

THE USE OF CULTURAL PRACTICES TO
ALTER THE MICRO-CLIMATE OF STRAWBERRIES

By

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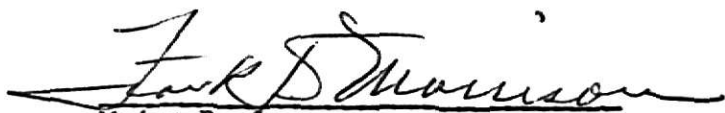
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INTRODUCTION

The strawberry, most widely grown small fruit in the United States, is among the first of the fresh fruits on the market in spring. Due to its wide adaptation to climate and soils, the strawberry is available fresh from Florida to Alaska for several months of the year. Based on the farm value this fruit crop constitutes over 7 percent of/ and ranks fifth among deciduous fruits and berries in the U.S.A. (32).

The cultivated strawberry belongs to the family Rosaceae and the genus *Fragaria*. It is a product of plantbreeding since the present cultivated varieties have been developed from crosses between two American species, *Fragaria virginiana* Duch. and *Fragaria chiloensis* (19).

The most important climatic factors that affect the strawberry plant are 1. temperature and 2. photoperiod. Other factors of varying importance are moisture (drought, heavy rainfall, high and low humidity) and the quality and intensity of light. This study was conducted to determine some of the effects on strawberry plants of modifying the micro-climate with various cultural practices.

LITERATURE CITED

The name strawberry indicates that the use of straw in growing berries, is a very old practice. According to Shoemaker (24) mulching is not absolutely necessary but it is useful for a number of reasons. These include: 1. as insulation against low winter temperatures; 2. to avoid injury to fruit buds from frost by delaying bloom; 3. to conserve moisture; 4. to check weed growth; 5. to reduce dirt and rot infected berries.

According to Colby (7) many growers contend that the leaves are mulch enough. He stated that at the Illinois Station 3 inches of wheat straw mulch was the best of many materials for frost protection.

In Kentucky, Armstrong (2) found that the unmulched plots and lightly mulched plots suffered severe winter injury. Early mulched plots showed a large increase in yield over spring mulched plots.

Adams (1) stated that a surface cover of straw mulch reduced runoff significantly and essentially eliminated erosion. A 2 inch straw mulch reduced evaporation significantly from a 0 - 6 inch depth during a hot rainless ten day period at Austin, Texas.

Rasmussen (21) investigated three methods of soil management which included straw mulch, short grass and clean cultivation in an orchard of Cox's orange trees. The conclusions from the study were: (1). the temperature of the top soil under straw was 2 - 6 C lower in summer and 2 - 3 C higher in winter than under the two treatments; (2). at the height of 10 cm above the ground the minimum temperature in May and June was about 5 C lower over straw than over grass or clean cultivation.

Gerard et al (12) studied the effect of tillage, straw mulches and grass upon soil moisture losses and soil temperature in the lower Rio Grande Valley,

Texas. Temperatures under soil mulch covers generally were higher in spring, summer and fall than straw mulch and grass covers. Straw mulch surfaces were intermediate in effect on soil temperatures at the 3 inch depths, but showed the lowest soil temperature at the 9 inch depth.

Bagian (3) demonstrated the influence of mulch on several growth factors and found that mulch can keep the soil cool during the day and relatively warm at night. In areas with a hot climate there is a lowering effect of mulch on the maximum temperature up to 20 F in comparison with soil which does not have a mulch covering. In colder areas mulch helps to prevent the roots of plants from being damaged in winter. The moisture condition of the soil is favorably influenced by mulching. A rapid discharge of water and erosion of the top soil is prevented, while the percolation of water is increased, the organic matter of the soil is also increased by mulching.

Webster (30) studied the effect of straw mulch on yield and soil moisture content in strawberry plantings. Straw mulch significantly increased yields and conserved soil moisture greater than the check treatment.

