CROP WATER DEMAND ESTIMATION FOR FEW RABI CROPS USING CROPWAT 8.0 & AQUACROP 6.1 MODELS

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ABSTRACT

The study shows that for both models crop water requirement and crop irrigation scheduling in Rabi season growing in study area (Allahabad, Karchana block) region. The daily ETc and monthly ETc is deferent through both model and net irrigation, total crop water requirement, gross irrigation are compensate the rabi season growing crops in study area Allahabad region. The study results CROPWAT 8.0 and AQUACROP 6.1 showed that daily ETc 0-4.50 and 0-6.0 mm/day. The CROPWAT 8.0, Total Crop Water Requirements for wheat 262 mm, Total Net Irrigation Requirement for wheat is 304.9 mm, & Total gross irrigation requirement for wheat 438.4 mm, for Barley CWR is 247.8mm, GIR 426.9, & NIR is 298.8 mm, for Mustard CWR is 217.4 mm and NIR 261.7 mm, & GIR 373.9 mm, CWR for pea 205.5 mm, NIR 264.5 mm, & GIR 426.9. The AQUACROP 6.1 model CWRs for wheat 536 mm, NIR 421.5 mm, & GIR 601.9 mm, for Barley CWRs 533 mm, NIR 300.8 mm, & GIR 429.7 mm, CWRs for Mustard 446 mm, NIR 339.5 mm, & GIR 513.0 mm, CWRs for Pea 593 mm, NIR is 357.1 mm, & GIR 510.0 mm. Thesis study proved that CROPWAT 8.0 model is useful for calculating the crop water irrigation needs for the proper management of water resources.

Keywords: CROPWAT 8.0, AQUACROP 6.1, Irrigation schedules, crop water requirement, USDA, FAO, S.C., NIR.

1. Introduction

Serious water shortage is developing in many nations particularly in India. India being an agricultural economy where 70% of population depends on agriculture is highly susceptible to the impacts of climate. Water arises as a valuable and scarce resource with the growing demand of increasing population and rapid industrialization. The water necessities of crop vary extensively from region to region, crop to crop and during entire crop period of individual crop. In India, Agriculture is the largest consumer of water and hence more effective use of water in agriculture is the highest priority. For better understanding of complicated interaction between climate, water and crop needs to be priority area in India.

It is necessary to know crop water requirements, irrigation scheduling to meet the irrigation demand and for sustainable development of agriculture. One of the major practices to be implemented by researchers for crop water requirement is software modeling. For determination of crop evapotranspiration, crop water requirement and irrigation scheduling CROPWAT 8.0 model and AQUACROP 6.1 is used. This software was developed by FAO (Food and Agriculture Organization). CROPWAT is a hands-on tool to help agro meteorologists, agronomists and irrigation engineers to carry out typical calculation for evapotranspiration and crop water usage studies and more particularly the design and management schemes. In this present study, some selected Rabi crops are used –Wheat, Barley, Mustard, and Pea.

The efficiency of water in agricultural production is generally low. Only 40 to 60% of the water is effectively used by the crop, the rest of the water is lost in the system or in the farm either through evaporation runoff, or by percolation into the groundwater. Irrigation scheduling, if properly managed can offer a good solution to improve water efficiency in the farm. Irrigation scheduling makes sure that water is consistently available to the plant and that it is applied according to crop requirements. To carried out irrigation scheduling using CROPWAT considering method of irrigation timing, irrigation at 100% critical depletion, irrigation at fixed interval per stage and method of irrigation application, Refill soil moisture content to 100% to field capacity.

Advantages of Irrigation Scheduling

- Reduce farmer's costs of water and labour through less irrigation, thereby making maximum use of soil moisture storage.
- Enable farmers to schedule watering to minimize crop water stress and maximize yields.
- Minimize water-logging problems by reducing the drainage requirements.

OBJECTIVES OF THE STUDY

- To estimate crop water demand for selected Rabi crops grown in Karchana block of Allahabad district using the CROPWAT 8.0 and AQUACROP 6.1 models.
- To validate the crop water demand for farmer field based on actual field data.
- To best suggest suited model for irrigation scheduling of selected crops in Karchana block of Allahabad district.

2. MATERIALS AND METHEODOLOGY

2.1 STUDY AREA

The study was carried out to study of scheduling of few Rabi crops. The district is administratively divided into 08 tehsils and 20 development blocks. District lies between 24° 47’ and 25° 27’N latitude and 81°09’ and 81°44’E longitude and altitude 98 m. The land utilization pattern in the Allahabad (Prayagraj) district area has sown under the Rabi crops 259.296 hectare, Kharif 229.439 hectare, and Zaid 10.283 hectares. The district is divided into eight tehsils named as Sadar, Karchana, Phulpur, Bara, Koraon, Meja, Soraon and Handia.Tehsils and divided in Development Blocks. There are twenty development blocks, Karchana, Kandahar, Holagarah, Mauaiam, Soraon are the development blocks in the Soraon tehsil,Bahria,Phulpur,Bahadurpur are development blocks in the Phulpur Tehsils,Pratappur,Saidabad,dhanupur,handiaTehsils,Jasra,shankargargah are the development block of Bara Tehsil, Chaka ,Kaundhyara are development blocks in the Karchana .Tehsil Uruwa ,Meja ,Manda are the development blocks in the Meja tehsil and Koraon is the development block in the Koraon tehsils.

2.2. Data Requirement

For this study, four types of data are required for this software. Those are meteorological data, rainfall data, crop data and soil data.

