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Assessment of water requirement for major crops of Mirzapur district in eastern Uttar Pradesh

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ABSTRACT

There is a dearth of information about water requirement of crops grown under semi aridic condition of Mirzapur district of Uttar Pradesh. Reference crop evapotranspiration (ET_0) was estimated by adopting the FAO Penman-Monteith approach for estimating water requirement,. Four rabi crops (wheat, mustard, potato and pea) and two kharif crops (rice and groundnut) widely grown by farmers were chosen for the study.The total water requirement of crops during the entire life cycle was highest in rice (729.97 mm) followed by groundnut (396.45 mm), wheat (345.33 mm), mustard (274.31 mm), potato (250.92 mm) and pea (198.75 mm). The water requirement for a plant throughout its life cycle was found to be highest in potato (30.11 liter), followed by rice (23.95 liter), mustard (18.52 litre), pea (17.89 litre), groundnut (17.84 litre) and wheat (6.91 litre). There was a considerable reduction in water requirement values of all the studied crops when contribution from effective rainfall was accounted for. In descending order, the water requirement values for the each crop were wheat (316.80 mm) > mustard (243.81 mm) > rice (228.12 mm) > pea (182.26 mm) > potato (146.93 mm) > groundnut (24.87 mm) respectively, when effective rainfall values were considered.

Key words: Water requirement, reference crop evapotranspiration (ET_0), penman-monteith approach, effective rainfall

INTRODUCTION

Water is a life line for human being. Life is impossible for humans as well as both animals and plants without water. About 70% of earth is covered by water but there is only little quantity of pure water is available and can be usable. Water is an essential element for plant growth and its food production. Unfortunately, there is competition between municipal, industrial and agriculture users for the little available water in the reservoirs. Estimating crop water requirements is a prerequisite for water project planning and management. The amount of water needed for evapotranspiration from planting time to harvesting for a given crop in a specific climate regime is determined by rainfall pattern. The population of India is expected to around 1.60 billion by the year 2050. The gross per capita availability of water is expected to decline from 5300 m^3 per year from 1951 to 1140 m^3 by 2050. The per capita availability of water less than 1700 m^3 is considered stress level, availability of water classified as “Scarce” and is considered a severe constraint on socio-economic development and environment quality. India shares 17% world population, 2.4% land mass and 4% of fresh water resources of the world. The per capita land availability has reduced from 0.48 ha to 0.13 ha and water availability has been reduced from 5300 m^3 to 1140 m^3 (Zhao *et al.* 2010).Water requirement of crops is known at different management levels within the irrigated area to accomplish effective irrigation management. The crop water requirements are met from the effective rainfall, irrigation water applied and the available soil moisture (Srivastava *et al.* 2006). Therefore, the present investigation was carried out to assess the water requirement of various crops grown in Mirzapur district of Uttar Pradesh.

MATERIALS AND METHODS

Study area: Mirzapur is located between geographical area of 4521 km^2 (latitude 23^0 52′ to 25^0 32′ N and longitude 82^0 72′ to 83^0 33′ E). The mean monthly maximum temperature during summer months (May to July) reaches up to 47°C and minimum during winter months (December and January). The mean annual rainfall is 750 mm..Major crops of the region *viz.* rice, wheat, groundnut, mustard, pea, and potato were chosen.

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Meteorological data: Daily meteorological data*viz.* rainfall, maximum and minimum temperature, relative humidity, wind speed at 2 m height, and sunshine hours for the period from 1997 to 2016 (20 years) were obtained from meteorological station located at KVK, Mirzapur as well as BHU, Varanasi (Table 1).