Moody et al (18) studied the influence of straw mulch on soil moisture. Soil temperature at the 4 inch depth was lower throughout the growing season under mulch conditions. Significant increase in growth of mulches over unmulched corn was attributed to the greater moisture under mulch during the period of high plant requirements. Mulched corn was 64 cm taller at tasseling and produced 42 bushels per acre more grain. Run-off was seven times greater from the unmulched plots.

Surtekov (26) showed that eight metric tons of straw per hectare applied as a mulch to field grown cucumbers, reduced the range of soil temperature, improved soil moisture retention and suppressed weed growth. Plant growth and

development were improved and there was an increase in yield.

Wiebe et al (31) investigated the effect of additions of straw on soil temperature, moisture and on yield of potatoes. The surface mulch reduced soil surface and sub surface temperatures very markedly. With strawberries the highest yields were obtained with the 5 ton incorporated treatment and the lowest with the surface mulch. No significant yield difference occurred in beans.

Schaler (23) found that straw and peat moss reduced soil temperature by 8 to 12 F in a study of mulch effects on soil conditions and muskmelon response. Soil moisture in the upper 6 inches was higher under peat moss and straw and generally lower under plastic.

Kanagawa (14) studied the effect of some organic mulches on the behavior of young peach trees. In the straw mulched plots the growth of young trees and the root density was increased. The effect of mulches on the reduction of maximum soil temperature was most remarkable in late spring (May) and in mid summer (August).

Micro-climate modification has a potentially wide application. Water in the atmosphere is very important in regulating the energy heat balance of the earth's micro-climate. Sprinkler and mist irrigation during mid day hours effectively lower the temperature and increase the humidity particularly under adverse climatic conditions.

Simmons (25) reported that supplemental irrigation applied during fruit bud formation significantly increased yields of Howard, Premier and Vermilion Cultivars of strawberries.

Gingrich (13) found that sprinkler irrigation increased yields of Catskill strawberries most with matted rows. Fruit size was increased but no

significant effect was noted on the number of crowns per plant.

Pesserl (19) studied the effect of mist on one year old strawberries mother plants for 10 to 15 minutes applied 2 to 3 times per day. According to him runner plants raised under these conditions were much stronger than those propagated without misting.

Miller et al (17) conducted tests to determine the effect of tree sprinkling on reduction of air temperature in an avacado orchard. Reduction in air temperature of 5 - 7 F was obtained when the air movement was 4 miles per hour.

Lombard et al (15) conducted trials with overhead sprinkler systems for environmental control and pesticide application in pear orchard. Sprinkling at 0 - 17 inch per hour on mature pear trees intermittently when the air temperature was over 90 F, reduced temperature 10 F in the air, 15 F in the fruit core and 13 F on the leaf surface. Fruit growth rate was increased and fruit maturity was advanced several days.

Toussiant (27) reported that on humid podsol with a water table below the surface, strawberry yields were increased by 22 percent as a result of sprinkler irrigation applied whenever the available moisture had fallen to 50 percent of field capacity during the growing season. Fruit size was considerably increased by the treatment.

Middleton, et al (16) demonstrated the importance of mist in modifying the micro-climate of green peas. Temperature of the foliage and temperature immediately above the leaves were lowered as much as 15 F with misting when the ambient temperature was in the 95 to 100 F range, and the relative humidity was about 30 percent. Relative humidity in the foliage was increased about 10 percent with misting.

Prasher (20) found that temperatures in mist plots were from 1 to 16 F below air temperature in an experiment on cabbage, cauliflower and broccoli. Less water was used in misting as compared to sprinkler irrigation. Under mist irrigation 93 percent of the cauliflower heads were graded as U.S. No. 1 as compared with only 77 percent under the sprinkler system.

Brink, et al (4) reported that the temperature in a tomato field was lowered as much 18 F 12 inches above soil surface and the temperature at the surface of muck soil was lowered 22 F by overhead sprinklers during the heat of the day.

