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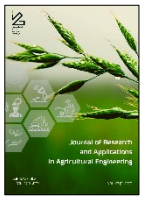

Impact of using different mulches on clay soil temperature, moisture, and saved water at AsSalt City-Jordan

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Mulch is applied to help retain soil moisture and to raise the soil temperature. This study was conducted to assess soil temperature, moisture, and the amount of water conserved under three mulch treatments—clear plastic, black plastic, and sawdust—compared with bare clay soil conditions in Jordan. Soil temperature and soil moisture were measured at three depths: 15, 30, 45 cm for each type for one month. Sawdust showed a highest average reading of moisture at 15 cm, the second was clear mulch followed by black mulch and at the lowest average for bare soil. he greatest amount of total water was conserved under the sawdust treatment. Soil temperature decreased with depth under the same type of mulch. Pearson Test showed a negative strong correlation between soil temperature and moisture for all treatment at (α= 0.01). Black mulch showed high correlation between temperature and moisture at depth of 30 cm. But sawdust and clear mulch showed high correlation at 15 cm soil depth. Two tailed t-test showed that clear mulch had non-significant differences at α = 0.05 and α = 0.01 for all factors except temperature at depth of 30 cm and 45 cm respectively. Black mulch and sawdust showed significant differences for temperature. Black had strong significant in positive direction, which mean increased soil temperature, but sawdust is negative. Saw dust was recommended to use after the winter, black was recommended to use in summer and clear was recommended to use during winter and early spring.

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1. Introduction

Mulch is applied by farmers as a layer of material spread over the soil surface to protect it from erosion, conserve soil moisture, suppress weed growth, and increase soil temperature. Different materials are commonly used as sawdust, wood chips, dried grass or large leaves such as banana or palm farms, and different type of plastic made from polyethylene (PE) can also be used [1]. When woody materials are used as mulch, soil microorganisms (bacteria and fungi) decompose this material and, in doing so, consume soil nitrogen that would otherwise be available for plant growth. So, nitrogen fertilizer should be added to avoid problems of plant growth related to lack of soil nitrogen. PE Plastic mulch is most expensive mulching material; although it is widely used by gardeners [7]. Mulch is an insulating barrier that protecting the structure of the soil at the surface from erosion and crusting over.

Recent studies have further emphasized the impact of mulch type on soil microclimate and water conservation. Zhang et al. [12] and Hailu Demo et al. [5] demonstrated that organic mulches such as sawdust are effective in improving soil moisture retention and cooling soil surfaces compared to synthetic mulches. Similarly, Kader et al. [13] and Chalker-Scott [3] highlighted that organic mulches support beneficial microbial activity and minimize evaporation, enhancing crop productivity and soil

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sustainability. Rajablariani et al. [10] and Xie et al. [11] reported a notable increase in soil temperature, with variations of plastic mulches depending on mulch color, local climate, and soil type.

The importance of using mulch is conserving moisture and protects soil from drying out, slowly releasing it into the soil for use by plants. Mulches also protect the soil from temperature variations and help to insulate the root zone from extremes of heat or cold [6]. Furthermore, the difference between day and night temperatures will be lower in a mulched soil. Mulch plays commonly used in planting processes because it is ease in use, reduce the period of planting, also it can be designed as we want in a local community.

According to the importance of mulch on soil temperature, moisture content, and other conditions of plant growth, the researchers were concerned with investigate and evaluate the uses of different types of mulch. Lerner [9] mentioned that applying the right type of mulch conserves soil moisture. Mulch can also cool the soil as well. He explained that mulch will control weeds problem and prevent the competition with plants for little available water in extremely dry conditions. Haddadin and Ghawi [4] compared clear and black plastic mulches at the university of Jordan research station in the Jordan Valley. They reported that highest values of soil temperature were under clear plastic followed by black plastic and bare soil. They concluded that black and clear plastic mulch respectively reduced significantly, the water consumptive, also significantly increased the soil temperature. But in 1986 Battikhi and Ghawi [2]concluded that there were no significant differences among clear, black and non-mulched treatments related to irrigation amounts, soil moisture content, and soil water distribution horizontally nor vertically, were not significantly different among treatments. This study established to evaluate the effect of three types of mulch; clear plastic, black plastic, and sawdust, on soil temperature, moisture content and saved water versus bare soil to determine which one of them is the best, since the proper usage of the right kind of mulch can be useful for soil by reduce the amount of irrigation's water required, through moderation of soil temperature and decrease evaporation especially in water poor country as Jordan.

