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The effects of two floating row covers, a spunbonded polyester and a highly perforated polyethylene, on enhancing Pikred tomato yield and extending the Romaine lettuce growing season were studied in 1984. Two field experiments were conducted for each crop. Tomato experiments were established in the spring of 1984 on April 20 and May 16 at the O.S.U. Vegetable Research Farm. Covers were combined with black plastic mulch. Four covering intervals were imposed, 3, 4, 5, and 6 weeks for each cover type. A bare soil and a black plastic mulched soil were used as checks.

Compared to bare and mulched soils, both covers increased air and soil temperatures, heat units, early vegetative plant growth and early yield (first of four harvests) in both plantings. At the early planting, floating row covers increased overall yield over mulched and bare controls, whereas, they only differed from bare soil at the late planting. Fruit set studied on three clusters was depressed with both covers in the early planting while it was improved by spunbonded polyester at the late planting. Floating row covers tended to increase catfaced

(misshapen) fruits at both plantings. Mineral uptake was not affected by floating row covers. Covering interval did not affect overall yield at either planting; however, a 5 week covering period had the highest early yield at the late planting. Covering tomatoes for 5 weeks from the transplanting date seemed to be the most adequate covering period .

Two lettuce experiments were conducted in the fall of 1984 at the O.S.U. North Willamette Agricultural Experiment Station. These were planted on September 16 and October 3. Covers used in these experiments were the same as in tomato trials, however black plastic mulch was not used. Two covering dates were imposed at each experiment, one immediately after transplanting and the other 1 week later. For the first experiment, and the first covering date, covers were removed at 3 and 7 weeks after covering. For the second covering date in this experiment, covers were removed at 3 and 6 weeks after covering. For the second experiment, covers were removed at 4 and 10 weeks after each covering date.

Both covers increased air and soil temperature and plant growth in both plantings. At the early planting, plants covered for 6 and 7 weeks grew faster and were larger at harvest than plants covered for 3 weeks. At the late planting, plants covered for 10 weeks outyielded those covered for 4 weeks. However, plants covered for 10 weeks were slightly damaged by covers, so cover removal would be critical. Both covers increased K and B plant concentrations at the early planting. The seven week covering interval seemed to be appropriate for a September Romaine lettuce planting.

Effect Of Floating Row Covers On Tomato And Romaine Lettuce

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TABLE OF CONTENTS

INTRODUCTION 1

LITERATURE REVIEW 5
- Growing Crops Under Protective Structure 5
- Use of Plastic Row Covers in Horticulture 7
- Light Transmission of Plastic Films 9
- Heat Retention 10
- Row Covers 12
- Floating Row Covers 15
- Ventilation of Row Covers 16
- Effect of Row Covers on Soil and Air Temperature 18
- Effect of Row Covers on Earliness and Yields 21
- Plastic Mulch 23

TOMATO EXPERIMENT ONE 28
- Materials and Methods 28
- Results and Discussion 31
  - Air temperature 31
  - Frost protection 32
  - Soil temperature 33
  - Heat units 34
  - Plant growth 34
    - Height and width 34
    - Fresh weight 35
    - Flower number 35
    - Fruit set 36
  - Yield and fruit size 37
  - Mineral content 40
  - Cull and catfaced fruits 41

TOMATO EXPERIMENT TWO 58
- Materials and Methods 58
- Results and Discussion 58
  - Soil temperature 59
  - Heat units 59
  - Plant growth 59
  - Yield and fruit size 61
  - Mineral content 63
  - Cull and catfaced fruits 63

LETTUCE EXPERIMENT ONE 80
- Materials and Methods 80
- Results and Discussion 81
  - Air temperature 81
  - Soil temperature 82
  - Plant growth 82

LETTUCE EXPERIMENT TWO 90
Materials and Methods 90
Results and Discussion 90
Air temperature 90
Soil temperature 91
Growth response 91

BIBLIOGRAPHY 96

APPENDIX 105

APPENDIX TABLES

Table		Page
1	Effect of FRC and covering interval on mean fruit weight (g) of large tomato fruit for 4 harvests, experiment one.	105
2	Effect of FRC and covering interval on mean fruit weight (g) of medium tomato fruit for 4 harvests, experiment one.	106
3	Effect of FRC and covering interval on mean fruit weight (g) of small tomato fruit for 4 harvests, experiment one.	107
4	Effect of FRC and covering interval on mean fruit weight (g) of large tomato fruit for 4 harvests, experiment two.	108
5	Effect of FRC and covering interval on mean fruit weight (g) of medium tomato fruit for 4 harvests, experiment two.	109
6	Effect of FRC and covering interval on mean fruit weight (g) of small tomato fruit for 4 harvests, experiment two.	111

LIST OF FIGURES

Figure		Page
1	Effect of FRC on air temperature on a hot day (May 29), tomato experiment one.	43
2	Effect of FRC on air temperature on a cool day (April 26-27), tomato experiment one.	44
3	Effect of FRC on mean air temperature in weekly increments, tomato experiment one.	45
4	Effect of FRC on early tomato yield, experiment one.	49
5	Effect of FRC on total tomato yield, experiment one.	50
6	Cumulative tomato yield as affected by FRC and harvest number, experiment one.	51
7	Effect of FRC on air temperature on a hot day (June 25), tomato experiment two.	65
8	Effect of FRC on air temperature on a cool day (May 31), tomato experiment two.	66
9	Effect of FRC on mean air temperature in weekly increments, tomato experiment two.	67
10	Effect of FRC and covering interval on early tomato yield, experiment two.	71
11	Effect of FRC on total tomato yield, experiment two.	72
12	Cumulative tomato yield as affected by FRC and harvest number, experiment two.	73
13	Effect of FRC on minimum and maximum air temperature in weekly increments, lettuce experiment one.	87
14	Effect of FRC on minimum and maximum air temperature in weekly increments, lettuce experiment two.	94

LIST OF TABLES

Table		Page
1	Effect of FRC on mean air and soil temperature (°C), tomato experiment one.	42
2	Effect of FRC on tomato plant growth (cm), experiment one.	46
3	Effect of FRC and covering interval on days to tomato flowering and ripening and fruit set of 3 clusters, experiment one (mean of 5 plants).	47
4	Effect of FRC and covering interval on tomato total yield (mt/ha) for 4 harvests, experiment one.	48
5	Effect of FRC and covering interval on yield (mt/ha) of large tomato fruit for 4 harvests, experiment one.	52
6	Effect of FRC and covering interval on yield (mt/ha) of medium tomato fruit for 4 harvests, experiment one.	53
7	Effect of FRC and covering interval on yield (mt/ha) of small tomato fruit for 4 harvests, experiment one.	54
8	Effect of FRC and covering interval on mean fruit weight (g) of all tomatoes for 4 harvests, experiment one.	55
9	Effect of FRC and covering interval on number of cull and catfaced fruit and weight of vines, tomato experiment one.	56
10	Effect of FRC and covering interval on mineral content of tomato leaf, experiment one.	57
11	Effect of FRC on mean air and soil temperature (°C), tomato experiment two.	64
12	Effect of FRC on tomato plant growth (cm), experiment two.	68
13	Effect of FRC and covering interval on days to tomato flowering and ripening and fruit set of the first 3 clusters experiment two (mean of 5 plants).	69

14	Effect of FRC and covering interval on tomato total yield (mt/ha) for 4 harvests, experiment two.	70
15	Effect of FRC and covering interval on yield (mt/ha) of large tomato fruit for 4 harvests, experiment two.	74
16	Effect of FRC and covering interval on yield (mt/ha) of medium tomato fruit for 4 harvests, experiment two.	75
17	Effect of FRC and covering interval on yield (mt/ha) of small tomato fruit for 4 harvests, experiment two.	76
18	Effect of FRC and covering interval on mean fruit weight (g) of all tomatoes for 4 harvests, experiment two.	77
19	Effect of FRC and covering interval on number of cull and catfaced fruit and weight of vines, tomato experiment two.	78
20	Effect of FRC and covering interval on mineral content of tomato leaf, experiment two.	79
21	Effect of FRC on mean air and soil temperature (°C), lettuce experiment one.	86
22	Effect of FRC, covering date and covering interval on lettuce yield, experiment one.	88
23	Effect of FRC, covering date and covering interval on lettuce mineral content, experiment one.	89
24	Effect of FRC on mean air and soil temperature (°C), lettuce experiment two.	93
25	Effect of FRC, covering date and covering interval on lettuce yield, experiment two.	95

The Effect Of Floating Row Covers On Tomato And Romaine Lettuce

INTRODUCTION

The growing season for vegetable crops in the Willamette Valley of Oregon is relatively short and cool. At Corvallis, weather records over a 37 year period show monthly mean minimum temperatures for the months of April to August to range from 3.8°C to 10.4°C. The mean maximum temperature for these months varies from 15.2°C to 26.9°C and the monthly average temperature, from 9.4°C to 18.7°C (Redmond, 1985)

The optimum temperature for tomato growth is between 21 and 23°C (Lorenz and Maynard, 1980). It is apparent that climatic conditions for western Oregon are less than optimal for growing a tomato crop. The situation is more severe early in the season when late frosts may occur. For these reasons the tomato crop is grown only on a small scale in the Willamette Valley and is mostly limited to home gardeners and local fresh market producers. Tomatoes are normally transplanted from May 15 for production starting in mid-August and lasting to mid-October. The average yield is about 50 tons per hectare.

On the other hand, weather records show that monthly average temperatures from the month of September to December decrease from 16.4°C to 4.8°C, the monthly minimum temperatures from 8.7°C to

1.4°C, and the monthly maximum temperatures from 17.9°C to 8°C. These conditions limit the production of Romaine lettuce beyond October when normally all Oregon Romaine lettuce harvest is completed. Early frost dates in the fall may make the situation worse. Romaine is usually planted in the field from March to August for production beginning from mid-June to the end of October. The average yield is about 32 tons (2500 15 kg cartons) per hectare.

Low temperatures during the growing season for tomato and Romaine result in low yield owing to a reduced growth for both plants, poor fruit set and excessive flower abscission for tomatoes. Cultural practices which modify the crop environment by increasing soil and air temperature, elevating soil moisture, and protecting plants from storm and disease will probably allow earlier tomato establishment and late Romaine production. The yield and the quality of the two crops could also be improved.

Solid, perforated and slitted polyethylene tunnels supported by wire hoops have been used to enhance earliness and increase yield of several vegetable crops in many places in the world.

Tomato and lettuce earliness have been speeded by using plastic row covers (Emmert, 1955). Higher and earlier tomato yields have been obtained when grown under perforated and non-perforated polyethylene (PE) tunnels (Bromert and Taber, 1973; Hall, 1963, 1965; and Kratky, 1977). Direct covering with solid and perforated PE, while eliminating the use of the structural support, has been employed to enhance earliness and increase yield of head lettuce. (Benoit, 1975; Benoit and Hartmann, 1974; Henriksen, 1981).

Floating row covers (FRC), porous, light, synthetic materials, which may be laid directly on seeded or transplanted crops without structural support, increased early and total yield of muskmelon and several other vegetable crops. (Mansour et al., 1984). These covers, beyond eliminating the use of wire hoops, also eliminated hand labor that would be required for ventilating tunnels. Spunbonded polyester (SPE) floating row cover enhanced earliness and increased yield of transplanted muskmelon by increasing soil and air temperature while allowing adequate ventilation and appropriate water penetration (Loy and Wells, 1982). Tomato total yield was significantly increased under SPE as compared to bare soil and black plastic mulch (BPM) (Loy and Wells, 1983). Early yield of seeded and transplanted muskmelon was increased when grown under a highly perforated polyethylene (HPPE) FRC (Hemphill and Mansour, 1986).

Black plastic mulches have been employed to increase yield of tomato (Bakhit, 1983; Jones et al., 1977) and lettuce yield (Hilborn et al., 1957).

Even though plastic row covers have several advantages in promoting plant growth and increasing yield, high temperatures created under row covers after a long covering period could be harmful for certain vegetable crops. Crop leaves may be burned and pollen viability and fruit set may be reduced. Defining the optimum covering period with plastic row covers for specific crops is critical in the success of growing a crop protected with plastic covers.

Successfully extending the growing season of a vegetable crop depends on the planting date. Defining the appropriate planting date for a crop forced with plastic is also an important factor in growing the crop out of season whether early or late.

Determining whether seedlings should be covered with plastic immediately after transplanting or sometime later is also an important factor in the survival of the young plants.

The objectives of this study were to:

1. Determine the effect of a SPE and a HPPE material (65 holes per square cm) on the microclimate of a warm season vegetable crop (tomato) and a cool season one (Romaine).
2. Evaluate the response of these crops to the FRC.
3. Determine response of the crop when covered for several time intervals.
4. Determine crop response from several planting dates to evaluate whether the magnitude of effects is greater from earlier or later planting dates.
5. Define the effect of covering date on survival of lettuce transplants.

LITERATURE REVIEW

Growing Crops Under Protective Structures

A protective structure improves the microclimate of a growing plant during cool and unfavorable growing seasons. It provides heat and ventilation and allows enough light to penetrate to the plant underneath, and provides enough ventilation and protection from wind and storm.

Forcing systems have been used to produce horticultural crops out of season for many centuries. Protective structures promote plant growth, providing earliness and high yields so that profit may be increased.

> "some of the reasons advanced for using protectors include earlier maturity, better prices, protection from dry weather, longer market season, larger market production, less insect damage, protection from rodents, stronger and healthier plants, ..., less cultivation and larger possible annual returns from every dollar invested" (Ware, 1936).

It is probably impossible to determine when plants were first protected from cold or which means have been employed for that protection. Hibbard (1932) reported that the early Greeks and Romans were probably the first to use forcing techniques by bringing plants from the garden into the house and placing them near the windows. Taft (1897) related that the Romans were able to grow vegetables throughout the year by raising crops in several primitive plant protectors. Ware (1936) stated that the ancients were able to grow cucumbers all year round by raising plants in mobile frames which could be moved under plant protectors depending on weather conditions. Wright (1931) reported that crops were first forced in greenhouses in the middle of the seventeenth century in Europe. In the United States, vegetables were first raised in greenhouses in 1764 (Taft, 1897).

Materials for protecting crops were wood, stone, glass, oiled paper, straw, nuts, bark, cans, fruit jars, bags and paper. Some of these materials are still used today. In France, cloches, frame lights and hot beds were used by small farmers for many centuries; they became part of the "French gardening system" (Webber, 1968).

With the development of the plastic industry during this century, several kinds of plastic have been introduced for the production of horticultural crops. Early attempts to employ plastic film in horticulture were frequent but generally accompanied by failure. The first succesful experiment with plastic film began in the 1940's in the United States and in 1950's in other countries (Keveren, 1973).

Early work on frost protectors in the United States started with Hibbard around the 1930's (Kohm, 1983). Hibbard (1932) studied the effects of several frost protectors on tomato plants. For six years, he used four classes of protective material: paper, cellulose compounds, glass and cloth. He employed the hot cap shape in covering plants. He reported that plant covers increased soil and air temperature, resisted wind and storm, prevented cutworm damage, enhanced plant growth and increased early and total yield, depending on weather conditions.

In 1936 Ware worked on the influence of plant protectors on the production of muskmelon. He used some of the same covering materials as Hibbard and he introduced another shape of plant cover which he called "continuous paper greenhouse". He confirmed the findings of Hibbard (1932) and added that the continuous paper row cover produced a better plant environment than did the single plant covers.

Comin and Sherman (1930) tried to substitute paraffin coated cloth and celluloid for glass covers, which were used mostly in covering hot beds and cold frames. They observed that the new materials did not have any advantage over glass except lightness and ease in handling.

Shadbolt et al. (1962) indicated that, before the introduction of plastic in horticulture, the most common plant covering material was the paper cap.

Use of Synthetic Row Covers in Horticulture

Plastic row covers have been used for almost 50 years in protecting and developing early or late horticultural crops. They became widely used about 20 years ago. Plastic films were employed in growing crops in the 1930's (Comin and Sherman, 1930; Hibbard, 1932). Newer plastic films were introduced in growing crops in the 1950's (Emmert, 1955).

"The inexpensive plastics excited not only researchers but farmers seeking a cheaper method of producing and preserving food and fiber" (Hall and Besemer, 1972).

Actually, the full potential of plastics used in protecting horticultural crops is well exploited. Their properties, availability, and method of use are very well known. They are applied for covering greenhouses and small supported or unsupported tunnels and are also used for covering the ground as mulch. Several types of plastic films have been used since the 1950's. Keveren (1973) reported that several plastic films were used in raising horticultural crops, including polyethylene (PE), ethylene-vinyl acetate (EVA), polypropylene, polyvinyl chloride (PVC), polyethylene terephthalate (polyester), and others. He agreed with Dubois (1978) that the PE films were the most commonly used, followed by PVC and EVA. Polyester films were first used in covering greenhouses in late 1950's in the United States, and were used after that in Italy for the same purpose. That film was commonly named mylar (Keveren, 1973).

In 1981 a spunbonded polyester (SPE) film was first tested as a crop row cover on tobacco in North Carolina. It was then evaluated in growing vegetable crops by Wells and Loy (1983) in New Hampshire.

"After two years of testing at the University of New Hampshire and with commercial growers, it appears that polyester is also a very promising row cover material for vegetable crops" (Wells and Loy, 1983).

Spunbonded polyester is a cloth-like material widely used in clothing and rugs. It is lightweight (20.4 g per square meter), porous to water, air and sunlight. It normally breaks down after three months of use (Wells and Loy, 1983).

Highly perforated PE (HPPE) row cover is perforated with many very small holes (65 holes per square cm). It began to be used in the northwest of the United States in 1983 (Mansour, 1984b).

Light Transmission of Plastic Films

Light intensity delivered to a plant through a plastic film is crucial for plant growth, flowering and fruiting. Light intensity must not fall below the minimum requirements. The various wavelengths of sunlight have a big influence on the heat created inside the row cover.

> "A plant protector must admit the short-wave radiation from the sun that is needed for photosynthesis and warming and, at the same time, the protector must prevent the loss of the heat by long-wave radiation as well as by convection" (Waggoner, 1958).

Clear PE transmits around 80 percent of the ultraviolet (UV), about 86 percent of the visible and 88 percent of the infrared (IR) radiation (Dubois, 1978; Keveren, 1973). Polyethylene loses more UV and IR than PVC; this phenomenon allows PVC films to produce more heat than PE. However, Frutos (1971) related that a new PE film was introduced and called PE IR. Its optical characteristics resemble those of PVC. Dubois (1978) related that the light transmission properties of a plastic film could be reduced by condensation of water on the internal surface of the film. He added that a continuous film of water instead of droplets gave better visible light transmission and reduced transmittance of IR radiation. He stated, also, that dirt from the atmosphere deposited on the covering film surface reduced light transmittance. A reduction from 80 percent to 50 percent transmittance has been detected after two months of usage.

Waggoner (1958) reported that clear PE had a high transparency to long wave radiation (3 to 15 micron). He added that, compared to glass 3.2 mm thick, PE (0.05 mm) absorbed only 13 percent of the long wave radiation emitted from the soil while PVC (0.05 mm) absorbed 50 percent and glass 99 percent.

Guttormsen (1972) stated that PE films transmitted radiation with wavelength more than 3 microns while glass was limited to wavelengths between 0.3 and 3 micron; PVC transmittance was between that of PE and glass. For a dry film he found that PE transmitted 86 percent of radiation (0.3-3 microns) while PVC transmitted 75 percent. Spunbonded polyester material was reported to transmit 75 to 80 percent of incident light (Natwick and Durazo, 1985; Wells and Loy, 1983). However, SPE trasmitted less light than did a slitted PE on a sunny day (Wells and Loy, 1982).

Heat Retention

Plastic row covers build up heat inside the protective structure by creating a "greenhouse effect" which protects plants from light frost and promotes faster plant growth.

Heat build up or "greenhouse effect" is due to the penetration of solar radiation through the film covering material and the trapping of long wave (IR) radiation emitted by the soil. The reduced permeability of plastic films to the IR radiation is variable and depends on the conditions of the material. The warmth created under the plastic protector depends also on the thermal properties of the soil and the weather conditions outside the cover, such as temperature, cloud cover, and winds.

Plastic films trap heat during the day time and lose some of it at night. The difference between these gains and losses define the potential of a plastic in providing heat at night. This difference has to be positive if plants are to be protected.

"In order for a shelter to provide any degree of frost protection, it is necessary that heat accumulation under the cover during the day be greater than that which is lost through the cover during the night" (Shadbolt and McCoy, 1960).

Heat is lost through a plastic cover by convection, conduction and radiation. This loss is variable with the film material and its environment. Plastic films with high IR transmission lose more heat by radiation at night than ones with a low transmission. PE films, owing to their high IR transmission, offer the least heat insulation when compared with PVC and glass. (Keveren, 1973; Dubois, 1978).

Waggoner (1958) reported that PE, PVC, and sisalglaze produced the same protection effects. He confirmed this finding in other work where he compared PE which absorbed only 1/8 of the earth radiation with neoprene which absorbed 9/10 of the same radiation. These changes in the film's properties are due mainly to a film of dew deposited on covers.

"All plastics, when covered by dew, are capable of producing a "greenhouse effect" regardless of their absorbtion spectra; and differences among them in degree of protection disappear".

This water condensation made the covers nearly opaque to soil radiation. He mentioned also that weather and soil conditions had an effect in that modification.

Contrary to Wagonner (1958), Hall and Besemer (1972) stated that PVC was slightly more effective in retaining heat than PE films. Benoit and Hartmann (1974) found that the same flat PE tunnel loses more heat by radiation when used in a region where wind speeds were high. They added that the high wind speed made the difference in temperature between covered and non-covered plots very small.

Even though plastic row covers were able to increase soil and air temperature and created the "greenhouse effect", they sometimes did just the opposite by reducing air temperatures below ambient. This phenomenon was called "temperature inversion" (Keveren, 1973), and appeared on cool nights. It happened when all the heat generated under a cover was lost and cold still air built up near the ground surface. This cool air remained cooler than the air above the cover which was mixed with warmer air from higher levels. Temperature inversion was related to the thermal conductivity of plastic. Polyethylene films were the most susceptible to temperature inversion; however, this problem was reduced when PE films were covered with dew or perforated (Keveren, 1973).

Row Covers

Row covers were defined by Wells and Loy (1985) as synonomous to low tunnels which were described by them also as:

"A row cover is defined as a flexible, transparent covering which is installed over single or multiple rows of vegetables for the purpose of enhancing plant growth and yield. The cover may or may not be supported with hoops and is intended to be left over plants for a relatively short period of time (2-8 weeks depending on the crop and the weather conditions)".

Producing crops under low tunnels began with Ware in 1936 when he grew melons under a continuous paper tunnel. He found that this shape produced large and vigorous plants while providing more uniform and favorable temperatures when compared with hot caps.

Plastic tunnels were first used in the United States by Emmert when he did his research on greenhouses, mulches and row covers. In California the first successful tunnel was used for growing cucumber in 1958 (Hall and Besemer, 1972). Shadbolt and McCoy (1960) showed the advantages of using tunnels over hot tents. Hall established the practical and commercial use of PE tunnels in growing tomato, pepper and cucumber (Hall and Besemer, 1972; Wells and Loy, 1985).

