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Soil moisture content as influenced by varied levels of irrigation and nitrogen in *Bt* cotton (*Gossypium hirsutum* L.) grown in alfisols of Southern Telangana

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Abstract
Field experiments were conducted during *kharif* 2014 and 2015 at Agricultural Research Institute, Rajendranagar to assess the influence of irrigation schedule and nitrogen level for *Bt* cotton in alfisols in Southern Telangana. Irrigation scheduled at 0.8 IW/CPE (I_1) recorded higher soil moisture content in 0-30 cm depth before and after irrigation. Rainfed (I_3) cotton registered higher mean water use efficiency of 3.05 kg ha^{-1} mm^{-1} followed by irrigation at 0.4 IW/CPE (I_2) and 0.8 IW/CPE (I_1) which registered 3.00 kg ha^{-1}mm^{-1} and 2.74 kg ha^{-1} mm^{-1}, respectively. Higher soil moisture content before and after irrigation throughout the crop growing period in 0-15 cm and 15-30 cm soil depth and higher water use efficiency (2.88 and 3.90 kg ha^{-1}mm^{-1}) was recorded with N_4 (225 kg ha^{-1}) over lower levels of nitrogen application. From the experiment, considering the net returns and B:C ratio it can be concluded that, higher seed cotton yield can be obtained with the irrigation scheduled at 0.4 IW/CPE and application of nitrogen at 150 kg ha^{-1} in *Bt* cotton in alfisols.

Keywords: Cotton, irrigation, nitrogen, soil moisture content, seed cotton yield

Introduction
Cotton (*Gossypium hirsutum* L.), is one of the major cash crops of India, popularly known as 'White gold' and 'King of fibres' for its role in the national economy in terms of foreign exchange earnings and employment generation. Undependable monsoon, unsuitable soil, improper sowing time, non-adoption of recommended technologies especially fertilizer use limiting cotton production at farmers' field (Ramasundaram and Hemachandra, 2001). Among these factors, marginal soils with shallow depth and low fertility status and; low and erratic distribution of rainfall are the important factors affecting cotton growth, development and seed cotton yield. Generally cotton grown in medium to deep black clayey soil, but in South Telangana Zone it is mainly grown on shallow sandy and sandy loams with low water holding capacity and low nutrient status resulting in poor yields under rainfed situation. This region receives an average rainfall of 524 mm during southwest monsoon period with erratic and uneven distribution besides, low water holding capacity of the alfisols, which necessitates the proper irrigation planning to ensure adequate yields and reduce risks of production. Farmers are using eexcessive nitrogen fertilizers leading to heavy pest incidence in certain pockets whereas in some areas it is below optimum mainly because of the risk associated with the investment under uneven and erratic distribution of rainfall. For obtaining higher seed cotton yields water, nutrients and soils are essential resources, of which water and nitrogen are yield limiting factors. Moisture stress had adverse effect on yield as well as excess irrigation decreases the yield and increases the growing season (Wanjura *et al.*, 2002 and Karam *e al.*, 2006) [8, 4]. Similarly nitrogen deficiency in cotton reduces vegetative and reproductive growth and induces premature senescence, there by potentially reduces the yields (Tewiodle and Fernandez 1997) [7], where as high nitrogen availability may shift the balance between vegetative and reproductive growth towards excessive vegetative development thus delaying maturity. Since both irrigation and nitrogen are costly inputs, efficient utilisation of these resources through optimum synergistic combination is essential for higher productivity of Bt cotton grown on alfisols under less rainfall receiving areas of South Telangana Zone. Scheduling irrigation in a scientific way is an option to tide over the challenges associated with rainfed system as it helps the farmer to apply water and fertilizers as per requirement of plant at particular growth stage. Keeping this in view, the present investigation was taken up to assess the influence of irrigation schedules and nitrogen levels on yield of cotton.

