

EFFECTS OF VARIOUS MULCHES ON
SOIL MOISTURE CONSERVATION

by

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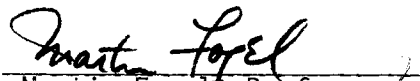
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DEDICATION

I dedicate this thesis to my parents,
my wife Jawhara, my daughter Najla,
and my son Abdulaziz, who gave me
abundant support during my studies.

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ABSTRACT

The purpose of this work was to study and evaluate the effect of various mulches on the soil moisture content for sandy loam soil under high temperatures. The straw, wood shavings, and rock fragments were used with different rates of application for covering soil. Treatments were compared to bare soil. The moisture content was significantly higher for mulched treatments. However, the effectiveness of wood shavings and rock fragments mulches did not seem different in soil moisture content, while straw mulch did.

The soil moisture content for the straw had the highest value at the end of the experiment. The straw mulch apparently conserved soil moisture over the other treatments. The conservation of soil moisture under 10, 15, 20 gm of straw mulch was occasioned by less direct contact soil surface with air surface and less possibility of heat transfer. The greatest savings in water was under 2.7 tons/ha of straw mulch.

CHAPTER 1

INTRODUCTION

The application of soil surface treatment, usually by some type of mulch, probably goes back as far as agriculture itself (Hanks et al., 1960). The covering of soil surfaces with crop residue or other material (such as gravel) has an attributed effect on conserving soil moisture.

Mulches are important in many agricultural areas. They help to maintain soil moisture by reducing evaporation, and by modifying the infiltration capacity of the upper soil surface when incorporated into the soil. Soil temperatures under mulch are lowered in summer and raised in winter. Moreover, mulch helps to control soil erosion by decreasing surface runoff. In addition, mulches reduce weed growth and thereby lessen the need of cultivation for weed control. Furthermore, organic matter and nutrient can be added by organic mulches for plants. Alderfer and Merkle (1943) found that organic matter was about 3.61 percent in the 0-3 inches surface layer after 4 years under straw mulch, organic matter for control plot was 3.09 percent.

Mulch is used primarily in areas where soil moisture is limited. It inhibits the water conveying mechanism by

lengthening the water diffusion pathway between the capillaries of soil surface and the air interface. The prolonged conservation of soil water done by a mulch-influenced diffusion pathway can increase plant survival (Ayling et al., 1981).

Conservation of water in arid and semi-arid regions is important for agricultural management. It is generally accepted that soil and water can be conserved by applying mulches in the form of straw, coarse rock fragments, and wood shavings. If large savings in water can be obtained with mulch, the benefits could be large to water short areas in the Kingdom of Saudi Arabia.

Precipitation is low and evaporation high in Saudi Arabia. Groundwater is the only reliable source of water for agriculture, and its supply is limited. There is a need to conserve as much of this limited water as possible. Mulch could provide one means.

Objectives

The objective of this study was to evaluate the loss and saving of soil moisture under straw, wood shavings, and rock fragments mulches. A secondary objective was to determine the cost of the most treatments, compared to water savings.

CHAPTER 2

LITERATURE REVIEW

General Definition and Benefit of Mulches

A mulch might best be defined as a protective covering, either spread or left upon the surface, for the purpose of increasing soil productivity, primarily through microclimatic modification (Birzins and Ayling, 1981).

In addition, mulching not only inhibits weed growth, but it improves the texture of soils, both heavy and light by the addition of humus. It conserves moisture from evaporating during hot weather and drought periods. Furthermore, it prevents the soil from washing away during heavy rains and retains the rain where it falls. It also modifies the temperature in the root zone and protects the plants (Meserve, 1957). These benefits vary from one type of mulch to another.

The Effects of Straw

Lal (1974) reported that 12.2, 7.2 and 8.3 percent of the rain received (during 1971 and during the first and second season of 1972) was approximately the same as soil moisture conserved in the soil. Moisture content was higher throughout the growing season under mulches than under

unmulched plots for both 0-10 and 10-20 cm depths. This was attributed to lower soil temperature and consequent reduction in evapotranspiration.

Kill and Foot (1971) found that long-fibered mulches (straw, hay) were more effective in reducing water loss than short-fibered mulches (sawdust, charcoal) due to less direct soil surface contact with the air. They suggested that long-fibered mulches are more desirable for moisture conservation, especially where rainfall is not frequent.

Russel (1939) studied soil moisture losses under a variety of conditions that were affected by surface cover such as straw. He indicated that application of straw at high rates reduced evaporation, 73 percent as compared with control. Moreover, he reported that water conservation increased significantly with mulches at high rates of application.

The effects of clean cultivation, a permanent sward, and a permanent straw mulch on soil moisture content were compared by Good and White (1958), who initially used about 8 tons/ha and subsequently made additions at a rate equivalent to 4 tons/ha each October. They found that soil moisture content remained close to field capacity throughout the summer under wheat straw mulch, while under the clean cultivation. Evaporation losses were about equal to a large part of the summer rainfall. Moody, Jones and Hillard

(1963) also found that a wheat straw mulch of 7.5 tons/ha had a desirable effect on soil moisture.

Awan (1964) found that soil moisture content under straw mulch was higher than that under a check plot. There were no obvious differences in soil moisture conservation between 2 and 4 ton applications. He concluded that where the soil temperatures were above the optimum for potato cultivation in the tropics, a reduction in soil temperature from mulching caused a significant increase in potato yield. He also added that mulching in an area of low precipitation was more effective in conserving soil moisture.

Ayling et al. (1981) found that under long-fiber mulches (straw), evaporation was lower than for sawdust and charcoal due to less direct ground surface contact with air which decreased heat transfer.

Stephenson and Schuster (1945) studied the effect of different mulches on soil properties. They reported that soil moisture content increased significantly under straw mulch in both the surface and second foot of soil in the dry part of the season. Moreover, moisture content of the soil beneath the straw mulch continued nearly unchanged throughout the season of May through October, but a small loss of moisture was noticed in the surface 2 feet in the

driest weather. None of the other treated plots displayed this constancy of moisture content.

Bushnel and Welton (1931) found that straw mulch reduced soil temperature below those of cultivated plots and also conserved soil moisture.

Tukey and Schoff (1963) reported that during the middle of the summer, soil moisture contents were significantly higher under mulched plots than those under cultivation or sod. Also, they indicated that the effect of mulching on reducing moisture loss through evaporation. The reduction was from one-third to one-fourth of that from cultivated soil. They added that soil moisture content losses were high under grass sod, while it was low under mulch in the top foot of soil during a prolonged period of drought.

Unger (1978) found that precipitation was conserved as soil water and that growing-season water was increased by covering Pullman clay loam soil with 8 or 12 metric tons/ha of straw. Likewise, Greb, Smika and Black (1970) found that precipitation storage in the central and northern Great Plains extended from 16 percent with no mulch to 37 percent with 6720 kg/ha of straw mulch. They further concluded that water storage was increased by residue or mulches during shorter fallow period as compared with the effect of no residue or mulches.

The Effect of Sawdust and Wood Shavings

Stuart et al. (1952) found that there were beneficial effects from applications of sawdust other than increased yield, such as greater ease of tillage and improved soil moisture content. Weed control was much easier in the sawdust plots than for manured plots. This might be due to the large number of weeds that grow from seeds carried by the manure. They stated that soil moisture content was higher with rotted and fresh sawdust mulch than with manure, and control treatments, but moisture content was highest with the sawdust treatment.

Latimer et al. (1947), in studying the comparative value of sawdust, hay and seaweed as mulch for apple trees, found that sawdust could reduce soil moisture loss as compared with other treatments. Although sawdust was found to be a good media for the growth of grass, it reduced tree growth and yield and produced pale-colored foliage.

Turk (1943) conducted a study of the effect of sawdust on plant growth. He found that sawdust protected the soil from the direct rays of the sun and from contact with wind and warm dry air. Furthermore, cracking of the soil surface seemed to be reduced by sawdust. In some instances, sawdust restrained capillary movement of moisture and increased absorption of rainfall.