Table 1: Climatic parameters of Mirzapur district (Average of 20 Years: 1997-2016)

Months	Maximum temperature (^{0}C)	Minimum temperature (^{0}C)	Mean temperature (^{0}C)	Sunshine hours	Maximum relative humidity (%)	Minimum relative humidity (%)	Mean relative humidity (%)	Wind speed (km/hr)
January	19.7	7.04	13.37	6.27	86.23	44.67	65.45	8.60
February	26.95	11.15	19.05	8.35	84.58	45.20	64.89	8.60
March	33.10	15.83	24.47	8.39	73.46	28.40	50.93	10.40
April	35.96	20.42	28.19	9.38	57.09	23.50	40.30	11.20
May	39.85	26.65	33.25	9.18	64.86	27.50	46.18	13.00
June	46.08	27.73	36.91	7.08	72.80	50.28	61.54	14.80
July	32.14	27.18	29.66	4.72	84.34	71.24	77.79	12.20
August	31.18	26.73	28.96	5.35	88.50	75.10	81.80	11.50
September	30.90	26.50	28.70	6.26	88.36	73.62	80.99	8.60
October	31.67	20.71	26.19	8.34	85.16	44.82	64.99	6.80
November	28.41	14.67	21.54	8.20	91.31	40.65	65.98	7.20
December	21.10	9.06	15.08	6.48	93.82	56.47	75.15	6.80

Estimation of reference evapotranspiration (ET_0): The daily reference evapotranspiration (ET_0) at the weather stations was estimated by Aquacrop model developed by Penman-Monteith model FAO (1992), Italy using daily weather data set. It is a physically based analytical approach, a combination of the energy balance and mass transfer method, specifying the resistance factors of the reference surface. The mathematical expression of the reference evapotranspiration (ET_0) is as follows:

$$ET_0 \frac{0.408\Delta\,(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34 u_2)} = \quad \ldots\ldots. (1)$$

Where,

ET_0= Reference evapotranspiration [mm/day^{-1}]

Where,

Re = Effective rainfall (mm), P = Total precipitation/ rainfall (mm)

Crop water requirement: Crops require the water mainly to meet the evapotranspirational demand. The potential crop evapotranspiration (PET) *i.e.,* crop water requirement was estimated with the following formula:

$$PET = K_c \times ET_0 \ldots\ldots 2$$

Where, ET_0 is crop reference evapotranspiration, Kc is crop coefficients.

R_n= Net radiation at the crop surface [MJ m^{-2} day^{-1}]
G= Soil heat flux density [MJ m^{-2} day^{-1}]
u_2 = Wind speed at 2 m height [m s^{-1}]
es = saturation vapour pressure [kPa]
e_a = Actual vapour pressure [kPa]
Δ = Slope vapour pressure curve [kPa/˚C^{-1}]
e_s-e_a= Saturation vapour pressure deficit [kPa]
γ = Psychometric constant [kPa/˚C^{-1}]
T = Mean daily air temperature at 2 m height [˚C]

Effective rainfall: Estimate effective rainfall used by the crops after rainfall losses due to surface rainfall and percolation. The value of effective rainfall was determined by following the empirical equation:

$$Re = 0.0011P_2 + 0.442$$

The crop data required by the Penman-Monteith model are the crop coefficient at different growth stages and initial and maximum root depths. The crop co-efficient (K_c) depend on the changing crop characteristics over the growing season. The growth stages of crops are divided into four stages, initial stage, development, mid season and late season. The general trend of variation of crop co-efficient (K_c) during different growth stages of cereals and vegetables crops are shown in Table 2.

Table 2: Period of growth, PET and K_c values of crop at different stages of crop growth

