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Validation of Crop-Water Use Relations Developed for Irrigated Groundnut Growing at Shallow Water Table Situations

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ABSTRACT

This study aimed to develop crop - water use relations and its validation for growing groundnut under different levels of irrigation at shallow water table condition (1.2-1.75 m from surface). Crop yield with respect to net irrigation depth and upward flux from water at 0.9 IW/CPE, where IW stands for net irrigation and CPE is cumulative pan evaporation, are the suitable levels of irrigation. The yield response to evapotranspiration (ET) was linear while curvilinear with irrigation depth (IW) and drainage loss (D). It was also curvilinear that is quadratic with IW, IW in conjunction with downward drainage loss (D) and with D and upward flux (U). Consequent upon the precise estimate of predictive yield output, the functions developed for groundnut separately with ET; IW in alliance with D and U are found best - fit relations. Relation evaluated between pod yield (q ha^{-1}) with IW in association with D and U in cm, offer as tool to be utilized for efficeint utilization of irrigation water with respect to groundwater contribution toward maximum yield benefit of groundnut grown on sandy loam to sandy clay loam Aeric Haplaquepts soil.

Introduction

Increasing scarcity of good quality water is a prime concern now-a-days as it eventually affects different water consumptive sectors. This has been creating an acute crisis of water especially in irrigated agriculture which consumes >70% of the available water in the world. Enhancing productivity of water per drop is therefore imperative for substantial increase of the efficiency with which available water resources are being used presently (Al-Kaisi *et al.*, 1999 and Oweis *et al.*, 1999). When amount of irrigation water is limited, scheduling should be adjusted to get more produce with less water and makes its use more prudently in crop production. Evaluation of crop - water use relationship *in situ* is thus essential though the relation is very complicated.

Eastern region of India belongs to sub-humid to humid i.e. high rainfall zone (600 - ≥ 1000 mm) of the country but crops grown in this region during post or pre monsoon periods often suffer by less or non-availability of good water. Study on crop water use relations is therefore needed to make headway for dealing the situation. Information in this regard for eastern India is insufficient.

Groundnut is one of the promising oilseed in Orissa, mainly grown in summer and covering an area of 5.654 million ha land i.e. 59.14% of total irrigated area of the state under oilseed (Orissa Agril. Statistics, 1999-2000). The aim of the study is to evaluating crop-water use relations by using different logical soil-water balance components and validates the relations by growing groundnut under shallow depth of water table situation in hot-humid eco-region in Orissa, India.

Materials and methods

An experiment was carried out in simple RBD by growing groundnut (*Arachis hypogaea* L) variety AK-12-24 with three replications in Aeric Haplaquepts, under various irrigation treatments during 1998-1999 and 1999-2000, at Water Technology Centre for Eastern Region farm at Deras (latitude 20°-30'N and longitude 87°-48'E), Orissa. The N, P_2O_5 and K_2O @ 20:40:40 kg ha^{-1} were applied to groundnut. Irrigation treatments comprised of water depth (IW) and different application frequencies e.g. IW/CPE and interval of days, where CPE stands for cumulative pan evaporation, are elaborated in Table 1. The amount and frequency of irrigation were selected based on the reports of Prihar and Sindhu (1994) and OUAT (1992-93). The water table fluctuated between 1.2 to 1.75 m during crop growth period. Daily evaporation was recorded from a USWB Class A pan evaporimeter.

Soil moistrue in 0.15 m increments up to 1.05 m depth (from three locations in each plot of all replications) were gravimetrically determined just befroe and after forty-eight hours of irrigation, and also after rainfall (recorded by IMD standard rain gauge), all throughout the cropping period. On considering various soil-water balance components e.g. precipitation, downward drainage loss, capillary contribution of ground water and evapotranspiration of crop, the soil - water balance equation appears as:

$$\Delta S = (P + I + U) - (R + D + E + T) \quad ...(1)$$

Where ΔS is change of root zone soil moisture storage, P is precipitation, I is irrigation, U is upward flux into the root zone, R is surface runoff, D is downward drainage loss, E is evaporation from the soil surface and T is transpiration by plants.

