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# Effect of deficit irrigation, phosphorous inoculation and cycocel spray on root growth, seed cotton yield and water productivity of drip irrigated cotton in arid environment

Sajjan Singh Rao*, Suresh Pal Singh Tanwar, Panna Lal Regar

*Central Arid Zone Research Institute, Regional Research Station, Pali-Marwar 306 401 Rajasthan, India*

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ABSTRACT

Irrigation water is scarce and expensive resource constraining crop production in arid and semi-arid region of India. Most producers' aims to maximize yield per unit of water applied but it requires a better understanding of crop response to various levels of water stress. A field experiment was conducted during 2009–2011 to investigate the effect of deficit irrigation through drip irrigation; phosphorus solubilizing bacterial (PSB) inoculation and chloromequat chloride (cycocel) spray on seed cotton yield and water productivity (WP) of cotton. Experimental treatments comprised of three drip irrigation levels designated as 1.0 ETc (full irrigation as control), 0.8 ETc and 0.6 ETc (regular deficit irrigation) which receive 80% and 60% of the 1.0 ETc irrigation, were kept in main plots. The factorial combination of PSB inoculation and cycocel spray were included as good management practices (GMP) in sub-plots. A furrow irrigation treatment was also kept as absolute control. The result reveals that drip irrigation in cotton at 1.0 ETc significantly increased mean seed cotton yield by 33.5% and saved 30% irrigation water as compared to furrow irrigation which recorded 1859 kg $ha^{-1}$ seed cotton yield with 582 mm irrigation water. Deficit irrigation at 0.8 ETc caused 17% water savings with only 6.4% reduction in yield as compared to 1.0 ETc. PSB inoculation and/or cycocel spray significantly increased number of bolls $plant^{-1}$, boll weight and seed cotton weight $plant^{-1}$ over control. The interaction effect of deficit irrigation and GMP was significant on seed cotton yield and water productivity. Therefore, deficit irrigation at 0.8Etc along with PSB inoculation and cycocel spray should be considered as useful tool for water saving and higher yield in arid and semi-arid regions where irrigation water supplies are limited.



## 1. Introduction

Water scarcity and intermittent drought are the major factors constraining agricultural crop production in North Western arid and semi-arid region of India. Irrigation water is becoming critical scarce resource and expensive due to higher demand by industry and urban consumption. The ground water is depleting at an alarming rate (GOR, 2007) and therefore framing strategies to reduce irrigation water losses and enhance crop water productivity (WP) at micro level needs special attention. Deficit irrigation (DI) is an option where water availability limits conventional irrigation and reduces the risk of yield reduction due to terminal dry spell (English and Raja, 1996; Pereira et al., 2002; Kijine et al., 2003; Zwart and Bastiaanssen, 2004; Fereres and Soriano, 2007). Cotton is semi-xerophyte and forced annual. Its vegetative growth and duration is linearly related to water supply over a wide input range. Maintaining the optimum moisture regime during different growth stages is important criteria for maximizing the seed cotton yield from the available water resources. Agronomy of high yielding Bt (*Bacillus thuringiensis*) transgenic cotton varieties needs better attention considering altered root system, short duration and increased susceptibility to excess soil moisture (Rajendran et al., 2005). Deficit irrigation is an optimizing strategy under which crops are deliberately allowed to sustain some degree of water deficit and yield reduction (English, 1990). The proper application of deficit irrigation practices can generate significant savings in irrigation water allocation and crops like cotton is well suited for deficit irrigation applied either throughout the growing season or at pre-determined growth stages (Kirda, 2002). Irrigation water supply under DI is

* Corresponding author. Present address: Principal Scientist, NBSS & LUP, Regional Centre, Udaipur, Rajasthan 313 001, India.
*E-mail addresses:* raoss61@yahoo.co.in, raoss61@gmail.com (S.S. Rao).

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reduced relative to that needed to meet maximum evpotranspiration (ET). Therefore, water demand for irrigation can be reduced. The goal is to achieve maximum yields and to eliminate yield fluctuations caused by water deficits.

Numerous cotton irrigation studies have focused on irrigation scheduling to optimize yield and water use relationships under deficit irrigation using drip, furrow and sprinkler irrigation. Fereres et al. (1985) indicated that drip irrigation promoted an early yield, increased the total yield, and was more advantageous than the furrow irrigation method. Ibragimov et al. (2007) reported that drip irrigation saved 18–42% water compared to furrow irrigation in Uzbekistan. Similar results were reported by Pettigrew (2004), Aujla et al. (2004), Jalota et al. (2006), Chunyan et al. (2007), Du et al. (2008), and Unlu et al. (2011). Several studies on the effect of water stress by reducing the drip irrigation level from 100 to 80 or 75% ET indicated that seed cotton yield was not significantly affected (Dagdelen et al., 2009; Singh et al., 2010; Sampathkumar et al., 2013). Therefore, information specific to a region is needed to develop and refine for limited irrigation strategies in cotton as an alternative to the conventional surface irrigation methods.