Meteorological data: This data is collected from Institute of Forestry, Sam Higginbottom University of agriculture; Technology and Sciences because the study area in Karchana Block of Allahabad, Division with same climatic zone and no specific meteorological center was available in Allahabad district for collection of meteorological data. To get more accuracy and effective development of irrigation project long term data was to be collected. In this present study 2 years from 2017 to 2018 of daily meteorological data were used. These data include Maximum Temperature & Minimum Temperature (°C), Mean Relative Humidity (%), Wind Speed (km/h), and Sunshine Hours (Hrs.).

Rainfall data: Daily rainfall data was also collected from Institute of Forestry, Sam Higginbottom University of agriculture; Technology and Sciences for 2 years from 2017 to 2018 which was used for calculation of effective rainfall. USDA soil conservation method is used in this software.

Crop data: This modelling needs some information of some selected crops like Wheat, Barley, Mustard and Pea. This information was obtained from FAO manual 56 for these crops including crop name, planting date, crop coefficient, rooting depth, length of plant growth stages, critical depletion and yield response factor.

Soil Data: Soil type in this area is Sandy Loam soil. This modelling needs some general soil data like total available moisture, maximum rain infiltration rate, maximum rooting depth, initial soil depletion and initial available soil moisture. This information was collected from FAO manual 56.

Cropping pattern : The cropping pattern adopted by farmers in the Karchana block Allahabad (Prayagraj) for the study plays an important role in a project designing .A study was conducted about the choice of crops farmers and their socio economic condition. The cropping pattern in the projected area was fallows:

(A). Rabi crop growing season (October to April)

Following are the various Rabi crops grown in study area

- Wheat
- Barley
- Mustard
- Pea

(B). Kharif crop growing season (June to October)

Only Paddy crop grown in study area.

(C). Zaid crop growing season (March to June)

Only Vegetables crops grown in study area.

2.3. CropWat 8.0 Details: There are several versions of CROPWAT have been released till now. The latest version of this software after modification is CROPWAT 8.0. This software uses monthly climatic data (temperature, relative humidity, wind speed, sunshine hours and rainfall) for calculation of reference evapotranspiration, crop water requirement and irrigation scheduling. This modelling allows for the development of irrigation schedules under different management and water supply conditions and to evaluate rain fed production, drought effects and efficiency of irrigation practices. It is based on FAO Penman- Monteith Equation.

2.3.1 AQUACROP 6.1 Details: AquaCrop is the crop growth model developed by FAO to address food security and assess the effect of the environment and management on crop production. It is based on Modified Penman-Monteith Equation AquaCrop simulates the yield response of herbaceous crops to water and is particularly well suited to conditions in which water is a key limiting factor in crop production. Aqua crop model imitates the crop behaviour in the base of use able water under different conditions of full irrigation, dry farming, supplement irrigation, and under irrigation. Improving water use efficiency (WUE) based on more production instead of consuming water unit is so important. Therefore, precise knowledge of relationship between water use and crop behaviour is necessary.

2.4. Estimation of Crop Water Requirement: Crop evapotranspiration and crop water requirement are undistinguishable, crop evapotranspiration refers to the amount of water that is lost through evapotranspiration, while crop water requirement means the amount of water which needs to be supplied. The crop water requirement module includes calculations, producing the irrigation water requirement of the crop daily and over the total growing season as variance between the crop evapotranspiration under standard conditions. The effective rainfall is called as crop water requirement in mm/day. The model calculates ETc. as ETc = Kc × ETo.

Where, Kc is crop coefficient and ETo is evapotranspiration (mm/day).

2.5. Reference crop evapotranspiration (ET_o): As water is abundantly available at the reference evapotranspiring surface, soil factors do not affect ET. Linking ET to a specific surface provides a reference to which ET from other surfaces can be related. ET_o values measured or calculated at different locations or in different seasons are comparable as they refer to the ET from the same reference surface. The only factors affecting ET_o are climatic parameters. So, ET_o is a climatic parameter and can be calculated from weather data. ET_o expresses the evaporating power of the atmosphere at a specific location and time of the year and does not consider the crop characteristics and soil factors.

2.6. Penman-Monteith method: Penman combined the energy balance with the mass transfer method in 1948 and derived an equation to calculate evaporation from open water surface from standard meteorological parameter of sunshine, temperature, humidity and wind speed. This supposed combination method was further industrialized by many investigators and extended it to interpret the equation as the maximum water which could be evapotranspiration due to solar and wind energy within the system, at given air and surface characteristics. The Penman-Monteith method of the combination equation is:

$$ET_0 = \frac{.408(R_n - G) + ¥\frac{900}{T+273}U_2(e_s - e_a)}{\Delta + ¥(1 + .34U_2)}$$

Where,

ET = reference evapotranspiration (mm/ day],

R= net radiation at the crop surface [MJ/ m^2/ day],

G = soil heat flux density [MJ /m^2/ day],

T=mean daily air temperature at 2 m height [°C]

U_2 = wind speed at 2 m height [m /s],

e_s= saturation vapour pressure (kpa),

e_a=actual vapour pressure (kpa),

$(e_s - e_a)$ = saturation vapour pressure deficit (kpa),

Δ= slope vapour pressure curv,

¥ = psychronetric constant (kpa/^{0}c),

3. RESULTS AND DISCUSSIONS:

3.1.1 CROPWAT Crop water requirement

Crop water requirement and irrigation scheduling of some selected crops are given as below.

The daily crop water requirement for Wheat was low during early crop growth period mainly due to low crop coefficient, but is increase sharply till the second week of December .The crop water requirement decrease considerably after third week of February due to decrease in the crop coefficient .The maximum daily water requirement of Wheat was nearly 3.50 mm/day.

