ISSN : 1812-5379 (Print)
ISSN : 1812-5417 (Online)
http://ansijournals.com/ja

JOURNAL OF AGRONOMY

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Journal of Agronomy 5 (1): 28-31, 2006
ISSN 1812-5379

Optimisation of Water Productivity Using Production and Cost Functions for Cotton

S.M. Kashefipour, S. Broomand Nasab and B. Sohrabi
Water Sciences Engineering Faculty, Shahid Chamran University of Ahwaz, Ahwaz, Iran

Abstract: In the present research the water-yield relationship has been determined for the cotton (*Si-Ocra* varity) under sprinkler irrigation. The research was carried out with five irrigation treatments at three replications for two consecutive years (2004 and 2005). The amount of water for irrigation was calculated and applied based on the class-A pan evaporation. The treatments were 120% (T_0), 100% (T_1), 70% (T_2), 40% (T_3) and 0% (T_4) of the accumulative pan evaporation. The two years average data showed that the maximum Marginal Water Use Efficiency (MWUE) was obtained for T_1 with a value of 4.18 kg ha^{-1} mm^{-1}. The water production function as an average for two years was obtained as: $Y_W = -1.522W^2 + 152.34W - 312.16$ with a correlation coefficient of 0.96 where, W and Y_W are the applied water (cm) and yield (kg ha^{-1}), respectively. This equation shows that the maximum yield could be obtained with 500 mm/year of applied water. However, for the regions with no restriction in water irrigation but limited agricultural lands the optimum applied water was obtained 430 mm/year and at this amount of water application the net income would be maximum. For the adverse conditions in which, water availability is a restricted factor the optimum applied water was calculated to be 346 mm/year.

Key words: Sprinkler irrigation, cotton, production, cost functions

INTRODUCTION

Cotton is a very sensitive plant to the amount and duration of irrigation (deficit and full irrigation). Excess irrigation, the irrigation starting time and uncontrolled water stress may seriously decrease the cotton yield. In the arid and semi arid areas the first irrigation is immediately started after sowing, but in wet areas, similar to the current research area, the first irrigation is usually postponed to the flowering time. This irrigation strategy has positive effect on the controlling of growing the green parts of the plant, increasing the cotton yield and also decreasing the maintenance and harvesting problems.

Deficit irrigation and its effects on the plant growing periods and water productivity is now one of the most important research subjects in the literature. Investigation on water productivity of wheat was carried out by Kang *et al.* (2002). In their research, water stress was implemented during different growing periods and by controlling the water application and measuring the soil moisture, photosynthesis rate, root and stem weights and yield they found that the best water productivity was obtained when the drought stress was applied at the first stage of growing season. The effect of the amount of water application for carrot, spinach, tomato and onion during the growing season was investigated by Imtiyaz *et al.* (2000). In their research the amount of application water was calculated based on the accumulative pan evaporation and applied through a sprinkler irrigation system. The treatments were 11(T_1), 22(T_2), 33(T_3), 44(T_4) and 55(T_5) mm of accumulative class A pan evaporation. The amount of water application was constant and equal to 18 mm during each irrigation for all treatments. They found that the maximum yield was obtained for the treatment T_2 in all cases. English and Raja (1996) analysed the effect of deficit irrigation and water stress for cotton in California and concluded that the deficit irrigation between 15-59% according to the irrigation interval could produce economic conditions. The relative sensitivity of cotton yield was investigated by De-Kock *et al.* (1990). According to their results water stress before flowering period causes in precocious of cotton-pods and immediately after this period it stops the cotton-pod growth. Water stress during maturating cotton-pod period increases the cotton yield. Therefore in the case of restriction in the available water resources the main important periods for supplying irrigation are: 1. flowering and 2. first step of growing cotton-pods. Sammis and Guitar (1981) investigated the yield of cotton under different water application with sprinkler irrigation and found that the cotton yield per unit of application water was consistent with rate of evapotranspiration.

Corresponding Author: Dr. S.M. Kashefipour, Water Sciences Engineering Faculty, Shahid Chamran University of Ahwaz, Ahwaz, Iran Tel: 0098 611 3364055 Fax: 0098 611 33365670

The interaction effect of deficit irrigation on the production function is also investigated by many researches. Al-Jamal *et al.* (2000) determined the yield or production function of onion in New Mexico under drip and sprinkler irrigation systems. For both irrigation systems all treatments were fully irrigated after sowing and during budding period. After this period the treatments were irrigated as designed for specifying the yield function. Kashyab and Panda (2003) undertook experiments on the effects of water stress and deficit irrigation on the production function of potatoes. The treatments in their research project were designed based on the allowable depleted soil moisture. Sarr *et al.* (2004) conducted a research project on the scheduling of irrigation and determining of production function for groundnut in Senegal. In this project they designed five treatments based on the applying different rates of water stresses during the all groundnut growing season. They found that the groundnut yield is significantly affected by water stress.