Row cover supports were first composed of wood or wire, over which plastic films were stretched. Polyethylene films were most commonly used in covering tunnels, followed by some use of PVC and EVA. Films could be solid, perforated or slitted. Perforations and slit number, dimensions and designs were variable.

Tunnels may have different shapes, heights and widths. Numerous tunnel designs emanated from France in the 1950's (Keveren, 1973). Tunnels supported on metal hoops appeared in 1956. They consisted of anchoring the metal hoops in the soil about 25 cm deep, stretching the cover on these hoops, and then covering the edges with dirt. Ventilation was insured by opening one side of the tunnel and then closing it when needed, or by perforating the film (Dubois, 1978; Keveren, 1973). Another system, the Nantais tunnel, was also designed in France in 1956. It is a double hooped tunnel. The plastic film was stretched and secured between two wire hoops having different diameters. Ventilation was by sliding the film between the two wire hoops.

Hall and Besemer (1972) reported that an inverted V tunnel shape was introduced in California for growing vegetables. This tunnel is also supported by wire hoops and covered with two plastics sheets. Ventilation was provided by opening the two plastic sheets from the top. Maximum ventilation could be obtained by completely removing one of the films. Plastics with different perforation designs and hole numbers were also used with this system.

Oval shape tunnels were also covered with two plastic sheets and used in growing cucumber and tomato in California (Hall, 1965). Hall also slightly modified the inverted V shape and worked with "an obtuse triangle tube shape".

Jensen and Sheldrake (1964 and 1965) used air to support row covers and to control heat and ventilation. With this system they were able to remove excess heat and humidity from inside the tunnel. Tunnels were inflated with air generated from a fan set up for that purpose. No other structural support was used.

Garrison (1973) developed a plastic covered trench system to provide more heat in the early stages of growing plants. It consisted in forming a "V" shaped trench in the ground 18 cm deep, 11 cm wide at the bottom and 41 cm wide at the top. Plants were planted in the bottom of the trench and covered with a perforated 1.5 mil PE film. Films were removed when plants first touched the covers. This same system was used by Wien and Bell (1981) in raising cucurbits. They made the trench "W" shaped; transplants were planted on the central ridge and covered with perforated PE material.

Wells (1976) indicated that triple plastic row covers were used in New Hampshire. This quonset shaped structure was 5 m wide, 30 m long and 1.5 m high.

Floating Row Covers

Plastic perforated films have also been laid directly on seeded or transplanted crops without structural support and were called recently floating row covers. Benoit and Hartman (1974) stated that this kind of cover was first introduced in Holland in 1965 and used in growing rhubarb and strawberries. The film used was 0.02 mm thick PE and the covering period was 43 to 60 days. This tunnel type was tested by several researchers in the 1970's for enhancing and increasing yields of some vegetable crops. Head lettuce was grown under these tunnels (Benoit, 1975; Benoit and Hartmann, 1974; Henriksen, 1981). Carrot was also raised under this tunnel shape by Geustermans et al. (1981).

Floating covers were also made from Agril P17 (polypropylene). These "resemble more a disarranged net of fine fiber than a plastic film" (Henriksen, 1981). Other materials include SPE (Gerber, 1983; Gerber et al., 1985a, 1985b, 1985c; Hemphill and Mansour, 1986; Mansour et al., 1984; Hochmuth and Stall, 1984; Kohm and Wien, 1983; Taber, 1983) nylon (Wells and Loy, 1985); HPPE (Crabtree and Mansour, 1985; Hemphill and Mansour, 1986; Hemphill et al., 1985; Mansour, 1984a; Mansour et al., 1984). Xiro, "a patented product from Switzerland", is a clear PE film punched with many small, closely spaced slits. It has about 35000 slits per square meter (Maurer, 1984; Mansour et al., 1984).

These plastic films are light and porous. Crops can lift them gradually during the growth period. In most cases covers were applied directly on seeded or transplanted plants without support hoops but leaving some slack to allow plant growth beneath the covers. Cover edges and ends were secured with soil.

Ventilation of Row Covers

Removing surplus heat and excess humidity and supplying covered plants with fresh air, enough CO_2 and adequate heat are indispensable in the success of forced crop production beneath a plastic protective structure. This can be done by adequate ventilation when needed.

"In greenhouses, ventilation is not only provided for the purpose of maintaining a supply of fresh air but is utilized as a method of controlling temperature and humidity" (Wright, 1931).

Dubois (1978) stated: "Ventilation has to be carried out at the right time to prevent fading of the flowers and burning of leaves touching the film, and wilting of the plant."

Several tunnel ventilation methods have been practiced.

Finding an efficient ventilation method was the focus of much research in this field.

"One of the problems of growing winter tomatoes is to find such methods for covering which will on the one hand enable maximum heat conservation, and on the other hand provide convenient ventilation" (Kloner, 1974).

Supplying the protective stucture with the appropriate amount of air by using less hand labor was the ultimate aim of these researchers. The usual practice for ventilating a tunnel is to open it from one or two edges at the bottom as needed. This system is labor costly and the cover was susceptible to wind damage.

Hall and Besemer (1972) found that the inverted "V" shaped tunnel covered with two plastic sheets was more easily ventilated by opening it from the top than were other designs requiring the lifting of the two bottom edges of a single sheet. Punching holes of different size, shape, number and design in the cover was also a ventilation method used by many workers. Shadbolt and McCoy (1960) ventilated plastic tunnels by punching holes about 30 cm apart on one side of the film. Then they increased the size of the holes and opened the ends of the tunnels as the plants grew. They reported that tearing of the film followed by plant damage sometimes occurred in windy conditions.

Hall (1971) stated that perforated row covers opened new possibilities for raising early vegetables. He used several cover perforation designs and combined them in different ways to grow tomato and cucumber. He found that perforated PE covers resulted in an earlier and higher cucumber yield compared to a solid film.

Tomato plants did not show a yield increase or earliness but fruits grown under perforated PE covers were larger compared to solid PE.

Frutos (1974), in raising tomato under tunnels, compared the effect of holes located on the ridge of the tunnel and on the side of it. He observed that the top perforated tunnels gave higher yield than the lateral perforated.

Cutting slits in the plastic film with different dimensions and numbers was also done for tunnel ventilation. Emmert (1955) indicated that plastic covers could be slitted in the top of the tunnel in order to provide ventilation and avoid opening the tunnels. Slitted PE films were used by several researchers in growing vegetables (Wells et al., 1977; Wells and Loy, 1981)

Wagonner (1958), in raising tomato out of season, compared a perforated PE row cover with a solid one with slits 40 cm long along the ridge of the tunnel. Slits were opened on warm days and otherwise closed with clothespins. He observed that fruit set was higher beneath slitted coverings than the perforated ones. Both types of ventilation reduced fruit set compared to exposed plants.

One reason for using floating row covers as a direct covering material is their porosity provides adequate ventilation. They do not require daily opening and closing. They can be left over the crop as long as no plant damage occurs (Mansour, 1984b).

Effect of Row Covers on Soil and Air Temperature

Thermal conductivity and light transmittance of a plastic covering material create a microclimate inside the tunnel. All researchers agree that daily soil and air temperatures inside a tunnel are always higher than those outside except for the temperature inversion phenomenon. Emmert (1955) and Wagonner (1958) found that plastic covers protected plants from frost up to -3.9°C. Wagonner (1958) added that frost protection provided by unheated plastic covering was abbout 1.7°C. Wien and Bell (1981) indicated that maximum air temperature beneath a PE tunnel reached 47.7°C when the temperature of the ambient air was 22.8°C. The minimum temperature early in the morning was 2.8°C under the clear PE when the ambient minimum was close to the freezing level. Guttormsen (1972) reported that the maximum air temperature could reach 40°C in closed tunnels when incoming solar radiation was high. The minimum night temperature under tunnels differed only a little from ambient temperature, which could be below 0°C. He concluded that plants grown in plastic tunnels could be exposed to extreme temperature variations whithin a 24 hour period. He found that a perforation totaling 6.5 percent of the film area reduced the maximum day temperature by 10°C on a sunny day and 4°C on a cloudy day whereas night minimum temperature remained almost unchanged. A 10°C decrease in the maximum day temperature was registered in a solid covered tunnel on a cloudy day.

In Hawaii, PE tunnels increased day air temperature by 2.2 to 3.9°C (Kratky, 1977). Shadbolt and McCoy (1960) found that the minimum air temperature inside PE "continuous covers" tunnel was 3°C higher than inside individual PE caps. Maximum air temperature during day time was 16.7°C above outside air temperature but this did not differ from the standard caps. They observed that continuous perforated PE covers provided the lowest air and soil temperatures when compared to non-perforated covers. This last finding was confirmed by Hall (1971) and Benoit and Hartmann (1974). The former indicated that flat perforated PE covering produced an average air temperature of 14.6°C and the solid one 17.1°C. However, both covers increased air temperature compared to non covered-areas.

Slitted PE applied as two covering sheets increased maximum air temperature by 6.1°C and the minimum temperature by 0.9°C whereas a single solid sheet ventilated by slits 30 cm long and 30 cm apart increased the minimum air temperature by 3.3°C. Maximum temperature under that cover reached 54.4°C (Wells et al., 1977). The frost protection of slitted PE covers was reported by Wells and Loy (1980) to be less than that of solid covers. The former provided 1.7 to 2.2°C of frost protection whereas the latter provided 2.8 to 3.9°C.

Floating row covers have also been reported to increase air and soil temperatures inside tunnels when used with or without ground mulches. A frost protection of 6°C was provided with perforated PE floating row cover (Anon, 1984). Spunbonded polyester provided frost protection of 1.6°C in the spring season and 3.8°C in the fall (Wells and Loy, 1983). A maximum of 48°C was reached with HPPE combined with BPM (Hemphill and Mansour, 1986; Taber, 1983). Spunbonded polyester raised the daily mean temperature by 9°C while HPPE increased it by 9.3°C (Mansour et al., 1984). They observed that SPE, HPPE and a highly slitted PE FRC increased the mean minimum temperature by 1.8, 1.4 and 1.4°C respectively.

Effect of Row Covers on Earliness and Yields

Plastic row covers have been successfully used in producing early and late vegetable crops and increasing their total yields; however, the benefits from such cropping systems depend enormously on the covering material, the environmental factors, the plant and others.

"The clear PE covers allow early vegetable planting resulting in 2-3 weeks earliness and in many cases increased total yield over non covered-crop" (Dubois, 1978).

Bean earliness was enhanced with plastic row covers in France (Keveren, 1973) and in Canada (Harris, 1965). Carrot production was earlier when grown under plastic row covers in the United Kingdom (Anon, 1984) and in New Hampshire (Kovalchuk, 1983). Early strawberry production was increased with row covers in California (Voth, 1972) and total yield was increased in Tunisia (Elliseche et al., 1974); however, Makus (1985) reported that row covers did not affect strawberry total yield and earliness up to the third harvest under Arkansas conditions.

Tomato raised under row covers bore four weeks earlier (Emmert, 1955; Hall and Besemer, 1972) and produced higher yield (Jensen and Sheldrake, 1965). Bell pepper production was increased with plastic row covers in Arizona (Kratky, 1977;

Oebker et al., 1973; Pratt et al., 1981). Cucurbit yields were elevated when grown under row covers (Hall, 1971; Shadbolt and McCoy, 1960).

Contrary to these findings, Worley and Harmon (1964) observed that early tomato plant growth was better where plastic row covers were used but there was no difference in early and total yield between covered and non-covered plants. Waggoner (1958) found that plastic shelters increased early tomato yield in one year and reduced it in another year when plastic shelters created excessively high temperatures. (Wells et al., 1977) found similar results. They indicated that tomato and pepper had variable results over years and in some trials they did not find differences in yield between covered and uncovered plots. "It is likely that the covers were left too long and the blossoms were damaged." Cucurbits grown under the same material showed year to year variation in yield but the pattern of yield increase was constant.

Highly slitted PE FRC used in Switzerland gave 1100 g potato tuber per plant while open ground yielded 600 g per plant. Eightynine percent of the total number of heads of lettuce were cut in the first harvest while only 29 percent were cut from open ground (Mueller, 1977).

In Oregon, FRC significantly increased onion and sweet corn growth and number of onion bunches (Mansour et al., 1984). Emergence speed and mean percent emergence were greater for the same crops compared to open ground. Transplanted muskmelon yielded significantly higher number of fruits per plant when grown under HPPE (Mansour et al., 1984). Zucchinis raised under FRC were ready to be harvested 40 days before similar plants grown outdoor (Maurer, 1984).

Plastic Mulch

Plastic ground mulch has been used to grow several high value horticultural crops in many countries. It was used to create more favorable soil conditions for plant roots to get better growth and higher yield.

> "The benefits obtained by mulching with plastic are: weed control under the black plastic, changes in soil temperature, reduced soil water evaporation, less soil compaction, better aeration and microbial activity in the soil, reduced fertilizer leaching, less fruit rot, no root pruning during cultivation and more carbon dioxide available to the young plants" (Sheldrake, 1967).

Mulching was defined by Hopen and Oebker (1976) as:

> "The practice of covering the soil around plants to make conditions more favorable for growth, development, and efficient plant production".

Several natural mulches were employed before the introduction of synthetic material. These included crop residues, sawdust, straw, compost, and manure. Polyethylene plastic films were the first synthetic materials used. Black plastic mulch (BPM) is the most common followed by clear PE.

Mulching with plastic was benefical to plant growth (Bhattacharya and Chhonkar, 1969; Carolus and Downes, 1958; Clarkson and Frazier, 1957; Harmon and Worley, 1964; and Waggonner et al., 1960). It enhanced seed emergence (Hassel, 1981; Libik and Wojtaszek, 1973) and increased earliness and yields of tomato, muskmelon and others. Summer strawberry production was increased by using plastic mulch in California (Voth, 1972). In Japan, rice mulched with plastic headed ten days earlier and produced 22 percent heavier grain weight and 69 percent higher yield than non-mulched rice (Furusawa et al., 1977). Early and total tomato yields were increased by 80 and 54 percent respectively when grown on plastic mulch (Bhattacharya and Chhonkar, 1969).

Black plastic mulch raised muskmelon production from 259 to 412 bushels per acre (Schales and Cialone, 1965). An August bean planting on plastic mulch produced 195 bushels per acre while a check yielded only 30 bushels (Emmert, 1957). Potato total yield was raised with the use of plastic mulch (Hamadi, 1974; Smith 1973). Early and total cucumber yields were increased during a two year experiment with BPM (Oyer, 1963). Muskmelon total yield and total fruit numbers were also significantly increased but earliness was not affected (Clarkson and Frazier, 1957). Chipman (1961) observed that a non-mulched soil gave the highest early tomato yield but the BPM yielded the heaviest total fruit weight. Early yields of cucumbers, squash and muskmelon were increased 126 percent, 182 percent and 247 percent, respectively, over a bare ground control. Total yields were also higher by 28, 58 and 81 percent, respectively (Hopen and Oebker, 1976).

Plastic mulch, in most cases, increased soil temperature. However, findings in this area were variable. Black plastic mulch raised mean soil temperature by 1.1°C at 5 cm depth and maximum soil temperature by 5°C compared to a non mulched area (Chipman, 1961). At the same depth BPM raised soil temperature by an average of 2.8°C whereas at 10 cm depth temperature was raised by 1.65°C (Hopen and Oebker, 1976).

Soil temperatures were lower under BPM than under clear PE (Giddense, 1964; Harmon and Worley, 1964; Knavel and Mohr, 1967; Lippert and Takatori, 1965; Schales, 1973; Smith, 1964), and higher under BPM than under white plastic (Giddens, 1964; Harmon and Worley, 1964). Black plastic mulch raised the temperature by 2.2°C while clear PE elevated it by 9.4°C (Schales and Cialone, 1965). Harris (1965) stated that BPM increased minimum soil temperature and decreased the maximum in spring, but during summer both temperatures were increased. The increase of soil temperature varied with the width of the plastic. Eight cm wide clear PE and BPM did not affect soil temperature as much as 15 to 61 cm wide plastic (Lippert and Takatori, 1965). Voth (1972) reported that an increase of about 5.5°C was gained using PE mulches in growing strawberry. Libik and Wojtaszek (1973) came to same result as Voth and found an increase of 5 to 6°C with BPM. However, they observed that the increase was consistent only at the beginning of the season. Harmon and Worley (1964) found that a soil temperature of 33.6 C under clear PE was detrimental to plant growth late in the season. They postulated that mulches gave definite temperature advantage early in the season.

Contrary to all these findings Bromert and Taber (1973) reported that BPM decreased early season soil temperature at 5 cm depth as compared with bare ground. They added that the maximum difference occurred at the time of maximum air temperature.

Plastic mulches had a positive effect on soil moisture conservation. They increased soil moisture in a late bean planting in Kentucky (Emmert, 1957) and in corn in North Dakota (Willis, 1963). Black plastic mulch conserved more soil moisture than did clear PE (Ashworth and Harrison 1983; Knavel and Mohr, 1967), and both clear PE and BPM produced higher soil moisture levels than the control when in widths ranging from 8 to 60 cm (Lippert and Takatori, 1965). Bhattacharya and Chhonkar (1969) supported these findings. They were able to save 4 acre inches of water when they grew tomatoes on BPM. Schales and Cialone (1965); however, suggested more irrigation may have been needed for cucumber on mulched soil because mulched plants were bigger than the check. Moisture content under BPM was more stable throughout the season and higher than in a non-covered soil (Libik and Wojtaszek, 1973).

Plastic mulch improved soil nutrient levels and modified the nutrient availability over time. It provided more favorable soil conditions for more efficient nitrogen utilization by tomato, and significantly increased calcium and magnesium levels in topsoil (Jones et al., 1977). Ammonia, P_2O_5, and K_2O amounts were greater under BPM than for non-mulched soil, but NO_3 amount did not differ (Libik and Wojtaszek, 1973). Nitrate movement and leaching were reduced under BPM (Clarkson, 1960). Black plastic mulch increased soil calcium and potassium levels compared to organic and petroleum mulches (Hopen and Oebker 1976).

Mulching with PE increased soil CO_2 levels (Baron and Gorske, 1981; Sheldrake, 1963) and CO_2 concentration of the microclimate surrounding plant leaves (Sheldrake, 1963).

"Research has shown that very high levels of CO_2 build up under the plastic. As the film does not allow the gas to penetrate, it has to come through the hole made in the film for the plant and a "chimney effect" is created supplying CO_2 to the actively growing leaves" (Sheldrake, 1967).

Mulching with PE films was used to control bottom rot and bacterial soft rot of a head lettuce crop. A 35 percent disease reduction was found compared to an uncovered control (Hilborn et al., 1957).

Plastic mulch positively affected soil salinity in Algeria by increasing soil moisture and reducing salts concentrations (Hamadi, 1974).

TOMATO EXPERIMENT ONE

Materials and Methods

In the spring of 1984 an experiment was conducted at the O.S.U. Vegetable Research Farm in Corvallis to determine the effect of two floating row covers (FRC) on early and total tomato yields. Four different covering periods were used to define how these different covering intervals affect crop response.

The soil was readied one day before transplanting. It was plowed, harrowed, and 1100 kg of 8-24-8 were broadcast per hectare. Weeds were controlled with the use of BPM in the rows and by hand between rows and in the unmulched check.

Treatments were bare ground and black plastic ground mulch controls and two FRC, spunbonded polyester (SPE) and highly perforated polyethylene (HPPE) over black plastic ground mulch. The four covering periods were 3, 4, 5, and 6 weeks from transplanting. All treatments were replicated five times in a factorial combination in a randomized block design. Type of cover and covering periods were the main effects.

Black plastic was laid by hand one day before the transplanting date. The film material was 1.5 m wide and 0.04 mm thick.

Each plot was composed of a single row of 5 Pikred tomato. Plants were spaced by 0.6 meter in the row and 1.20 meter between rows. Plants were seeded on March 2 and raised in a heated greenhouse for one month, then put in a non-heated plastic shelter for two weeks for holding and hardening. During this two week period, the weather was not favorable for field transplanting. Transplants were therefore clipped above the second true leaves. Plants were transplanted on April 20 and immediately received a starter solution. The appropriate FRC treatments were imposed on the same date. A guard row on each side of the plot area was planted 10 days later.

Growth and yield component data were taken from the inner three plants leaving one guard plant at each end.

Spunbonded polyester was 1.5 m wide; it was described by Natwick and Durazo (1985) as:

> "a cloth-like material used in the rug and clothing industry, produced in rolls of varying weights and lengths, the white non-woven material is lightweight, porous to water and transmits 75 to 80 percent of available sunlight".

This film was laid by hand on the transplants allowing adequate slack for plant growth. No structural support was used. The edges and the ends were sealed with soil.

THe highly perforated polyethylene plastic row cover was a clear film 1.4 m wide and 0.04 mm thick. It contained 65 holes per square cm. It was applied directly on transplants and secured with soil the same way as described for the SPE application.

Irrigation was by overhead sprinklers as needed. Pesticides and fungicides were also applied as needed.

Air and soil temperatures at 5 cm above and below the soil were automatically recorded by a Campbell Scientific CR-5 multipoint recording instrument. Climatological mesurements were taken in one replication. Thermocouples were sheltered from solar radiation. Temperature recording started 18 days after the covering date and terminated at the last day of the covering period. Measurments were recorded every three hours for a period of 18 days then every hour for the remaining time.

At the first removal date the length of the cotyledon leaves and the first two new branches were measured in that treatment and the uncovered plots. At the second removal date the first four branches were measured for the first and the second removal dates and the uncovered plots. At the third and fourth removal dates height and width of the plants were measured for these treatments and previous treatment.

The first flowering date was recorded for each treatment. Flowers and fruit set in three marked clusters located on the same branch were counted. First fruit ripening was recorded. Leaf samples for mineral analysis were taken at first ripe fruit stage. Samples consisting of young mature leaves were taken from the three inner plants, washed, dried, ground and analysed later in the OSU tissue analysis lab. The tissue was analysed for total N, P, K, Ca, Mg, Mn, and Zn. Total nitrogen was determined by Kjeldahl method (Schuman et al., 1973) and the other elements were analysed together by the inductively coupled aragon plasma spectrometer method (Jones, 1978).

There were four harvests, beginning August 28 and ending September 14. At the fourth harvest all ripe and green fruit were picked. For each harvest, fruit were sorted by hand and classified as large, medium, small, or undersized (over 7.5 cm, 6-7.5 cm, 5-6 cm, under 5 cm diameter, respectively). The latter were regarded as cull fruit. Total marketable fruit weight and number were recorded for each harvest and size. Fruit showing catface disorder were counted for the second and the third harvest. Plants were cut above the ground and weighed after the last harvest.

Data were subjected to analysis of variance for the main and simple effects. When interaction significance warranted it, further analyses were done on covering intervals for each cover type.

Results and Discussion

Air temperature

1984 was a year with an exceptionally cool and wet spring and early summer.

> "Spring did not bring the usual rate of warming expected during the transition to summer. Mean temperature rose only 9.1 degrees F from March to June in contrast with the long term average rise of 15.5 degrees" (Redmond, 1985).

The month of April, when the early planting was established, was cooler than March, and wet. Even though that period was very marginal for growing a warm season crop such as tomato, the establishment of that crop was chosen to evaluate the effectiveness of the FRC.

