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Comparative effects of drip and furrow irrigation on the yield and water productivity of cotton (*Gossypium hirsutum* L.) in a saline and waterlogged vertisol

Daleshwar Rajak [a], *M.V. Manjunatha* [a,*], *G.R. Rajkumar* [a], *M. Hebbara* [a], *P.S. Minhas* [b]

[a] *University of Agricultural Sciences, ARS, Gangavathi 583227, India*
[b] *Central Soil Salinity Research Institute, Karnal 132001, India*

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ABSTRACT

Field experiments were conducted on a saline vertisols during 2000–2002 for evaluating the response of cotton (*Gossypium hirsutum* L.) to applied irrigation water (IW, 0.8, 1.0, 1.2 and 1.4 times the evapotranspiration, ET) with drip and furrow irrigation method in four different blocks varying in soil salinity (EC_e, surface 0.6 m) and water table depths (WT). The initial EC_e and average WT for the blocks I, II, II and IV were 8.0 ± 0.4, 1.25 ± 0.08; 9.1 ± 0.7, 1.15 ± 0.08; 10.4 ± 0.5, 1.05 ± 0.09 and 15.1 ± 0.8 dS m^{-1}, 0.95 ± 0.07 m, respectively. The growth and yield performance of cotton irrigated through furrows, even though with good quality canal water (EC_w 0.25 dS m^{-1}), was poor when compared with drip irrigation with marginally saline water (EC_w 2.2 dS m^{-1}). The crop responded to applied water and the maximum cotton yield (1.78 Mg ha^{-1}—average for two years) was obtained from block I under drip irrigation applied at 1.2 ET while the lowest yield (0.18 Mg ha^{-1}) was from block IV when applied water equaled 0.8 ET with furrow irrigation. Due to creation of better salt and moisture regimes, water productivity also considerably improved with drip irrigation. Production functions developed could be represented as: Y (Mg ha^{-1}) $= 0.2070\ AW - 0.0012\ AW^2 + 0.0807\ EC_e - 0.0049\ EC_e{}^2 - 0.0014\ AW \times EC_e - 6.5945$ ($R^2 = 0.974^{**}$) for drip irrigation and $Y = 0.3853\ AW - 0.0021\ AW^2 + 0.0253\ EC_e - 0.0005\ EC_e{}^2 - 0.0016\ AW \times EC_e - 14.9117$ ($R^2 = 0.877^{**}$) for furrow irrigation where AW and EC_e represent applied water and time weighted mean soil salinity, respectively. Though the gross income (US$ 223–690 ha^{-1}) was more with drip than furrow (US$ 67–545 ha^{-1}) irrigation, the net profit per unit of applied water was higher with furrow irrigation. It was concluded that the drip system provide for opportunities to enhance the use of saline waters in water scarcity areas especially those existing at the tail end of canal commands.

1. Introduction

Land and water are the two most important natural resources for agricultural development and economic advancement of any country. With a low per capita availability of land and water in India compared to other countries, enhancing agricultural productivity has become essential to meet food demands forever growing population. Thus, available water for irrigation needs to be utilized judiciously. At the same time, land degradation due to soil salinity and water logging is threatening the sustainable use of these resources. Globally, more than 45 million hectares of land have been affected due to these twin

* *Corresponding author*. Tel.: +91 8533 271030; fax: +91 8533 271030.
E-mail address: mvmgvt@rediffmail.com (M.V. Manjunatha).

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problems with an annual loss of US$ 11.4 billion (Ghassami et al., 1995). In Tungabhadra Project (TBP) command, 80,000 hectares of land in Karnataka state has been affected by salinity and water logging (Jayashankar, 1997). In addition to this, about 60% of the groundwater in the command is having the problem of salinity and sodicity (Annonymous., 1994). Surface irrigation with these waters on heavier textured soils of the area usually leads to build up of salinity and sodicity problems and thus unsustainable crop yields. Therefore, there is need to adopt specialized and efficient methods of irrigation like micro irrigation which can help in attaining the twin objectives of higher productivity and optimum use of water. Earlier reports by Ayers et al. (1986) and Saggu and Kaushal (1991) show that saline water can be efficiently used through drip irrigation even on saline soils. Moreover, it results in considerable saving in irrigation water (Tan, 1995; Yohannes and Tadesse, 1998; Cetin and Bilgel, 2002) thus reducing the risks of secondary salinisation. However, such an option has not been studied at large with cotton crop using poor quality water in saline vertisols. Keeping this in view, a field experiment was conducted to evaluate the comparative effect of drip and furrow irrigation on salinity build up vis-a-vis cotton performance in a saline vertisols.