The crop water requirement for Barley was low during early crop growth period mainly due to low crop coefficient, but is increase sharply till the second week of December .The crop water requirement decrease considerably after third week of February due to decrease in the crop coefficient .The maximum daily water requirement of Barley was nearly 3.50 mm/day.

The crop water requirement for Mustard varies during the crop growing season due to variation in reference evapotranspiration .Initially crop water requirement for Mustard was low due to low crop coefficient, but is increase sharply till the third week of December .The crop water requirement decrease considerably after first week of January due to decrease in the crop coefficient .The maximum daily water requirement of Mustard was nearly 4.50mm/day.

The crop water requirement for Pea varies during the crop growing season due to variation in reference evapotranspiration .Initially crop water requirement for Pea was low due to low crop coefficient, but is increase sharply till the second week of December .The crop water requirement decrease considerably after first week of January due to decrease in the crop coefficient .The maximum daily water requirement of Pea was nearly 3.00 mm/day.

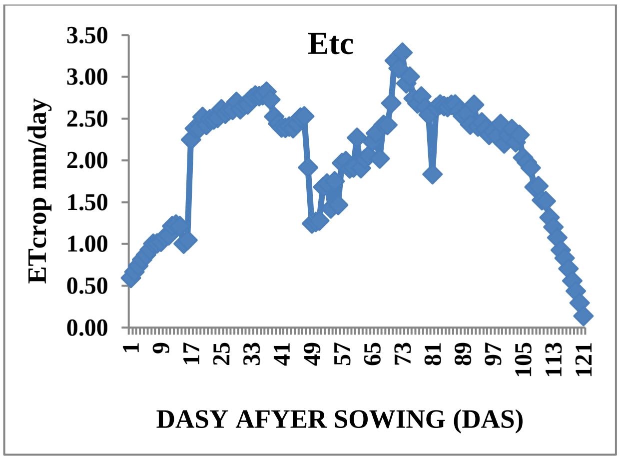


Fig. 1 Daily Crop Water Requirement Wheat

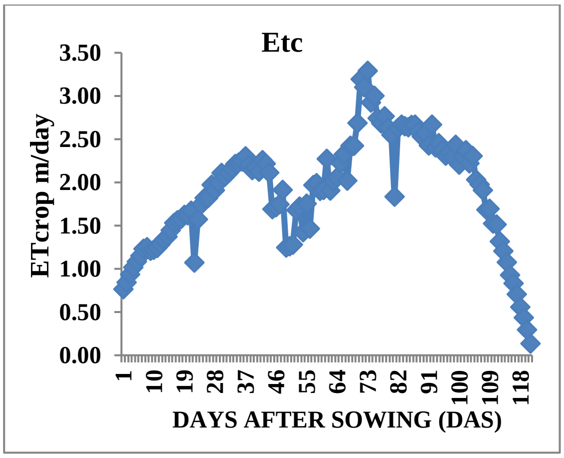
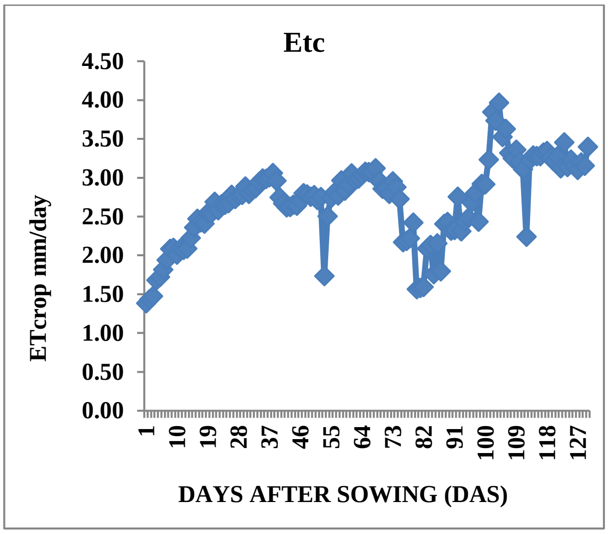


Fig. 2 Daily Crop Water Requirement Barley



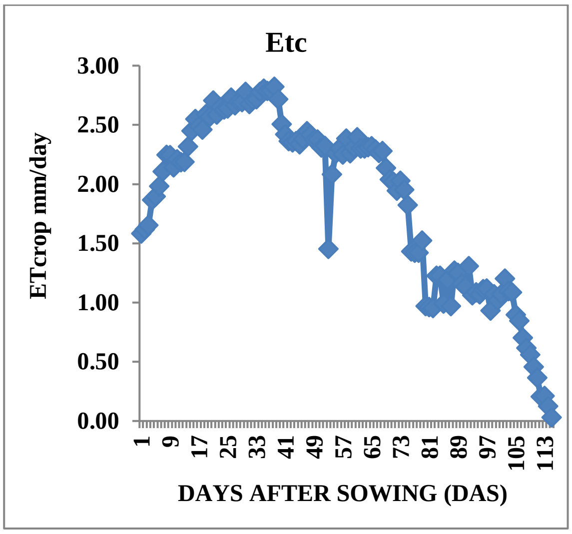


Fig. 3 Daily Crop Water Requirement Mustard

Fig. 4 Daily Crop Water Requirement Pea

3.1.2 CROPWAT IRRIGATION SCHEDULING:

Table 1. Irrigation Scheduling of Wheat

No.of irrigation	Date	Day	stage	Net Irri (mm)	Gross Irri. (mm)
1	**15-Nov (Sowing)**	1	initial	22.2	31.8
2	**09-Dec**	25	initial	35.6	50.8
3	**08-Jan**	55	Mid	56.6	83.7
4	**03-Feb**	81	Mid	58.7	83.9
5	**22-Feb**	100	Mid	59.6	85.1
6	**18-Mar**	124	End	72.1	103
	29 Mar Harvesting				
	Total	135		304.8	438.4