From May 5 to June 1, FRC combined with BPM increased daily minimum, maximum and mean air temperature compared to BPM which raised the temperature over non-covered soil. Spunbonded polyester combined with BPM raised daily mean air temperature by 2.7°C over BPM and 3.6°C over bare ground, while HPPE combined with BPM increased that mean by 4.1 and 7.2°C. Black plastic increased the mean by 0.9°C over bare ground (Table 1).

Spunbonded polyester and HPPE elevated daily mean minimum air temperatures by 1.1 and 0.9°C over BPM, while BPM resulted in an increase of 0.2°C over bare ground.

Compared to BPM, SPE raised the daily maximum by 4.2 while HPPE increased it by 7.2°C. Black plastic raised the maximum by 1.7°C over bare ground.

On a hot sunny day (May 29) when maximum air temperature reached 30.2 outside, the temperature was 39, 38 and 32.5°C under SPE, HPPE and over BPM, respectively (Figure 1). On a cloudy day with 5.6 mm rain the same temperatures were 18.5, 21.2, 23.3 and 24.5°C for bare ground, BPM, SPE and HPPE, respectively.

Frost protection

Seven days after planting the temperature outdoor dropped to -1°C. Spunbonded polyester and HPPE allowed 2.4 and 1.2°C of frost protection compared to BPM. The temperature over BPM was -1.3 which was slightly lower than over bare ground (-1°C) (Figure 2). These temperatures were not enough to damage tomato plants and no adverse effect was observed for any of the treatments.

Soil temperature

Daily mean, minimum, and maximum soil temperatures were increased by using FRC compared to BPM which also raised the temperature over bare ground (Table 1). Spunbonded polyester increased minimum, maximum and mean soil temperatures over BPM by 1.8, 1.9, and 1.8°C, whereas HPPE increased temperature by 1.8, 3.3, and 2.6°C. Black plastic mulch increased temperatures by 1.8, 3.4, and 2.6°C over bare ground.

The increase in air and soil temperatures by using FRC was due to the "greenhouse effect" created by both SPE and HPPE. Results obtained were in agreement with Edge and Gerber (1984), Hemphill and Mansour (1986), Kohm and Wien (1983), Mansour et al. (1984), McCraw et al. (1984) and Wells and Loy (1982 and 1983).

Although solid polyester plastic films, owing to their higher degree of light transmission and their higher retention of the IR radiation than PE films (Dubois, 1978; Keveren, 1973), were known to provide more heat than the PE plastic films, SPE resulted in less temperature increase than HPPE. This result was possibly due to the structure of the spunbonded polyester which is more porous than HPPE. Therefore, SPE lost more heat than did the HPPE.

Minimum air temperatures beneath SPE and HPPE were always similar while maximum air temperatures were nearly always higher with HPPE. However, on the coolest day, when minimum temperature was below 0°C, SPE provided more frost protection than HPPE. Maximum air temperatures observed with FRC were lower than those reported by Hemphill and Mansour (1986) when they raised muskmelon under FRC. They reported that maximum temperatures were often over 47°C. This may have been due to higher ambient temperatures when they conducted their studies.

The increase of the soil temperature with BPM agreed with the findings of Chipman (1961), Clarkson (1960), Giddens (1964), Knavel and Mohr (1969), Libik and Wojtaszek (1973), Schales and Cialone (1965), Smith (1964) and Waggoner et al. (1960). Black plastic usually produced slightly higher minimum and maximum air temperatures than bare ground. On the coolest day, however minimum air temperature over BPM was slightly lower than over bare ground. This phenomenon was due to heat being released from the soil to the air while BPM was a barrier to that heat loss (Kohm, 1983).

Heat units

Heat units calculated from a base of 10°C (Holmes and Robertson, 1959) showed an increase for SPE and HPPE treatments over BPM by 56 and 88 percent while BPM raised heat units by 23 percent over non-covered control (Table 1). Highly perforated PE covered plots had 42 percent more heat units than SPE.

Plant growth

Height and width

At the first and second removal dates (three and four weeks from the covering date) FRC increased the length of the new growth over BPM and bare ground. Similar results were obtained with the height and the width measured at the third and the fourth removal dates (5 and 6 weeks from the covering date); however, the difference in height between HPPE and SPE was significant at the third removal date only (Table 2).

Fresh weight

Fresh plant weight measured after green fruit removal was increased with FRC compared to BPM and with BPM over bare ground (Table 9). There were no differences in plant growth between HPPE, SPE, or BPM.

The strong relationship between plant growth and temperature increase was in agreement with the findings of Abdalla and Verkerk (1968), Bendix and Went (1956), Durand (1967), Hall (1963), Lingle and Davis (1973), Rykbost et al (1975), Went (1944), and Worley and Harmon (1964).

Flower number

Total flower number of the first three clusters on a branch was not affected by FRC or by covering period. Plants covered with FRC bloomed 7 days earlier than those on bare ground and 3 to 4 days earlier than on BPM. Mulched plants bloomed 3 days before those on bare ground. There was no difference between SPE and HPPE. Covering interval affected flowering date with SPE but not with HPPE (Table 3).

Ripening of the fruit (Table 3) was slightly advanced by FRC and BPM over bare ground. Five and six week covering periods slightly enhanced ripening date. Differences were significant between HPPE treatments but not between SPE treatments.

Total flower number counted on three clusters was almost the same for all treatmeants. This result was in agreement with Abdella and Verkerk (1968) but it disagrees with the findings of Lewis (1953) and Calvert (1957). The former related that tomato grown at 35/25°C had fairly comparable flower number per cluster to tomato grown at 25/18 degrees C, while the latter reported that tomato flowers were increased in the first three clusters when plants were subjected to a cold temperature after cotyledon expansion until the appearance of the first inflorescence.

It is possible that under the conditions of this investigation, differences in maximum and minimum temperatures between treatments were not large enough to influence early flower number.

Fruit set

Total fruit set was reduced by HPPE compared to BPM which reduced fruit set compared to bare ground (Table 3). Spunbonded polyester plots produced less fruit set than bare ground but they did not differ from BPM and HPPE. Fruit set was not influenced by covering intervals. All treatments including bare ground showed a very low fruit set. This ranged from 9 percent for HPPE treatment to 20 percent for the bare ground treatment.

This decrease of fruit set with FRC may be due to high temperatures. This would be in agreement with the findings of Jensen and Sheldrake (1965), Kohm (1983), Loy and Wells (1983), Shelby et al. (1978) and Wells et al. (1977). In this study several factors may have caused reduction of fruit set with FRC. First is the high temperatures under FRC for two successive days (34-39°C beneath SPE and 36-38°C beneath HPPE). These might have reduced pollen germination (Abdella and Verkerk, 1968; Loy and Wells, 1983; Shelby et al., 1978; Smith and Cochran, 1935). Second is the exaggerated vegetative growth of covered plants (Kraus and Kraybill, 1918; Rylski and Kempler, 1972). Third is the contact of the plant with the row covers. The HPPE was more confining due to its narrower width and reduced slack. Elliseche et al. (1974) observed a reduced bean fruit set with narrow PE film.

Yield and fruit size

At the first harvest SPE increased fruit yield over BPM which increased fruit yield over bare ground (Table 4). Highly perforated PE tended to increase this yield by 13 percent compared to BPM. There was no difference between the two covers. Covering intervals across all treatments did not affect yield. However, there was an effect between HPPE covering intervals where the 3 week covering period had the best yield. At the second harvest FRC tended to increase yield over BPM which had almost the same yield as bare ground.

At the third harvest there were differences between FRC and

BPM and bare ground but not between BPM and bare ground. Covering intervals across all treatmeants had no effect but among HPPE the best yield was produced by a 4 week covering interval followed by the 5 week interval. Total yield was significantly increased by FRC over BPM and bare ground. Spunbonded polyester did not differ from HPPE and BPM did not differ from bare ground. Covering intervals had no effect on total yield.

Total fruit number was affected in similar way as total fruit yield (Table 4).

Interaction between FRC and covering intervals was highly significant for the number and yield of large fruit for the first harvest but not for the other harvests or for total yield. Spunbonded polyester and HPPE plots had the highest number and yield of large fruit at the first harvest and for the overall yield but differences were not significant. Number and yield of medium and small fruit were increased by SPE over HPPE and BPM in the first harvest and for the total yield (Tables 5, 6, and 7).

Overall average fruit weight was adversely affected by FRC and BPM compared to bare ground which had the highest average fruit weight in each harvest. This is a function of lower fruit number for bare ground. Covering intervals across all row cover treatments did not affect average fruit weight in the first three harvests. However, the 3 and 4 week covering intervals had the highest average fruit weights. This pattern was the same for total yield but differences among covering intervals occurred. Interaction between FRC and covering intervals occurred at the first two harvests and for the overall yield. Covering intervals with SPE did not affect fruit size while fruit size decreased for the 5 and 6 week covering intervals with HPPE (Table 8).

The increase in yield at the first harvest with the decrease in total fruit set was contradictory to the findings of Loy and Wells (1983), Wagonner (1958), and Wells et al. (1977) who found no differences in tomato early yield between covered and uncovered plants when temperatures were excessively high and fruit set was reduced.

In this investigation fruit picked at the first harvest was obtained from clusters other than those where fruit set was studied. This could be the reason for higher yield harvested from FRC and BPM treatments while the three clusters studied had less fruit set in cover treatments and BPM.

Increase in yield with BPM compared to bare ground in the first harvest was in agreement with Bhattacharya and Chhonkar (1969), Burga-Mendoza and Pollack (1973) and Carolus and Downes (1958).

Increase in total yield with FRC compared to other treatments was due to better conditions provided with the row covers. This result supported the findings of Loy and Wells (1983), Nelson et al. (1985) and Wells and Loy (1982).

The lack of effect of BPM on total yield compared to bare ground was in agreement with Smith (1973) but in disagreement with the findings of Bhattacharya and Chhonkar (1969), Burga-Mendoza and Pollack (1973), Carolus and Downes (1958), Chipman (1961), Emmert (1957), and Paterson and Earhart (1973). In this study the lack of response of the total yield to BPM may have been due to the excessive vegetative growth of the mulched plants (19 percent increase over bare ground) (Table 9).

Floating row covers produced more large, medium and small fruit but their average weight was less than on BPM or bare ground. This result confirmed the obervations of Bhattacharya and Chhonkar (1969) and Papadopoulos and Tiesson (1983). The later related that when tomato fruit number increased, average fruit weight decreased owing to competition among developing fruits. The former also reported that tomato had a tendency to produce smaller fruit at higher temperatures.

Mineral content

Elements analysed during this study (Table 10) did not show differences between row covers and BPM nor between covering intervals. Ashworth and Harrison (1983) did not find differences in soil nutrient levels between BPM and a non-mulched soil. Waggoner et al. (1960) found a higher nitrate soil concentration under BPM than in bare ground but did not observe differences in potassium, calcium, magnesium and others. Lingle and Davis (1958) reported an increase in K, Ca, Mg, and Na when soil temperature rose from 10-13 to 21-24°C. This range of increase in soil temperature was not observed during the total temperature recording period in this experiment. The small increase in soil temperature when covered with black plastic or with FRC may have been the reason for the similarity in mineral content between treatments.

Cull and catfaced fruits

Floating row covers increased weight of cull fruit over bare ground and tended to produce a higher number of catfaced fruit than BPM which also tended to produce more catfaced fruit than bare ground. The differences were not significant. The three and 4 week covering intervals tended to yield more catfaced fruit than five and 6 week covering intervals (Table 9). Catfaced tomato fruit were observed by Knavel and Mohr (1969), Papadopoulos and Tiessen (1983) and Worley and Harmon (1964). The former related this physiological disorder to high air temperatures during the pollination period "Apparently, high air temperature ....at pollination increased catfacing"; while Knavel and Mohr (1969), according to other findings, reported that the exposure of tomato plants in early stages to a long cold temperature period induced catfacing (they did not confirm these findings during their study), but concluded that the susceptibility of tomato to catfacing was hereditary. In this investigation FRC may not have provided enough heat (and yet promoted earlier flowering) at early growth stages to inhibit catface disorder thus showing more damaged fruit (if catfacing is due to low temperature at flowering). A portion of the increased catfacing was a function of higher total fruit numbers for the mulched as well as the covered treatments.

Table 1. Effect of FRC on mean air and soil temperature (°C), tomato experiment one.

Tmt and date	Air temperature			Soil temperature			Heat
	Min	Max	Mean	Min	Max	Mean	Units
Bare							
05/08-05/10	7.6	19.0	13.4	10.6	15.9	13.3	10.0
05/11-05/17	6.9	20.6	13.8	10.6	18.2	14.4	26.4
05/18-05/25	5.9	19.1	12.5	11.1	18.2	14.6	20.8
05/26-05/31	6.6	24.5	15.6	11.9	21.3	16.6	33.5
Mean	6.8	20.8	13.8	11.1	16.1	13.6	
BPM							
05/08-05/10	7.8	20.9	14.4	12.6	17.6	15.1	13.1
05/11-05/17	7.1	21.8	14.4	12.2	18.8	15.5	31.1
05/18-05/25	6.1	20.4	13.2	12.8	19.2	16.0	26.8
05/26-05/31	6.9	26.7	16.8	13.9	22.4	18.2	40.7
Mean	7.0	22.5	14.7	12.9	19.5	16.2	
SPE							
05/08-05/10	8.6	26.2	17.4	14.4	19.9	17.2	22.1
05/11-05/17	7.9	26.2	17.1	13.9	20.8	17.3	38.5
05/18-05/25	7.2	24.8	16.0	15.2	20.6	17.9	58.6
05/26-05/31	8.6	29.5	19.1	15.1	24.3	19.7	54.5
Mean	8.1	26.7	17.4	14.7	21.4	18.0	
HPPE							
05/08-05/10	8.3	28.2	18.3	14.0	21.2	17.6	24.7
05/11-05/17	7.6	30.2	18.9	13.5	22.4	18.0	50.2
05/18-05/25	7.2	27.8	17.5	15.2	22.8	19.0	71.9
05/26-05/31	8.3	32.7	20.5	16.0	24.9	20.5	62.9
Mean	7.9	29.7	18.8	14.7	22.8	18.8	

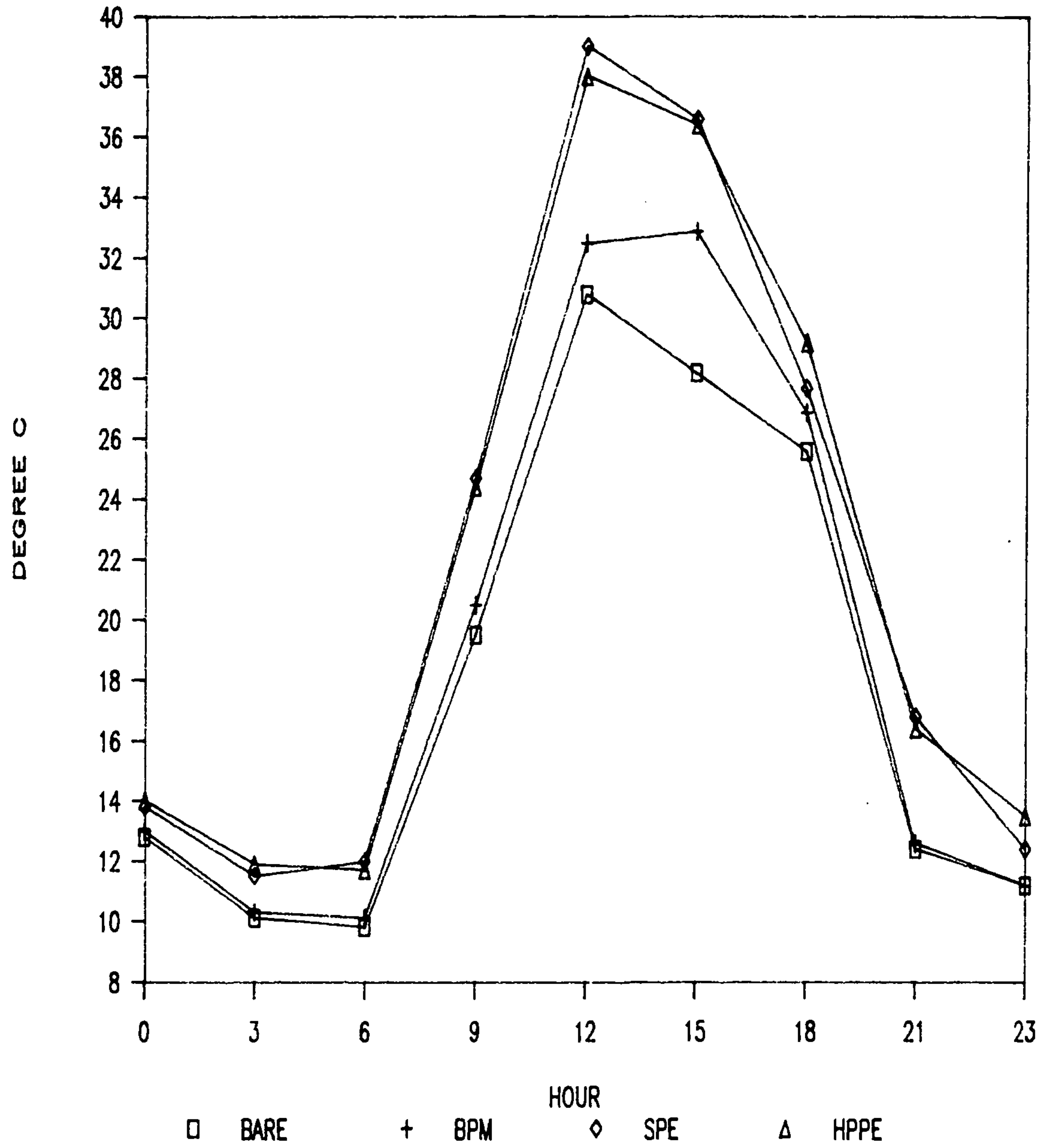

Figure 1. Effect of FRC on air temperature on a hot day (May 29), tomato experiment one.

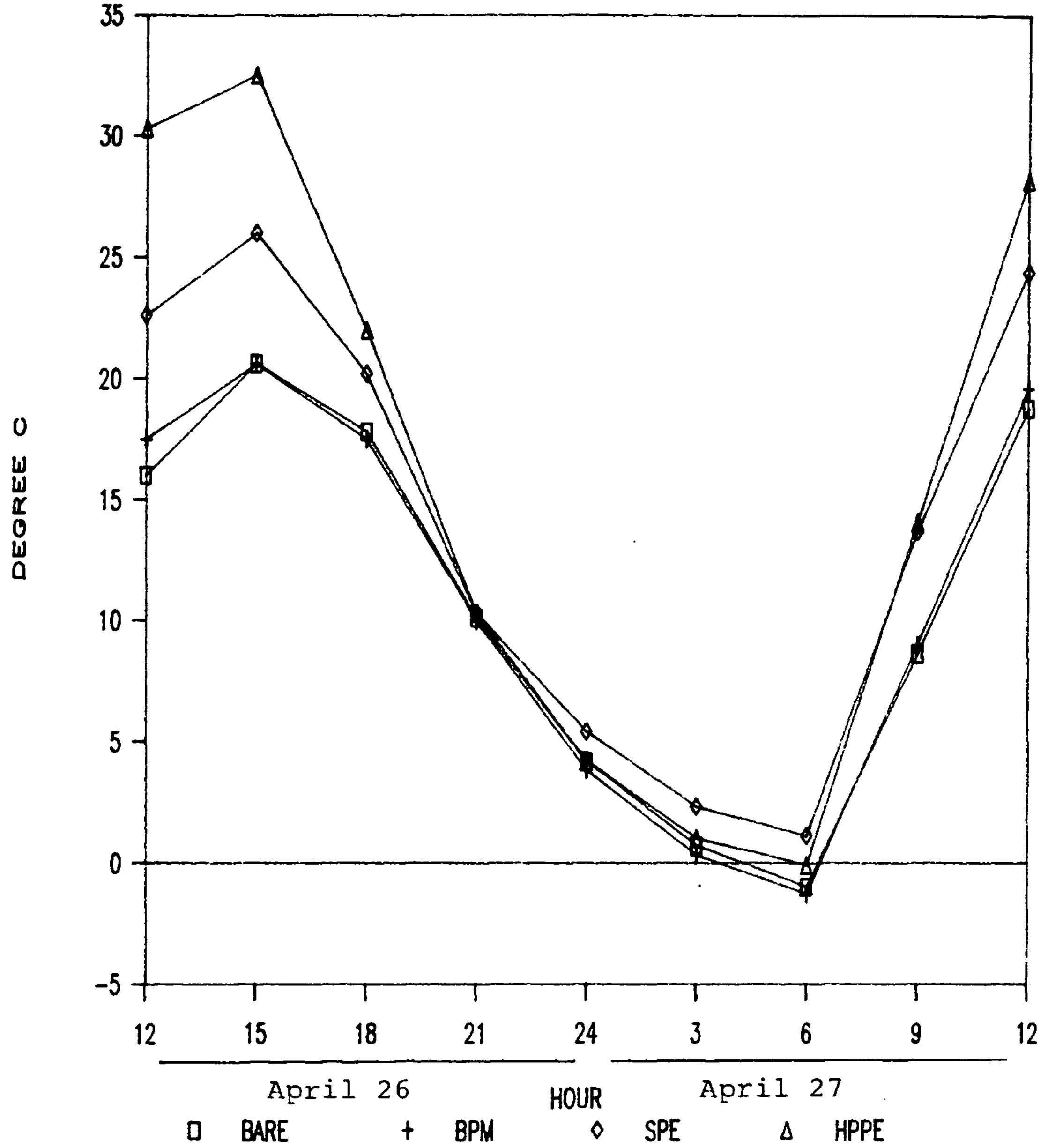

Figure 2. Effect of FRC on air temperature on a cool day (April 26-27), tomato experiment one.

