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Mulching Material Impact on Yield, Soil Moisture and Salinity in Saline-irrigated Sorghum Plots

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ABSTRACT
The aim of the study was to evaluate the comparative effectiveness of mulching technique and material for sustainable sorghum fodder yield. Intrusion of seawater into good quality aquifers is the main problem limiting agricultural production in the Al-Batinah coastal region of Oman. Due to high temperatures of the region between April and October, there is very high water evaporation rate. Surface mulch has significant effect on reducing evaporation of water; therefore, it can decrease salt accumulation as well. This study was conducted to compare effects of two different mulching materials (date palm leaves and black plastic in addition to control without any mulch) and resultant growth of sorghum. There were two levels of water salinity (3 and 6 dS m^{-1}) and three levels of water application rates (1.0, 1.2 and 1.4 ETc). The results indicated that date palm leaves mulch was more effective in conserving soil water content, reducing salt accumulation in the soil, reducing soil temperature and resulting in higher yield of sorghum compared to the plastic mulch that was successful to maintain moisture at even higher level than date palm mulch but it raised soil temperature as well. Resultantly, lesser yield of sorghum was recorded in this treatment.

Key words: Soil cover, saline groundwater, drip irrigation, seawater intrusion, arid agriculture

INTRODUCTION
Sultanate of Oman is characterized by high temperatures and low rainfall. Mean annual rainfall does not exceed 100 mm. The annual potential evaporation is significantly greater than annual precipitation. Due to high evaporation there is a need to conserve the soil moisture for a longer period so that plants can use it effectively. The main source of irrigation water in the Al-Batinah coastal region of Oman is groundwater. The area that is closer to the coast already has high saline groundwater as a result of seawater intrusion into its aquifers (Hussain *et al.*, 2006). Living with salinity is the only way of having sustaining agricultural production in the salt-affected Al-Batinah coastal region of Oman. With high temperatures and high water evaporation rate, enhancement of salt accumulation on soil surface subsequent to irrigations is inevitable unless surface protection measures are employed. This can be accomplished by using surface mulch cheaply obtained from plant residues. In tomato study, Al-Wahaibi *et al.* (2007) found that mulching with date palm residues was superior in terms of tomato fruit yield and controlling increase in soil salinity and temperature as compared to black plastic mulch and control. Yang *et al.* (2007) found that surface mulch had significant effect in reducing water evaporation and reducing soil salinity level of the desalinized plots planted with winter wheat.

Kar and Kumara (2007) found that soil moisture depletion from potato plots decreased with straw surface mulching thus increasing plant growth and tuber production as compared to non-mulched plots that indicated higher soil moisture depletion. In their study of seven soil management practices, Gicheru *et al.* (2006) reported that manure and surface mulched treatments had significantly higher soil moisture content than other treatments. In applying pelleted paper to cropland as a mulch, Unger (2001) found that pellet applications resulted in greater soil aggregate mean weight diameters and lower percentages of small aggregates which imply greater soil productivity. Jemison and Reberg-Horton (2004) used Short Paper Fiber residuals (SPF), a by-product of the pulping process used in paper production as surface mulch that significantly resulted in higher amounts of water in the soil at each sampling date indicating that the material did reduce evaporative losses. This increased available water led to significantly higher marketable potato yield. In their study with corn, Bu *et al.* (2002) found that surface applied mulches resulted in reduced soil water loss by evaporation and in reduced salt accumulation on surface in addition to controlling weeds.

In their study with banana, McIntyre *et al.* (2000) found that mulched treatments produced over three times more biomass than bare soil treatments. Mulched banana took up more water from both the 0-0.3 and 0.3-0.5 m depths than banana grown without mulch and soil water recharged more quickly in the mulched treatments as a result of increased porosity from 0-0.3 m depth.

De *et al.* (1983) found that mulching with rice straw or transpiration suppression by foliar application of kaolin or atrazine increased the yield of grain sorghum. These materials decreased soil moisture depletion and thus increased water-use efficiency. In their study, using crop residue mulch, Barros and Hanks (1993) found that dry matter and seed yields were significantly greater for mulched than for bare plots. Mulched plots had a higher WUE (yield/ET) than did bare plots for a given irrigation level but increased as irrigation level increased. Dong *et al.* (2008) found that plastic mulching both reduced salinity and increased soil temperature resulting in more stand establishment and lint yield of cotton under plastic mulching than the plots without mulching.

