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Maize Crop Production and Water Use Efficiency as Affected by Planting Methods

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Abstract: Agricultural production in Pakistan on one hand is constrained by scare water availability, soil salinity/sodicity and waterlogging problems on the other hand irrigation application losses on the field are around 25-40%. To evaluate two planting methods (basin and furrow-bed) studies on the same fields were conducted for three consecutive years (1999-2001) adopting two planting methods (basin and furrow-bed). The results indicated that under furrow-bed on the average, there was 29% less, irrigation depths with 42% greater grain yield compared to basin. The water use efficiency (WUE) was 68% greater with 35% less weed infestation under furrow-bed compared to basin. Generally, for maize greater benefits of raised beds can be achieved on problematic soils especially during seasons with high/concentrated rainfalls.

Key words: Maize, crop production, water, efficiency, planting method

Introduction

Pakistan is an agricultural country with the world's largest contiguous irrigation system, the Indus basin irrigation system (IBIS). In IBIS, field crops are irrigated using the basin irrigation method. Application losses in fields are around 25-40% under flood and basin irrigation (World Bank, 1997). Low application efficiencies reported in IBIS result from over irrigation, improper irrigation methods and timings, non-scientific irrigation scheduling and nonleveled fields (Gill, 1994).

In poorly drained soils, after irrigation and/or heavy rainfed water is ponded on the soil surface for a longer duration causing temporary water logging. In these soils planting on raised beds provides better option for managing irrigation and excessive rain water (Qureshi and Lennard, 1998). According to Shafiq *et al.* (2002) effect of furrow-beds on root development and function are by far the most important role of furrow bed in crop development. The root system seems as a bridge between the impacts of agricultural practices on soil and changes in short function and harvested yield (Klepper, 1990).

Furthermore, furrow ridge/furrow-bed method of irrigation provides an opportunity to farmers for managing that water resources more efficiently. In the face of increasing shortages of water in future and aggravating problem of waterlogging and salinity, improvements in the irrigation efficiency is a vital necessity. Efficient use of irrigation water not only saves available water supplies but also have a direct impact on alleviating waterlogging and salinity. Chaudhry *et al.* (1994) observed water saving of 25-53% for cotton under furrow bed over basin with an increased in yield of 6-52%.

Under the growing water scare situation and

decreasing/stagnant crop productivities, there is a need to develop and evaluate improved irrigation methods with higher water use efficiencies and provide more water for crop production. Considering the importance of problems, research was initiated at farmer's fields with specific objective. Assess the potential of a combination of permanent raised-beds and no tillage crop establishment practices for improving irrigation efficiency and maize crop productivities. The generated information when coupled with other soil and crop management practices may help sustainable crop production under water scare areas.

Materials and Methods

Characteristics of study area: Two experimental fields comprising of 0.84 and 1.62 ha were established near Mardan, Pakistan. It falls in semi-arid zone both for summer and winter seasons with mean seasonal rainfall of 250 mm during summer (May-September) and 300 mm during winter (October-April). Soils of the study area belongs to Mardan soil series classified as fine Ustertic Camborthid, developed in filled basin and river beds, grayish brown, non to slightly calcareous material of Holocene age. The physico-chemical characteristics of soil at initiation of experiments is given in Table 1.

Study layout and sowing of crops: The study was laid out using completely randomized block design with two treatments (basin and furrow bed) and four replications under Field 1 and three under Field 2. Water channels serving the fields were renovated. Water inlet structures were installed at each treatment plot. Irrigation stream size was same for both planting methods.

Table 1: Soil chemical characteristics of fields planted under maize

Soil depth	AB-DTPA extractable (mg kg ⁻¹)			pH _{1:1}			EC _{1:1}		
	P	K	Organic matter (%)	Min.	Max.	Mean	Min.	Max.	Mean
Field No.1									
0-15	3.4	72	0.31	7.9	9.2	8.8	0.26	2.30	0.73
15-30	1.2	59	0.43	7.8	9.6	8.8	0.20	2.20	0.69
Field No. 2									
0-15	2.0	148	0.52	7.9	8.9	8.2	0.20	0.40	0.31
15-30	2.0	136	0.34	8.0	8.9	8.3	0.22	0.31	0.27

Irrigations were measured using broad-crested weir type flume. Maize crop was sown for three consecutive years on Field 1 and two on Field 2 following maize-wheat cropping system. Fertilizer was applied @ 90-60 N P₂O₅ kg ha⁻¹. Half of the N and full dose of P₂O₅ was applied at the time of crop sowing, while remaining half of N was top dressed when the crop was knee high with 2nd or 3rd irrigation. Under basin, it was broadcasted and in furrow-bed it was applied in furrows before irrigation. Urea and DAP were used as sources of nutrients. Under basin method, sowing was done with traditional drill, whereas under furrow-bed sowing was done with bed forming cum planting machine. It forms two beds (one complete and two half on each side) and plant two rows of maize at 15 cm away from the edges of beds. The size of beds were equal to 125 cm at the top. Seed was covered with soil depth of 4-5 cm.

