5-1968

The Influence of Petroleum Mulch on the Germination and Yield of Tomatoes

Clarence Frank Williams
Utah State University

THE INFLUENCE OF PETROLEUM MULCH ON THE GERMINATION AND YIELD OF TOMATOES

by

Clarence Frank Williams

A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Horticulture

UTAH STATE UNIVERSITY
Logan, Utah

1968

ACKNOWLEDGMENTS

I would like to acknowledge and express my sincere appreciation to the following persons:

Dr. Alvin R. Hamson, chairman of my graduate committee, for his direction, suggestions and personal consideration which made the completion of this study possible.

Dr. J. LaMar Anderson of the Plant Science Department and Dr. Paul D. Christensen of the Soils Department for their suggestions and guidance as committee members.

Dr. R. L. Ferm and Chevron Research Corporation for supplying materials for this project.

Dr. Leonard H. Pollard for his help in getting financial assistance for carrying out my graduate program.

Dr. Alice Denny for her time and extreme effort in helping to prepare this manuscript for approval.

Mr. Linnis Mills for his encouragement, suggestions and help in this study.

My parents for their encouragement and support during this study.

Karilyn, my wife, for her patience, encouragement, and unending faith, and for the many hours spent in typing of the thesis.

Clarence Frank Williams

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

The Influence of Petroleum Mulch on the

Germination and Yield of Tomatoes

by

Clarence Frank Williams, Master of Science

Utah State University, 1968

Major Professor: Alvin R. Hamson
Department: Plant Science

The effects of petroleum mulches on the emergence and yield of tomatoes were studied at the Farmington Field Station, Greenville Field Station, North Logan, and the greenhouse. The mulches were applied as surface overlays above the seed or incorporating before planting.

Seedling emergence and yields were measured. Data recorded from trials conducted under cool weather conditions indicated that petroleum mulch overlays can be effective in increasing seedling emergence.

The increased seedling emergence with petroleum mulch is due to increased soil temperature, less moisture loss from the surface, and a minimum of soil crust formation.

(69 pages)

INTRODUCTION

Machine planting and harvesting of many vegetable crops is becoming more important each year. Many crops previously transplanted and hand harvested are now being direct seeded and mechanically harvested with a minimum of manual labor.

Once-over mechanical harvesting makes uniformity of maturity a principal requirement and uniform germination of the utmost importance. When direct seeding small-seeded vegetable crops in the early spring, uniform stands are not generally obtained. Seed viability is seldom the cause of the uneven stands in the crop.

Unsuccessful emergence of small-seeded vegetable crops is due in part to planting in soil that is too cold during the early spring, to a lack of moisture, to crusting of soil prior to seed germination, and to salt damage caused by a high accumulation of fertilizer around the seed.

Growers in the early spring encountering the problems of cold soil, unavailable water, and crust formation on the soil surface must direct seed some vegetable crops as early as possible to produce and harvest their crop in order to avoid the danger of an early freeze damaging unharvested crops later in the season. An early fall frost may damage 40 percent or higher of a tomato crop in a single year.

Many types of mulches have been used to control environmental conditions in such a manner as to favor the growth of the crop. Mulches have been used successfully for increasing yield and earliness in tomatoes. They are also applied to the soil to conserve moisture when the plant reaches 2 to 3 inches in height. In recent years petroleum mulches and petroleum resins of a consistency suitable for spray application have been used quite successfully.

Petroleum mulches have been shown to hasten seed germination by increasing soil temperatures from 5C to 10C. The petroleum mulches also tend to retain soil moisture near the surface where it is available to germinating seedlings. In view of this, it seemed quite important that work be carried out on petroleum mulches under the climatic conditions of Utah to evaluate its use as a possible aid for some of the growers of the state.

Objectives

This investigation was set up to study the following:

1. The effect of petroleum mulches on seedling emergence.

2. The effect of petroleum mulches on total yield.

3. Possible deleterious effects of petroleum mulches on germination and growth of seedlings.

4. The effect of petroleum mulches on soil temperature increase.

REVIEW OF LITERATURE

Petroleum Mulches

Petroleum products such as asphalts, green cokes, and fluid cokes have been effective in attempts to alter the microclimate of the soil to produce uniform stands of emerging seedlings.

Petroleum mulch, as defined by Takatori, Lippert, and Whiting (1964), is an emulsion of petroleum resin that is of a consistency suitable for spray application. The emulsion, upon drying, forms a black coating over the soil surface which is in direct contact with the soil particles. The film is of such a texture that seeding penetration is in no way affected, and it appears to be non-toxic to seedlings. The petroleum mulch contains 50 to 60 percent solids by weight. The mulch is applied in a thin continuous layer to the soil surface directly over the seed. Takatori, Lippert, and Whiting (1964) indicated that the minimum width for effectively raising soil temperature and conserving soil moisture is 6 inches.

Chepil (1955, 1956) found in studies conducted on different types of soil that 2 weeks after application to clay soil the asphalt was completely broken down. This was caused by expansion and contraction of soil particles during wetting and drying. When sprayed over dune sand or loamy sand the asphalt layer remained in tact for a period of 2 months. When the asphalt was mixed with the soil, there was a high degree of soil aggregation, and erosion due to wind decreased for approximately 2 years. To retain soil moisture in the root zone on sandy soil, a continuous layer of asphalt approximately 1/8 inch thick was positioned 2 feet below the soil surface (Chem. and Eng. News, 1966).

Moldenhauer, et al. (1964) applied straw and asphalt mulch to exposed sub-soil and concluded that the asphalt compared favorably to the straw in controlling erosion. Asphalt also had advantage over the straw in that the black color warmed the soil and seedling emergence occurred earlier to give added control of erosion.

Bement, et al. (1961) worked with asphalt emulsions to hasten the establishment of grass seedlings. Seedlings penetrated the asphalt film 6 days after seed planting and developed seed heads in 60 days. Seedlings in check plots emerged about 2 weeks later than those in treated plots and were spindly and few in number.

Thomas (1961) showed that a thin layer of asphalt over the row caused crop seeds planted in cool weather to germinate faster, enhanced early germination and developed a better stand. The main beneficial effect of the asphalt mulch was the warming caused by the black color which absorbs radiant heat. The moisture barrier formed was also important in conserving moisture.

Takatori, Lippert and Whiting (1963, 1964) conducted extensive tests on the effects of petroleum mulches and plastic films on soil temperatures. Maximum temperatures at the soil surface were 10C higher under 6 inch wide bands of petroleum mulch than under the control. At a depth of 1.5 inches under the 6 inch band, the maximum soil temperature was increased by 7C over the control. The average surface soil temperature between 11 a.m. and 3 p.m. for the 6 inch band was 7 degrees higher than the control. The soil temperature was 4 degrees higher than the control at a depth of 1.5 inches. The soil temperature under the petroleum mulch was also higher than that under plastic films. This was believed due to the direct contact of the petroleum mulch with the soil surface. Studies by Alpert and Louis (1963) showed an increase in soil temperature of 3C attributed to increased absorptivity of the sun's rays. Retention of soil moisture or reduced evaporative cooling contributed another 7C increase for a total increase of 10C due to petroleum mulch.

Adequate soil moisture is very important in obtaining an even stand. Soil moisture retention under 6 inch bands of petroleum mulch strips maintained soil moisture levels sufficiently high to support 8 days of plant growth. The control had only sufficient moisture for a little over 3 days of growth (Alpert and Louis, 1963).

Lippert, Takatori and Whiting (1963)and Takatori, Lippert and Whiting (1964) found that under conditions of slower evaporation, a petroleum mulch significantly conserved soil moisture under a 6 inch wide band as compared to the control. The percentage of soil moisture was higher under the petroleum mulch 4 days after planting dry land seed cotton than under the control (Hatchett and Bloodworth, 1963). Work conducted by Wilson and Hedden (1965) in Ohio with liquid mulches showed that the top 3 inches of soil under asphalt mulch had 1.5 percent more moisture than the control.

Conserving soil moisture in the surface of the soil for use by the plant is very important, but the prevention of soil crust, which the emerging seedling is often unable to penetrate, is equally important. According to Army and Hudspath (1960) crusting was due to rapid evaporation of large amounts of water from the soil surface. The thin film of asphalt slows down the rate of evaporation with less formation of damaging crust.

Soil moisture is very important in obtaining a good stand. After seeding, the field should never be allowed to dry during seed germination and early seedling growth. "Stop and start" growth situations must be avoided. Doneen and MacGillivray (1943) found that tomato seeds germinated best when soil moisture was maintained at 12 percent.

New materials being used as soil conditioners are green coke and fluid coke. These materials are the remaining black solid material, primarily carbon, produced when crude oil undergoes the petroleum-refining process at high temperatures.

Work on petroleum coke is very recent, and little data about it has as yet been obtained. It is thought that it may have the same effect on soil moisture and temperature as the petroleum asphalt mulch (Lippert, 1966). In Arizona, studies conducted with cotton planted in dry soil, watered up and coke treated gave a better stand than did the asphalt (Cannon, 1966). Green coke was more effective when the material was pressed into the soil surface after application, however (Takatori, 1966).

Seed Germination

In the direct seeding of tomatoes, depth of seed placement is very important if a uniform stand is to be obtained. If seeds are planted too deep, uneven emergence will result. If seeds are planted too shallow, excessive drying will occur. Sims, et al. (1968) suggest that seeds should be planted at a depth of 3/4 to 1 inch and a rate of 1/2 to 3/4 pounds per acre. This distributes 12 to 20 seeds per foot with single-row planting.

Soil temperature at time of planting is also critical in seed germination. Katowski (1926) found that tomatoes have highest germination at 18C (64.4F). Wilcox and Martain (1963) reported that an increase of 1C can more than double tomato top growth. Two weeks after planting, foliar growth of plants grown on soil with a temperature of 17C was twice that of plants grown on soil at a temperature of 13C when compared on a dry weight basis. Root growth was also much slower at the cooler temperature. Sims, et al. (1968) state that the critical temperature for tomato seed germination was 13.9C 2 inches under the surface of the soil. At 10C it takes 43 days and at 20C, 8 days. The degree from 13C to 14C can mean 6 days earlier germination.

The length of time for germination is not only critical for even emergence, but has a tremendous effect of time of harvest in the fall when early harvest is of the utmost importance.

With direct seeding of tomatoes the placement of starter fertilizer below the seed can injure the young seedling. This occurs (Nelson, 1958) when large amounts of fertilizer salts are dissolved in the soil solution around the germinating seed or emerging seedling. The cells are plasmolyzed due to the osmotic effect of the high salt concentration, and the young seedling cannot get sufficient water for sustained growth. In fact, if soil moisture becomes too low there may be a loss of water from the seed or seedling to the soil. If the seed or seedling is not destroyed, it is retarded to such an extent that growth is reduced, resulting in an uneven stand.

