

Response of cotton (*Gossypium hirsutum*) to single and paired row method of sowing under drip and furrow irrigation in saline Vertisols

M V MANJUNATHA¹, M HEBBARA² and G RAVISHANKAR³

University of Agricultural Sciences, Dharwad, Karnataka 583 227

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ABSTRACT

A field experiment was conducted during 2004–06 to study the response of cotton (*Gossypium hirsutum* L.) to various levels of drip and furrow irrigation in saline vertisols. The canal water (EC_{cw} , 0.20 dS/m) and well water (EC_{ww} , 4.0 dS/m) was used for furrow and drip irrigation respectively. Crop performance was better under drip compared to furrow method of irrigation. The highest (1.34 tonnes/ha) and lowest (1.10 tonnes/ha) seed cotton yields were recorded in case of drip irrigation at 1.2 evapotranspiration in single row method and furrow irrigation at 1.0 evapotranspiration in paired row method of sowing, respectively. Net saving in irrigation water through drip irrigation was 13.8 and 10.6% at the irrigation levels of 1.0 evapotranspiration and 1.2 evapotranspiration, respectively, compared to the same level of irrigation through furrow method. The highest (17.19 kg/ha-cm) and lowest (13.00 kg/ha-cm) water production efficiencies were achieved in case of paired row method of sowing at 1.0 evapotranspiration through drip irrigation and 1.2 evapotranspiration through furrow irrigation, respectively. In drip irrigation, higher gross benefit:cost ratio and net profit/cm of water used was achieved under paired row method of sowing than the single row method due to reduction in system cost. To minimize the system cost of drip irrigation (up to 35%) without reductions in yield and net economic returns, one could adopt paired row method of sowing in cotton in saline vertisols. Even though the gross B:C ratio are marginally less in drip irrigation than furrow irrigation, use of poor quality groundwater through drip irrigation seems to be a feasible solution, especially in water scarcity areas.

Key words: Cotton, Drip irrigation, Marginal quality waters, Saline-waterlogged soils, Water productivity

Land degradation due to soil salinity and waterlogging is threatening the sustainable use of soil and water resources. On the global scale, millions of hectares of productive land had been inflicted by these twin problems rendering them under/unproductive. In India, it has been estimated that 8.4 million ha of cultivated land had already been affected by these problems (Ritzema *et al.* 2008). In Tungabhadra Project command of Karnataka, 80 000 ha of land has been affected by salinity and waterlogging. In addition to this, about 60% of the groundwater in the command is having the problem of salinity and sodicity. Development of technologies for efficient and safer utilization of poor quality water for crop production is a top priority since water allocation to agriculture is anticipated to reduce by 10–15%. Recent advances in irrigation technique involving efficient water use through micro irrigation holds key to enhance the total crop production and improve the economy of the farmers of

the tail end irrigation commands. Several workers reported higher cotton yields by adopting drip irrigation even with saline water and achieved considerable saving in irrigation water, besides achieving higher water production efficiency (Cetin and Bilgel 2002, Daleshwar *et al.* 2006). The necessity for exploiting limited availability of canal and poor quality groundwaters in tail end command for cotton in Vertisols has prompted to take up this study and compare its economic feasibility.

MATERIALS AND METHODS

A field experiment was conducted during 2004–05 and 2005–06 at Agricultural Research Station, Gangavati, Karnataka. The site is located at 15°15'40" N latitude; 76°31'45" E longitude with semi-arid climate with an altitude of 419 m above mean sea level. The soil was clay in texture (47.6% clay, 29.5% silt and 22.9% sand) having an infiltration rate of 14 mm/hr and a bulk density of 1.31 g/cm³ (Manjunatha *et al.* 2004). The experiment was laid out in completely randomized block design with 5 replications. The treatments comprises two methods of irrigation [drip and furrow]; two types of sowing [single row and paired row]

¹Professor and Head, Department of Agricultural Engineering

²Associate Professor (Soil Science), College of Agriculture

³Assistant Professor of Agronomy (Senior Scale), Krishi Vignana Kendra, Hagari, Bellary district

and two quantities of applied irrigation water, IW [1.0 and 1.2 times the evapotranspiration]. To meet both the crop water and leaching requirement of the saline soil, the irrigation levels were fixed based on the earlier findings of the Daleshwar *et al.* (2006). Each treatment consisted of four lines (each 30 m in length) of cotton with a buffer strip of 1.5 m in between, to minimize the effects of lateral movement of water and salt. The crop received rainfall of 292.7 and 254.9 mm during 2004–05 and 2005–06, respectively.

