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Water requirements and irrigation scheduling of maize in Northern Gangetic plains

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■ **ABSTRACT :** The irrigation requirements for different crops varies from climatic conditions and soil types. The study was conducted to determine irrigation requirement and irrigation scheduling for maize. The irrigation efficiency and field efficiency of 80 per cent and 70 per cent were considered for the study, respectively. The average ET_ocalculated was 3.77 and 3.63 mm/dayfor 2015 and 2016, respectively. The total irrigation requirement for maize was 171 and 118.4 mm for both 50 per cent and 60 per cent critical depletion regarding 2015 and 2016, respectively.The total gross irrigation and net irrigation was 128.9 mm and 90.3 mm for 50 per cent critical depletion and 159.2 mm and 111.4 mm for 60 per cent critical depletion in 2015 while total gross irrigation and net irrigation was 128.6 mm and 90.0 mm for 50 per cent critical depletion and 156.0 mm and 119.2 mm for 60 per cent critical depletion in 2016.The rain efficiency was found 25.6 per cent and 39.4 per cent and by this efficiency, effective rainfall was 179.1 mm and 219.5 mm for 2015 and 2016, respectively.

■ **KEY WORDS :** Maize, Critical depletion, Irrigation requirements, Gangetic plains, Irrigation efficiency

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Maize (*Zea mays* L.) is famous as "corn," one of the versatile cash crops which are cultivated mainly under various climatic differences. It is grown widely for various purposes like animals fodder, food grain, corn, green cobs and popcorn throughout the year. It can be survived in a different texture of soils ranging from clay or sandy loam to the black soil. Mainly soils with proper organic matter content increase soil storage of water which is considered for a better yield of maize (*Zea mays* L.). Irrigation is required immediately in the field after sowing. Subsequently, water should be provided on the third or fourth day, depending upon the soil type and season. Few amount of irrigationis recommended, usually for maize (*Zea mays* L.) crop, up to 25 to 30 days, *i.e.,* it is required to irrigate once in a week.

Water stagnancy should be avoided and should have good drainage, during the early stage of this crop because of its sensitiveness towards both moisture stress and excessive moisture. About 60 cm rainfall distribution requires during the growing season without any irrigation. During flowering period, low soil moisture requires particularly during the growing period will markedly reduce the yield. Water use efficiency of maize has approximately twice as of C3 crops because it belongs to C4 plants group having the potential of the efficient use of solar energy, water, nitrogen and CO_2 in photosynthesis process at the same location of the experiment (Huang *et al.*, 2006).

Further irrigation should be applied during the developing period, *i.e.*, the most vulnerable stage if necessary. The irrigation quantities will depend on the intensity of rainfall pattern. The agricultural water management depends on the climatic situations as about 80 per cent of maize (*Zea mays* L.) is cultivated during rainy season especially in rainfed status. However, depending on the rains and moisture-holding capacity of the soil will be assured irrigation facilities are available in areas, irrigation should be applied as when it required (Doorenbos and Kassan, 1979). Irrigation is necessary to minimize the evapotranspiration deficit due to insufficient precipitation (Doorenbos and Pruitt, 1977).

Maize requires water in particular definite quantities for their optimal growth and excessive, or shortage amounts of water could retard growth and the crop yields will be lower at long last. The grain yield of maize is affected by irrigation and is obtained highest at complete restitution of evapotranspiration. Conditions molding the water use efficiency by crops include the type of crop, stage of growth, changes in climatic parameters like temperature, wind velocity, humidity, sunshine,etc, available water supply and soil characteristics (Clarke *et al*., 1998) and irrigation always associated with energy. Water use efficiency of maize depends on physiology, genotype, soil-used, water holding capacity, climatic data and agronomical practices (Huang *et al.*, 2006). Hence, water requirement and energy consumption to meet water requirement and scheduling is necessary.

Irrigation is energy intensifier operation and the energy requirement per hectare of irrigated land varies with the depth of pumped water, irrigation system types and water quantity needed for crop growth (Kumar and Kumar, 2018).

METHODOLOGY

The study is to estimate irrigation requirement and irrigation scheduling of maize (*Zea mays* L.) irrigation of Pusa farm for the year 2015 and 2016 at different critical depletion factor. This chapter provides abrief description of the study area, detailed information of process and equations involves in calculating the irrigation requirement and irrigation scheduling of maize (*Zea mays* L.) using cropwat of software (Smith, 1991; 1994 and Ratna *et al.*, 2016).

Description of the study area:

The study is carried out for Pusa, located in the Samastipur district of north Bihar. Its latitude is 25.98^0 N; longitude is $85.67^{0,}$ E and about 52 m above mean sea level. Climate is subhumid and sub-tropical with reasonably good rainfall during monsoon. According to meteorological data recorded at Agrometeorological Observatory, Pusa (Bihar), average maximum and minimum temperature were 26.8°C and 17.0°C, respectively. The meteorological data were collected for 2015 and 2016 from Department of Meteorology, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur (Bihar). These data include average month wise data maximum and minimum temperature, relative humidity, wind speed and sunshine hours.