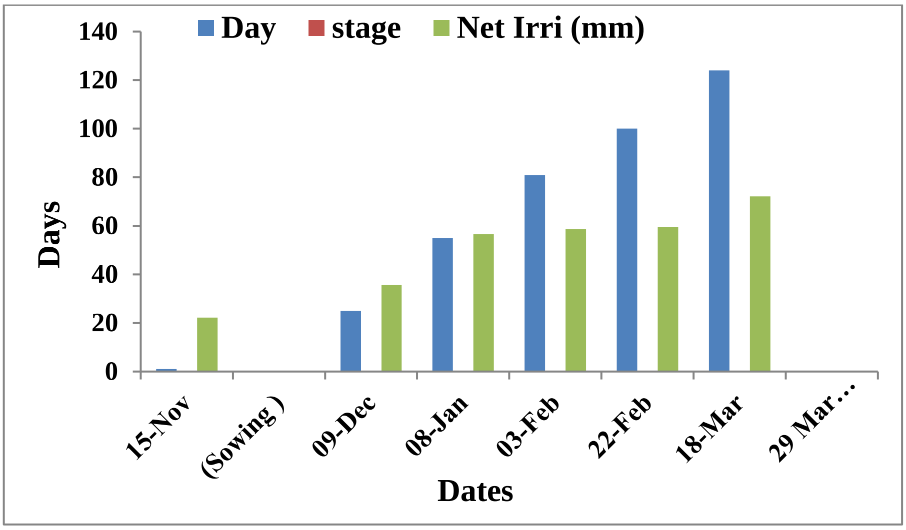


Figure 5. Irrigation Scheduling of Wheat

Table 2. Barley crop Scheduling

No.of irrigation	Date	Day	stage	Net Irri (mm)	Gross Irri. (mm)
1	**15-Nov (Sowing)**	1	initial	22.2	31.8
2	**09-Dec**	25	initial	35.6	50.8
3	**05-Jan**	52	Mid	54.2	77.4
4	**30-Jan**	77	Mid	53.2	76
5	**18-Feb**	96	Mid	55.5	79.3
6	**16-Mar**	122	End	78.1	111.5
	24 Mar Harvesting				
	Total	135		298.8	426.9

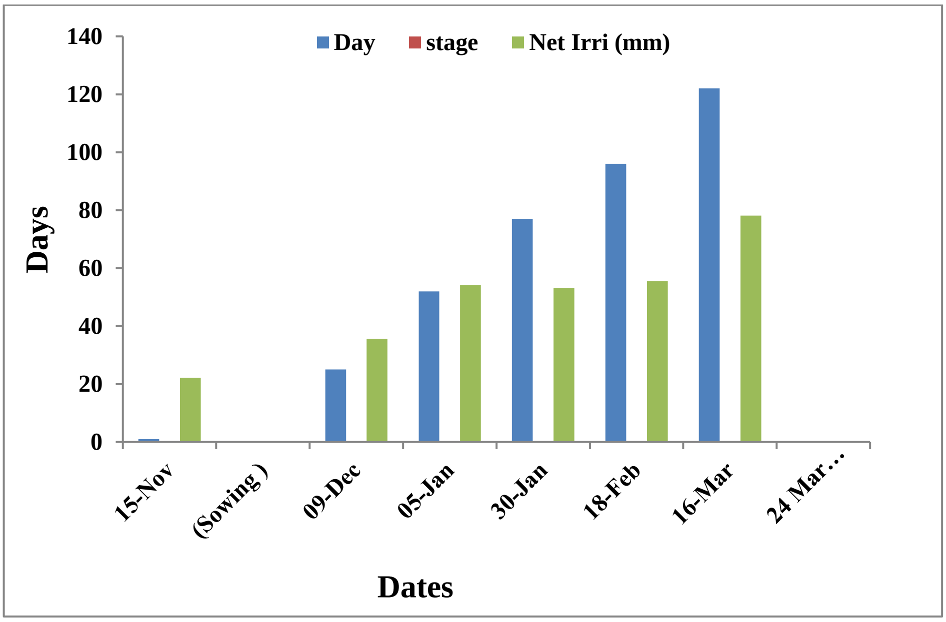


Figure 6. Irrigation Scheduling of Barley

Table 3. Mustard crop Scheduling of Mustard

No.of irrigation	Date	Day	stage	Net Irri (mm)	Gross Irri. (mm)
1	**15-Oct (Sowing)**	1	initial	32.6	46.6
2	**01-Nov**	18	initial	29.1	41.6
3	**23-Nov**	40	Dev.	38.5	55
4	**15-Dec**	62	Mid	49.5	70.7
5	**11-Jan**	89	Mid	48.4	69.1
6	**09-Feb**	118	End	63.6	90.9
	21Feb. Harvesting				
	Total	130		261.7	373.9