The incorporation of water in plant and addition of water through dew were too small to considered. Besides as the field was leveled so surface runoff was negligible and hence eliminated. The equaiton 1 then turns to

$$\Delta S = (P + I + U) - (D + E + T) \quad ...(2)$$

Water loss through evaporation from soil (E) and transpiraiton by plant (T) was considered together as evapotranspiration loss (ET). After forty-eight hours of irrigation, the balance equation grossly estimate the water loss through downward drainage as follows:

$$\Delta S = (I + P) - ET - D \quad ...(3)$$

Table 1. Estimates of different water - use of groundnut and sunflower under various irrigation treatments

Treatments detail		Pod yield, kg/ha	Field water use efficiency, kg-ha cm^{-1}	Actual water use efficiency, kg-ha cm^{-1}	Yield estimate (kg ha^{-1}) by the contribution of	
S. No.	IW, cm				Irrigation	Ground water
1	2-3, growth stages	693	721.87	36.13	14	679
2	4, IW/CPE 0.3	987	104.67	43.80	187	710
3	4, IW/CPE 0.6	895	82.08	43.51	278	706
4	4, IW/CPE 0.9	1667	77.79	64.19	763	904
5	4, IW/CPE 1.2	1008	33.28	46.37	488	520
6	4, IW/CPE 1.5	1234	35.99	50.35	496	738
7	6, IW/CPE 0.3	849	141.5	40.95	174	675
8	6, IW/CPE 0.6	1000	77.76	43.12	299	701
9	6, IW/CPE 0.9	1529	63.71	58.87	460	1069
10	6, IW/CPE 1.2	1102	34.13	42.17	424	678
11	6, IW/CPE 1.5	833	22.95	41.09	423	410
12	2-3, three times	523.5	24.58	35.76	401	122
13	3, 7 days	1428.5	34.51	41.25	722	706
14	4, 10 days	1476	38.88	55.18	1043	433
15	5, 13 days	1116	26.60	33.10	569	547
16	3, 10 days	1548	41.88	45.91	874	673
17	3, 13 days	1509	42.98	43.89	919	589
18	4, 7 days	1557	28.85	42.70	983	574
19	4, 13 days	1238	32.44	35.53	569	669
20	5, 7 days	1190	19.20	34.35	827	363
21	5, 10 days	1428	30.67	43.74	1063	365

The 'water budget method' (Mishra and Ahmed, 1987) was followed for determining ground water capillary flux into the root zone. Before supply of irrigation the soil - water balance equaiton would be:

$$\Delta S = (P + U) - ET \quad ...(4)$$

Where U is the estimate of upward flux from water table below the surface.

The precipitation during 1998-1999 from December to May was nil and 179 mm during 1999-2000. To assess the contribution of irrigation water and capillary upward flux separately to crop yield (Y); the two parameters were introduced e.g.

Yield asessment (kg ha^{-1}) from the contribution of

Irrigation water = Y(IW-D) / (IW-D) + U

Ground water = YU / (IW-D) + U

The estimates of yield in expense of irrigation and groundwater contribution and water use efficeincies of crop are displayed in Table 1.

Crop yield variation with different water balance components was first assessed and then evaluated by solving different regression equations, containing various logical soil-water balance components as independent variables (Table 2).

Groundnut was again grown in 2001 under different levels of irrigation water and the pod yield was compared with the yield predicted by using different crop-water use relations, which are presented in Table 3.

Results and Discussion

Soil profile (1.05 m depth) was initially acidic to neutral in reaction (pH 6.1-6.9), non saline in nature (EC_e 0.1-0.5 dS m^{-1}), sandy loam to sandy clay loam in texture and had 1.92 and 0.77 cm^3 cm^{-3} water per 1.05 m depth, at -0.033 MPa and -1.5 MPa respectively. Data on pod yield of groundnut (Table 1) reflect that application of water (including depth and application frequency), significantly influenced the yield over the yield obtained under water stress i.e. application of 3 cm water at five and three diferent growth stages of crop. The yield obtained under irrigation with 6 cm water (IW) at 0.9 IW/CPE, 3 cm at 7, 10 and 13 days intervals, 4 cm at 7 and 10 days and 5 cm at 10 days intervals were on par with the highest yield obtained at 4 cm IW at 0.9 IW/CPE, but

