and continued through June 30, 1957.

The monthly yield of fruit and prices received for salable fruit are presented in Table V. The total returns for the crop was $609.15. The total costs of production charged to the crop was $644.50.

Condensation and Light

Condensation along the walls and roof inside the greenhouse was a serious problem during cold, cloudy periods. Condensation evaporated during periods favorable for ventilation. The ventilators were opened

TABLE III

MISCELLANEOUS PRODUCTION AND MARKETING COST FOR 0.03 ACRE OF GREENHOUSE TOMATOES

Item	Amount Charged To Spring Crop
Production Costs	
Value of plants (31 doz. at $0.80 per doz.)	$ 24.60
Interest on Capital Invested in greenhouse structure at $3\frac{1}{2}$ per cent per year	22.20
Water	8.50
Taxes	5.86
Twine	4.50
Chemicals for pest control	4.03
Fertilizer	3.37
Electricity	3.11
Pollinator	3.00
Metal Stakes	1.30
Wood Stakes	0.50
Marketing Costs	
Grading	22.88
Hauling to market	5.00
TOTAL	$108.75

TABLE IV

MONTHLY HOURS OF HEATER OPERATION, AND VOLUME OF BUTANE GAS CONSUMED FOR HEATING 0.03 ACRE OF SPRING CROP GREENHOUSE TOMATOES

Month	Hours of Operation	Cubic Feet of Gas Consumed	Gallons of Gas Consumed
January 3-31	305	2,013	358.85
February 1-28	273	1,827	319.41
March 1-31	339	2,233	396.63
April 1-17	121	804	141.57
TOTALS	1,038	6,877	1,216.46

TOTAL COST OF GAS AT $0.17 PER GALLON: $206.89

TABLE V

MONTHLY YIELDS OF FRUIT AND PRICES RECEIVED
FROM 0.03 ACRE OF SPRING CROP GREENHOUSE TOMATOES

Month	Pounds of No. 1 Fruit	Prices Received Per Pound	Pounds of Combination Fruit	Prices Received Per Pound	Monthly Income	Pounds of Non-salable Fruit
April	545	$0.35	70	$0.20	$204.75	45
May	383	0.35	228	0.20	179.65	228
June 1-20	379	0.30	292	0.20	172.10	281
June 20-30	132	0.25	131	0.15	52.65	33
TOTALS	1,439		721		$609.15	587

PERCENTAGE OF TOTAL SALABLE YIELD GRADED AS U. S. NO. 1 --- 66 per cent

AVERAGE PRICE RECEIVED FOR U. S. NO. 1 ---------------------- $0.33/LB.

AVERAGE PRICE RECEIVED FOR U. S. COMBINATION GRADE ---------- $0.19/LB.

at every opportunity for the control of diseases favored by high humidities, and for removal of condensation which reduced light intensity.

Light conditions were relatively poor during February. A period of daily rainfall resulted in a high outside relative humidity, a condition unfavorable for evaporation of condensation even during periods of ventilation. The accompanying overcast skies and the condensation resulted in reduced light intensities inside the greenhouse.

Fertilization

The amounts of fertilizer applied for the production of tomatoes on 0.03 acre has been compared with the amounts removed per acre in Ohio (15). This data and the results of the soil tests on which the crop was produced are presented in Table VI.

Nitrogen deficiency symptoms were observed two weeks before the end of harvest. Nitrogen application was not considered to be profitable at that time.

Watering

The tendency of the clay soil to hold water, the additional seepage of water through the underground walls during the period of daily rainfall in February, and the accompanying low light intensities decreased the need for a general watering until April 3, 1957. Spot watering was required for the plants around the heater.

TABLE VI

RESULTS OF SOIL TESTS, AND COMPARISON OF FERTILIZER APPLIED TO AND NUTRIENTS REMOVED BY 0.03 ACRE OF GREENHOUSE TOMATOES

Soil Tests				Pounds of Fertilizer Applied			Pounds of Fertilizer Removed (a)		
Sample	pH	Available Phosphate	Available Potash	NO_3	P_2O_5	K_2O	NO_3	P_2O_5	K_2O
1	6.1	Low (b)	High (d)	3.22	17.16	15.68	11	6.93	22.26
2	6.0	Very Low (c)	Low (e)						

(a) Derived from pounds removed per acre calculated from Ohio date (15).

(b) From five to fifteen pounds of available phosphorous per acre.

(c) From zero to five pounds of available phosphorous per acre.

(d) Above one hundred eighty pounds of available potassium per acre.

(e) From eighty to one hundred thirty pounds of available potassium per acre.

The method of watering by hose was very acceptable from the standpoint of the control of fungus diseases, and from the lack of damage to the plants by the hose as the water was being applied.

Marketing

The supply of greenhouse tomatoes was not sufficient to meet the demand at even one of the selected stores catering to higher income customers. The nearest time supply approached demand was a one week period preceding Easter during which time two hundred pounds of greenhouse ripened tomatoes were produced and marketed. This resulted in the store selling two hundred pounds less shipped tomatoes.

