Effect of irrigation methods and levels on cotton (*Gossypium hirsutum* L.) yield and irrigation water productivity

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Abstract— **To investigate the effect of irrigation methods and levels on water productivity and cotton (Gossypium hirsutum L.) yield, a field experiment was conducted at Research Farm of Department of Soil Science, Punjab Agricultural University, Ludhiana during kharif 2011. Three irrigation methods tested includes drip irrigated beds, ridge and flat flood. Three levels of irrigation were also tested i.e. IW/PAN-E ratio of 1.0, 1.25 and 1.5 in ridge and flat flood, while in drip irrigation equivalent ratios of 0.20, 0.30 and 0.40 were maintained. The highest mean cotton seed yield of 2.3 t/ha was observed under drip irrigated beds at IW/PAN-E ratio of 0.40. The ridge and flat methods yielded 1.9 and 1.7 t/ha, respectively at equivalent IW/PAN-E ratio of 1.5. The irrigation water productivity (IWP) was also observed to be highest under drip irrigated beds. The water productivity decreases with increase in irrigation level. The results revealed that drip irrigated beds could successfully be used for higher cotton seed yield and water productivity.**

Index Terms— Irrigation, Drip bed, Ridge, Flat, Cotton, Water productivity

I. INTRODUCTION

Cotton is one of the most important cash crop grown both under irrigated and rainfed conditions. India is having maximum (7.5 – 8.5 M Ha) area with minimum (405 kg lint ha^{-1}) yield in the world (CICR 2005). Like most major field crops, cotton production is also adversely affected by water stress (Pettigrew 2004; Dagdelen et al. 2006; Basal et al. 2009). Insufficient soil water content due to water stress during the sensitive growth stages, such as the peak flowering and fruit-setting stages, can lead to a reduced number of fruiting positions, boll shedding, and poorly developed bolls (Aujla et al. 2005; Aujla et al. 2008). On the other hand, over irrigation of cotton can cause undesired excessive vegetative growth which may reduce cotton yields (Wanjura et al. 2002; Karam et al. 2006). Knowing the optimum water requirement is essential to achieving a balance between vegetative and reproductive growth in cotton. Fereres and Soriano (2007) reported that substantial water savings could be achieved with little impact on the quantity of the crop yields by using deficit irrigation. Wanjura et al. (2002) found that the maximum yield of cotton produced with 740 mm of water. Ertek and Kanber (2003) reported that, in a single season, there was no significant difference in yield among crop-pan coefficients of 0.75, 0.90, and 1.05 for a screened evaporation pan. In similar study, Basal et al. (2009) reported that deficit drip irrigation of cotton at 75% of full irrigation requirements did not decrease seed cotton yield. Many studies have shown that drip irrigation increased seed cotton yield and water use efficiency (WUE) significantly, relative to increases obtained with surface irrigation (Janat 2004). In addition, exposing the cotton crop to moderate water stress improved the water use efficiency (WUE) by almost 15% (Basal et al. 2009). Studies have shown that cotton gives a better response when the crop is irrigated at 20% soil water availability and that involves 6 to 9 irrigations depending on amount of rainfall. Studies on scheduling irrigation based on IW/CPE ratio indicated that the crop gave optimum yield when irrigated at IW/CPE ratio of 0.9. Since cotton is a socioeconomic crop, increasing the WUE and economic returns requires the adoption of new irrigation methods and management practices. Therefore, the main objective of this study was to determine the best irrigation level under drip, ridge and flat method of irrigation for optimal seed lint yield and water productivity.