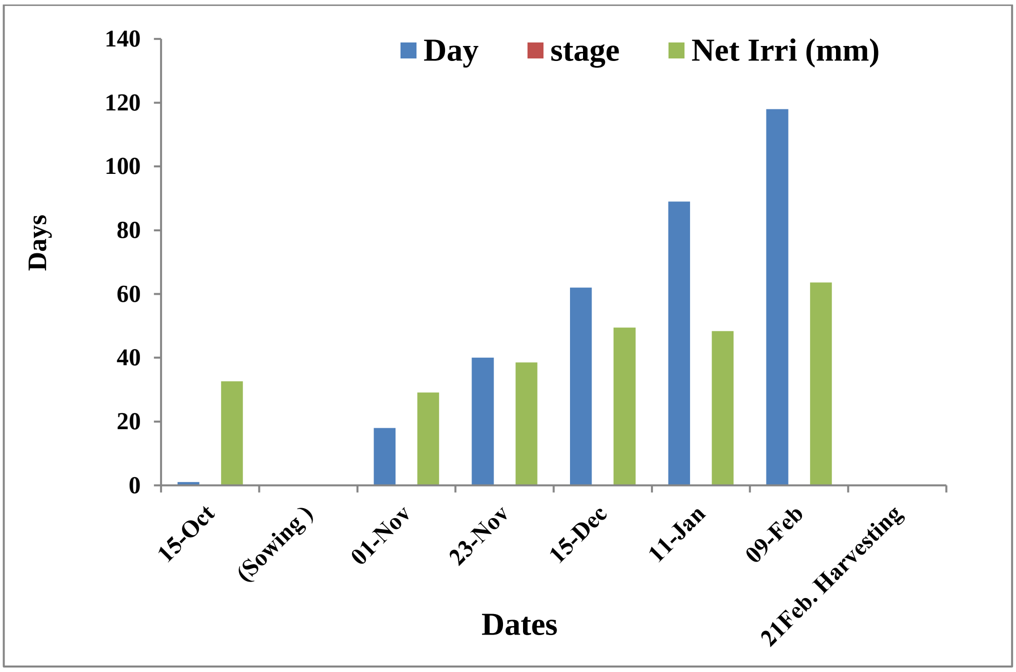


Fig.7. Irrigation Scheduling of Mustard

Table 4. Pea crop Scheduling of Pea

No.of irrigation	Date	Day	stage	Net Irri (mm)	Gross Irri. (mm)
1	**15-Oct (Sowing)**	1	initial	33.2	47.4
2	**06-Nov**	23	initial	41.6	58.4
3	**02-Dec**	49	Dev.	55.9	79.9
4	**28-Feb**	75	Mid	58.1	83
5	**13-Feb**	122	End	75.1	108.2
	16 Feb. Harvesting				
	Total	125		264.5	377.8

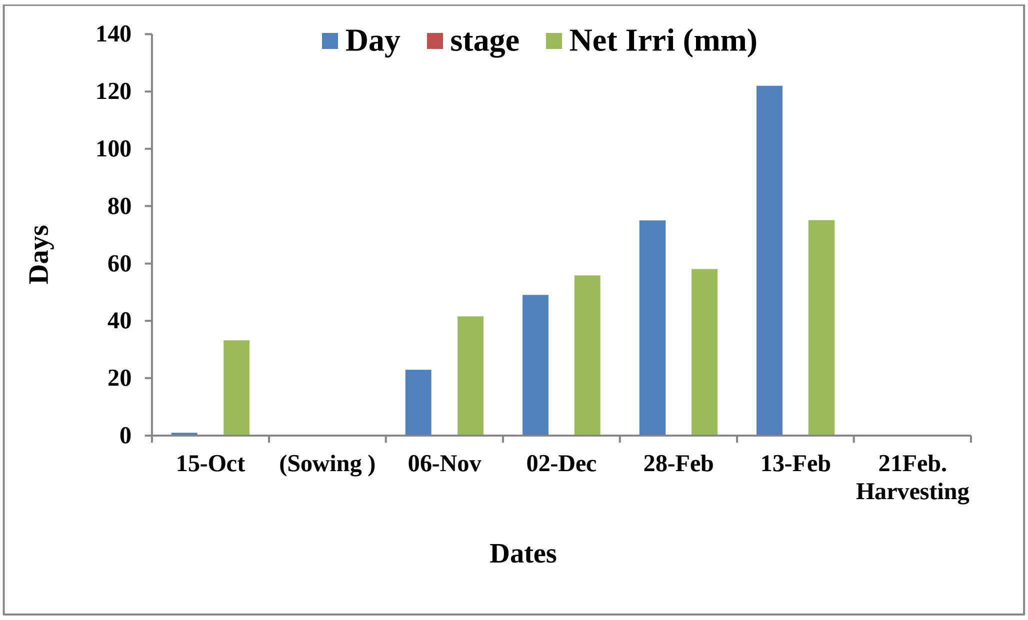


Fig. 8. Pea Crop Irrigation Scheduling Pea

3.1.3 Crop Water Requirement (AquaCrop 6.1 Model)

The daily crop water requirement for Wheat was low during early crop growth period mainly due to low crop coefficient, but is increase sharply till the second week of December .The crop water requirement decrease considerably after third week of February due to decrease in the crop coefficient .The maximum daily water requirement of Wheat was nearly 5.49 mm/day.

The crop water requirement for Barley was low during early crop growth period mainly due to low crop coefficient, but is increase sharply till the second week of December .The crop water requirement decrease considerably after third week of February due to decrease in the crop coefficient .The maximum daily water requirement of Barley was nearly 5.35 mm/day.

The crop water requirement for Mustard varies during the crop growing season due to variation in reference evapotranspiration .Initially crop water requirement for Mustard was low due to low crop coefficient, but is increase sharply till the third week of December .The crop water requirement decrease considerably after first week of January due to decrease in the crop coefficient .The maximum daily water requirement of Mustard was nearly 5.35 mm/day.

The crop water requirement for Pea varies during the crop growing season due to variation in reference evapotranspiration .Initially crop water requirement for Pea was low due to low crop coefficient, but is increase sharply till the second week of December .The crop water requirement decrease considerably after first week of January due to decrease in the crop coefficient .The maximum daily water requirement of Pea was nearly 5.50 mm/day.

