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Research paper

Leaching Fraction of Irrigation Water and Tillage Treatment for Growing Forage Sorghum (*Sorghum bicolor*) on Sondus Agricultural Project Soils

Salah Abdel Rahman Salih[1], Mohamed Abdel Mahmoud Elsheikh[1] and

Abdel Moneim Elamin Mohamed[2]

1 Faculty of Agricultural Technology and Fish Science, University of Neelain, Sudan

2 Faculty of Agriculture, University of Khartoum

Corresponding author: salah.55@hotmial.co.uk

ABSTRACT

This study was conducted during 2013 and 2014 summer seasons at the demonstration farm of the Faculty of Agricultural Technology and Fish Science, University of Neelain (Jebal Awlia area) south of Khartoum to investigate the most suitable irrigation water quantity and the best tillage treatment for growing Abu Sabein in salty affected soil. The irrigation water quantities used were crop water requirement (CWR) + 10% or 20% of the crop water requirement as a leaching fraction (LF). Three tillage treatments namely, disc plow, chisel plow and disc harrow were used and zero tillage as a control. The variables compared were plant height, number of leaves/plant, stem diameter, leaves/stem ratio, fresh and dry weight and water use efficiency. The soil of the site was found to be non-saline to slightly saline, non sodic to slightly sodic, slightly calcareous and slightly alkaline. The results showed that CWR + 20% LF gave higher results than CWR + 10% LF, also chisel plow gave higher values than the other tillage treatments for all the variables during the two seasons.

Key words: Salt-affected soils, irrigation water requirement, leaching fraction, tillage, forage sorghum.

اثر هامش غسيل التربة من ماء الري وطريقة الحرث على اداء علف الذرة (ابو سبعين) في تربة مشروع سندس

صلاح عبد الرحمن صالح[1]، محمد عبد المحمود الشيخ[1]، عبد المنعم الامين محمد[2]

1 كلية التقانة الزراعية وعلوم الاسماك، جامعة النيلين

2 كلية الزراعة، جامعة الخرطوم

اجريت هذه الدراسة خلال صيفي 2013 و 2014 في مزرعة كلية التقانة الزراعية وعلوم الاسماك، جامعة النيلين بجبل اولياء جنوب الخرطوم لمعرفة المقدار المناسب من ماء الري واحسن طرق الحرث لأداء جيد لعلف ابوسبعين المزروع بأراضي متأثرة بالملوحة. استخدمت مقادير من مياه الري بزيادة 10 و20 % من حاجة المحصول كهامش لغسل الملوحة مع ثلاثة انواع من الحرث هي المحراث القرصي والخلخال والهرو مع رابع دون حرث كشاهد. شملت القراءات طول النبات وعدد الاوراق في النبات وقطر الساق ونسبة الاوراق الي السيقان والوزن الطري والجاف وكفاءة استخدام ماء الري. صنفت الاراضي بالموقع علي انها غير ملحية الي ملحية خفيفة وغير صودية الي صودية خفيفة، كلسية خفيفة وخفيفة القلوية. اوضحت النتائج ان اضافة 20% من الماء كهامش لغسل الملوحة اعطت نتائج اعلي من اضافة زيادة بمقدار 10% كما وأن الحراثة بالمحراث القرصي اعطت نتائج اعلي من المعاملات الاخري لكل المتغيرات المقاسة خلال الموسمين.

Introduction

Salt-affected soils occur in all continents and under almost all climatic conditions. Their distribution, however, is relatively more extensive in the arid and semi-arid regions compared to the humid regions (Kaushik and Sethi, 2005). Saline soils have salts level high enough that either crop yield begins to suffer or cropping is impractical. Excessive salts injure plants by disrupting the uptake of water into roots and interfering with the uptake of competitive nutrients (David, 2007). When plants grow under saline conditions, they are subjected to three types of stress, water stress caused by the osmotic pressure, mineral toxicity stress caused by the salt and disturbances in the balance of mineral nutrition (Ahmed and Ahmed, 2007).