Table 2. Regression analysis and assessment of crop - water use functions

Variables		Expression of crop-water use functions	R^2	F-statistics
Independent, Y	Dependent, x, (cm)			
Groundnut pod yield (Y) in q ha^{-1}	Evapotrans-piration (ET)	Y = 1.87+0.37 (ET) ...... (1)	0.56**	24.67**
	Net water applied (IW)	Y = 6.93+0.26 (IW) - 0.003 $(IW)^2$ ....(2)	0.34*	4.75*
	Drainage loss (D)	Y = 6.90+0.53(D)-0.01 $(D)^2$ ...... (3)	0.34	4.56
	IW, percolation losl (D)	Y=8.09-0.92(IW) +1.88(D) + 0.02 $(IW)^2$-0.03$(D)^2$-0.03(IWxD) .... (4)	0.55*	3.64*
	IW, D, ground-water flux (U)	Y = -7.21+0.05(IW) + 0.52(D)+ 2.27(U)-0.01$(IW)^2$-0.06$(D)^2$-0.08$(U)^2$ + 0.04(IWxD) + 0.02(DxU) - 0.02 (IWxU) ...... (5)	0.74*	3.41*

'**' and '*' significant at 0.05 and 0.01 P

Table 3. Validation of different water - use relations and selection of best-fit functions

Groundnut pod yield obtainedunder different irrigation depth q ha^{-1}	Predicted pod yield (q/ha) by using different crop-water use relations				
	(1)	(2)	(3)	(4)	(5)
9.29	10.06	11.91	13.75	12.18	9.38
8.29	8.94	11.72	13.72	12.60	8.57
7.57	9.2	11.51	13.64	13.17	10.01
8.50	8.76	11.72	13.75	12.56	8.91
t-values between obtained and predicted yield	2.87	9.04**	14.57**	10.34**	1.51
Remarks	May be adopted	Not adopted	Not adopted	Not adopted	May be adopted

'**' Signifcant at 0.01 P

seasonal water depth in those treatments were varied (Fig. 1).

Water use efficiencies

The field water use efficiency was highest at 3 cm water applied at five crop growth stages though the yield was substantially low. A comparative higher value of field water use efficiency than its corresponding actual water use efficiency value may due to no-consideration of ground water contribution in the estimation of former albeit it contributed 23.2 to 98 per cent of total consumptive use of crop. It showed an exponential decrease with increasing amount of water depth (x) e.g. $y = 1.74e^{-0.04x}$, R^2=0.66* and thus indicates that the water use efficiency was reduced with increase of IW up to a certain range and get constant thereafter. The actual water use efficiency was highest at irrigation with 4 cm water (IW) applied at 0.9 IW/CPE followed by 6 cm IW at 0.9 IW/CPE (Table 1). In both the cases the yield was at par with the yield maximum. The actual water use efficiency didn't show any relation with either yield or net water depth.

Estimate of pod yield (kg ha^{-1}) in expense of irrigation water contribution was highest at 6 cm water at 1.2 IW/CPE followed by 3 cm IW with 7 days interval. Contribution of upward capillary flow towards yield was highest at 6 and 4 cm IW applied at 0.9 IW/CPE. In surface method of irrigation the treatment, whcih produces high yield with less loss of water through downward percolation, as conspicuous under 3 cm water with 13 days interval where 40 percent loss of net irrigation was registered, may be preferred. But in a situation where sizeable amount of water comes from groundwater then irrigation to be planned in a way, which facilitates maximum possible contribution of ground water through capillary flow during cropping period. Assessment of yield in repsect of irrigaiotn applied and contribution of irrigation and ground water is thus reflects that irrigation with 4 and 6 cm IW at 0.9 IW/CPE, as effective schedule to successfully grow groundnut on sandy loam to sandy clay loam Aeric haplaquepts, at high water table situation.

Crop - water use relations

Yield response bore linear relationship with evapotranspiration loss while quadratic with net water depth (IW) and percolaiton loss of water (Fig. 1). The quadratic response of applied water to groundnut yield was also noted by Gulati and Lenka, (1999). Hexem and Heady (1978) and Martin *et al.* (1984) also showed that the functional relationship between water applied and yield can be quadratic, polynormical or exponential.