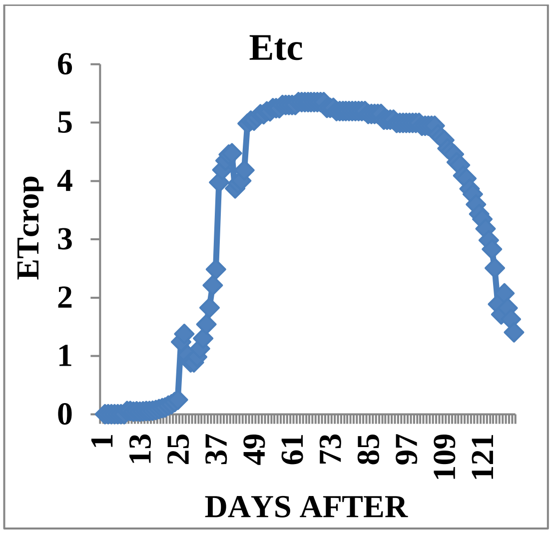


Fig. 8 Daily Crop Water Requirement Wheat

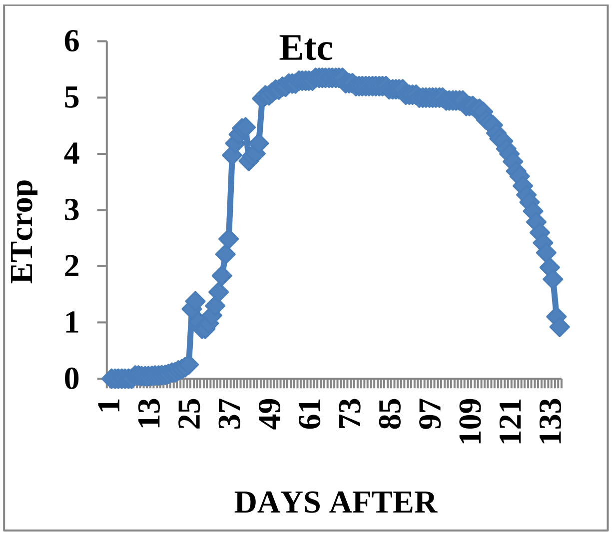


Fig. 9 Daily Crop Water Requirement Barley

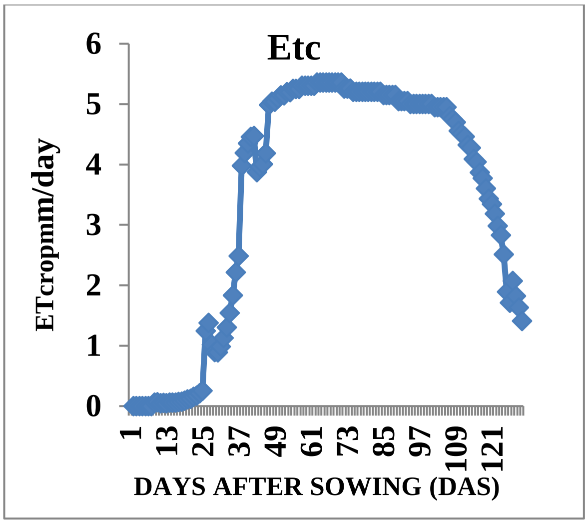


Fig. 10 Daily Crop Water Requirement Mustard

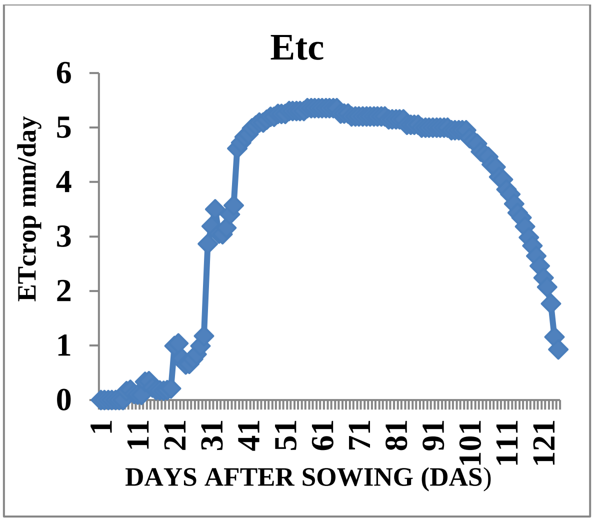


Fig. 11 Daily Crop Water Requirement Pea

3.1.2 AQUACROP IRRIGATION SCHEDULING:

Table 5. Irrigation scheduling of wheat

No.of irrigation	Date	Day	stage	Net Irri (mm)	Gross Irri. (mm)
	15Nov (Sowing)	1	initial	0.0	0.0
1	**30 Dec**	46	initial	60.9	87.1
2	**11 Jan**	58	Mid	62.1	88.7
3	**22 Jan**	69	Mid	58.7	83.8
4	**2 Feb**	80	Mid	57.5	82.1
5	**14 Feb**	92	End	61.5	87.8
6	**26 Feb**	104	End	59.7	85.2
7	**11 Mar**	116	End	61.1	87.2
	29 Mar Harvesting				
	Total	135		421.5	601.9