In arid and semi-arid regions, availability of phosphorus (P) for plants is limited due to reduced P diffusion and poor uptake by roots (Nye and Tinker, 1977; Schnek and Barber, 1979). This low availability of P to plants is because the majority of soil P is found in insoluble forms, while the plants absorb it only in two soluble forms, the monobasic ($H_2PO^{-}{}_4$) and the diabasic ($HPO^{2-}{}_4$) ions (Bhattacharyya and Jha, 2012). Hardie and Leyton (1981) attributed that P could increase the plant resistance to drought stress and has a tendency to moderate the adverse effect of drought stress in plants. Thus, P insufficiency is expected to have a large and rapid negative effect on the rate of leaf expansion and final growth (Fernandez et al., 2007). To circumvent P deficiency, phosphate-solubilizing microorganisms (PSM) could play an important role in supplying P to plants in a more environment friendly and sustainable manner (Gyaneshwar et al., 2002; Khan et al., 2007). Several studies revealed that phosphate solubilizing bacteria (PSB) as inoculants solubilize the soil fixed and applied phosphates and increase the P uptake by plants and also the crop yield (Kundu and Gaur, 1980; Goldstein et al., 1993; and Qureshi et al., 2012). PSB play an important role in enhancing P availability to plants by lowering soil pH and by microbial production of organic acids and mineralization of organic P by acid phosphatases (Singh et al., 2006). These organisms besides providing P also facilitate the growth of plants by improving the uptake of nutrients and stimulating the production of some phytohormones. PSB have high potential as bio-fertilizers especially in P-deficient soils to enhance the growth and yield performance of crops (Bhattacharyya and Jha, 2012). Hence an attempt was made to assess the effect of phosphate solubilizer i.e. *Bacillus* sp. on the growth and yield of cotton.

Plant growth retardants (PGRs) are widely used in cotton production to improve crop management. Previous research has demonstrated changes in crop growth, dry matter (DM) partitioning and lint yield of cotton after the application of PGRs (Mondino et al., 2004; Mao et al., 2014). An important objective for using PGRs in cotton is to balance vegetative and reproductive growth as well as to improve yield and its quality. Growth retardants like chloromequat chloride (cycocel, CCC) reduce internodes length, thereby, reducing plant height and stimulating the translocation of photosynthates towards sink (Prakash and Prasad, 2000). Cycocel has been associated with increased photosynthesis through increased total chlorophyll concentration in plant leaves. Visual growth-regulating activity of cycocel is expressed as reduced plant height and width, shortened stem and branch internodes and leaf petioles, influence leaf chlorophyll concentration and $CO_2$ assimilation, and thicker leaves (Sawana et al., 2001). PGRs modify plant growth and divert energy allocation within the plant, promote crop earliness, improve square, flower and boll retention and keep harmony between vegetative and reproductive growth, thus, improving lint yield and quality (Sawana, 2014).

The objectives of this study were (i) to investigate the effects of deficit irrigation regimes on root growth, seed cotton yield and water productivity of cotton (ii) to evaluate the effect of PSB inoculation and cycocel spray on cotton under deficit irrigation regimes, and (iii) to study the interaction effect of deficit irrigation and PSB inoculation and cycocel spray in arid region of India.

## 2. Materials and methods

### 2.1. Soil and climate

A field experiments was carried out at the Central Arid Zone Research Institute, Regional Research Station, Pali-Marwar located at 25°45′ N latitude, 75°50′ E longitudes at an elevation of 225 m above mean sea level under arid sub-tropical climatic conditions. The experimental soil was fine sandy clay loam in texture, mixed hyper-thermic belonging to the family Lithic Calciorthids having 30–45 cm depth and underlying dense layer of *murrum* (highly calcareous weathered granite fragment coated with lime) up to 10–15 m depth. The soil had 7.9 pH, 0.37% organic carbon, 95 mg $kg^{-1}$ available N, 4.6 mg $kg^{-1}$ Olsen's extractable P and 101 mg $kg^{-1}$ exchangeable K content in 0–15 cm soil depth. The volumetric soil water content at field capacity and permanent wilting point of the top 0–44 cm soil depth was 19.3% and 8.8% with 1.41 g $cm^{-3}$ bulk density on an average. The basic infiltration rate was 11.5 mm $h^{-1}$. A complete description of the soil is shown in Table 1. Weather parameters including minimum and maximum temperature (°C), pan evaporation (mm), and the irrigation (amount and frequency) recorded during the crop growth period for three years are shown in Fig. 1.

### 2.2. Experimental detail and irrigation system

The experiment was conducted for three years during the 2009, 2010, and 2011 cotton growing seasons. The experimental design was split plot with irrigation treatments as the main plot and good management practice (GMP) as the sub-plot in a randomized complete block design replicated four times. The three levels of drip irrigation based on crop evapotranspiration (ETc) viz: $I_1$—1.0 ETc (full irrigation as control), $I_2$—0.8 ETc and $I_3$—0.6 ETc (as regular deficit irrigation) which receive water at 80% and 60% of control treatment (full), were kept as main treatments. The four subplot treatment consists of $G_1$—control, $G_2$—seed inoculation with phosphorus solubilizing bacteria (PSB), $G_3$—Foliar spray of Cycocel, $G_4$—$G_2$ + $G_3$. A surface drip irrigation system was used for irrigation. A 12 mm diameter polyethylene pipe with on-line drippers at 0.60 m intervals was placed on one side of each cotton row. The average discharge of emitters was 2.0 L $h^{-1}$ at the 0.15 MPa. A field plot of size 4.8 m in width and 40 m in length comprising 4 laterals at 1.2 m spacing were kept for every irrigation treatment. Each irrigation treatment was further divided into four sub-plots (4.8 m × 10.0 m) to which sub-treatments were randomly allocated. The size of each replicate was 14.4 m wide and 40.0 m long. A separate conventional furrow irrigation treatment was also kept for comparison as absolute control. A field layout of experiment is depicted in Fig. 2.

The crop water demand was calculated as $ETc = E_{pan} \times K_p \times K_c$ where, $E_{pan,}$ pan evaporation (mm); $K_{p,}$ pan-coefficient (0.75); $K_{c,}$ crop coefficient which varies for different growth stages of crop as per FAO irrigation water management training manual No. 3 (Brouwer and Heibloem, 1986) and FAO, 56 (Allen et al., 1998). For cotton, it was 0.45, 0.75, 1.15, and 0.70 for initial (0–25 days), devel-