Crop/Spacing	Stages of crop growth	From	To	Stages of development (days)	Stage length (days)	PET (mm)	K_c
Rice	Nursery	22.6.16	30.6.16	9	20	7.49	1.20
0.25 x 0.20 m		1.7.16	11.7.16	11		4.48	1.20
	Initial	12.7.16	31.7.16	20	25	4.48	1.10
		1.8.16	5.8.16	5		4.11	1.10
	Development	6.8.16	31.8.16	26	35	4.11	1.15
		1.9.16	9.9.16	9		4.01	1.15
	Mid season	10.9.16	30.9.16	21	40	4.01	1.20
		1.10.16	19.10.16	19		4.03	1.20
	Late	20.10.16	31.10.16	12	30	4.03	1.05
		1.11.16	18.11.16	18		3.21	1.05
Groundnut	Initial	26.6.16	30.6.16	5	20	7.49	0.40
0.30 x 0.15 m		1.7.16	15.7.16	15		4.48	0.40
	Development	16.7.16	31.7.16	16	35	4.48	0.78
		1.8.16	19.8.16	19		4.11	0.78
	Mid season	20.8.16	31.8.16	11	45	4.11	1.15
		1.9.16	30.9.16	30		4.01	1.15
		1.10.16	4.10.16	4		4.03	1.15
	Late	5.10.16	19.10.16	15	15	3.21	0.60
Wheat	Initial	15.11.16	30.11.16	16	25	3.21	0.70
0.20 x 0.10 m		1.12.16	9.12.16	9		2.08	0.70
	Development	10.12.16	31.12.16	22	65	2.08	0.93
		1.1.17	31.1.17	31		2.18	0.93
		1.2.17	12.2.17	12		3.18	0.93
	Mid season	13.2.17	28.2.17	16	30	3.18	1.15
		1.3.17	14.3.17	14		4.88	1.15
	Late	15.3.17	28.3.17	15	15	4.88	0.25
Mustard	Initial	20.10.16	31.10.16	12	20	4.03	0.27
0.45 x 0.15 m		1.11.16	8.11.16	8		3.21	0.27
	Development	9.11.16	31.11.16	22	60	3.21	0.68
		1.12.16	31.12.16	31		2.08	0.68
		1.1.17	7.1.17	7		2.18	0.68
	Mid season	8.1.17	31.1.17	24	30	2.18	1.15
		1.2.17	6.2.17	6		3.18	1.15
	Late	7.2.17	26.2.17	20	20	3.18	1.10
Potato	Initial	5.11.16	24.11.16	20	20	3.21	0.50
0.60 x 0.20 m	Development	25.11.16	30.11.16	6	30	3.21	0.83
		1.12.16	24.12.16	24		2.08	0.83
	Mid season	25.12.16	31.12.16	7	40	2.08	1.15
		1.1.17	31.1.17	31		2.18	1.15
		1.2.17	2.2.17	2		3.18	1.15
	Late	3.2.17	27.2.17	25	25	3.18	0.75
Pea	Initial	5.10.16	14.10.16	10	10	4.03	0.50
0.60 x 0.15 m	Development	15.10.16	31.10.16	17	20	4.03	0.78
		1.11.16	3.11.16	3		3.21	0.78
	Mid season	4.11.16	28.11.16	25	25	3.21	1.15
	Late	29.11.16	30.11.16	2	10	3.21	1.10
		1.12.16	8.12.16	8		2.08	1.10

RESULTS AND DISCUSSION

Effective rainfall: Thehighest rainfall and effective rainfall was found in the month of July (316.66 and 250.28 mm) and the lowest in December (1.16 and 0.51 mm). Soil water balance monthly values of water storage, potential evapotranspiration (PET), actual evapotranspiration (AET), water deficit, and water surplus were also computed (Table 3) Similary, the maximum and minimum values of PET were recorded in the month of May and

December, respectively. The higher values of water storage were recorded during July-September and minimum in May. AET values were highest in the month of June and minimum in November. Water deficit was maximum in the month of May and July in the month of July, August and September. There was no surplus water in any month of the year.