Carolus (5) reported that strawberries respond to frequent irrigation during arid periods. With daily air temperature above 90 F, night air temperature below 55 F, and relative humidity below 30 percent, light water applications during the day resulted in 200 more crates of harvested berries per acre than in other areas of the field that had received the same total water application but in two 2.5 inch water applications. At the peak of the harvest, the berries were over 85 percent larger, brighter and kept longer.

Carolus (6) observed that when peaches were sprinkled for 50 hours with a total of 3.5 inches of water during a two week period before harvest there was an 18 percent increase in the size of Redhaven fruit and 22% size increase in Richhaven fruit.

Dmitreva, et al (11) demonstrated the use of vermiculite on tomatoes and concluded the following:

1. Vermiculite creates good aeration for root system and has great ability to retain moisture.
2. It does not have the sharp temperature fluctuations.

3. It is sterile.
4. The vegetative period of tomatoes grown on vermiculite was reduced to 3 weeks as compared to tomatoes grown on soil.

Darrow (9) reported mother plants that produce and support many runners plants were found to be much weaker and produced much less fruit than plants which produced none or few runner plants.

Denisen (10) stated under favorable growing conditions many varieties, especially the virus free strains, produce many runner plants and become overcrowded. Severe inter-plant competition generally results in reduced yields and inferior berries.

Waldo (29) explained the relation of reduced yields with runner production. Runner plants, when allowed to develop freely, influence the fruit producing capacity of the mother plants. With a relative small number of plants/per acre there was less shading and therefore greater photosynthesis than with the larger number of plants per acre.

Darrow (8) while studying the effect of photoperiod and temperature on strawberry concluded that although the strawberry is a short day plant, flower buds can be initiated during long days provided the temperature is low enough, 60 F or less. He further stated, the difference in the day length temperature reaction is responsible for some varieties being better adapted to the North, others to the South.

Waldo (28) found that fruit bud differentiation in all varieties and species studied under Maryland conditions with one exception, takes place during September and early in October.

Darrow (8) from a survey made in 1923 of several varieties of strawberries at different experiment stations from Massachusetts to Minnesota

revealed that fruit bud differentiation takes place during the latter part of September occurring slightly earlier in early maturing varieties.

Robertson (22) reported that flowers appearing from late April until about early June were derived from primordia formed in late summer or early autumn of the previous year. Flowers borne from mid or late July onward, were initiated a few weeks before emergence. Early formed runners developed flower primordia at an early stage in their growth and generally flowered in mid to late summer with their mother plants.

MATERIALS AND METHODS

The strawberry cultivar, Surecrop is one of the most productive varieties grown in Kansas and thus was used for this experiment. A total of 200 strawberry plants were planted at the Horticulture Research Farm near Manhattan, Kansas on April 8, 1968. Plants were set two feet apart with four feet between rows. The soil type was a sandy loam. Analysis indicated 2 percent organic matter in the soil.

Five experimental treatments were used comprising (1) control, (2) straw mulch, (3) perlite, (4) vermiculite and (5) mist irrigation. Each treatment was replicated four times in a randomized block design. Before planting one bale (40 lb.) of straw mulch was incorporated two inches into the soil in a two foot band in each straw mulch treatment. After planting, one bale of straw was spread around the plants three inch depth in each straw mulch treatment. On June 12, 1968 one bag (27 lb.) of perlite and one bag of vermiculite was applied two inch depth to each respective treatment. The surface mulch treatments were applied to extend one foot to each side of the plant row. On July 23, 1968 an overhead mist irrigation system consisting of 1/2 inch copper tubing with eight nozzles was set up above strawberry plants in each mist treatment. Monarch F-97-S nozzles which delivered a solid cone spray of about 120 angle were spaced at 30 inch intervals. The mist system was set 15 inches above the ground level with a coverage diameter of 52 inches and precipitation rate of 293 inches per hour or 3.1 gallon per hour operated at 30 lbs. of pressure per square inch. The overall length of the nozzle was approximately 1 7/8 inches with the caps made of 13/16 inch hexagon stock and bodies made of 11/16 inch hexagon stock. The mist was operated manually 2 to

EXPLANATION OF PLATE I

Fig. 1. Perlite mulch treatment on strawberries.

