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Influence of Irrigation Methods on the Productivity of Summer Maize under Saline/sodic Environment

Muhammad Shafiq, Iqbal Hassan and Zahid Hussain
Water Resources Research Institute, National Agricultural Research Centre, Islamabad-45500, Pakistan

Abstract: Field experiment on summer maize was conducted in farmer's field at Mardan. The experimental area was sandy clay loam in texture with variable soil salinity and sodicity level. Maize crop was sown with furrow-bed and basin irrigation method. The regression models for total biomass and grain yield with soil salinity and sodicity gave better R^2 values under furrow-bed than basin irrigation method. There was about 24, 45 and 68 % increase in total fresh biomass, dry straw and grain yield under furrow-bed system from that of basin irrigation method, respectively. The water use efficiency of 3.15 and 6.57 kg ha^{-1} m m^{-1} was achieved in basin and furrow-bed irrigation, respectively.

Key words: Maize, irrigation method, salinity/sodicity, productivity

Introduction

In Pakistan about 21.6 million hectares are cultivated. Out of which 83 % is irrigated with an average cropping intensity of 106 % (Anonymous, 1997a). The low cropping intensity and crop productivities are mainly because of shortage of canal water and secondary salinization; water logging and salinity are worsening land degradation problems, whilst the source of water, causing watertables to rise is limited. Heavy monsoon rains cause temporary waterlogging especially on sodic soils with low permeability. About 35 % area of Indus basin is affected by either waterlogging or salinity or both. The estimated loss of productivity is around 25 % (Anonymous, 1997b).

Furrow-bed irrigation method is emerging as the most efficient method for use of available soil and water resources. It is especially appropriate under soils with poor water permeability, temporary/seasonal waterlogging and salinity and areas with irrigation water shortage (Queshi and Lennard, 1998; Kahloon *et al.*, 1998). Under well-drained soil conditions bed planting e.g., wheat is not advisable. Water saving at the cost of heavy yield losses does not have much attraction when irrigation shortage is not severely felt (Kahloon *et al.*, 1998).

Non-permanent bed/ridge and furrow irrigations produced yield increases of 20-50 % for wheat (Qureshi and Aslam, 1986; Hameed and Solangi, 1993), 17-48 % for cotton (Chaudhry *et al.*, 1994; Berkhout *et al.*, 1997; Kahloon *et al.*, 1998), 45 % for canola (Khan *et al.*, 2000) and saved irrigation water by 25-50 % (Chudhry *et al.*, 1994; Kahloon *et al.*, 1998).

As under irrigated areas, water shortages, soil salinity/sodicity and waterlogging are posing great problems and affecting cop yields so improved irrigation and soil management practices and cropping systems are urgently required.

The present study was therefore undertaken with a view to find out the influence of two irrigation methods (furrow-bed and basin) on the productivity of summer maize under saline sodic environment.

Materials and Methods

A field study was conducted during 1999 at Mardan, Pakistan. The study site is located on 34.12 °E latitude and 72-03 °N longitude. The soil of the site belongs to Mardan series classified as fine Ustertic Camborthid developed in filled basin and river beds, grayish brown, non to slightly calcareous material of Holocene age. The soil texture is mainly sandy clay loam with AB-DTPA extractable P and K of 2.56 and 72 mg $kg,^{-1}$, respectively. The study site falls in semi-arid zone both for Kharif and Rabi seasons, with mean seasonal rainfall of 250 mm during the Kharif. The Kharif season (summer season) is from May to September.

The experimental area Mardan comprised of 3.59 ha (272 m in length and 132 m in width). The experiment was laid out in randomized complete block design with two treatments i.e., furrow-bed and basin. The block size was 136 x 61 m^2 and plot size of 68 x 61 m^2. Water channel serving the experimental field was renovated. Water check structures were installed to maintain constant head during irrigation. Water control structures and field inlets were installed to control measured irrigations. Irrigations were measured using broad-crested weir type flume installed closer to the plots under irrigation.

The fertilizer was applied at the rate of 90 and 60 kg ha^{-1} N and P_2O_5. Half of the N and full dose of P_2O_5 was applied at the time of maize sowing, while doing final land preparation with rotavator. The remaining half of N was top dressed with 3rd irrigation, 47 days after sowing. Under basin irrigation it was broadcasted and in furrow bed treatment it was applied in furrows before irrigation. Urea and di ammonium phosphate were used as sources of N and P.