Present study was conducted with the objective to evaluate the comparative effectiveness of mulching technique and material for conserving moisture through reduction of evaporation, consequent less salinization due to accumulation of salts and subsequent increase in sorghum fodder yield.

MATERIALS AND METHODS

The experiment was conducted at Agricultural Research Center (ARC) in Rumais (latitude 23.6°N, longitude 58.0°E at 24 m above MSL), during the end of March to the end of June 2007. The climate is semiarid with a mean annual precipitation of 100 mm. Monthly average temperature from seeding to harvest was 31.3°C where, highest temperature was 43.7°C and the lowest 18.4°C. Soil texture was sandy loam.

The experiment consisted of 3 variable factors: Mulching (Control, date palm and black plastic), Irrigation Rate (1.0, 1.2 and 1.4 ETc) and Water Quality (ECw 6 and 9 dS m^{-1}) that were replicated 3 times in split block design. Total number of plots was: 3×2×3×3 = 54. Each plot area was 10 m^2 (2 * 5 m^2). The layout of the experiment has been presented as Fig. 1. The soil surface was leveled and chemical fertilizer was applied at the rate of 230 kg ha^{-1} Urea, 120 kg ha^{-1} P_2O_5 and 125 kg ha^{-1} K_2O fertilizers. The fertilizers were added manually. Holes were drilled 5 cm deep by a steel rod of 5 cm in diameter with rows of 15 cm apart. Two grains of sorghum (variety Super Dan) were seeded in each hole. Then the holes were filled with soil. Date palm residue mulch and

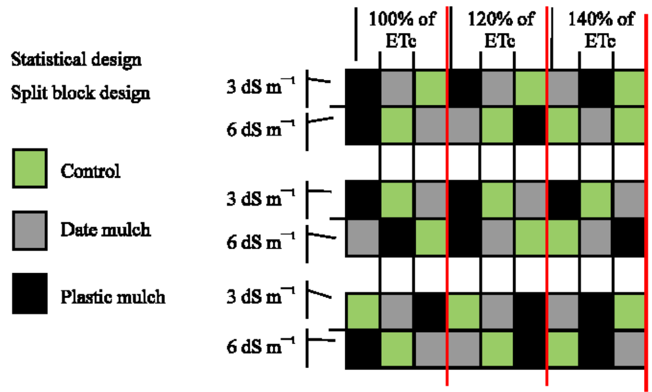

Fig. 1: Experiment design of plots showing control (bare soil), date mulch and plastic mulch at two water EC levels and three application rates

plastic film were placed on the surface of the plots. The plots were 3 m apart from each other. The seeds were planted 15 cm apart along five rows. The planting density was 16 plants m^{-2}.

Irrigation treatments were obtained by applying water to meet requirements (100, 120 and 140% of ETc) of water evaporated from Class-A Pan Evaporation. Drip irrigation system was used. Discharge rate of the irrigation system was 5.1 L h^{-1} with dripper uniformity of 97%. The soil texture was loamy sand with bulk density of 1.5 g cm^{-3}, field capacity of 15% and permanent wilting point of 7.5%. The crop coefficient of sorghum (Kc) was calculated as:

- 0.4 during the initial stage (20-25 days)
- 0.75 during the development stage (30-40 days)
- 1.15 during the mid stage (40-45 days)

Plants were irrigated every two days. Measured amount of irrigation was applied using water meters. Meter readings were taken before and after irrigation. Soil samples were taken from the plots for physical and chemical analysis before planting and after harvesting. The collected data were analyzed using MSTATC program. Electrical conductivity of soil was measured (Ece dS m^{-1}) in a saturated paste extract. In addition to the soil samples analysis, 18 plots were selected randomly to measure the soil moisture, soil temperature and soil salinity.

Field measurement of soil salinity: Soil salinity at five different depths (5, 10, 15, 20 and 25 cm) was recorded at 09:00-10:30 a.m. every week, starting from the third week after planting until harvest. The salinity was measured by CON 11 handheld conductivity/TDS/temperature RS232C meter (Spectrum Technologies). Data were taken close to a dripper at the middle of the plot. Collected data were analyzed using ANOVA procedure. Once a week, a calibration for the meter was made by comparing with laboratory data. To get the relationship between meter reading and the laboratory EC analysis, 6 soil samples were measured using the salinity meter in the field and then analyzed in the lab using two methods 1: 5 extract and saturated paste extract, the results have been shown in Table 1.

