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Reducing Water Use of Wheat by Closing Cracks in the Field

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Abstract

In irrigated areas, the cracking patterns are greatly influenced by total amount of water entering the soil and length of the fallow period. Shrinkage cracks provide a direct path for water vapor to move from soil pores near the crack walls to the atmosphere. This study was conducted at Gezira Agricultural Research Station farm, Sudan to describe the changes of the water use of wheat crop and yield components, by closing the cracks in the field. In this experiment two basins were used, one as control plot and the other as experimental plot. In the experimental plot the cracks were closed after second and third irrigation using hand tool, where as in the control plot it was left as naturally. To find out evaporation from the soil, the loss of soil moisture in 15 days at 0-20, 20-40 and 40-60 cm depths was analyzed in both control and experimental fields. The water requirement for the grand growth period of wheat crop was reduced by 4.6 % in the closed crack field. The yield components were measured in both open and closed crack fields in order to evaluate the effect of imposed treatments on crop yield. There was an increase of 11.1 % in irrigation production efficiency, 4.50 % in harvest index, 5.03 % in grain yield, 6.50 % in bio mass yield and 2.44 % in the weight of 1000 grains by closing the cracks in the field. The results show that there is a reduction in the water use during grand growth period of wheat crop by closing the cracks in the field.

Key words: Evaporation, Closing Cracks, Water use of Wheat

Introduction

Cracks develop when an expanding type of clay dries. The width and depth of cracks are associated with the degree of desiccation, the amount and type of clay, and the amount and frequency of rainfall and irrigation. Desiccation is also often related to the type and density of vegetation. In areas with thick, well developed surface mulch and wide cracks, the mulch will fall into the cracks. During the next rain, expansion of the soil plus mulching due to wetting will cause the soil to heave, thus causing gilgi surface relief. This process churns and mixes the soil materials to approximately the depth of cracking, thus often preventing the development of textural B horizon. The churning and mixing tend to incorporate organic matter and may help in maintaining a better structure.

The important factor in the depth from which a bare soil loses water in the tropics is the amount of soil cracking that takes place during drying (Russel, 1973). Ritchie and Adams (1974) reported that shrinkage cracks are the dominant factors influencing evaporation from swelling clay soils. Ringrose-Voase et al (2000) studied the physical properties of puddle soil during drying and found that crack volume depends upon the extent of drying and its interaction with the proportion of clay minerals with shrink/swell properties.

Corbeels et al (1998) reported that in wheat growing regions on cracking clay, due to the cracking properties of the soil, considerable evaporative losses occurred up to 0.45 m soil depth. They also stated that increase in water use efficiency and crop productivity can be achieved from the reduction of soil evaporation. Zein and Robinson (1971) studied the cracking in Vertisols of Sudan and reported that the average depth of cracks is inversely related to the amount of precipitation or irrigation and the average width of cracks is directly related to the periods of fallowing. He also found that the total volume of cracks in the irrigated area of the Gezira ranges between 222 and 313 m^3 per ha.

Romeo and Tuong (2000) studied the management of cracked soil in rice cultivation. They found that straw mulching helps to conserve moisture in the soil profile and reduce crack development during the fallow period. They also stated that shallow tillage formed small soil aggregates, which blocked and impeded water flow in the cracks and reduced the amount of water that recharged the ground water via the bottom of the cracks and crack faces.

In the beginning of the growing season of wheat, loss of water is mainly due to evaporation because the plant hardly covers the ground. Thus we have to reduce evaporation losses so as to save water as much as possible. Wheat is said to have an intermediate transpiration coefficient, but the value differs considerably under different climatic conditions (Farah, 1967).

Materials and Methods

1. Characteristics of experimental site

This experiment was conducted in the farm of the Gezira Research Station to study evaporation from shrinkage cracks. The station is located at latitude 14.4^o N, longitude 33.5 ^{o} E and has an altitude of 405 m above mean sea level.

1.1. Soil

The soil is an alkaline deeply cracking Vertisols and is classified as “fine, montmorillonitic, Isohyperthermic, Entic chromusterts, Suleimi series", with clay content of about 40-50 %. It swells when wet and shrinks when dry. It has low infiltration rate and gentle slope, thus surface gravity irrigation is used.

1.2. Climate

The station is located in Wad Medani which falls in the dry zone, the mean air temperature is 29 °C, sun shine duration is 87%, relative humidity is 39%, and wind speed is 2 m /s at 2 m height, the normal annual rainfall is about 300 mm and the annual evaporation is 2500 mm (Adam, 1998).