Turk and Partridge (1947) showed that the effectiveness of sawdust was lower in moisture conservation for sand and sandy loam than straw and other mulches. This might be due to the high moisture absorbing ability. In other words, evaporation of water from sawdust itself was sufficient to offset any beneficial effect of the mulch in decreasing evaporation of water from the soil below.

Denisen et al. (1953) showed that sawdust mulching conserved soil moisture compared with an unmulched plot. They also found that there was no significant difference between oat straw, sawdust and chopped corn cobs mulch in conserving soil moisture.

Yadav (1974) indicated that moisture was conserved under sawdust and wheat straw during a dry spell, which produced significantly higher grain yields than a control. Moreover, sawdust conserved the highest amount of moisture in the 5-15 cm soil layer and a high moisture content in the entire soil profile.

The effect of sawdust mulch on crop growth and physical and biological properties of Cecil soil was studied by White, Cidden and Morris (1959); these authors found that higher yield of crops on mulched soil resulted from an increase in soil moisture content and reduction in soil temperature as compared to the unmulched plots. On the other hand, sawdust, used either as mulch or mixed with

soil, decreased the nitrate content of the soil because soil nitrogen can be moved to and immobilized in low N residues. Similarly, Webster (1961) reported yields and soil moisture content significantly increased with sawdust mulch applied to the soil surface and sawdust mixed with the soil as compared with control plots and other treatments. Moisture content measurements indicated that the sawdust treatment conserved soil moisture; this was considered the major reason for the increased yield.

Slate (1954) found that a sawdust mulch of 2.5 cm depth was satisfactory to conserve moisture in the soil. The work of Slate (1954) was not confirmed by Johnson (1944), who found that 3 inches was a sufficient depth of sawdust mulch to conserve moisture when used with tomato and fall potatoes as compared with incorporated sawdust and untreated check. Yields of fallow potatoes and tomatoes in plots with sawdust mulch were lower than the yields from incorporated sawdust.

Studies of tomato response to mulching on ridged and flat rows was investigated by Chipman (1961), who found that moisture levels were greater under sawdust mulch than under black polyurethane mulch.

Ayling et al. (1981) examined the effect of short-fiber mulches, charcoal and sawdust on the growth of Eucalyptus saligna. They found that sawdust, control and

charcoal plots had high evaporation rates due to the more direct ground surface contact with air and the increased possibility of heat transfer. This would lead to greater upward water flow and the possibility of capillary flow through the mulches. In comparison with other mulches, it was concluded that short fibers may not have been more beneficial for germination and soil-water conservation. Kill and Foot (1971) found that short-fibered mulches were less effective in reducing soil and water loss than long-fibered mulches when comparing various cellulose pulp mulches.

Coarse Fragment Effects

The effect of mulches on orchard soil was studied by Turk et al. (1947), who found that gravel and other mulches of low moisture-absorbing ability were effective in conserving soil moisture. This effect was believed due mainly to a high percolation and low absorption of rain by the rocks. On the other hand, nitrates, which made no contribution to the food supply of microorganisms, were decreased under a gravel mulch. Hanks and Woodruff (1957) found that under gravel mulch, evaporation rates were greater than those for unmulched plots at zero wind speed.

Gupta and Yadav (1979) reported that moisture lost from soil under various mulches indicated that maximum soil moisture was lost under control and stone mulch plots while

minimum moisture lost under rubble mulch. This might be due to the complete soil covering contributed by the rubble mulch. The lower moisture maintained by stone might be due to the reduced loss of moisture through the spaces between stones.

In a study by Hanks, Bower and Bark (1961), it was noted that evaporation rates were greater from bare soil than from soils with mulches of straw, painted black gravel, or aluminum.

Benoit (1962) found that high losses of moisture occurred mainly in the top 6-inch layer of unmulched soil leaving the layer dry. On the other hand, soil moisture was essentially uniform from the soil surface down from mulched plots.

The influence of coarse fragments on soil moisture and soil temperature was studied by Meiman (1962), who used 0 to 20 (by volume) and 0 to 62 percent surface cover of sandstone fragments in or on clay loam soil. The measured reduction of moisture loss from 10 inches of soil associated with a 62 percent surface cover was 0.16 inches for a 54-day drying cycle, while the 22 to 44 percent cover had no effect at all. He concluded that available water was not increased by the coarse fragments in the soil.

CHAPTER 3

MATERIALS AND METHODS

This experiment was run on July 1986 in the greenhouse on the west side of the Campbell Avenue Farm at the University of Arizona. The soil was collected from the top 30 cm of soil from the west side of the farm. The soil sampled is classified as Gila fine-loamy, mixed (calcareous) thermic typic torrifuvent (USDA, 1972). The soil was air-dried for two days and sieved through a 2 mm sieve. To ensure a homogeneous mixture, the soil was mixed thoroughly. Mechanical analysis by the hydrometer method (Black et al., 1965) indicated that soil texture was a sandy loam. The soil properties are given in Table 1. A moisture extraction curve was obtained with a pressure plate apparatus (Figure 1).

Three different types of mulches applied at four rates were used for the experiment. Each rate was replicated two times in a completely randomized design. The test was carried out in cans (15.3 cm diameter, 17 cm long), which were filled with 3.8 kg of well-mixed soil. The cans filled with soil were dropped 6 times on a level surface from a height of 2 cm to obtain uniform packing.

Table 1. Selected physical and chemical properties of Gila soil.

Soil Parameter	Gila Soil
pH	7.8
E.C. (ds/m)	0.52
Porosity (%)	43
B.D. (gm/cm ³)	1.51
Pore volume (cm ³)	1080.6
Texture	SL
Sand (%)	58.1
Silt (%)	31.4
Clay (%)	10.5

