Determination of the Optimal Date for Sowing of Wheat in Canal Irrigated Areas using FAO CROPWAT Model

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ABSTRACT

Mismatch between available water supplies and crop water requirements both, in terms of quantity and timing are a major cause of low water use efficiency in canal irrigated areas in India. FAO CROPWAT model adequately predicts the effects of water stress on yield. The applicability of the model was studied with the help of operating schedule data of a small *Noorpur* distributary of Western *Yamuna* Canal system. The expected yields of wheat under different sowing dates, during a large period of sowing followed by farmers in north Indian Plains (First week of November to third week of January), were estimated corresponding to the most probable canal operation schedule. Third week of November was found to be the optimal sowing period for wheat. This paper concludes that CROPWAT is a powerful tool to simulate different crop water need scenarios under different planting dates and thus enables the user to select most optimal sowing date to realize higher yields and water use efficiencies by matching the probable canal water supplies with crop needs.

Key words: CROPWAT, Canal command, Wheat, Sowing date;

INTRODUCTION

Growing competition for water from domestic and industrial sectors is likely to reduce its availability for irrigation. The need to meet the growing demand for food will require increased crop production from less and less water. Achieving greater efficiency of water use is a a challenge in the near future and will include the employment of techniques and practices that deliver a more accurate supply of water to crops.

Crop growth simulation models and hydraulics of water movement in crop root zone help in making predictions for irrigation scheduling under different conditions of water supply. The CROPWAT model developed by the FAO Land and Water Development Division (FAO, 1992) is based on simple water balance principle that allows the simulation of crop water stress conditions. It also helps in estimations of yield based on well established methodologies for determination of crop evapotranspiration and yield responses to water. Smith and Kivumbi (2002) described in detail the use of CROPWAT model in management of deficit irrigation situations. Marica and Cuculeanu (2000) and Tuinea and Palade (2000) found CROPWAT model useful in assessment of impacts of draught.

In north Indian plains, wheat is a predominant crop grown in *Rabi* season. It is sown from first week of November to First week of January. Crop sown on different dates require different irrigation schedules. Operation of canals somehow, is independent of agricultural; operations in their command area. Crops grown on different dates experience water stress of different magnitudes in areas under exclusive command of canals, consequently, wheat sown on different dates result into different yields and water use efficiencies (Rajput and Patel, 2005).

Canal delivery schedules are seldom prepared on the basis of the actual water requirements of the command area. Also, the canal operation schedules are rarely adhered to the fixed pattern. This result into mismatch between water needs and canal water availability. Consequently the water use efficiency in canal command areas is very low. Determination of probable canal operation schedules and matching the crop water needs with it by appropriately selecting the crop planting date may help in achieving high water use efficiency as well as high yields. Water needs of crops grown on different dates may be simulated and resulting desired irrigation schedules may be compared with the availability of canal water with a view to achieve highest water use efficiency.

MATERIALS AND METHODS

In the present study, CROPWAT model was used for determining irrigation schedule for wheat sown on different dates under the agro climatic conditions of western Uttar Pradesh, India Villages Lakhan and Masauta, District Ghaziabad were selected specifically because they provided a unique opportunity to study different scenarios of irrigation water availability including exclusive canal irrigated areas, exclusive tube well irrigate area as well as areas with both canal and tube well irrigation facility, in the close proximity, for comparisons. Resulting irrigation schedules were then compared with the probable canal water supplies to determine optimal sowing dates for wheat to match water needs with likely water availability with a view to achieve maximum yields. In case of fields exclusively irrigated by tube wells and both with canal as well as tube wells also were considered and appropriate wheat sowing dates were in those situations were also determined.

The study area falls within the command area of Noorpur distributary of Western Yamuna canal system. Though rotational water distribution system (*warabandi)* is said to be in vogue on the canal system but last 20 years data of operation pattern of the distributary indicated no fixed pattern of its operation. Based on the frequency of operation weeks of the distributary in different years a most likely operation schedule during *Rabi* season was developed (Table 1).

