Determination of water use and crop yield production functions for Soyabean using drainage lysimeters.

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Abstract

Conservation is the key to proper Water Resource Management.Proper water policies should be based on the principle of profit maximization with least waste of this valuable natural resource,

"WATER".

Need of the availability of country specific and location specific data on the crop water requirement for most profitable yield level has initiated this study.It has been revealed from the results that,in the dryzone of Srilanka higher total yield levels could be reached with adequate water issues in the dryseason than in the wet season especially with respect to non rice annuals like Soyabean(Glycine max).

Allocation of the wright quantity in the wright season has to be stressed as a viable policy for Water managers,Decision makers,and the Polititions.

Introduction

Water and yield (input-output) analysis is the key to the understanding relationships between water and yield .At what moisture status should irrigation be applied in order to obtain maximum yield or what would be the yield loss if water applications are inadequate. For many if not all crops in a given climate dry-matter production is proportionate to the amount of transpiration.

Literature review

Heady and Dillon(1961) described the production function as a concept of physiological and biological sciences. Kentsch(1959)used multiple regression to obtain a quadratic equation for yield for water variables for periods within the growing season.

Hall and Butcher(1968) developed a dynamic programming model for the optimal allocation of irrigation in quantity and time. Yaron(1971) distinguished between two types of water yield relationships.One was the total water input with fixed intraseasonal water distribution and the second relationship for flexible water inputs or dated water input.The curves for various years tended to be parallel.

Yield water use functional relationships.

A considerable amount of evidence has accumulated to indicate that upto a minimum amount of actual evapotranspiration (AET) producing near maximum yield, the relationship between yield and ET is nearly linear.The correlation is even higher when total drymatter is considerd as compared to grain yield .Yet two basic inconsistancies remain to be revealed.

1)To explain the results of those studies that obtained a curvilinear relation between yield and water use.

2)To show how unique relationship between yield and actual evapotranspiration can hold when it is known the same AET deficits can give different yields if imposed at different times or conversly how the same yield can be obtained for different values of ET.

The relationship between yield and seasonal ET is quite well represented by a straight line function for Corn and Sorghum.If the upper bound of yield is related to the depth of water applied,rather than ET,a curvilinear relationship will result.

Critical moisture sensitive stages of crops .

A number of research had shown that the yield response to moisture deficit at a particular growth stage may not be a function of that growth stage alone,but may be affected by the degree of stress in earlier growth stages.There may be a tendency for stress imposed at any one growth stage to harden the plant against damage from stress at a later stage as far as grain yield is concerned.

Nevertheless critical growth stages of different crops are still important.

Critical moisture sensitive stages for selected crops

Crop	Critical moisture sensitive stage	Reference
Snapbean	During flowering and pod development	Kattan and Fleming(1956)
Pea	At the start of flowering and when the pods are swelling.	Salter(1962,63)
Soybean	Period of major vegetative growth and blooming.	Runge and Odell (1960).

Experimental production functions

The following section present experimentally determined water yield production functions for the major economic crops.

Wheat:

The relationship between total amount of water (X) to the estimate of relative grain yield (Y) for northern Negan and Lakhish region may be described by the following linear equation

$Y = -10.7 + 0.208\,X$; $r^2 = 0.767$

In Jordhan Rift and the Betshean vally following equation was given.

$Y = -58.3 + 0.268\,X$; $r^2 = 0.933$

Materials and methods

Lysimeter tanks were made using galvanized iron sheets with the top open and bottom closed.In the middle of the tank bottom a two inch diameter hole was made and a same diameter elbow joint was welded to it from outside.S-loan tubes of the required length were connected to the elbow joint so that there would not be any leaking of water.These tanks were buried in pits of the same dimention from where soil wasremoved for placement of the tanks.Only 7.5cm of the tanks were kept above ground level and 90 cm thick soil monolith from the soil surface was repacked toapproximate original bulk density .

This was done by taking 5cm layers seperately from the surface up to 90cm and by keeping these eighteen layers seperately before packing.Later these were packed back to the original bulk density by placing all the soil taken from 5cm deep layer of the profile in a 5cm deep layer in the tank in the same sequence as was found in the soil profile.

Four tanks were arranged to drain into one collecting pit with four separate outlets for the purpose of drainage measurement independantly from each tank. These four tanks were treated as one block and three such blocks were constructed for each experiment for the Soyabean crop which was grown in 2.44mx2.44mx1.22m tanks.Each of those four tanks in one block carried one of the four chosen treatments.Thus the experiment consisted of 4 treatments and 3 replications in a randomized complete block design.