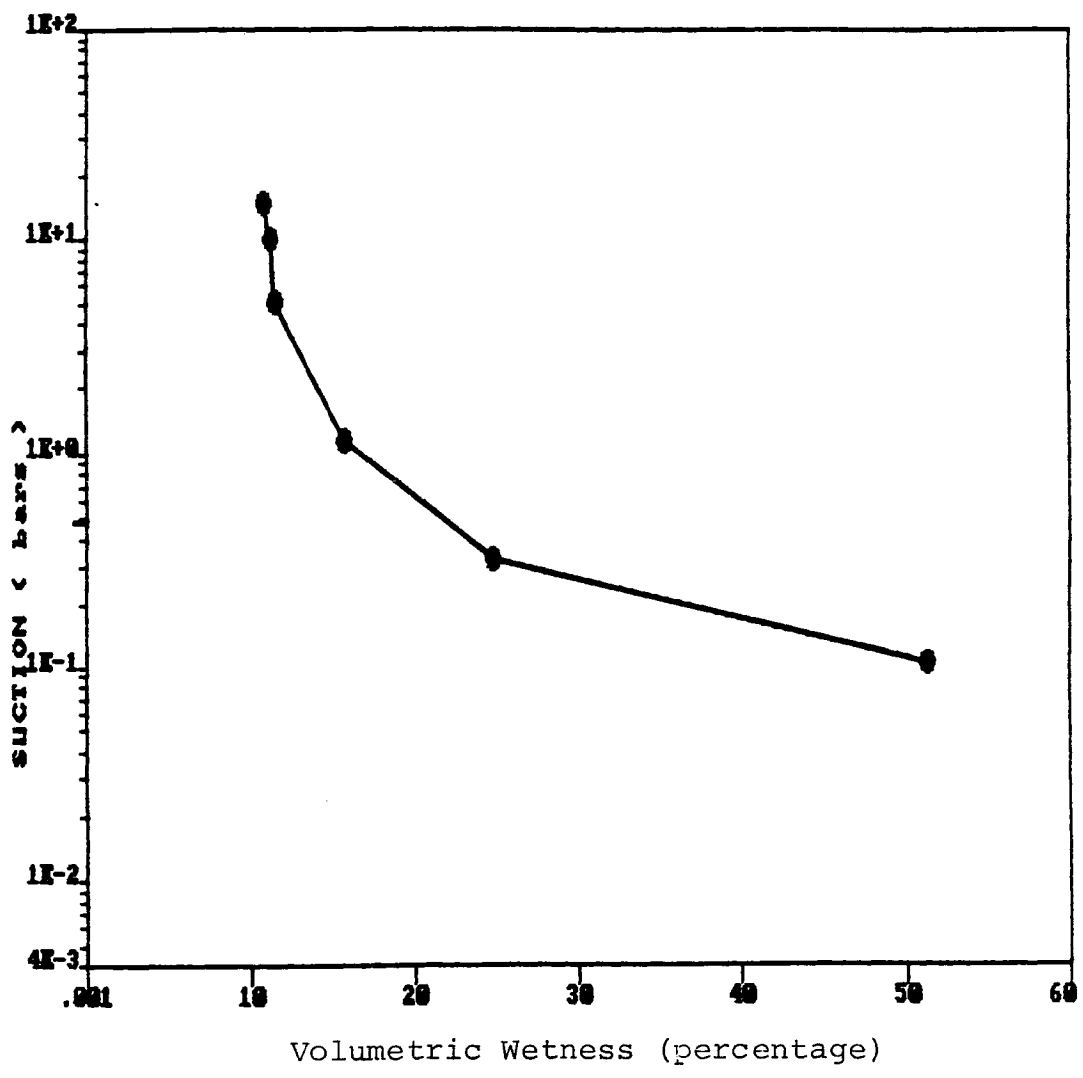


Figure 1. Soil moisture extraction curve for Gila soil (sandy loam soil).

After packing, the soil cans were wetted from the top to an initial volumetric water content of 24.42 percent, which accounted for about 75 percent of the total pore volume of the soil. To ensure uniform moisture for all columns, cans were covered with plastic (clear polyurethane cling wrap) to prevent evaporation (Figure 2). The soil cans were then allowed to equilibrate for 7 days. At the beginning of the test, the plastic cover was removed and mulch applied (Figure 3). The mulch treatments and application rates were:

<u>Mulch</u>	<u>Application Rate</u>
Wheat straw	20, 15, 10 and 5 gms
Wood shavings	20, 15, 10 and 5 gms
Rock fragments	100, 70, 50, 30 percent of surface
Control	No mulch

The wheat straw consisted of stem fragments 4 cm to 8 cm long. The wood shavings were bedding material of mixed pine and Douglas fir. The mulch was crushed rock ranging from 3 to 5 cm in diameter. The mulches were evenly distributed on the soil surface of each can. The equivalent tons/ha application for different rates of application was calculated by the following (Appendix A):



Figure 2. Evaporation reduced by packing cans with plastic.



Figure 3. Surface of soil can at field capacity at the beginning of experiment.

Diameter of cans = 15.3 cm

Surface area = 183.85 cm²

$$\begin{aligned} \text{Tons/ha} &= \text{application rate (gms)} \times \frac{1 \text{ kg}}{1000 \text{ gms}} \\ &\times \frac{10,000 \text{ m}^2}{1 \text{ ha} \times \text{area (0.018385 m}^2)} \times \frac{1 \text{ ton}}{1000 \text{ kg}} \end{aligned}$$

During the experimental period, air temperature, measured each day by a thermometer. Temperatures ranged from 49-52 C^o during the study period. After three days from starting, soil samples were taken at 0-3.5, 3.5-7, 7-10.5, and 10.5-14 cm from extra uncovered cans which were prepared to avoid disturbing the mulched cans. The samples were weighed before and after oven drying overnight at 105 C^o to determine moisture content. Sampling was repeated every two days at the same time; sampling was halted after 8 days when the 0 to 3.5 cm layer of soil reached wilting point (10 percent on volume) as indicated by the pressure plate results (Figure 4).

When 0-3.5 cm of soil in the extra test cans reached the wilting point, all cans in the experiment were sampled. Two replicate samples were taken in each can at depths 0-3.5, 3.5-7, 7-10.5, and 10.5-14 cm. Samples were sealed in soil cans with electrical type, transported to the



Figure 4. Surface of soil can at wilting point at the end of experiment.

laboratory, and the moisture content determined on a volumetric basis.

Analysis of variance (ANOVA) was used to test the effect of the mulch treatments and their application rate on soil moisture content at each of the four depths. Treatment means were compared using the least significant difference (LSD) and Student Newman-Keuls (SNK). The analysis used is listed in Appendix B.

CHAPTER 4

RESULTS AND DISCUSSION

The conservation of soil moisture is a function of several factors, such as depth of soil, surface residue cover, soil texture, and other factors. The application of mulches on soil conserves considerable amounts of water. However, moisture conservation is a dynamic process in which moisture is transferred downward in the soil profile, while water loss is taking place at the surface of the soil.

Straw Mulch

The profiles of mean moisture content under straw mulch are given in Figure 5 and Table 2. The profiles indicate that moisture content was higher under all applications of straw as compared with the control for all depths. Student-Newman Keul's test indicated the difference was significant between all treatments and the controls, with moisture content increasing with rates of application. There were no differences in soil moisture conservation between the 15 gm and 20 gm application rates. There was a significant difference between these application rates and both the 5 and 10 gm application rates. The

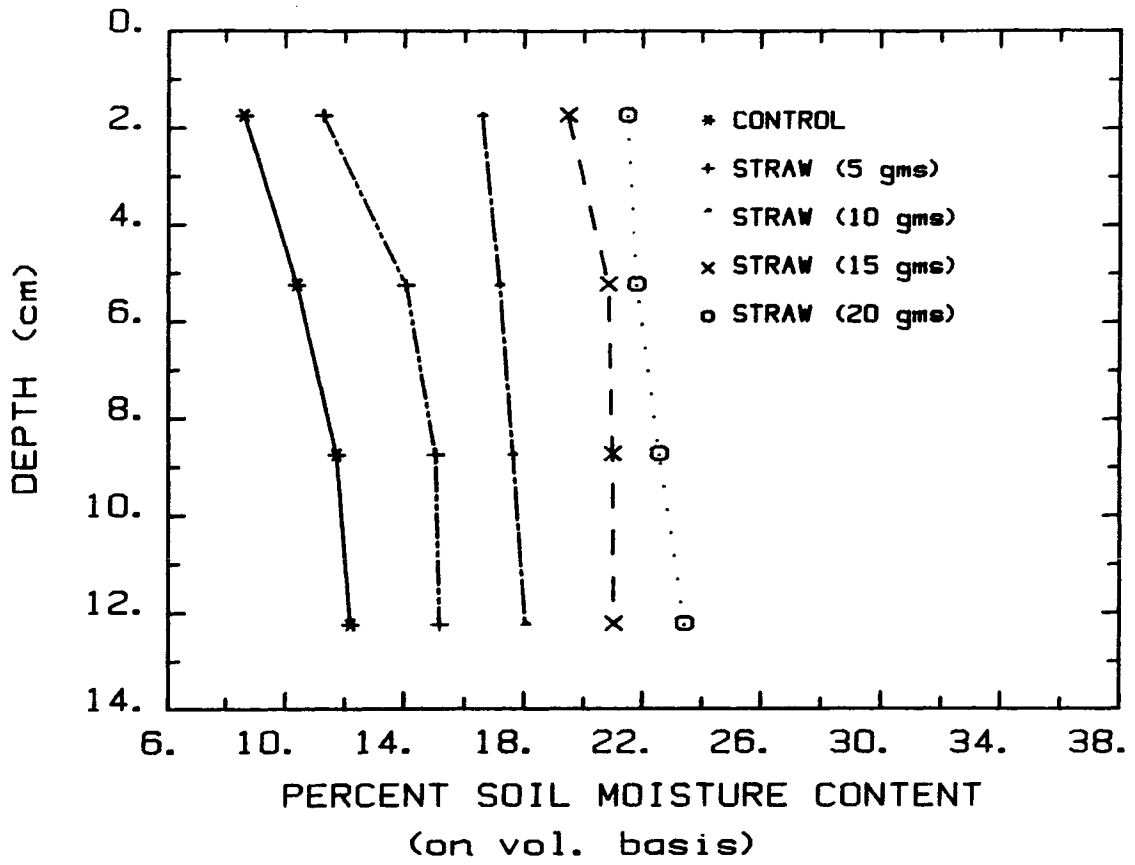


Figure 5. Percent soil moisture content remaining under straw mulch at different depths after eight days.

Table 2. Means of soil moisture content (on a volume basis) at different depths as affected by wheat straw mulching rates.