Materials and Methods

The field experiment was carried out at Agricultural Research Institute, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad during *kharif* seasons of 2014 and 2015 to determine the optimum irrigation and nitrogen levels for higher seed cotton yield. The experimental site was sandy loam in texture, neutral in reaction, low in available nitrogen, phosphorus and high in available potassium. The experiment was laid out in split plot design with three irrigation levels (I_1- 0.8 IW/CPE, I_2 - 0.4 IW/CPE and I_3 - Rainfed) as main plots and four nitrogen levels (N_1- 0 kg ha^{-1}, N_2 - 75 kg ha^{-1}, N_3 - 150 kg ha^{-1} and N_4 - 225 kg ha^{-1}) as sub plot treatments replicated thrice. The cotton cultivar Mallika BG II was sown at a spacing of 90 cm X 60 cm. A uniform dose of 60 kg ha^{-1} P_2O_5 as single super phosphate was applied to all the treatments as basal. Potassium @ 60 kg ha^{-1} as muriate of potash was applied in four equal splits along with nitrogen fertilizer as top dressing. Nitrogen was applied as per the treatments (wherever it was required) in the form of urea (46% N) in four equal splits ($1/4^{th}$ each at 20, 40, 60 and 80 DAS). Effective rainfall (mm) during crop growing season was calculated using soil water balance method to impose the irrigation treatments as per the IW/CPE ratio. Irrigations were scheduled as per the treatments based on IW/CPE ratio with a depth of 50 mm. Amount of irrigation water (mm) given was calculated based on the number of irrigations given during entire growing season. Soil samples were collected with the help of screw auger from 0-15 cm and 15-30 cm depth randomly from each treatment before irrigation and one day after irrigation and estimated the moisture content of soil by gravimetric method and expressed in percentage on oven dry weight basis. Water use efficiency (kg ha^{-1} mm^{-1}) was calculated as a ratio between Seed Cotton Yield (kg ha^{-1}) and total water applied (mm) to the treatment. Irrigation scheduled at 0.8 IW/CPE (I_1) was received 5 and 7 irrigations, where as 0.4 IW/CPE (I_2) was received 3 and 4 irrigations and rainfed (I_3) cotton was received only one irrigation in 2014 and 2015, respectively. Of which, first irrigation was given common to all plots for proper germination and establishment. Total amount of water includes supplementing the water through irrigation for proper germination and establishment of the crop, water applied as per the treatments imposed and effective rainfall.

Results and Discussions

Effect of irrigation on soil moisture content (%) before irrigation

Irrigation scheduled at 0.8 IW/CPE (I_1) recorded the soil moisture content in the range of 10.3 -11.5% in 0-15 cm soil depth and 10.5 - 12.2% in 15-30 cm soil depth except at 32 DAS where it recorded 9.5% soil moisture content in 0-15cm soil depth in 2014 (Fig. 1). Irrigation scheduled at 0.4 IW/CPE (I_2) recorded the soil moisture content in the range of 7.6 – 10.6% in 0-15 cm soil depth and 8.4 – 11.7% in 15-30 cm soil depth. However, rainfed (I_3) cotton experienced water deficit stress in top 30 cm depth of soil from flowering to final picking stage resulting in lower drymatter production and seed cotton yield. Whereas, in 2015 irrigation scheduled at 0.8 IW/CPE (I_1) recorded the higher soil moisture content of 9.6-13.3% at 0-15 cm soil depth and 10.0-13.8% in 15-30 cm soil depth over 0.4 IW/CPE (I_2) and rainfed (I_3) cotton before irrigation to the crop (Fig. 1). This might be due to more plant height, relatively higher leaf area index and more branches causes shade leading to minimised evaporation losses. It resulted in higher drymatter production and seed cotton yield. Irrigation scheduled at 0.4 IW/CPE (I_2) recorded the soil moisture content in the range of 9.1 – 11.0% in 0-15 cm soil depth and 9.4-11.6% in 15-30 cm depth of soil. The crop under 0.4 IW/CPE (I_2) experienced stress at square initiation stage but coincided with irrigation schedule resulted in more plant height and LAI. Rainfed (I_3) cotton was experienced the stress at square initiation stage to flowering stage. Later with good distribution of rainfall maintained 8.4 – 10.5% soil moisture content at 0-15 cm soil depth and 8.7 – 11.5% soil moisture content at 15 – 30 cm soil depth. Crop received 330 mm rainfall from flowering to final picking stage in 20 rainy days produced more growth and relatively good seed cotton yield.