Conventionally the decreasing loss of irrigation water boost up crop yield provided other input components of soil water balance are less active

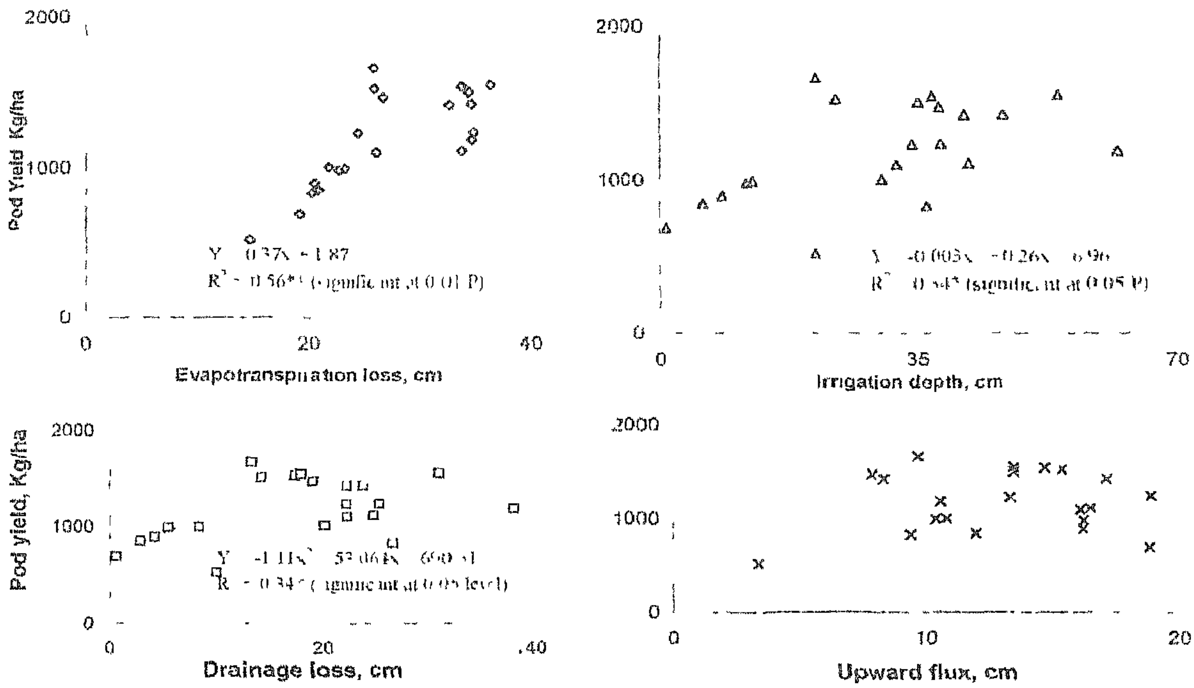

Fig. 1. Yield variation of groundnut with different soil water balance components

or inoperative. But such trend was not present in pod yield with respect to drainage loss of water (Fig. 1). This may due to sufficient contribution of groundwater to crop.

The groundwater flux in combination with water retains in soil after the loss through drainage usually fulfills evapotranspiration need of crop, during irrigation interval. Therefore applied water, percolaiton loss and upward flux are inextricably linked with each other, and may have direct or indirect influence on crop yield. Therefore, the quadratic regressions of yield on IW with D, and with D and U are found to be highly significant (Table 2).

Validation of crop - water use relations

The predicted pod yield of groundnut (Table 3) by using different crop - water use relations those listed in Table 2, reveal that it varies from the yield obtained practically. However the differences between yield predicted by using the relations containing ET alone and IW with D and U, with yield observed are found non-significant, and thereby indicates the merit of these funcitons as best-fit in terms of their adaptability to assess the yield estimate of irrigated groundnut.

Therefore for a known volume of irrigation, the application of water both in terms of amount and applicaiton frequency can be monitored to allow less water loss through downward drainage and get the desired level of pod yield of groundnut. Monitoring of irrigaiton supply also controls the upward flux from groundwater table partly, so for some estimated level of groundwater contribution irrigation can also be adjusted by allowing the expected loss of water for high yield of groundnut.

Conclusions

The study indicates that 4 and 6 cm water at 0.9 IW/CPE are appropriate irrigaiton schedule for successful growing of groundnut. It also offers two best - fit water - use funcitons relating yield with evapotranspiration loss and with seasonal water depth, percolation loss and upward flux from groundwater table. The relations can be exploited for assessing groundnut yield with known volume those soil-water balance components. The study thus offer helps for judicious use of irrigaiton water with respect to ground water contributon, to get maximum yield of groundnut grown on sandy loam to sandy clay loam, acidic Aeric Haplaquepts under high water table condition.

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