The total area of salt-affected soils in Sudan is 4.8 million ha. The majority of the area is located in the low rainfall regions in the higher terraces along the Nile River, south Khartoum, north Gezira and the White Nile scheme, north of Kosti due to climate conditions (desert, semi-desert and semi-arid), natural causes of weathering of salt bearing rocks, poor soil and water management in irrigated areas including insufficient drainage system (FAO, 2000). The potential of utilizing these salty soils in Sudan for agricultural production is very large due to their proximity to large consumption centers and the availability of good quality irrigation water from the tow Niles in addition to the presence of some basic infrastructures.

Forage sorghum (*Sorghum bicolor* L. Moench) has recently witnessed increasing importance in the semi-arid tropics and drier parts of the world where livestock constitutes a major component of the production system. Compared to other cereals, specially maize, sorghum is more drought tolerant, less input demanding and can thrive better under harsh conditions (Mohamed, 2007). In Sudan, where the second largest animal wealth in Africa exists, forage sorghum constitutes the bulk of the animal feed in the country (Mohammed and Talib, 2008). The sharp increase in demand for animal products and the great potential of Sudan as a forage exporting country has led to dramatic increase in the area allocated to fodder crops particularly around urban centers, e.g. Khartoum State (MAAW, 2007). The relatively good stands of Abu Sabein in these soils suggest this fodder crop is highly salt – tolerant (Elkarouri and Mansi, 1980).

Material and methods

This study was conducted at the Demonstration Farm of the Faculty of Agricultural Technology and Fish Science, University of Neelain, inside Sondos Agricultural Project South of Khartoum during the summer seasons of 2013 and 2014. The soil of the site was found to be non-saline to slightly saline, non sodic to slightly sodic, slightly calcareous soil with pH ranged from 7.5 to 8.0, SAR, from 1.7 to 10.0, ECe, from 0.6 to 3.0 ds/m, CaCO3, from 1.6 to 3.8. Average bulk density value obtained was 1.28 g/cm3, average field capacity value obtained was 22.8% on dry weight basis, soil texture of the all depths is sandy clay loam. The experimental area was planted with Abu Sabein. The treatments were compared in complete randomized block design replicated three times. Crop water requirement was predicted using the modified Penman equation. Plant height and number of leaves/plant were measured at the 4^{th}, 5^{th}, 6^{th}, 7^{th}, 8^{th}, 9^{th} and 10^{th} week after sowing, while fresh and dry yield, stem diameter and leaves: stem ratio were measured at harvest. Crop water use efficiency was calculated from the ratio of crop yield to the amount of water used.

Results and discussions

Tables 1.a, 1.b, 2.a and 2.b illustrate plant height from the fourth week until the tenth week during 2013 and 2014 seasons. There were no significant differences between the irrigation water quantities on plant height from the fourth till the eighth week during 2013 season, but a significant difference ($P \leq 0.05$) was found for the ninth and tenth week. Whereas, during 2014 season, a highly significant difference ($P \leq 0.01$) was found for all the weeks with the superiority of CWR + 20% LF than CWR + 10% LF in both seasons. Pardossi *et al*. (1998) stated that water stress is one of the first and most evident effects in the crop production in saline soil.

As for tillage treatments, no significant difference for the fourth, fifth, eighth and ninth week but significant difference ($P \leq 0.05$) for the rest weeks was found during 2013 season. Whereas, for 2014 season a highly significant difference ($P \leq 0.01$) were found for all the weeks, with superiority of chisel plow followed by disc plow, then disc harrow and lastly zero tillage for both seasons. Effect of tillage on plant height may be due to the conservation of soil physical properties that influence water transfer, aeration, thermal regime, and root growth as cited by Cosper (1983).

Tables 3.a, 3.b, 4.a and 4.b show the effect of irrigation quantities and tillage treatments on number of leaves/plant of Abu Sabein from the fourth week until the tenth week during 2013 and

2014 seasons. No significant effect was found due to water quantities and tillage treatments at all weeks during the two seasons.

Tables 5.a and 5.b show the effect of irrigation quantities and tillage treatments on fresh weight, dry weight, stem diameter and leaves/stem ratio of Abu Sabein during 2013 and 2014 seasons. Analysis of variance for the effect of irrigation water quantities and tillage treatments on fresh weight and stem diameter showed a significant difference ($P \leq 0.05$) with superiority of CWR + 20% LF than CWR + 10% LF and chisel plow than the other three tillage treatments during the two seasons, but there was no significant effect in dry matter and leaves/stem ratio due to water quantities and tillage treatments. Improvements in crop yields as a result of deep plowing were related to enhanced water intake rates and depth of penetration and nearly doubled the effective available water holding capacity (Rasmussen *et al.*, 1972).