The crop under 0.8 IW/CPE (I_1) and 0.4 IW/CPE (I_2) treatments maintained favourable soil moisture content at 0-30 cm depth of soil resulted in better availability of soil moisture for absorption along with nutrients. Which in turn leads to more plant height, leaf area index during crop growth period resulted in higher drymatter production, translocation of photosynthates to bolls, retention of more number of bolls with higher boll weight and higher seed cotton yield. Whereas, rainfed (I_3) cotton however, maintained the soil moisture around wilting point at 0-30 cm depth of soil. Being cotton crop having deep rooted system might have absorbed moisture from beyond 30 cm soil depth and comparatively gave lower seed cotton yield over irrigation scheduled at 0.8 IW/CPE (I_1) and 0.4 IW/CPE (I_2).

Effect of irrigation on soil moisture content (%) after irrigation

Higher soil moisture content was observed at 0-15 cm soil depth compared to 15-30 cm depth of soil during 2014 (Fig. 2). Irrigation scheduled at 0.8 IW/CPE (I_1) was recorded the soil moisture content of 18.6 – 21.3% at 0-15 cm soil depth and 18.7-19.8% at 15-30 cm soil depth. Whereas, irrigation scheduled at 0.4 IW/CPE (I_2) was recorded 18.5-21.2% and 17.8-17.9% of soil moisture content at 0-15 cm and 15-30 cm depth of soil, respectively. The irrigations were coincided with flowering and boll development stages resulted in better absorption of water, nutrient uptake leads to increased yield attributes and finally higher seed cotton yield over rainfed cotton. In 2015, higher soil moisture content was observed at 0-15 cm soil depth compared to 15-30 cm depth of soil. Irrigation scheduled at 0.8 IW/CPE (I_1) was recorded 19.8 – 22.5% of soil moisture content at 0-15 cm soil depth and 18.7 - 21.4% at 15-30 cm soil depth (Fig. 2). Whereas, irrigation scheduled at 0.4 IW/CPE (I_2) was recorded 20.2-21.5% and 17.8-20.9% of soil moisture content at 0-15 cm and 15-30 cm depth of soil, respectively. The irrigations were coincided with flowering and boll development stages resulted in better absorption of water, nutrient uptake leads to increased yield attributes and finally higher seed cotton yield over rainfed cotton.

Effect of nitrogen on soil moisture content (%) before irrigation

Graded levels of nitrogen application had shown positive effect on soil moisture content. In 2014, application of nitrogen at N_4 (225 kg ha^{-1}) and N_3 (150 kg ha^{-1}) resulted in higher plant height, more vegetative growth covering the soil causes shade on the soil. It results in less evaporation losses of water in turn increased soil moisture content (Fig. 3). Whereas, in 2015, incremental increase in nitrogen dose resulted in more vegetative growth and covering the soil, which in turn might reduce the evaporation losses of water.

Application of nitrogen at N_4 (225 kg ha^{-1}) recorded the higher soil moisture content throughout the crop growing period at 0-15 cm and 15-30 cm soil depth and was followed by N_3 (150 kg ha^{-1}) (Fig. 3). Lower soil moisture content was recorded in crop which received reduced levels of nitrogen *i.e.*, N_1 (0 kg ha^{-1}) and N_2 (75 kg ha^{-1}) during square initiation to flowering stage resulted in poor plant growth and development.