Table 3: Soil water balance obtained from Mirzapur district of Uttar Pradesh

Months	Rainfall (mm)	Effective rainfall (mm)	PET (mm)	Water Storage	Δs	AET	Water deficit	Water Surplus
January	18.05	8.34	67.58	121.48	9.19	27.24	26.39	0.00
February	18.18	8.40	89.04	100.71	-20.77	38.95	28.81	0.00
March	5.14	2.30	151.28	61.87	-38.84	43.98	99.86	0.00
April	9.91	4.49	188.70	54.82	-7.05	16.96	136.04	0.00
May	15.00	6.88	224.75	26.53	-28.28	43.28	224.56	0.00
June	138.66	82.46	224.70	51.08	24.54	163.20	68.40	0.00
July	316.62	250.28	138.88	150.00	173.29	105.71	0.00	0.00
August	311.97	245.01	127.41	150.00	238.63	101.37	0.00	0.00
September	216.10	146.93	120.30	150.00	99.40	93.60	0.00	0.00
October	39.30	19.08	124.93	99.88	-50.12	89.42	3.58	0.00
November	2.94	1.31	96.30	77.53	-22.35	25.30	79.70	0.00
December	1.16	0.51	64.48	112.29	34.76	35.92	11.51	0.00

Crop water requirement

Crop water requirement without considering effective rainfall: The bar chart Figure (1) represented the water requirement of four *rabi* crops (wheat, mustard, potato and pea) and two *kharif* crops (rice and groundnut). From the results (Table 4), it showed that for the *khariff* season water required by rice per plant was 23.95 litre, per day 26.06 mm and for total duration 729.97 mm. The corresponding values for groundnut were per plant 17.84 litre, per day 12.00mm and for total duration 396.45 mm. The *rabi* season wheat crop required 6.91 litre per plant, 9.92 mm per day and 345.33 mm for total duration of the crop. An amount of 18.52 litre per plant, 8.92 mm per day and 274.31 mm per total duration of crop was required by mustard crop. The water required for the potato crop was 30.11 litre per plant, 8.45 mm per day and 250.92 mm per total duration of crop. The corresponding values for Pea crop were 17.89 litre per plant, 11.29 mm per day and 198.75 mm per total duration of crop, when effective rainfall were not considered. Thus, from the results it is clear that total water requirement of rice at all the stages of crop growth was maximum followed by wheat. On the other hand, the minimum water requirement was noted in pea. The water requirement per plant of potato was relatively higher than other crops studied wheat, mustard and pea showed more or less similar water reouirement per plant. Similar results were found by Kumari *et al.* (2017); Yadav *et al.* 2018 and Mehanuddin *et al.* (2018).

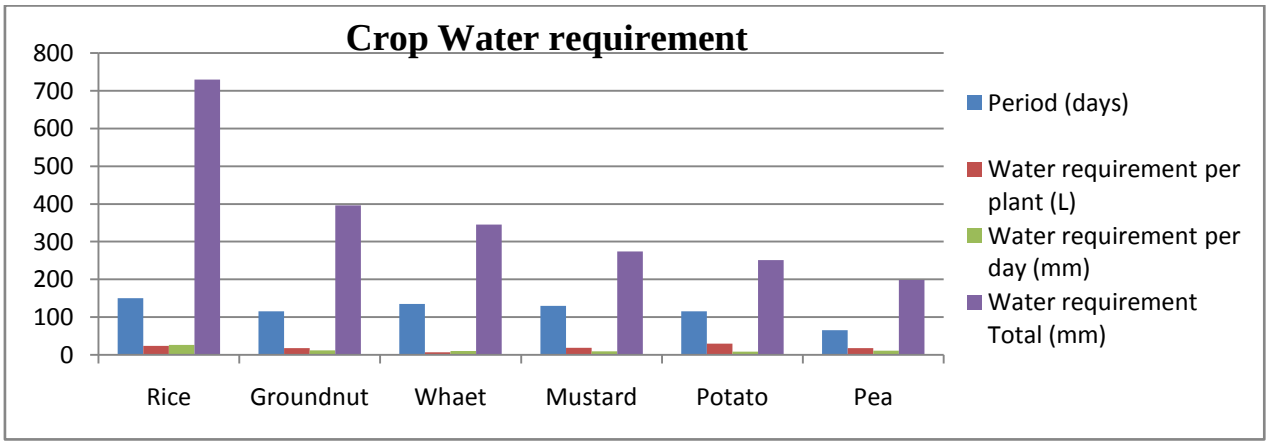

Fig 1: Water requirement major crops without considering effective rainfall

Table 4: Water requirement of major crops grown in Mirzapur district without considering effective rainfall