Tables 6.a and 6.b show water use efficiency during 2013 and 2014 seasons. As for the effect of water quantities there was no significant different during 2013 season, but a highly significant difference ($P \leq 0.01$) was found during 2014 season in which CWR+10% LF gave higher values than CWR+ 20% LF. This may be due to the little amount of water used in CWR+10% LF. Light, frequent irrigation resulted in significantly higher water use efficiency (WUE) as mentioned by Saeed and ElNadi (1998). For tillage treatments, there was a significant difference ($P \leq 0.05$) during 2013 season in which chisel plow gave higher values than the other three tillage treatments. While during 2014 the four tillage treatments differ significantly ($P \leq 0.05$) from each other in which chisel plow gave higher values followed by disc plow, disc harrow and lastly zero tillage. Tillage affects water use efficiency by altering the hydrological properties of soil and affecting water utilization by crops and results in increasing yield as mentioned by Arora and Gajri (1996). Interaction between irrigation water quantities and tillage treatments gave no significant difference during the two seasons.

Table 1: Effect of irrigation water quantity on plant height of Abu Sabein

a- Season 2013

Water amount	Plant height						
	4th week	5th week	6th week	7th week	8th week	9th week	10th week
CWR +10% L.F	17.97a	32.81a	48.36a	80.56a	101.89a	127.33b	144.64b
CWR +20% L.F	19.54a	36.11a	52.22a	88.00a	112.83a	145.08a	162.22a
S.E ±	1.00	1.58	2.62	3.41	5.15	4.94	4.2

b- Season 2014

Water amount	4th week	5th week	6th week	7th week	8th week	9th week	10th week
CWR +10% L.F	16.25b	38.47b	59.28b	84.14b	107.53b	131.5b	155.28b
CWR +20% L.F	18.28a	41.08a	63.61a	88.19a	110.39a	136.55a	161.75a
S.E ±	0.34	0.58	0.78	0.59	0.77	0.84	0.92

Means in the same column with similar letters are not significantly different at P 0.05

Table 2: Effect of tillage treatments on plant height of Abu Sabein

a- Season 2013

Tillage treatments	Plant height						
	4th week	5th week	6th week	7th week	8th week	9th week	10th week
Zero tillage	17.31a	30.67a	42.5c	72.33c	98.72a	133.00a	141.72b
Disc plow	17.64a	36.28a	54.72ab	87.06ab	112.33a	141.56a	162.94a
Chisel plow	20.67a	39.06a	58.17a	96.22a	113.17a	139.22a	169.67a
Disc harrow	19.39a	31.83a	45.78bc	81.50bc	105.22a	131.06a	139.39b
S.E±	1.42	2.24	3.71	4.83	7.29	6.99	5.93

b- Season 2014

Tillage treatments	4th week	5th week	6th week	7th week	8th week	9th week	10th week
Zero tillage	13.50c	34.39c	51.00d	76.72d	97.17d	118.44d	140.50d
Disc plow	16.33b	40.39b	64.67b	90.44b	116.44b	142.78b	169.22b
Chisel plow	24.61a	48.61a	73.28a	97.39a	121.11a	148.56a	178.56a
Disc harrow	14.61c	35.72c	56.83c	80.11c	101.11c	126.33c	145.78c
S.E±	0.48	0.82	1.1	0.83	1.09	1.18	1.3

Means in the same column with similar letters are not significantly different at P 0.05

Table 3: Effect of irrigation water quantity on number of leaves/plant of Abu Sabein

a- Season 2013

Water amount	Number of leaves/plant						
	4th week	5th week	6th week	7th week	8th week	9th week	10th week
CWR +10% L.F	6.58a	6.92a	7.36a	6.81a	8.72a	8.97a	9.31a
CWR +20% L.F	6.75a	6.86a	7.17a	7.08a	9.00a	8.64a	9.11a
S.E ±	0.16	0.17	0.18	0.22	0.32	0.36	0.21

b- Season 2014

Water amount	4th week	5th week	6th week	7th week	8th week	9th week	10th week
CWR +10% L.F	6.44a	6.89a	7.36a	7.58a	8.06a	8.42a	9.14a
CWR +20% L.F	7.03a	7.06a	7.47a	7.61a	8.06a	8.56a	8.78a
S.E ±	0.22	0.24	0.17	0.19	0.17	0.21	0.18