MATERIALS AND METHODS

1967 Experiments at Farmington Field Station

The trial at Farmington included tomatoes direct-seeded on May 15. The treatments were applied immediately following planting. The treatments applied in 6 inch bands were as follows:

1. Soft Asphalt
2. Hard Asphalt
3. CR 67 R 5892 (Hard Asphalt)
4. CR 67 R 5976 (Hard Asphalt)
5. CR 67 R 5894 (Green Coke)
6. CR 67 R 5890 (Green Coke)
7. CR 67 R 5975 (Fluid Coke)
8. CR 67 R 6119 (Aqua humus)
9. CR 67 R 5889 (Green Coke)
10. CR 67 R 6109 (Fluid Coke)
11. CR 67 R 6110 (Fluid Coke)
12. Control

(For the physical properties of these compounds see Table 1.)

The petroleum asphalt mulches were applied at the rate of 100 gallons per acre and were spread with a 3 gallon pressurized knapsack sprayer. The petroleum coke mulches were applied with a small hand spreader at the rate of 700 to 900 pounds per acre.

Table 1. Physical properties of experimental material used

Material[a]		Physical properties
Soft asphalt,	CR 62R-755	Softening point of asphalt by Ring and Ball method = 24C
		Viscosity at 99C = 370 csks
		Percent solids = 60% by wt
		Asphalt above 300 in penetration test at 25C
Hard asphalt,	CR 61R-739	Penetration of asphalt component = 120/150 at 25C
		Percent solids = 60% by wt
Hard asphalt,	CR 67R-5892 and CR 67R-5976	Softening point of asphalt by Ring and Ball method = 88C
		Percent solids = 55% by wt
Green coke	CR 67R-5894	
Aqua Humus		
Green coke	CR 67R-5890	All solids passing 40-mesh screen
Fluid coke	CR 67R-5975	
Green coke	CR 67R-5889	
Fluid coke	CR 67R-6109	
Fluid coke	CR 67R-6110	

[a]All materials furnished by Chevrol Research Corporation.

The plot area was divided into four block, with the treatments being randomized in each block. Each plot consisted of a row 3 feet wide and 25 feet long; 100 seeds were planted per row.

Ammonium nitrate fertilizer was applied as a 150 pound per acre field application before planting and as a 50 pound band application 1 to 2 inches directly below the seed during planting.

The tomatoes were allowed to develop to market maturity before harvesting. The picking dates were September 26 and October 4. A third picking date was impossible due to killing of the plants by frost. The fruit picked from each treatment was weighed and counted.

1967 Experiments at Greenville Field Station

Trials conducted at the Greenville Field Station on direct seeded tomatoes planted June 29, consisted of the same treatments as those at Farmington. This trial also included a combination of perlite and vermiculite with the seed below the individual mulch application. The treatments were replicated four times. Each plot was 3 feet wide and 10 feet long. The seed was planted with a Planet Jr. planter at a depth of 3/4 to 1 inch. Germination counts were taken on three different dates.

Another trial similar to the one in Farmington was conducted except that water was applied as needed rather than at the regular 7 to 10 day interval, and the row length was 10 feet.

Seeds were planted with the Planet Jr., and germination counts were taken on three dates.

An identical trial to the preceding one was conducted with hard and soft asphalt applied as an overlay to the fluid cokes and the green cokes. Each coke appeared in combination with hard or soft asphalt in two replications.

1967 Experiments at North Logan

Trials conducted at the Alvin Hamson garden in North Logan on direct seeded tomatoes planted August 11 included the same treatments as those at the Framington Station with the addition of two white resin materials. The experiment consisted of both incorporation and pre-emergent application of materials.

Incorporation of mulch materials was accomplished by placing them on the soil surface before planting and then using a rototiller with L-shaped teeth to mix them with the soil to a depth of 1 to 1-1/2 inches. The treatments were replicated four times with each treatment randomized within each replication.

Watering was accomplished by overhead sprinklers at time intervals necessary to keep the soil moist.

Soil temperatures were taken over a 24-hour period in the unincorporated treatments by means of thermocouples attached to a switch box and potentiometer. Air temperatures were also recorded.

Germination counts were taken August 22 and 27.

1968 Experiments in the Greenhouse

Germination: Germination tests on direct-seeded tomatoes were conducted in a growth chamber under controlled conditions. The materials applied in 6 inch bands were as follows:

1. Soft Asphalt
2. CR 67 R 5976 (Hard Asphalt)

3. CR 67 R 6119 (Aqua humus)
4. CR 67 R 5894 (Fluid Coke)
5. CR 67 R 5890 (Green Coke)
6. Control

(See Table 1 for physical properties.)

Oversized redwood flats, 6 inches by 18 inches by 36 inches, were used for control studies with the six treatments separated by 1/2 inch sheets of styrofoam insulation.

The growth chamber was programed for an 11 hour night at 11C and a 13 hour day at 15C. This gave an average temperature of 13C, which is the approximate average temperature for mid-April in Salt Lake County.

The florescent lights were turned on by a time clock at 6 a.m. and off at 7 p.m. approximating the day length for mid-April. To simulate the slow warming of the sun the incandescent lights were turned on at 9 a.m. and off at 6 p.m. Light intensity in the growth chamber was measured to be approximately 70 to 75 percent of that of average sunlight during mid-April in Salt Lake County, according to the U. S. Weather Bureau records.

Soil temperatures at 1/2 to 2 inch depths were recorded under each treatment over a 24 hour period with a multi-point recorder.

Each treatment was replicated four times with the treatments randomized within each block. The soil was brought to chamber temperature before the seeds were planted. Seeds were planted 50 to a treatment with germination counts taken every day after the emergence of the first seedling. The germination count was taken over a period of 13 days.

Moisture studies: Trials on soil moisture content were run in the same type oversized redwood boxes as the controlled chamber trials. The materials used in 6 inch bands included:

1. Soft Asphalt
2. CR 67 R 5894 (Fluid Coke)
3. Control

(See Table 1 for physical properties.)

The flats were sub-irrigated to field capacity after the application of mulch materials.

The experiment was run in duplicate with one experiment being shaded with a screening material to stop direct sunlight. Each set was replicated four times with treatments randomized within each replication.

Soil samples were taken with a small hand auger. The first sample was taken after all excess moisture had drained off. This was done in an attempt to determine a standard soil moisture content for each treatment. After the first sampling, random samples were taken every 5 days. To determine soil moisture, samples were weighed immediately and then dried in an oven at 105C for a period of 24 hours. They were again weighed following which soil moisture contents were calculated.

Nitrogen movement: Experiments were done to trace the movement of nitrogen in the soil under a layer of asphalt. Nitrogen fertilizer at the rate of 20 lbs. per acre of actual nitrogen was placed in a narrow band 2 inches below the surface of the soil with a 1/2 inch layer of soil between the fertilizer and the band of soft asphalt. Soil was then placed over the asphalt and 25 tomato seeds were planted.

The flats were sub-irrigated to keep the soil moist. Germination counts were taken for a period of 10 days after the emergence of the first tomato seedlings.

The trials were run in three phases, the first being replicated four times at a temperature of 15.5C and lower. The second was replicated four times at a temperature of 21C. The third was replicated four times at a temperature above 26C. While this contained no seed, soil samples were taken, the first sample at the time of asphalt application and the second, four days later. Soil samples were analyzed by the Kjeldahl procedure to determine nitrogen. The samples were taken from the top 0 to 1-1/2 inches and from 1-1/2 to 4 inches.

RESULTS

Farmington Field Station 1967

The results of the petroleum mulch on direct-seeded tomatoes are shown in Tables 2 through 5. The analysis of variance for yield is given in Table 2. The analysis indicated no significance between the different mulch treatments and the control for the interaction between the harvest date and mulch treatment. Table 3 indicates the average yields for both the early harvest and the late harvest. The high for the early picking was 11.5 lbs. from treatment CR 67 R 5894, a green coke. The low was 6.2 lbs. from treatment CR 67 R 5891, a fluid coke. The highest total yield was 41.6 lbs. from treatment CR 67 R 6109, a fluid coke, while the lowest total yield was 24.5 lbs. for treatment CR 67 R 5891, a fluid coke. The control had an early yield of 10.6 lbs. and a total yield of 37.0 lbs.

The results from the analysis of variance (Table 4) indicates no significant increase in the total number of fruits produced due to the various mulching treatments used over the control.

The analysis of variance for soluble solids (Table 5) indicates that no significant increase or decrease occurred due to the use of the various mulching materials.

Greenville Field Station, 1967

Results from the use of various petroleum mulches in combination with the soil conditioners perlite and vermiculite on the emergence of

Table 2. Analysis of variance for yield of tomatoes at Farmington with eleven petroleum mulch treatments and the control, 1967

Source of variation	Degrees of freedom	Mean square	F
Total	71		
Replications	2	92.792	
Treatments	10	72.429	2.125
Error (a)	22	34.081	
Harvest Date	1	10,420.874	143.540**
Error (b)	2	72.602	
Harvest Date X Asphalt Treatment	11	30.071	1.423
Error (c)	22	21.12	

**Significant at 1 percent level.

Table 3. Average weights of tomatoes, first and second harvest, for the eleven petroleum mulch treatments and the control at Farmington, 1967

	Average weight			Average weight	
Treatment	Sept. 26	Oct. 4	Treatment	Sept. 26	Oct. 4
Hard asphalt CR67R5892	9.6	38.7	Fluid Coke CR68R5891	6.2	24.5
Hard asphalt CR67R5976	10.0	30.8	Green Coke CR68R5889	8.8	28.5
Green Coke CR67R5894	11.5	38.5	Hard asphalt	10.0	31.9
Green Coke CR67R5895	10.3	33.3	Soft asphalt	10.7	37.0
Green Coke CR67R5890	7.5	25.6	Fluid Coke CR67R6109	9.3	41.6
Fluid Coke CR67R5975	7.0	32.7	Control	10.6	37.0

Table 4. Analysis of variance for the number of tomato fruit with petroleum mulches and the control

Source of variation	Degrees of freedom	Mean square	F
Total	35		
Replications	2	460.7512	.5272
Treatments	10	155.9810	.1753
Error	35	887.0712	

Table 5. Analysis of variance for percent solids in tomato fruit with petroleum mulch and the control

Source of variation	Degrees of freedom	Mean square	F
Total	23		
Dates	1	.0213	.1366
Asphalts	10	.1530	1.0450
Residual	11	.1463	

tomato seedlings is given in Table 6. The analysis of variance for seedling emergence indicates no significant difference between the various treatments and the control.