Treatment (gms/183.85 cm ²)	Depth (cm)				Mean*
	0-3.5	3.5-7	7-10.5	10.5-14	
	%	%	%	%	
Control	8.60	10.39	11.73	12.19	10.73a
20 gms	21.48	21.80	22.56	23.42	22.30d
15 gms	19.46	20.98	20.84	21.02	20.58d
10 gms	16.58	17.18	17.62	18.06	17.36c
5 gms	11.28	14.06	15.05	15.19	13.89b
Mean	15.48w	16.86x	17.56x	17.98x	

* Mean values accompanied by the same letters are not different at the 5% level of significance.

difference between the 5 and 10 gm rates was also significant.

The analysis also indicates that there were no significant differences in the mean moisture content of the 3.5-7, 7-10.5, and 10.5-14 cm depths for all application rates. But, the data show that application rates of 20, 15 and 10 gms resulted in higher soil moisture contents than 5 gm rate and the control for all depths. At the end of the experiment, the 20 gm, 15 gm and 10 gm of straw mulch still had 22.3 percent, 20.58 percent, and 17.36 percent moisture content (on a volume basis), whereas the soil in the control was only 10.73 percent. Soil moisture content was significantly higher for the 3.5-7, 7-10.5 cm and 10.5-14 cm depths than 0-3.5 cm for all treatments.

The indicated differences between moisture contents under different treatments is attributed to difference in the rates of the applied straw mulch. All applications of straw resulted in higher soil moisture content than the control.

Wood Shavings

The profiles of mean moisture content influenced by wood shavings mulch rates for different depths are given in Figure 6 and Table 3. The profiles shown in Figure 6 indicate that accumulated moisture in the upper soil layer under 20 gm of wood shavings was greater than the moisture

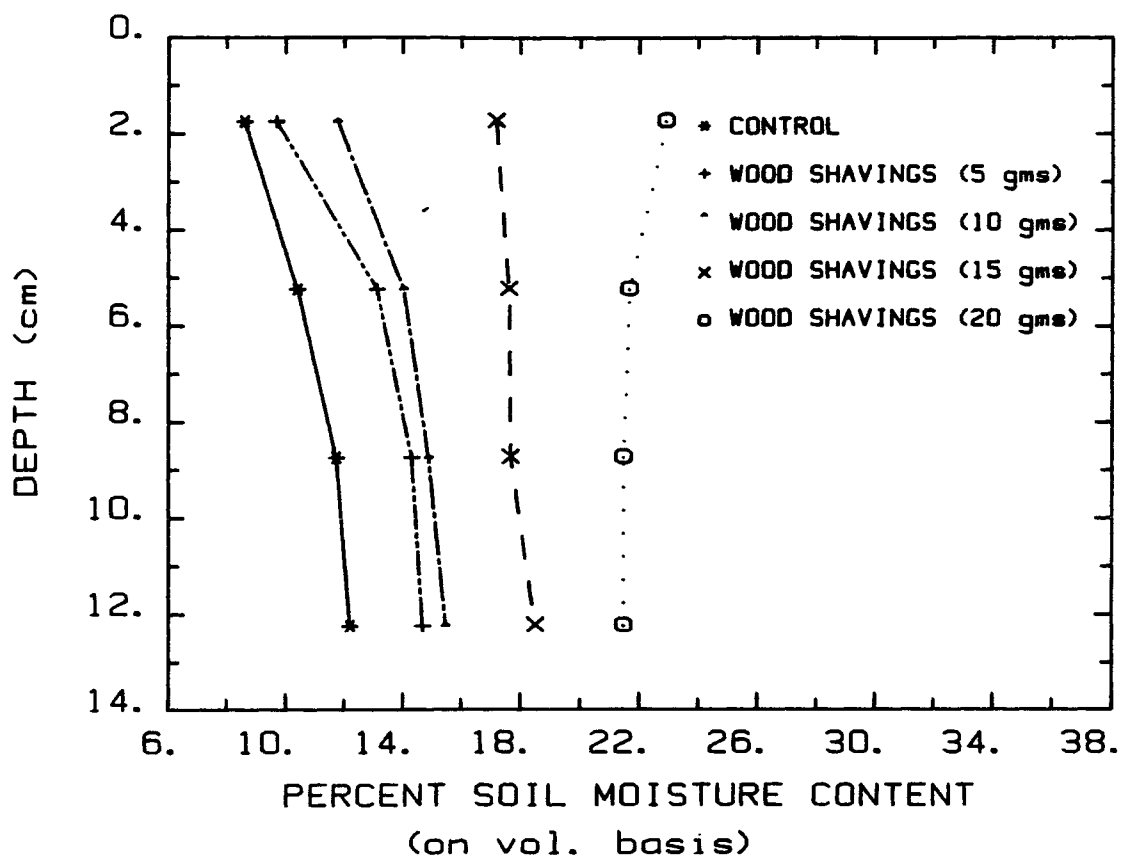


Figure 6. Percent soil moisture content remaining under wood shavings mulch at different depths after eight days.

Table 3. Means of soil moisture content (on a volume basis) at different depths as affected by wood shavings mulching rates.

Treatment (gms/183.85 cm ²)	Depth (cm)				Mean*
	0-3.5	3.5-7	7-10.5	10.5-14	
	%	%	%	%	
Control	8.60	10.39	11.73	12.19	10.73a
20 gms	22.90	21.66	21.46	21.47	21.94d
15 gms	17.18	17.61	17.67	18.59	17.74c
10 gms	11.77	14.03	14.87	15.47	14.04b
5 gms	9.68	13.12	14.29	14.67	12.94b
Mean	14.03w	15.36x	16.00x	16.46x	

* Mean values accompanied by the same letters are not different at the 5% level of significance.

content at lower levels. A similar finding was reported by Dunn et al. (1952). This might be due to a high moisture absorbing ability of sawdust. In contrast, moisture content was uniform for all depths under 15 gm of wood shavings. At the lower application rates, soil moisture increased with depth.

Soil moisture content at the 0-3.5 cm depth was lower under 10 gm and 5 gm of wood shavings than under 20 gm and 15 gm. The more direct contact between the soil surface and the air layer could be the reason for the lower moisture content under low rates of application (Kill and Foot, 1971). The analysis summarized in Table 3 indicates that soil moisture was significantly higher under 20 gm of wood shavings than under the other treatments. It is apparent from the data that moisture content is related to the thickness and absorptivity of the wood shaving layer. There were also no significant differences in soil moisture content between 10 gm of wood shavings mulch and 5 gm of mulch, while there were significant differences in soil moisture between 0-3.5 cm and other depths.

The soil moisture content was significantly higher for all mulches than for the control with moisture content being higher as the rate of application increased. However, there were no differences between the 5 and 10 gm application rates.

Rock Fragments

There was a general decrease in the moisture content under low application rates of coarse fragment mulch, but the moisture profiles were relatively uniform under high application rates (Figure 7 and Table 4). The analysis indicated that there was no significant difference between 30 percent cover and the control (Table 4). There was no significant difference in soil moisture between 100 percent and 70 percent surface cover, but there were significant differences between these application rates and the other treatments. Moisture content for the 50 percent application rate was significantly different from all other application rates.

The decrease of soil moisture content with the decrease in surface cover; this may be attributed to the amount of exposed soil between the stones. The analysis given in Table 4 indicates that there was no significant difference among treatments for 7-10.5, 10.5-14 cm depths; but, there were significant differences between 0-3.5 and 7-10.5 and 10.5-14 cm depths, while there were no significant differences between depths below the 3.5-7 layer. The soil with 100 percent, 70 percent applications had moisture contents of 20.86 percent and 19.31 percent, whereas the soil of the control and 30 percent cover had only 10.73 percent wilting point, and 11.98 percent, respectively.