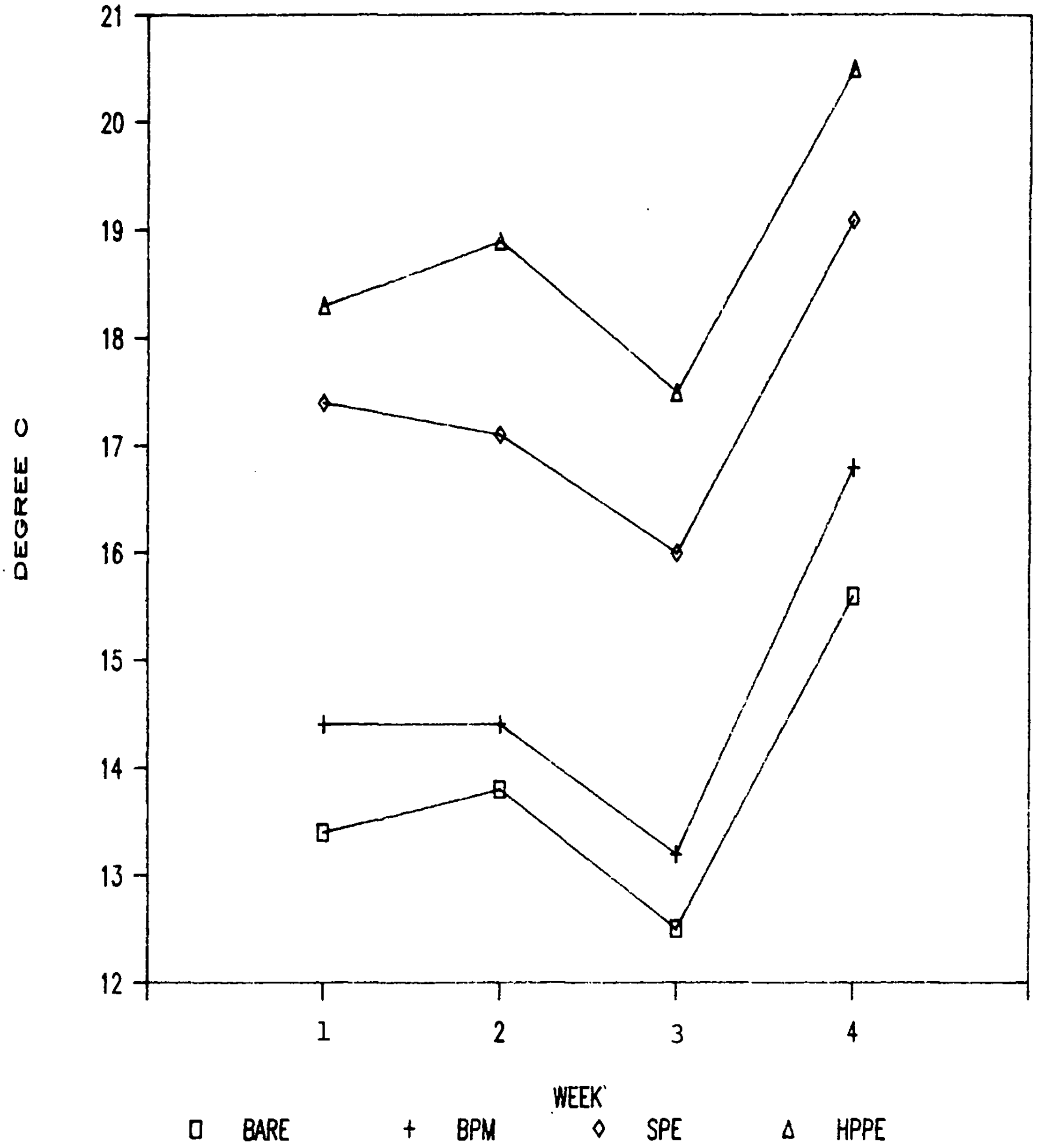

Figure 3. Effect of FRC on mean air temperature in weekly increments, tomato experiment one.

Table 2. Effect of FRC on tomato plant growth (cm), experiment one.

Treatment	3 Week CI[y] Length	4 Week CI new growth	5 Week CI Height	5 Week CI Width	6 Week CI Height	6 Week CI Width
Bare	3.51	8.17	15.46	17.32	18.66	23.56
BPM	5.71	9.60	13.79	19.56	20.46	30.86
SPE	10.20	16.25	18.33	31.82	27.39	43.29
HPPE	12.86	18.90	23.13	34.63	29.39	50.76
Sig[z]	**	**	**	**	**	**
LSD 1%	1.92	3.45	3.06	4.19	5.13	10.09
LSD 5%	1.37	2.46	2.18	2.99	3.66	7.84

[y]CI: Covering interval.
[z]**: Significance at 1% level.

Table 3. Effect of FRC and covering interval on days to tomato flowering and ripening and fruit set of 3 clusters, experiment one (mean of 5 plants).

Treatment	Days to flowering	Number of flowers	Fruit set	Days to ripening
Bare	65.10	18.35	3.65	128.00
BPM	62.40	15.85	2.40	126.55
SPE	58.80	17.45	2.05	125.80
HPPE	58.05	16.20	1.45	125.60
Sig.[z]	**	NS	**	**
LSD1%	1.24		1.11	1.42
LSD5%	0.94	NS	0.84	1.07
CI1[x]	61.55	17.60	2.40	127.60
CI2	61.15	17.25	2.85	127.15
CI3	61.10	17.85	2.05	126.05
CI4	60.55	17.15	2.25	125.15
Sig.	NS	NS	NS	**
LSD1%				1.42
LSD5%				1.07
C*CI[y]	NS	NS	NS	NS
SPE1	60.80	19.80	2.60	127.40
SPE2	58.40	18.00	2.80	126.20
SPE3	58.00	15.20	1.20	125.60
SPE4	58.00	16.80	1.60	124.00
Sig.	*	NS	NS	NS
LSD5%	2.06			
HPPE1	58.20	15.40	1.60	127.60
HPPE2	58.00	17.20	1.00	126.80
HPPE3	58.00	14.80	1.60	124.60
HPPE4	58.00	17.40	1.60	123.40
Sig.	NS	NS	NS	*
LSD5%				2.75

[x]CI: Covering interval.
[y]C: Covers.
[z]**, *, NS: Significance at 1% and 5% levels and no significance, respectively.

Table 4. Effect of FRC and covering interval on tomato total yield (mt/ha) for 4 harvests, experiment one.

	Weight				Number			
	Harvest of				Harvest of			
Tmt	08/27	09/06	09/12	Total[w]	08/27	09/06	09/12	Total[w]
Bare	16.24	30.26	13.50	92.14	85,725	154,125	74,475	544,725
BPM	21.36	29.97	15.43	97.15	117,900	164,700	85,950	581,625
SPE	26.29	37.94	20.03	109.64	152,325	222,975	110,925	673,425
HPPE	24.07	36.46	20.04	112.68	132,075	215,325	110,025	678,150
Sig[z]	**	NS	**	**	**	**	**	**
LSD1%	5.27		5.31	16.66	31,197	52,840	27,972	92,808
LSD5%	3.96		3.99	12.53	23,456	39,729	21,032	69,781
CI1[x]	22.13	34.47	16.89	103.05	119,025	191,925	89,775	612,900
CI2	22.57	37.21	18.53	107.96	120,375	204,750	101,250	630,450
CI3	23.24	28.19	15.84	101.04	132,975	157,725	90,000	615,600
CI4	20.02	34.75	17.74	99.56	115,650	202,725	100,350	618,975
Sig.	NS	NS	NS	NS	NS	NS	NS	NS
C*CI[y]	NS	NS	NS	NS	NS	NS	*	NS
SPE1	28.43	39.27	20.74	115.07	160,200	224,100	108,000	683,100
SPE2	25.66	43.82	16.61	105.38	147,600	245,700	91,800	634,500
SPE3	29.20	30.11	19.45	106.23	176,400	181,800	116,100	664,200
SPE4	21.87	38.57	23.32	111.89	125,100	240,300	127,800	711,900
Sig.	NS	NS	NS	NS	NS	NS	*	NS
LSD5%							46,670	
HPPE1	28.58	39.16	14.23	113.18	146,700	212,400	69,300	657,900
HPPE2	20.96	40.04	26.35	120.58	99,000	220,500	141,300	670,500
HPPE3	25.14	32.95	20.62	117.41	148,500	204,300	119,700	729,900
HPPE4	21.60	33.68	18.99	99.55	134,100	224,100	109,800	654,300
Sig.	*	NS	*	NS	**	NS	*	NS
LSD1%					39,032			
LSD5%	5.64		7.98		27,442		46,670	

[w]Only ripe fruits are included in the first three harvests. Green and ripe fruits are included in the total yield. The fourth harvest is not shown but is included in total yield.
[x]CI: Covering interval.
[y]C: Covers.
[z]**, *, NS: Significance at 1% and 5% levels and no significance, respectively.

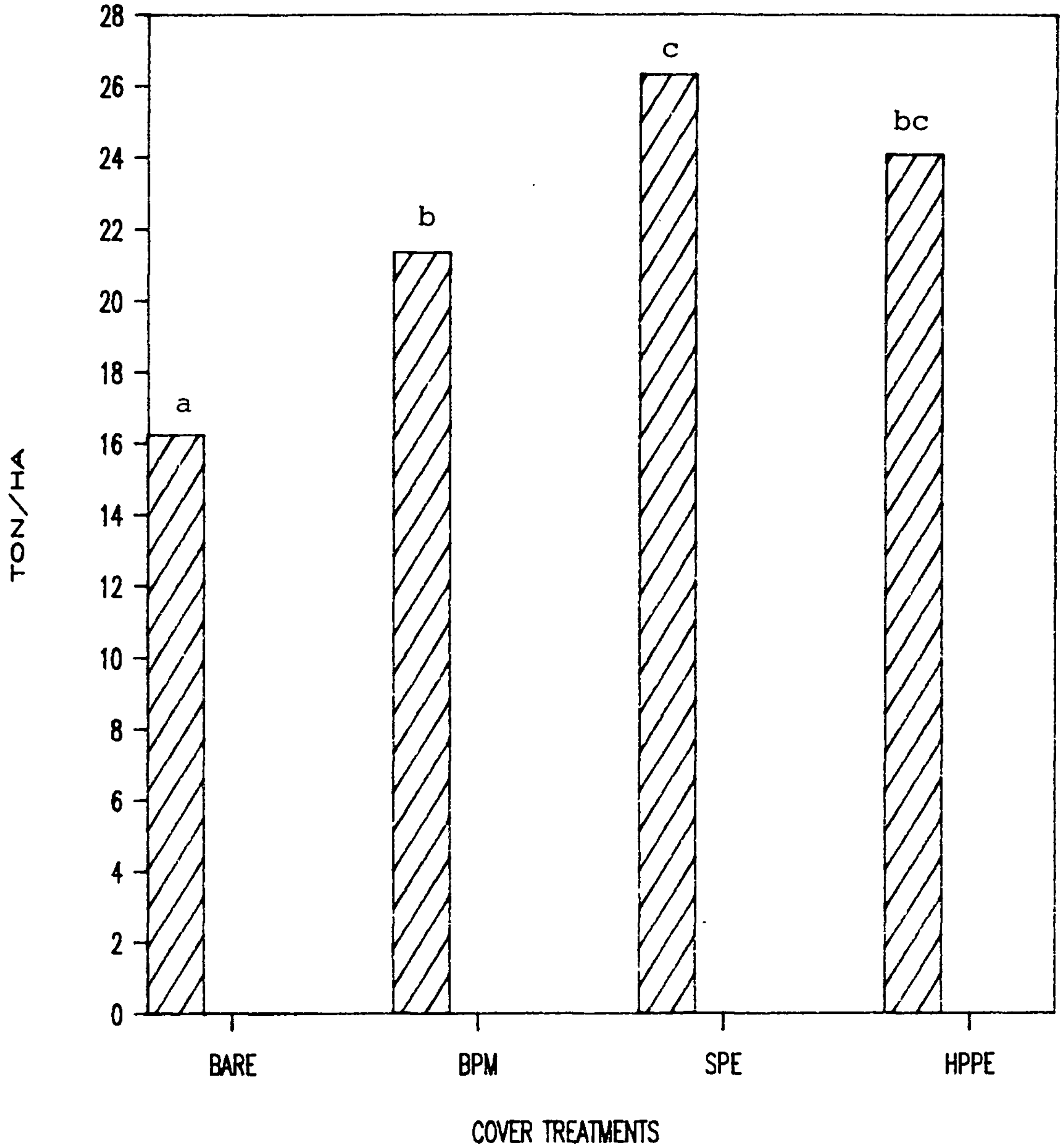

Figure 4. Effect of FRC on early tomato yield, experiment one.

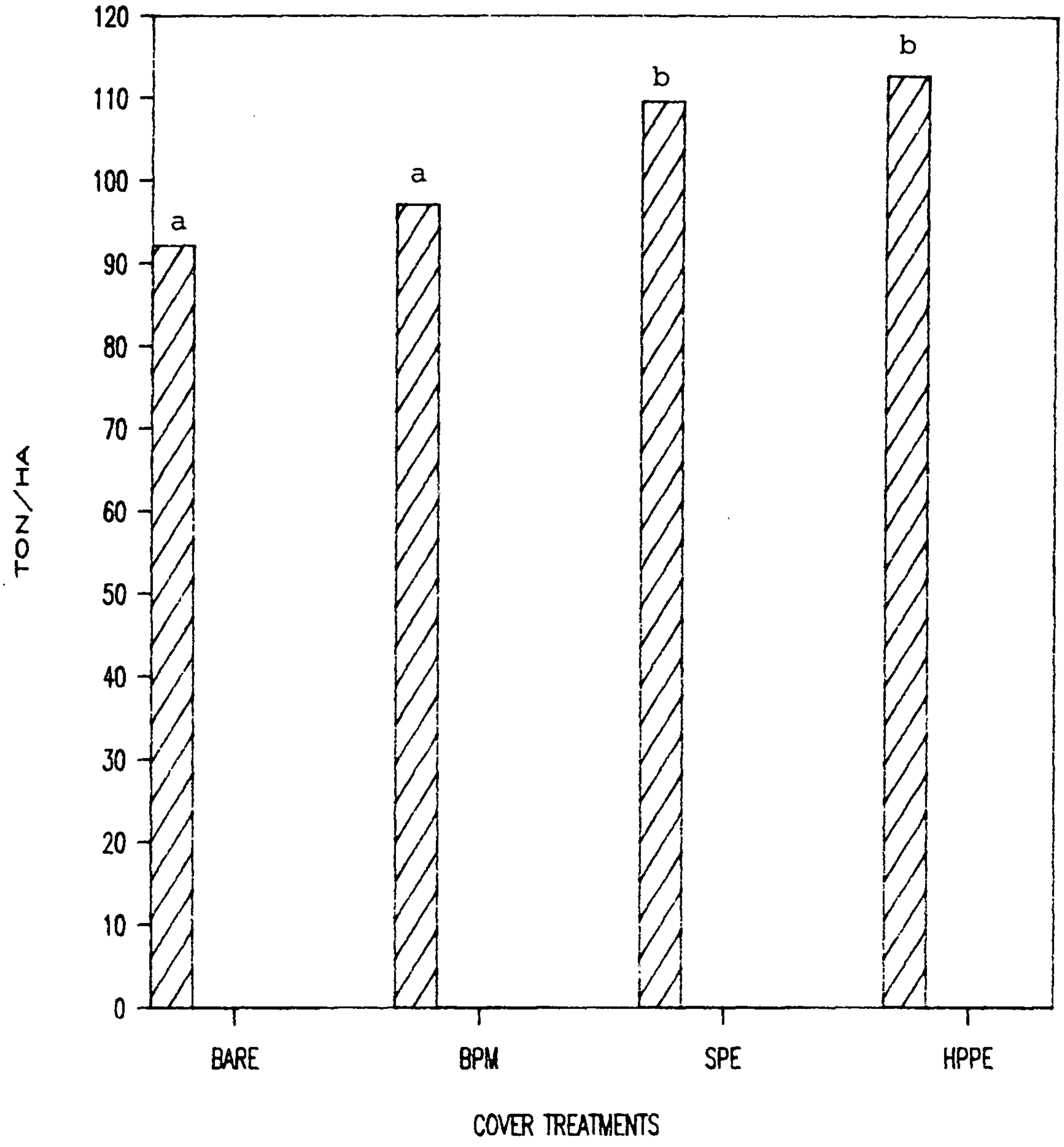

Figure 5. Effect of FRC on total tomato yield, experiment one.

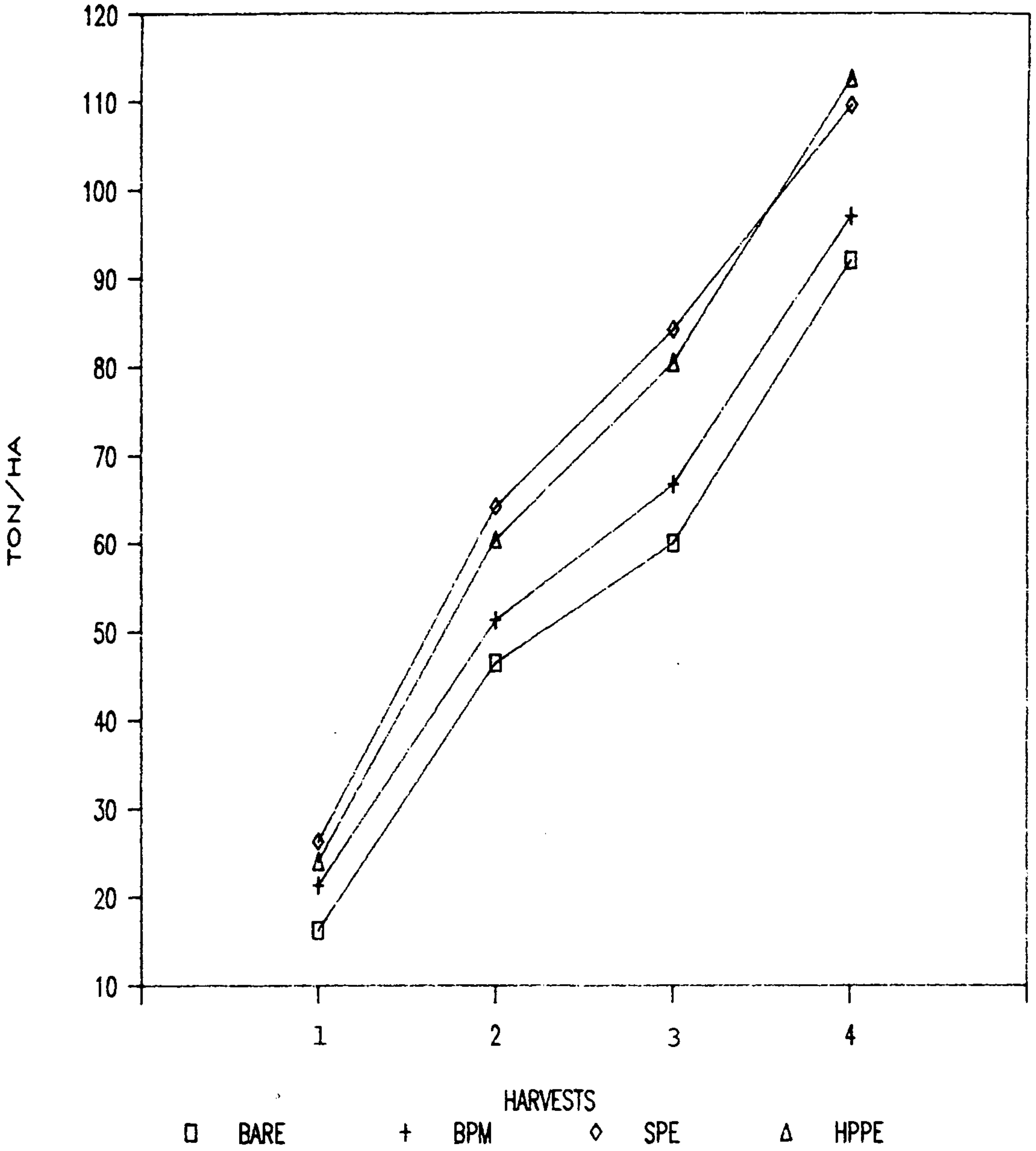

Figure 6. Cumulative tomato yield as affected by FRC and harvest number, experiment one.

Table 5. Effect of FRC and covering interval on yield (mt/ha) of large tomato fruit for 4 harvests, experiment one.

	Weight				Number			
	Harvest of				Harvest Of			
Tmt	08/27	09/06	09/12	Total[w]	08/27	09/06	09/12	Total[w]
Bare	6.61	12.28	4.52	26.74	22,050	41,625	16,200	91,800
BPM	8.16	11.00	5.26	29.15	27,900	39,600	18,450	103,500
SPE	8.58	10.60	6.49	29.06	30,150	36,000	22,050	100,575
HPPE	8.80	10.90	7.58	33.77	29,925	38,475	25,200	117,225
Sig.[z]	NS	NS	NS	NS	NS	NS	NS	NS
CI1[x]	11.22	11.27	6.84	30.84	29,925	37,575	23,625	106,200
CI2	8.17	12.79	6.57	33.35	30,375	44,550	22,050	114,750
CI3	7.41	10.09	4.80	27.65	25,875	36,675	16,200	98,325
CI4	7.52	10.42	5.65	26.70	24,525	36,900	20,025	93,825
Sig.	NS	NS	NS	NS	NS	NS	NS	NS
C*CI[y]	**	NS	NS	NS	**	NS	NS	NS
SPE1	11.22	12.14	8.95	35.93	39,600	39,600	31,500	124,200
SPE2	8.17	13.08	5.77	29.78	28,800	43,200	18,900	101,700
SPE3	7.41	7.71	4.02	24.04	26,100	27,900	14,400	84,600
SPE4	7.52	9.49	7.23	26.48	26,100	33,300	23,300	91,800
Sig.	**	NS	NS	NS	**	NS	NS	NS
LSD1%	5.31				17,543			
LSD5%	3.96				13,190			
HPPE1	12.70	14.51	7.00	40.38	44,100	49,500	22,500	139,500
HPPE2	10.37	13.89	9.59	42.23	32,400	45,000	32,400	139,500
HPPE3	6.26	8.83	7.17	30.21	22,500	36,900	23,400	111,600
HPPE4	5.88	6.36	6.55	22.25	20,700	22,500	22,500	78,300
Sig.	**	NS	NS	NS	**	NS	NS	NS
LSD1%	5.31				17,543			
LSD5%	3.99				13,190			

[w] Only ripe fruits are included in the first three harvests. Green and ripe fruits are included in the total yield. The fourth harvest is not shown but is included in total yield.
[x] CI: covering interval.
[y] C: covers..
[z] **, NS: Significance at 1% level and no significance, respectively.

Table 6. Effect of FRC and covering interval on yield (mt/ha) of medium tomato fruit for 4 harvests, experiment one.

	Weight					Number			
	Harvest of					Harvest of			
Tmt	08/27	09/06	09/12	Total[w]		08/27	09/06	09/12	Total[w]
Bare	6.89	13.40	6.29	43.35	!	38,475	72,000	34,425	246,150
BPM	8.87	12.70	7.04	43.60	!	51,300	69,525	39,600	249,300
SPE	12.35	17.17	9.56	50.69	!	70,875	94,950	53,100	287,550
HPPE	10.88	15.50	8.35	50.17	!	63,450	84,600	47,925	285,750
					!				
Sig.[z]	**	NS	*	*	!	**	*	*	*
LSD1%	3.46				!	19,997			
LSD5%	2.60		2.24	6.42	!	15,035	19,805	13,275	37,416
CI1[x]	9.62	14.76	6.98	45.74	!	54,000	79,200	38,700	255,375
CI2	9.74	16.74	8.29	49.90	!	55,575	91,575	46,350	283,950
CI3	11.20	12.08	7.54	47.55	!	64,125	66,600	42,750	273,375
CI4	8.88	15.20	8.43	44.61	!	51,300	83,700	47,250	256,050
					!				
Sig.	NS	NS	NS	NS	!	NS	NS	NS	NS
C*CI[y]	NS	NS	NS	NS	!	NS	NS	NS	NS
SPE1	11.53	16.83	8.35	48.56	!	66,600	93,600	46,800	273,600
SPE2	13.01	20.19	7.50	48.88	!	73,800	110,700	42,300	278,100
SPE3	15.67	14.60	10.40	53.57	!	91,800	81,000	56,700	305,100
SPE4	9.17	17.08	11.86	51.57	!	51,300	94,500	66,600	293,400
					!				
Sig.	NS	NS	NS	NS	!	NS	NS	NS	NS
HPPE1	12.27	15.37	4.93	46.72	!	70,200	80,100	27,000	262,800
HPPE2	8.43	17.05	11.82	53.57	!	46,800	92,700	65,700	300,600
HPPE3	13.59	14.51	8.75	55.65	!	76,500	81,000	54,000	321,700
HPPE4	11.05	15.07	7.83	44.73	!	63,900	84,600	45,000	258,300
					!				
Sig.	NS	NS	*	NS	!	NS	NS	*	NS
LSD5%			4.09		!			25,968	

[w]Only ripe fruits are included in the first three harvests. Green and ripe fruits are included in the total yield. The fourth harvest is not shown but is included in total yield.
[x]CI: covering interval.
[y]C: covers..
[z]**, *, NS: Significance at 1% and 5% levels and no significance, respectively.