The two way interactions of mulch materials x soil conditioners, dates x soil conditioner, date x mulch materials, and the three way interaction of date x soil conditioner x mulch material indicate no significance.

The results on germination of tomato seedlings under various petroleum mulch treatments identical to those used at Farmington are given in Table 7. As indicated by the analysis of variance, no significant difference exists between the various mulch treatments or for the two-way interaction of the various mulch materials x counting date.

Table 6. Analysis of variance for emergence of tomato seedling with perlite and vermiculte with thirteen petroleum mulch treatments and the control at Greenville, 1967

Source of variation	Degrees of freedom	Mean square	F
Total	335		
Replications	3	3873.873	
Soil conditioners	2	1,894.461	2.389
Error (a)	6	792.78	
Treatments	13	150,753.8101	.5758
Treatments x Soil conditioners	26	219,648.8001	.8390
Error (b)	117	261,780.3001	
Dates	1	31,185.02	139.89**
Dates x soil conditioners	2	268.17	1.2031
Dates x treatments	13	170.66	.7656
Dates x soil conditioners x treatments	26	232.18	1.0416
Error (c)	126	222.91	

**Significant at 1 percent level.

Table 7. Analysis of variance for emergence of tomato seedlings with thirteen petroleum mulch treatments and the control at Greenville, 1967

Source of variation	Degrees of freedom	Mean square	F
Total	167		
Replications	3	1,206.1300	
Treatments	13	283.7606	.9962
Error (a)	39	284.8407	
Dates	2	11,452.72	53.61**
Treatment x Dates	26	169.1901	.7920
Error (b)	84	213.6201	

**Significant at 1 percent level.

Germination results from the use of hard and soft asphalt as overlays to control loss of the dry materials, green coke and fluid coke, during periods of wind is given in Table 8. The analysis of variance indicates no significance in the use of the overlays to stop the loss of the various dry mulch treatments, in the two-way interactions, mulch treatments x overlays, and counting date x overlay, or in the three-way interaction, counting date x treatment x overlay. The two-way interaction counting date x mulch treatment indicates significance at odds of 19 to 1. The Duncan's multiple range test for the two-way interaction, counting date x mulch treatment, is given in Table 9. The table indicates that the control had the greatest number of seeds germinated on the early count in addition to the greatest total number germinated on the final count.

North Logan, 1967

At North Logan incorporation and pre-emergence methods of application were used for the various mulching materials to observe any effect on tomato seedling emergence. The results on germinations are given in Tables 10 and 11. The analysis of variance (Table 10) indicates a significant difference between methods at odds of 99 to 1. Duncan's multiple range test (Table 11) gives the comparison between the incorporated, having the highest number germinated, and the pre-emergent application, having the poorest germination. There was no significance indicated for the various mulch treatments or the two-way interaction, method x mulch treatments.

Soil temperatures taken at 1 inch, 2 inch, and 3 inch depths over a 24 hour period varied little from each other and, therefore, are not given.

Table 8. Analysis of variance for emergence of tomato seedlings with soft and hard asphalt used as overlays with thirteen petroleum mulch and the control at Greenville, 1967

Source of variation	Degrees of freedom	Mean square	F
Total	167		
Relications	1	.09	
Overlays	1	2,561.521	2.371
Error (a)	1	1,080.220	
Treatments	13	411.770	1.454
Treatments x overlays	13	200.630	.7087
Error (b)	26	283.081	
Dates	2	11,533.152	119.70**
Dates x overlays	2	252.110	2.616
Dates x treatments	26	433.830	4.503*
Dates x overlays x treatments	26	247.891	2.572
Error (c)	56	96.350	

**Significant at 1 percent level.

*Significant at 5 percent level.

Table 9. Comparison of means for the number of seedlings emerging for petroleum mulch according to counting date at Greenville, 1967

Treatment	Date	Mean number emerging/plot
Control	8 July	59a
R5876	8 July	46a
Hard asphalt	8 July	44a
R5892	8 July	34a
R5889	8 July	30abc
Soft asphalt	8 July	25abc
5894	8 July	24 bc
6109	8 July	20 bc
5975	8 July	20 bc
5891	8 July	20 bc
6110	8 July	14 bc
Aqua humus	8 July	13 bc
5890	8 July	8 c
	Comparison on July 10	
Hard asphalt	10 July	107a
Control	10 July	96 b
5891	10 July	94 b
5976	10 July	71 bc
6110	10 July	59 c
5889	10 July	55 c
5975	10 July	55 c
6109	10 July	50 c
5892	10 July	41 c
5890	10 July	41 c
5894	10 July	40 c
Soft asphalt	10 July	40 c
Aqua humus	10 July	35 c
	Comparison July 17	
Control	17 July	118a
5891	17 July	108ab
5976	17 July	107ab
Hard asphalt	17 July	106ab
6109	17 July	104ab
6110	17 July	91ab
Soft asphalt	17 July	84abc
5889	17 July	83abc
5894	17 July	76 bc
5975	17 July	75 bc
5892	17 July	74 bc
5890	17 July	52 bc
Aqua humus	17 July	31 c

abc = Any two means with the same subscript are not significantly different at the 5 percent level, according to Duncan's multiple range test.

Table 10. Analysis of variance for emergence of tomato seedling with fifteen petroleum mulch treatments applied as a preemergent or incoperated application at North Logan, 1967

Source of variation	Degrees of freedom	Mean square	F
Total	63		
Replications	1	196.06	
Methods	1	6,400.000	106.561**
Error (a)	1	60.060	
Treatment	15	43.600	.492
Treatments x methods	15	88.530	1.000
Error (b)	30	88.52	

**Significant at 1 percent level.

Table 11. Comparison of means for method of petroleum mulch application at North Logan, 1967

Method	Mean
Incoperated	51.5a
Premergent	31.5 b

ab = Any two means with the same subscript are not significantly different at the 5 percent level, according to Duncan's multiple range test.

Greenhouse, 1968

Seedling emergence

The results for emergence of tomatoes in the growth chamber under the five mulch materials and the control are given in Tables 12 through 16. The analysis of variance for seedling emergence (Table 12) indicates significance at odds of 99 to 1. The two-way interaction, dates x mulch, was also significant at odds of 99 to 1.

Table 12. Analysis of variance for tomato seedling emergence in the growth chamber with five petroleum mulch treatments and the control

Source of variation	Degrees of freedom	Mean square	F
Total	233		
Replications	3	1,942.82	
Treatments	5	2,236.831	8.401**
Error (a)	15	266.252	
Dates	12	725.013	55.77**
Dates x treatments	60	48.07	3.69**
Error (b)	129	13.00	

**Significant at 1 percent level.

Table 13. Comparison of means for treatments on tomato seedling emergence in the growth chamber

Treatments	Mean
Soft asphalt	23.20 a
Hard asphalt R-5976	14.30 ab
Fluid coke R-6110	14.27 ab
Green coke R-5890	9.80 b
Control	8.30 bc
Aqua humus	.44 c

abc = Any two means with the same subscript are not significantly different at the 5 percent level, according to Duncan's multiple range test.

Table 14. Comparison of means for the interaction of petroleum mulch and a period of 13 counting dates on tomato seedling emergence in the growth chamber

Treatment	Counting date number	Mean
Soft asphalt	13	38.3 a
Soft asphalt	12	36.6 a
Soft asphalt	11	33.6 a
Soft asphalt	10	32.0 ab
Soft asphalt	9	30.6 abc
Soft asphalt	8	28.6 abcd
Soft asphalt	7	28.3 bcde
Fluid coke	13	26.0 bcde
Hard asphalt	13	26.0 bcde
Hard asphalt	12	24.3 bcdef
Fluid coke	12	24.3 bcdef
Soft asphalt	6	23.6 cdefg
Fluid coke	11	23.6 cdefg
Fluid coke	10	21.3 defgh
Hard asphalt	11	21.0 defgh
Fluid coke	9	20.0 efghi
Hard asphalt	10	19.3 efghi
Hard asphalt	9	18.0 fghi
Soft asphalt	5	17.6 fghi
Green coke	13	17.3 fghi
Fluid coke	8	16.3 ghij
Hard asphalt	8	16.0 ghij
Control	13	15.3 hijk
Hard Asphalt	7	15.3 hijk
Fluid coke	7	15.3 hijk
Hard asphalt	6	14.6 hijk
Green coke	12	14.6 hijk
Green coke	11	14.3 hijk
Fluid coke	6	14.3 hijk
Control	12	14.3 hijk
Soft asphalt	4	14.0 ijk
Control	11	14.0 ijk
Control	10	13.0 ijk
Green coke	10	13.0 ijkl
Green coke	9	13.0 ijkl
Control	9	12.6 ijkl
Hard asphalt	5	12.3 jkl
Soft asphalt	3	10.6 jkl
Control	8	10.3 jkl
Hard asphalt	4	10.3 jkl
Green coke	8	10.0 jklm
Green coke	7	9.3 klm
Fluid coke	5	9.3 klm
Control	7	9.0 klm
Green coke	6	8.3 klmn
Green coke	5	7.0 klmn

Table 14. Continued

Treatment	Counting date number	Mean	
Soft asphalt	2	6.3	klmn
Green coke	4	6.3	klmn
Control	6	6.3	klmn
Hard asphalt	3	6.0	klmn
Fluid coke	4	5.6	klmn
Green coke	3	5.6	klmn
Control	5	5.3	klmn
Green coke	2	5	klmn
Fluid coke	3	4.3	lmn
Soft asphalt	1	3.7	lmn
Fluid coke	2	3.6	lmn
Control	4	3.3	lmn
Control	3	2.3	mn
Green coke	1	2.3	mn
Hard asphalt	2	2.0	mn
Control	2	1.3	n
Fluid coke	1	1.3	n
Aqua humua	13	1.0	n
Control	1	.7	n
Aqua humus	13	.6	n
Aqua humus	12	.6	n
Aqua humus	11	.6	n
Aqua humus	10	.6	n
Aqua humus	9	.6	n
Aqua humus	8	.6	n
Aqua humus	7	.6	n
Hard asphalt	1	.5	n
Aqua humus	6	.3	n
Aqua humus	5	.3	n
Aqua humus	4	0	n
Aqua humus	3	0	n
Aqua humus	2	0	n
Aqua humus	1	0	

abcdefghijklmn = Any two means with the same subscript are not significantly different at the 5 percent level, according to Duncan's multiple range test.