Data collection and analysis: During 1999, at Field 1 irrigations were applied as per turn of the farmers. Whereas, during 2000 and 2001 irrigations on both fields were scheduled based on soil moisture contents as dried at a temperature range of 100-110°C. Criteria for time of irrigation was 75% depletion of available water in top 30 cm depth. Soil moisture depletion trend was used to predict date of irrigation. Two to three days before the predicted date of irrigation soil samples from 0-15, 15-30, 30-60 and 60-90 cm depths were collected to determine soil moisture deficit. Volumetric moisture contents of available water in root zone were used to estimate depth of net irrigation. Non-recording rain gauge was installed at the experimental site to measure rainfall depth. Yield and yield components data were recorded from 3.63 m² area from randomly selected three locations of each treatment. For weed dry matter determination above ground biomass was harvested and dried two times during the early growth period. Crop yield and yield components data were analyzed statistically and treatments were evaluated as per procedure described by Steel and Torrie (1980).

Results and Discussion

Seasonal rainfall: The seasonal rainfall during Kharif season ranged from 191 to 363 mm received in 10 to 18 rainfall events (Table 2). It was 67 to 105% of average of

250 mm rainfall of the area. The distribution and total amount was quite variable which affected crop germination, crop stand establishment and consequently the yield of crops.

Irrigation economy: For Kharif maize, furrow-bed planting method saved 2 to 42% of irrigation water with an average value of 29% compared to basin (Table 3). The overall less irrigation water applied under furrow-bed compared to basin planting method may be attributed to less areas (50% of total) wetted, soil surface configuration and greater speed of water flowing down furrows. Considering 120% cropping intensity in irrigated areas, with the same amount of available irrigation water equal to 25% more area can be irrigated during both the seasons. Through adopting furrow-bed planting system on large areas the waterlogging problems can also be controlled.

Weed dry matter: The weed growth/biomass in furrow-bed method were consistently less than basin treatment (Table 4). There was seasonal variation, which may be attributed to total amount of rainfall and its distribution. On cumulative basis dry weed biomass under furrow-bed was 27 and 35% less compared to basin at two sampling times. It was further observed that weeds in furrow-bed had been almost entirely confined to the furrows. The drier soil surface condition of the raised bed appears to be the main cause of this phenomenon. No till/minimum soil disturbing farming practice may further reduce the weed infestation under permanent bed system. Because of concentration of weeds in furrows their control was easy and economical.

Yield and yield components: Considering the yield as a criteria for performance evaluation of planting method, the furrow-bed out yielded than basin for all the seasons under both the fields (Table 5). The average increase in total fresh weight was 32%, whereas dry straw and grain yield by 35 and 42%, respectively. The plants without cobs were 35% less under furrow-bed compared to basin, while cob length was 18% more. The managed raised bed treatment managed produced continuously encouragingly good yield increase. The increase in yield under furrow-

Table 2: Rainfall distribution during maize growing seasons

1999		2000				2001			
Field No. 1		Field No.1		Field No. 2		Field No. 1		Field No. 2	
DAS	Amount	DAS	Amount	DAS	Amount	DAS	Amount	DAS	Amount
9	64	4	2	3	27	0	16	-	-
11	23	5	4	7	4	1	8	5	5
12	2	13	5	13	3	5	16	6	16
13	3	19	8	14	20	7	3	12	16
20	4	26	27	15	16	12	29	13	8
21	3	30	4	19	17	15	50	17	16
30	56	36	3	21	5	23	29	19	3
32	32	37	20	22	5	30	16	24	29
34	4	38	16	41	13	31	8	27	50
35	15	42	17	42	36	59	16	35	29
48	8	44	5	43	56	Total	191	42	16
49	25	45	5	69	11			43	8
77	19	64	13	65	20			7	16
82	4	65	30	69	5			Total	212
Total	263	66	56	75	7				
		87	11	79	14				
		88	20	Total	259				
		92	5						
		Total	251						

DAS: days after sowing

Table 3: Depth of irrigation applied to Kharif maize at the Experimental Area, Mardan