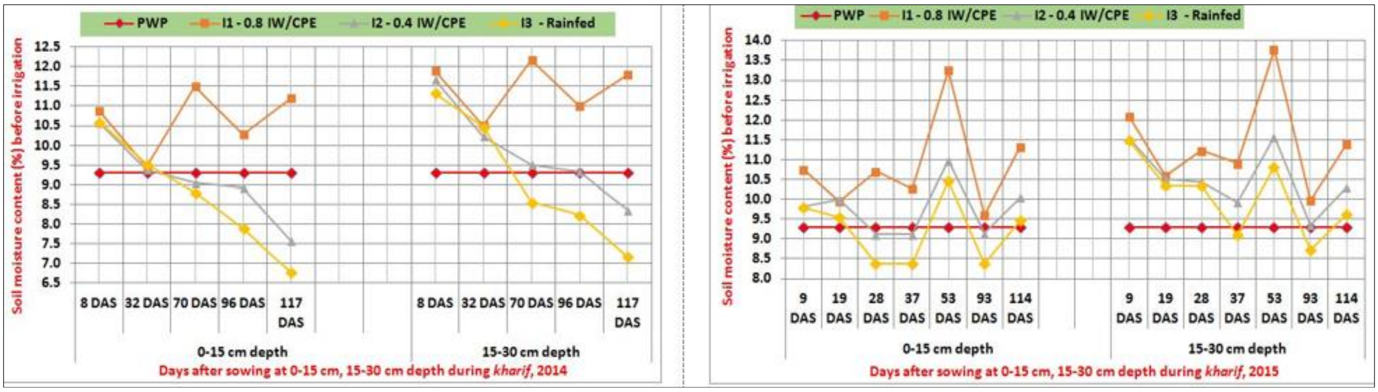

Fig 1: Soil moisture content (%) before irrigation as influenced by irrigation levels in cotton during *kharif*, 2014 and 2015

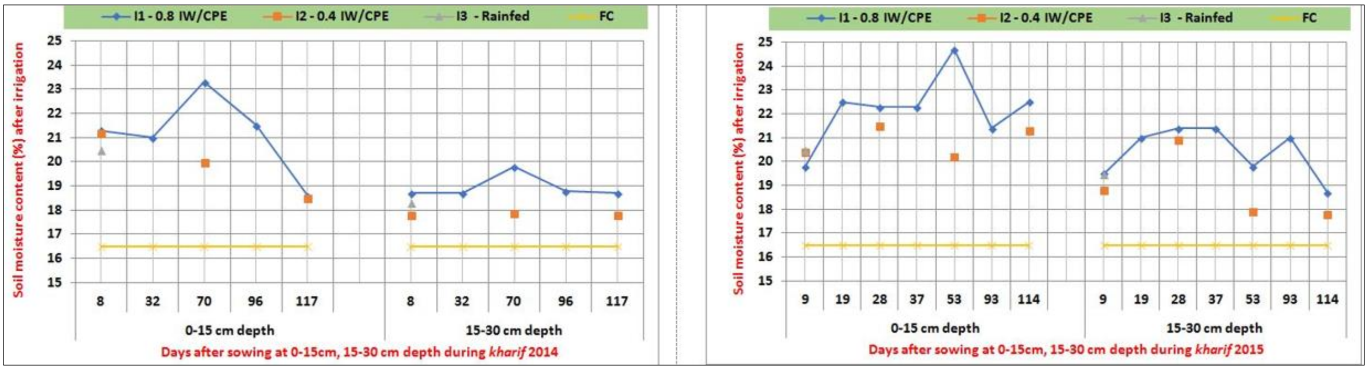

Fig 2: Soil moisture content (%) after irrigation as influenced by irrigation levels in cotton during *kharif*, 2014 and 2015

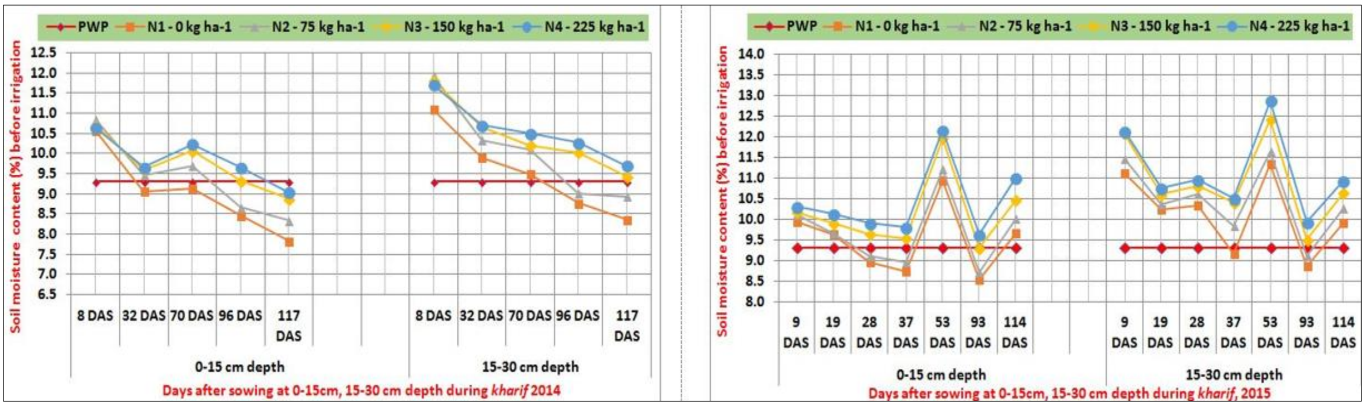

Fig 3: Soil moisture content (%) before irrigation as influenced by nitrogen levels in cotton during *kharif*, 2014 and 2015