Crop/ Stages of growth	Stage length (days)	Water requirement (mm)		Spacing(m^2)	WaterRequirement (litre)
		Total	Daily		Per plant
Rice					
1. Nursery	20	140.03	7.00	0.03	4.20
2. Initial	25	121.17	4.85	0.03	3.63
3. Development	35	164.39	4.70	0.03	4.93
4. Mid season	40	192.94	5.80	0.03	7.84
5. Late	30	111.45	3.71	0.03	3.34
Total	150	729.97	26.06		23.95
Groundnut					
1. Initial	20	41.86	2.09	0.05	1.88
2. Development	35	116.82	3.34	0.05	5.26
3. Mid season	45	208.87	4.64	0.05	9.40
4. Late	15	28.89	1.93	0.05	1.30
Total	115	396.45	12.00		17.84
Wheat					
1. Initial	25	49.06	1.96	0.02	0.98
2. Development	65	140.90	2.17	0.02	2.82
3. Mid season	30	137.08	4.57	0.02	2.74
4. Late	15	18.30	1.22	0.02	0.37
Total	135	345.33	9.92		6.91
Mustard					
1. Initial	20	19.99	1.00	0.07	1.35
2. Development	60	102.24	1.70	0.07	6.90
3. Mid season	30	82.11	2.74	0.07	5.54
4. Late	20	69.96	3.50	0.07	4.72
Total	130	274.31	8.94		18.52
Potato					
1. Initial	20	32.10	1.61	0.12	3.85
2. Development	30	57.42	1.91	0.12	6.89
3. Mid season	40	101.78	2.54	0.12	12.21
4. Late	25	59.63	2.39	0.12	7.16
Total	115	250.92	8.45		30.11
Pea					
1. Initial	10	20.15	2.02	0.09	1.81
2. Development	20	60.95	3.05	0.09	5.49
3. Mid season	25	92.29	3.69	0.09	8.31
4. Late	10	25.37	2.54	0.09	2.28
Total	65	198.75	11.29		17.89

Crop water requirement with considering effective rainfall: From the results (Table 5 and Fig. 2), it revealed that rice crop required per plant 6.84 litre, per day 7.78 mm and for total duration 228.12 mm.water. For the groundnut crop, water requirement was 1.12 litre per plant, 0.81 mm per day and 24.87 mm total duration. The water required for the wheat crop was 6.34 litre per plant, 9.21 mm per day and 316.80 mm per total duration of crop. The corresponding values for water required by mustard were 16.46 litre per plant, 7.74 mm per day and 243.81 mm per total duration of crop. The water required for the potato crop, was 17.63 litre per plant, 4.14 mm per day and 146.93 mm per total duration of crop. The water requirement for the pea crop was 16.40 litre per plant, 10.33 mm per day and 182.26 mm per total duration of crop, Total water requirement varied among the crops and maximum value was recorded for wheat and minimum for groundnut when effective rainfall values were considered. Similar results were found by Nithya and Shivapur, (2016); Raut and Jadhav, (2012).