II. Materials and methods

The study was conducted during kharif 2011 at the research farm of the Department of Soil Science, PAU, Ludhiana, Punjab, India (30°56'N latitude, 70°52'E longitude and 247 m above mean sea level). The region experiences semi-arid climate with extremely hot during summers and cold during winter. The annual average temperature is 18.7 ºC and annual average total precipitation is 700 mm. The soils in the research field are deep, medium textured and well drained. The

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percentage of sand, silt and clay in the experimental soil were 71.4, 16.7 and 11.9 respectively. Field capacity, wilting point and bulk density of top 30 cm of the soil were 19.5 %, 8.7 % and 1.50 Mg/m^3 (Table 2). Soil was sampled from 0-15 cm depth to determine soil chemical characteristics e.g. nitrozen, phosphorus, potash, pH, EC and OC etc. Phosphorus was determined colorimetrically and K by flame photometer. The concentration (kg/ha) of available N, P_2O_5 and K_2O were 126.4, 36.4 and 141.8 respectively (Table 2). Basic intake rate was measured by double ring infiltrometer and found as 2.0 cm $hr^{-1.}$ The cotton seed was sown in first week of June. Drip laterals were placed in the centre of the bed. The treatments consisted of three methods of growing crop (flat, ridge and drip irrigated beds) and three levels of irrigation i,e, IW/PAN-E ratio of 1.0, 1.25 and 1.5, whereas in case of drip beds, irrigation was applied at IW/PAN-E of 0.20, 0.30 and 0.40 as I1, I2 and I3 respectively. In drip irrigated beds two cotton rows were planted at a spacing of 67.5 cm. Similarly, in flat sown and ridge methods, a spacing of 67.5 cm between row to row and 90 cm between plant to plant was maintained. Irrigation depth was kept constant i.e. 30, 40 and 60 cm in case of ridge, drip bed and flat method of irrigation. Nitrozen, Phosphorus and Potassium per hectare were applied @ 100 kg N and 50 kg P_2O_5 and 50 K_20. The sources of NP and K were Urea, Diammonium Phosphate (DAP) and Muriate of Potash (MOP) respectively. The entire quantity of P and K with one half of N were applied as basal dose at the time of final land preparation and the remaining half N was applied as top dress. All other agronomic practices were kept uniform for all treatments. The crop was harvested in the last week of October.

III. RESULTS AND DISCUSSION

Amount of irrigation applied

A common irrigation was applied to help establishing the onion seedlings in all the plots irrespective of different irrigation treatments. Subsequently, the irrigation water was delivered through drip, ridge and flat methods of irrigations, as per treatments. The amount of water applied under different irrigation levels for drip bed, ridge and flat method is presented in Table 2. Irrespective of irrigation levels, minimum irrigation water was applied in drip bed (375 mm) followed by ridge (540 mm) and highest water was applied under flat irrigation method (675 mm). Under drip irrigation, 300, 375 and 450 mm of water was applied for maintaining IW/PAN-E ratios of 0.25, 0.30 and 0.40 respectively (Table 2). Similarly, 440, 540 and 640 mm water was applied under ridge and 525, 675 and 825 mm water was applied to flat irrigation at 1.0, 1.25 and 1.5 IW/PAN-E ratios respectively. However, irrespective of irrigation methods maximum mean application of irrigation water was observed under I3 treatment i.e. 638 mm followed by I2 (530 mm) and least under I1 (422 mm) treatments. Muhammad et al (2008) reported that amount of irrigation applied under drip irrigation was 98 mm as compared to 210 mm under furrow irrigation thus, showed a water saving of 53%. Ibragimov et al. (2007) indicated that under drip irrigation and optimal mode (70-70-60% of FC) of irrigation scheduling, 18-42% of the irrigation water use saved in comparison with furrow irrigated cotton grown under the same conditions. Cetin et al. (1994) observed that drip, sprinkler, mobile nozzle and subsurface irrigation used 31, 28, 28 and 27% less water than furrow irrigation.