CROPWAT is a computer program for irrigation planning and management, developed by the Land and Water Development Division of FAO (FAO, 1992). Its basic functions include the calculation of reference evapo-transpiration, crop water requirements and plan irrigation. Based on daily water balance, the user can simulate crop yield under different water supply conditions and estimate yield reductions and water use efficiencies. Typical applications of the water balance include the development of irrigation schedules for various crops.

The critical soil water content varies for different crops and different crop stages and is determined by the rooting density characteristics of the crop, evaporation rate and, to some extent, by the soil type. Further reduction in soil moisture results in reduction in evapotranspiration that directly influences the crop yield.

The average monthly values from 19 years data of the study area (1983 to 2002) were calculated from daily meteorological parameters like maximum temperature, minimum temperature, relative humidity, wind speed and sunshine hours and are tabulated in Table 2. Penman-Montieth equation was used in ETo calculations with the following values for Angstrom's Coefficients: a = 0.25, b = 0.5. Effective rainfall values were determined to assess the net irrigation water requirements. Fig. 1 represents the monthly variations in rainfall and effective rainfall for the study area.

Soils of the study area were loamy sand (medium) with total available soil moisture of 240.0 mm/m depth. Maximum infiltration rate was 40 mm/h and the root-restricting layer was located at 0.90 m depths. Winter wheat was taken as the test crop with the following parameters (Table 3). Irrigation at 45% of readily soil moisture depletion was considered as the criteria for irrigation.

Nine different sowing dates namely, November 1, November 8, November 15, November 22, December 1, December 8, December 15, December 22 and January 1, were simulated for estimating their schedule for irrigation and expected yields. The simulations using CROPOWAT model were done for all the nine sowing dates under the exclusive canal irrigated area.

RESULTS AND DISCUSSION

Most probable operation schedule of Noorpur distributary for *Rabi* season was developed and is presented in Table 1. In exclusive canal irrigated areas, irrigation water is available only at per the canal operation schedule, irrespective of the actual crop water requirements. Wheat sown on different dates are likely to receive different number of irrigations from canal water supplies (Table 4). Estimated values of reference crop evapo-transpiration, effective rainfall, and net irrigation water requirement and likely number of canal irrigations, expected yield and resulting water use efficiency in exclusively canal irrigated area resulting from the use of CROPWAT model are presented in Table 5. Values of total evapo-transpirational water requirement steadily increased with the increasing delay in sowing of wheat from November 1 to January 1. The probable canal pattern indicated possibility of only four irrigations except for wheat sown during November 15 to December 1, when five canal irrigations would be possible. It was assumed that about 40 mm depth of irrigation water would be available per canal irrigation.

In all cases of wheat sowing dates, actual evapo-transpirational water requirements were higher than the expected canal water supplies (Table 5). It may also be noted from Table 5 that deficit of canal water in meeting crop water needs of wheat progressively increased with increasing delay in wheat sowing. Wheat sown on November 22 resulted in maximum wheat yield (4.0 t/ha) and also in highest water use efficiency (2.0 Kg/m^3). Yield of wheat sown a week after and a week earlier resulted in the next best yields (3.8 and 3.6 t/ ha, respectively) and water use efficiencies (1.9 and 1.8 Kg/m^3, respectively). Wheat sown between November 15 and December 1 is likely to receive five canal irrigations and consequently result in higher yield and water use efficiency.

Fig. 2 presents a comparative picture of the expected wheat yields and water use efficiencies under different situations of availability of irrigation water for wheat sown on different dates between November 1 and January 1. The figure 2 indicates that in general, appropriate date for wheat sowing falls between November15 and December 1

CONCLUSIONS

November 22 to December 1 was found to be the most appropriate sowing date for wheat in exclusive canal irrigated areas. The study confirmed that CROPWAT is a potent tool to determine optimal sowing date of crops with a view to maximize the crop yields and water use efficiency.