Frequent requests were made by the store manager to lower the wholesale price charged for greenhouse tomatoes, but at no time did the supply exceed the demand.

CHAPTER V

DISCUSSION

Construction

The construction cost was considerably higher than that reported by Kentucky. This was due in part to the use of solid footing, block foundation, and high grade lumber. The necessity of excavation, placement of drainage material and productive soil were items that are not necessary annually. The application of the plastic was slow being the first with which the laborers had worked. Valuable space was taken by the heater in one end of the house.

Production of Fruits

There was no observable difference in the response of the two soils used to the rate of fertilizer applied. Vegetative and reproductive growth indicated that adequate amounts of fertilizer had been applied. Lower amounts of nitrates were applied than were found to have been removed under similar conditions (Table VI, page 43). The soil used was top soil and high in organic matter, which justifies the addition of relatively low amounts of nitrates. Soil tests determined the available phosphate was low, justifying the addition of relatively high amounts of phosphate.

Desirable moisture control of the greenhouse soil was not obtained during the early stages of plant growth. Many factors were responsible for this condition. The unusually rainy weather which began after planting in the greenhouse and which continued through February resulted in water seeping through the underground walls and poor drainage conditions. The clay content of the soil reduced drying by evaporation during short periods of higher temperatures. Ventilation practices aimed at lowering the high relative humidity inside were impractical at times because of the high relative humidity outside.

High soil moisture during early flowering increased nitrogen uptake while low light intensity reduced photosynthate production. The resulting low carbohydrate content relative to the nitrogen content of the plants promoted rapid growth and plants deficient in carbohydrates for best fruit set.

Temperatures near freezing the night of January 16, 1957, and January 18, 1957, resulted in partial defoliation of the plants. This further reduced total available photosynthate. These factors were responsible for the low early yield and low total yield.

Training

All methods of training tested were acceptable. However, there were advantages and disadvantages to each of the methods.

The disadvantages encountered in training the plants to strings were 1) damage to plants and fruits when three of the strings broke, and 2) the difficulty in estimating the potential size of the plant's stem so that the loop tied around the base of the plant would not girdle the stem as the stem grew in diameter. The lower cost of string as compared to stakes, and the short time required to train the plant around the string as compared to tying were advantages for string training.

The disadvantage in training plants to one inch square stakes was the reduction in light from the shadows cast by stakes spaced so closely. This was apparent during early stages of plant growth. An advantage of training plants to wooden stakes was the similarity of tying procedures used for the greenhouse crop and the field tomato crop.

The disadvantage of training tomato plants to wire stakes was the extra care required in tying the plants to the stakes to prevent the string from slipping down the stake, and the buckling of the stakes with a heavy fruit crop. The cost per stake of the wooden and wire stakes was the same. The advantages of the wire stakes were the lack of shadows cast when spaced closely, the property of the metal to reflect light, and the number of years the stakes may be used.

Pest Control

Ventilation practices, spray application, variety selection, and other cultural practices provided adequate pest control. Aphids and white flies were the most common insect pests. Malathion was effective in controlling these insects. The soil used was not sterilized. Captan proved effective in controlling fungus diseases, although Sclerotinia Stem Rot (*Sclerotinia Sclerotiorum*) caused the death of one plant.

Blossom-end rot, a non-parasitic disease, affected a large number of fruits on the plants near the heater. The fluctuation in water supply in this area is believed to be the cause of this disease.

Fruit cracking was most common during the latter part of the season. Abundant moisture supplied by irrigation, and high temperatures favoring rapid growth during this period, are believed responsible for fruit cracks.

Marketing

The wholesale price of both grades of greenhouse tomatoes sold on the Knoxville market was consistently lower than the wholesale price of greenhouse tomatoes sold on the Ohio markets reported by the Agricultural Marketing Service during this period. The wholesale price of greenhouse tomatoes on the Knoxville market was never lower than the reported wholesale price of the area's first locally harvested field crop. After July 1, 1957, late season greenhouse tomatoes could not compete with locally produced field tomatoes because of the price differential.

Greenhouse tomatoes were bought by consumers at prices charged to the exclusion of shipped tomatoes during the three months of greenhouse tomato production.

The advertising of greenhouse tomatoes on the Knoxville market done by the store manager was primarily for the benefit of the store since at no time was supply in excess of demand.

Throughout the entire greenhouse tomato season, the wholesale buyer continually called for more fruit even though he appeared convinced a lower price was necessary to move the fruit. The requests for lowering of the prices of the greenhouse tomatoes by the store manager was viewed as an attempt to please customers since no spoilage was reported.