The soil moisture was measured by using Time Domain Reflectometry (TDR). Access tubes were installed up to 60 cm soil depth and moisture was measured at 15 cm intervals (four depths; 0-15, 15-30, 30-45 and 45-60 cm) in each selected plot. Green forage yield was recorded for each plot at

Table 1: Calibration for the handheld salinity meter

	Agricultural Research Lab Analysis ($dS\ m^{-1}$)	
Salinity meter	1: 5 extract	Saturated paste extract
0.684	0.275	0.57
0.844	0.351	0.96
0.954	2.120	0.77
1.569	2.600	0.96
0.921	0.591	0.95
0.319	0.350	0.22

the time of harvesting. Collected data were analyzed using ANOVA procedure through MSTATC program.

RESULTS AND DISCUSSION

Green forage yield: The data indicated significant differences of sorghum green forage yield due to different irrigation rates as well as mulch treatments (Table 2). Date palm mulch proved superior over plastic mulch while water application rate of 120% ETc was found better than 100% ETc. There was not much material gain from highest irrigation rate of 140% ETc because it gave only 5% more yield than 120% ETc that also remained insignificant in statistical terms.

Date palm residue mulch contributed 13% more green fodder yield over control whereas it was only 2% more in case of plastic mulch. Thus, superiority of date palm mulch as well as irrigation rate of 120% was clearly decisive. These results are in line with findings of Al-Wahaibi *et al.* (2007), Kar and Kumar (2007) and Jemison and Reberg-Horton (2004). The experimental results of these authors were almost similar while they worked on different crops. The 13% increase in green fodder yield in date palm mulch was very clearly superior to plastic mulch that had just 2% more yield than control (Table 3).

Mulch type vs. soil salinity: *In situ* monitoring data of the experiment revealed that soil salinity at different depths under mulching treatments remained varying during crop growth. Table 4 shows the differences in soil salinity between the mulch treatments with date palm treatment resulting in lowest soil salinity.

The weekly on site observations indicted that salt concentration was continuously changing because of experimental treatments; differences in ECw or putting mulch (plastic or date palm residues). Salts were moving, accumulating or even diluting. The consistent monitoring indicated that field values of EC, in general, were increasing with time till Gonu cyclone with a huge amount of rainfall occurred (five weeks after growing of crop). After that salinity values dropped. However, increasing trend of salinity again became obvious two weeks after the cyclone. It was evident that there were significant differences in soil salinity between different types of mulches; date palm mulch having the lowest salinity (Table 4). These findings also agree with other studies conducted using crop residue mulch (Al-Wahaibi *et al.*, 2007; Kar and Kumar, 2007; Jemison and Reberg-Horton, 2004).

Mulch type vs. soil moisture: Table 5 indicates that more moisture percentage was recorded in soil covered with mulches as compared to bare soil surface indicated by control treatment. It was observed that moisture content with date palm residue had the highest average of soil moisture of

Table 2: Effect of irrigation rates on sorghum green fodder yield (t ha^{-1})

Irrigation rate (%)	Mean yield	Total yield	Yield (%)
100	47.13B	851.5	100
120	56.71A	1020.8	120
140	59.20A	1065.6	125

Table 3: Effect of mulches on sorghum green forage yield (t ha^{-1})

Mulch	Mean	Total	Yield (%)
C	51.87B	933.7	100
D	58.69A	1056.4	113
P	52.65B	947.7	102

Table 4: Average surface soil salinity for the different mulch treatments (dS m^{-1})

Type of mulch	Dried date palm leaves	Plastic mulch	Control
Average of soil salinity	1.15	1.55	1.19

Table 5: Average soil moisture (%) for the different mulch treatments

Type of mulch	Date palm mulch	Plastic mulch	Control
Average soil moisture	16.55	14.9	14.81

Table 6: Average soil moisture (%) for the different depths

Depth	15 cm	30 cm	45 cm	60 cm
Average soil moisture	14.4	15.37	16.17	15.72

16.55%. There were significant differences between different types of mulches, depths and the individual interactions. The highest average of soil moisture was at depth 45 cm with a value of 16.17% (Table 6).