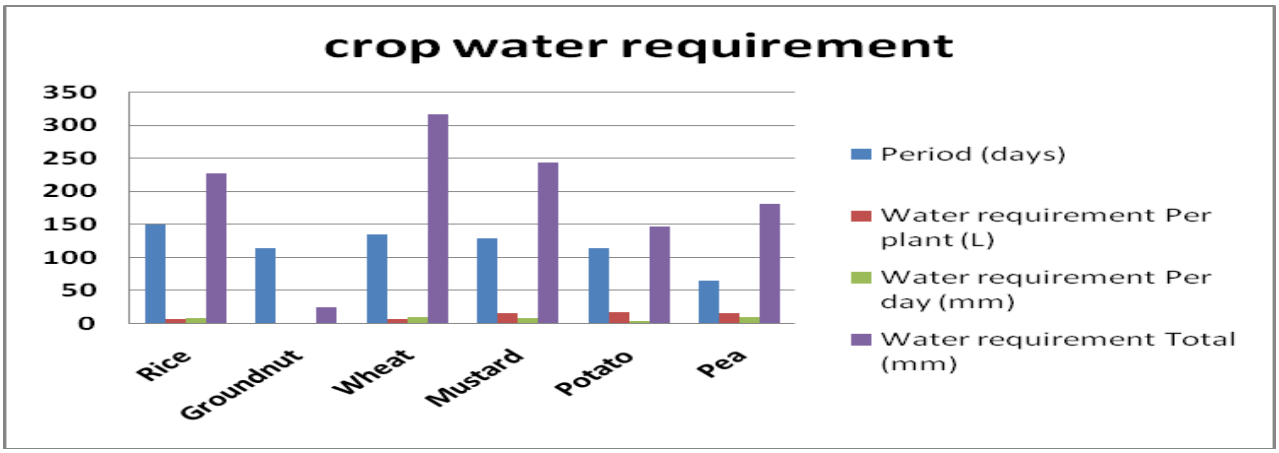

Fig 2: Water requirement of major crops with considering effective rainfall

Table 5: Water requirement of major crops grown in Mirzapur district with consideration of effective rainfall

Crop/ Stages of growth	Stage length (days)	Water requirement(mm)		Spacing (m^2)	Water requirement (litre)
		Total	Daily		Per plant
Rice					
1. Nursery	20	49.57	2.48	0.03	1.49
2. Initial	25	0.00	0.00	0.03	0.00
3.Development	35	0.00	0.00	0.03	0.00
4. Mid season	40	77.75	1.94	0.03	2.33
5. Late	30	100.80	3.36	0.03	3.02
Total	150	228.12	7.78		6.84
Groundnut					
Initial	20	9.18	0.46	0.05	0.41
2.Development	35	0.00	0.00	0.05	0.00
3. Mid season	45	15.69	0.35	0.05	0.71
4. Late	15	0.00	0.00	0.05	0.00
Total	115	24.87	0.81		1.12
Wheat					
1. Initial	25	47.25	1.89	0.02	0.95
2.Development	65	126.23	1.94	0.02	2.52
3. Mid season	30	125.28	4.18	0.02	2.51
4. Late	15	18.04	1.20	0.02	0.36
Total	135	316.80	9.21		6.34
Mustard					
1. Initial	20	17.66	0.88	0.07	1.19
2.Development	60	98.29	1.64	0.07	6.63
3. Mid season	30	70.66	2.36	0.07	4.77
4. Late	20	57.20	2.86	0.07	3.86
Total	130	243.81	7.74		16.46
Potato					
1. Initial	20	0.00	0.00	0.12	0.00
2.Development	30	56.27	1.88	0.12	6.75
3. Mid season	40	90.65	2.27	0.12	10.88
4. Late	25	0.00	0.00	0.12	0.00
Total	115	146.93	4.14		17.63
Pea					
1. Initial	10	17.05	1.71	0.09	1.53
2.Development	20	52.38	2.62	0.09	4.71
3. Mid season	25	87.98	3.52	0.09	7.92
4. Late	10	24.86	2.49	0.09	2.24
Total	65	182.26	10.33		16.40

The results of the present study can be used as a guide for selecting the amount and frequency of irrigation water for the crops in Mirzapur conditions. This Provides comprehensive decision support for researcher, policy makers and state development agencies for developing strategies to increase sustainable and alternative agricultural production systems. This gives better resource use efficiency for water and maximizing farm net income. Furthermore, it provides a strong basis for further studies regarding water resource management strategies in all the regions of eastern Uttar Pradesh.

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