Fig. 2. Vermiculite mulch treatment on strawberries.

PLATE I

Fig. 1



Fig. 2



EXPLANATION OF PLATE II

Fig. 1. Strawmulch treatment on strawberries.

Fig. 2. Mist irrigation system in operation.

PLATE II

Fig. 1



Fig. 2

3 times a day for approximately 15 minutes whenever the atmospheric temperature exceeded 80 F. This treatment was continued during July and August, 1968. On May 15, 1969 three bags of perlite and three bags of vermiculite were applied on the respective mulch treatments with an average depth of one inch.

Runner counts were made on September 11, 1968. Strawberries were harvested 7 different times from June 3 to June 23, 1969. Harvesting was confined to 10 feet of each 20 feet plot.

The temperature of the micro-climate of strawberry plants was measured using thermometers placed at 2 inches above the ground level. The thermometers were shaded using aluminum foil to protect from direct sun rays.

Strawberry plants were mowed on July 9, 1969 in the conventional manner of strawberry culture.

Thermocouples made of 36 guage (.005") were soldered to 24 guage (.0201") extension wire. Twenty four extension wires were connected to a Honeywell electronic 15, strip chart multipoint potentiometer. Thermocouples were placed immediately adjacent to strawberry plant crowns and secured to stakes. The micro-climatic temperature fluctuations in the strawmulch, mist and control plots were recorded.

RESULTS AND DISCUSSION

Production of Runner Plants:

The greatest number of runners per plant were produced in the control plot. There was no significant difference in runner production between strawmulch-mist treatment and perlite-vericulite treatments, as shown in table 1.

Table 1.

Runner production of Surecrop Strawberry
grown with various mulches

Treatment	Average runners per plant
Control	14.3
Straw	12.1
Perlite	10.2
Vermiculite	10.0
Mist	12.0
LSD 5% = 1.65	

Even though there was statistical differences between control and other treatments, the differences in the number of runners would not necessarily indicate that a significant difference in total yield would be attained in commercial strawberry production since the cultural practices followed at latter periods, such as during bud set, could influence the fruit bud set and subsequent yield.

Fruit Production

During the first bearing season (1969), the maximum yield of strawberries was obtained from the second picking. The duration of the entire picking was three weeks. Throughout the plants pickings in pounds, strawmulch treatment produced significantly larger yields of strawberries, followed in order by mist, perlite and vermiculite. The control plots had the lowest yield as shown in table 2.

Table 2.

Strawberry yields from environmental control treatments

Picking date	Treatments				
	Control	Strawmulch	Perlite	Vermiculite	Mist
1. June 3, '69	16.00	20.75	17.75	16.75	19.00
2. June 6, '69	18.25	25.50	23.50	21.00	24.00
3. June 9, '69	12.75	17.50	17.75	15.50	18.75
4. June 11, '69	11.25	15.25	14.00	13.50	14.00
5. June 16, '69	5.75	8.75	6.25	6.00	7.75
6. June 19, '69	2.75	5.25	3.25	2.75	4.00
7. June 23, '69	1.50	3.50	2.50	2.25	2.75
Total ^{1/}	68.25 ^{2/}	96.50 ^{2/}	85.00 ^{2/}	77.75 ^{2/}	90.25 ^{2/}

^{1/} Total yield from 4 replications.

^{2/} Yield is reported in pounds.