2. Experimental layout and crop husbandry

Elneilain cultivar of wheat was sown for the experiment. Two plots of sizes 14 x 60 m were used for the experiment, each plot consists of six sub plots. The borders, which include the two outer rows and one meter at either end, were excluded during data collection. The seed rate of 143 kg/ ha was used in both plots. The seeds were treated with insecticide against aphids. Nitrogen fertilizer in the form of urea was applied at the rate of 86 kg/ha in two applications. Phosphorus was applied at sowing at the rate of 43 kg $P_2 0_5$ /ha. The crop was hand weeded once at the crop establishment stage. One of the two plots was left as control and in the other plot; the cracks were closed after the second and third irrigation by slight hand tillage using a hand tool.

3. Water measurement

Two concrete pipes (19 cm in diameter) were fixed in the entrance of the field channel with their outer sides sealed with clay to ensure that water applied passes only through the pipe. The two pipes were prepared for the installation of the discharge measurement instrument (Vane Flow Meter). While using the vane, the vane cradle was placed in the pipe and the four leveling screws were adjusted until the radius of the cradle was in line with the inside curve of the pipe. Approximate weight had been put in the arm of the instrument until it is levelled. The discharge readings were taken every ten minutes.

The discharge was calculated in liters per second using the following equation:

$$Q = 0.696 (LW)^{0.5} \quad (1)$$

Where,
Q = Discharge (l/s)
L = Length of specific arm (cm)
W = Weight used (gm)

4. Soil moisture

The soil moisture was determined using the gravimetric method. Samples were collected using auger from different depths (0 - 20, 20 - 40 and 40 - 60 cm). First sampling was done six days after the second irrigation when the field was dry enough to be entered. Samples were weighed by a sensitive balance to determine the wet weight and placed in the oven at 110°C for 24 hrs and were weighed again to determine the dry weight. Again after 15 days, i.e. on the day before next irrigation samples were taken one meter beside the holes of the first sample to determine the loss of moisture in both the plots. The soil moisture loss in both plots was calculated after first and second closing of cracks using the following formula:

Soil moisture loss (%) = ((initial moisture-final moisture)/initial moisture)*100 (2)

5. Yield and yield components evaluated

In order to evaluate the impact of closing cracks on yield parameters of wheat, five yield components such as Irrigation production efficiency(IPE), Harvest index(HI), grain yield, Biomass yield and weight of 1000 grains were analyzed in both the plots.

IPE was calculated using the following formula:

$$IPE\ (kg/\ m^3) = grain\ yield\ (kg/\ ha)/\ total\ water\ used\ (m^3/\ ha) \qquad (3)$$

The actual grain yield from entire plots was taken for calculating IPE. The harvest index was calculated as:

$$HI = grain\ yield\ /\ biomass\ yield \qquad (4)$$

For biomass yield, a sample plot (1 m^2) was taken in each subplot of control and experiment plots.

Results and Discussion

In the experimental field the cracks were closed two times by hand tillage in order to save the soil moisture that may be lost through evaporation from cracks surfaces. Closing cracks in the experimental field was performed without puddling the soil. The first closure of cracks was done following the second irrigation while the second closure incident was performed after the third irrigation. The first closure of cracks was especially easier than the second as the crop was in the first stage of establishment at the time of the first closure. It was difficult to perform the second closure in the same way as the first one as the crop was in an advanced stage of establishment and there was a danger of damaging the crop.

1. Water consumption

Water consumption is influenced by a number of factors including species and cultivar differences. This influence may result from differences in growth rate, evapotranspiration, or length of growing season and cultivation practices (Biran et al, 1981). The water applied in each irrigation to both the control and the treatment plots are given in Table 1 and Fig. 1. Since the first closing of cracks was after second irrigation, there is not much difference in the quantity of water irrigated in both the control and treatment plots during first and second irrigation. Total water used in the third and fourth irrigation amounted to 3032 and 2944 m^3/ha in the open and closed cracks plots respectively. The percent of water saved by closing the cracks was high in 5^{th} and 7^{th} irrigation, it was clear that the fourth irrigation represent the greatest application through the growing season. This may be due to anthesis or grain filling stage of the crop in that period. This result is in confirmation with the findings of Day and Intalap (1970), who reported that the consumptive use of water of wheat is higher during flowering and dough stage. The total water applied during the grand growth period in seven irrigations for a 115 day crop was 9149 m^3/ha for the closed cracks field and 9589 m^3/ ha for the open cracks field. The water requirement for the grand growth period of wheat crop was reduced by 4.6 % in the closed crack field. After closing the cracks, the consumption of water in closed cracks field was less than that in the open cracks field during all irrigations. Closing the cracks reduced evaporation from the cracks' surface and increased the storage of water in the root zone.