2. Material and methods

This study was conducted in Al Balqa Applied university campus at Assalt city of Jordan. The study area was 4000000 cm^2 divided in to four equal plots as shown in Figure 1. Soil texture was determined using a soil sample collected from the centre of each of the four plots. All treatments were ploughed and received similar amount of water about 700000 cm^3. After 2 days the centre of each plot was drilled by Auger at 50 cm depth and 5 cm in diameter; plastic tube was inserted inside the holes in the middle of each plot for measuring soil temperature and moisture, taking in consideration that soil should tamping well around these tubes to give the real moisture of soil. Four treatments were used: (1) 0.01 cm thickness of clear plastic mulch, (2) 0.01 cm thickness of black plastic mulch, (3) 2 cm-thickness of sawdust (wood shaving made from carpentry scraps), and (4) bare soil.

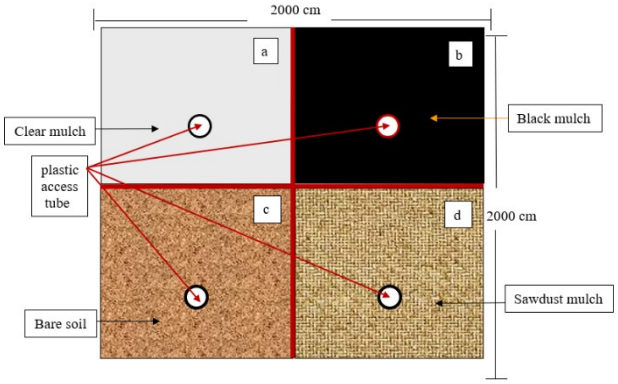

Fig. 1. Field experimental Site shows four treatments:
(a) clear plastic
(b) black plastic (c) bare soil (d) saw dust mulch

ECOSCAN pH5 digital thermometer was used to measure soil temperature. TDR (TRIME-FM) was used to measure soil moisture content [8]. All of these measurements were carried out at three depths: 15, 30, 45 cm for each plot daily at 2:00 pm for one-month (May 1 to May 31 of 2024), where the maximum temperatures generally ranged between approximately 27 and 33 degrees Celsius during the day, while the minimum temperatures were generally between 16 and 21 degrees Celsius at night. As for the atmospheric humidity, it ranged during the daytime hours between 40% and 65%, with a relative increase during the night hours to often reach 70% or higher, especially on cloudy or dewy days. Paired sample t-test by using SPSS analysis at ($\alpha = 0.05$) to show the significant value for each soil moisture and temperature for different type of mulch compared with bare soil as a control as. A Pearson correlation statistical analysis was required to determine if there were correlation between depth with soil moisture and temperature under each type of treatment.

3. Result and Discussion

3.1. Soil Texture

The result of soil samples showed that all plots are clay soil in general but different percentages for each sample. The soil analysis was 50% clay, 36% silt and 14% sand for plot A, 46% clay, 40% silt and 14%sand for plot B, 57% clay, 22% silt and 21% sand for plot C and 51% clay, 31% silt and 18% sand for plot D.

3.2. Soil moisture content

The results in Table 1 showed accumulated increasing of soil water content readings along days of the month for all treatment sawdust, clear and black that used versus of bare soil, with some differences were showed in water content according to the type of mulch. Also, soil moisture content decreased by depth in different percentages according mulch type as shown in Figure 2.