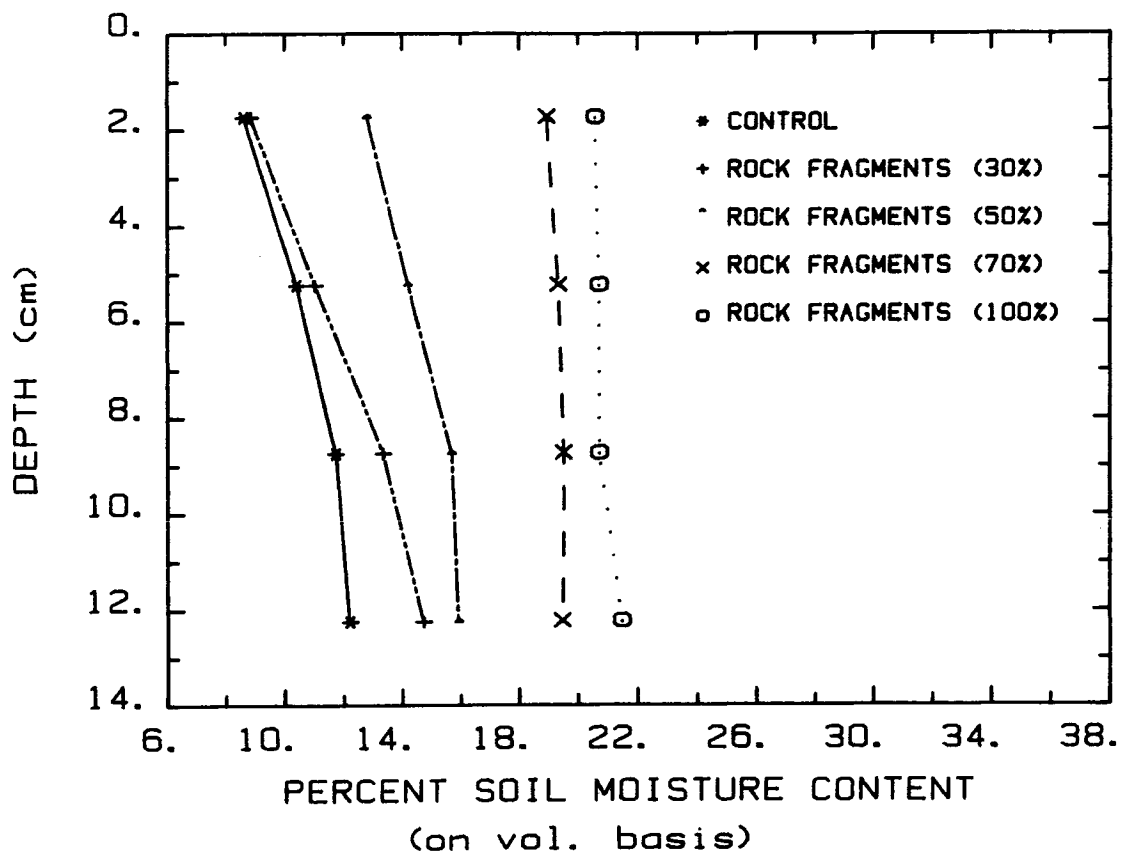


Figure 7. Percent soil moisture content remaining under rock fragments mulch at different depths after eight days.

Table 4. Means of soil moisture content (on a volume basis) at different depths as affected by rock fragments cover rates.

Treatment (%/183.85 cm ²)	Depth (cm)				Mean*
	0-3.5	3.5-7	7-10.5	10.5-14	
	%	%	%	%	
Control	8.60	10.39	11.73	12.19	10.73a
100% cover	20.57	20.71	20.72	21.45	20.86c
70% cover	18.93	19.33	19.51	19.45	19.31c
50% cover	12.78	14.19	15.69	15.91	14.65b
30% cover	8.83	11.03	13.35	14.72	11.98a
Mean	13.94w	15.13wx	16.20x	16.75x	

* Mean values accompanied by the same letters are not different at the 5% level of significance.

Apparently, a rock fragment cover that exposes more than 50 percent of the soil is ineffective.

Comparison of Mulch Treatments

For the lightest application rates of mulches, the analysis of the moisture profiles, given in Table 5, indicates that no significant difference was found between straw, wood shavings and rock fragments, but there was a significant difference between straw, wood shavings and the control. On the other hand, no significant difference was found between the rock fragment treatments, and the control. The moisture content was low for all treatments because the soil cover did not greatly reduce evaporation. The soil surface was in more direct contact with the air interface. Figure 8 indicates that there was no marked difference in the soil moisture content between 5 gm of straw, 5 gm of wood shavings, and 30 percent of rock fragments for 3.5-7, 7-10.4 and 10.4-14 cm depths. Apparently, the light mulch treatments had little effect, but after the soil surface layer became dry, it acted much as mulch to reduce moisture loss from the lower layer. Hanks and Woodruff (1958) have observed similar cases.

At heavier applications of mulch, the analysis given in Table 6 indicates that there was a significant difference between straw and all other treatments. There was no significant difference between wood shavings and rock

Table 5. Means of soil moisture content (on a volume basis) at different depths as affected by lightest application of mulching materials.

Depth in cm	Level of Treatment Application				Mean*
	Control (0)	Straw (5 gm)	Wood Shavings (5 gm)	Rock Fragments (30 %)	
	%	%	%	%	
0-3.5	8.60	11.28	9.68	8.83	9.59w
3.5-7	10.39	14.06	13.12	11.03	12.15x
7-10.5	11.73	15.05	14.29	13.35	13.61x
10.5-14	12.19	15.19	14.67	14.72	14.20x
Mean	10.73a	13.89b	12.94b	11.98ab	

* Mean values accompanied by the same letters are not different at the 5% level of significance.

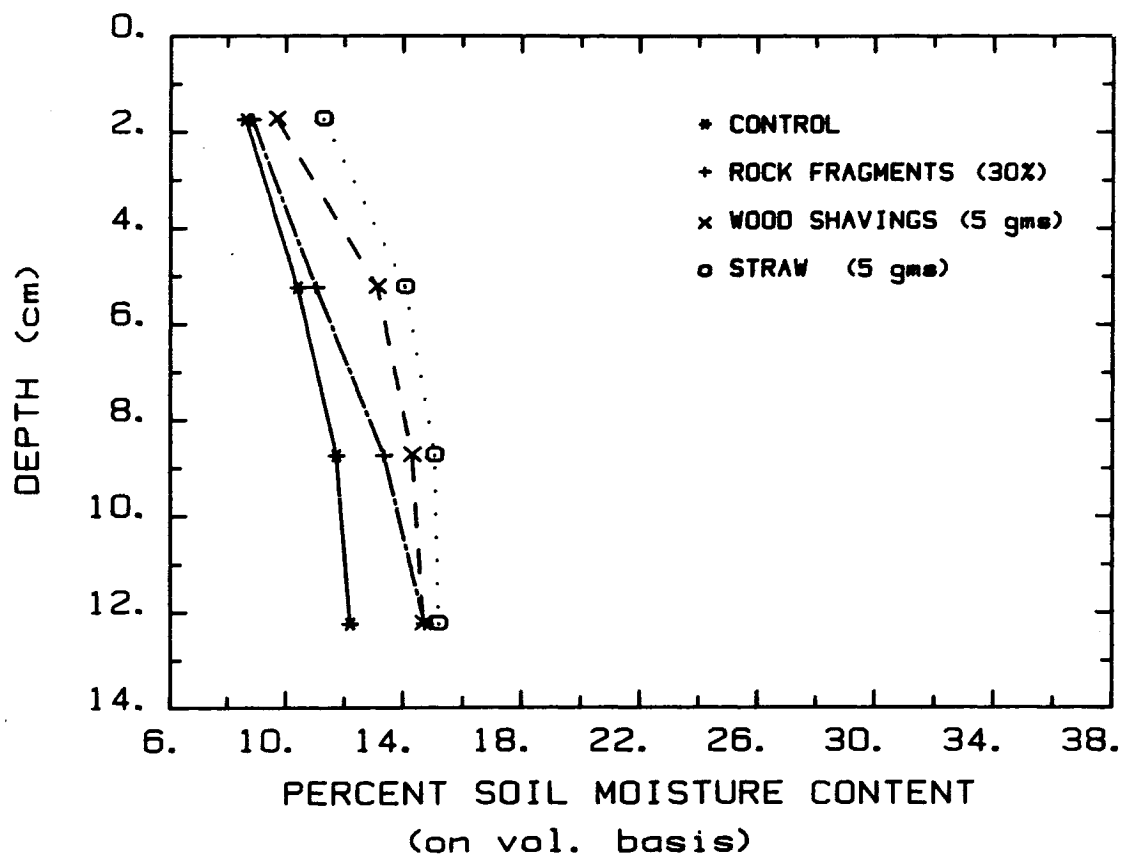


Figure 8. Difference in soil moisture under lightest application rate of mulches at different depths.