Table 7. Effect of FRC and covering interval on yield (mt/ha) of small tomato fruit for 4 harvests, experiment one.

	Weight					Number			
	Harvest of					Harvest Of			
Tmt	08/27	09/06	09/12	Total[w]	!	08/27	09/06	09/12	Total[w]
Bare	2.73	4.57	2.68	22.05	!	25,200	40,500	23,850	206,775
BPM	4.32	6.27	3.11	24.39	!	38,700	55,575	27,900	228,825
SPE	5.36	10.15	3.97	29.89	!	51,300	92,025	35,775	285,300
HPPE	3.92	10.05	4.11	28.74	!	37,800	92,250	36,900	275,175
Sig.[z]	**	**	**	**	!	**	**	**	**
LSD1%	1.67	2.78	1.24	4.63	!	15,843	24,712	10,742	43,375
LSD5%	1.26	2.09	0.93	3.48	!	11,912	18,580	8,077	32,613
CI1[x]	3.80	8.43	3.07	26.46	!	35,100	75,150	27,450	251,325
CI2	3.74	7.68	3.67	24.70	!	34,425	68,625	32,850	231,750
CI3	4.65	6.02	3.48	25.64	!	43,650	54,450	31,050	243,900
CI4	4.15	8.91	3.65	28.25	!	39,825	82,125	33,075	269,100
Sig.	NS	*	NS	NS	!	NS	*	NS	NS
LSD5%		2.09			!		18,580		
C*CI[y]	NS	NS	NS	NS	!	NS	NS	*	NS
SPE1	5.67	10.29	3.42	30.57	!	54,000	90,900	29,700	285,300
SPE2	4.48	10.55	3.31	26.71	!	45,000	91,800	30,600	254,700
SPE3	6.11	7.79	4.97	28.61	!	58,500	72,900	45,000	274,500
SPE4	5.17	11.99	4.19	33.65	!	47,700	112,250	37,800	326,700
Sig.	NS	NS	NS	NS	!	NS	NS	*	NS
LSD5%					!			16,153	
HPPE1	3.69	9.27	2.25	26.07	!	32,400	82,800	19,800	255,600
HPPE2	2.17	9.09	4.90	24.77	!	19,800	82,800	43,200	230,400
HPPE3	5.27	9.60	4.65	31.54	!	49,500	86,400	42,300	297,000
HPPE4	4.66	12.24	4.63	32.56	!	49,500	117,000	42,300	317,700
Sig.	NS	NS	NS	*	!	NS	NS	*	NS
LSD5%				6.14	!			16,153	

[w]Only ripe fruits are included in the first three harvests. Green and ripe fruits are included in the total yield. The fourth harvest is not shown but is included in total yield.
[x]CI: Covering interval.
[y]C: Covers.
[z]**, *, NS: Significance at 1% and 5% levels and no signficance, respectively.

Table 8. Effect of FRC and covering interval on mean fruit weight (g) of all tomatoes for 4 harvests, experiment one.

Treatment	Harvest Of 08/27	09/06	09/12	Total[w]
Bare	196	198	186	170
BPM	183	182	185	166
SPE	174	171	184	162
HPPE	180	168	179	164
Sig.[z]	*	**	NS	NS
LSD1%		16		
LSD5%	12	12		
CI1[x]	189	181	194	168
CI2	192	179	187	171
CI3	173	184	181	164
CI4	178	174	173	160
Sig.	NS	NS	NS	**
LSD1%				8
LSD 5%				6
C*CI[y]	*	**	NS	*
SPE1	181	174	193	167
SPE2	173	182	194	165
SPE3	167	165	165	160
SPE4	177	162	183	157
Sig.	*	**	NS	*
LSD1%		32		
LSD5%	25	24		12
HPPE1	195	184	208	170
HPPE2	212	180	187	180
HPPE3	157	160	160	157
HPPE4	156	147	159	149
Sig.	*	**	*	*
LSD1%		32		
LSD5%	25	24	33	12

[w]Only ripe fruits are included in the first three harvests. Green and ripe fruits are included in the total yield. The fourth harvest is not shown but is included in total yield.
[x]CI: Covering interval
[y]C: Covers
[z]**, *, NS: Significance at 1% and 5% levels and no significance, respectively.

Table 9. Effect of FRC and covering interval on number of cull and catfaced fruit and weight of vines, tomato experiment one.

Treatment	Cull fruit (mt/ha)	Catfaced fruit (number/ha)	Weight of vines (mt/ha)
Bare	4.44	13,275	16.07
BPM	5.76	18,900	19.77
SPE	6.35	21,375	20.98
HPPE	7.22	26,325	23.10
Sig.[z]	**	NS	**
LSD1%	1.82		3.20
LSD5%	1.36		2.40
CI1[x]	6.28	20,700	20.72
CI2	5.53	24,975	20.39
CI3	6.61	16,650	19.30
CI4	5.36	17,550	19.54
Sig.	NS	NS	NS
C*CI[y]	NS	NS	NS
SPE1	7.58	21,600	23.32
SPE2	5.82	23,400	20.06
SPE3	6.74	14,400	19.86
SPE4	5.25	26,100	20.67
Sig.	NS	NS	NS
HPPE1	7.31	32,400	25.78
HPPE2	7.49	32,400	23.89
HPPE3	7.33	25,200	21.42
HPPE4	6.75	15,300	21.33
Sig.	NS	NS	NS

[x]CI: Covering interval.
[y]C: Covers.
[z]**, NS: Significance at 1% level and no significance, respectively.

Table 10. Effect of FRC and covering interval on mineral content of tomato leaf, experiment one.

	% dry wt. (g)					ppm dry wt.	
Tmt	N	P	K	Ca	Mg	Mn	Zn
Bare	3.20	0.33	2.55	6.03	0.93	66.25	24.25
BPM	2.98	0.38	2.40	6.15	0.89	58.00	24.50
Sig.	NS	NS	NS	NS	NS	NS	NS
SPE	3.05	0.35	2.46	5.69	0.87	30,15	22.05
HPPE	2.85	0.38	2.37	5.87	0.87	29.92	25.20
Sig.[z]	NS	NS	NS	NS	NS	NS	NS
CI1[x]	2.93	0.38	2.57	5.46	0.87	65.75	23.62
CI2	2.95	0.35	2.40	5.89	0.92	77.25	22.05
CI3	2.94	0.36	2.35	5.87	0.85	65.50	16.20
CI4	2.98	0.36	2.34	5.91	0.88	76.75	20.02
Sig.	NS	NS	NS	NS	NS	NS	NS
C*CI[y]	NS	NS	NS	NS	NS	NS	NS
SPE1	3.03	0.38	2.82	5.21	0.94	65.75	29.25
SPE2	3.18	0.33	2.33	5.69	0.87	77.25	23.50
SPE3	2.96	0.36	2.29	6.09	0.85	65.50	21.75
SPE4	3.05	0.32	2.39	5.79	0.81	76.75	22.75
Sig.	NS	NS	NS	NS	NS	NS	NS
HPPE1	2.84	0.39	2.33	5.72	0.80	68.25	19.00
HPPE2	2.72	0.37	2.47	6.09	0.97	88.50	22.25
HPPE3	2.91	0.36	2.42	5.66	0.85	68.75	22.25
HPPE4	2.91	0.41	2.28	6.03	0.85	76.75	23.25
Sig.	NS	NS	NS	NS	NS	NS	NS

[x]CI: Covering interval.
[y]C: Covers.
[z]NS: No significance at 1% and 5% levels.

TOMATO EXPERIMENT TWO

Materials and Methods

In this experiment materials and methods were similar to the first experiment but the planting date was May 16. Plants were raised in the greenhouse for one month starting on April 2 ending on May 8, and hardened for one week before transplanting at the OSU Vegetable Farm. Plant size was normal at transplanting so they were not clipped.

Harvest started on August 30 and terminated on September 24. Growth parameters measured did not include flowering date at five and six week covering intervals because flowers had already opened before the covers were removed. Flower number and fruit set were studied on the first, second, and third cluster. Leaf mineral analysis was done at the first ripe fruit stage.

Results and Discussion

For the period from May 16 to June 26, air temperature at 5 cm above the soil was increased with SPE and HPPE (Table 11). Day time maximum temperatures were increased by 3.1°C for SPE and 4.7°C for HPPE compared to BPM. Black plastic raised maximum day temperature by 1.8°C over bare soil. Minimum air temperature for the same period was raised in a similar way with both covers (1.8°C) over BPM which increased minimum temperature by 0.4°C over non-covered soil. On a hot sunny day, maximum air temperature reached 34°C beneath covers, 30.3 above bare soil and 31.7 above black plastic (Figure 7). On a cool day minimum air temperatures were 5.9 and 5.4°C under SPE and HPPE, while ambient and BPM minimum temperatures were 2.4 and 2.6°C (Figure 8). On a cloudy day with 2.4 mm precipitation maximum air temperature was elevated by 1.8 and 2.8°C with SPE and HPPE compared to BPM which did not affect maximum air temperature on that day.

Soil temperature

Floating row covers slightly elevated minimum soil temperature compared to BPM. Maximum soil temperatures were almost the same for all covered and non-covered soils (Table 11).

Heat Units

Spunbonded polyester and HPPE elevated total heat units by 40 and 58 percent over BPM which increased total heat units by 20 percent over bare soil (Table 11).

Similar to the first experiment, air and soil temperature and heat units were increased; however, the magnitude of increase in this planting was less than that of the early planting even though ambient temperature was higher in the second planting. This result corroborates the findings of Wells (1984) who reported that the maximum benefit from FRC with regard to air and soil temperature occurred early in the growing season.

Plant growth

For the 3 week covering interval, length of the new growth was increased by FRC compared to BPM and by black plastic compared to bare soil. A similar pattern of increase in height and width was observed in the other covering intervals; however, FRC did not differ from BPM for 5 and 6 week covering intervals. There was no difference between cover types for the 3, 4,and 5 week covering intervals (Table 12).

Total fresh vegetative weight of defruited plants after the last harvest was greater for FRC and BPM than bare ground but there was no difference between covers and BPM and between SPE and HPPE (Table 19).

Flowering date was 3 days earlier for HPPE than bare ground but it was not affected by SPE compared to BPM or bare ground (Table 13).

As in the first experiment, FRC and BPM showed an increase in early plant growth (height and width, fresh weight, and flowering date) over bare ground.

Flower number was slightly higher for BPM and bare soil than for FRC in each of the first three clusters and in the total of the three clusters (Table 13). Differences were significant for the first, second and total clusters but not for the third cluster.

Fruit set, in the first, second and total of the 3 clusters, was increased with the 4 and 5 week covering intervals compared to the 3 week interval among HPPE, then decreased for the 6 week covering period. Spunbonded polyester had no effect in the first and third cluster but fruit set was increased with 6 week covering interval among SPE treatments in the second cluster and tended to be increased with covering interval for total flowers in the three clusters. Fruit set among cover treatments, BPM and bare soil was not affected (Table 13).

Fruit set was improved with longer covering intervals among SPE treatments while it was decreased with the 6 week covering interval among HPPE treatments, even though differences in maximum temperatures between covers were not great. The depression in fruit set with HPPE for the 6 week covering interval was possibly due to the contact of plants with HPPE film which is narrower than SPE. McCraw et al. (1984) reported that tomato plants under SPE without hoops had less fruit set than plants under a supported SPE.

First ripe fruit date was slightly advanced by HPPE compared to BPM and bare ground but not by SPE (Table 13).

Yield and fruit size

Tomato plants under highly perforated PE outyielded those on bare soil and BPM by 96 and 87 percent, respectively, at the first harvest (Table 14). Spunbonded polyester increased first harvest yield by 74 percent over BPM and by 81 percent over bare ground. Black plastic did not affect first harvest yield compared to bare ground but yield was increased from the second harvest and for total fruit harvested.

Covering interval did not affect yields except in the first harvest where the 3 week covering interval produced the lowest yield. Significant interaction between covers and covering intervals appeared only in the first harvest where the 5 week covering interval for both covers produced a yield increase over other covering intervals, BPM and bare soil. Spunbonded polyester and HPPE 5 week covering interval raised first harvest yield by 123 and 87 percent over the corresponding 3 week intervals. Floating row covers did not increase overall yield over BPM but they increased it over bare ground. Fruit number showed a similar pattern as fruit weight at each harvest and for the overall yield (Table 14).

Yield and number of large, medium and small fruit responded in a similar way as the total fruit weight and number at every harvest and for overall yield (Tables 15, 16 and 18).

Average fruit weight calculated for total fruit harvested was greater for SPE and BPM than for bare ground and HPPE (Table 19). This may have been due to the larger fruit number for HPPE.

The moderate increase in air and soil temperatures with FRC over BPM and with BPM over bare ground was the reason for increased early yield with FRC and enhanced vegetative growth with BPM. However, the higher temperature offered by BPM over bare ground was not enough to influence early yield. The beneficial effect of FRC in early stages of plant growth was also observed in this second experiment. This result agreed with the findings of Edge and Gerber (1984) and McCraw et al. (1984).

Similarly to the first experiment, increases in yields were associated with an increase in large, medium, and small fruit yield and number. In contrast to the first planting, however, average fruit weight was increased with SPE and BPM over bare soil.

Mineral content

Similarly to the first experiment, treatments did not affect the uptake of the elements analysed (Table 20).

Cull and catfaced fruits

Floating row covers and BPM significantly increased cull fruit weight and catfaced fruit number over bare ground (Table 19). However, since there was no difference between FRC and BPM, it did not appear that covers were responsible. Furthermore, since temperatures at this second planting were adequate, it is assumed that this is largely a function of increased yields and numbers as in the first experiment.

Table 11. Effect of FRC on mean air and soil temperature (°C), tomato experiment two.

	Air temperature			Soil temperature			Heat
Tmt and date	Min	Max	Mean	Min	Max	Mean	Units
Bare							
05/16-06/05	6.3	21.7	14.0	11.5	19.7	15.6	86.0
06/06-06/12	6.8	17.0	13.4	10.8	19.9	15.3	23.9
06/13-06/19	7.0	23.5	15.2	12.4	25.7	19.1	36.6
06/20-06/26	10.1	25.3	17.7	14.2	24.5	19.3	53.7
Mean	7.6	22.6	15.1	12.2	22.5	17.3	
BPM							
05/16-06/05	6.5	23.3	14.9	13.4	20.4	16.9	104.4
06/06-06/12	6.9	22.4	14.7	13.4	20.6	17.0	32.7
06/13-06/19	7.4	26.0	16.7	15.8	25.0	20.4	47.0
06/20-06/26	10.8	25.7	18.2	16.8	23.8	20.3	57.7
Mean	8.0	24.4	16.2	14.9	22.5	18.7	
SPE							
05/16-06/05	7.7	27.0	17.4	15.0	22.1	18.6	154.9
06/06-06/12	8.1	27.3	17.3	14.3	20.2	17.2	54.1
06/13-06/19	9.6	28.7	19.2	17.5	24.5	21.0	64.1
06/20-06/26	12.0	27.1	19.6	17.7	22.9	20.3	66.8
Mean	9.4	27.5	18.5	16.1	22.4	19.3	
HPPE							
05/16-06/05	7.7	29.7	18.7	15.5	23.5	19.5	182.9
06/06-06/12	8.0	28.0	18.0	15.0	21.0	18.0	55.9
06/13-06/19	9.6	30.5	20.1	17.7	24.5	21.2	70.5
06/20-06/26	12.5	28.1	20.3	18.5	23.0	20.7	72.2
Mean	9.5	29.1	19.3	16.7	23.0	19.9	

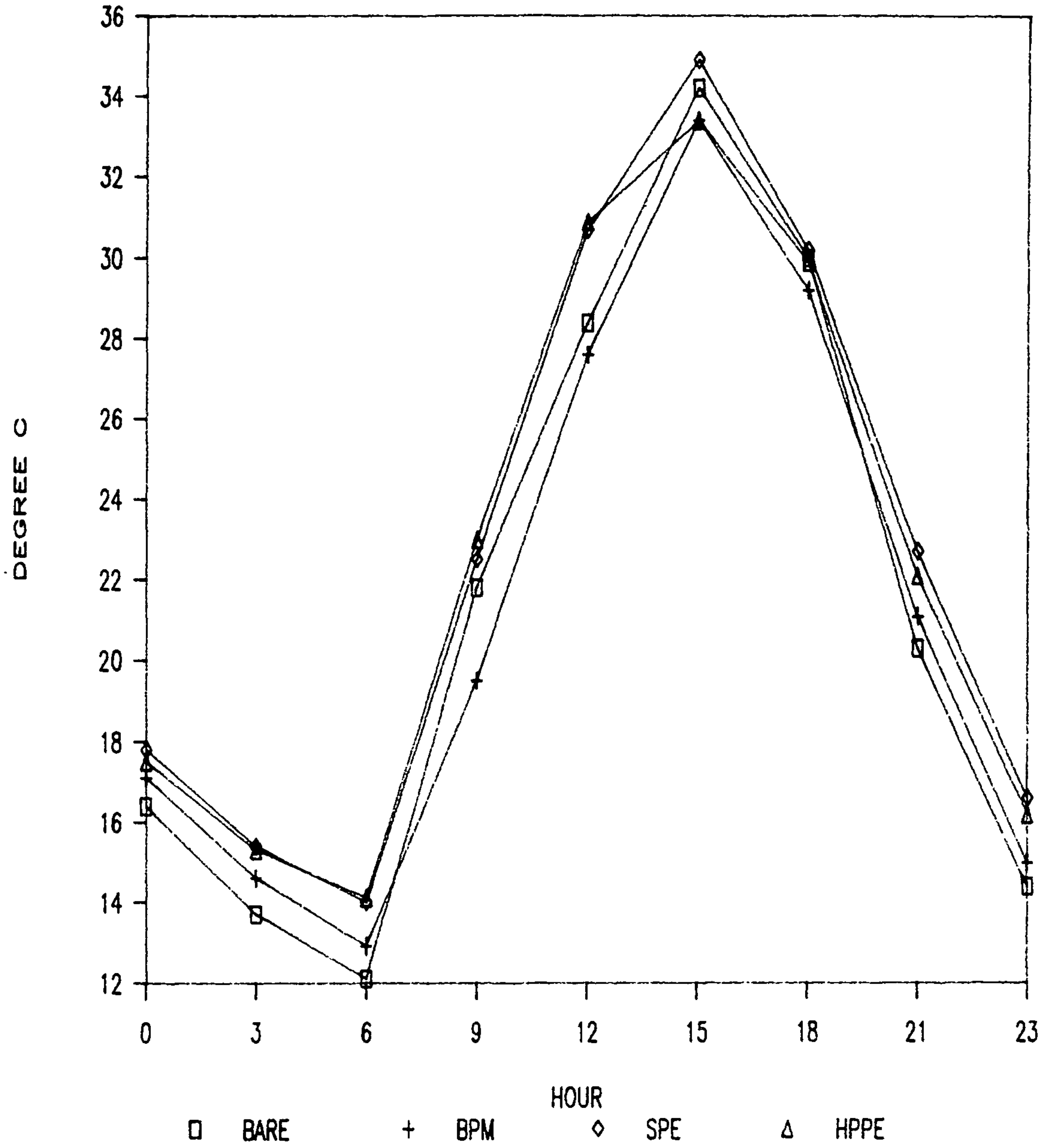

Figure 7. Effect of FRC on air temperature on a hot day (June 25), tomato experiment two.

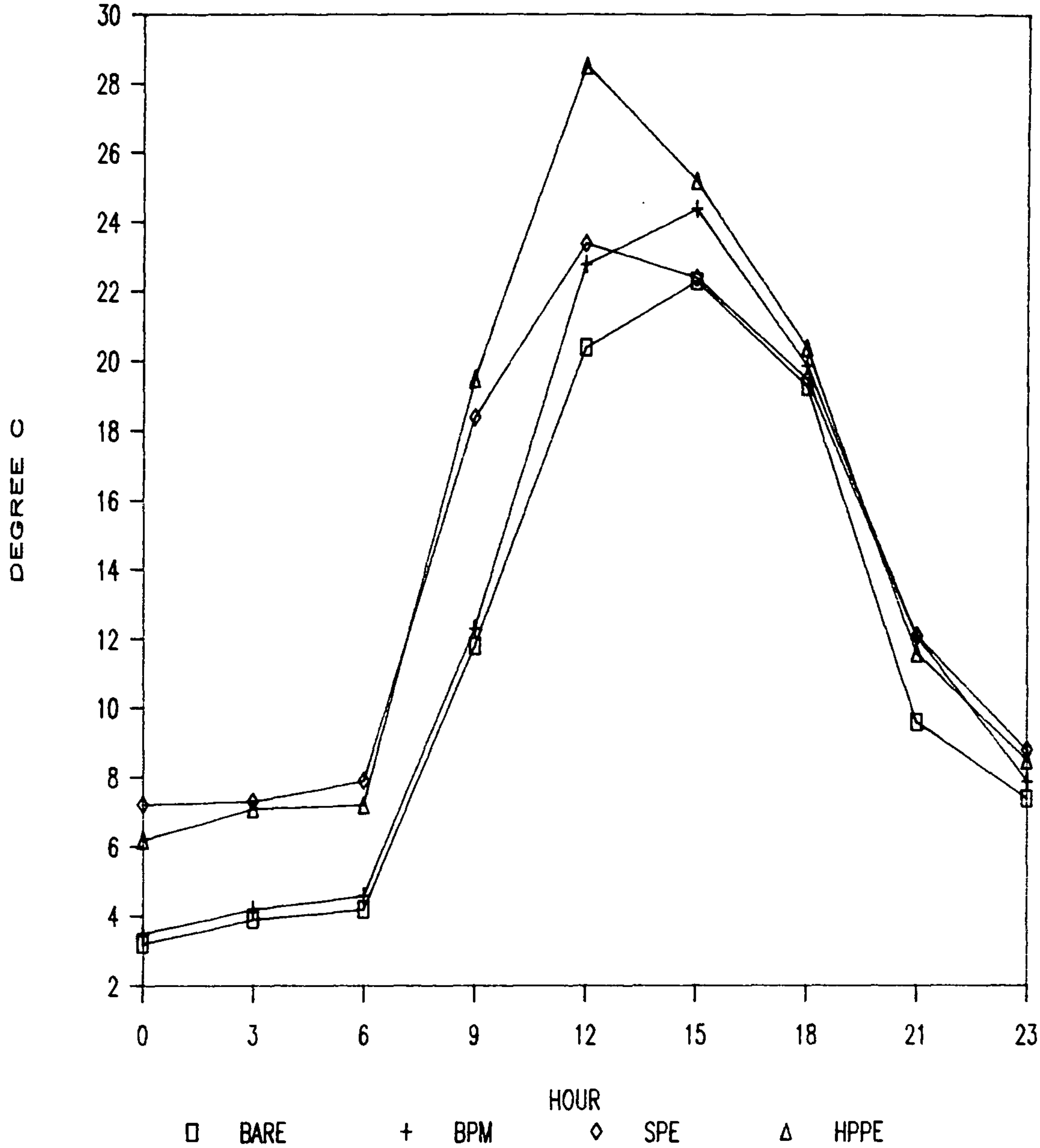

Figure 8. Effect of FRC on air temperature on a cool day (May 31), tomato experiment two.