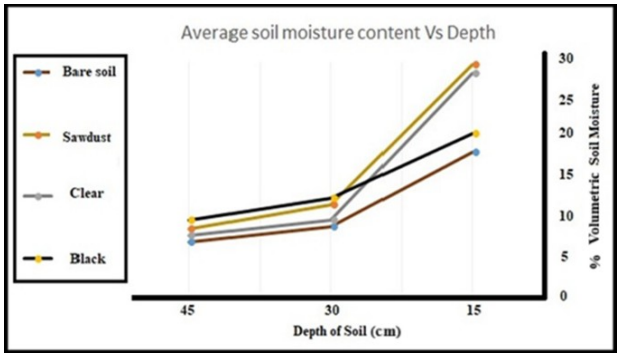

Fig. 2. Average soil moisture Vs. Depth of soil under all treatment

Sawdust showed a highest average of moisture at 15 cm of soil; the second one was for a clear mulch then followed by the black mulch and at the tail of arrangement was bare soil. The reason of these differences between mulches, because of the differences in mulch functions. Sawdust prevents passing of sun light to the soil surface, so the soil temperature was less than other mulch treatments, and the evaporation rate was lower too, so on this meant highest moisture. While clear-mulch worked as a greenhouse, it allowed passage of sun light to soil layer and prevented the vapor of evaporation process that resulted from increasing of soil temperature to go outside the mulch layer. Because of these processes the vapor condensate on the inner surface of the clear mulch at upper part of soil causing increasing of moisture at this depth than other mulches. The decreasing of moisture at 15 cm under black mulch, was resulted by heated the top layer of soil by conduction process which increased the evaporation at these layers, that led decreasing in soil moisture content.

A bare soil moisture content was the lowest. Because it wasn't covered by any mulch, the top layer heated directly, led the evaporation to be highest, so on the soil moisture decreased. Also, Figure 2 showed differences in soil moisture by the depths, 30 and 45 cm. The order of soil water content was as following: black > sawdust > clear > bare soil. The black was more efficient in conserving water content at these depths. Because it heated by conduction process, which meant increasing soil temperature at surface more than deeper layers.

So, the evaporation could be neglected at these depths, and so on moisture content was increased. In other side, the sawdust prevent the sun light to reach to the deep layers so, it wasn't heated enough; this made an evaporation to be less and water content higher there. Under clear mulch, soil layer heated by convection, which meant that the sunlight reached to deep layer, which increased temperature and evaporation rate respectively, so the moisture content decreased.

3.3 Volume of Saved Water

The volume of soil water content at each depth for each type of mulches could be expressed as the following equation:

$$\theta\_v \times A \times D = V \quad (1)$$

Where θ_v = average volumetric water content at each depth for each treatment plot, D = depth of measuring θ_v (15, 30 and 45 cm), A = area of each treatment plot, V = volume of soil water content (m^3). To determine which type of mulch is the best; saved water for each treatment was calculated by calculating the difference between volume of soil water content at each depth for each type of mulches and volume of soil water content at each depth for bare soil. Total saved water was equal summation of saved water for each depth for each type as shown in Table 2. The higher value of total saved water for sawdust.

Table 1. All reading for soil Temperature and soil moisture for all treatment at all depth along study period (1 May to 31 May)