The main purposes in this study were to investigate the effect of deficit irrigation on the cotton yield and to optimise the applied water using production and cost functions.

Optimisation Models for Water Productivity: There are many research studies in the literature presenting mathematical models of water productivity applicable for different regions. These studies may be categorised in two main subjects including: 1. optimisation of water productivity when the area of agricultural land is limited but there is no restriction in water resources 2. optimisation of water productivity when water resources for irrigation are limited without any restriction in agricultural land sources. For the first case, the following equation is recommended when the availability of irrigation water is not a restricted factor for agricultural development:

$$P_C \frac{\partial Y_W}{\partial W} = \frac{\partial C_W}{\partial W} \qquad (1)$$

where:

P_C = yield unit price (CU* kg^{-1}),
Y_W = yield function (kg ha^{-1} mm^{-1}),
W = water application (mm),
C_W = cost function(CU ha^{-1} mm^{-1})

This equation also shows the maximum net income, for a situation that availability of water is not a restricted factor.

For the second case, the following equation is presented to optimise the water productivity, when the availability of irrigation water is a restricted factor :

$$W\left(P_C \frac{\partial Y_W}{\partial W} - \frac{\partial C_W}{\partial W}\right) = P_C \times Y_W - C_W \qquad (2)$$

The product function, Y_W, cannot be known a priori, since yields will be affected by a number of unpredictable factors. Therefore, the production function used only for an estimate of the true values. However, when the only variable is water it could be a function of water and would be very useful and practicable for evaluation of deficit irrigation. The production equation as a function of water application is generally defined as quadratic or higher order polynomial equations depending on the plant type and variety, climate and land conditions, etc (English and Raja, 1996) The cost function, C_W, can also be defined as a function of water application and generally in a form of a linear equation.

Water Use Efficiency (WUE) is an indicator for analysing and evaluating of the relationship between water application and yield. This indicator is defined as:

$$\text{WUE (kg/ha mm)} = Y/I \qquad (3)$$

where, Y = yield (kg/ha) for the irrigated treatment and I = application water. Another indicator that is frequently used for evaluating of water application in irrigation systems, namely Marginal Water Use Efficiency (MWUE) and defined as Vories *et al.* (1991):

$$\text{MWUE (kg / ha. mm)} = (Y - Y_0)/I \qquad (4)$$

where, Y_0 = yield for the non-irrigated treatment (kg/ha).

MATERIALS AND METHODS

The experiments were carried out with cotton (*Si-Ocra* varity) in a 60×100 m field area located in the cotton research centre, Golestan province, north of Iran. Five irrigation treatments based on the accumulative pan evaporation including: 120% (T_0), 100% (T_1), 70% (T_2), 40% (T_3) and non-irrigated (T_4) were planned as the main plots with three replications for each plot. Therefore, in total 15 plots of a 12×12 m each with 6 m spacing were conducted and irrigated using a sprinkler irrigation system. Distribution uniformity of the system was controlled to be at a standard level. Irrigation interval for two years (2004 and 2005) was 13 days and the soil moisture was determined before and 24 h after irrigation. Soil characteristics such as soil texture, soil moisture percentage for Field Capacity (FC) and Wilting Point (WP)

Table 1: Soil characteristics of the research site for the depth of 0-90 cm

FC (%)	WP (%)	Clay (%)	Silt (%)	Sand (%)	pH
32.7	17.1	37.3	55.3	7.4	7.7

Table 2: Water application, seed cotton yield, WUE and MWUE for all treatments

	Treatment	T_0	T_1	T_2	T_3	T_4
Year 2004	[1]WA (mm^{-1})	530.00	465.00	391.00	304.00	191.00[2]
	[2]Yield (kg ha^{-1})	3708.00	3855.00	3627.00	2984.00	2331.00
	[3]WUE (kg ha^{-1} mm^{-1})	7.00	8.29	9.28	9.82	12.20
	[4]MWUE (kg ha^{-1} mm^{-1})	2.60	3.28	3.31	2.15	-
Year 2005	WA (mm^{-1})	427.00	342.00	309.00	278.00	145.00
	Yield (kg ha^{-1})	3088.00	3252.00	2735.00	2330.00	1401.00
	WUE (kg ha^{-1} mm^{-1})	7.23	9.51	8.85	8.38	9.66
	MWUE (kg ha^{-1} mm^{-1})	3.95	5.41	4.32	3.34	-
Average	WA (mm^{-1})	478.00	404.00	350.00	291.00	168.00
	Yield (kg ha^{-1})	3398.00	3553.00	3181.00	2657.00	1866.00
	WUE (kg ha^{-1} mm^{-1})	7.11	8.79	9.09	9.13	11.11
	MWUE (kg ha^{-1} mm^{-1})	3.21	4.18	3.76	2.72	-

[1]: Water Application +Effective Rainfall, [2]: Effective rainfall, [3]: Water Use Efficiency, [4]: Marginal Water Use Efficiency

and pH were determined and a summary of them has been illushown in Table 1. Soil type was classified as Silty Clay Loam. Cotton was planted in 1/05/2004 for the first year and in 25/04/2005 for the second year.