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Table 1 Probable operation schedule of *Noorpur* distributary during *Rabi*

S N	Month	Week
1	November	1-8
2	December	8-15
3	January	15-20
4	February	8-15
5	March	1-8
6	April	1-8
7	May	8-15

Table 2 Meteorological Data (19 years average)

Months	Max Temp (°C)	Min Temp (°C)	Relative Humidity	Wind speed (km/d)	Sunshine hours	Evapo-transpiration* (mm)
January	20.5	6.4	70.3	80.4	5.8	1.83
February	23.3.	8.9	66.0	100.6	7.0	2.67
March	29.4	13.7	57.0	110.4	8.0	4.06
April	36.1	18.7	45.8	115.7	9.3	5.70
May	39.8	24.2	42.9	145.3	8.1	6.70
June	38.2	26.6	53.2	165.4	6.5	6.28
July	34.9	26.8	70.6	134.9	5.3	4.84
August	33.3	26.0	75.8	103.3	5.3	4.22
September	33.8	24.2	70.2	93.4	7.1	4.29
October	33.0	17.4	60.5	58.1	7.9	3.35
November	28.1	11.3	60.6	45.9	7.2	2.17
December	22.6	7.1	67.5	60.1	5.5	1.66

Table 3 Crop parameters

Growth Stages	Initial	Development	Mid	Late	Total
Stage Lengths (days)	30	45	45	25	145
Crop Coefficients (K_c)	0.70	0.70	1.15	0.40	
Rooting Depths (m)	0.35	0.70	0.90	0.90	
Depletion Levels (P)	0.50	0.70`	0.50	0.80	
Yield Factors (K_y)	0.40	0.60	0.80	0.40	1.00

Table 4 Water use efficiency under exclusively canal irrigated area

S N	Sowing date of wheat	Durations of probable canal supplies	No. of expected canal irrigations
1	November 1	Dec 8-15, Jan15-20, Feb 8-15, Mar1-8	4
2	November 8	Dec 8-15, Jan15-20, Feb 8-15, Mar 1-8	4
3	November 15	Dec 8-15, Jan15-20, Feb 8-15, Mar 1-8, Apr 1-8	5
4	November 22	Dec 8-15, Jan15-20, Feb 8-15, Mar 1-8, Apr 1-8	5
5	December 1	Dec 8-15, Jan15-20, Feb 8-15, Mar 1-8, Apr 1-8	5
6	December 8	Jan15-20, Feb 8-15, Mar 1-8, Apr 1-8	4
7	December 15	Jan15-20, Feb 8-15, Mar 1-8, Apr 1-8	4
8	December 22	Jan15-20, Feb 8-15, Mar 1-8, Apr 1-8	4
9	January 1	Jan15-20, Feb 8-15, Mar 1-8, Apr 1-8	4

Table 5 Water use efficiency under exclusive canal irrigated area

Date of sowing	ETc during the crop period (mm)	Effective rainfall, (mm)	No. of likely canal irrigations	Expected amount of canal water supplies (mm)	Expected wheat yield (t/ha)	Water use efficiency (Kg/m^3)
Nov 1	262	43	219	160	2.8	1.75
Nov 8	269	43	226	160	2.9	1.80
Nov 15	325	43	282	200	3.6	1.80
Nov 22	347	43	304	200	4.0	2.00
Dec 1	337	43	294	200	3.8	1.90
Dec 8	373	47	326	160	2.9	1.81
Dec 15	403	51	352	160	2.9	1.81
Dec 22	469	58	411	160	2.6	1.62
Jan 1	507	67	440	160	2.6	1.62