Bare soil		1-May	2-May	3-May	4-May	5-May	6-May	7-May	8-May	9-May	10-May	11-May	12-May	13-May	14-May	15-May	16-May	17-May	18-May	19-May	20-May	21-May	22-May	23-May	24-May	25-May	26-May	27-May	28-May	29-May	30-May	31-May
15 cm	Temp.	21.2	21.6	22.1	22.9	23.5	24.0	24.7	25.4	26.1	26.8	27.6	28.2	29.0	29.8	30.4	31.0	31.7	32.5	33.3	34.0	34.9	35.7	36.3	37.0	37.8	38.5	39.3	39.8	40.2	40.7	41.0
	Moist.	19.0	19.2	19.3	19.5	19.7	19.8	19.9	20.1	20.2	20.3	20.5	20.7	20.8	21.0	21.2	21.3	21.5	21.7	21.8	22.0	22.1	22.3	22.5	22.6	22.8	23.0	23.1	23.3	23.5	23.6	23.8
30 cm	Temp.	19.7	20.3	20.6	21.0	21.7	22.4	22.8	23.3	23.9	24.5	25.1	25.6	25.9	26.4	27.0	27.3	27.8	28.6	29.1	29.8	30.3	30.7	31.1	31.8	32.2	32.9	33.3	33.6	33.9	34.1	34.3
	Moist.	9.0	9.1	9.1	9.2	9.3	9.3	9.4	9.5	9.5	9.5	9.6	9.8	9.8	9.9	9.9	9.9	10.0	10.0	10.1	10.2	10.3	10.3	10.4	10.5	10.5	10.6	10.7	10.7	10.8	10.9	11.0
45 cm	Temp.	17.2	17.5	17.7	17.9	18.3	18.9	19.2	19.6	20.0	20.4	20.9	21.4	21.7	22.2	22.8	23.1	23.6	24.0	24.7	25.3	26.0	26.2	26.5	26.8	27.0	27.3	27.6	27.8	28.1	28.3	28.4
	Moist.	5.8	5.6	5.5	5.4	5.3	5.2	5.2	5.1	5.0	5.0	4.9	4.8	4.7	4.6	4.4	4.3	4.1	4.0	3.9	3.7	3.5	3.3	3.1	3.0	2.8	2.7	2.6	2.6	2.5	2.4	2.0

Clear		1-May	2-May	3-May	4-May	5-May	6-May	7-May	8-May	9-May	10-May	11-May	12-May	13-May	14-May	15-May	16-May	17-May	18-May	19-May	20-May	21-May	22-May	23-May	24-May	25-May	26-May	27-May	28-May	29-May	30-May	31-May
15 cm	Temp.	24.5	24.7	25.0	25.3	25.6	25.8	26.0	26.3	26.5	26.7	27.0	27.2	27.4	27.8	28.1	28.5	28.9	20.2	29.5	29.7	29.9	30.2	30.4	30.7	31.0	31.4	31.6	31.6	31.8	31.9	32.0
	Moist.	33.4	33.1	32.8	32.7	32.5	32.3	32.0	31.9	31.8	31.6	31.4	31.2	30.9	30.7	30.5	30.3	30.1	29.8	29.6	29.5	29.3	29.1	28.9	28.6	28.5	28.3	28.2	27.9	27.8	27.6	27.4
30 cm	Temp.	22.4	22.8	23.1	23.5	23.8	24.1	24.3	24.6	24.8	25.2	25.5	25.7	26.0	26.4	26.7	26.9	27.1	27.3	27.6	27.9	28.2	28.5	28.9	29.1	29.3	29.6	30.0	30.4	30.8	31.1	31.3
	Moist.	13.1	12.9	12.8	12.6	12.5	12.4	12.2	11.9	11.8	11.6	11.5	11.3	11.1	10.9	10.8	10.6	10.4	10.2	10.1	10.0	9.9	9.8	9.6	9.5	9.5	9.4	9.3	9.1	9.0	8.9	8.7
45 cm	Temp.	19.2	19.5	19.7	20.0	20.3	20.5	20.8	21.2	21.4	21.6	21.9	22.1	22.3	22.5	22.8	23.0	23.2	23.5	23.7	23.9	24.2	24.4	24.7	25.0	25.2	25.4	25.8	26.1	26.3	26.4	26.5
	Moist.	9.6	9.5	9.4	9.2	9.1	8.9	8.8	8.6	8.5	8.3	8.1	8.0	7.9	7.8	7.7	7.6	7.5	7.5	7.4	7.4	7.4	7.3	7.2	7.2	7.2	7.1	7.1	7.0	7.0	6.9	6.9