'NHH 44' cotton was sown in July and August during rainy season *kharif*, 2004 and 2005, respectively, in single row (0.9 m×0.6 m) and paired row (0.45 m×1.35×0.60 m) under both the methods of irrigation. Other agronomic practices and plant protection measures were followed as per the recommended package of practice. The crop received 150, 75 and 75 kg/ha of nitrogen, phosphorus and potash respectively. The crop was irrigated with the available canal water (EC_{cw} , 0.2 dS/m) under furrow irrigation, while well water (EC_{ww} , 4.0 dS/m) was used for irrigation through drippers. The lateral lines were laid along each row in case of single row system and one lateral in between two rows in case of paired row system. The spacing of 'on line' emitters along the lateral was 0.6 m. Fluctuations in water-table depth during the cropping period were measured with the help of observation wells installed in the study area. Groundwater samples were also collected from these observation wells and were analyzed for salinity. Final harvest of the crop was made during May.

Using climatological and crop factors, irrigation scheduling was calculated based on the estimated evapotranspiration (ET) rate of the crop as suggested in the FAO-24 in case of surface irrigation. For drip irrigation, the method suggested in INCID (1994) was followed for irrigation scheduling. The required amount of water was applied through pressure compensated drippers at regular intervals. Source of water for drip irrigation was an open shallow dug well located near the site. Since experimentally determined crop factor (Kc) values were not available, the values estimated by Doorenbos and Pruitt (1977) 0.45, 0.75, 1.15, 0.85 and 0.70 for initial, developmental, mid season, late season and harvest stages, respectively were used. Actual ET was estimated by multiplying reference ET and Kc for different months based on crop growth stages. Water production efficiency was calculated by dividing the seed cotton yield/ha by the total depth of water applied including the effective rainfall.

Soil samples, down to 0.9 m at 0.15 m intervals, were drawn initially at sowing, and finally at crop harvest (240 days). Samples were air-dried and ground to pass a mesh of 2 mm size and were analyzed for soil salinity of saturation extract. The economic feasibility of the drip and furrow irrigation systems were worked out by considering the fixed cost of the system, cost of cultivation, water used and the marketable yield of produce. The useful life of the drip system

is approximately 15 years and the procedure used by INCID (1994) was adopted for calculating benefit : cost ratio. The depreciation cost and the rate of interest was worked out for the crop period with a rate of 6.67% and 10% respectively. The income from the produce was estimated using lowest prevailing average market price @ Rs 2 000/100 kg.

RESULTS AND DISCUSSION

Water-table depth

Rainfall received during the cropping period of 2004–05 and 2005–06 was 292.7 mm and 254.9 mm, respectively. It was observed that shallow water-table was recorded during October–November due to rainfall coupled with canal running period. Deeper water-table was observed during April. During the cropping period of 2004–05, average water-table depth and mean salinity of groundwater was 1.00 m and 4.25 dS/m, respectively. While during 2005–06, average water-table depth and mean salinity of groundwater was 1.00 m and 4.50 dS/m, respectively.

Vegetative growth and yield parameters

The effect of different levels of drip and furrow irrigation on biometric parameters, such as plant height, number of branches/plant, bolls/plant and seed cotton yield were analyzed statistically and the results are presented in Table 1. During 2004–05, highest seed cotton yield was recorded in case of single row method of sowing with drip irrigation at 1.2 evapotranspiration, followed by drip irrigation with single row at the irrigation level of 1.0 evapotranspiration. During 2005–06, highest seed cotton yield was recorded in case of drip irrigation with single row method of sowing at 1.2 evapotranspiration level of irrigation, followed by drip irrigation with paired row method of sowing at 1.0 evapotranspiration, while the lowest yield was recorded in case of furrow irrigation with paired row method of sowing at 1.0 evapotranspiration level of irrigation. The overall growth recorded in terms of parameters like plant height and number of branches/plant was better under drip irrigation as compared with furrow irrigation (Table 1). Plants also showed better growth when applied irrigation water, IW equaled 1.2 evapotranspiration. Number of bolls/plant was also higher under drip irrigation with irrigation level equal to 1.2 evapotranspiration. Better growth ultimately resulted in higher seed cotton yield from drip-irrigated crop than the furrow irrigated. Daleshwar *et al.* (2006) reported that a frequent and consistent application of water in the vicinity of root through drippers provides better soil moisture in the root zone and thus resulting in higher yields.