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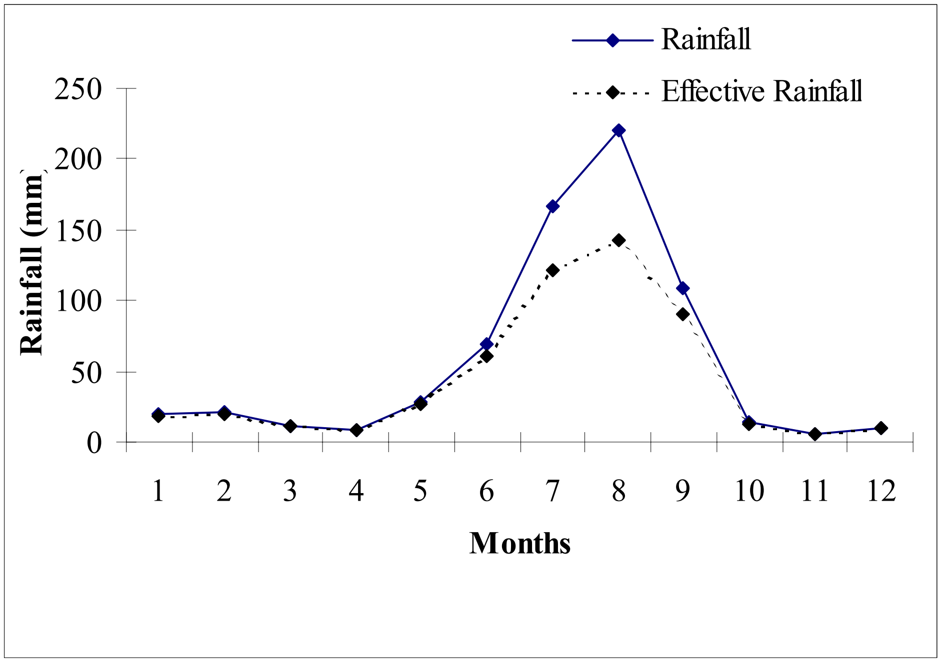

Fig. 1 Monthly variation in rainfall and effective Rain in the study area

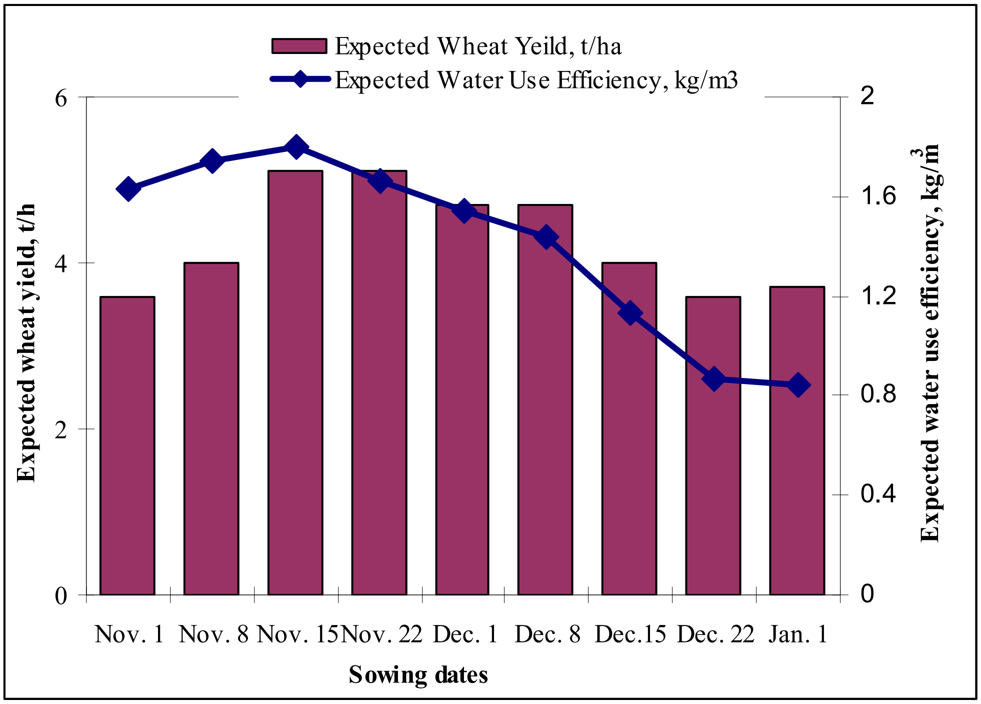

Fig. 2 Effect of sowing date of wheat on its yield and water use efficiency