Table 15. Comparison of means for each given counting date for the interaction of petroleum mulch and counting date in the growth chamber

Treatment	Mean	Treatment	Mean
First counting		Fifth counting	
Soft asphalt	3.7 a	Soft asphalt	17.6 a
Green coke	2.3 a	Hard asphalt	12.3 b
Fluid coke	1.3 a	Fluid coke	9.3 b
Control	.7 a	Green coke	7.0 b
Hard asphalt	.5 a	Control	5.3 bc
Aqua humus	0 a	Aqua humus	.3 c
Second counting		Sixth counting	
Soft asphalt	6.3 a	Soft asphalt	23.6 a
Green coke	5 a	Hard asphalt	14.6 b
Fluid coke	3.6 a	Fluid coke	14.3 b
Hard asphalt	2.0 a	Green coke	8.3 bc
Control	1.3 a	Control	6.3 bc
Aqua humus	0 a	Aqua humus	.3 c
Third counting		Seventh counting	
Soft asphalt	10.6 a	Soft asphalt	28.3 a
Hard asphalt	6.0 ab	Hard asphalt	15.3 b
Green coke	5.6 ab	Fluid coke	15.3 b
Fluid coke	4.3 ab	Green coke	9.3 b
Control	2.3 b	Control	9.3 b
Aqua humus	0 b	Aqua humus	.6 c
Fourth counting		Eighth counting	
Soft asphalt	14.0 a	Soft asphalt	28.6 a
Hard asphalt	10.3 ab	Fluid coke	16.3 b
Green coke	6.3 b	Hard asphalt	16.0 b
Fluid coke	5.6 b	Control	10.3 b
Control	3.3 b	Green coke	10.0 b
Aqua humus	0 c	Aqua humus	.6 c

Table 15. Continued

Treatment	Mean	Treatment	Mean
Ninth counting		Thirteenth counting	
Soft asphalt	30.6 a	Soft asphalt	38.3 a
Fluid coke	20.0 b	Fluid coke	26.0 b
Hard asphalt	18.0 b	Hard asphalt	26.0 b
Green coke	13.0 b	Green coke	17.3 c
Control	12.6 b	Control	15.3 c
Aqua humus	.6 c	Aqua humus	.6 d
Tenth counting			
Soft asphalt	32.0 a		
Fluid coke	21.3 b		
Hard asphalt	19.3 bc		
Control	13.0 c		
Green coke	13.0 c		
Aqua humus	.6 d		
Eleventh counting			
Soft asphalt	33.6 a		
Fluid coke	23.6 b		
Hard asphalt	21.0 bc		
Green coke	14.3 c		
Control	14.0 c		
Aqua humus	.6 c		
Twelfth counting			
Soft asphalt	36.6 a		
Fluid coke	24.3 b		
Hard asphalt	24.3 b		
Green coke	14.6 c		
Control	14.3 c		
Aqua humus	.6 d		

abcd = Any two means with the same subscript are not significantly different at the 5 percent significant level, according to Duncan's multiple range test.

Table 16. Total number of seeds germinating under each treatment, along with the percentage of total seeds germinating and average number per replication in the growth chamber

Treatment	Total seed count	Percent emergence	Average per replication
Green coke	78	39	19.5
Fluid coke	116	58	29.0
Hard asphalt	110	55	27.4
Soft asphalt	152	76	38.0
Control	76	38	18.9
Aqua humus	34	17	8.5

Duncan's multiple range test (Table 13) indicates soft asphalt to give significantly better emergence than the control. The various other materials were not significantly different from the control for seedling emergence.

One treatment, aqua humus, though not significantly lower than the control was significantly lower than all other treatments in the experiment.

Duncan's multiple range test for the two-way interaction, mulch trestment x counting date, indicates significance at odds of 19 to 1 for the soft asphalt treatment (Table 14). Table 15 presents a comparison of emergence for each treatment on a given date. The treatment, hard asphalt, was significant at odds of 19 to 1 over the control for the last two counting dates. CR 67 R 6110 (Fluid Coke) was significantly greater for the last four counting dates. Soft asphalt when compared with the control for each counting date was significantly greater at 19 to 1 odds for the last eleven days. No treatment was significantly greater than the control for the first 2 days of seedling emergence.

Table 16 indicates the total number of seedlings that emerged from the total 200 seeds planted. The soft asphalt has a total of 152 seedlings emerge of 76 percent of the seeds planted. The control had a total of 76 seedlings emerge or 38 percent of the seeds planted germinated. Aqua humus had a total of 17 percent of the seeds planted germinate.

The soft asphalt averaged 38.0 seeds germinating of the 50 seeds planted per replication. The control averaged 18.9 seeds germinating of the 50 seeds planted per replication.

Effects of hard and soft asphalt on soil temperatures

The soil temperature was measured over a 24 hour period on the second and twelfth day after planting at 1/2 and 2 inch depth with a multipoint recorder and copper constantan thermocouples. The temperature effects of the hard and soft asphalt are plotted in Figures 1 through 4.

The temperature of the soil at the 1/2 inch depth under the soft asphalt mulch, 2 days after planting, is shown in Figure 1. During the morning hours the temperature under the soft asphalt was slightly cooler than under the hard asphalt and equal to the control until the hour between 7 and 8 a.m. At approximately 10 a.m. the temperature under the soft asphalt began to increase faster than the control. The rapid rise in temperature continued until approximately noon, after which time the rise in temperature was gradual. The maximum temperature was reached at 4 p.m. At this time the soft asphalt and the hard asphalt were 4C warmer than the control. The maximum temperatures reached by the two treatments and the control are given in Table 17. The average soil

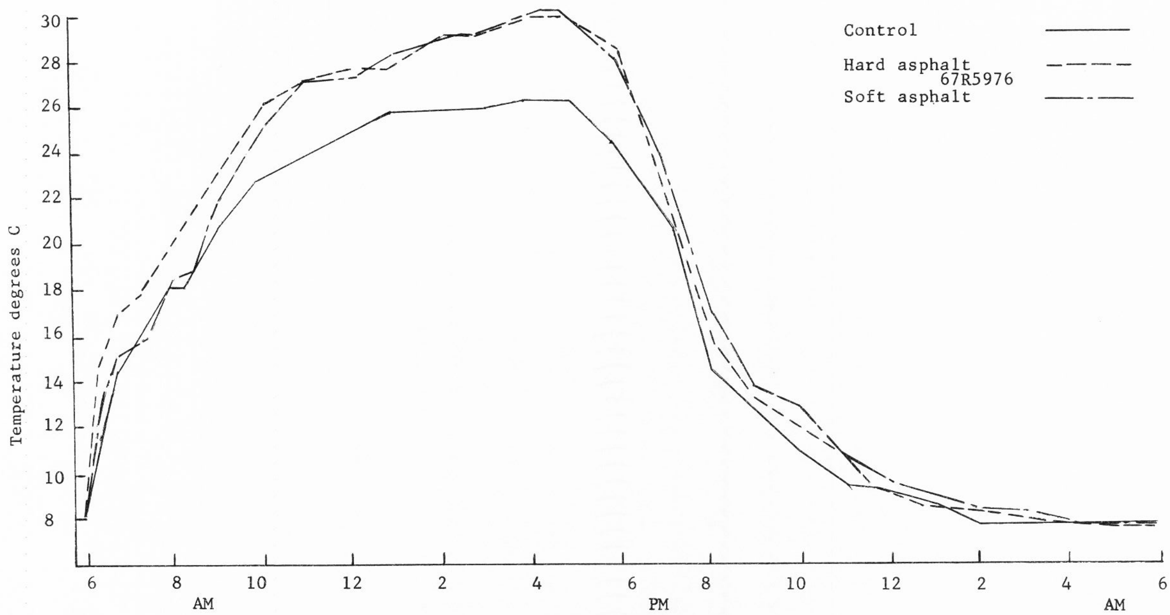

Figure 1. Soil temperature at 1/2 inch depth two days after planting.

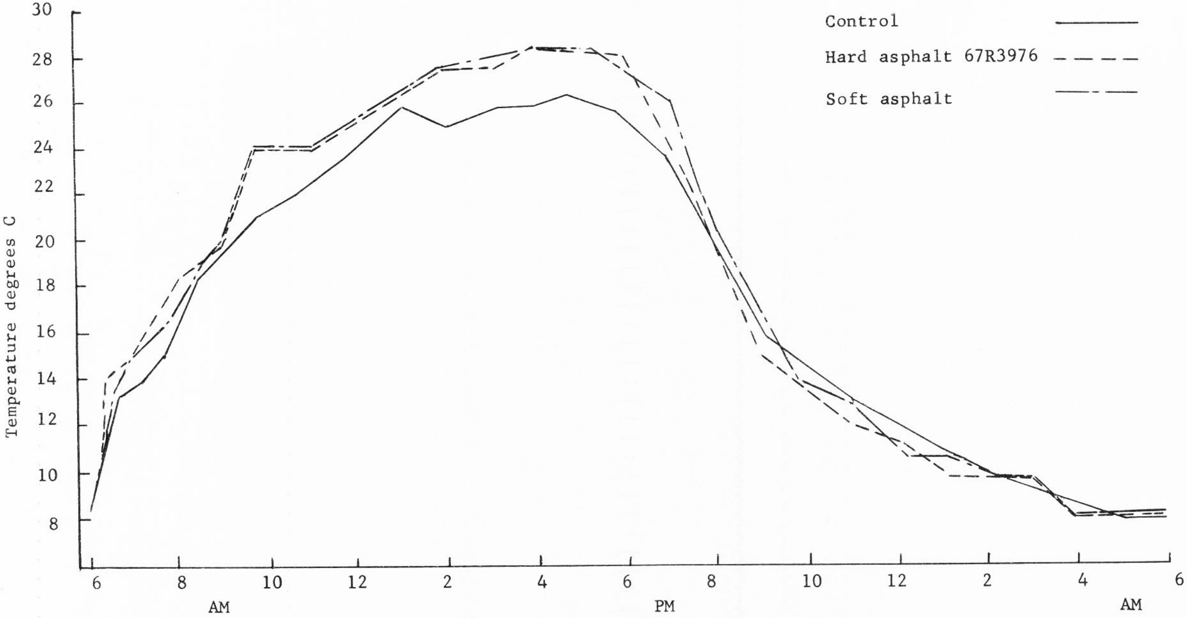

Figure 2. Soil temperature at 2 inch depth two days after planting.