Planting method	Field No. 1			Field No. 2		Cumulative average
	1999	2000	2001	2000	2001	
Basin	407	204	205	205	363	277
Furrow	238	166	130	200	244	196
Bed	(-42)	(19)	(-37)	(-2)	(-33)	(-29)

Table 4: Dry weed biomass in maize as affected by planting methods

Planting methods	Field No. 1				Field No. 2			Cumulative average
	1999	2000	2001	Average	2000	2001	Average	
First sampling (t ha ⁻¹)								
Basin	0.99a	0.26c	0.14c	0.46	0.47	0.69	0.58	0.51
Furrow-bed	0.84b	0.23c	0.22c	0.43	0.21	0.35	0.28	0.37
Average	0.91A	0.24B	0.18B	-	0.34	0.52	-	(-27)*
Second sampling (t ha ⁻¹)								
Basin	1.32	0.56	0.43	0.77A	0.69	0.84	0.77	0.77
Furrow-bed	0.88	0.43	0.27	0.53B	0.42	0.50	0.46	0.50
Average	1.10A	0.49B	0.35B	-	0.56	0.67	-	(-35)

* Figure given in parenthesis percent decrease under furrow-bed over basin irrigation method

Table 5: Yield and yield components of Kharif maize under two planting methods

Planting methods	Field No. 1				Field No. 2			Cumulative average
	1999	2000	2001	Average	2000	2001	Average	
Total Fresh Biomass (t ha ⁻¹)								
Basin	20.05	12.23	1.87	11.38B*	16.30	19.70	18.00B	14.03
Furrow-bed	23.03	14.59	6.96	14.86A	24.91	23.26	24.09A	18.55
Average	21.54A	13.41B	4.41C		20.60	21.48		(+32)
Dry Straw (t ha ⁻¹)								
Basin	5.16	6.66	1.69	4.50B	7.73	6.25	6.99B	5.50
Furrow-bed	6.93	7.11	4.82	6.29A	10.33	7.80	9.07a	7.40
Average	6.05B	6.88A	3.25C		9.03A	7.02B		(+35)
Grain Yield (t ha ⁻¹)								
Basin	2.16c	2.51bc	0.75d	1.81B	3.15	3.34	3.24	2.38
Furrow-bed	3.43a	3.03ab	2.59bc	3.02A	4.07	3.79	3.93	3.38
Average	2.79A	2.77A	1.67B		3.61	3.57		(+42)
Cob Length (cm)								
Basin	12.6a	13.1a	6.8b	10.8B	15.98	15.37	15.67	12.77
Furrow-bed	13.5a	13.4a	14.3a	13.7A	17.87	16.37	17.12	15.09
Average	13.1A	13.2A	10.5B		16.93	15.87		(+18)
Plants Without Cobs (% of total)								
Basin	32.4b	29.5b	76.8a	46.2A	29.50	12.33	20.92	36.1
Furrow-bed	26.4b	22.4b	22.03b	23.7B	29.93	15.67	22.80	23.3
Average	29.4B	25.9B	49.5A		29.72A	14.00B		(-35)

Figures sharing the same letters in the columns and rows are statistically non significant 0.05 level

Table 6: Water use efficiency (WUE) of Kharif maize at the experimental area, Mardan

Planting methods	Field No. 1			Field No. 2		Cumulative average
	1999	2000	2001	2000	2001	
Basin	3.15	6.09	1.66	7.35	5.02	4.65
Furrow	6.57	8.53	7.00	10.05	6.78	7.79
Bed	(108)	(40)	(32)	(37)	(35)	(+68)

Figures given in the parenthesis are percent increase under furrow-bed over basin

bed may be attributed to better root environment which encouraged plant height, other yield components and consequently grain yield. The greater difference under Field 1, than Field 2 may be due to high saline/sodic environment. Under these conditions furrow-bed provide good promise. During 2001, there was season rainfall just after sowing under Field 1 which affected crop germination especially under basin and tremendously affected cropstand establishment, plant growth and yield. Furrow-bed method is more efficient to produce higher yield when the rainfall is high and concentrated during growing seasons. The Field 1 with sodic/permeability problem recorded the largest yield increase especially when high rainfalls were received during early growing season (2001).

Water use efficiency (WUE): The WUE under basin and furrow bed irrigation system was estimated for all crop seasons under both the fields (Table 6). Furrow-bed planting method consumed less amount of irrigation water and gave higher maize grain yield. Under raised-bed most of the water was utilized beneficially by the plants through transpiration, which increased its efficiency. The increase in WUE for maize ranged from 35 to 322% with an average value of 68% for maize (water sensitive crop) greater benefits of raised-bed can be achieved on problematic soils especially during seasons with high/concentrated rainfalls.

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