The maize variety sarhad white was sown on July 8, 1999 using seed rate of 40 kg ha^{-1}. Under furrow-bed treatment sowing was done with bed forming cum planting machine. It forms beds and plants maize in two rows on the shoulders of beds in a single operation. Sowing in basin was done with the help of bullock drawn drill. After sowing, plots were divided into three equal units for irrigation. Soil moisture contents were monitored during the crop growing season. Soil samples from 0-15, 15-30, 30-60 and 60-90 cm depths were collected from each replication. The samples were dried at a temperature range of 100 to 110 °C to estimate soil moisture contents on dry weight basis. Volumetric moisture contents in the profile were determined (Gardner, 1986). Non-recording rainguage was installed at the experimental area to measure rainfall depth.

Seedling emergence, crop stand, growth, yield and yield component data were recorded from grid size of 400 m^2. At silking stage maize plant roots' biomass was determined for 0-10, 10-20 and 20-30 cm depths. It was done through extracting 20 cm diameter cores around the plants and washing the soil through 500 μ sieve. To facilitate soil particals dispersion the cores were dipped overnight in 5 % of sodium hexametaphosphate solution. Soil and crop characteristics i.e., seedling emergence, crop stand, plant height and yield were determined. Data were analyzed statistically by Steel and Torrie (1980).

Results and Discussions

Spatial variability in soil salinity and sodicity: The difference in maximum and minimum values of pH in different layers ranged from 2.09 to 2.45. Mean value of pH 1:1 ranged from 8.04 to 8.60 and soil pH increased with depth (Table 1). The coefficient of

Table 1: Statistical analysis of soil pH and $EC_{1:1}$ (dS m^{-1}) in soil profile of the experimental area, Kharif 1999, Mardan, Pakistan

Soil depth (cm)	Min.	Max.	Mean ± S.D	Coefficient of variation
pH				
0-15	7.03	9.12	8.04 ± 0.52	6.5
15-30	7.23	9.64	8.27 ± 0.66	8.0
30-60	7.42	9.87	8.49 ± 0.71	8.4
60-90	7.62	9.90	8.60 ± 0.65	7.6
EC				
0-15	0.26	2.30	0.73 ± 0.56	76.4
15-30	0.20	2.20	0.69 ± 0.53	76.8
30-60	0.24	2.44	0.71 ± 0.58	80.8
60-90	0.23	2.15	0.73 ± 0.62	84.5

Min: Minimum Max: Maximum

Table 2: Water used by kharif maize in 1999 under two irrigation methods at the experimental area of Mardan, Pakistan

Irrigation methods	Volumetric water contents (mm) in root zone (0-90 cm) depth					
	At sowing	At harvest	Difference (mm)	Irrigation applied (mm)	Rain fall (mm)	Total water used (mm)
Basin	218	224	-6	407	265	666
Furrow-bed	233	199	34	238 (+42)	265	537 (-19)

Table 3: Correlation between pH, EC and total biomass, grain yield of kharif maize under two irrigation methods

Parameters	Irrigation method	Regression model	R^2
Total biomass	Basin	$13.04-2.88pH_1+3.1pH_2-3.56pH_3+2.02pH_4$	0.49*
	Furrow-bed	$20.69-2.59pH_1+0.52pH_2-1.72pH_3+1.6pH_4$	0.77*
	Basin	$3.67-0.49EC_1+0.62EC_2-0.42EC_3-0.15EC_4$	0.42*
	Furrow-bed	$4.29-0.22EC_1+0.93EC_2-2.23EC_3-0.38EC_4$	0.62**
Grain yield	Basin	$1.21-0.37pH_1+0.36pH_2-0.62pH_3+0.50pH_4$	0.48*
	Furrow-bed	$2.93-0.28pH_1+0.19pH_2-0.46pH_3+0.23pH_4$	0.79**
	Basin	$0.48-0.58EC_1-0.24EC_2-0.12EC_3+0.35EC_4$	0.31*
	Furrow-bed	$0.50-0.02EC_1+0.19EC_2-0.22EC_3+0.15EC_4$	0.52*

Subscript 1=0-15, 2=15-30, 3=30-60 and 4=60-90 cm depth **: $p<0.01$ *: $P<0.05$

Table 4: Effect of irrigation methods on roots distribution of kharif maize 1999, at the experimental area of Mardan, Pakistan

Irrigation methods	Soil depth (cm) 0-10		10-20		20-30		
	Dry biomass (g/plant)	% of total depth	Dry biomass (g/plant)	% of total depth	Dry biomass (g/plant)	% of total depth	Total dry root biomass (g/plant)
Basin	13.68	60	5.67	25	3.45	15	22.8
Furrow-bed	24.97 (+83)	75	5.10 (-10)	15	3.52 (+2)	10	33.59 (+47)

Figures given in parenthesis indicate percent increase (+) or decrease (-) under furrow-bed over basin method

Table 5: Effect of irrigation methods on yield and yield components of kharif maize