Irrigation water requirements:

FAO approved Penman-Monteith method better to predict ET_o, ET_c and irrigation water requirement (FAO, 1998; Smith, 1991 and Kang *et al.*, 2009).

FAO Penman-Monteith method is expressed as:

$$ETo = \frac{0.408\,\Delta(R_n - G) + \frac{\gamma\,900}{T+273}\mu_2(e_s - e_a)}{\Delta + \gamma(1+0.34\mu_2)} \quad ......(1)$$

Crop co-efficient approach:

Estimation of the standard reference crop to determine its evapotranspiration rate, *i.e.*, reference evapotranspiration (ET_o) (Allen *et al.*, 1989 and Allen *et al.*, 1994). The ratios of ET_c/ET_o, called crop co-efficient (K_c), are used to determined Crop evapotranspiration under standard conditions (ET_c) to ET_o, (Allen, 1998; Kirda *et al.*, 1999 and Kang *et al.*, 2009) and depends mainly on climatic factors *i.e.*, temp., RH, wind speed, sunshine hours, rainfall etc. (Saravanan and Saravanan, 2014). The evapotranspiration of a crop under irrigation (ETc in mm) is gained by multiplying the reference evapotranspiration (ET0) with a crop and growing stage-specific co-efficient:-

$$ET_c = K_c * ET_o \quad .... (2)$$

This crop co-efficient has been derived for four growing stages: the initial, the development, the mid and the late phases (Sacks *et al*., 2010).

Rainfall :

According to USDA soil conservation service effective rainfall can be calculated according to:

$$P_{eff} = P_{month} * (125 - 0.2 * P_{month}) / 125,\ P_{month} <= 250\ mm \quad ... (3)$$

$$P_{eff} = 125 / 3 + 0.1 * P_{month},\ P_{month} > 250\ mm \quad ... (4)$$

Yield reduction:

Yield reduction is expressed as a percentage of the maximum production achievable in the area under optimal conditions and computed concerning a single stage of crop cycle or the whole growing season.

$$(1-\frac{ya}{ym})=K_y(1-\frac{ETo}{ETm}) \quad \ldots (5)$$

RESULTS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Crop water requirements:

The amount of irrigation water required to meet the irrigation water requirements of the crop was estimated. The average monthly irrigation requirements in crops for 2015 and 2016 (mm/ months) is determined by calculating the average of monthly irrigation requirements in Table 1 and 2 for 2015 and 2016,

Table 1: Showing irrigation requirements for 2015 (mm/ months)

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Jul.	2	Init	0.3	1.33	4	11.4	4
Jul.	3	Init	0.3	1.22	13.5	44.4	0
Aug.	1	Deve	0.32	1.18	11.8	54.2	0
Aug.	2	Deve	0.53	1.68	16.8	62.4	0
Aug.	3	Deve	0.78	2.71	29.8	54.6	0
Sep.	1	Deve	1.03	4.02	40.2	46.9	0
Sep.	2	Mid	1.14	4.74	47.4	41.7	5.6
Sep.	3	Mid	1.14	4.53	45.3	28.3	17
Oct.	1	Mid	1.14	4.36	43.6	4.3	39.3
Oct.	2	Mid	1.14	4.23	42.3	0	42.3
Oct.	3	Late	0.98	3.16	34.8	0	34.7
Nov.	1	Late	0.7	1.9	19	0.1	18.9
Nov.	2	Late	0.46	1.02	9.2	0	9.2
Total					357.5	348.2	171

Table 2: Showing irrigation requirements for 2016 (mm/ months)

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Jul.	2	Init	0.3	0.95	2.9	17.4	2.9
Jul.	3	Init	0.3	1.13	12.4	48.8	0
Aug.	1	Deve	0.32	1.53	15.3	33.4	0
Aug.	2	Deve	0.52	2.76	27.6	24.2	3.4
Aug.	3	Deve	0.76	3.48	38.3	33.6	4.7
Sep.	1	Deve	1	3.57	35.7	51	0
Sep.	2	Mid	1.1	3.19	31.9	61.3	0
Sep.	3	Mid	1.1	3.41	34.1	44.5	0
Oct.	1	Mid	1.1	3.78	37.8	21.8	15.9
Oct.	2	Mid	1.1	3.96	39.6	6.6	33
Oct.	3	Late	0.95	3.06	33.7	4.4	29.3
Nov.	1	Late	0.69	1.93	19.3	0.1	19.2
Nov.	2	Late	0.45	1.11	10	0	10
Total					338.7	347.3	118.4

respectively. The total amount of irrigation requirement for 2015 and 2016 was computed 171 mm and118.4 mm because of differences in useful rainfall pattern of both years.