There was a highly significant difference in yield between control and strawmulch treatment (table 2). The average yield of fruit per plant was

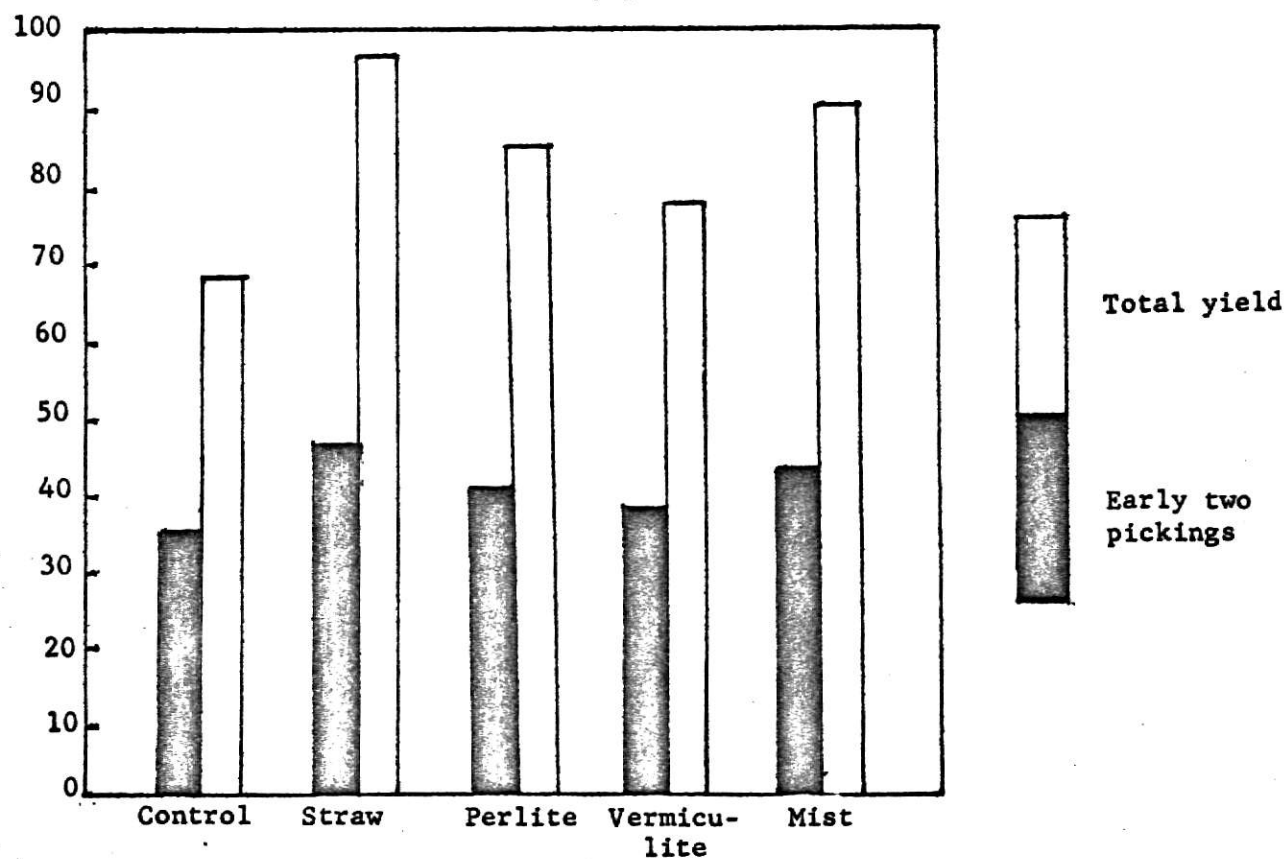
Table 3.

Analysis of variance

Treatment	Mean Yield
Control	17.06
Straw	24.12
Perlite	21.25
Vermiculite	19.93
Mist	22.56

LSD 5% = 3.12

Fig. 1.