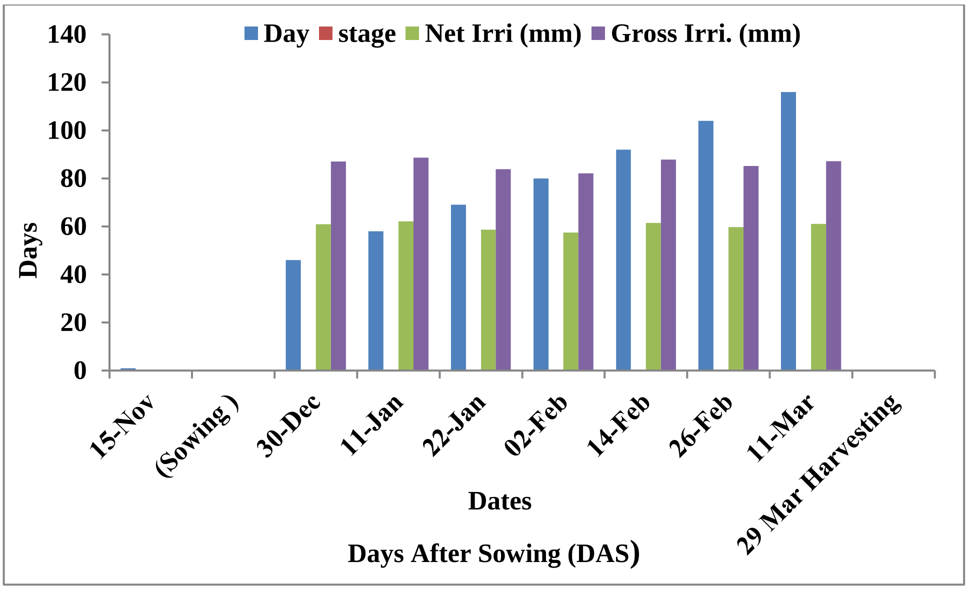


Fig.12 Wheat Crop Irrigation Scheduling

Table 6. Scheduling of Barley crop

No.of irrigation	Date	Day	stage	Net Irri (mm)	Gross Irri. (mm)
	15Nov (Sowing)	1	initial	0.0	0.0
1	**30 Dec**	46	initial	60.9	87.0
2	**11 Jan**	57	Mid	62.1	88.7
3	**2 Feb**	77	Mid	57.5	82.1
4	**27 Feb**	100	Mid	59.7	85.2
5	**12 Mar**	113	End	60.6	86.5
	24 Mar Harvesting				
	Total	130		300.8	429.5

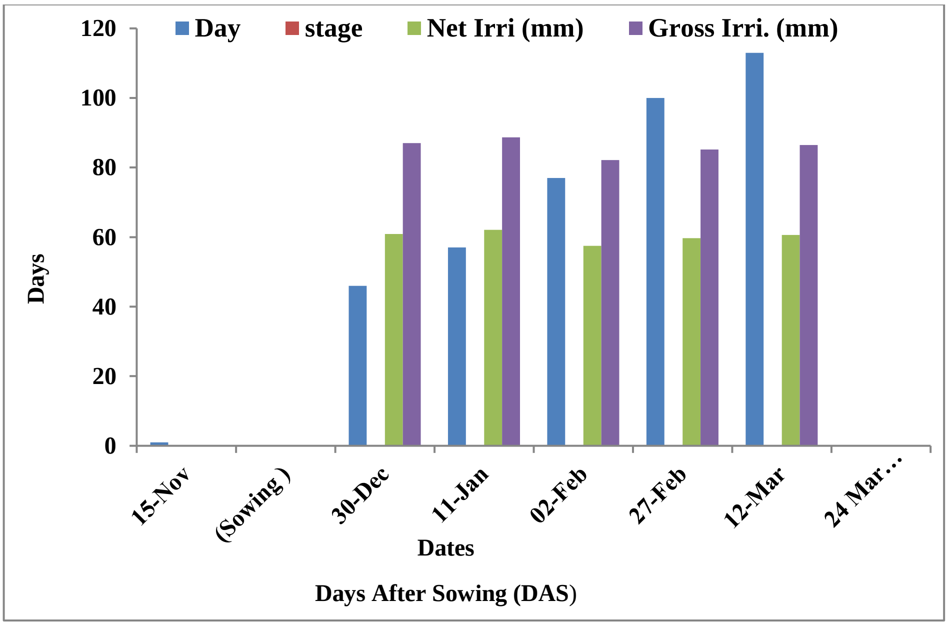


Fig.13 Barley Crop Irrigation Scheduling

Table 6. Scheduling of Mustard crop

No.of irrigation	Date	Day	stage	Net Irri (mm)	Gross Irri. (mm)
	15Oct (Sowing)	1	initial	0.0	0.0
1	**29 Nov**	48	initial	60.9	87.1
2	**11 Dec**	59	Mid	62.1	88.7
3	**22 Dec**	69	Mid	58.7	83.8
4	**2 Jan**	79	Mid	57.5	82.1
5	**26 Jan**	102	End	59.7	85.2
6	**9 Feb**	115	End	60.6	86.5
	21 Feb Harvesting				
	Total	135		359.5	513.4