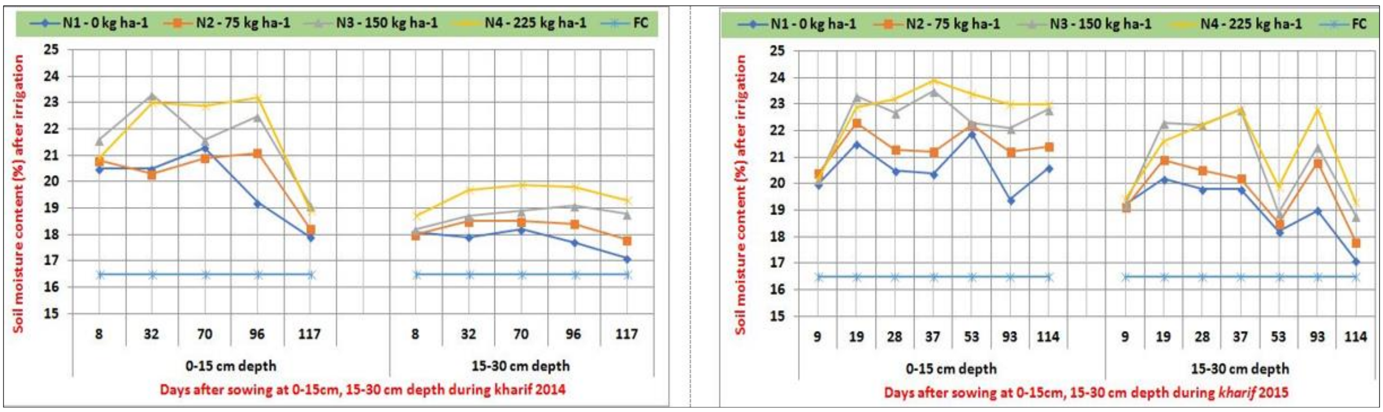

Fig 4: Soil moisture content (%) after irrigation as influenced by nitrogen levels in cotton during *kharif*, 2014 and 2015

Effect of nitrogen on soil moisture content (%) after irrigation

Each incremental increase in level of nitrogen application resulted in higher soil moisture content. Application of higher levels of nitrogen N_4 (225 kg ha^{-1}) maintained relatively higher soil moisture content (18.9 – 23.2%) at 0-15 cm soil depth and 18.7-19.9% at 15-30 cm soil depth over lower levels of nitrogen application in 2014 (Fig. 4). Irrespective of the nitrogen application, the soil moisture content was recorded above field capacity. Application of nitrogen at N_4 (225 kg ha^{-1}) maintained relatively higher soil moisture content (20.2 – 23.9%) at 0-15 cm soil depth and 19.3 - 22.8% at 15-30 cm soil depth over lower levels of nitrogen application during 2015 (Fig. 4).

Total water requirement

In 2014, irrigation scheduled at 0.8 IW/CPE (I_1) was received 585 mm of water and was followed by 0.4 IW/CPE (I_2) with 506 mm of water and by rainfed (I_3) cotton which received 406 mm of water. Whereas, in 2015, irrigation scheduled at 0.8 IW/CPE (I_1) was received 654 mm of water and was followed by 0.4 IW/CPE (I_2) with 509 mm of water and by rainfed (I_3) cotton which received 382 mm of water.