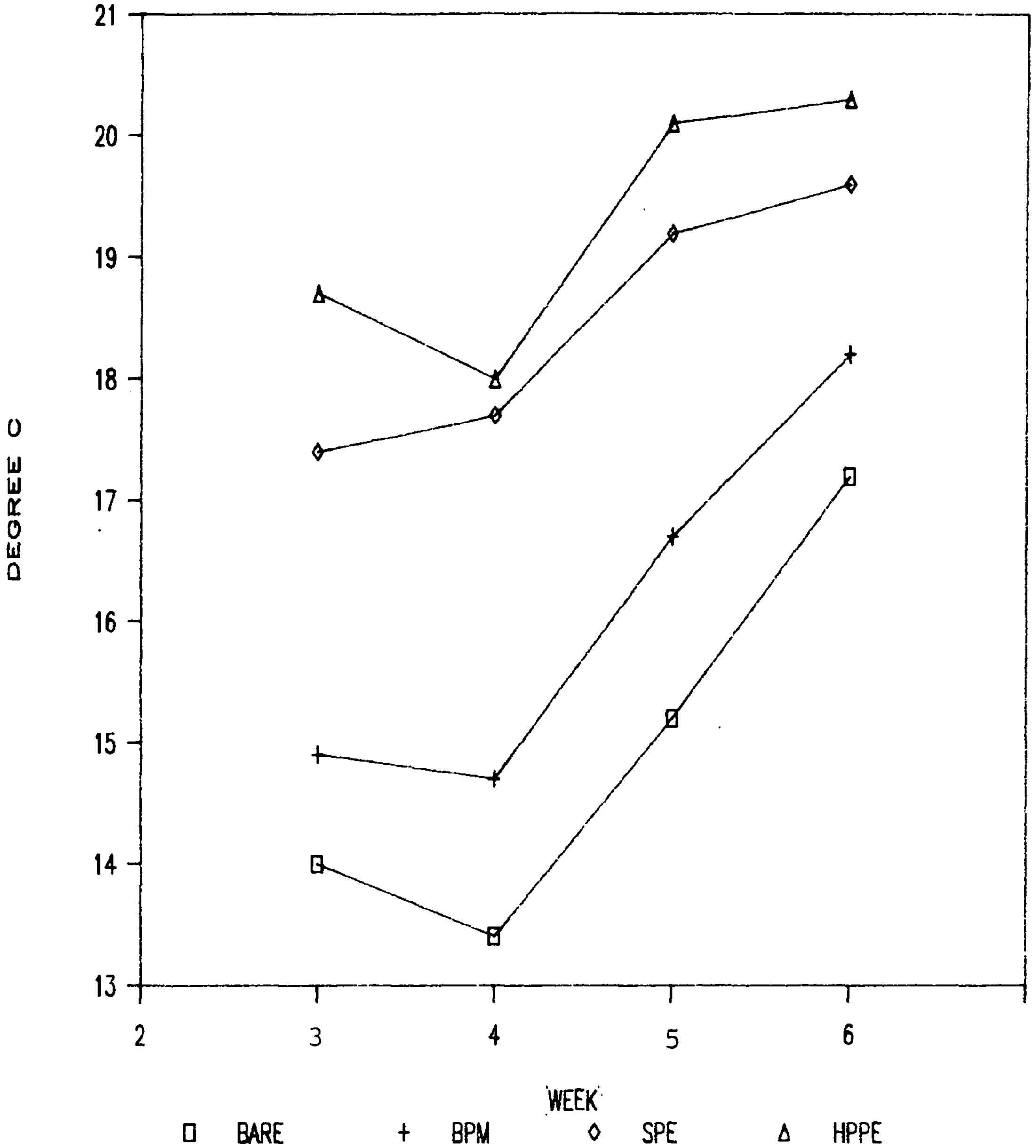

Figure 9. Effect of FRC on mean air temperature in weekly increments, tomato experiment two.

Table 12. Effect of FRC on tomato plant growth (cm), experiment two.

Treatment	3 Week CI[x]	4 Week CI		5 Week CI		6 Week CI	
	Length[y]	Height	Width	Height	Width	Height	Width
Bare	2.14	23.66	31.69	31.66	36.39	43.39	42.46
BPM	5.24	27.73	37.39	39.19	48.23	45.73	58.06
SPE	7.91	32.06	41.33	38.06	53.16	43.06	65.79
HPPE	9.77	31.19	42.86	35.86	54.19	43.40	69.06
Sig.[z]	**	**	**	**	**	NS	**
LSD1%	3.01	3.27	4.24	5.55	8.35		9.23
LSD5%	2.18	2.33	3.02	3.96	5.96		6.58

[x]CI: Covering interval.
[y]Length of the first 2 new growths.
[z]**, NS: Significance at 1% level and no significance, respectively.

Table 13. Effect of FRC and covering interval on days to tomato flowering and ripening and fruit set of the first 3 clusters, experiment two (mean of 5 plants).

Tmt	Days to flowering[w]	Days to ripening	Number of flowers				Fruit set			
			1st	2nd	3rd	Total	1st	2nd	3rd	Total
Bare	60.6	101.40	7.00	6.65	5.30	18.95	1.10	2.10	2.25	5.45
BPM	61.1	102.25	6.75	6.10	5.30	18.15	1.20	1.85	2.05	5.10
SPE	60.0	100.60	5.85	5.80	5.10	16.75	1.35	2.05	2.30	5.70
HPPE	58.2	99.20	6.20	5.50	4.85	16.55	2.05	1.75	1.50	5.30
Sig.[z]	*	**	**	*	NS	**	NS	NS	NS	NS
LSD1%		1.57	0.84			1.84				
LSD5%	1.3	1.18	0.63	0.83		1.38				
CI1[x]	60.9	101.40	6.80	5.85	5.05	17.70	1.25	1.60	2.15	5.00
CI2	59.1	100.00	6.20	5.95	5.20	17.35	1.45	2.30	2.15	5.90
CI3		100.70	6.55	6.25	5.05	17.85	1.85	1.80	2.00	5.65
CI4		101.35	6.25	6.00	5.25	17.50	1.15	2.05	1.80	5.00
Sig.	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C*CI[y]	NS	NS	NS	NS	NS	NS	*	*	NS	*
SPE1	61.8	60.80	6.00	5.40	5.20	16.60	2.00	1.20	2.80	4.20
SPE2	58.2	58.40	6.20	6.00	5.40	17.60	2.00	2.00	2.20	6.20
SPE3		58.00	6.00	6.00	5.20	17.20	1.60	2.20	2.20	6.00
SPE4		58.00	5.20	5.80	4.60	15.60	1.60	2.80	2.00	6.40
Sig.		NS	NS	NS	NS	NS	*	*	NS	*
LSD5%							1.55	1.39		2.64
HPPE1	58.4	58.20	6.60	5.40	4.20	16.20	1.00	1.20	1.60	3.80
HPPE2	58.0	58.00	6.00	5.80	5.40	17.20	2.20	2.80	2.00	7.00
HPPE3		58.00	6.20	5.40	4.00	15.60	3.40	2.00	1.60	7.00
HPPE4		58.00	6.00	5.40	5.80	17.20	1.60	1.00	0.80	3.40
Sig.		NS	NS	NS	NS	NS	*	*	NS	*
LSD5%							1.55	1.39		2.64

[w]Days to flowering were measured for four and five week covering intervals only.
[x]CI: Covering interval.
[y]C: Covers.
[z]**, *, NS: Significance at 1% and 5% levels and no significance, respectively.

Table 14. Effect of FRC and covering interval on tomato total yield (mt/ha) for 4 harvests, experiment two.

	Weight				Number			
	Harvest of				Harvest of			
Tmt	08/30	09/07	09/13	Total[w]	08/30	09/07	09/13	Total[w]
Bare	11.76	25.33	26.14	110.32	59,400	125,325	137,250	591,075
BPM	12.28	40.52	37.51	147.82	62,775	180,675	184,275	731,925
SPE	21.32	42.87	29.62	138.17	101,700	197,100	153,900	692,100
HPPE	23.02	39.28	33.21	143.90	116,775	184,950	173,250	764,325
Sig.[z]	**	**	**	**	**	**	**	**
LSD1%	3.94	7.84	7.07	15.98	19,489	34,367	35,683	84,121
LSD5%	2.96	5.89	5.31	12.02	14,653	25,840	26,829	63,249
CI1[x]	14.36	37.85	31.91	128.12	73,350	169,650	154,125	636,075
CI2	16.99	38.22	30.58	139.60	88,650	173,925	162,225	718,650
CI3	19.61	33.76	31.61	136.24	95,400	161,550	161,100	711,000
CI4	17.42	38.18	32,38	136.26	83,250	182,925	171,225	713,700
Sig.	*	NS	NS	NS	*	NS	NS	*
LSD1%								
LSD5%	2.96				14,653			63,249
C*CI[y]	**	NS	NS	NS	**	NS	NS	NS
SPE1	13.36	43.40	35.63	130.25	62,100	191,700	176,400	642,600
SPE2	20.37	47.24	24.30	144.71	98,100	210,600	137,700	715,500
SPE3	29.75	38.32	28.41	139.20	146,700	185,400	144,900	702,000
SPE4	21.79	42.52	30.16	138.54	99,900	200,700	156,600	708,300
Sig.	**	NS	NS	NS	**	NS	NS	NS
LSD1%	7.88				38,978			
LSD5%	5.93				29,307			
HPPE1	14.56	36.79	38.06	128.60	81,900	156,600	174,600	632,700
HPPE2	23.76	37.31	30.74	145.86	131,400	167,400	165,600	778,500
HPPE3	27.27	39.26	31.40	147.32	127,800	189,000	168,300	796,500
HPPE4	26.49	43.78	32.63	153.80	126,000	226,800	184,500	849,600
Sig.	**	NS	NS	NS		*	NS	*
LSD1%	7.88				38,978			
LSD5%	5.93				29,307	44,964		124,695

[w]Only ripe fruits are included in the first three harvests. Green and ripe fruits are included in the total yield. The fourth harvest is not shown but is included in total yield.
[x]CI: Covering interval.
[y]C: covers.
[z]**, *, NS: Significance at 1% and 5% levels, and no significance, respectively.

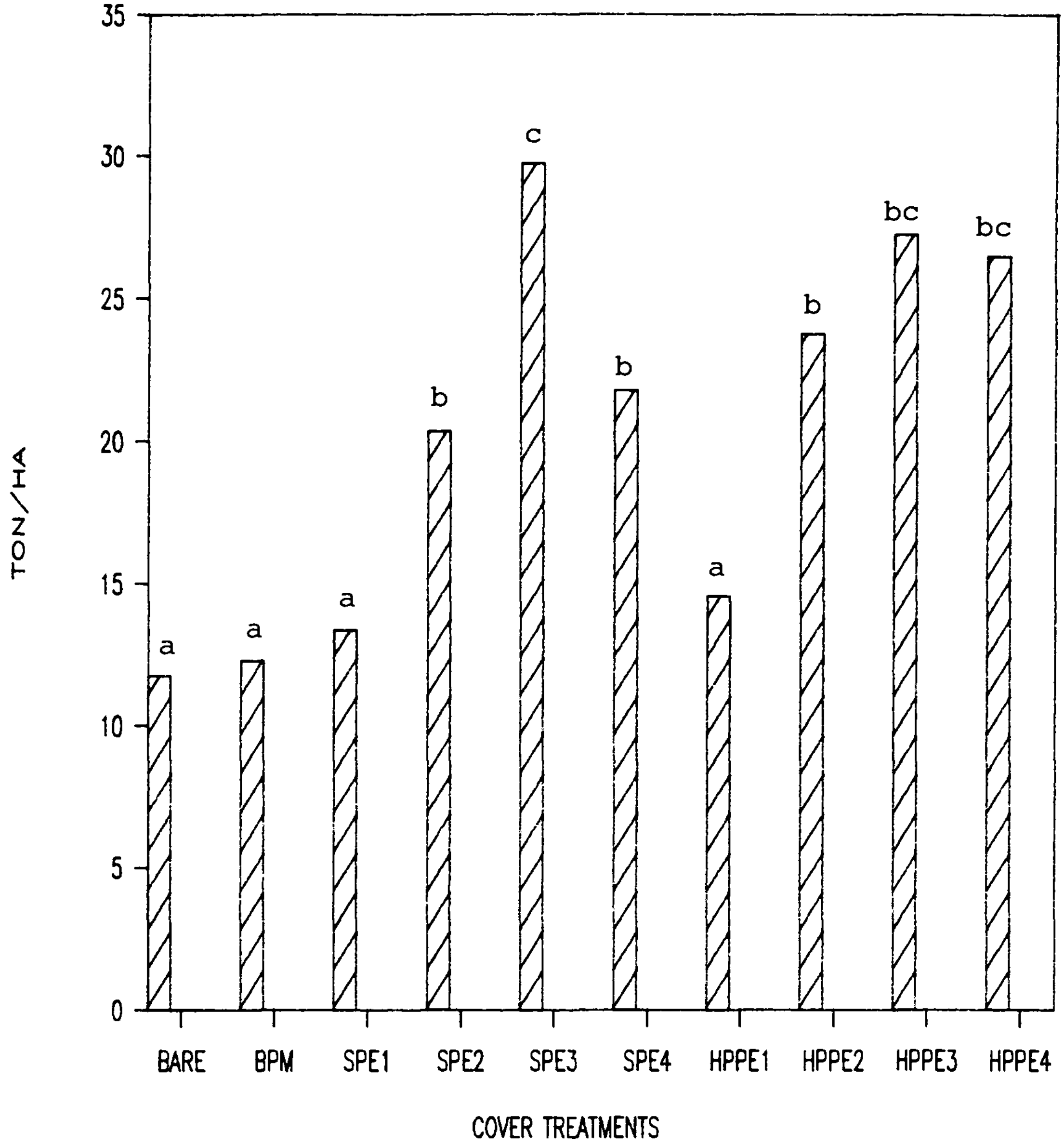

Figure 10. Effect of FRC and covering interval on tomato early yield, experiment two.

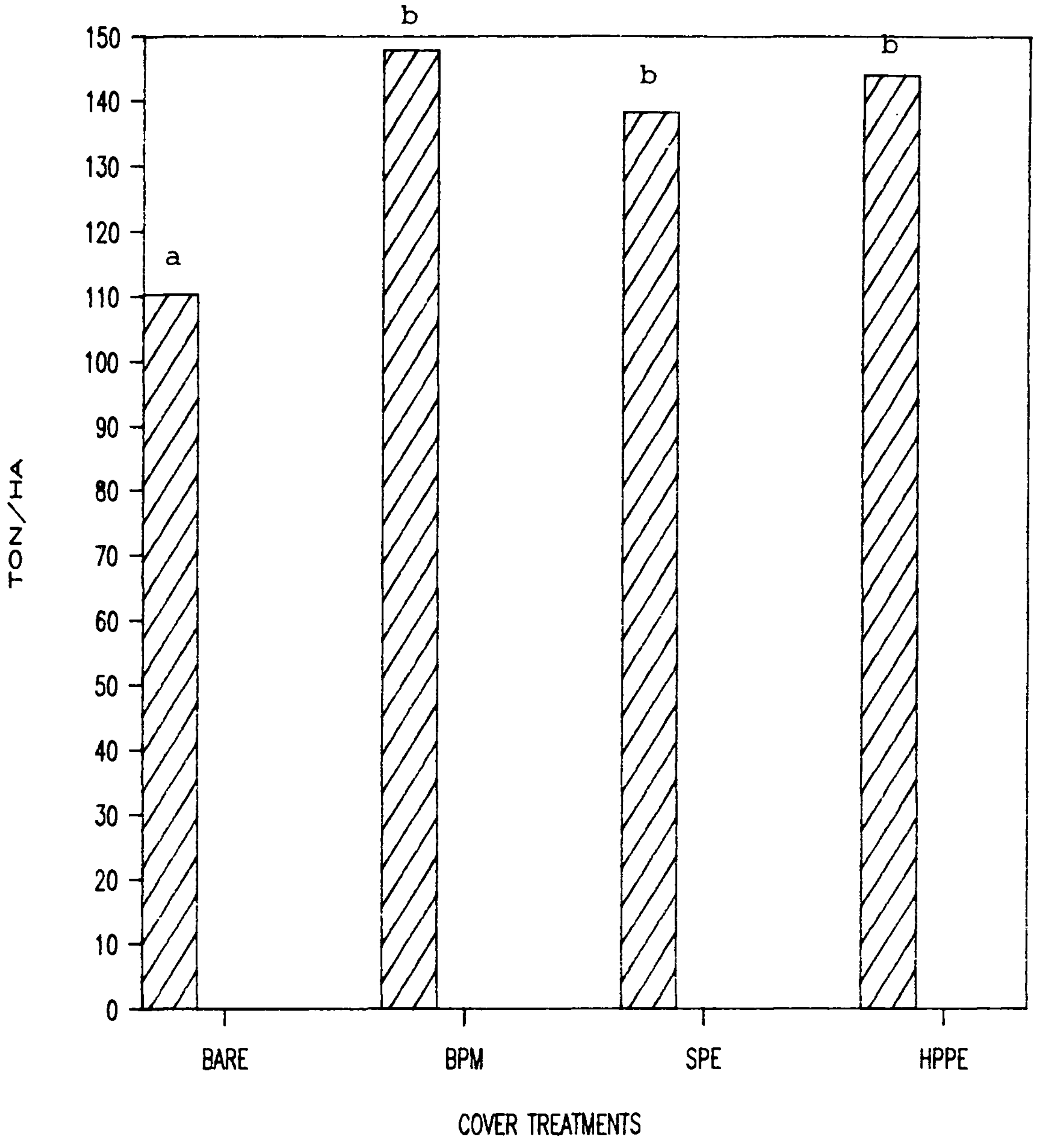

Figure 11. Effect of FRC on total tomato yield, experiment two.

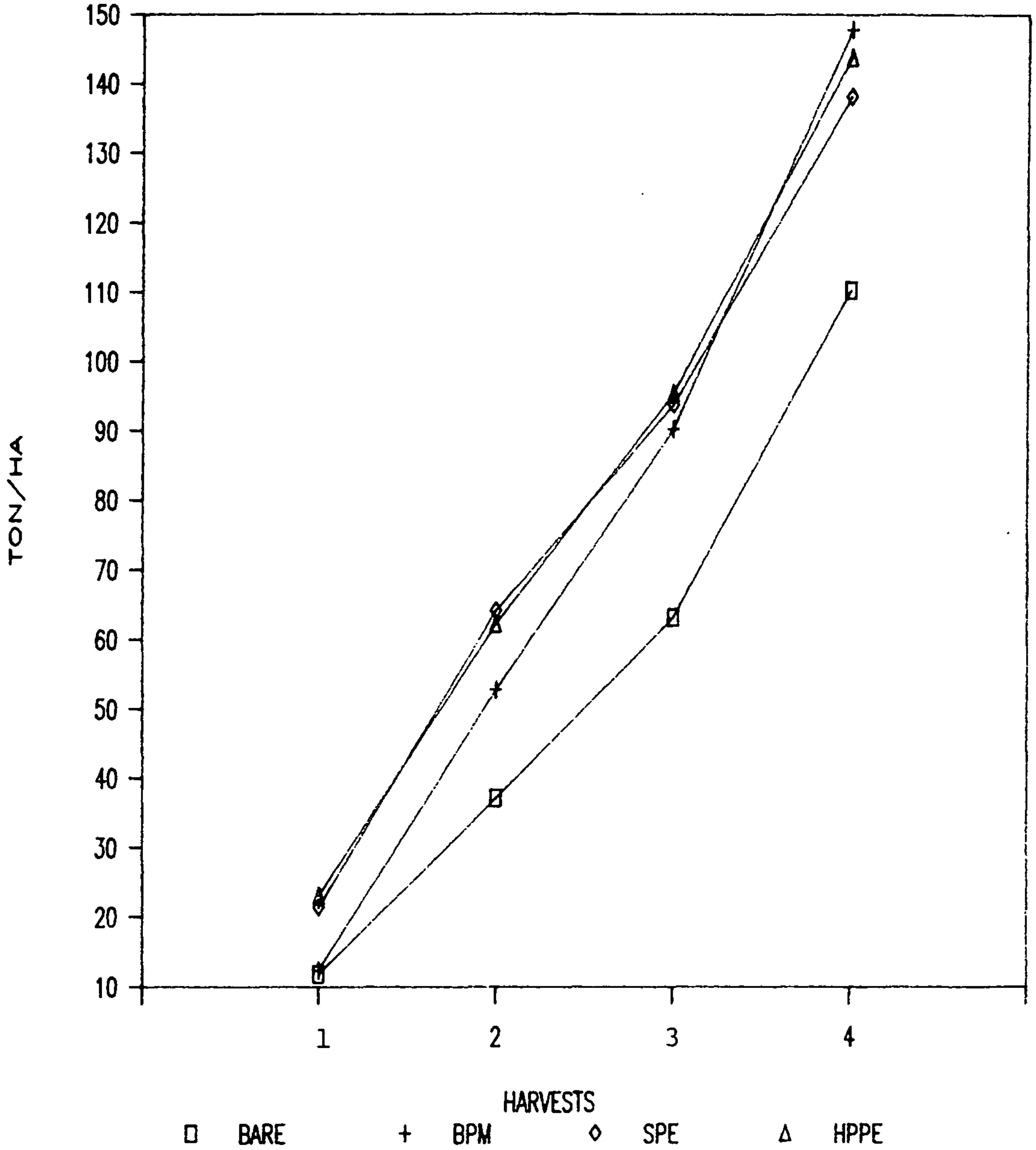

Figure 12. Cumulative tomato yield as affected by FRC and harvest number, experiment two.

Table 15. Effect of FRC and covering interval on yield (mt/ha) of large tomato fruit for 4 harvests, experiment two.