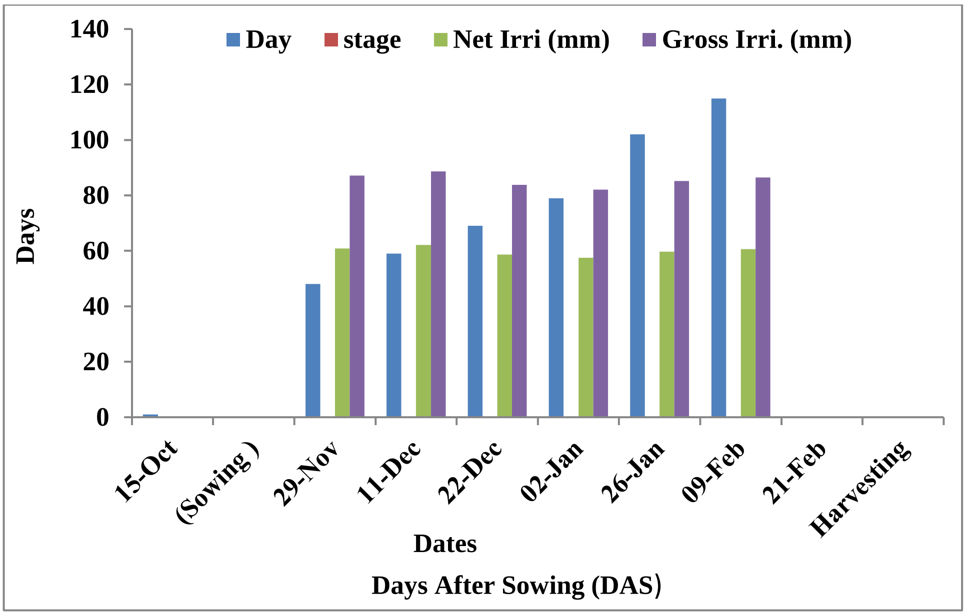


Fig.14 Mustard Crop Irrigation Scheduling

Table 7. Scheduling of Pea crop

No.of irrigation	Date	Day	stage	Net Irri (mm)	Gross Irri. (mm)
	15 Oct (Sowing)	1	initial	0.0	0.0
1	**25 Nov**	42	initial	60.0	85.7
2	**7 Dec**	53	Mid	62.3	89.0
3	**18 Dec**	65	Mid	58.7	83.8
4	**29 Dec**	75	Mid	57.3	81.8
5	**22 Jan**	100	End	59.7	85.2
6	**5 Feb**	113	End	59.1	84.4
	16Feb Harvesting				
	Total	135		357.1	509.9

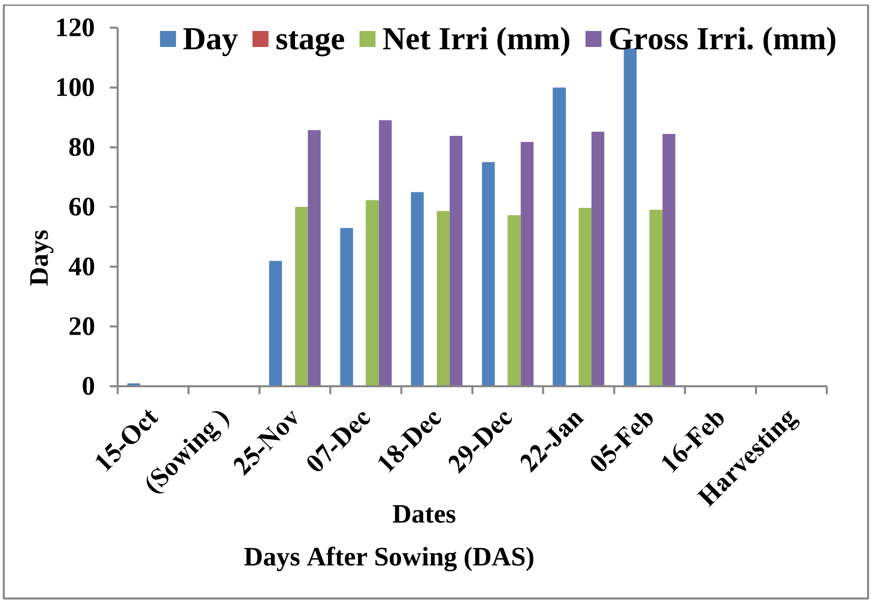


Fig.15 Pea Crop Irrigation Scheduling

4. CONCLUSION

This study summarizes the conclusion carried out by results and analysis of determination of crop water requirement and irrigation scheduling using deferent approaches by CROPWAT 8.0 and AQUACROP 6.1 models. Through the CROPWAT 8.0, Crop Water Requirements for wheat 262 mm, Net Irrigation Requirement for wheat is 304.9 mm and six irrigation date 15 Nov.,09 Dec.,8 Jan.,3 Feb., 22 Feb.,18 Mar., Barley CWR is 247.8mm, NIR is 298.8 mm, and six irrigation date 15 Nov.,9 Dec., 8 Jan.,3 Feb.,22 Feb.,18 Feb.,18 Mar., Mustard CWR is 217.4 mm and NIR for mustard 261.7 mm, and six irrigation date 15 Oct., 1 Nov., 23 Nov.,15 Dec.,11 Jan.,9 Feb., CWR for pea 205.5 mm, NIR 264.5 mm and five irrigation date 15 Oct.,6 Nov.,2 Dec.,28 Feb.,13 Feb.

The second approach AQUACROP 6.1 model CWRs for wheat 536 mm, NIR 421.5 mm and seven irrigation date 30 Dec., 11 Jan., 22 Jan., 2 Feb., 14 Feb.,26 Feb., 11 Mar., Barley CWRs 533 mm & NIR 300.8 mm and five irrigation date 30 Dec., 11 Jan., 2 Feb., 27 Feb., 12 Mar., CWRs Mustard 446 mm & NIR 339.5 mm and irrigation date 29 Nov., 11 Dec., 22 Dec., 2 Jan., 26 Jan., 9 Feb., CWRs for Pea 593 mm, NIR is 357.1 mm and six irrigation date 25 Nov., 7 Dec., 18 Dec., 29 Dec.,22 Jan., 5Feb.,. In this study the suitable results by the CROPWAT 8.0 model, we suggest the farmers to adopt the irrigation requirement and irrigation scheduling because conserve the water resources and maintain their crop production, labour, field efficiency, water productivity etc.

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