Water applied, yield and water production efficiency

The net amount of irrigation water applied during the cropping period of cotton ranged from 56.0 to 70.5 cm. The maximum amount of irrigation water was applied in case of furrow irrigation at 1.2 evapotranspiration (70.5 cm), while

Table 1 Effect of methods and levels of irrigation on growth and yield parameters of cotton

Treatment	Plant height (cm)			Branches/plant			Bolls/plant			Cotton yield (tonnes/ha)		
	2004	2005	Pooled	2004	2005	Pooled	2004	2005	Pooled	2004	2005	Pooled
<i>Drip irrigation</i>												
T ₁ , Single row 1.0 ET	92.4	81.1	86.8	17.2	14.3	15.8	38.2	23.1	30.6	1.14	1.29	1.21
T ₂ , Single row 1.2 ET	95.4	81.6	88.5	18.6	12.7	15.6	43.4	27.4	35.4	1.21	1.48	1.34
T ₃ , Paired row 1.0 ET	98.2	78.6	88.4	17.8	20.0	18.9	41.8	26.2	34.0	1.10	1.39	1.25
T ₄ , Paired row 1.2 ET	97.2	82.3	89.7	16.8	20.5	18.6	40.0	31.8	35.9	1.13	1.35	1.24
<i>Furrow irrigation</i>												
T ₅ , Single row 1.0 ET	94.4	69.6	82.0	18.0	14.9	16.4	41.8	28.3	35.0	1.06	1.30	1.18
T ₆ , Single row 1.2 ET	90.4	74.3	82.3	18.0	11.8	14.9	40.8	29.2	35.0	1.09	1.24	1.16
T ₇ , Paired row 1.0 ET	87.0	77.5	82.2	17.4	13.7	15.6	49.8	25.5	37.6	1.06	1.14	1.10
T ₈ , Paired row 1.2 ET	89.0	84.5	86.8	18.7	12.3	15.5	50.0	22.9	36.5	1.11	1.15	1.13
SEM±	1.29	0.78	0.68	0.53	0.28	0.30	0.95	0.46	0.47	0.03	0.02	0.02
CD (P = 0.05)	3.74	2.25	1.965	NS	0.81	0.88	2.76	1.33	1.35	0.09	0.05	0.06

ET, Evapo-transpiration

the minimum in case of drip irrigation at 1.0 evapotranspiration (56.0 cm). In all, 11 and 12 furrow irrigations were applied for 1.0 evapotranspiration and 1.2 evapotranspiration, respectively. In case of drip irrigation, irrigation interval was uniformly fixed as 3 days. In all, total of 54 irrigations were applied through drippers. The net saving in irrigation water was to the extent of 13.8 and 10.6% in case of drip irrigation at 1.0 and 1.2 evapotranspiration, respectively as compared with the same levels of irrigation through furrow method. The highest and lowest water production efficiencies of 17.19 kg/ha-cm and 13.0 kg/ha-cm were achieved in case of drip irrigation at 1.0 evapotranspiration and furrow irrigation at 1.2 evapotranspiration with paired row method of planting, respectively (Fig 1). Higher water production efficiencies in case of different drip irrigation treatments was due to higher seed cotton yield accompanied by saving of irrigation water as compared to furrow method of irrigation. These results corroborated the earlier findings of Tiwari *et al.* (2003), Manjunatha *et al.* (2004) and Daleshwar *et al.* (2006).

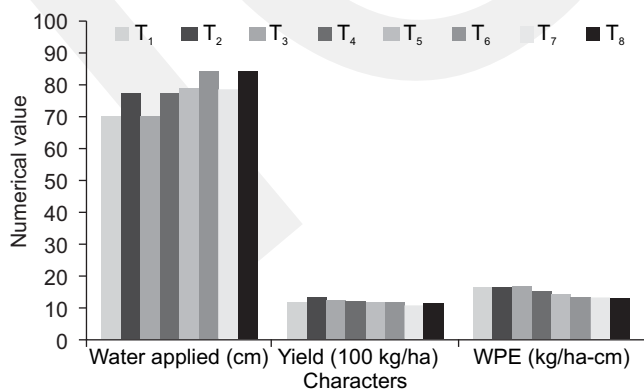


Fig 1 Water applied, yield and water production efficiency of cotton under drip and furrow irrigation (mean data of 2004–05 and 2005–06)

Soil salinity

Build-up in soil salinity (0–90 cm) was observed in both the methods of irrigation at the end of second year. The build-up was relatively higher under drip irrigated plots (from 9.5 to 12.0 dS/m) than furrow irrigation (from 8.6 to 10.0 dS/m). This was mainly due to application of higher salinity water for irrigation through. Even though good quality canal water (EC_w 0.2 dS/m) was used for furrow irrigation, build-up in soil salinity was also observed at all the irrigation levels. Similar increase in soil salinity was also reported by Daleshwar *et al.* (2006). This build-up in salinity due to use of poor quality water can be lowered considerably by harvesting rainwater during monsoon months with a provision of drainage system.