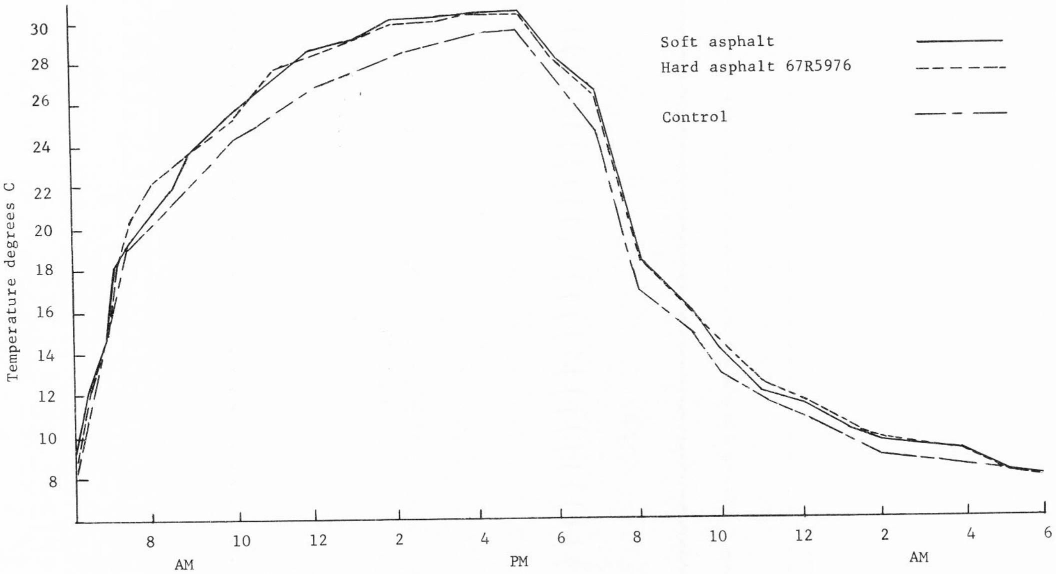

Figure 3. Soil temperature at 1/2 inch depth twelve days after planting.

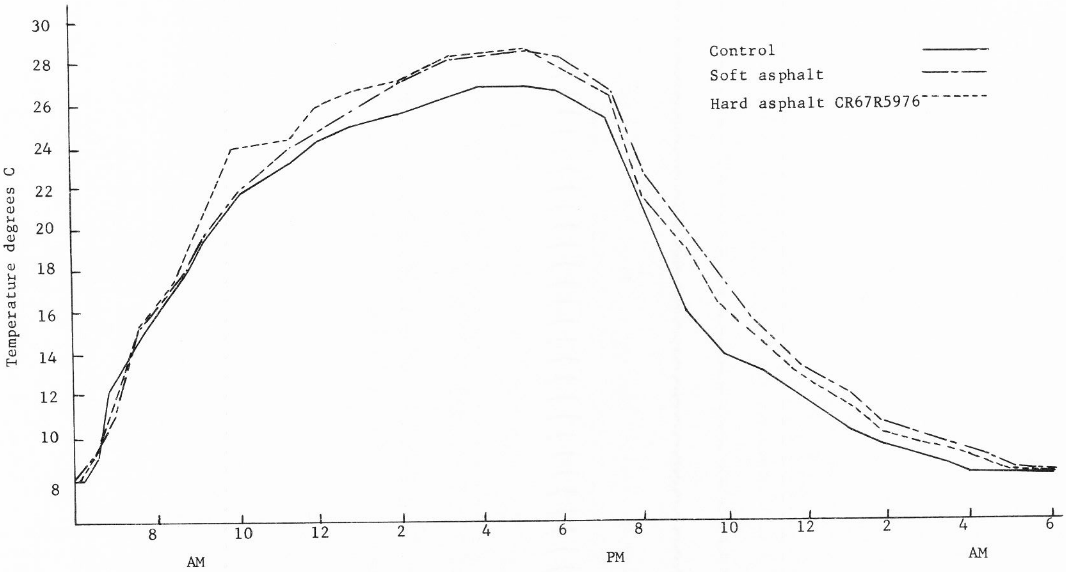

Figure 4. Soil temperatures at 2 inch depth twelve days after planting.

Table 17. Maximum and average temperatures taken over a 24 hours period two days after planting under petroleum mulch treatments and the control record in the growth chamber

	Maximum temperature °C		Average temperature per 24 hour period °C	
Treatment	1/2" depth	2" depth	1/2" depth	2" depth
Soft asphalt	30	28	18.0	17.5
Hard asphalt	30	28	18.2	17.5
Fluid coke	28	25	17.4	15.6
Green coke	28	25	17.5	16.3
Aqua humus	29	27.5	17.9	17.0
Control	26.5	26.5	16.6	16.8

temperatures over the 24 hour period are also given in Table 17. The soft asphalt had an average soil temperature over the 24 hour period 1.4C higher than the control. The hard asphalt had an average of 1.6C over the control. During the 24 hour period, soil temperatures under the soft asphalt fell below the control only during the period between 7 a.m. and 8 a.m. The soil temperature under the hard asphalt never fell below the control.

The temperatures under soft asphalt, in addition to those under the hard asphalt and the control, began to drop quite rapidly between 5 and 6 p.m. until 8 or 9 p.m. after which time the temperature continued to decline but at a much slower rate. The lowest temperatures were reached at 4 a.m. after which they remained quite constant until 6 a.m. when they again began a rapid increase. Figure 2 shows that soft asphalt and hard asphalt at the 2 inch depth had a similar effect on soil temperature to the 1/2 inch depth. The temperature raised rapidly in the morning at a rate approximately 2 hours behind the temperature to the 1/2 inch depth. At 2 p.m. the rise in temperature became much slower, reaching maximum at 4 p.m. The difference in soil temperature was 2C higher for both soft and hard asphalt over the control at the 2 inch depth. Table 17 indicates the maximum temperatures for this depth. The soil temperature at the 2 inch depth was similar to the 1/2 inch depth; it began to decline rapidly between 5 to 6 p.m. The decline was not as rapid in comparison to the 1/2 inch level. At 9 p.m. the decline was slower. This decline continued with no real leveling off period as did the temperature at the 1/2 inch depth. It was in the cooling off period that the temperature of the soft asphalt fell below the control and remained below, except for a short period between 2 and 4 a.m.

The hard asphalt followed the same trend as the soft asphalt and fell below the control except for the short period between 2 and 4 a.m.

The average temperature at the 2 inch depth for the soft asphalt, the hard asphalt, and the control over the 24 hour period is given in Table 17. The soft asphalt and hard asphalt had an average temperature of 0.6C over the control.

The temperatures taken 12 days after planting for the soft asphalt, the hard asphalt, and the control are given in Figures 3 and 4. The temperatures were similar to those taken 2 days after planting for both the 1/2 inch and 2 inch depths, respectively. There was the exception that the temperature under the control at the 1/2 inch depth taken at the later date was somewhat higher during the day, with the maximum temperature only 2C less than that for either the soft or hard asphalt. The maximum temperatures for the three treatments are given in Table 18.

Table 18. Maximum and average temperatures taken over a 24 hour period twelve days after planting, 1/2 and 2 inches under petroleum mulch treatments and the control recorded in the growth chamber

Treatment	Maximum temperature °C		Average temperature °C per 24 hour period	
	1/2" depth	2" depth	1/2" depth	2" depth
Soft asphalt	30.5	28.5	18.9	18.0
Hard asphalt	30.0	28.5	18.9	17.8
Fluid coke	28.0	26.5	17.4	16.8
Green coke	30.5	28.0	18.9	17.5
Aqua humus	28.5	27.0	17.7	16.7
Control	28.0	26.5	17.4	16.3

The average temperatures over this 24 hour period for the treatments soft asphalt, hard asphalt and the control are given in Table 18. Both soft and hard asphalt increased soil temperatures at the 1/2 inch depth by 1.5C over the control. At the 2 inch depth the soft asphalt increased soil temperature 1.7C over the control, while the hard asphalt increased the soil temperature 1.5C over the control.

Hard and soft asphalt and the control indicated a possible warming trend between temperatures taken 2 days after planting in addition to those taken 12 days post planting at the 1/2 inch depth. At the 2 inch depth only hard and soft asphalt showed a possible warming trend.

Effects of fluid coke and green coke on soil temperatures

The effects of fluid and green cokes on soil temperatures are plotted in Figures 5 through 8.

The soil temperatures under fluid and green cokes at the 1/2 inch level are given in Figure 5 for two days after planting. The temperature effects under these materials were similar to those for soft and hard

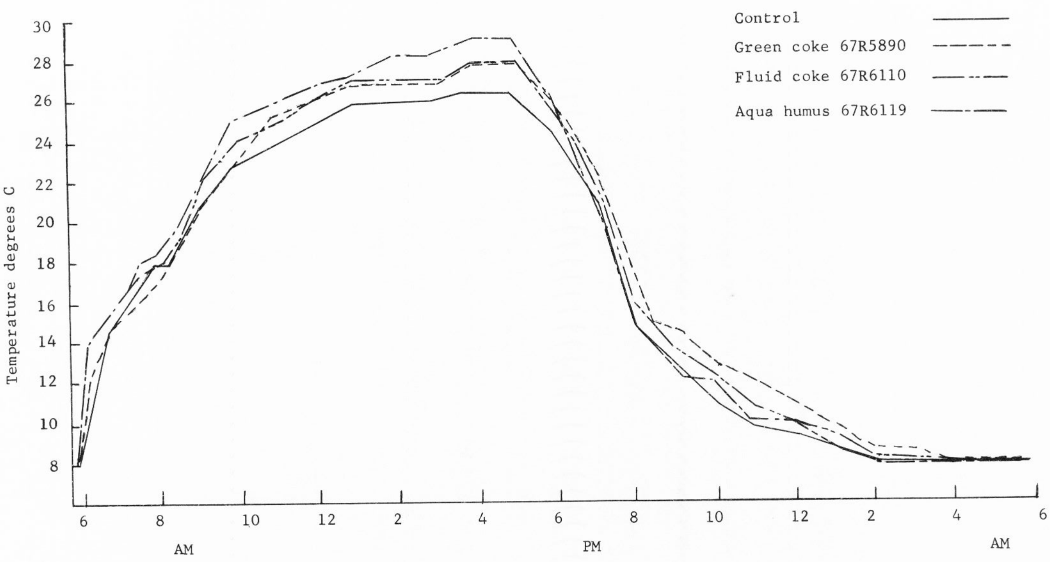

Figure 5. Soil temperature at 1/2 inch depth two days after planting.