The influence of plant environment
on strawberry production

4.8 lbs. and 3.4 lbs. from strawmulch and control respectively. Significant differences were also noted between control and mist, strawmulch and perlite, and strawmulch and vermiculite treatments. No significant differences were observed between control-vermiculite, strawmulch-mist, perlite-vermiculite, perlite-mist and vermiculite-mist treatments. The absence of a significant difference between strawmulch and mist treatments suggest the possibility of further increasing yield of strawberries with the combination of mist over strawmulch. In this research the distance between nozzles was wide and the mist coverage was not complete over the entire treatment. Velocity of wind also reduced the beneficial effect of mist. If all these conditions were met, mist treatment may have out yielded all other treatments.

In accordance with Darrow's (8) findings, it can be postulated that the strawmulch and mist treatments in this experiment facilitated greater fruit bud formation in the latter part of September by modifying the micro-climate of the strawberries. Greater fruit bud formation consequently may have led to greater yield from these treatments. Significant beneficial effects from perlite and vermiculite mulches were not obtained. The light weight of these materials resulted in insufficient mulch being retained around the plants in the perlite and vermiculite treatments.

Thermometer Temperature Measurements:

Micro-climate temperatures of strawberry plants were recorded with thermometers on June 27 and July 3, 1969 which were relatively warm days. The minimum air temperature was 56 F, 70 F and maximum 89 F and 102 F on the farm. The recording periods were 10 a.m., 1 p.m., and 4 p.m. The mist treatment was turned on for 15 minutes and observations were recorded after turning

off the mist.

Table 4.

Micro-Environment temperatures
on June 27, 1969

Time	Treatment	Mean temp (F)	LSD .05
10 a.m.	Control	81.5	4.4
	Strawmulch	80.1	
	Mist	75.7	
1 p.m.	Control	89.6	3.3
	Strawmulch	88.2	
	Mist	84.6	
4 p.m.	Control	95.0	1.2
	Strawmulch	93.2	
	Mist	85.5	

There were significant differences between mist-control and mist-strawmulch treatments as indicated in table 4. No significant difference was observed between control-strawmulch treatments at 10 a.m. and 1 p.m. However, there were significant differences between strawmulch-control, strawmulch-mist and control-mist at 4 p.m.

Observed air temperatures of mist and strawmulch treatments were significantly different from control at 10 a.m., but at 1 p.m. and 4 p.m. only the mist treatment was significantly different from control and strawmulch treatments as shown in table 5. Mist irrigation in all observations lowered temperature from 3.6 F to 12.6 F as compared to control whereas strawmulch on an average lowered temperature 1.8 F against control. Temperature measurements

Table 5.

Micro-environment temperatures
on July 3, 1969

Time	Treatment	Mean temp (F)	LSD .05
10 a.m.	Control	93.2	2.5
	Strawmulch	91.4	
	Mist	86.0	
1 p.m.	Control	103.5	5.3
	Strawmulch	103.5	
	Mist	95.9	
4 p.m.	Control	108.9	3.4
	Strawmulch	108.0	
	Mist	95.8	

which were more quantitative than from thermometers may have shown that the cooling effect of strawmulch to have been greater than shown in the data. However, the influence of straw for altering the micro-climate was less than for mist irrigation under these conditions.

Strawberry plants were mowed on July 9, 1969 after harvest. Micro-climatic temperature was recorded with thermocouples on July 22, 1969 from strawmulch and control treatments. The minimum and maximum air temperature on the farm was 74 F and 90 F respectively.

Table 6.

Micro-environment temperature
recorded with thermocouples

Treatment	10 a.m.	11 a.m.	12:00	1 p.m.	2 p.m.	3 p.m.	4 p.m.
Strawmulch	80.34	85.51	91.72	92.81	92.81	93.64	93.17
Control	80.81	82.01	84.70	89.26	93.97	89.61	88.49
LSD/.05	15.8	8.6	14.7	10.5	6.2	16.3	12.4

There was no significant difference between strawmulch and control treatments at 5 percent level of confidence in all observations. While mowing, most of the straw was removed thus increasing the exposure of the soil to the sun rays. Temperatures were recorded only on one day so reading during a variety of weather conditions were not obtained. It has been proved by various workers that strawmulch helps to maintain lower soil temperature during the day than for un-mulched conditions. However, these results are not associated with the yield because these observations were taken after harvest and before new fruit buds were being initiated.