Table 6. Means of soil moisture content at different depths as affected by heavier application rate of mulching materials.

Depth in cm	Level of Treatment Application				Mean*
	Control (0)	Straw (10 gm)	Wood Shavings (10 gm)	Rock Fragments (50%)	
	%	%	%	%	
0-3.5	8.60	16.58	11.77	12.78	12.44w
3.5-7	10.39	17.18	14.03	14.19	13.95x
7-10.5	11.73	17.62	14.87	15.69	14.98x
10.5-14	12.19	18.06	15.47	15.91	15.41x
Mean	10.73a	17.37c	14.04b	14.65b	

* Mean values accompanied by the same letter are not different at the 5% level of significance.

fragments, but the difference between these treatments and the controls was significant. The moisture content of soil from different depths of soil cans at the end of the experiment shows marked differences between straw and rock fragments for both 3.5-7 and 7-10.5 cm depths. And, there was also a marked difference in soil moisture content between straw and wood shavings for the same depths (Figure 9).

Considering moisture content with depth, the straw mulch had a uniform moisture profile with depth under 10 gm of straw. The other mulches produced differences no longer than 3.8 percent at each depth. The higher moisture content under the straw should be expected to reduce soil surface contact with the layer above and reduce soil temperature.

Statistically, there was no significant difference in moisture content between 0-3.5, 3.5-7 cm depth under all treatments, but there was a difference between straw with wood shavings and rock fragments.

The analysis of the soil moisture content at 15 gm and 70% surface cover of soil indicated a significant difference between treatments and control (Table 7). Also, the analysis indicated that wood shaving differed significantly from straw and rock fragment.

Wood shavings mulch had lower moisture content than straw due to less insulation between air surface and soil

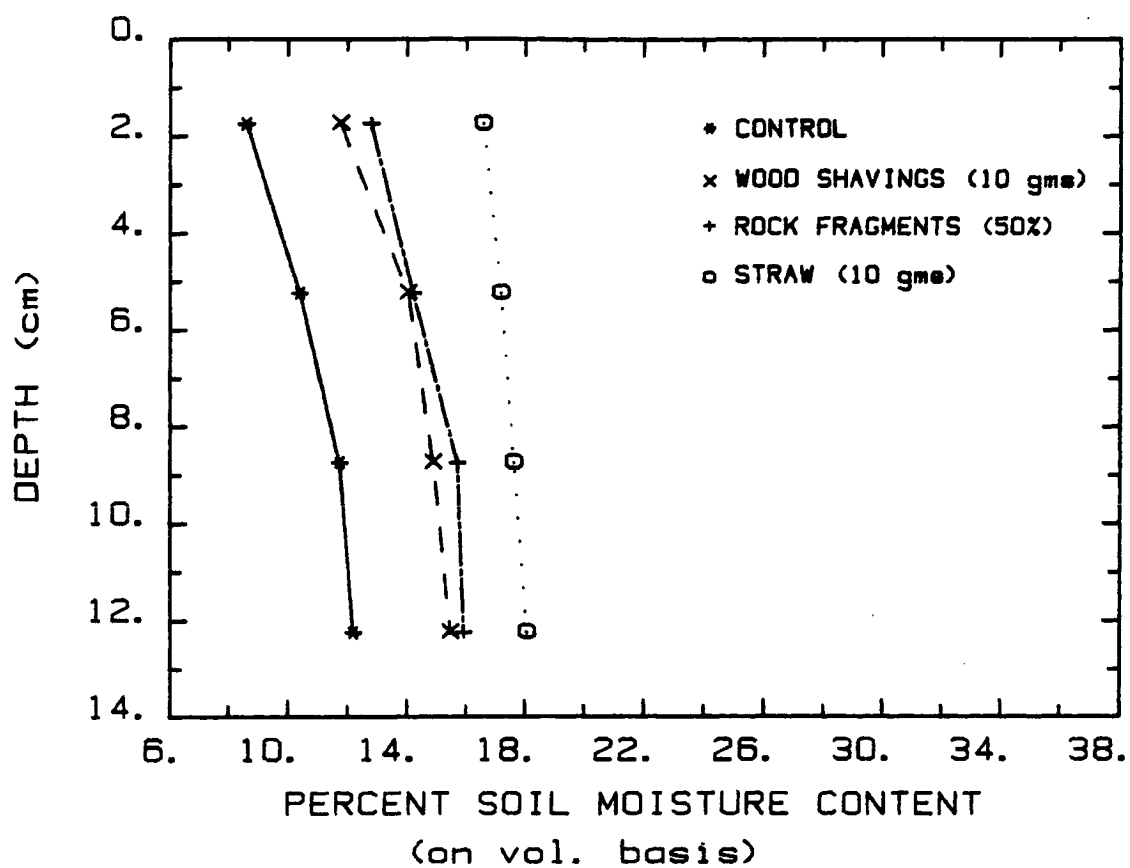


Figure 9. Difference in soil moisture under heavier application rate of mulches at different depths.

Table 7. Means of soil moisture content at different depth as affected by high application rate of mulching materials.

Depth in cm	Level of Treatment Application				Mean*
	Control (0)	Straw (15 gm)	Wood Shavings (15 gm)	Rock Fragments (70%)	
	%	%	%	%	
0-3.5	8.60	19.46	17.18	18.93	16.04x
3.5-7	10.39	20.84	17.61	19.33	17.04x
7-10.5	11.73	20.98	17.67	19.51	17.47x
10.5-14	12.19	21.02	18.50	19.45	17.80x
Mean	10.73a	20.58c	17.74b	19.31bc	

* Mean values accompanied by the same letters are not different at the 5% levels of significance.

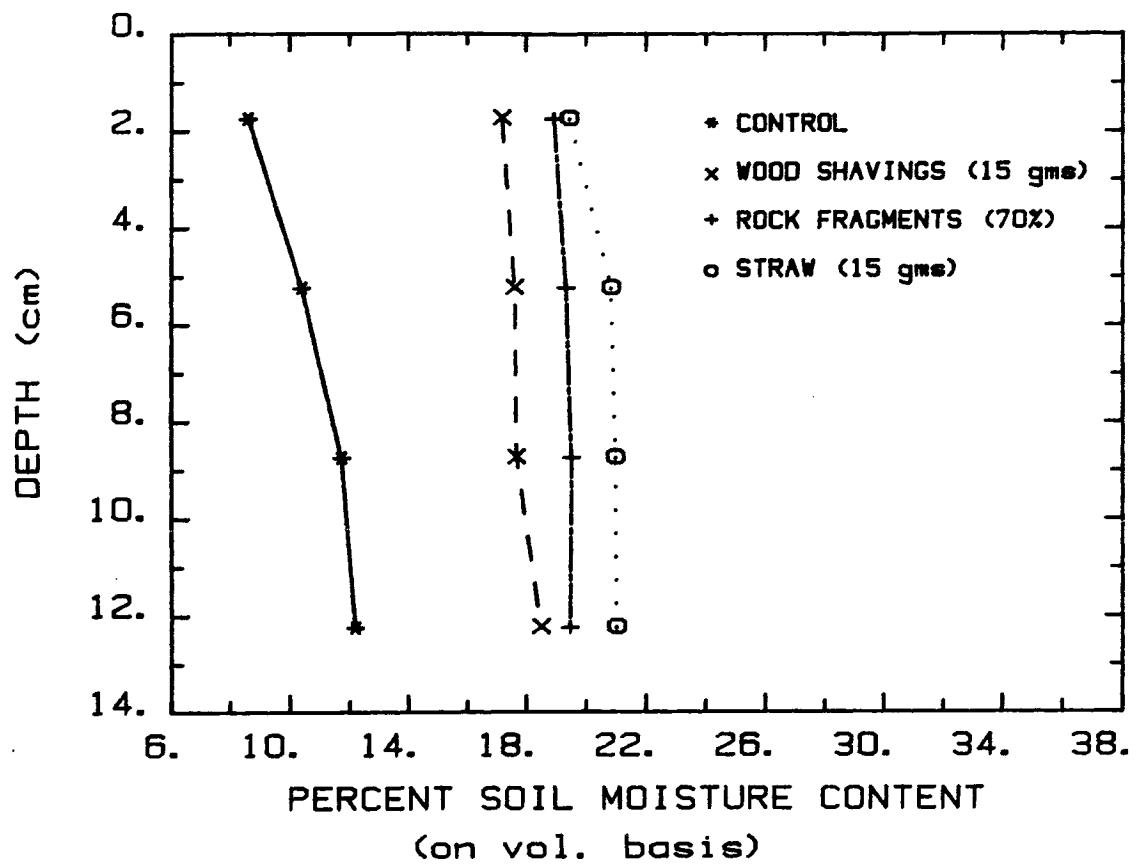


Figure 10. Difference in soil moisture under high application rate of mulches at different depths.