Economic analysis of drip irrigation system

The system cost of drip irrigation was Rs 76 081 and 49 500/ha incase of single row and paired row method of planting. Lesser system cost incase of paired row method is due to reduction in laterals and drippers. In case of single row system, lateral lines were laid parallel along each row while, in case of paired row system, one lateral was provided in between two rows. The spacing of the 'on line' emitters along the lateral was 0.6 m. The maximum gross income from the produce (Rs 29 707) was obtained in case of drip irrigation with single row method of planting with 1.2 evapotranspiration level of irrigation, whereas the minimum of Rs 22 000 was obtained in case of furrow irrigation with 1.0 evapotranspiration in paired row method of planting (Table 2). The gross benefit : cost ratio was highest (1.78) in case of furrow irrigation with 1.0 evapotranspiration in single row method and the lowest (1.30) under drip irrigation with 1.0 evapotranspiration in single row method of planting. This may be due to no fixed cost in return less seasonal total cost in case of furrow irrigation. The net profit achieved per cm of water used was maximum in case of furrow irrigation

Table 2 Economic analysis of single row and paired row method of cotton sowing under drip and furrow irrigation (mean data of 2004–05 and 2005–06)

Particulars	Drip irrigation				Furrow irrigation			
	Single row		Paired row		Single row		Paired row	
	ET, 1.0	ET, 1.2	ET, 1.0	ET, 1.2	ET, 1.0	ET, 1.2	ET, 1.0	ET, 1.2
Fixed cost (Rs/ha)	76 081	76 081	49 500	49 500				
Life (years)	15	15	15	15				
Annual cost (Rs/ha)	7 205	7 205	4 687	4 687				
Cost of cultivation (Rs/ha)	11 500	11 500	11 500	11 500	13 250	13 250	13 250	13 250
Seasonal total cost (Rs/ha)	18 705	18 705	16 187	16 187	13 250	13 250	13 250	13 250
Water used (cm)	72.42	79.72	72.42	79.72	81.42	86.92	81.42	86.92
Cotton yield (tonnes/ha)	1.21	1.34	1.24	1.23	1.17	1.16	1.10	1.13
Income (Rs) from produce @ Rs 2 000/100 kg	24 260	26 860	24 900	24 720	23 580	23 260	22 000	22 600
Net seasonal income (Rs)	5 555	8 155	8 713	8 533	10 330	10 010	8 750	9 350
Gross cost of production (Rs)	21 286	20 687	18 420	17 902	13 250	13 250	13 250	13 250
Gross income (Rs)	27 608	29 707	28 336	27 340	23 580	23 260	22 000	22 600
Gross B : C ratio	1.30	1.44	1.54	1.52	1.78	1.75	1.66	1.7
Net profit/cm of water used (Rs)	76	102	120	107	126	115	107	108
Water production efficiency (kg/ha-mm)	16.75	16.86	17.19	15.50	14.50	13.38	13.51	13.00

with 1.0 evapotranspiration (Rs 126) and minimum in case of drip irrigation at 1.0 evapotranspiration (Rs 76) in single row method of planting.

It was found that cotton response was better under drip irrigation than furrow irrigation with 1.0 evapotranspiration and 1.2 evapotranspiration level of irrigation in both single row and paired row method of planting. Build-up in soil salinity (0–90 cm) was observed in both the methods of irrigation at the end of second year. Salinity build was marginally higher under drip irrigated plots than furrow irrigation mainly due to application of higher salinity water for irrigation. To minimize the system cost of drip irrigation (up to 35%) without compromising yield and economic returns, one could adopt a paired row method of sowing in cotton in saline vertisols.

The scarcity of freshwater in arid and semi-arid regions makes saline water a valuable alternative water source for irrigation. Under such circumstances, especially in the tail end commands where the availability of good water for irrigation is a major constraint, the use of poor quality ground water through drip irrigation in conjunction with good water is a feasible solution even though the gross B:C ratio are marginally lesser in drip irrigation as compared to surface irrigation. On the long run, the system may fetch higher income even with poor quality water compared to furrow method of irrigation.

The long-term effects on the use of poor quality water for irrigation on soil physico-chemical properties needs to be studied.

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