Following four soil moisture depletion patterns were maintained till 2 weeks before harvest as four treatments.Namely first one at field capacity T1,second one till the soil moisture content in the root zone reaches 25% of the available moisture depletion level T2,third one till the soil moisture content in the rootzone reaches 50% of the available moisture depletion level T3,and the last one till the soil moisture content in the rootzone reaches 75% of the available moisture depletion level T4.

Approximate depletion rates were determined using the neutron probe.Three calibration curves were obtained one for the first 15cm layer,the other for the next 30cm layer and last one for the balance 45cm layer.

Best fit was given by a qudratic equation.

Three equations obtained are given below.

Equation for 0-15 cm layer Eqn (1).

$Y = -0.029 + 0.417X - 0.059\ X^2$ (R = 0.98ns).

Equation for 15 – 45 cm layer Eqn (2).

$Y = -0.006 + 0.287X + 0.005\ X^2$ (R = 0.68ns).

Equation for 45 –90 cm layer Eqn (3).

$Y = 0.118 + 0.173\ X + 0.0003X^2$ (R = 0.604ns)

Where Y is the volumetric water content in cms of water per cm depth of soil and X is the count ratio which indicates the ratio of average count in soil to average standard count.

Note: Eventhough above three equations are not significant at 0.5% and 0.1% level they are significant at 1% level. Since 90%correlation between X and Y is justified for decision making in agriculture sector,I used the above three relationships.

Procedure used in obtaining the moisture content of the profile is given in appendix 1.Relation between actual moisture content,calculated moisture content,and the error are given below for the three equations.

Equation 1.

Actual moisture content cm water/cm depth of soil.	Calculated moisture content cm water/cm depth of soil.	Error (actual-calculated)
0.162	0.183	-0.021
0.165	0.200	-0.035
0.078	0.091	-0.031
0.129	0.115	0.014
0.221	0.190	0.031
0.211	0.189	0.022

Equation II

Actual moisture content cm water per cm soil depth.	Calculated moisture content cm water per cm soil depth.	Error
0.187	0.172	0.015
0.199	0.173	0.026
0.287	0.217	0.070
0.196	0.205	-0.009
0.222	0.208	0.014
0.243	0.214	0.029
0.245	0.227	0.018

Equation III

Actual moisture content cm water cm depth of soil	Calculated moisture content cm water cm depth of soil.	Error
0.205	0.225	-0.020
0.243	0.231	0.012
0.284	0.254	0.030
0.221	0.254	-0.033
0.217	0.220	-0.005
0.257	0.266	-0.009
0.263	0.243	0.020

Above values are reported since there was a slight disparity between the equations derived from the computer and the reported equation which was derived manually.

All the drainages were collected from each tank independently and were converted to a linear measurement by dividing from the surface area of the tank.Irrigations were given as indicated in appendix II.

A simple water balance equation was used to determine evapotranspiration values.

ie $W1 - W2 = S = E + d - (I + R)$

Where W1 is the profile storage in day 1,W2 is the profile storage in day 2, S is the change in storage,E the crop evapotranspiration ,d the drainage,In the irrigation and R is the precipitation (All rainfall values = or < 7.5cm taken).

From stage by stage ET values seasonal ET values were estimated.From stage by stage ET + P values seasonal ET + P values are calculated. Total seasonal water supply was taken from seasonal irrigation + rainfall.These were correlated with grain yield during 1984,85,86 Yala season and 85/86 Maha season. These were also correlated to relative yield as a percentage.

Results and Discussion

Seasonal evapotranspiration values were correlated with mean grain yield (from three reps) obtained from the lysimeter tank and the borders seperately.

Inside tank results.

1984 Yala season

$Y = 0.002X + 1.274$ r^2 =0.875 (where Y = mean grain yield at 12% moisture in mt/ha, X = seasonal ET).

1985 Yala season

$Y = 0.002X + 1.025$ r^2 =0.781

1985/86 Maha season

$Y = 0.003X + 0.217$ r^2 = 0.34

1986 Yala season

$Y = 0.002X - 0.246$ r^2= 0.942

Seasonal evapotranspiration plus percolation values were also correlated to grain yield as above.