IV. Cotton seed yield

Cotton seed yield was observed to be significantly affected by irrigation methods and levels. Irrespective of irrigation levels, minimum cotton yield was observed in flat flood irrigation (1.7 t/ha) followed by ridge (1.9 t/ha) and highest cotton yield was recorded under drip irrigated bed (2.3 t/ha). Under drip bed irrigation, 1.9, 2.2 and 2.4 t/ha of yield was recorded for IW/PAN-E ratios of 0.25, 0.3 and 0.4 respectively (Table 3). Similarly, 1.7, 1.8 and 2.2 t/ha yield was observed under ridge and 1.5, 1.6 and 1.9 t/ha was observed under flat flood irrigation at 1.0, 1.25 and 1.5 IW/PAN-E ratios respectively. However, irrespective of irrigation methods maximum mean cotton seed yield was observed under I3 treatment i.e. 2.2 t/ha followed by I2 (1.9 t/ha) and least under I1 (1.7 t/ha) treatments. Cetin and Bilgel (2002) reported that the drip irrigation increased the seed cotton yield by 21% and 30% over furrow and sprinkler irrigation respectively.

V. Irrigation Water Productivity (IWP)

Irrigation water productivity (IWP) was observed to be significantly affected both by the irrigation methods and levels. Irrespective of irrigation levels, IWP was observed to 0.58, 0.35 and 0.25 t/ha-cm under drip irrigated bed, ridge and flat flood irrigations, respectively. Under drip irrigated bed, 0.63, 0.59 and 0.53 t/ha-cm of IWP was recorded for IW/PAN-E ratios of 0.25, 0.3 and 0.4 respectively (Table 4). Similarly, IWP of 0.39, 0.33 and 0.34 was observed under ridge and 0.28, 0.24 and 0.23 was observed under flat flood irrigation at 1.0, 1.25 and 1.5 IW/PAN-E ratios respectively. However, irrespective of irrigation methods maximum mean IWP was observed under I1 treatment i.e. 0.43 followed by I2 (0.39) and least under I1 (0.37) treatments. Shirahatti et al. (2007) concluded that the drip irrigation was the most efficient method and increase in yield was up to 28.4%. The water use efficiency (WUE) among the treatments varied from 21.2 to 39.41 kg ha^{-1} cm whereas in control, it was only 16.5 kg ha^{-1} cm. Muhhamad et al (2008) reported water saving of 53.3% under drip irrigation system as compared to furrow irrigation system.

Table 1 : Physical and chemical properties of the soil collected from experimental site.

Soil depth (cm)	pH	EC (dS m^{-1})	OC (%)	Av. N (kg ha^{-1})	Av. P (kg ha^{-1})	Av. K (kg ha^{-1})	Bulk density (Mg m^{-1})	Infilt. Rate (cm hr^{-1})	PWP (%)	FC (%)
0-15	7.8	0.21	0.42	126.4	36.4	141.8	1.50	2.0	8.7	19.5
15-30	7.5	0.17	0.31	106.3	32.3	132.6	1.62	--	7.9	17.8

Table 2: Amount of irrigation water (mm) applied under different treatments

Irrigation method	Irrigation levels			
	I1	I2	I3	Mean
Drip irrigated bed	300	375	450	375
Ridge	440	540	640	540
Flat	525	675	825	675
Mean	422	530	638	

Table 3 : Effect of different irrigation methods and levels on cotton seed yield (t/ha)

Irrigation method	Irrigation levels			
	I1	I2	I3	Mean
Drip irrigated bed	1.9	2.2	2.4	2.3
Ridge	1.7	1.8	2.2	1.9
Flat	1.5	1.6	1.9	1.7
Mean	1.7	1.9	2.2	
LSD (< 0.05)	0.3	0.3	0.4	

Table 4: Irrigation water productivity (q/ha-cm) under different irrigation methods and levels

Irrigation method	Irrigation levels			
	I1	I2	I3	Mean
Drip irrigated bed	0.63	0.59	0.53	0.58
Ridge	0.39	0.33	0.34	0.35
Flat	0.28	0.24	0.23	0.25
Mean	0.43	0.39	0.37	
LSD (< 0.05)	0.21	0.16	0.14	

Conclusions

Based on the obtained results of the effect of different irrigation methods and levels on yield and water productivity of cotton, it is concluded that drip irrigated beds yielded maximum, while the flat flood methods the lowest yield. Irrigation water productivity was also observed to be maximum under drip irrigated beds followed by ridge and least under flat flood irrigation. Maximum cotton yield was recorded at IW/PAN-E = 0.4 in drip irrigated beds.