2. Soil moisture

The soil moistures at different depths analyzed in both the control and treatment plots are given in tables 2 and 3 and figs. 2 and 3. In both plots, the initial moisture of the bottom layer (40-60 cm depth) of the soil profile was the lowest compared to the other depths. This is due to the low permeability of the Gezira soil. But after a drying period of 15 days, the middle layer had the highest moisture value. This is conceivable as the top layer is exposed to the atmosphere and hence greater evaporation is expected. Adding to this the possibility of small runoff or run-on during irrigation. In contrast the middle zone was protected from losses through evaporation and had a better chance to keep more water as compared to the layer beneath. The loss of soil moisture at a period of 15 days in the top layer was 49 % in the closed crack field, whereas it was 58 % in the open crack field after first closing. The difference between soil moisture losses of open and closed crack fields in the middle and bottom layer was marginal. It is clear that the first closure of cracks was more effective in conservation of profile moisture. After second closing, the moisture loss on the top layer was 50.7 % in the open crack field and it was 47.6 % in the closed crack field.

3. Yield and yield components

The yield components were measured in both the open and closed crack fields in order to evaluate the effect of the imposed treatments on crop yield and given in table 4. There was an increase of 5.03 % in grain yield and 6.5 % in biomass yield in the closed crack field. A marginal increase of 2.44 % in weight of 1000 grain was also noticed because of closing the cracks. As the water irrigated in the closed crack field was reduced, there was a good increase of 11.1 % in the irrigation production efficiency. Though the increase was 5.03 % and 6.5 % in the grain yield and biomass yield by closing the cracks, the harvest index was increased only by 4.5 % in the closed crack fields.

Conclusion

From the experimental results it is evident that there is a reduction in the water use during grand growth period of wheat crop by closing the cracks in the field. The process of closing cracks does not need any special type of instruments or skilled workers. The workers can easily do this operation using hand tools while doing normal weeding. It is also suggested that for wheat crop, two closing's is sufficient, as after that the canopy itself shades the soil.

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Table 1: Quantity of water irrigated in open and closed crack fields

		Irrigation							
		1	2	3	4	5	6	7	Total
Quantity of water irrigated (m^3/ha)	Field with open cracks	1148	1115	1300	1732	1363	1462	1469	9589
	Field with closed cracks	1152	1108	1249	1695	1221	1429	1295	9149
Quantity of water saved (m^3/ha) in closed cracks field over open crack field		-4	7	51	37	142	33	174	440
Per cent of water saved in closed cracks field over open crack field		-	-	3.9	2.1	10.4	2.3	11.8	4.6

Table 2: Soil moisture content (w/w %) at different depths after first closing

	Soil depth cm	Soil moisture	
		Initial	Final (after 15 days)
Field with open cracks	0-20	31.3±1.04*	13.1±0.93*
	20-40	31.4±1.03	20.2±1.05
	40-60	29.7±1.6	17.4±0.75
Field with closed cracks	0-20	29.6±1.15	15.0±1
	20-40	31.8±0.72	20.9±0.89
	40-60	27.8±0.6	16.8±0.85

The results were expressed as mean ±S.D. Statistical significance was determined by t-test, with the level of significance set at $P < 0.05$. *significant

Table 3: Soil moisture content (w/w %) at different depths after second closing

	Soil depth cm	Soil moisture	
		Initial	Final (after 15 days)
Field with open cracks	0-20	26.6±0.6*	13.1±0.35*
	20-40	26±1.1	18±0.35
	40-60	20.3±0.86	17.6±0.6
Field with closed cracks	0-20	25.2±1.16*	13.2±0.6*
	20-40	26.1±1.56	18.1±0.55
	40-60	22.0±1.77	18.3±0.53

The results were expressed as mean ±S.D. Statistical significance was determined by t-test, with the level of significance set at $P < 0.05$.*not significant

Table 4: Changes in the yield components in open and closed cracks fields

	IPE (kg of grain / m^3 of water)	Harvest index	Grain yield (Kg/ha)	Bio mass yield (Kg / ha)	Weight of 1000 grain (gm)
Field with open cracks	0.18	0.22	1750	7700	41
Field with closed cracks	0.20	0.23	1838	8200	42
Percent increase in closed cracks field over open cracks field	11.1	4.50	5.03	6.50	2.44