Covering soils with date palm residue reduced the amount of water lost through evaporation. Resultantly, more moisture percentage was recorded in soil covered with mulches as compared to bare soil surface indicated by control treatment (Table 5).

The soil moisture at different depths is important with the view of water availability and uptake by the plants. Under normal irrigation and rooting pattern, the typical extraction pattern for the root zone is 40-30-20-10% water uptake from the upper to the lower quarter of the root zone. Where irrigation is applied more frequently, crops tend to extract more water from the upper root zone and less from the lower root zone. Under these conditions, the root zone is generally shallower and the extraction pattern might be 60-30-7-3.

It is up to that consideration, the depths of 45 cm (under the top half of the soil) were found to have the highest average of soil moisture. These results may be considered reasonable since it supported the reported conclusions of many studies regarding the significant reduction in crop water requirement when localized irrigation systems and mulching are used.

Variation in soil temperature: Significant differences in soil temperature due to types of mulches and different depths were recorded (Table 7). However, differences due to individual interactions were not assessed significant in statistical terms (Table 8).

The soil temperatures for the different mulch treatments at different soil depths revealed that maximum temperature of 36.03°C was recorded in plastic mulch in the surface layer (Table 10). It indicates general widening of differences in temperatures between different mulches closer to the

Table 7: ANOVA for temperature

Source of variation	SS	df	MS	F	p-value	F crit
Mulch	127.85	2	63.93	21.13	0.00	3.06
Depth	32.82	4	8.21	2.71	0.03	2.44
Interaction	9.17	8	1.15	0.38	0.93	2.01
Within	408.52	135	3.03			
Total	578.36	149				

Table 8: Average soil temperatures as affected by mulch treatments

Type of mulch	Date palm	Plastic	Control
Average of soil temperature (°C)	33	35	34

Table 9: Average soil temperatures for the different depths

Depth (cm)	5	10	15	20	25
Average soil temperature (°C)	35.0	34.3	34.0	34.2	33.6

Table 10: Average soil temperatures of mulch treatments

	Type of mulch			
Depth (cm)	Date palm	Plastic	Control	Mean
5	33.91	36.03	35.04	34.99
10	33.06	35.70	34.18	34.31
15	33.00	35.49	33.62	34.04
20	33.00	35.68	33.91	34.19
25	33.07	34.29	33.28	33.55
Mean	33.32	35.74	34.28	

soil surface while there is a sharp narrowing between mulches in the down profile. Soil temperatures under date palm mulch are less than the control and plastic mulch. Mulching with pruned leaves of date palm has the lowest average of soil temperatures with a value of 33.21°C. For the different depths, the highest average of soil temperatures is at the surface depth (5 cm) with a value of 35°C (Table 8, 9). The temperature under plastic mulch increased due to absorbance of all light waves being black in color. Al-Wahaibi *et al.* (2007) also recorded more surface soil temperature under plastic mulch. Both type of mulches reduced evaporation (Table 5) but simultaneous increase in temperature under plastic mulch (Table 8) proved as a negative point that would have caused a significant damage to plants, especially roots that consequently contributed towards decrease in green fodder yield when compared with date palm mulch. However, in cooler climates plastic mulching is favored since temperature increase is required for better crop productivity. Dong *et al.* (2008) found that plastic mulching both reduced salinity and increased soil temperature resulting in more stand establishment and lint yield of cotton under plastic mulching than the plots without mulching.

CONCLUSION

Mulching with shredded date palm leaves proved as the best management practice to conserve soil moisture, reduce salt accumulation in soil and controlling increase in surface soil temperature. These all collectively resulted in more green fodder yield of sorghum as compared to control and plastic mulch treatments. Contrary to the date palm mulch that indicated a cooling effect on soil surface by its well-aerated insulating texture, black plastic mulch resulted in highest soil surface temperature and highest salinity. Date palms cover approximately 50% of cropped area in Oman. The huge residues of this crop could be utilized very positively by mulching. This management practice can effectively contribute to sustain agriculture through water saving and reducing negative effects of water salinity. These findings could be transferred to local farmers through agricultural extension.

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