	Weight					Number			
	Harvest of					Harvest of			
Tmt	08/27	09/06	09/12	Total[w]		08/27	09/06	09/12	Total[w]
Bare	5.51	9.85	9.98	36.16	!	18,675	34,425	34,650	125,550
BPM	5.50	22.09	17.43	64.78	!	17,100	71,775	59,400	216,450
SPE	11.08	19.70	11.43	55.68	!	34,875	65,700	39,600	185,400
HPPE	10.92	17.82	11.44	50.42	!	35,100	56,700	40,050	165,150
					!				
Sig.[z]	**	**	**	**	!	**	**	**	**
LSD1%	2.74	5.26	4.37	10.13	!	8,682	16,612	14,771	33,784
LSD5%	2.06	3.95	3.28	7.61	!	6,528	12,490	11,106	25,401
CI1[x]	6.64	19.26	14.57	54.93	!	20,700	62,325	49,500	182,925
CI2	7.41	17.77	11.57	50.53	!	24,525	58,050	40,950	171,225
CI3	10.22	14.85	12.66	50.80	!	33,075	49,500	42,300	167,175
CI4	8.74	17.59	11.47	50.78	!	27,450	58,725	40,950	171,225
					!				
Sig.	**	NS	NS	NS	!	**	NS	NS	NS
LSD1%	2.74				!	8,682			
LSD5%	2.06				!	6,528			
C*CI[y]	**	NS	*	NS	!	**	NS	NS	NS
SPE1	6.01	22.35	14.67	55.27	!	17,100	72,000	48,600	180,000
SPE2	11.00	21.79	10.12	57.47	!	34,200	72,000	38,700	193,500
SPE3	16.11	15.61	10.89	56.86	!	54,000	54,000	36,900	189,000
SPE4	11.18	19.05	10.04	53.13	!	34,200	64,800	34,200	179,100
					!				
Sig.	**	NS	*	NS	!	**	NS	NS	NS
LSD1%	5.49				!	17,363			
LSD5%	4.13		6.57		!	13,055			
HPPE1	6.09	20.68	18.84	56.59	!	18,000	63,900	63,000	184,500
HPPE2	8.89	17.63	9.40	47.98	!	31,500	55,800	34,200	163,800
HPPE3	14.64	16.27	9.56	48.54	!	45,500	52,200	32,400	154,800
HPPE4	14.09	16.72	7.95	48.59	!	45,000	54,900	30,600	157,500
					!				
Sig.	*	NS	*	NS	!	**	NS	*	NS
LSD1%	5.62				!	17,363			
LSD5%	4.22		6.57		!	13,055		23,865	

[w]Only ripe fruits are included in the first three harvest.
Green and ripe fruits are included in the total yield.
The fourth harvest is not showen but is included in total yield.
[x]CI: Covering interval.
[y]C: Covers.
[z]**, *, NS: Significance at 1% and 5% levels and no significance, respectively.

Table 16. Effect of FRC and covering interval on yield (mt/ha) of medium tomato fruit for 4 harvests, experiment two.

	Weight				Number			
	Harvest of				Harvest of			
Tmt	08/27	09/06	09/12	Total[w]	08/27	09/06	09/12	Total[w]
Bare	4.10	12.13	12.18	54.73	21,600	62,325	66,600	296,775
BPM	4.79	14.66	15.63	61.59	26,325	76,500	85,500	332,100
SPE	7.04	18.98	13.32	60.22	38,700	96,075	74,700	321,300
HPPE	7.04	16.25	16.58	67.54	47,700	83,475	88,650	367,650
Sig.[z]	**	**	*	**	**	**	*	**
LSD1%	2.29	4.27		9.54	12,062	20,736		50,541
LSD5%	1.72	3.21	2.99	7.17	9,069	15,591	16,510	38,001
CI1[x]	5.04	14.93	13.33	54.83	27,675	75,600	69,975	291,600
CI2	6.54	16.40	14.13	64.05	35,550	81,900	79,200	341,100
CI3	6.74	15.20	13.84	62.42	37,350	80,325	75,600	343,575
CI4	6.25	15.50	16.41	62.79	33,750	80,550	90,675	341,550
Sig.	NS	NS	NS	NS	NS	NS	NS	NS
C*CI[y]	NS	NS	NS	NS	NS	NS	NS	NS
SPE1	4.60	17.85	15.68	55.77	25,200	91,800	82,800	297,900
SPE2	6.35	20.97	10.38	63.51	35,100	100,800	65,700	328,500
SPE3	9.18	18.57	11.76	58.67	51,300	97,200	65,700	319,500
SPE4	8.04	18.52	15.46	62.94	43,200	94,500	84,600	339,300
Sig.	NS	NS	NS	NS	NS	NS	NS	NS
HPPE1	5.99	12.65	16.00	54.76	36,000	63,000	83,700	297,000
HPPE2	10.31	15.02	15.44	69.40	56,700	72,900	83,700	372,600
HPPE3	9.21	18.23	15.67	71.80	49,500	96,300	82,800	392,400
HPPE4	9.05	19.10	17.21	74.22	48,600	101,700	104,400	408,600
Sig.	NS	NS	NS	*	NS	*	NS	*
LSD5%				12.48		25,475		62,984

[w]Only ripe fruits are included in the first three harvests. Green and ripe fruits are included in the total yield. The fourth harvest is not shown but is included in total yield.
[x]CI: Covering interval.
[y]C: covers..
[z]**, *, NS: Significance at 1% and 5% levels and no significance, respectively.

Table 17. Effect of FRC and covering interval on yield (mt/ha) of small tomato fruit for 4 harvests, experiment two.

	Weight				Number			
	Harvest of				Harvest of			
Tmt	8/27	9/06	9/12	Total[w]	8/27	9/06	9/12	Total[w]
Bare	2.14	3.33	3.98	19.42	19,125	28,575	36,000	168,750
BPM	1.97	3.76	4.44	21.44	19,350	32,400	39,375	183,375
SPE	3.19	4.19	4.86	22.26	28,125	35,325	39,600	185,400
HPPE	3.45	5.20	5.18	25.92	33,975	44,775	44,550	231,525
Sig.[z]	**	*	NS	*	**	*	NS	**
LSD1%	1.23				10,075			44,230
LSD5%	0.92	1.17		3.87	7,575	10,053		33,256
CI1[x]	2.67	3.65	4.00	18.35	24,975	31,725	34,650	161,550
CI2	3.03	4.04	4.87	25.01	28,575	33,975	42,075	206,325
CI3	2.63	3.70	5.10	23.01	24,975	31,725	43,200	200,250
CI4	2.42	5.09	4.49	22.67	22,050	43,650	39,600	200,925
Sig.	NS	NS	NS	**	NS	NS	NS	*
LSD1%				5.15				
LSD5%				3.87				33,256
C*CI[y]	NS	NS	NS	NS	*	NS	NS	NS
SPE1	2.75	3.20	5.27	19.19	19,800	27,900	45,000	164,700
SPE2	3.01	4.47	3.79	23.72	28,800	37,800	33,300	193,500
SPE3	4.45	4.14	5.74	23.67	41,400	34,200	42,300	193,500
SPE4	2.57	4.94	4.66	22.46	22,500	41,400	37,800	189,900
Sig.	NS	NS	NS	NS	*	NS	NS	NS
LSD5%					15,151			
HPPE1	2.47	3.45	3.20	17.24	27,900	29,700	27,900	151,200
HPPE2	4.56	4.65	5.90	28.47	43,200	38,700	47,700	242,100
HPPE3	3.41	4.74	6.16	26.98	32,400	40,500	53,100	249,300
HPPE4	3.34	7.95	5.47	30.99	32,400	70,200	49,500	283,500
Sig.	NS	**	NS	*	*	**	NS	*
LSD1%		3.11				26,359		
LSD5%		2.20		8.89	15,151	18,679		85,833

[w]Only ripe fruits are included in the first three harvests. Green and ripe fruits are included in the total yield. The fourth harvest is not shown but is included in total yield.
[x]CI: Covering interval.
[y]C: Covers.
[z]**, *, NS: Significance at 1% and 5% levels and no significance, respectively.

Table 18. Effect of FRC and covering interval on mean fruit weight (g) of all tomatoes for 4 harvests, experiment two.

Treatment	Harvest of 08/07	Harvest of 09/13	Harvest of 09/24	Total[w]
Bare	196	204	191	187
BPM	193	224	203	202
SPE	217	218	194	200
HPPP	195	215	194	190
Sig.[z]	NS	*	NS	**
LSD1%				9
LSD5%		12		7
CI1[x]	203	226	206	202
CI2	193	217	190	194
CI3	203	208	197	192
CI4	203	209	188	191
Sig.	NS	*	**	**
LSD1%			15	9
LSD5%		12	11	8
C*CI[y]	NS	NS	NS	NS
SPE1	233	228	198	203
SPE2	212	225	185	202
SPE3	206	207	197	198
SPE4	218	211	196	195
Sig.	NS	NS	NS	NS
HPPE1	177	240	220	205
HPPE2	179	220	187	189
HPPE3	214	207	189	186
HPPE4	210	193	177	181
Sig.	NS	**	**	*
LSD1%		31	32	
LSD5%		22	22	13

[w]Only ripe fruits are included in the first three harvests. Green and ripe fruits are included in the total yield. The fourth harvest is not shown but is included in total yield.

[x]CI: Covering interval.

[y]C: Covers.

[z]**, *, NS: Significance at 1% and 5% levels and no significance, respectively.

Table 19. Effect of FRC and covering interval on number of cull and catfaced fruit and weight of vines, tomato experiment two.

Treatment	Cull fruit (mt/ha)	Catfaced fruit number(ha)	Weight of vines(t/ha)
Bare	4.82	9,675	15.53
BPM	6.17	29,925	25.03
SPE	6.64	25,650	23.12
HPPE	7.97	33,075	24.10
Sig.[z]	**	**	**
LSD1%	2.05	13,618	2.95
LSD5%	1.54	10,239	2.21
CI1[x]	6.35	30,825	21.05
CI2	5.97	18,900	21.86
CI3	5.95	26,775	22.05
CI4	7.34	21,825	22.82
Sig.	NS	NS	NS
C*CI[y]	*	NS	NS
SPE1	7.72	41,400	22.08
SPE2	6.21	18,000	23.59
SPE3	6.51	27,900	22.91
SPE4	6.10	15,300	23.91
Sig.	*	NS	NS
LSD5%	3.09		
HPPE1	6.46	36,900	22.07
HPPE2	6.21	16,200	23.91
HPPE3	7.59	36,000	24.83
HPPE4	1.64	43,200	25.58
Sig.	*	NS	NS
LSD5%	3.09		

[x]CI: Covering interval.
[y]C: Covers.
[z]**, *, NS: Significance at 1% and 5% levels and no significance, respectively.

Table 20. Effect of FRC and covering interval on mineral content of tomato leaf, tomato experiment two.

	% dry wt. (g)					ppm dry wt.	
	N	P	K	Ca	Mg	Mn	Zn
Bare	3.10	0.33	2.55	6.03	0.95	108.75	24.25
BPM	2.86	0.38	2.40	6.15	0.90	124.00	25.50
Sig.[z]	NS	NS	NS	NS	NS	NS	NS
SPE	2.75	0.32	2.37	5.65	0.87	129.50	22.05
HPPE	2.79	0.34	2.52	5.90	0.87	134.00	25,20
Sig.	NS	NS	NS	NS	NS	NS	NS
CI1[x]	0.26	3.83	2.57	5.46	0.87	101.88	23.62
CI2	2.89	0.35	2.40	5.89	0.92	124.13	22.05
CI3	2.79	0.36	2.35	5.87	0.85	142.63	16.20
CI4	2.76	0.36	2.34	5.91	0.88	158.38	20.02
Sig.	NS	NS	NS	NS	NS	NS	NS
C*CI[y]	NS	NS	NS	NS	NS	NS	NS
SPE1	2.56	0.33	2.22	6.10	0.87	101.00	20.25
SPE2	2.94	0.32	2.41	5.68	0.83	117.00	21.00
SPE3	2.77	0.32	2.30	6.26	0.83	136.00	20.50
SPE4	2.73	0.34	2.38	5.89	0.87	164.00	21.50
Sig.	NS	NS	NS	NS	NS	NS	NS
HPPE1	2.72	0.33	2.57	5.60	0.81	102.75	21.75
HPPE2	2.83	0.32	2.53	6.00	0.80	131.25	21.50
HPPE3	2.81	0.35	2.23	5.93	0.83	149.25	29.50
HPPE4	2.79	0.32	2.47	5.66	0.80	152.75	23.50
Sig.	NS	NS	NS	NS	NS	NS	NS

[x]CI: Covering interval.
[y]C: Covers.
[z]NS: No significance at 1% and 5% levels.

LETTUCE EXPERIMENT ONE

Materials and Methods

During the fall of 1984, a study on the effect of two floating row covers (FRC), spunbonded polyester (SPE) and highly perforated polyethylene (HPPE), was conducted on Romaine lettuce at the O.S.U. North Willamette Agricultural Experiment Station.

Soil was plowed, and rototilled to form the seedbed, after 1000 kg of 10-20-22 were broadcast per hectare. Weeds were controlled chemically by a surface application of pronamide at 1.7 kg per hectare immediately after planting.

Cover treatments included SPE, HPPE and an uncovered control. Two covering dates were imposed in order to evaluate the effect of FRC on transplant survival. One treatment was to cover immediately after transplanting and the other, one week later. For the first covering date, the covers were removed at 3 and 7 weeks after covering. For the second covering date, covers were removed at 3 and 6 weeks after covering. All treatments were replicated four times in a randomized block design. Since all covering intervals were independent treatments, data were analysed as a randomized block design.

Seedlings were raised in a heated greenhouse for four weeks and then put outside for hardening and reducing growth rate. Each plot consisted of two rows of ten plants each of "Parris Island Cos" Romaine lettuce. Plants were spaced 0.6 m between the rows and 0.15 m in the row.

Transplants were planted on September 19 and the appropriate covering treatments were applied. One week later the second set of covering treatments was applied. Row covers were laid on the transplants in a simlar way as in the tomato experiments. Irrigation and fungicides were applied as needed.

Air temperature at 2.5 cm above the soil and soil temperature at 2.5 and 5 cm below the soil level were automatically recorded by a Leeds and Northrup Speedomax 250 multipoint recorder every half hour for the total growing season. Temperature records were not replicated.

All treatments were harvested on November 7. The ten inner plants were harvested from each plot. Plant fresh weight, length, and width were measured for all ten plants. Number of leaves was counted on three plants. Plant dry weight was measured on five plants. Leaves taken at harvest time from three plants were analysed for N, P, K, Ca, Mg, Mn, Zn, and B. Leaves were washed, dried, and ground for later analysis. Total nitrogen was determined by Kjeldhal method (Schuman et al., 1973) and the other elements were analysed together by the inductively coupled argon plasma spectrometer method (Jones, 1978).

Results and Discussion

Air temperature

Weather conditions for October and December were abnormal. Temperatures for November were near normal. Mean maximum temperatures for October and December were 2.6°C and 1.2°C below normal, respectively. Mean minimum temperature for the same period was normal for October and 1.8°C colder in December. Overall monthly mean was again about normal for October and 1.7°C below normal in December.

The mean maximum temperature for the total period was increased by 2°C with HPPE compared to SPE which increased the temperature by 2 degrees C over bare ground (Table 21). The minimum temperature tended to be the same for both FRC and bare ground. The HPPE raised daily mean temperature by 2.4°C over bare ground and 1.1°C over SPE which elevated mean air temperature by 1.3°C over bare ground (Table 21).

Soil temperature

Minimum soil temperature at 2.5 cm depth was slightly increased with HPPE and SPE (Table 21). Maximum soil temperature was increased with HPPE by 4.4°C over bare ground but was not affected by SPE.

The increases in soil and air temperatures confirmed the findings of the tomato experiments; however, the magnitude of increase in this experiment was lower. This was due to lower ambient temperatures, shorter days and less sunlight in the fall than at the end of spring and beginning of summer.

Plant growth

The mean fresh weight of ten plants was lower in the non-covered than the covered plots. A seven-week covering period yielded heavier plants than the six and the three week covering time. The uncovered treatment had the least mean fresh weight. Covering date did not affect transplant survival or plant weight (Table 22).

Plant length and width were increased with FRC and with the length of the covering period but they were not influenced by the covering date (Table 22). Numbers of leaves responded similarly.

The increased growth (fresh weight, length, width, leaf number) of the covered plants was due to the increased soil and air temperatures. Increasing lettuce growth by using perforated row covers was reported by Benoit (1975), Benoit and Hartmann (1974) and Henriksen (1981). Benoit (1975) and Benoit and Hartmann (1974) related that air and soil temperatures were important in determining lettuce growth. Increasing soil temperature from 4 to 7°C increased daily root growth by 1 to 2 cm. The 4°C increase in minimum soil temperature may have been the main reason for this growth increase but other factors may be included. Wells (1984) did not find an increase in lettuce yield covered with SPE due to excessively high temperature under the cover. The phenomenon of reduced plant growth from high temperature stress was not observed in this experiment. Plants harvested had a normal color and were not bruised by the covers. A seven week covering time seemed to be adequate for normal healthy lettuce plants from a mid-September planting.

Plant dry weight increased with FRC and tended to be highest with the longest covering time (Table 22). Relative dry weight (percentage of dry weight over fresh weight measured relative to the bare ground treatment) was lower for the plants covered for 6 and 7 weeks than for those covered for 3 weeks, indicating that covered plants were more succulent.

The increase in absolute dry matter from row covers was a function of the increased growth rate, larger leaf surface area and increased photosynthesis with the longer covering periods. It may also possibly be due to a higher CO_2 concentration under FRC (Mansour, 1986). The decrease of the relative dry weight with the increased length of the covering period was possibly related to a lower water stress of the plants covered for the longer period (6-7 weeks) resulting in more succulent plants.

Leaf mineral analysis showed a general increase in potassium and boron concentration in the longest covered plants whereas calcium concentration of covered plants tended to be slightly depressed with covers (Table 23).

The increase of K and B concentration in these plants may have been due to an increase in K and B uptake by these bigger plants which were able to take up more of these soil nutrients than the less developed plants. The decrease of Ca concentration in the larger plants may have been due to the competition between K and Ca in the soil. Ca was possibly depressed by K uptake (Mengel and Kirkby, 1982) and plants which had high K concentration showed low Ca content. Low Ca concentration was also possibly due to a higher dilution effect in the bigger plants. The lack of effect of increasing temperature on N, P and Mg uptake corroborates the findings of Knavel (1974) even though an increase in P would have been expected at higher temperatures.

Table 21. Effect of FRC on mean air and soil temperature (°C), lettuce experiment one.

	Air			Soil					
				2.5 cm Depth			5 cm Depth		
Tmt and date	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Bare									
09/20-09/26	6.6	24.4	15.5	9.0	21.1	15.0			
09/27-10/03	8.2	25.0	16.6	9.3	20.5	14.9			
10/04-10/10	9.8	22.5	16.1	11.6	20.5	16.0			
10/11-10/17	4.1	16.1	10.1	6.1	15.3	10.7			
10/18-10/24	5.6	12.5	9.1	6.9	13.2	10.1			
10/25-10/31	3.9	12.9	8.4	5.2	12.7	8.9			
11/01-11/05	6.0	13.6	9.8	6.3	12.3	9.3			
Mean	6.3	18.3	12.3	7.8	16.7	7.8			
SPE									
09/20-09/26	7.5	27.0	17.3	10.7	22.9	16.8	8.8	28.3	18.6
09/27-10/03	8.7	29.8	19.2	10.7	23.1	16.9	9.8	26.1	17.9
10/04-10/10	10.5	24.0	17.3	12.2	19.9	16.1	9.1	26.9	18.1
10/11-10/17	5.2	17.5	11.4	8.1	14.5	11.3	3.5	18.6	11.4
10/18-10/24	6.1	14.5	10.3	8.2	12.2	10.1	5.3	14.4	9.9
10/25-10/31	4.1	13.5	8.8	6.8	11.2	9.1	2.9	14.5	8.7
11/01-11/05	6.1	14.3	10.2	8.0	11.2	9.6	5.7	14.6	10.1
Mean	6.9	20.3	13.6	9.3	16.7	13.0	6.5	20.8	13.6
HPPE									
09/20-09/26	8.3	30.4	19.3	9.4	27.9	18.7	10.0	27.5	18.8
09/27-10/03	8.5	30.6	19.5	9.7	28.2	18.9	10.2	27.5	18.9
10/04-10/10	11.0	25.3	18.4	12.0	24.6	18.3	12.4	24.2	18.3
10/11-10/17	5.6	19.4	12.5	7.5	19.7	13.6	7.9	19.3	13.4
10/18-10/24	6.4	16.5	11.5	7.9	16.2	12.1	8.3	16.0	12.1
10/25-10/31	4.3	15.7	10.0	6.1	15.1	10.6	6.7	14.6	10.6
11/01-11/05	6.2	15.3	10.8	7.6	13.9	10.7	7.8	13.2	10.5
Mean	7.2	22.3	14.7	8.6	21.1	14.9	9.1	20.6	14.9

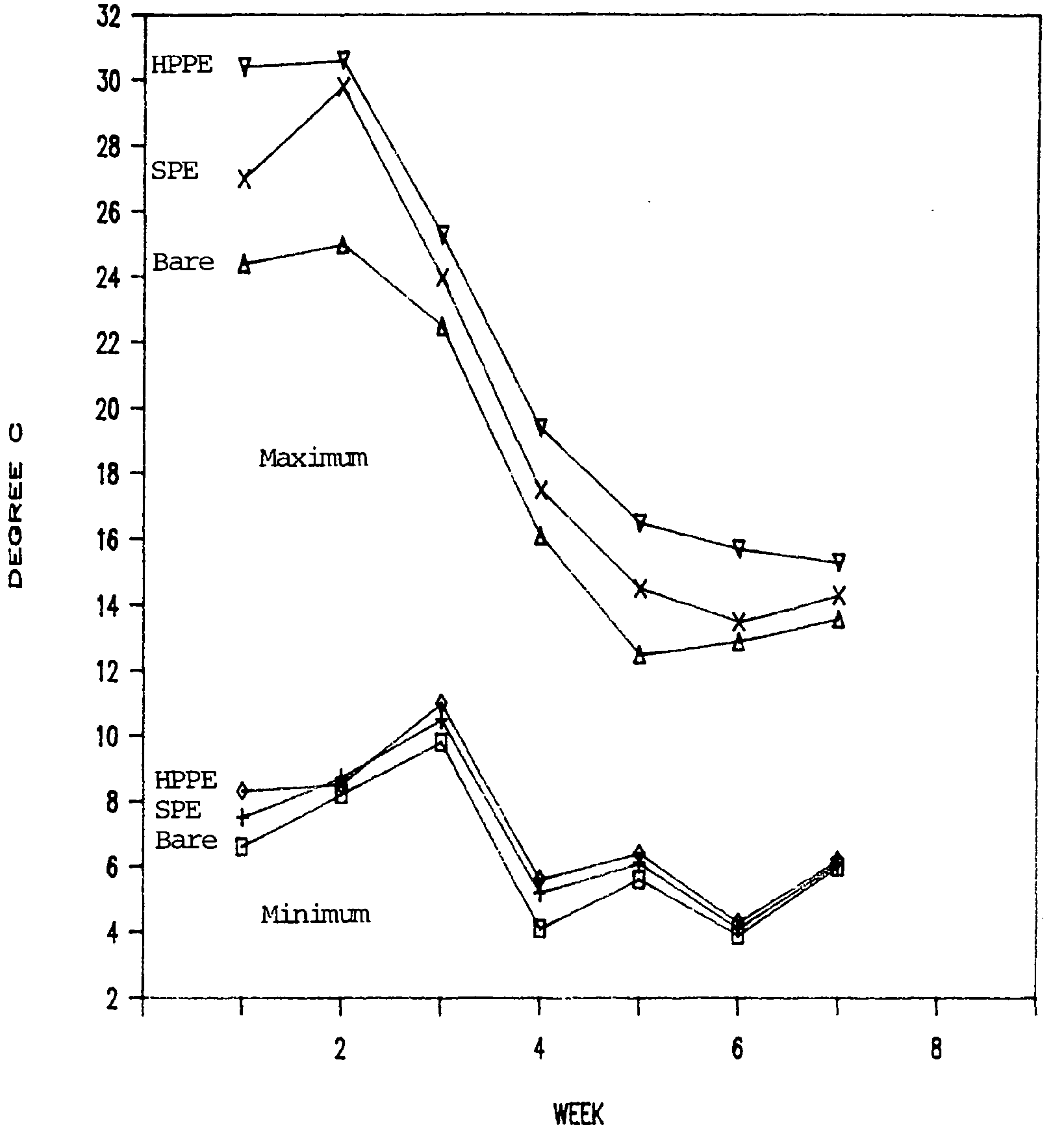

Figure 13. Effect of FRC on minimum and maximum air temperature in weekly increments, lettuce experiment one.