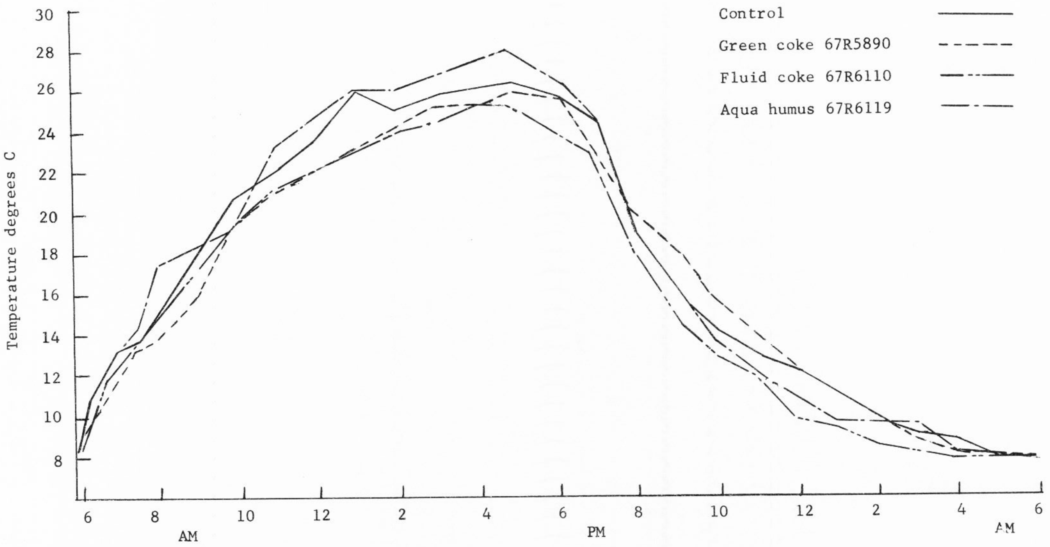

Figure 6. Soil temperature at 2 inch depth two days after planting.

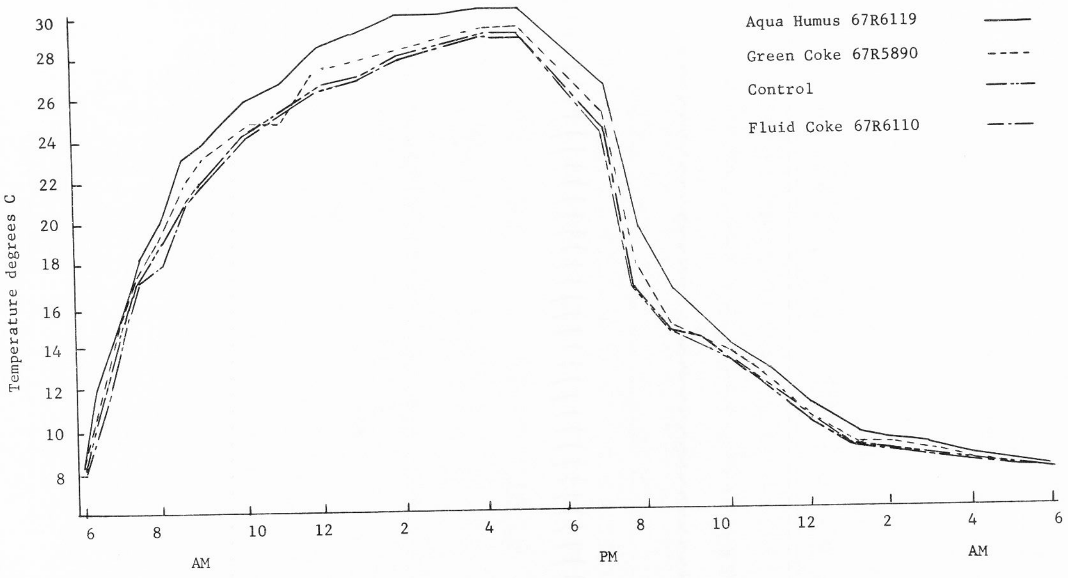

Figure 7. Soil temperature at 1/2 inch depth twelve days after planting.

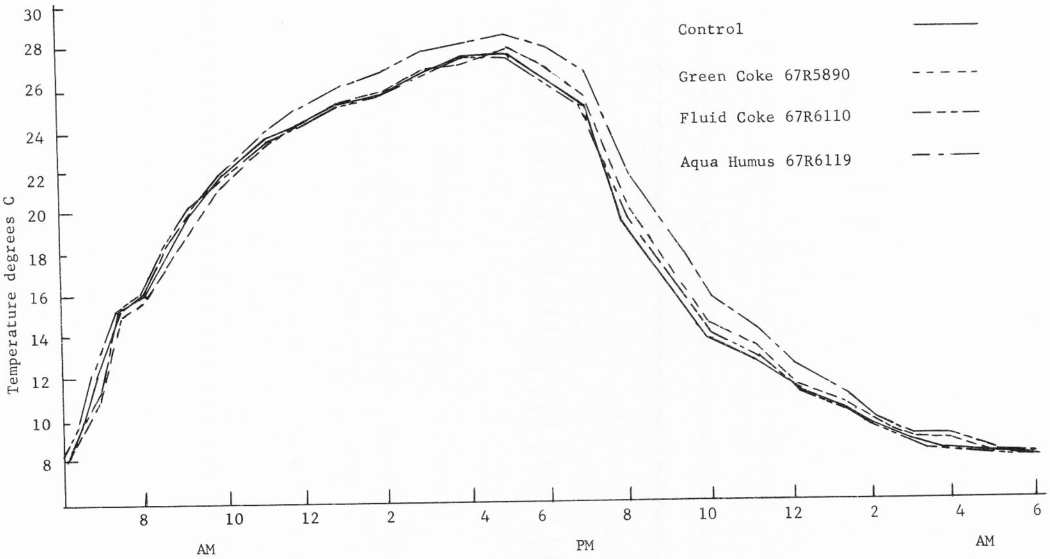

Figure 8. Soil temperature at 2 inch depth twelve days after planting.

asphalt, with the exception that the warming effect was not as pronounced. During the hours from 6 a.m. to 10 a.m. the green coke followed the warming trend of the bare soil, while after 10 a.m. it began to warm the soil above the control. The fluid coke was somewhat warmer than the bare soil during all the morning hours.

The maximum soil temperature under both fluid and green cokes was 1.5C higher than the control. The maximum temperatures for the treatments and the average temperatures for the 24 hour period are given in Table 17. Both treatments had an average increase in temperature of 0.9C over the control.

Neither treatment had soil temperatures which dropped below the control except for a short period between 7 a.m. and 8 a.m. when the temperature under green coke fell below the control.

The soil temperatures at the 2 inch depth under both fluid and green cokes are given in Figure 6. At the 2 inch depth the warming and cooling trend was similar to the control, with the exception that the treatments with the cokes had soil temperatures usually less than the control at all times during the 24 hour period. The maximum soil temperature under the fluid coke was 1C lower than the control, while that under the green coke was only 0.5C lower. The maximum temperature over the 24 hour period (Table 17) indicated that green coke was 0.5C lower and fluid coke was 1.2C lower than the control. The average temperature over the 24 hour period was lower for both treatments when compared to the control (Table 17).

The effect on soil temperature 12 days after planting is given in Figure 7 for the 1/2 inch depth and Figure 8 for the 2 inch depth. The temperatures at this time under both cokes were nearly identical and followed closely the soil temperature movement of the control. The maximum and average temperature effects over the 24 hour period are given in Table 18.

Effects of aqua humus on soil temperature

The effect of aqua humus on soil temperature is given in Figures 5 through 8, while the effect of soil temperature under aqua humus is given in Figure 5 for 1/2 inch depth 2 days after planting.

The soil under aqua humus warmed faster in the morning than the control, but in the afternoon it tended to be identical to the control. The maximum temperature was 2.5C warmer than that of the control (Table 17), while the average temperature over the 24 hour period was 1.3C higher. At the 2 inch depth (Figure 6) the effect on soil temperature followed that of the soft and hard asphalts at the same depth but dropped below the control after 9 p.m.

The effect of aqua humus on soil temperature 12 days after planting is given in Figures 7 and 8. At both the 1/2 and 2 inch depths the effects seemed to resemble that of the control.

The maximum temperature effect of aqua humus 12 days after planting and the average temperature effect over the 24 hour period are given in Tables 17 and 18.

Nitrogen studies

The results of tomato seed emergence counts at temperatures below 16C with the seed separated from the fertilizer by a layer of asphalt mulch is given in Table 19. The analysis of variance indicates no significant difference for treatments or for the two-way interaction of

Table 19. Analysis of variance for emergence of tomato seedlings with soft asphalt sublayer above nitrogen fertilizer in the greenhouse at a temperature below 16C

Source of variation	Degrees of freedom	Mean square	F
Total	119		
Replication	3	8.62	
Treatments	2	36.08	1.775
Error (a)	6	20.70	
Dates (counting)	9	5.770	5.170*
Treatments x Dates (counting)	18	1.295	1.160
Error (b)	81	1.116	

*Significant at 5 percent level.

treatments x counting date. Seedlings which emerged showed no symptoms of fertilizer burn for any treatments in the experiment.

Tomato seeding counts at temperatures above 21C are indicated in Table 20. The analysis of variance indicates significance at odds of 99 to 1 for treatments. Duncan's multiple range test (Table 21) indicates the control and the fertilizer treatment without the asphalt layer are significant at odds of 19 to 1 over the fertilizer plus asphalt layer. The control had an average stand count of 10.44 over four replications. The fertilizer plus asphalt layer had an average stand count of less than half that of the control or fertilizer alone.

Analysis of soil nitrogen

The results of tests run on soil samples to check the effect of a barrier of asphalt to the movement of applied nitrogen fertilizer indicated no significance. The average percent nitrogen at the 0 to 1/2 inch and 1/2 to 2 inch depth for the control and the asphalt barrier treatment is given in Table 22.

Table 20. Analysis of variance for emergence of tomato seedlings with soft asphalt sublayer above nitrogen fertilizer in the greenhouse at temperatures above 21C

Source of variation	Degrees of freedom	Mean square	F
Total	107		
Replication	3	142.39	
Treatments	2	401.291	5.648*
Error (a)	6	71.042	
Dates	8	252.690	54.932*
Dates x treatments	16	6.890	1.497
Error (b)	72	4.60	

*Significant at 5 percent level.

Table 21. Comparison of means for treatments of soft asphalt used as a sublayer above nitrogen fertilizer in the greenhouse

Treatment	Mean
Control	10.44 a
Fertilizer	9.19 a
Fertilizer plus asphalt layer	4.13 b

ab = Any two means with the same subscript are not significantly different at the 5 percent level, according to Duncan's multiple range test.