Means in the same column with similar letters are not significantly different at P 0.05

Table 4: Effect of tillage treatments on number of leaves of Abu Sabein

a- Season 2013

Tillage treatments	Number of leaves/plant						
	4th week	5th week	6th week	7th week	8th week	9th week	10th week
Zero tillage	6.50a	6.83a	7.28a	6.33a	8.89a	8.72a	9.39a
Disc plow	6.33a	7.22a	7.33a	7.44a	9.44a	9.61a	9.56a
Chisel plow	7.17a	6.89a	7.44a	7.17a	7.89a	8.22a	8.89a
Disc harrow	6.67a	6.61a	7.00a	6.83a	9.22a	8.67a	9.00a
S.E±	0.22	0.23	0.25	0.3	0.46	0.51	0.29

b- Season 2014

Tillage treatments	Number of leaves/plant						
	4th week	5th week	6th week	7th week	8th week	9th week	10th week
Zero tillage	6.00a	6.00a	6.61a	6.83a	7.44a	7.44a	8.61a
Disc plow	6.78a	7.06a	6.61a	8.00a	8.44a	8.78a	9.44a
Chisel plow	7.72a	8.11a	6.61a	8.00a	9.11a	9.67a	9.67a
Disc harrow	6.44a	6.72a	6.61a	8.00a	7.22a	8.06a	8.11a
S.E±	0.31	0.34	0.25	0.27	0.24	0.3	0.26

Means in the same column with similar letters are not significantly different at P 0.05

Table 5: Effect of irrigation water quantity and tillage treatments on fresh weight, dry weight, stem diameter and leaves/stem ratio of Abu Sabein for 2013 and 2014 seasons

a- Water amount

Water amount	2013				2014			
	Fresh weight ton/ha	Dry weight ton/ha	Stem diameter mm	Leaves/ stem ratio	Fresh weight ton/ha	Dry weight ton/ha	Stem diameter mm	Leaves/ stem ratio
CWR+10% LF	25.11a	6.48a	7.14b	0.77a	26.07b	6.83a	7.11a	0.82a
CWR+20% LF	24.68a	6.05a	8.41a	0.69a	26.5a	6.89a	7.75a	0.67a
S.E ±	1.48	0.38	0.33	0.04	0.11	0.08	0.56	0.06

b- Tillage treatments

Tillage treatments	Fresh weight ton/ha	Dry weight ton/ha	Stem diameter mm	Leaves/ stem ratio	Fresh weight ton/ha	Dry weight ton/ha	Stem diameter mm	Leaves/ stem ratio
Zero tillage	20.04b	5.57a	6.31b	0.70a	22.88d	5.66d	5.73b	0.73a
Disc plow	22.70b	5.87a	7.61b	0.68a	26.24b	6.89b	7.62ab	0.70a
Chisel plow	30.98a	7.61a	10.87a	0.81a	31.61a	8.35a	9.75a	0.75a
Disc harrow	23.85b	6.03a	6.31b	0.75a	24.40c	6.55c	6.62b	0.82a
S.E±	2.1	0.54	0.46	0.05	0.16	0.11	0.79	0.08

Means in the same column with similar letters are not significantly different at P 0.05

Table 6: Effect of irrigation water quantities, tillage treatments and their interaction on water use efficiency of Abu Sabein for 2013 and 2014 seasons

a- Irrigation water amount

Water amount	Water use efficiency (WUE)	
	Season 2013	Season 2014
CWR +10% L.F	3.61a	3.57a
CWR +20% L.F	3.22a	3.45b
S.E.±	0.20	0.20

b- Tillage treatments

Tillage treatment	Water use efficiency (WUE)	
	WUE season 2013	WUE season 2014
Zero tillage	3.03b	3.14d
Disc plow	3.12b	3.60b
Chisel plow	4.24a	4.33a
Disc harrow	3.27b	3.35c
S.E.±	0.28	0.02

CWR=crop water requirement, L.F = leaching fraction.

Means in the same column with similar letters are not significantly different at P 0.05.

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