surface. Turk and Partridge (1947) suggested that this effect might be due to absorbed moisture content from beneath the mulch, particularly mulches of wood shavings, and a loss of moisture from the wood shavings itself (Figure 10). No significant difference was found between the straw and rock fragment mulches. At high mulching levels, the analysis given in Table 7 indicates that, statistically, there was no significant difference between depths under any of the mulch treatments; but, that there were differences in soil moisture content between straw and wood shavings for all depths except at the 3.5-7 cm depth. Moisture content also was different between rock fragments and wood shavings for all depths except for the 10.5-14 cm depth.

At the highest application rates the analysis given in Table 8 showed no significant difference between the treatments but a significant difference between treatments and control. There was a marked difference in moisture content between straw and rock fragment for all depths.

The data indicated that soil moisture content was higher under wood shavings than under straw and rock fragments for 0-3.5 cm depth for the reason previously mentioned. But, soil moisture was higher under straw than wood shavings for 7-10.5 and 10.5-14 cm depths.

The thickness of cover could be the major reason for higher moisture content of soil under all mulches. However,

Table 8. Means of soil moisture content at different depths as influenced by highest application rate of mulching materials.

Depth in cm	Level of Treatment Application				Mean*
	Control (0)	Straw (20 gm)	Wood Shavings (20 gm)	Rock Fragments (100 %)	
	%	%	%	%	
0-3.5	8.60	21.48	22.90	20.57	18.39w
3.5-7	10.39	21.80	21.66	20.71	18.64w
7-10.5	11.73	22.56	21.46	20.72	19.12w
10.5-14	12.19	23.42	21.47	21.45	19.64w
Mean	10.73a	22.32b	21.87b	20.86b	

* Mean values accompanied by the same letters are not different at the 5% level of significance.

as the amount of applied cover materials increase, the moisture value increases. After 8 days, the straw, wood shavings, and rock fragments still had, respectively, 11.59 percent, 11.14 percent and 10.13 percent moisture content greater than in the control (Figure 11).

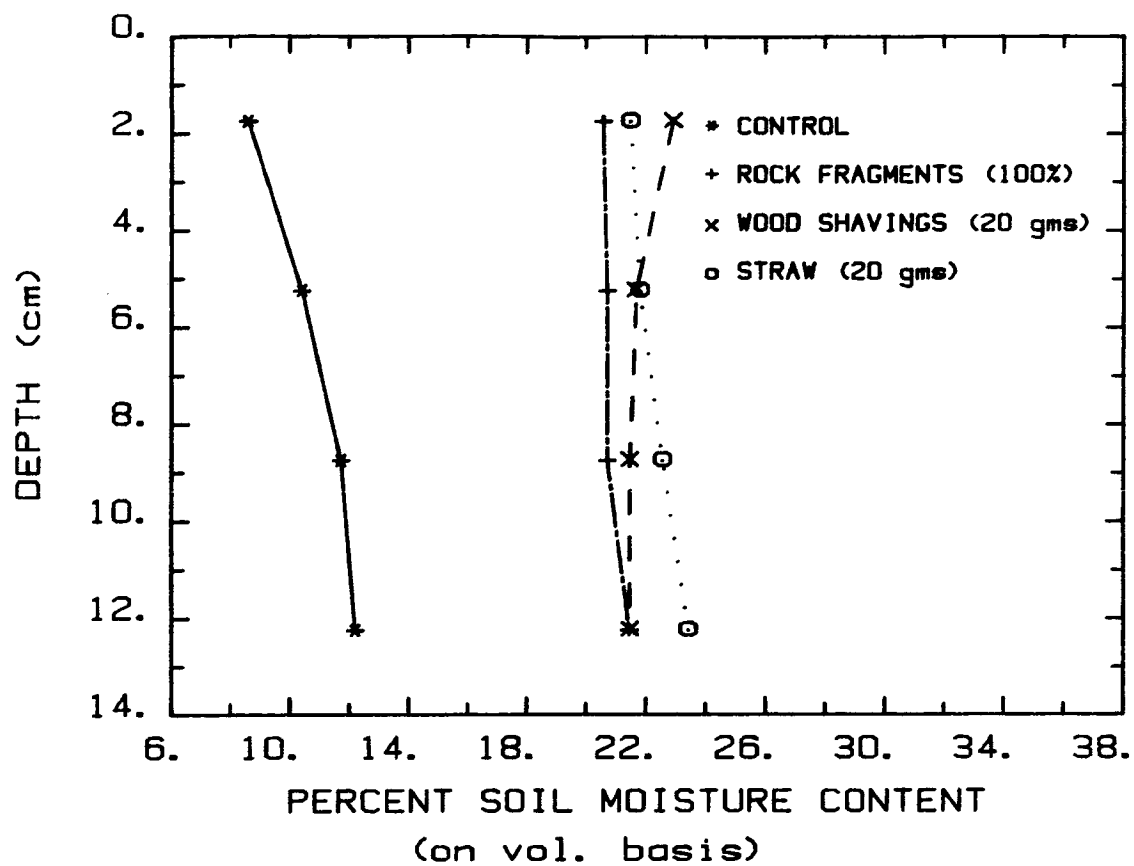


Figure 11. Difference in soil moisture under highest application rate of mulches at different depths.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

This experiment was conducted in 1986 at the University of Arizona to determine the effects on evaporation of various applications of three types of mulches and to study the changes in soil moisture content at different soil depths resulting from the application of these mulches. The soil used was Gila sandy loam. The mulches (straw, wood shavings, and rock fragments) were each applied at four different rates.

The effects of the mulches on soil moisture content were significantly different among the different types of mulches. The soil moisture content also varied with the application rate of the mulches. At the heavier applications, all mulches resulted in an increase in soil moisture content. In general, soil moisture increased as the rates of application increased, but low rates of application did not significantly affect soil moisture loss, particularly at the soil surface. Moisture content was also more uniform with soil depth under the higher rates of application.

It is likely that one or more of the following factors contributed to the result: diffusion rate of soil

water, reduced soil temperature, improved organic matter, and reduced direct solar radiation at the soil surface.

Conservation of soil moisture with mulch treatments could contribute to increased production of crops. Moisture content was distributed uniformly with depth under 10 gms of straw, while it remained close to field capacity at 10.5 to 14 cm below the soil surface under 20 gms of straw. The effect was more pronounced with straw than with rock fragments and wood shavings.

Straw appeared to be the most effective treatment. Significant effects on soil moisture were obtained at application rates of 5.4 tons/ha. Application rates of 8.2 tons/ha were required to demonstrate a significant effect of wood shavings. Rock fragment mulch required an application rate of 70% surface cover.

The study was carried out at daytime air temperature averaging from 49 °C to 52°C. It is assumed that the straw mulch reduced direct solar radiation and lowered soil temperatures more effectively than the other mulches at moderate application rate. It is possible that wood shaving and rock fragment mulches were not as effective as straw because of the more direct soil surface contact with air.