The crop water requirements were calculated for maize at 50 per cent and 60 per cent critical depletion fraction and for both critical depletion, the crop water requirements were 171 and 118.4 mm for the year2015 and 2016, respectively. There was no change in irrigation requirements for different critical depletion factor because it was calculated by metrological data. The irrigation efficiency of 80 per cent was considered for the study.

Irrigation scheduling:

Irrigation scheduling is done for regulating an optimum water supply for better yield, with soil water within readily available water capacity. It indicates and evaluates irrigation schedules to improve irrigation water management; irrigation practices and their correlated water use efficiency; crop yield under rain-fed conditions and estimate the workability of supplementary irrigation.

Part A (2015):

The total gross irrigation was 128.9 mm with 100.0 per cent efficiency irrigation schedule and 25.6 per cent rain efficiency. The actual irrigation requirement for 50 per cent critical depletion was 177.4 mm for 2015. On the other hand for 60 per cent critical depletion, total gross irrigation was 159.2 mm with 100.0 per cent efficiency irrigation schedule and 25.6 per cent rain efficiency. The actual irrigation requirement was 177.4 mm for 2015. The scheduling of irrigation for maize was same till 80 days from sowing after that, the requirements of irrigation changes from 80-85 days and 90-95 days for 50 per cent and 60 per cent critical depletion, respectively for maize as shown in Fig 1 and 2.

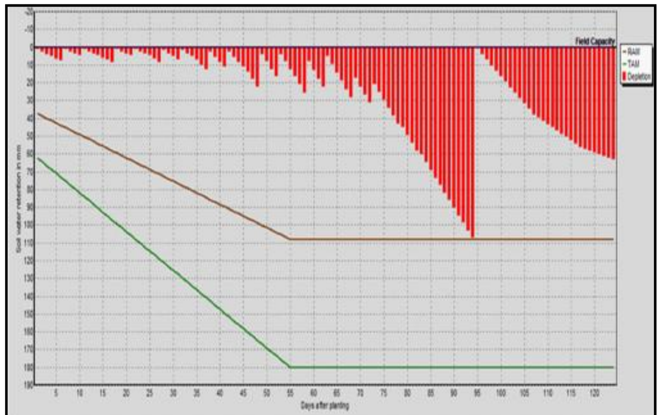

Fig. 2 : **Showing irrigation scheduling for critical depletion factor of 60 per cent for 2015**

Part B (2016):

The total gross irrigation was 128.6 mm with 100.0 per cent efficiency irrigation schedule and 39.4 per cent rain efficiency. The actual irrigation requirement for 50 per cent critical depletion was 118.1 mm for 2016. On the other hand for 60 per cent critical depletion, total gross irrigation was 156.0 mm with 100.0 per cent efficiency irrigation schedule and 39.4 per cent rain efficiency.

The actual irrigation requirement was 118.1 mm for 2016. The scheduling of irrigation for maize was same till 85 days from sowing after that, the requirements of irrigation changes from 85 days to 128 days for 50 per

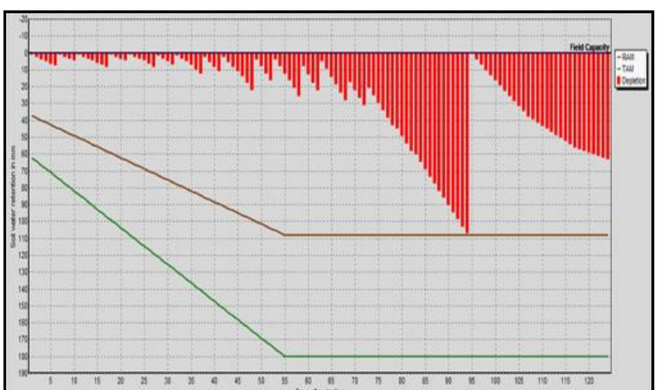

Fig. 1 : **Showing irrigation scheduling for critical depletion factor of 50 per cent for 2015**

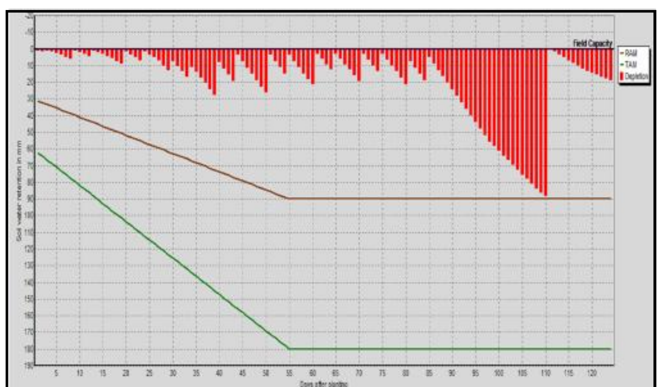

Fig. 3 : **Showing irrigation scheduling for critical depletion factor of 50 per cent for 2016**

