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Early Prediction of Wheat Yield in South-Western Punjab Sown by Different Planting Methods, Irrigation Schedule and Water Quality Using the CERES Model

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ABSTRACT

In South Western region of the Indian Punjab, productivity of wheat crop in cotton-wheat cropping system is constraint by limited availability of good quality irrigation water and late sowing due to indiscriminate nature of the proceeding cotton crop. Two Field experiments were conducted for two years to assess wheat productivity with two planting methods (flat and bed), two irrigation schedules (Farmer's practice and model based) and conjunctive use of canal (good quality) and tube well (poor quality) waters. The results suggest that wheat productivity per unit of irrigation water was more in bed planting method and model based scheduling of irrigation than flat planting and Farmer's practice of irrigation. The CERES model responded to irrigation schedules and flat planting method and predicted wheat yield in different treatments within deviation of 2-12%.

Key words: Planting method, irrigation schedule, conjunctive water use, CERES model

Wheat (*Triticum aestivum* L.) is the most important *rabi* crop of Punjab state. It covers 3.4 m ha out of total 4.22 m ha cultivated area. It contributes about 50 per cent in the central pool of the country. In Punjab, there are three main hydrological agro-climatic zones. Each zone has a distinct cropping system. For example, maize-wheat system in Foot-hill (*Kandi*) zone, rice-wheat in Central zone and cotton-wheat in South Western zone. In South Western zone, productivity of wheat is relatively lower than the Central zone because of its late sowing as a consequence of the indeterminate behavior of the preceding cotton crop. Khera *et al.* (1987) reported that irrigation interval in late sown wheat after potato in the central zone should be shorter than those sown on normal date. The frequent irrigation saves the wheat crop from low temperature during the initial growth period and also minimizes the effect of forced maturity during the hot month of March and April. But in South Western zone, the availability of good quality of irrigation water is insufficient. The water supply from the canals is erratic and the ground water is of poor quality. Thus there is a need to select an appropriate soil and water management technology for the enhancing crop water productivity of wheat in this region. In the Central zone, growing wheat on raised beds following rice has been reported to give the same yield as these sown on the flat beds but with lies irrigation water (Dhillon *et al*., 2000 and Hobbs and Gupta, 2003). The present investigation aimed at (1) to study the effect of planting method, irrigation scheduling and conjunctive use of poor and good quality water on wheat yield in cotton-wheat system (2) to test the ability of CERES model for predicting wheat yield in different planting methods and irrigation schedules.

Materials and Methods

Two independent experiments were conducted for two years during *rabi* seasons of 2002-03 and 2003-04 at the Farm of Regional Research Station Bathinda. The farm is located at an altitude of 211 m above mean sea level and is intersected by 30°9′ N latitude and 74°56′E longitude. Geologically, the farm area forms a

Table 1a. Physical and Hydraulic properties of the soil profile of the expeperimental site

Depth, cm	Sand, %	Silt, %	Clay, %	Texture	Bulk density, Mg m^{-3}	Hydraulic conductivity, mm hr^{-1}
0-15	80.0	12.5	7.5	loamy sand	1.58	8.7
15-30	92.5	5.0	2.5	silt	1.58	39.3
30-45	81.3	10.0	8.8	loamy sand	1.54	36.9
45-60	72.5	17.5	10.0	silt	1.55	4.7
60-75	72.5	17.5	10.0	silt	1.49	32.9
75-90	68.8	20.0	11.3	silt	1.59	12.8
90-105	72.5	17.5	10.0	silt	1.72	2.60
105-120	70.4	17.5	12.2	silt	1.73	4.6
120-135	71.6	18.8	9.7	silt	1.75	1.9
135-150	69.1	20.0	10.9	silt	1.73	2.1
150-165	51.6	31.3	17.2	silt	1.81	0.7
165-180	37.9	42.5	19.7	silt	1.75	1.2

Table 1b. Chemical properties of the experimental site

Depth, cm	pH	EC, dSm^{-1}	OC, %	NH_4-N, kg ha^{-1}	NO_3-N, kg ha^{-1}
0-15	8.8	0.366	0.420	17.65	23.52
15-30	8.9	0.284	0.315	11.76	31.36
30-45	8.7	0.311	0.120	7.84	29.41
45-60	8.5	0.332	0.150	15.68	39.20
60-75	8.5	0.229	0.105	5.89	27.44
75-90	8.8	0.303	0.090	3.92	27.44
90-105	8.8	0.297	0.405	15.68	31.36
105-120	8.7	0.379	0.240	7.84	43.12
120-135	8.5	0.372	0.210	11.76	47.04
135-150	8.6	0.369	0.210	3.92	31.36
150-165	8.7	0.342	0.150	0.20	35.28
165-180	8.7	0.310	0.075	0.20	45.09

part of the Indo Gangetic alluvial plains. The soil was loamy sand in texture and belonged to Gahri Bhagi series (mixed, hyperthermic, Ustochreptic Camborthid). The physical and chemical properties of the soil are given Table 1. The organic carbon of the surface soil was 0.4 %, hydraulic conductivity 8.7 mm hr^{-1}. The water table is more than 8 m deep. The climatic parameters were recorded at meteorological laboratory at a distance of 200 meters from the experimental field. The details of maximum temperature and evaporation from open pan and rainfall during the crop growing seasons of both the years are given in Figure 1. During the year 2002-03 and 2003-04, total evaporation from the open pan was 454 mm and 477 mm and rainfall 71mm and 33 mm, respectively.