Table 22. Average percent nitrogen fertilizer above and below the soft asphalt sublayer in comparison to that without the sublayer on the first and second sampling dates

Treatment	Sampling date	Percent nitrogen 0-1/2 inches	Percent nitrogen 1-1/2 - 4 inches
Fertilizer	May 15	1.18	1.21
	May 25	1.08	1.15
Fertilizer plus	May 15	1.28	1.26
asphalt layer	May 25	1.27	1.37

The percentage of fertilizer at the 0 to 1/2 and 1/2 to 2 inch depths were very similar and indicated no significance.

Soil moisture

The results for soil moisture retention are given in Tables 23 through 25. The analysis of variance for soil moisture at the 0 to 2 and 2 to 4 inch depths, respectively, are indicated in Tables 23 and 24.

Significance in the analysis of variance for soil moisture loss at the 0 to 2 inch depth (Table 23) due to methods was understandable under shaded conditions. The various treatments indicate no significance in retarding moisture loss. Table 25 gives the average percent moisture for both shaded and unshaded conditions. The percent of soil moisture showed little difference for all trestments for a specific date of sampling in either the shaded or unshaded conditions.

In the analysis of variance for soil moisture content at the 2 to 4 inch depths (Table 24) the method of sun exposure was significant, as it was in the 0 to 2 inch depths. The average soil moisture content was similar to the 0 to 2 inch depths with little difference between treatments (Table 25).

Table 23. Analysis of variance for retention of soil moisture at the 0 to 2 inch depths under soft asphalt and fluid coke in the greenhouse

Source of variation	Degrees of freedom	Mean square	F
Total	95		
Replication	3	10.071	
Methods	1	682.631	11.948**
Error (a)	3	57.130	
Treatment	2	1.970	.667
Treatment x method	2	.135	.046
Error (b)	12	2.955	
Date	3	973.250	444.061**
Date x methods	3	83.860	38.29**
Date x treatments	6	1.218	.556
Date x methods x treatments	6	2.081	.949
Error (c)	54	2.190	

**Significant at 1 percent level.

Table 24. Analysis of variance for retention of soil moisture at the 2 to 4 inch depth under soft asphalt and fluid coke in the greenhouse

Source of variation	Degrees of freedom	Mean square	F
Total	95		
Replication	3	6.456	
Method	1	595.021	11.909**
Error (a)	3	49.962	
Treatments	2	1.390	.443
Treatments x methods	2	3.250	1.032
Error (b)	12	3.150	1.015
Date	3	825.261	
Date x treatments	6	46.202	18.553**
Date x method	3	1.091	.439
Date x treatments x methods	6	.998	.040
Error (c)	54	2.496	

**Significant at 1 percent level.

Table 25. The average percent soil moisture for the depth 0 to 2 inch for shade and unshaded condition under soft asphalt, fluid coke and the control over a period of 24 days under rapid drying conditions in the greenhouse

		Average soil moisture	
Treatment	Date	Unshaded	Shaded
Fluid coke	April 1	22.7	23.0
	April 14	9.2	15.0
	April 19	6.8	14.2
	April 24	4.0	12.2
Soft asphalt	April 1	23.0	22.0
	April 14	8.5	15.0
	April 19	6.5	13.8
	April 24	3.7	11.0
Control	April 1	21.5	21.5
	April 14	8.5	16.0
	April 19	6.0	11.5
	April 24	5.0	10.8
	2 to 4 inch depth		
Fluid coke	April 1	22.8	24.2
	April 14	10.0	16.2
	April 19	8.8	16.2
	April 24	7.2	13.7
Soft asphalt	April 1	22.8	23.0
	April 14	12.0	16.2
	April 19	8.0	15.2
	April 24	7.2	12.5
Control	April 1	22.5	23.5
	April 14	10.0	15.0
	April 19	8.0	15.0
	April 24	6.5	12.0

DISCUSSION

Petroleum Mulch

The petroleum-in-water mulch and the fluid and green cokes are relatively easy to handle. The application of these products could be made with little added expense by many farmers. It may, however, pay farmers with small acreages to have mulches, particularly liquid materials, applied by custom applicators. This is due to the special care that must be given to equipment during and after the use of such substances. If the equipment is allowed to stand over a short period of time with material in the sprayer, cleaning becomes extremely difficult.

Seed bed preparation is very important if asphalt mulch is to be used, especially with the liquid types. The planting area should be as free from clods and as level as possible so that an even, continuous band will be formed over the planted row. The soil surface should also contain a small amount of moisture. If the soil surface is too dry, there is a tendency for the mulch to form a poor surface to surface contact and, with the first watering, the mateial tends to float off the soil, breaking the surface contact which existed and minimizing the desired warming effect.

The test materials remain attached to the soil surface for about six weeks before starting to break and disintegrate. Rate of disintegration depends largely on two weathering factors, wind and moisture, either in the form of rain or from overhead irrigation. Expansion and contraction due to wetting and drying conditions in the field also cause the asphalt to disintegrate.

Good weed control is very important in the use of asphalt mulch. The concern is that with the first cultivation the beneficial effect of increasing soil temperature and retention of soil moisture will be lost with the breaking up of the continuous band. This means the first cultivation, if possible, should take place when the soil temperature is sufficiently high for good plant growth and moisture is readily available.

An important factor for using a petroleum mulch is the warming effect it produces. However, if the soil temperature is sufficiently above the critical temperature for rapid germination the use of the mulch is of no value. The germination of tomato seeds may be cited as an example. When the soil temperature is above 14C, additional heat is of little importance in increasing the speed of germination, and the petroleum mulch is of no value. If soil temperature is 13C or below, there can be as much as 6 days difference in the rate of germination and emergence. The use of petroleum mulch in this instance is of extreme importance and value. The experiments at Greenville and North Logan indicated no significance for seedling emergence with any treatment over the control, as the soil temperatures were sufficiently high to negate the value of a petroleum mulch.

Weather conditions are also of extreme importance when using petroleum mulches. Overcast, cloudy days will eliminate the effectiveness of it. This was the case with the trial run at the Farmington Field Station. The day the seeds were planted and the mulch applied the sky was overcast, and there were intermittent showers. During the following three-week period weather conditions continued to remain very poor; there were large amounts of moisture and almost steadily overcast skies. At the end of this time, eroded soil completely covered all mulch bands. This could account for the poor success of this trial.

Seedling Emergence

In the experiments conducted in the greenhouse with the five different mulch materials, soft asphalt was the only treatment that was significantly better than the control for seedling emergence. The treatments of hard asphalt and fluid coke were not significant but tended to be much higher than the control. Green coke gave results which were no different than those from the control, while results from aqua humus were much below the control and were significantly poorer than all mulch treatments.

The interaction, counting date x treatment, was significant at odds of 99 to 1. The soft asphalt increased the number of emerging seedlings and indicated significance over the control after the first 2 days of counting. Many seeds in the control were observed to have rotted or were unable to produce seedlings sufficiently strong to emerge through the soil surface. The seeds under the mulch materials were germinating, and the seedlings were breaking through the soil surface sufficiently fast so that they were able to out grow the soil organisms which could have caused their death.

Results of counts of the two treatments, hard asphalt and fluid coke, were significantly higher than the control for the last two and the last four counting dates, respectively. This accounts for the trend, in analyzing the treatments, as they tend to be much higher than the control.

Upon investigation of soil temperatures, it was found that the average temperature under the control was above the critical mark for good tomato germination, with the treatments being only 2 to 2-1/2C warmer than the control. This result points to factors other than the warming of the seed alone for increased germination. It was noticeable that a crust formed on the surface of the soil over the check plants. The petroleum mulch treatments tended to reduce the crusting effect and under the cool growing condition, water loss from the soil beneath the petroleum mulches seemed to be less, with the result that the soil moisture remained higher between waterings.

Control seeds subjected to relatively dry condition, with possibly less than the 12 percent moisture considered necessary for good germination by Doneen and MacGillevray (1943) and the seedlings under the crust on the soil surface were unable to grow sufficiently fast to compete successfully with soil borne organisms. After the completion of the experiment the crust was borken, and it was observed that a large number of seedlings remained just below the soil surface, with signs of being weakened by deleterious organisms.

Seedling emergence under the aqua humus was very poor, even though soil temperatures were above those of the control. Upon breaking the soil surface, it was observed that many of the seeds had not germinated and those that had showed little growth.

Aqua humus has the property of dispersing when moisture is applied. This occurs to such an extent that it spreads over the entire soil surface. This film may act as a sealant and allowing only small amounts of oxygen to diffuse into the soil, and accounting for poor germination of the seed.

Temperature effects of hard and soft asphalts are approximately equal, but the effects on seedling emergence were much less under the hard asphalt when compared to that of the soft. Moisture under both treatments remained about the same. There was, however, a noticeable difference in anticrusting properties observed. The soft asphalt tended to have less crusting, and the seedlings consequently had less difficulty in breaking through the surface.

Temperature effects may also account for some increase in seedling emergence when fluid coke was used, but not to the extent that the data indicates. The properties of anticrusting and moisture retention may also be of particular interest. Crusting of the soil surface was noticeably less under the treatment of fluid coke than under green coke or that formed on the control. The larger sized particles of the fluid coke also acted as a more efficient barrier in retaining moisture than did the smaller sized ones of green coke.

Soil Temperature and Liquid Asphalts

The main property of soft and hard asphalts that influence soil temperature is their black color, which abosrbs heat from direct sunlight and conducts it down into the soil. The property of the liquid materials that brings about the conduction of heat into the soil is the surface to surface contact formed by the mulch material being in direct contact with the soil surface.

The black color was responsible for the increase in soil temperature between 6 a.m. and 6 p.m. This increased heat seemed to be radiated into the atmosphere very rapidly between 6 and 8 p.m. At that time the soil temperature under the asphalt neared that of the control. From 8 p.m. until 4 a.m. when the temperatures seemed to level off, the cooling was gradual. The heat radiated may have raised the air temperature near the soil level several degrees during the period of rapid cooling.

It was apparent that the gain in soil temperature was radiated into the atmosphere until it reached the temperature near that of the control after which time both temperatures were similar.

Hard asphalt tends to warm the soil faster and has an average soil temperature above that of soft asphalt, yet the effect on seedling emergence was much less in comparison.

Soil Temperature and Cokes

Fluid and green cokes showed little effect on soil temperature. This was due to the inability to form a continuous band over the soil surface. Instead, there was a tendency to have low areas where the solid material collected and other areas with no covering.