Black		1-May	2-May	3-May	4-May	5-May	6-May	7-May	8-May	9-May	10-May	11-May	12-May	13-May	14-May	15-May	16-May	17-May	18-May	19-May	20-May	21-May	22-May	23-May	24-May	25-May	26-May	27-May	28-May	29-May	30-May	31-May
15 cm	Temp.	22.3	22.6	23	23.7	24.2	24.7	25	25.8	26.8	27.5	28.2	28.9	29.7	30.5	31.0	31.4	32.0	32.8	33.6	34.1	34.9	35.7	36.3	37.0	37.9	38.8	39.6	40.2	40.9	41.4	41.8
	Moist.	30.8	30.6	30.5	30.3	30.1	29.9	29.8	29.6	29.5	29.3	29.1	29.0	28.8	28.6	28.4	28.2	28.0	27.9	27.6	27.5	27.3	27.2	27.0	26.8	26.6	26.4	26.1	25.8	25.5	25.3	25.0
30 cm	Temp.	20.1	20.6	21	21.3	21.8	22.1	22.7	23.1	23.5	23.9	24.4	24.8	25.2	25.5	25.9	26.3	26.7	27.1	27.5	27.8	28.2	28.6	28.9	29.3	29.7	30.0	30.5	30.8	31.2	31.5	31.8
	Moist.	11.6	11.5	11.3	11.1	10.9	10.8	10.7	10.5	10.4	10.2	10.0	9.9	9.7	9.5	9.3	9.2	9.1	8.9	8.7	8.6	8.4	8.3	8.2	8.1	7.9	7.7	7.5	7.4	7.3	7.1	6.9
45 cm	Temp.	18.1	18.6	19	19.3	19.6	19.9	20.3	20.5	20.9	21.3	21.7	22.0	22.4	22.7	22.9	23.2	23.6	23.8	24.1	24.5	24.8	25.2	25.4	25.6	25.9	26.3	26.6	26.8	27.1	27.3	27.5
	Moist.	7.8	7.6	7.4	7.3	7.2	7.1	7	6.8	6.7	6.6	6.4	6.3	6.1	6.0	5.8	5.6	5.4	5.3	5.2	5.1	5.0	4.8	4.6	4.4	4.3	4.2	4.1	4.0	3.8	3.8	3.7

Sawdust		1-May	2-May	3-May	4-May	5-May	6-May	7-May	8-May	9-May	10-May	11-May	12-May	13-May	14-May	15-May	16-May	17-May	18-May	19-May	20-May	21-May	22-May	23-May	24-May	25-May	26-May	27-May	28-May	29-May	30-May	31-May
15 cm	Temp.	16.7	16.7	16.8	16.9	17.1	17.2	17.4	17.4	17.6	17.7	17.9	18.0	18.1	18.3	18.3	18.5	18.7	18.9	19.1	19.2	19.5	19.6	19.9	20.1	20.2	20.4	20.5	20.7	20.9	21.0	21.3
	Moist.	35.9	35.6	35.5	35.4	35.2	35.0	34.8	34.7	34.5	34.3	34.1	33.9	33.6	33.3	33.1	32.9	32.7	32.5	32.3	32.0	31.8	31.6	31.3	31.1	30.8	30.5	30.2	30.0	29.7	29.4	29.2
30 cm	Temp.	15.3	15.5	15.8	15.9	16.1	16.3	16.3	16.5	16.6	16.8	17.0	17.1	17.3	17.4	17.5	17.7	18.0	18.1	18.2	18.4	18.5	18.6	18.8	19.0	19.2	19.3	19.5	19.6	19.6	19.7	19.8
	Moist.	14.8	14.5	14.3	14.1	13.9	13.8	13.7	13.5	13.3	13.2	13.0	12.9	12.8	12.6	12.5	12.3	12.1	12.0	11.9	11.7	11.5	11.4	11.2	11.0	10.9	10.7	10.5	10.4	10.3	10.2	10.1
45 cm	Temp.	14.1	14.2	14.4	14.5	14.6	14.8	15.0	15.2	15.3	15.4	15.5	15.6	15.6	15.7	15.9	16.2	16.3	16.5	16.5	16.5	16.7	16.9	17.0	17.1	17.4	17.5	17.6	17.8	17.9	17.9	18.0
	Moist.	11.8	11.6	11.4	11.3	11.1	10.9	10.8	10.6	10.5	10.3	10.2	10.0	9.9	9.8	9.7	9.5	9.4	9.2	9.1	9.0	8.9	8.7	8.6	8.5	8.5	8.4	8.4	8.4	8.3	8.2	8.2