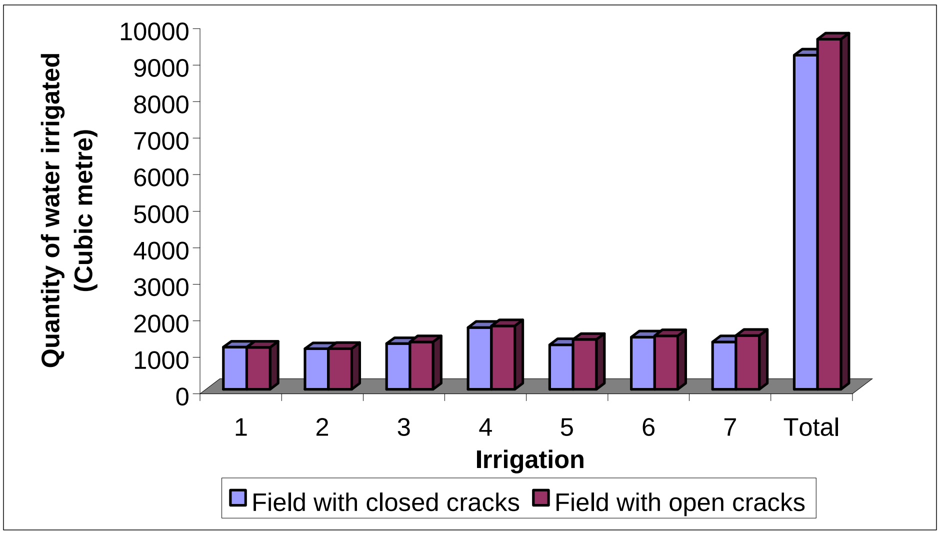

Fig. 1. Water irrigated in open and closed crack fields

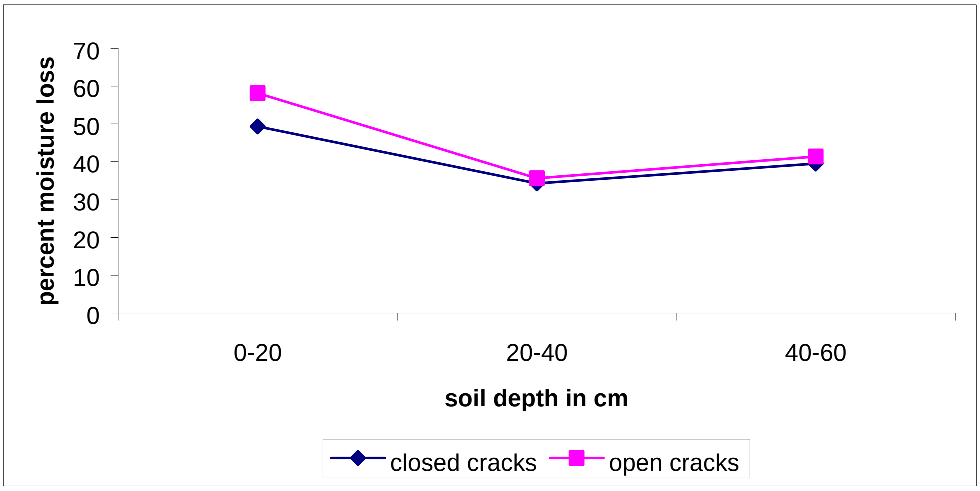

Fig. 2. Percent of soil moisture loss at different depths after first closing

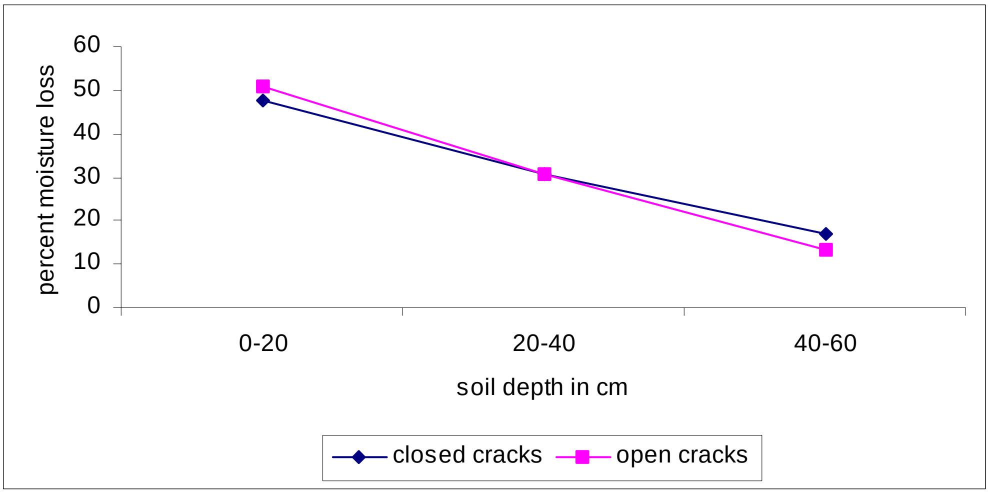

Fig. 3. Percent of soil moisture loss at different depths after second closing