For sowing of wheat crop, the field was wetted with pre-sowing irrigation of 75 mm and prepared by performing tillage operations (2 discing, 2 cultivatings and one planking) for the two independent experiments. In each experiment, sixteen plots of size 7m x 5 m were prepared and

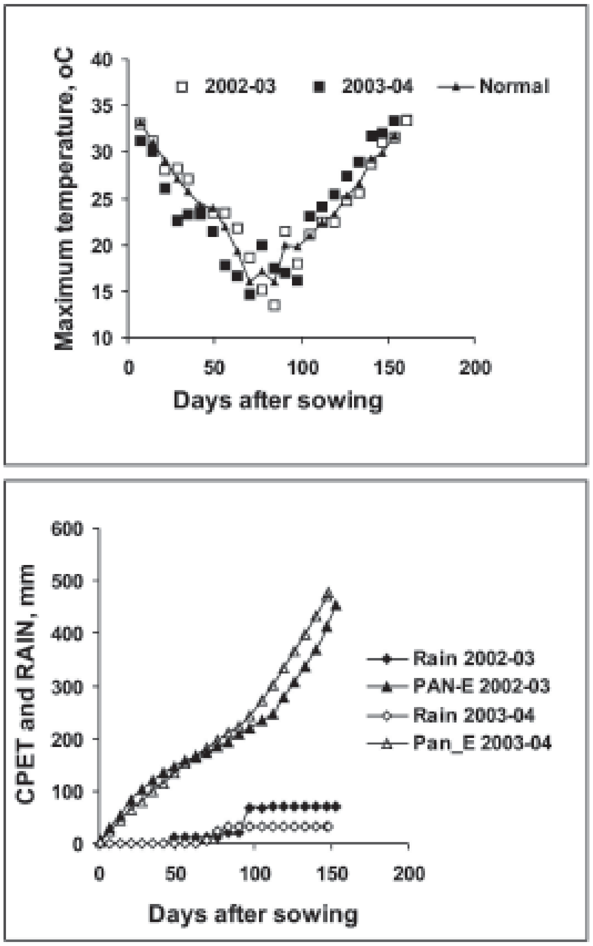

Fig. 1. Maximum temperature, cumulative open pan evaporation (CPET) and rain during the wheat crop season

were embanked with earthen dikes to prevent runoff.

Experiment 1

In this experiment, treatments of two planting methods (flat and bed) and two irrigation schedules (model-based and Farmer's practice) were quadruplicated in a randomized block design. The model used to schedule irrigation was based on weather parameters and soil type (Jalota and Arora, 2000). In the flat sowing treatment, the plots were kept as such and in bed planting, beds were made with PAU bed planter. The size of a bed was 67.5 cm (37.5 cm raised bed and 30 cm furrow). The crop was sown on November 15 during 2002-03 and November 20 during 2003-04. Wheat (variety PBL 343) was sown at 15 cm row spacing while on beds two rows of wheat crop were sown on a single bed at row spacing of 15 cm. The seed rate applied was 100 kg ha^{-1}. Fertilizers 60 kg N ha^{-1} as urea, 60 kg ha^{-1} P_2O_5 as single super phosphate and 30 kg ha^{-1} K_2O as muriate of potash were broadcasted at the time of sowing and remaining half of nitrogen (60 kg N ha^{-1}) was applied at the time of first irrigation (30 days after sowing). The post sowing irrigations were applied according to irrigation treatments and dates for the same are given in Table 2. The crop was harvested on April 15 in both the years.

Experiment 2

This experiment was conducted with the treatments of three water qualities (canal water, tubewell water (RSC 6.4 and EC 2.8 $dS^{-1}m$) and alternate canal and tube well water) and two irrigation schedules in the tube well water treatment only (Farmer's practice and model based) with four replications. Dates of pre-sowing irrigation, land preparation and fertilizer application dates were the same as in the experiment 1. Results were statistically analysed using standard procedures for randomized block design. Means were compared by using least significant differences (LSD) at 0.05% probability level. Using the experimental crop data, soil data and weather parameters, CERES model was tested to predict grain yield of wheat.