Table 7.

Micro-environment temperature recorded with
thermocouples for mist & control
on July 22, 1969

Treatment	10 a.m.	11 a.m.	12:00	1 p.m.	2 p.m.	3 p.m.	4 p.m.
Mist	81.50	84.75	85.64	82.44	85.26	85.18	76.20
Control	81.91	90.00	94.16	95.46	89.05	96.30	96.45
LSD .05	0.82	6.0	8.2	4.1	2.6	7.6	8.1

There was no significant difference between mist and control at 10 a.m. and 11 p.m. as indicated in table 7. However, there was significant difference between these treatments from 12:00 noon to 4 p.m. Mist was turned on for 15 minutes at 10:30, 1 p.m., 2:30 and 4 p.m. and the observations were recorded immediately after the mist was turned off. The minimum and maximum air temperature on the farm on July 22, 1969 was 68 F and 92 F respectively.

As the atmospheric temperature increased, cooling effect of mist was simultaneously increased. At 4 p.m. the effect of mist was highly significant. Mist in these observations reduced temperature from 2 F to 16 F. In the morning hours the effect of mist was negligible but in spite of evaporation in the afternoon mist lowered the temperature significantly. Frequent mist of longer duration may lead to favorable micro-environment temperature of strawberry plants under rather unfavorable climatic conditions of high temperature and low precipitation which, during some years may characterize summer conditions in Kansas. The combination of mist and strawmulch treatments may have the advantage of reducing temperature by altering the micro-climate of strawberry plants as well as conserving moisture in the soil.

The results presented are by no means conclusive and there is a great deal of opportunity for further investigation.

SUMMARY AND CONCLUSION

The purpose of this study was to evaluate the potential of mulch materials and mist irrigation in manipulating the micro-environment in a strawberry planting and the effect of the manipulation on the fruit production of plants. Micro-climate modification has a potentially wide application. The findings reported in this study could be summarized as follows:

1. Early rooting and number of runner plants was not affected by the treatments in this study.
2. The total yield of strawberry fruit was significantly increased over control treatments by mulching with straw and perlite and by mist irrigation.
3. Air temperature measured at the plant leaf level was reduced by 2 F to 16 F by mist irrigation treatment.
4. More favorable micro-climate for strawberries can be produced by straw-mulch or overhead mist irrigation particularly under adverse climatic conditions.

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The most important climatic factors that affect the strawberry plant are: 1. temperature and 2. photoperiod. Other factors of varying importance are moisture (drought, heavy rainfall, high and low humidity) and the quality and intensity of light. Kansas has a distinctly continental climate with characteristically changeable temperature and precipitation. Keeping in view the importance of temperature in the growth and development of the strawberry, this study was conducted at the Horticulture Research Farm near Manhattan, Kansas with an effort to modify micro climate of strawberry plants with various cultural practices.

Surecrop strawberry, a productive cultivar grown in Kansas, was used for this experiment. Five treatments were used comprising (1) control (2) strawmulch (3) perlite (4) vermiculite and mist irrigation.

Results of this study showed that strawmulch treatment produced significantly larger yield of strawberries followed by mist, perlite, vermiculite and control.

Significant difference in temperature was observed between mist and control treatment. Mist irrigation in these observations lowered temperature from 2 at mid morning to 15 F at mid afternoon. The effect of mist was highly significant when the atmospheric temperature was high and wind velocity was low. The soil was not compacted by the mist and little water penetrated more than an inch. There was no leaf burning on account of mist irrigation. On the basis of this investigation, it should be possible to alter micro-climate of strawberry plants with suitable cultural practices that would be beneficial, particularly under Kansas climatic conditions.