Parameters	Irrigation methods Basin	Furrow-bed
Plant population (plants per 9m^2)	58NS	63NS
Plant height (cm)	182b	205a
Plants with-out cobs (% of total)	32.9NS	24.7NS
Cob length (cm)	12.7NS	13.5NS
Total fresh biomass (t ha^{-1})	19.54NS	24.16NS (24)
Dry straw (t ha^{-1})	4.92b	7.13a (45)
Grain yield (t ha^{-1})	2.10b	3.53a (68)
Harvest index (%)	29.9b	33.1a
Water use efficiency (kg ha^{-1} mm^{-1})	3.15	6.57

* Figures given in parenthesis are percent increase under furrow-bed over basin. Figures with different letters are significantly different at $p<0.05$ NS= Non significant.

variation for different layers was low and almost of same magnitude ranging from 6.5 to 8.4 %. The difference in pH of 0-15 cm and 60-90 cm soil depths ranged from 0.04 to 1.36 with an average value of 0.56 and coefficient of variation 60 %.

The average values of $EC_{1:1}$ for different layers ranged from 0.69 to 0.73 dS m^{-1} with coefficient of variation of 76.4 to 84.5 % (Table 1). The higher values of coefficient of variation indicated that soil salinity in different layers varied greatly than soil pH.

Water used: The water used by Kharif maize 1999 under both irrigation methods was estimated by taking difference of soil moisture contents in the soil profile (0-90 cm) at sowing and harvest plus irrigation and rainfall depths. It was 666 and 537 mm under basin and furrow-bed irrigation methods, respectively (Table 2). The water used by Kharif maize 1999 in furrow-bed irrigation system was 19 % less than basin irrigation. Chaudhry *et al.* (1994) and Kahloon *et al.* (1998) also observed similar results.

Spatial variability in yield: There was a quite variation in total biomass and grain yield which may be attributed to spatial distribution of soil salinity/sodicity in the experimental area. The models gave better R^2 values under furrow-bed than basin irrigation method (Table 3). The magnitude of R^2 for models showed that relationship between total biomass and grain yields and pH was more than their relation with EC. Kharif maize 1999 showed reduction in dry matter accumulation and yield at higher levels of soil sodicity and salinity. Soil salinity/sodicity may have a two fold effect on plants. Salts in soil solution decreased the availability of water to the roots and salts taken up by the plants can accumulate to toxic levels in certain tissues. Both factors affected growth and finally the yield.

Total roots dry biomass was 47 % higher under furrow-bed than that of the basin irrigation method (Table 4). However, under furrow-bed system roots were (75 %) mainly concentrated in the top 0-10 cm of the soil depth, which represents height of raised beds at the time of crop harvest. Furrow-bed helped to prevent temporary waterlogging by draining excess water from the furrows, maintained soil water and provided optimal aeration for the root zone. This system of irrigation also increased the water holding capacity of root zone and the amount of available water. The better physical environment engineered in furrow-bed system encouraged healthy root and plant growth.

All the yield components (Table 5) performed better in furrow-bed system as compared to basin irrigation. The increase in plant height under the furrow-bed system was significant from that of the basin irrigation. There was about 24, 45 and 68 % increase in total fresh biomass, dry straw and grain yield under furrow-bed system from that of the basin irrigation system, respectively. Qureshi and Aslam (1986) and Hameed and Solangi (1993) observed 20-50 % increased yield under beds for wheat. This increase was 17-48 % for cotton (Chaudhry *et al.*, 1994; Berkhout *et al.*, 1997; Kahloon *et al.*, 1998) and 45 % for canola (Khan *et al.*, 2000). This may be attributed to better soil environment and water management under the furrow-bed system, which have influenced the plant growth and consequently the yield.

Water use efficiency (WUE): The WUE under basin and furrow-bed irrigation system was estimated for Kharif maize 1999. The WUE of 3.15 and 6.57 kg ha^{-1} mm^{-1} was achieved in basin and furrow-bed irrigation, respectively (Table 5). Water used by the crop in furrow-bed irrigation system was 19 % less than basin irrigation, but grain yield was 68 % higher than basin irrigation, which consequently increased WUE by 109 %. Irrigation water requirement in the furrow-bed system was almost 42 % less from that of the basin. This shows that farmers can save water by adopting the furrow-bed system or can increase the cropping intensity if water is in short. The WUE in furrow-bed irrigation system was a good indication for increased productivity of water use for Kharif maize.

Under the emerging water scarce situation furrow-bed irrigation method has the great potential for increasing land and water productivities and reducing waterlogging problem. Under maize furrow-bed increased crop yield (68%) along with irrigation water saving (42%).

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