2. Materials and methods

2.1. Experimental site and treatment details

A field experiment was conducted during 2000–2002 at Agricultural Research Station, Gangavathi, Karnataka, India which is situated in the north–eastern dry zone of the state (15°15′40″ N latitude; 76°31′45″ E longitude and altitude of 419 m above mean sea level). The soil of the site was clay in texture (clay, silt and sand 47.6, 29.5 and 22.9%, respectively) having an infiltration rate of 14 mm h^{-1} and a bulk density of 1.31 g cm^{-3} (Manjunatha et al., 2002). Due to existence of shallow water table and its variable salinity, differential salinity gradients have been naturally created along the slope of the land. Thus, the area was sub-divided into four blocks (each of 20 m × 20 m) based on initial soil salinity ($EC_{e,}$ surface 0.6 m) and average water table depth (WT) viz., block I (EC_e 8.0 ± 0.4 dS m^{-1}, WT 1.25 ± 0.08 m), block II (EC_e 9.1 ± 0.7 dS m^{-1}, WT 1.15 ± 0.08 m), block III (EC_e 10.4 ± 0.5 dS m^{-1}, WT 1.05 ± 0.09 m) and block IV (EC_e 15.1 ± 0.8 dS m^{-1}, WT 0.95 ± 0.07 m). The experiment was laid out in each block with two methods of irrigation i.e. drip and furrow method in main plot and four quantities of applied irrigation water, IW viz. 0.8, 1.0, 1.2 and 1.4 times the evapotranspiration, ET in the sub-plots. The quantities of IW were fixed on the higher side to meet both the crop water and leaching requirement of the saline soil. Each treatment consisted of four lines (each 20 m in length) of cotton with a buffer strip of 1.5 m in between treatments to minimize the effects of lateral water and salt movement. Cotton (cultivar: Laxmi) was sown on August 1 and 2 during 2000 and 2001 keeping spacing of 0.75 m × 0.30 m, respectively and harvested on March 29, 2001 and April 3, 2002. Recommended package of other agronomic practices and plant protection measures were followed. Applied fertilizers equaled 80, 40 and 40 kg ha^{-1} of nitrogen, phosphorus and potash, respectively. Rainfall received during the cropping period of 2000–2001 and 2001–2002 was 467.5 and 483.5 mm while the evapotranspiration was calculated to be 570 and 580 mm, respectively. The crop was irrigated with the available canal water (EC_w 0.2 dS m^{-1}) under furrow irrigation while well water (EC_w 2.2 dS m^{-1}) was used for irrigation through drips. The lateral lines were laid parallel along each row, and the spacing of the 'on line' emitters (4 L h^{-1}) along the lateral was 0.6 m. Water table depths were monitored at weekly at the observation wells installed in the study area. Ground water samples were also collected from these observation wells and were analyzed for salinity.

2.2. Estimation of irrigation water requirements

Reference evapotranspiration (ET_0) was calculated using modified Penman method (Doorenbos and Pruitt, 1977). Since, experimentally determined crop factor values were not available, the values were estimated to be 0.45, 0.75, 1.15, 0.85 and 0.70 for initial, developmental, mid season, late season and harvest stages, respectively (Doorenbos and Pruitt, 1977). The actual evapotranspiration was then estimated by multiplying reference evapotranspiration and crop factor for different months based on crop growth stages. The irrigation water requirements for the crop were estimated by subtracting the effective rainfall from the calculated crop evapotranspiration on daily basis using relationship;

$$\mathrm{IR} = \mathrm{ET}_0 \times K_c - R_e \tag{1}$$

where IR, ET_0, K_c and R_e refer to net depth of irrigation (mm d^{-1}), reference potential evapotranspiration (mm d^{-1}), crop factor and effective rainfall (mm d^{-1}), respectively. At Gangavathi, the average monthly rainfall during August–October was 115.0, 182.7 and 172.0 mm, respectively (Table 1). Since crop season falls during this period, 60% of the total rainfall received during this period was considered as effective rainfall. Net volume of water required per plant for drip irrigation was calculated using relationship;

$$V = \mathrm{IR} \times A \times B \tag{2}$$

where V, IR, A and B refer to net volume of water required by a plant (l d^{-1} $plant^{-1}$), net depth of irrigation (mm d^{-1}), area under each plant (m^2) and fraction of area (A) covered with foliage, respectively. Water productivity was calculated by dividing the cotton yield per hectare by the depth of water applied including the effective rainfall.

2.3. Soil salinity

Soil samples, down to 0.6 m at 0.15 m intervals, were drawn initially at sowing, 90 days after 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 (1:2.5 soil: water extract). Time weighted mean salinity (TWMS) was calculated as;

$$\mathrm{TWMS} = \frac{\{(\mathrm{EC_{ei}} + \mathrm{EC_{e90}})/2\} \times 90 + \{(\mathrm{EC_{e90}} + \mathrm{EC_{ef}})/2\} \times 150}{N} \tag{3}$$

where EC_{ei}, EC_{e90} and EC_{ef} refer to soil salinity (dS m^{-1}) initially at sowing, after 90 days of sowing and finally at crop harvest (dS m^{-1}), respectively while N is total crop period (240 days).