References

[1] Aujla MS, h ind HS, Buttar GS (2005) Cotton yield and water use ei ciency at various levels of water and N through drip irrigation under two methods of planting. Agric Water Manag 71: 167-179.

[2] Aujla MS, h ind HS, Buttar GS (2008) Response of normally sown and paired sown cotton to various quantities of water applied through drip system. Irrig Sci 26: 357-366.

[3] Ali, H., D. Muhammad, M.N. Aftzal and S.A. Abid. 2005. Seed cotton yield of different cultivars as affected by sowing time under agro-climatic conditions of southern Punjab. The Indus Cotton 2(3):186-189.

[4] Basal H, Dagdelen N, Unay A, Yilmaz E (2009) Ef ects of dei cit drip irrigation ratios on cotton (Gossypium hirsutum L.) yield and ibre quality. J Agron Crop Sci 195: 19-2

[5] Cetin, O., E. Ozyurt and S. Sener.1994. The effect of different irrigation methods on the yield and water use effieciency of cotton in Harran plain. 17th ICID European Regional Conference on Irrigated and Drainage, Varna Bulgaria, Vol.1. Yield response to water as affected by irri. Schedule: 241-246 (Cab Abstr. 1996-1997).

[6] CICR (2005). Central institute for cotton research. Micro irrigation management in cotton. Technical Bulletin. No.13.pp 1-43.

[7] Dagdelen N, Basal H, Yılmaz E, Gurbuz T, Akcay S (2009) Different drip irrigation regimes affect cotton yield, water use efficiency and quality in western Turkey. Agric Water Manag 96: 111-120.

[8] Dagdelen N, Yılmaz E, Sezgin F, Gürbüz T (2006) Water-yield relation and water use efficiency of cotton (Gossypium hirsutum L.) and second crop corn (Zea mays L.) in western Turkey. Agric Water Manag 82: 63-85.

[9] Ertek A, Kanber R (2003) Effects of different drip irrigation programs on the boll number and shedding percentage and yield of cotton. Agric Water Manag 60: 1-11

[10] Fereres E, Soriano MA (2007) Deificit irrigation for reducing agricultural water use. J Experimental Botany 58: 147-159.

[11] Ibragimov, N., S.R. Evett, Y. Esanbekov, B.S. Kamilov, L. Mirzaev and P.A. Lamers. 2007. Water use efficiency of irrigated cotton in Uzbekistan under drip and furrow irrigation. Agric.Water Manag. 90: 112-120.

[12] Janat M (2004) Assessment of nitrogen content, uptake, partitioning, and recovery by cotton crop grown under surface irrigation and drip fertigation using isotopic technique. Commun Soil Sci Plant Anal 35: 2515-2535.

[13] Karam F, Rai c L, Randa M, Daccache A, Mounzer O, Rouphael Y (2006) Water use and lint yield response of drip irrigated cotton to length of season. Agric Water Manag 85: 287-295

[14] Pettigrew WT (2004) Moisture deficit effects on cotton lint yield, yield components, and boll distribution. Agron J 96: 377-383

[15] Shirahatti, M. S., C.J. Itnal and D.S. Mallikarjunapp Gouda. 2007. Impact of differential methods of irrigation on yield levels of cotton in red soils. Karnataka J. Agric. Sci. 20: 96-98

[16] Wanjura DF, Upchurch DR, Mahan JR, Bruke JJ (2002) Cotton yield and applied water relationships under drip irrigation. Agric Water Manag 55: 217-237.