Results and Discussion

The results of experiment 1 showed that grain yields of wheat in flat and bed treatments were not statistically different during both the years (Table 3). However yield was relatively higher in 2003-04 than in 2002-03. This may be attributed to adequate water supply in the former year provided by more number of irrigations (Table 2). Although during 2003-04 evaporation from open pan was more and rainfall was lesser than during 2002-03 (Figure1). The yields under two irrigation schedules *i.e* Farmer's practice and model based were at par statistically. In experiment 2 the effect of water quality showed that yields were at par with canal water applied throughout or alternately with tube well water. These results confirm the earlier observations of Bajwa and

Table 2a. Dates of irrigation application in different treatments during the two years in Experiment 1

Treatments	Dates of Irrigation application				
	I	II	III	IV	V
			Year 2002-03		
Farmer's Practice	12/12/02	16/01/03	07/03/03	27/03/03	-
Model based	12/12/02	16/01/03	07/03/03	-	-
			Year 2003-2004		
Farmer's Practice	18/12/03	22/01/04	19/02/04	05/03/04	25/03/04
Model based	18/12/03	22/01/04	19/02/04	05/03/04	-

Table 2b. Dates of irrigation application in different treatments during the two years in experiment 2

Treatments	Dates of Irrigation application				
	I	II	III	IV	V
		Year 2002-03			
Canal water throughout	12/12/02	16/01/03	07/03/03	27/03/03	-
Tube well water as Farmer's Practice	11/12/02	16/01/03	07/03/03	27/03/03	-
Tube well water as Model based	11/12/02	16/01/03	07/03/03	-	-
Alternate canal and Tube well water	12/12/02	16/01/03	07/03/03	27/03/03	-
		Year 2003-2004			
Canal water throughout	18/12/03	22/01/04	19/02/04	05/03/04	25/03/04
Tube well water as Farmer's Practice	17/12/03	20/01/04	20/02/04	04/03/04	24/03/04
Tube well water as Model baesd	26/12/03	20/01/04	16/02/04	04/03/04	-
Alternate canal and Tube well water	17/12/03	22/01/04	22/02/04	05/03/04	24/03/04

Table 3. Effect of different sowing methods, irrigation schedules and water quality on grain yield of wheat

Treatments	2002-03	2003-04	Mean
Experiment 1			
Sowing method			
Bed sowing	3289	3777	3533
Flat sowing	3342	3722	3532
CD 5%	NS	NS	NS
Irrigation Schedules			
Farmer's Practice	3292	3670	3481
Model based	3338	3829	3584
CD 5%	NS	NS	NS
Experiment 2			
Canal water throughout	3607	3965	3786
Tube well water as Farmer'practice	3480	3740	3610
Tube well water as model based	3399	3685	3542
Alternate canal and tubewell water	3571	3852	3712
CD 5%	NS	NS	NS

Josan (1989) who reported non- significantly differed yields in good quality water applied throughout and applied alternately with poor quality water in rice and wheat crops. However, wheat yield in tubewell water irrigation treatment was non-significantly decreased than the canal water.

The amount of water applied in the bed planting treatment was lesser by 100 mm, 75 mm than the flat sowing during 2002-03 and 125mm and 100 mm during 2003-04. It may be ascribed to lesser amount of water per unit irrigation in the bed treatment (50mm) compared to flat (75 mm). These results confirm the earlier observations by Dhillon *et al.* (2000). Similarly the amount of total irrigation water applied was lesser by 75 mm when it was scheduled as per model compared to Farmer's practice during both the years. The water use efficiency of irrigation water was highest in the treatment where wheat was sown on beds and irrigation was scheduled as per model. The water productivity based on the

Table 4. Comparison of experimentally observed and CERES model predicted grain yield of wheat in different irrigation schedules in flat sowing planting method during two years

Treatment	2002-03			2003-04		
	Observed	Predicted	Deviation, %	Observed	Predicted	Deviation, %
Model based irrigation	3336	3277	-1.8	3659	3520	-3.9
Farmer's Practice	3350	3277	-2.2	3784	3520	-7.5
Canal water throughout the crop season	3607	3277	-10.1	3965	3520	-12.6

irrigation water in bed and flat planting methods was 1.51 kg m^{-3} and 1.46 kg cm^{-3} during 2002-03 and 1.28 and 1.22 kg m^{-3} during 2003-04, respectively. The higher water productivity in bed planting is not due to increase in grain yield but due to lesser amount of water applied per irrigation than the flat planting method. The water productivity with respect to water quality showed that it was 1.20 and 1.19 kg m^{-3} during 2002-03 and 1.32 and 1.28 kg m^{-3} during 2003-04 in canal water throughout and alternate canal and tube well water, respectively.

Wheat yield predicted with the CERES model was reasonably closer to the observed with a deviation ranging from -1.80 to -12.6 % amongst the different treatments of irrigation schedules in flat sowing method (Table 4). However, it could not be applied for treatments of bed planting and water quality, as there is no provision for such management in the present version of the model.

CONCLUSIONS

The results of the present study indicate that in cotton-wheat system, bed planting method and irrigation scheduling based on the weather demand and soil type gave higher water productivity. But expenditure on beds preparation may add up in the cost of production and shrinks the profit. Therefore, flat sowing and irrigation scheduling based on weather demand and soil type are the economically sustainable soil and water management practices. Poor quality water can also be used if applied alternately with canal water of good quality. CERES model responds to irrigation schedules in flat bed sowing and predicts wheat yield reasonably.

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