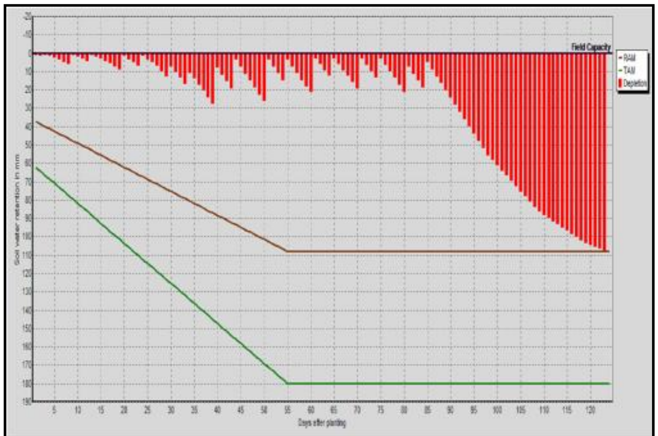

Fig. 4 : Showing irrigation scheduling for critical depletion factor of 60 per cent for 2016

Table 3: For critical depletion 50 per cent for 2015

Total gross irrigation	=128.9 mm
Total net irrigation	=90.3 mm
Total irrigation losses	=0.0 mm
Actual water use by crop	=356.5 mm
Potential water use by crop	=356.5 mm
Efficiency irrigation schedule	=100.0 %
Deficiency irrigation schedule	=0.0 %
Total rainfall	=700.2 mm
Effective rainfall	=179.1 mm
Total rain loss	=521.1 mm
Moist deficit at harvest	=87.1 mm
Actual irrigation requirement	=177.4 mm
Efficiency rain	=25.6 %

Table 4: For critical depletion 60 per cent for 2015

Total gross irrigation	= 159.2 mm
Total net irrigation	= 111.4 mm
Total irrigation losses	= 0.0 mm
Actual water use by crop	= 356.5 mm
Potential water use by crop	= 356.5 mm
Efficiency irrigation schedule	= 100.0 %
Deficiency irrigation schedule	= 0.0 %
Total rainfall	= 700.2 mm
Effective rainfall	= 179.1 mm
Total rain loss	= 521.1 mm
Moist deficit at harvest	= 66.0 mm
Actual irrigation requirement	= 177.4 mm
Efficiency rain	= 25.6 %

Table 5: For critical depletion 50 per cent for 2016

Total gross irrigation	= 128.6 mm
Total net irrigation	= 90.0 mm
Total irrigation losses	= 0.0 mm
Actual water use by crop	= 337.6 mm
Potential water use by crop	= 337.6 mm
Efficiency irrigation schedule	= 100.0 %
Deficiency irrigation schedule	= 0.0 %
Total rainfall	= 557.2 mm
Effective rainfall	= 219.5 mm
Total rain loss	= 337.7 mm
Moist deficit at harvest	= 28.1 mm
Actual irrigation requirement	= 118.1 mm
Efficiency rain	= 39.4 %
Actual irrigation requirement	= 118.1 mm
Efficiency rain	= 39.4 %

Table 6: For critical depletion 60 per cent for 2016

Total gross irrigation	= 156.0 mm
Total net irrigation	= 109.2 mm
Total irrigation losses	=0.0 mm
Actual water use by crop	=337.6 mm
Potential water use by crop	= 337.6 mm
Efficiency irrigation schedule	= 100.0 %
Deficiency irrigation schedule	= 0.0 %
Total rainfall	= 557.2 mm
Effective rainfall	= 219.5 mm
Total rain loss	= 337.7 mm
Moist deficit at harvest	= 8.9 mm
Actual irrigation requirement	= 118.1 mm
Efficiency rain	= 39.4 %

cent and 60 per cent critical depletion, respectively for maize as shown in Fig 3 and 4.

Conclusion :

In the present study, information on rainfall, climatic parameters, cropping system, crop yields, water table depth below ground surface, area cultivated under different crop were obtained from different departments. Based on the results of the study, the following conclusions could be drawn that the total gross irrigation was 128.9 and 159.2 mm (from Table 3 and 4) for 50 per cent and 60 per cent, respectively in 2015 while for

2016, it was 128.6 and 156.0 mm (from Table 5 and 6) for 50 per cent and 60 per cent, respectively, irrigation requirements were the same for both of case. From this study, it concluded that for the same meteorological climatic data the irrigation requirements were same,but the irrigation scheduling would be different shown in Fig A, B, C and D for different critical depletion factor. The actual water used by crop was estimated 356.5 mm and 337.6 mm for 2015 and 2016, respectively.

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