Soil Temperature and Aqua humus

Because of the black color and the complete coverage of the soil surface due to dispersion of this material it tended to form a greater surface-to-surface contact. It also acted like the liquid mulches in absorbing more of the radiant heat which it conducted into the soil beneath. It was similar to the liquid mulches in that it tended to radiate this gain in heat into the atmosphere during the rapidly cooling period between 6 and 8 p.m.

Soft Asphalt and Soil Moisture

The ability of soft asphalt to conserve moisture is due to the continuous film placed over the soil surface; this acts as a barrier to water moving up through the soil to the surface to be lost into the atmosphere. This ability to conserve soil moisture is effective only under conditions of slow drying or during periods of cool weather. Such conditions were reproduced in the growth chamber. The effect of the soft asphalt or fluid coke was no greater than that of the control under rapidly drying conditions in the greenhouse, simulating those of possible July or August.

Nitrogen Movement and Soft Asphalt Barrier

The damage caused by the nitrogen fertilizer resulted from the movement of the nitrogen with the wetting front during irrigation and concentrating it in areas near the seed. This problem is intensified if the soil is then allowed to become extremely dry for a period of time.

The barrier formed by the asphalt had a tendency to retard water movement up through the soil, requiring additional time to wet the soil profile above the asphalt layer in comparison to the control.

The results from soil analysis indicated that the barrier of soft asphalt affected the movement of the nitrogen fertilizer only to the extent that the water was affected. The nitrogen tended to move through the asphalt barrier at will with the wetting front. The movement was such that the percentage of nitrogen at the depth 0 to 1/2 inch was similar to that at the 1/2 to 2 inch depth.

The analysis of variance for tomatoes emerging at temperatures above 21C indicates a significant increase for the control treatments over treatments with the asphalt layer. This was due to the retarding of the moisture to the soil surface by the asphalt barrier and not by movement of the fertilizer. The treatments with the asphalt layer were extremely difficult to sub-irrigate; they remained drier during the entire experiment.

Soil Conditioners and Petroleum Mulch

The results from the use of soil conditioners in combination with petroleum mulch indicates no significant difference over the petroleum mulch alone in enhancing tomato seedling emergence. The anticrusting effect of the soil conditioners vermiculite and perlite are no greater in combination with petroleum mulch than the petroleum mulch alone. It was also observed that soil moisture was harder to maintain at a level for good germination where vermiculite was used. This problem was overcome by frequent waterings during the early growing stages, and no effect was noticeable in the statistical analysis.

Methods of Petroleum Mulch Application

The main method of petroleum mulch application was a pre-emergent 6 inch band over the soil surface above the seed. The benefit from this application was the warming of the soil due to absorption of the sun's rays, the anticrusting property, and the soil moisture retention.

The significance of the method of incorporation of petroleum mulch over the pre-emergent application at a time when soil temperature was above the critical 14C for rapid seedling emergence indicated that the possible improvement in soil structure due to the petroleum mulch was the important factor for enhanced seedling emergence.

SUMMARY AND CONCLUSIONS

These studies were conducted during the 1967 growing season to determine the effects of petroleum mulches on the emergence of tomatoes. Tomatoes were direct seeded at the Farmington Field Station, the Greenville Field Station, and North Logan. Thirteen different types of mulch materials were applied at 6 inch band widths over the seeded rows. The liquids were applied at the rate of 100 gallons per acre and the solid materials at the rate of 700 to 900 pounds per acre. The petroleum mulches were divided into five categories; soft asphalt, hard asphalt, fluid coke, green coke, and aqua humus. Soft asphalt, hard asphalt, green coke (CR 67R5890), fluid coke (CR 67R6110), and aqua humus were also applied to a tomato seed bed placed in a growth chamber.

In addition, soft asphalt was studied in the greenhouse as a possible preventative to the loss of moisture from the soil surface and as possible barrier to the movement of nitrogen fertilizer when placed between the seed and the banded fertilizer.

Temperatures were recorded in flats that were placed in a growth chamber at the 1/2 and 2 inch depths under petroleum mulches, with copper-constanton thermocouples and a multipoint recorder.

Treatments at the Farmington Field Station indicated no significance, apparently due to prevailing cloudy weather conditions at the time of seeding and during the weeks that followed. At Greenville and North Logan, soil temperatures were sufficiently high that the warming effect due to the use of the petroleum mulch was of no value. Significance at odds of 99 to 1 at North Logan due to the method of application indicated that when soil temperature was sufficiently high the possible effect of building a better soil structure with the incorporated mulch materials was of more importance.

The number of plants emerging in the growth chamber under conditions near the critical point for best emergence was increased significantly by the application of soft asphalt. The treatments of hard asphalt and fluid coke also increased seedling emergence significantly during the later part of seedling emergence. The material aqua humus indicated definite deleterious effects on seedling emergence in the field at Greenville and North Logan. The growth chamber results were significantly lower than all treatments and appeared lower than the control.

Hard asphalt, soft asphalt and aqua humus increased soil temperature at the 1/2 and 2 inch depths during the hours between 6 a.m. and 6 p.m. The temperature then fell rapidly until approximately 8 p.m. at which time the soil temperatures neared that of the control. All temperatures then followed the cooling trend of the control during the hours of darkness. Fluid and green cokes had little effect on soil temperatures.

The increase in soil temperature due to hard and soft asphalts was also accompanied by increased soil moisture retention and less surface crusting of the soil. Fluid coke had little effect on increasing soil temperature but seemed to effectively control the loss of soil moisture and reduce soil crusting.

The effect of slowing soil moisture loss was only under conditions of slow drying. Under rapid drying conditions of the greenhouse soft asphalt had no effect in conserving soil moisture. This result is confirmed by the work of Takatori, Lippert and Whiting (1964).

When the soil was sufficiently warm the method of incorporation for the asphalt mulch indicated significance in enhancing seedling germination over the pre-emergent application.

The movement of nitrogen fertilizer was reduced by the layer of soft asphalt placed between the seed and the fertilizer band to the extent that water movement was slowed.

The value of the asphalt layer was economically unwise due to the rapid break down in the moist soil. At the time the second sampling was made the layer of asphalt was indistinguishable.

BIBLIOGRAPHY

Anonymous. 1966. Asphalt layer aids crops. Chem. and Eng. News 44(40):24.

Army, T. J., and E. B. Hudspeth. 1960. Alternation of the microclimate of the seed zone. Agron. Jour. 52:17-22.

Alpert, N., and R. A. Louis. 1963. Recent developments in petroleum products for agriculture. Sixth World Petroleum Conf., Francfort, Maine.

Bement, R. E., D. F. Hervey, A. C. Everson, and L. O. Hylton, Jr. 1961. Use of asphalt-emulsion mulches to hasten grass-seedling establishment. Jour. Range. Mgnt. 14:102-109.

Cannon, M. D. 1966. Asphalt and coke trials on cotton in Arizona. Proc. of the Petroleum Mulch Conf. Riverside, Calif. p. 9.

Chepil, W. S. 1955a. Effect of asphalt on some phases of soil structure and erodibility by wind. Soil Sci. Soc. Am. Proc. 19:125-128.

Chepil, W. S. 1955b. Asphalt increases resistance of soil to wind erosion; effect lasts two years. Crops and Soils 7(4):29.

Chepil, W. S. 1956. Asphalt cuts erosion till seedlings start. Crops and Soils 8(7):41.

Doneen, L. D. and J. H. MacGillivray. 1943. Germination (emergence) of vegetable seed as affected by different soil moisture. Plant Physiology 18:524-529.

Hatchett, W. P., and M. E. Bloodworth. 1963. Effect of petroleum agriculture mulch as a covering for dryland seed drills. Texas Agr. Exp. Sta. Progress Report 2265.

Kotowski, F. 1926. Temperature relations to germination of vegetable seed. Proc. Am. Soc. Hort. Sci. 23:176-184.

Lippert, L. F. 1966. Comment. Proc. of the Petroleum Mulch Conf. Riverside, Calif. p. 11.

Lippert, L. F., F. H. Takatori, and F. L. Whiting. 1963. Soil moisture under bands of petroleum and polyethylene mulches. Proc. Am. Soc. Hort. Sci. 85:541-546.

Moldenhauer, W. C., J. Maddy, B. L. Schmidt, and W. D. Shrader. 1964. Establishing vegetation on exposed subsoil. U.S.D.A. Bull. 280.p.

Nelson, W. L. 1958. Safe and efficient fertilizer placement. Proc. of the Thirty-fourth Annual Meeting of the Nation Joint Committee on Fertilizer Application. pp. 16-19.

Sims, W. L., M. P. Zobel, and R. C. King. 1968. Mechanized growing and harvesting of processing tomatoes. Univ. of Calif. Agri. Ext. Serv. AXT-232.

Takatori, F. H. 1966. Comment. Proc. of the Petroleum Mulch Conf. p. 10.

Takatori, F. H., L. F. Lippert, and F. L. Whiting. 1963. Petroleum mulch aids germination and stand establishment in preliminary vegetable crop studies. Calif. Agr. 17(6):2-3.

Takatori, F. H., L. F. Lippert, and F. L. Whiting. 1964. The effect of petroleum mulch and polyethylene films on soil temperature and plant growth. Proc. Am. Soc. Hort. Sci. 85:532-539.

Thomas, W. I. 1961. Asphalt improves germination growth of crops in winter. Progressive Agr. in Arizona 8(2):4.

Wilcox, G. E., and G. C. Martain. 1963. Soil temperature critical for tomatoes. Crops and Soils 15(9):23.

Wilson, J. D., and O. K. Hedden. 1965. Field study, liquid mulch. Ohio Rept. Res. Develop. Biol. Agr. Home Econ. 50(1):305.

VITA

Clarence Frank Williams

Candidate for the Degree of

Master of Science

Thesis: The Influence of Petroleum Mulch on The Germination and Yield of Tomatoes

Major Field: Horticulture

Biographical Information:

Personal Data: Born at Salt Lake City, Utah, February 16, 1940, son of Clarence F. and Joey Williams; married Karilyn Veater, March 17, 1961; two children--Richard and Clinton.

Education: Attended elementary school in Hunter, Utah; graduated from Cyprus High School in 1958, received the Bachelor of Science degree from Utah State University, with a major in Plant Science, in 1967; did graduate work in vegetable crops and completed requirements for a Master of Science degree at Utah State University in 1968.

Professional Experience: 1961-65, Designer Utah State Department of Highways, Salt Lake City, Utah; 1965-66 research aid, Utah State University, Logan, Utah; 1966-68, research assistant for Utah State University at Farmington Field Station, Farmington, Utah.