RESULTS

It should be noted that the effective rainfall was calculated equal to 191 mm for the year 2004 and 145 mm for the year 2005 from the measured data and is added to the water application for all treatments in this table. Water Use Efficiency (WUE) and Marginal Water Use Efficiency (MWUE) were calculated and appended to Table 2.

According to the data in Table 2 the yield function for the best equation was obtained as the following equations:

$$Y_W = -1.3936W^2 + 144.96W + 18.342 \quad R^2 = 0.97 \quad \text{year 2004} \tag{5}$$

$$Y_W = -1.778W^2 + 166.37W - 680.14 \quad R^2 = 0.92 \quad \text{year 2005} \tag{6}$$

$$Y_W = -1.522W^2 + 152.34W - 312.16 \quad R^2 = 0.96 \quad \text{Average} \tag{7}$$

where, Y_W = yield (kg/ha) and W = water application (cm). The best equations for the cost functions were obtained as the following equations based on all costs per unit area (ha).

$$C_W = 89454W + 7125076 \quad R^2 = 0.97 \quad \text{year 2004} \tag{8}$$

$$C_W = 108639.5W + 6787250 \quad R^2 = 0.99 \quad \text{year 2005} \tag{9}$$

$$C_W = 99047W + 6956163 \quad R^2 = 0.99 \quad \text{Average} \tag{10}$$

where, C_W = cost (Rial/ha, 1US $= 9000 Rials).

DISCUSSION

According to Eq. 7, which is a two years average of production function, the maximum yield may be obtained with 50.0 cm of water application and the yield would be 3500 kg ha^{-1}. This calculated yield was close to the one that was measured for the treatment T_1. It should be again noted that in Eq. 5 to 7 the effective rainfall is added to the applied water for both years. Eq. 5 also shows that the maximum yield does not obtain with the maximum water application. Table 2 shown that with decreasing the applied water the value of WUE increased and the maximum marginal water use efficiency was observed for the treatment T_1. However, the question is that "does the maximum yield or the maximum water use efficiency as defined in the literature give the maximum net income?" According to Eq. 1, 7 and 10 the optimum water application for a situation, in which the availability of application water is not a restricted factor was obtained equal 42.97 cm and the corresponding yield would be calculated 3424 kg ha^{-1}. This amount of applied water is about what was used for the fully irrigated treatment. If availability of water is a restricted factor the optimum water application was obtained 34.62 cm and the corresponding yield was calculated 3138 kg ha^{-1}. This amount of applied water is about 67% of accumulative of pan evaporation.

Net income (NI) as a function of water application (W) may be written as (P_C = 4700 Rials/kg):

$$NI = P_c Y_w - C_w \quad \text{or} \quad NI = -7001.2W^2 + 601717W - 892099 \tag{11}$$

Equation 11 shows that the maximum income may be obtained with 42.97 cm of water application. For a situation with the irrigation water being a restricted factor the income would be about 89% of the maximum income.

REFERENCES

Al-Jamal, M.S., T.W. Sammis, S. Ball and D. Smeal, 2000. Computing the crop water production function for onion. Agric. Water Manage., 46: 29-41.

De-Kock, J., L.P. De-Bruyn and J.J. Human, 1990. The relative sensitivity to plant water stress during the reproductive phase of upland cotton. Irrigation Sci., 11: 239-244.

English, M. and S.N. Raja, 1996. Perspectives on deficit irrigation. Agric. Water Manage., 32: 1-14.

Imtiyaz, M., N.P. Mgadla and B. Chepete, 2000. Response of six vegetable crops to irrigation schedules. Agric. Water Manag., 45: 331-342.

Kang, S., L. Zhang, Y. Liang, X. Hu, H. Cai and B. Gu, 2002. Effects of limited irrigation on yield and water use efficiency of winter wheat in the Loess Plateau of China. Agric. Water Manage., 55: 203-216.

Kashyap, P.S. and R.K. Panda, 2003. Effect of irrigation scheduling on potato crop parameters under water stressed conditions. Agric. Water Manage., 59: 49-66.

Sammis, T. and J. Guitar, 1981. Effects of decreased watering on crop yield. Available from the National Information Service, Spring Field, Wrri Report No. 36.

Sarr, B., J. Lecoeur and P. Clouvel, 2004. Irrigation scheduling of confectionery groundnut in Senegal using a simple water balance model. Agric. Water Manage., 67: 201-220.

Vories, E.D., D.J. Pitts and J.A. Fergusen, 1991. Response of cotton to different soil water deficits on clay soils. Irrigation Sci., 12: 199-203.