Table 1: Water balance parameters of cotton under varied levels of irrigation schedules and nitrogen levels

Treatments	Rainfall (mm)		Effective Rainfall (mm)		Amount of irrigation water (mm)		Total amount of water (mm)		Water Use Efficiency (kg/ha-mm)		Seed cotton yield (kg ha^{-1})
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	Pooled
Irrigation (I)											
I_1 - 0.8 IW/CPE	367	376	335	304	250	350	585	654	2.45	3.00	1700
I_2 - 0.4 IW/CPE	367	376	356	309	150	200	506	509	2.51	3.50	1524
I_3 - Rainfed	367	376	356	332	50	50	406	382	2.42	3.72	1201
Nitrogen (N)											
N_1 - 0 kg ha^{-1}	367	376	349	315	150	300	499	515	1.70	2.22	977
N_2 -75 kg ha^{-1}	367	376	349	315	150	300	499	515	2.40	3.60	1506
N_3 -150 kg ha^{-1}	367	376	349	315	150	300	499	515	2.86	3.90	1704
N_4 -225 kg ha^{-1}	367	376	349	315	150	300	499	515	2.88	3.90	1714

Effect of irrigation and nitrogen on Water Use Efficiency

Increasing irrigation frequency resulted in reduced water use efficiency (Table 1). During 2014, higher water use efficiency of 2.51 kg ha^{-1} per mm of water was registered with irrigation scheduled at 0.4 IW/CPE (I_2) and was followed by 0.8 IW/CPE (I_1) and rainfed (I_3) cotton with water use efficiency of 2.45 and 2.42 kg ha^{-1} per mm of water, respectively. Whereas in 2015, higher water use efficiency of 3.72 kg ha^{-1} per mm of water was obtained with rainfed (I_3) cotton and was followed by irrigation scheduled at 0.4 IW/CPE (I_2) with water use efficiency of 3.50 kg ha^{-1} per mm of water. However, the reduced water use efficiency of 3.0 kg ha^{-1} per mm of water was recorded with 0.8 IW/CPE (I_1).

Increased water use efficiency was recorded with incremental increase in nitrogen levels from N_1 (0 kg ha^{-1}) to N_4 (225 kg ha^{-1}). Higher water use efficiency (2.88 and 3.90 kg $ha^{-1}mm^{-1}$) was found with N_4 (225 kg ha^{-1}) and was followed by N_3 (150 kg ha^{-1}) with water use efficiency of 2.86 and 3.90 kg ha^{-1} mm^{-1} in 2014 and 2015, respectively. Whereas, water use efficiency of 2.40 and 3.60 kg ha^{-1} mm^{-1} was recorded with N_2 (75 kg ha^{-1}) and the lowest water use efficiency of 1.70 and 2.22 kg $ha^{-1}mm^{-1}$ was recorded with N_1 (0 kg ha^{-1}) in 2014 and 2015, respectively. Higher water use efficiency when nitrogen applied at higher doses might be due to favourable effects of nitrogen on growth attributes like plant height, leaf area, drymatter production and its translocation to the bolls increases the, boll number, boll weight and seed cotton yield resulted in higher water use efficiency. The results were in accordance with the findings of Bandyopadhyay *et al*. (2009) [1].

Effect of irrigation and nitrogen on Seed cotton yield

The results revealed that, significantly higher seed cotton yield (1714 kg ha^{-1}) was obtained with N_4 (225 kg ha^{-1}) and was followed by N_3 (150 kg ha^{-1}) with seed cotton yield of 1704 kg ha^{-1} (Table 1). However, which were comparable with each other and significantly superior over N_2 (75 kg ha^{-1}) and N_1 (0 kg ha^{-1}). The substantial increase in seed cotton yield due to application of higher levels of nitrogen might be due to favorable effect of nitrogen on growth attributes like plant height, increased number of bolls $plant^{-1}$, drymatter accumulation $plant^{-1}$ and its subsequent translocation towards sink improved the seed cotton yield. These results are in conformity with Dadgale *et al.* (2014) [3]. Similar positive response of nitrogen on seed cotton yield was observed by Basavanneppa (2005) [2] and Meena *et al.* (2007) [5].

Conclusion

From the experiment, considering the amount of applied, water use efficiency, net returns and B:C ratio it can be concluded that, higher seed cotton yield can be obtained with the irrigation scheduled at 0.4 IW/CPE and application of nitrogen at 150 kg ha^{-1} in Bt cotton in alfisols.

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