Table 22. Effect of FRC, covering date and covering interval on lettuce yield, experiment one.

	Covering Period (Weeks)	Fresh Weigh (g/plant)	Length (cm)	Width (cm)	Leaves Number	Dry Weight (g/plant)	Dry Wt/ Fresh Wt (%)
Bare		67.98	13.50	11.10	15.00	5.07	5.06
SPE1[x]	3	99.35	15.10	15.00	17.00	7.74	4.98
SPE2[y]	6	157.84	20.90	17.60	23.00	8.69	3.08
SPE3[y]	3	106.33	16.35	13.55	18.00	7.99	5.01
SPE4[x]	7	117.17	18.85	15.40	20.00	7.21	3.59
HPPE1[x]	3	104.07	16.85	14.45	18.00	7.38	4.57
HPPE2[y]	6	148.22	21.20	16.19	22.00	7.58	3.10
HPPE3[y]	3	110.58	17.60	14.95	20.00	8.49	4.63
HPPE4[x]	7	137.70	20.35	16.10	24.00	7.43	3.05
Sig.[z]		**	**	**	**	**	**
LSD1%		37.53	2.67	2.50	3.46	1.95	0.98
LSD5%		27.87	1.98	1.85	2.56	1.45	0.73

[x]Covered immediately after planting.
[y]Covered one week after planting.
[z]**: Significance at 1% level.

Table 23. Effect of FRC, covering date and covering interval on lettuce mineral content, experiment one.

Covering Period		% Dry weight (g)				ppm Dry wt		
	N	P	K	Ca	Mg	Mn	Zn	B
Bare	3.07	0.43	5.11	0.96	0.26	125.75	24.00	19.25
SPE1[x] 3	2.75	0.38	4.32	0.82	0.24	100.00	21.75	17.25
SPE2[y] 6	3.26	0.50	6.88	0.89	0.28	116.75	24.50	22.75
SPE3[y] 3	2.98	0.44	5.10	0.91	0.26	76.50	19.25	20.50
SPE4[x] 7	2.71	0.40	6.21	0.79	0.23	109.00	23.75	22.25
HPPE1[x]3	3.21	0.38	5.26	0.86	0.26	115.50	24.00	18.25
HPPE2[y]6	3.07	0.43	7.39	1.00	0.28	96.75	17.50	23.50
HPPE3[y]3	2.86	0.44	5.59	0.91	0.26	94.50	18.75	20.00
HPPE4[x]7	3.00	0.45	6.99	0.89	0.26	98.50	22.25	23.25
Sig.[z]	NS	NS	**	*	NS	NS	NS	**
LSD1%			1.12					3.65
LSD5%			0.82	0.11				2.69

[x]Covered immediately after planting.
[y]Covered one week after planting.
[z]**, *, NS: Significance at 1% and 5% levels and no significance, respectively.

LETTUCE EXPERIMENT TWO

Materials and Methods

This experiment was also established at the OSU North Willamette Agricultural Experiment Station. Materials and methods were similar to experiment one. The planting date was on October 3. Seedlings were started on August 29 and grown in the greenhouse for two weeks and then hardened outside for two weeks. Covering time was also immediately after planting and one week later. Removal times were changed to four and ten weeks from the covering date. All treatments were replicated five times in a factorial combination of treatments in randomized block design.

Air and soil temperatures were recorded in a similar manner as in the first lettuce experiment and continued for the total growing season from October 3 to December 14.

Because of the occurrence of several hard freezes and subsequent cold temperatures, plants were harvested on December 14, weighed, measured and evaluated for frost protection which was graded from one for the non-damaged plants to ten for the most damaged ones.

Results and Discussion

Air temperature

Air temperatures recorded for the total growing period showed a slight increase in minimum air temperature with FRC and an increase of 2.3 and 3.2°C in maximum air temperature with SPE and HPPE, respectively (Table 24). On one hot day (October 7), maximum ambient air temperature reached 30.6°, 31.7° under SPE and 33.9° under HPPE. On a very cool day (December 5) the outdoor temperature dropped to -4.4° and to -2.2° and -2.9°C beneath SPE and HPPE, respectively. Covered plants were frosted but were less damaged than non-covered plants (Table 25).

Soil temperature

Minimum soil temperature at 2.5 cm depth was increased 1.5°C with SPE and 1°C with HPPE. Uncovered plot temperatures dropped to below 4°C (minimum temperature required for lettuce root growth (Benoit, 1975; Benoit and Hartman, 1974)) after the seventh week and after the eighth week under FRC. Maximum temperature was elevated by 0.8°C beneath SPE and 2.5°C beneath HPPE (Table 24).

The magnitude of the temperature increase was reduced for this experiment in comparison to the first lettuce experiment. This was due to the decrease in ambient temperature, shorter days and reduced sunlight at the end of November and beginning of December.

Growth response

Mean plant fresh weight was increased with FRC. However, there was no difference between SPE and HPPE (Table 25). Plant weight was increased by 83 percent under spunbonded polyester covers and by 63 percent with HPPE covers over those on bare soil.

Plants covered immediately after transplanting outyielded those covered a week later by 18 percent. Plants were 22 percent heavier with a ten week covering period, than with a four week covering period. Mean plant length increased in a similar way to plant fresh weight. Plants covered ten weeks were less damaged by frost and cold weather than plants covered four weeks (Table 25).

The increase in plant growth was due to the effect of FRC on soil and air temperature, and to the effect of FRC on frost protection. Even though plant growth was nearly doubled by FRC, FRC did not produce a marketable plant over the period of this experiment. Fall season commercial planting would have to be adjusted accordingly. Plants covered for ten weeks showed some abrasion damage from contact with the covers, so cover removal time may be critical.

Table 24. Effect of FRC on mean air and soil temperature (°C), lettuce experiment two.

	Air temperature			Soil temperature					
				2.5 cm depth			5 cm depth		
Tmt and date	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Bare									
10/03-10/09	10.2	23.7	17.0	11.4	21.1	16.2			
10/10-10/16	5.2	16.4	10.8	7.5	15.6	11.6			
10/17-10/23	4.3	12.5	8.4	6.0	13.1	9.5			
10/24-10/30	5.0	13.1	9.1	6.1	13.1	9.6			
10/31-11/06	5.2	13.3	9.3	5.9	12.2	9.1			
11/07-11/13	5.6	12.3	8.9	6.3	12.1	9.2			
11/14-11/20	3.1	10.6	6.8	4.3	10.7	7.5			
11/21-11/27	2.5	7.9	5.2	3.4	8.1	5.8			
11/28-12/04	1.0	8.3	4.6	1.5	7.3	4.4			
12/05-12/09	-0.3	5.4	2.6	0.3	2.7	1.5			
Mean	4.3	12.6	8.4	5.4	11.9	8.6			
SPE									
10/03-10/09	11.0	25.5	18.2	12.5	20.9	16.7	9.6	28.6	19.1
10/10-10/16	6.1	17.5	11.8	8.8	15.0	11.9	4.5	18.3	11.4
10/17-10/23	5.1	14.6	9.8	7.4	12.3	9.8	4.0	15.0	9.4
10/24-10/30	5.2	13.9	9.5	7.5	11.4	9.5	4.1	14.6	9.4
10/31-11/06	5.4	14.0	10.0	7.6	11.0	9.3	4.8	14.4	10.0
11/07-11/13	6.1	13.1	10.0	7.6	10.6	9.1	4.9	13.6	9.3
11/14-11/20	3.9	14.1	9.1	6.1	9.5	7.8	2.8	13.7	8.3
11/21-11/27	2.8	8.7	5.7	4.8	7.1	5.9	2.1	8.4	5.2
11/28-12/04	1.3	9.8	5.6	3.2	6.6	4.9	0.0	9.4	4.7
12/05-12/09	0.2	8.1	4.2	2.1	3.8	3.0	-1.1	6.8	2.8
Mean	4.8	14.1	9.5	6.9	11.1	9.0	3.7	14.5	11.7
HPPE									
10/03-10/09	11.4	27.5	19.5	12.3	25.7	19.1	12.7	25.3	19.1
10/10-10/16	6.6	19.0	12.8	8.3	19.5	13.9	8.6	19.3	13.9
10/17-10/23	5.4	17.0	11.2	7.1	16.8	12.0	7.5	16.5	12.1
10/24-10/30	5.3	15.6	10.5	7.0	15.0	10.9	7.5	14.3	10.9
10/31-11/06	5.6	15.2	10.4	7.1	14.2	10.7	7.5	13.7	10.6
11/07-11/13	6.1	14.0	10.0	7.2	13.3	10.3	7.5	12.8	10.1
11/14-11/20	3.6	15.8	9.7	5.3	13.7	9.5	5.6	12.9	9.3
11/21-11/27	2.9	9.8	6.4	4.4	9.4	6.9	4.7	9.1	6.9
11/28-12/04	0.8	12.9	6.9	2.1	10.3	6.1	2.7	9.3	6.0
12/05-12/09	0.2	9.9	5.1	1.2	6.7	4.2	2.1	6.2	4.2
Mean	4.9	15.8	10.4	6.4	14.6	10.5	6.8	14.2	10.5

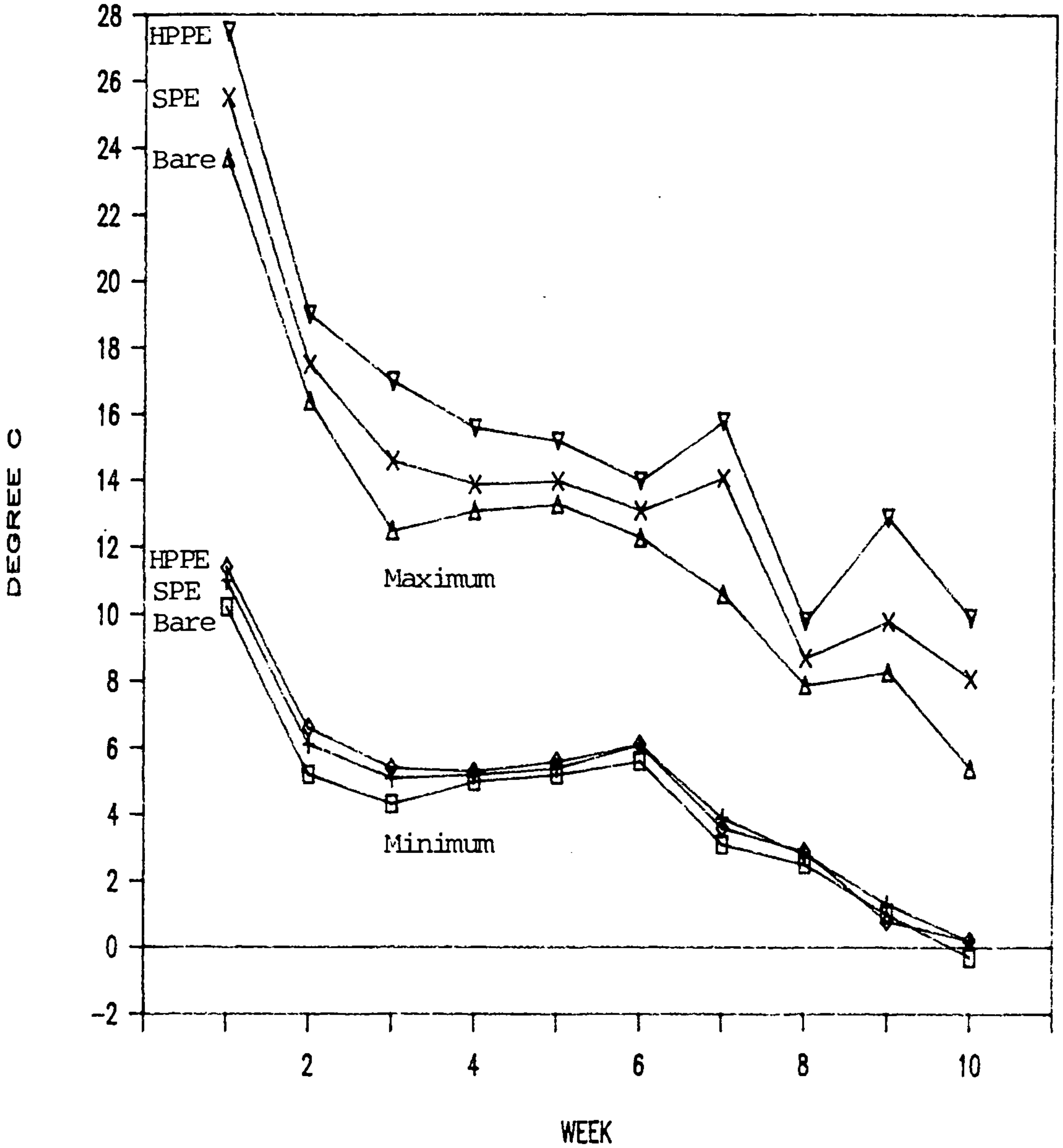

Figure 14. Effect of FRC on minimum and maximum air temperature in weekly increments, lettuce experiment two.

Table 25. Effect of FRC, covering date and covering interval on lettuce yield, experiment two.

Tmt	Covering Period (Weeks)	Fresh Weight (g/plant)	Length (cm)	Frost Damage[v]
Bare		30.25	9.88	8.75
SPE		55.40	14.67	5.40
HPPE		49.50	14.50	4.95
Sig.[z]		**	**	**
LSD1%		8.15	1.41	1.49
LSD5%		6.09	1.05	1.11
CD1[x]		48.70	13.61	5.80
CD2		41.40	12.42	6.93
Sig.		**	**	*
CI1[y]	4	40.63	12.51	6.77
CI2	10	49.47	13.52	5.97
Sig.		**	*	NS
C*CD[w]		NS	NS	NS
C*CI		NS	NS	NS
CI*CD		NS	NS	NS
C*CD*CI		*	NS	**
SPE11	4	48.40	14.00	5.60
SPE12	10	71.80	16.90	3.80
SPE21	4	48.40	13.40	6.80
SPE22	10	53.00	14.38	5.40
Sig.		*	NS	*
HPPE11	4	46.00	14.08	4.80
HPPE12	10	64.00	16.42	3.40
HPPE21	4	40.60	13.68	6.00
HPPE22	10	47.40	13.80	5.60
Sig.		**	NS	**
LSD1%		16.29		2.98
LSD5%		12.18		2.22

[v]0-10 scale 1=non-damaged plants 10= severely damaged plants.
[w]C: Covers.
[x]CD: Covering date.
[y]CI: Covering interval.
[z]**, *, NS: Significance at 1% and 5% levels and no significance, respectively.

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APPENDIX

Appendix 1. Effect of FRC and covering interval on mean fruit weight (g) of large tomato fruit for 4 harvests, experiment one.

Treatment	Harvest Of 08/27	09/06	09/12	Total[w]
Bare	302	294	268	291
BPM	294	286	289	285
SPE	286	296	293	290
HPPE	295	283	310	287
Sig.[z]	NS	NS	**	NS
LSD1%			21	
LSD5%			16	
CI1[x]	294	298	286	290
CI2	302	281	299	289
CI3	293	286	296	286
CI4	288	294	279	288
Sig.	NS	NS	NS	NS
C*CI[y]	NS	*	NS	NS
SPE1	284	310	280	291
SPE2	277	304	313	292
SPE3	284	273	283	283
SPE4	297	298	297	293
Sig.	NS	*	NS	NS
LSD5%		19		
HPPE1	293	286	318	286
HPPE2	321	282	296	301
HPPE3	284	277	313	280
HPPE4	283	288	311	283
Sig.	NS	*	NS	NS
LSD5%		19		

[w]Only ripe fruits are included in the first three harvests.
Green and ripe fruits are included in the total yield.
The fourth harvest is not shown but is included in total yield.
[x]CI: covering interval.
[y]C: Covers.
[z]**, *, NS: Significance at 1% and 5% levels and no significance, respectively.

Appendix 2. Effect of FRC and covering interval on mean fruit weight (g) of medium tomato fruit for 4 harvests, experiment one.

Treatment	Harvest of 08/27	09/06	09/12	Total[w]
Bare	176	185	186	176
BPM	172	184	177	176
SPE	174	182	180	176
HPPE	176	183	177	175
Sig.[z]	NS	NS	NS	NS
CI1[x]	178	188	180	179
CI2	173	183	179	176
CI3	175	180	177	174
CI4	174	182	185	173
Sig.	NS	NS	NS	*
LSD5%				4
C*CI[y]	NS	NS	NS	NS
SPE1	174	184	179	177
SPE2	181	184	178	175
SPE3	179	180	183	176
SPE4	177	180	180	176
Sig.	NS	NS	NS	NS
HPPE1	174	189	181	177
HPPE2	181	186	182	178
HPPE3	159	177	163	172
HPPE4	172	179	185	171
Sig.	NS	NS	NS	NS

[w]Only ripe fruits are included in the first three harvests. Green and ripe fruits are included in the total yield. The fourth harvest is not shown but is included in total yield.
[x]CI: Covering interval.
[y]C: Covers.
[z]*, NS: Significance at 5% level and no significance, respectively.

Appendix 3. Effect of FRC and covering interval on mean fruit weight (g) of small tomato fruit for 4 harvests, experiment one.

Treatment	Harvest of 08/27	09/06	09/12	Total[w]
Bare	110	112	110	107
BPM	111	113	111	106
SPE	105	110	111	104
HPPE	105	110	111	104
Sig.[z]	NS	NS	NS	NS
CI1[x]	108	112	111	105
CI2	110	111	111	106
CI3	107	112	113	105
CI4	106	110	109	105
Sig.	NS	NS	NS	NS
C*CI[y]	NS	NS	NS	NS
SPE1	105	114	114	107
SPE2	100	114	109	103
SPE3	105	106	112	104
SPE4	112	106	111	103
Sig.	NS	NS	NS	NS
HPPE1	111	114	115	103
HPPE2	109	108	109	107
HPPE3	105	112	111	106
HPPE4	95	106	107	102
Sig.	NS	NS	NS	NS

[w]Only ripe fruits are included in the first three harvests.
Green and ripe fruits are included in the total yield.
The fourth harvest is not shown but is included in total yield.
[x]CI: Covering interval.
[y]C: Covers.
[z]NS: No significance at 1% and 5% levels.

Appendix 4. Effect of FRC and covering interval on mean fruit weight (g) of large tomato fruit for 4 harvests, experiment two.

Treatment	Harvest of 08/27	09/06	09/12	Total[w]
Bare	291	286	285	288
BPM	326	308	294	299
SPE	328	299	290	300
HPPE	312	313	284	306
Sig.[z]	**	**	NS	**
LSD1%	28	21		14
LSD5%	21	16		10
CI1[x]	329	309	292	300
CI2	305	302	284	295
CI3	309	297	298	303
CI4	315	299	279	296
Sig.	NS	NS	NS	NS
C*CI[y]	NS	NS	NS	NS
SPE1	366	309	302	304
SPE2	323	303	273	300
SPE3	296	289	290	301
SPE4	326	295	295	297
Sig.	NS	NS	NS	NS
HPPE1	335	329	301	307
HPPE2	284	312	276	293
HPPE3	320	304	297	314
HPPE4	311	307	261	310
Sig.	NS	NS	**	NS
LSD1%			33	
LSD5%			24	

[w]Only ripe fruits are included in the first three harvests. Green and ripe fruits are included in the total yield. The fourth harvest is not shown but is included in total yield.
[x]CI: Covering interval.
[y]C: Covers.
[z]**, *, NS: Significance at 1% and 5% levels and no significance, respectively.

Appendix 5. Effect of FRC and covering interval on mean fruit weight (g) of medium tomato fruit for 4 harvests, experiment two.

Treatment	Harvest of 08/27	09/06	09/12	Total[w]
Bare	193	196	187	185
BPM	182	191	183	186
SPE	181	196	180	187
HPPE	176	196	188	184
Sig.[z]	NS	NS	NS	NS
CI1[x]	185	199	193	188
CI2	185	199	179	188
CI3	183	189	184	182
CI4	180	193	182	184
Sig.	NS	NS	NS	*
LSD5%				4
C*CI[y]	NS	NS	NS	NS
SPE1	182	193	189	187
SPE2	177	205	167	192
SPE3	179	191	180	183
SPE4	188	197	185	186
Sig.	NS	NS	NS	NS
HPPE1	173	201	192	184
HPPE2	181	204	185	186
HPPE3	185	189	189	183
HPPE4	166	188	183	181
Sig.	NS	NS	NS	NS

[w]Only ripe fruits are included in the first three harvests. Green and ripe fruits are included in the total yield. The fourth harvest is not shown but is included in total yield.
[x]CI: Covering interval.
[y]C: Covers.
[z]*, NS: Significance at 5% level and no significance, respectively.

Appendix 6. Effect of FRC and covering interval on mean fruit weight (g) of small tomato fruit for 4 harvests, experiment two.

Treatment	Harvest of 08/27	09/06	09/12	Total[w]
Bare	114	118	112	115
BPM	102	116	114	117
SPE	113	120	121	120
HPPE	106	116	118	114
Sig.[z]	**	NS	NS	NS
LSD1%	10			
LSD5%	8			
CI1[x]	113	118	115	114
CI2	108	118	117	122
CI3	105	116	117	115
CI4	110	117	114	114
Sig.	NS	NS	NS	*
LSD5%				6
C*CI[y]	NS	NS	NS	NS
SPE1	130	118	116	116
SPE2	105	120	114	122
SPE3	106	121	130	122
SPE4	112	120	125	119
Sig.	NS	NS	NS	NS
HPPE1	106	116	111	117
HPPE2	106	120	131	119
HPPE3	107	117	118	108
HPPE4	105	112	111	109
Sig.	NS	NS	NS	NS

[w]Only ripe fruits are included in the first three harvests.
Green and ripe fruits are included in the total yield.
The fourth harvest is not shown but is included in total yield.
[x]CI: Covering interval.
[y]C: Covers.
[z]**, *, NS: Significance at 1% and 5% levels and no significance, respectively.