Table 2. Total and average Soil moisture and Volume of Saved Water at different depths for each plot

Mulch type	Black			Clear			Sawdust			Bare soil		
Depth of soil	15 cm	30 cm	45 cm	15 cm	30 cm	45 cm	15 cm	30 cm	45 cm	15 cm	30 cm	45 cm
Total	646.2	391	304.7	887.4	290.3	241.4	921	361.7	271.1	572.2	277	215.5
Average	20.85	12.6	9.8	28.6	9.7	7.8	29.7	11.7	8.7	18.5	8.9	7.0
volume of water content	31.27	37.84	44.23	42.94	29.03	35.04	44.56	35.00	39.35	27.69	26.81	31.28
Saved water	3.58	11.03	12.95	15.25	2.22	3.76	16.88	8.20	8.07	0.0	0.0	0.0
Total saved water	27.56 m3			21.23 m3			33.15 m3			0.0		

3.4. Soil Temperature

Soil temperature decreased with increasing the depth under all type of mulch as shown in Table 1 along days of the month for all treatment because top layer facing more solar radiation more than deep layer. Figure 3 showed that clear mulch allowed the solar radiation to pass through to the deep layers of 30 and 45 cm and heat the soil there more than the surface, due to the convection process that also increased the temperature of the soil in the upper part of the soil by less than the black mulch and more than the bare soil.

In bare soil there was no mulch used so no conduction nor convection was effective, but it received the solar radiation directly which heated soil layers but in less rate of heating than black and clear mulches respectively. Sawdust prevented solar radiation to penetrate to soil layer, so it kept it without heating, so it had lowest soil temperature.

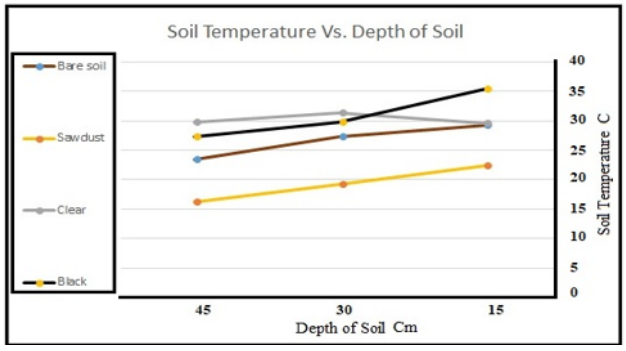

Figure 3. Average Soil Temperature Vs. Depth of Soil under all treatment

3.5 Statistical analysis

Pearson correlation Test showed that a negative strong relation between soil temperature and soil moisture for all treatment at (α= 0.01) as shown in Table 3. That meant it had a high correlation but opposite in direction. Black mulch showed high correlation between temperature and moisture at depth of 30 com. But sawdust ~~and~~ clearly showed high correlation at 15 cm depth of soil. Paired sample t- test were used by SPSS analysis to examine the significant value for each soil moisture and temperature for different type of mulch versus bare soil at (α = 0.05) as shown in Table 4. Two tailed t-test results showed that clear mulch had non-significant differences at α = 0.05 and α = 0.01 for all factors except temperature at depth of 30 cm and 45 cm respectively where the calculated t was more than tabulated t at α = 0.05 and α = 0.01 which was 2.0042 and 2.750 respectively. Black mulch and sawdust showed significant differences for temperature factors, black had strong positive significant which mean increased soil temperature, but sawdust is negative.