Profitability of Production

It should not be inferred from the results of this experiment that the production of greenhouse tomatoes in the Knoxville, Tennessee area is unprofitable. Experience in greenhouse tomato production combined with climatic conditions more favorable to optimum yields would have resulted in higher total yields than obtained in this experiment. Lack of experience in using butane as fuel for heating greenhouses resulted in heater failure two nights when the first flower clusters were developing. Experience gained from using butane for heating greenhouses would have resulted in the installation of an inexpensive thermostatically controlled alarm from the greenhouse to a nearby worker's house. When temperatures inside the greenhouse resulted in the closing of the electrical circuit from the thermostat to the alarm, the worker would have been aware of a heating system failure. Appropriate action would have followed, and detrimental effects causing failure of the first fruit set would not have occurred.

Excessive amounts of water available to the plants and low light intensities during February resulted in a high nitrogen-low carbohydrate condition in the plants which was detrimental to the production of high yields as indicated by Howlett's (14) experiments. After the effects of excessive moisture were apparent, back filling around the foundation provided adequate control of moisture seepage through the underground walls.

Adequate provisions to insure optimum light intensity were believed to have been made. However, the relatively high number of days with overcast skies during February were not conducive to high early yields of greenhouse tomatoes.

It is believed that if these three conditions -- heater failure, excessive moisture, and low light intensity -- had not existed, yields approaching or equal to the eight to ten pounds average yield per plant obtained by greenhouse tomato producers in Ohio would have been obtained in this experiment.

CHAPTER VI

CONCLUSIONS

Construction of Plastic Greenhouse

The construction of a plastic greenhouse can be accomplished at a lower cost than the cost of the greenhouse constructed at the University of Tennessee. The following factors would decrease cost: 1) selection of suitable site to eliminate excavation and hauling of soil; 2) use of temporary foundation; 3) use of rough lumber framing.

More space could have been provided for plants by locating the heater just outside the house.

Production of Fruits

Environmental factors such as temperature, light, and water which are usually controlled in greenhouses were not controlled on certain occasions during this experiment. Provisions for drainage and heat were believed to have been adequate. Extremes of rainfall and low light intensity, plus the failure of the heater on two occasions, resulted in a large percentage of the early flower clusters failing to set fruit. These factors contributed toward a yield of only 5.87 pounds of salable fruit per plant instead of an expected yield of eight to ten pounds of salable fruit per plant. Another factor contributing to a lower yield of U. S. No. 1 fruits than has been reported by other producers was the grading practiced. The fruits sold through the store as U. S. No. 1 fruits were superior to the lower standards of the U. S. No. 1 grade. Fruits weighing less than four ounces were not sold in this "fancy" grade, nor were rough or otherwise defective fruits.

Marketing

Evidence from this study indicates that a market definitely exists for greenhouse tomatoes in the Knoxville, Tennessee area. The limited supply of greenhouse tomatoes produced prohibited collection of data which could be used to evaluate how large the market is that does exist.

The possibility of profitable production of greenhouse tomatoes also exists. Production experience and more favorable climatic conditions should result in yields approaching or equalling the eight to ten pounds of salable fruit per plant reportedly obtained by Ohio producers. In this experiment, an eight pound salable yield per plant would have resulted in a total salable yield of 2,944 pounds; 1914 pounds (65 per cent) would have been U. S. No. 1 fruits and 1039 pounds (35 per cent) would have been Combination grade fruits. A total revenue of $827.32 would have resulted from this yield increase based upon the average price of $0.33 per pound for U. S. No. 1 fruits and $0.19 per pound for the Combination grade fruits.

CHAPTER VII

SUMMARY

A greenhouse covered with polyethylene was constructed at the University of Tennessee from plans modified from those of University of Kentucky. This greenhouse was used for the production of a spring crop of tomatoes in a study designed to explore the profitability of producing and marketing greenhouse tomatoes on the Knoxville, Tennessee market.

The cost of constructing the greenhouse was $1,268.04, of which $161.89 was charged against the production of the spring crop of tomatoes.

Standard production practices were used. A total of 217 man hours of labor was required to produce the crop on 0.03 acre which at the wage rate of $0.75 per hour amounted to a cost of $162.75.

A 160,000 BTU butane gas heater was the source of heat. A total of 1,216.46 gallons of butane gas was used at a cost of $206.89. A $2.00 monthly storage tank rental fee added to this value resulted in a $218.89 cost of heating.

Miscellaneous costs charged to the production of the spring crop was $100.97.

Total charges to the spring crop were $644.50. A total yield of 2,747 pounds of fruit was produced from 368 plants for an average yield of 7.46 pounds of fruit per plant. A total salable yield of 2,160 pounds was produced from these plants for an average salable yield of 5.87 pounds of fruit per plant. The income from sales was $609.15. Uncontrollable environmental factors were responsible for the total salable yield per plant being lower than the average 8-10 pounds reportedly obtained by producers in Ohio.

The fruits were marketed through one store which caters to the higher income group of people.

A market for greenhouse tomatoes definitely exists in the Knoxville, Tennessee area.

Unprofitable returns from this experiment were largely due to high construction costs, and low salable yields resulting from uncontrolled climatic factors.

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