For the 8-day trial under straw mulch application rate of 2.7, 5.4, 8.2 and 10.9 tons/ha of straw, the savings in water were 250.5, 313, 371 and 403 m³ of water/ha,

respectively. One ton of straw costs about \$118. In contrast, one ton of wood shavings cost \$302.17. The water savings under 2.7, 5.4, 8.2 and 10.9 tons/ha of wood shavings was 233.5, 253, 320 and 395.83 m³/ha, respectively. Rock fragments are expensive to collect and transport, although they are usually plentiful in arid areas. This is sufficient to limit the cost effectiveness of using rock fragments in conserving soil moisture. It appears that straw mulch saves more water per hectare at a lower cost than the other mulches used in the study.

The estimated savings from the use of straw and wood shavings are given in Tables 9 and 10. The cost of irrigation water was estimated from personal observation in Saudi Arabia. The simulated may be low. Total cost of irrigation water for the Central Arizona Project has been estimated at 7 cents/m³ (Bush et al., 1986) for 1986. The savings given in the tables are for the eight days of the study starting at field capacity. Actual savings over a longer period would be expected to be higher. This is apparent from the estimates given in Tables 9 and 10.

The straw mulch is more cost effective than is the wood shavings treatment. Cost effectiveness drops as application rate exceeds 2.7 tons/ha. Application rate of 2.7 tons/ha mulch appears to yield the greatest savings in

Table 9. Costs and savings using wheat straw mulch.

Appli- cation Rates (tons)	Costs \$/ton	Water Savings (m ³)	Estimated Costs of Irrigation Water (\$/m ³)	Savings Within Mulch (\$)	Total Cost of Mulch (\$)	Net Benefit Per ha. (\$)
2.7	118	250.5	2.65	663.8	354	309.8
5.4	118	313.2	2.65	827.5	641.9	185.6
8.2	118	371.3	2.65	980.2	962.9	17.3
10.9	118	402.7	2.65	1063.9	1283.8	-219.9

Table 10. Costs and savings using wood shavings mulch.

Appli- cation Rates (tons)	Costs \$/ton	Water Savings (m ³)	Estimated Costs of Irrigation Water (\$/m ³)	Savings Within Mulch (\$)	Total Cost of Mulch (\$)	Net Benefit Per ha. (\$)
2.7	302	233.5	2.65	618	815.4	-197.4
5.4	302	253.2	2.65	670	1643.8	-973.8
8.2	302	320.1	2.65	848.3	2465.7	-1617.4
10.9	302	395.8	2.65	1048.9	3287.6	-2238.7

water and among the other treatments in this study. Additional data are needed to define more precisely the cost effectiveness of straw mulch. Further study is needed to determine water savings that might be obtained with other types of mulches and their cost effectiveness. Additional studies must also be carried out under actual field conditions.

APPENDIX A

CALCULATION OF THE EQUIVALENT TONS/HA FOR DIFFERENT
RATES OF STRAW AND WOOD SHAVINGS MULCHES

Calculation of the equivalent tons/ha for different rates of straw and wood shavings mulches.

Diameter of can = 15.3 cm

Radius of cans (r) = $\frac{15.3}{2}$ = 7.65 cm

Area of can = $3.1415927 \times r^2$
 $= 3.1415927 \times (7.65)^2$
 $= 183.85 \text{ cm}^2$

Convert area from cm^2 to m^2 = $\frac{183.85}{100 \times 100}$ = 0.018385 m^2

Straw mulch rates from gms/183.85 cm^2 to tons/ha.

for 20 gms

$$= 20 \text{ gms} \times \frac{1 \text{ kg}}{1000 \text{ gms}} \times \frac{10,000 \text{ m}^2}{1 \text{ ha} \times 0.018385 \text{ m}^2} \times \frac{1 \text{ ton}}{1000 \text{ kg}}$$

$$= \frac{200,000 \times \text{ton}}{18385 \times \text{ha}} = 10.88 \text{ tons/ha}$$

For 15 gms

$$= 15 \times \frac{10,000 \times 1 \text{ ton}}{18385 \times 1 \text{ ha}} = 8.16 \text{ tons/ha}$$

For 10 gms

$$= 10 \times \frac{10,000 \times 1 \text{ ton}}{18385 \times 1 \text{ ha}} = 5.44 \text{ tons/ha}$$

For 5 gms

$$= 5 \times \frac{10,000 \times 1 \text{ ton}}{18385 \times 1 \text{ ha}} = 2.72 \text{ tons/ha}$$

Wood shavings mulch rates from gms/183.85 cm² to tons/ha.

For 20 gms

$$= 20 \times \frac{10,000 \times 1 \text{ ton}}{18385 \times 1 \text{ ha}} = 10.88 \text{ tons/ha}$$

For 15 gms

$$= 15 \times \frac{10,000 \times 1 \text{ ton}}{18385 \times 1 \text{ ha}} = 8.16 \text{ tons/ha}$$

For 10 gms

$$= 10 \times \frac{10,000 \times 1 \text{ ton}}{18385 \times 1 \text{ ha}} = 5.44 \text{ tons/ha}$$

For 5 gms

$$= 5 \times \frac{10,000 \times 1 \text{ ton}}{18385 \times 1 \text{ ha}} = 2.72 \text{ tons/ha}$$

APPENDIX B

PERCENT SOIL MOISTURE CONTENT VARIANCE OF GILA SOIL
UNDER ALL TREATMENTS AT DIFFERENT DEPTHS

Table B.1. Percent moisture content variance of Gila soil as affected by straw mulch.

Source of Variation	Sum of Squares	DF	Mean Square	F
Subgroup (depth*application rate)	766.49	19	40.34	
Depth	36.03	3	12.01	5.94
Application rate	760.80	4	180.20	89.16
Interaction	9.66	12	.81	.40
Error	40.42	20	2.02	

Total	806.91	39		

Table B.2. Percent moisture content variance of Gila soil as affected by wood shavings mulch.

Source of Variation	Sum of Squares	DF	Mean Square	F
Subgroup (depth*application rate)	683.79	19	35.99	
Depth	33.73	3	11.24	5.51
Application rate	616.63	4	154.16	75.61
Interaction	33.43	12	2.79	1.37
Error	40.78	20	2.04	

Total	724.57	39		

Table B.3. Percent moisture content variance of Gila soil as affected by rock fragments mulch.

Source of Variation	Sum of Squares	DF	Mean Square	F
Subgroup (depth*application rate)	703.01	19	37.00	
Depth	46.08	3	15.36	8.10
Application rate	632.88	4	158.22	83.49
Interaction	24.05	12	2.00	1.06
Error	37.90	20	1.90	

Total	740.91	39		

Table B.4. Percent moisture content variance of Gila soil as affected by lightest application rate of mulches.

Source of Variation	Sum of Squares	DF	Mean Square	F
Subgroup (depth*treatments)	150.79	15	10.05	
Depth	100.85	3	33.62	14.79
Treatments	43.89	3	14.63	6.44
Interaction	6.04	9	.67	.30
Error	36.37	16	2.27	

Total	187.16	31		

Table B.5. Percent moisture content variance of Gila soil as affected by heavier application rate of mulches.

Source of Variation	Sum of Squares	DF	Mean Square	F
Subgroup (depth*treatments)	224.82	15	14.99	
Depth	41.90	3	13.97	6.07
Treatments	178.34	3	59.45	25.84
Interaction	4.57	9	.51	.22
Error	36.81	16	2.30	

Total	261.64	31		

Table B.6. Percent moisture content variance of Gila soil as affected by higher application rate of mulches.

Source of Variation	Sum of Squares	DF	Mean Square	F
Subgroup (depth*treatments)	484.71	15	32.31	
Depth	13.72	3	4.57	2.90
Treatments	463.50	3	154.50	97.65
Interaction	7.49	9	.83	.53
Error	25.32	16	1.58	

Total	510.02	31		

Table B.7. Percent moisture content variance of Gila soil as affected by highest application rate of mulches.

Source of Variation	Sum of Squares	DF	Mean Square	F
Subgroup (depth*treatments)	752.58	15	50.17	
Depth	7.28	3	2.43	1.68
Treatments	728.68	3	242.89	168.04
Interaction	16.62	9	1.85	1.28
Error	23.13	16	1.45	

Total	775.71	31		

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