Table 3. Results of Pearson correlation test at α= 0.01

Treatment plot	Relation			
	Statistical analysis	Temp. Vs. Moisture at 15 cm depth	Temp. Vs. Moisture at 30 cm depth	Temp. Vs. Moisture at 45 cm depth
Black	Pearson Correlation	- 0.795**	- 0.883**	-0.773**
	Sig. (2-tailed)	0.000	0.000	0.000
Clear	Pearson Correlation	- 0.822**	- 0.743**	- 0.712**
	Sig. (2-tailed)	0.000	0.000	0.000
Sawdust	Pearson Correlation	- 0.894**	- 0.785**	- 0.756**
	Sig. (2-tailed)	0.000	0.000	0.000
Bare soil	Pearson Correlation	- 0.703**	- 0.681	- 0.672**
	Sig. (2-tailed)	0.000	0.000	0.000

This difference was because the sawdust prevented passing of solar radiation to soil so it will decrease temperature. But there were not significant differences related for moisture at 3 depths for all treatment.

Table 4. comparison between effects of sawdust, clear and black on soil temperature and moisture for different depth versus bare soil.

Variable factors	Bare		Clear			Black			Sawdust		
	Mean	D.F	Mean	t	SIG	Mean	T	SIG	Mean	t	SIG
Temperature 15cm	29.2	30	29.6	0.120	0.951	35.3	5.242	0.005	22.4	-3.087	0.008
Temperature 30 cm	27.3	30	31.4	10.172	0.001	29.7	8.553	0.003	19.2	-2.755	0.009
Temperature 45cm	23.4	30	29.7	5.706	0.004	27.3	3.539	0.006	16.2	-3.209	0.007
Moisture 15cm	18.5	30	28.6	1.475	0.425	20.8	0.322	0.801	29.7	1.706	0.301
Moisture 30cm	8.9	30	9.7	0.136	0.903	12.6	0.639	0.567	11.7	0.471	0.712
Moisture 45cm	7.0	30	7.8	0.172	0.834	9.8	0.578	0.636	8.7	0.361	0.756

4. Conclusion

According to the results of this study, the best mulch type depended on aims of uses and the crop or trees type. It was concluded that sawdust was most effective in maintaining soil temperature at acceptable level and was most effective in the upper part of the soil in maintaining soil moisture. Saw dust had a higher total water saving value. Therefore, it was recommended to use after the winter to maintained soil moisture for long time. Black mulch maintained a high

temperature especially in the upper part of the soil which was required to control insect and weeds, but it accepted in middle and deep soils. In the same time, it played a main role in maintaining soil moisture in middle and deep layers of soil. Therefore, it was recommended to use black in summer. Clear mulch-maintained soil temperature and moisture in average level so that it was recommended to use during winter and early spring. The results showed consistency with the findings of Zhang et al. [12], who found that sawdust increases soil moisture content compared to bare soil and plastic mulch, which we also observed with the highest moisture readings at 15 cm depth under sawdust. The finding that black plastic mulch enhanced temperatures in the upper soil layers agrees with Rajablariani et al. [10] and Xie et al. [11], who reported that black mulch raises root zone temperatures, especially during summer, and better controls weed growth. Additionally, the results of decreased temperature and higher moisture levels under organic mulch (sawdust) compared to plastic and bare soil are consistent with Chalker-Scott [3] and Hailu Demo et al. [5], who indicated the ability of organic mulch to cool soil and improve moisture under hot and dry conditions.

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