Inside tank results

1985 Yala season

$Y = 0.0005X` + 1.528$ r^2 =0.8

1985/86 Maha

$Y = 0.001X` + 1.263$ r^2 =0.17

1986 Yala

$Y = 0.002X` - 0.245$ r^2 =0.93

Where X` = Seasonal ET + Percolation

Since there were year to year variation in grain yield this parameter was expressed as a relative yield making maximum value as 100.

Correation between relative yield and seasonal ET(mm) are given below.

Inside tank

1984 Yala season

$Y = 0.064X + 41.367$ r^2 = 0.87

1985 Yala season

$Y = 0.087X + 46.936$ r^ = 0.78

1985/86 Yala season

$Y = 0.152X + 9.725$ r^ = 0.34

1986 Yala season

$Y = 0.23X - 32.37$ r^ 2 = 0.94

Seasonal ET + P was also correlated to relative grain yield .

Inside tank

1985 Yala

$Y = 0.022X + 71.03$ $r^2 = 0.80$

1985/86 Maha

$Y = -0.04X + 56.66$ $r^2 = 0.17$

1986 Yala

$Y = 0.221X - 32.201$ $r^2 = 0.93$

Conclusion

Theoretically there shold be a negative intercept on the Y-axis.This was very clearly seen in the year 1986 dry season.Overall reduction in yield during this year was due to heavy lodging and a pest incidence but the ideallistic theoretical trend remained unaffected.Varied response in other years could possibly be due to confounding effects of various other factors like weed control,plant population and perhaps many more climatic parameters.

In addition to substantiating the form of the functional relationship between yield and water use,the results of various studies other than Srilankan work allow some observations to be made regarding the most efficient use of irrigation.

A major effect was the severe depression of yield caused by stress during "critical growth stages" of various crops.Crops vary in their tolerence to water stress and excessive water supply therefore ,differential effects may be observed in different crops.

If a crop is supplied with seasonal quantity of water less than its potential requirements severe yield reduction could occur if this deficit occurs during the period of such sensitivity.

An important result found in many cases is that the maximum ETof a crop does not necessarily correspond to the maximum yield. The application of water more than PET(potential evapotranspiration) requirements may increase the total yield of some crops such as sugarcane.

Considerable scatter in data obtained by many researchers when plotting crop yield versus water use,largely results from the time of occurance of water deficits in relation to the stages of growth.

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Appendix I

Proceedure in calculating water content in the profile is given below.
Three equations given below were used in the calculations.

0-15cm layer,

$Y = -0.029 + 0.417X - 0.059X^2$ $\quad R = 0.98$ ns

For 15 – 45 cm layer,

$Y = -0.006 + 0.287X - 0.005X^2$ $\quad R = 0.68$ ns

For 45-90 cm layer,

$Y = 0.118 + 0.173X - 0.003X^2$ $\quad R = 0.604$ ns

Where Y is the volumetric water content and X is the count ratio.

A sample calculation.

Depth of reading	counts	count ratio	volumetric water content. cm water/cm soil.	layer factor	water content in each layer.
Surface(7.5cm)	633,633	0.635	0.212	15	3.18
20 cm	633,633	0.635	0.178	10	1.78
30 cm	714,731	0.724	0.204	10	2.04
40 cm	735,714	0.751	0.212	10	2.12
50 cm	769,745	0.759	0.251	10	2.51
60 cm	758,767	0.764	0.252	10	2.52
70 cm	792,772	0.786	0.256	25	6.40

Total water content in 90cm profile = 20.55 cm
Note: Though F-test was not significant in both linear and qudratic fit ,when more data were added to previous Maha calibration data, qudratic fit showed an improvement over the linear fit since a higher percentage of variability in Y was explained by the qudratic fit than the linear one.So I used that form in this exercise.

Appendix II

When the rootzone reaches the indicated deficits given below full profile deficits were given as an irrigation.

From 07/06 to 22/06 is taken as stage I where,

T1 = S(15) = 0.000 where S(15) is the change in total soil moisture storage in the first 15 cm soil layer from the surface.
T2 = S(15) = 0.525
T3 = S(15) = 1.050
T4 = S(15) = 1.575

From 22/06 to 17/07 is taken as stage II where,

T1 = S(60) = 0.000 cm
T2 = S(60) = 1.875cm
T3 = S(60) = 3.750 cm
T4 = S(60) = 5.625 cm

From 17/07 to 21/08 is taken as stage III where,

T1 = S(90) = 0.000cm
T2 = S(90) = 2.850cm
T3 = S(90) = 5.700 cm
T4 = S(90) = 8.550 cm.

During the growth stage IV no irrigations were given for all treatments.