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Effect of surface and sub surface drip irrigation at different ETc levels on growth and yield of Bt cotton (*Gossypium hirsutum* L.)

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Abstract: A field experiment was conducted at Irrigation Water Management Research Centre (IWMRC) Belvatagi, Navalgund taluk of Dharwad district under vertisols during *kharif* 2015-16 to compare surface and sub surface drip irrigation methods in Bt cotton (*Gossypium hirsutum* L.) with different ETc levels. The experiment was laid out in split plot design with methods of irrigation *i.e.,* surface drip and sub surface drip irrigation as main plots with ETc levels at 1.0, 0.8 and 0.6 as sub plots along with one control (surface irrigation @ 0.6 IW/CPE ratio). Sub surface drip irrigation recorded numerically higher seed cotton yield (3,109 kg ha^{-1}) compared to surface drip irrigation (2,758 kg ha^{-1}). ETc levels did not influence seed cotton yield significantly. Interaction effect of method of irrigation and ETc levels was significant. Sub surface drip irrigation with 1.0 ETc significantly increased plant height (98.08 cm), number of monopodia (3.58), number of sympodia (17.68), total number of bolls per plant (39.03) and seed cotton yield (3,471 kg ha^{-1}). Significantly higher water use efficiency (7.06 kg/ha^{-mm}) was recorded in surface drip irrigation with 1.0 ETc.

Keywords: Cotton yield, Surface drip, Sub surface drip

Introduction

Cotton (*Gossypium hirsutum* L.) is one of the major cash crop of India, sustaining country's largest organized industry, textile industry and is popularly known as White Gold for its role in national economy in terms of foreign exchange earnings and employment generation. India has the credit of larger area under cotton with 11.7 million hectare and ranks second in cotton production with 29.0 million bales and the average yield of cotton is 540 kg ha^{-1} (Anon., 2013). In Karnataka state, cotton is grown both as rain fed and irrigated crop. Karnataka ranks 4th in area with 5.78 lakh ha and 6th in total production with 16.90 lakh bales of lint and the average yield is 529 kg ha^{-1} (Anon., 2013).

Increasing cotton production in India is of prime importance to satisfy the native mill consumption and to fetch higher foreign exchange. The productivity of cotton in India is low as it is grown under rain fed conditions where lack of proper distribution of rains or heavy rains and terminal moisture stress occurs. Water, being the prime natural resource for assured crop production, has to be used judiciously and in scientific manner. Day by day the competition for water is increasing from industry, domestic and agriculture sectors. The estimated cotton requirement by 2020 is around 230 lakh bales with a share of 65 to 75 per cent in textiles. Even after tapping all the water resources for irrigation almost 50 per cent areas will still remain rain fed. Whether it is irrigated or rain fed agriculture water holds the key for enhancing and sustaining agricultural production. Since, sustainability and enhanced productivity are the need of the hour, the focus has to shift from high input use to resource conservation technologies. Water use efficiency is very low in surface irrigation in the country in all the crops including cotton. Hence use of micro irrigation such as surface drip and sub surface drip irrigation, a new approach for irrigation water management plays a key role to bring more area under irrigation with the available water thereby increasing the cotton productivity and water use efficiency.

Drip irrigation permits more efficient use of irrigation water as compared to other irrigation methods. Average water saving by drip irrigation in cotton is up to 57.8, 52.8 and 47.5 per cent at 0.6, 0.8 and 1.0 ETc respectively as compared to conventional furrow irrigation method in cotton at Coimbatore (Nalayini *et al.,* 2006). In addition, in recent years sub surface drip irrigation is also gaining importance due to reduced evaporation losses with higher water use efficiency. Sub surface drip irrigation (SDI) is the irrigation of crops through buried plastic tubes containing embedded emitters located at regular spacing which provides the ultimate in water use efficiency for open-field agriculture, often resulting in water savings. The extent of water saved in sub surface drip is by 20 per cent over surface drip irrigation (Martinez and Reca, 2014). The information is meagre hence the study was initiated.

Material and methods

A field experiment was conducted at Irrigation Water Management Research Centre, Belvatagi during *kharif* 2015. The centre comes under Northern dry zone of Karnataka. The soil type is clay in texture with pH of 8.20, organic carbon 0.45 per cent and. EC 0.27 dS/m. The initial available N, P_2O_5 and K_2O of the soil were 220, 34.5 and 710 kg ha^{-1}, respectively. The values of field capacity and bulk density were 40.5 per cent and 1.35 g/cc, respectively. Split plot design was adopted with four replications. In the main plots two irrigation methods (M_1= surface drip and M_2= sub surface drip) and in sub plots three ETc levels (I_1 = 1.0 ETc I_2 = 0.8 ETc and I_3 =0.6 ETc) along with control (surface irrigation at 0.6 IW/CPE ratio) were included. Bt cotton hybrid Brahma (BG II) was sown with spacing of 60 cm x 120 cm on 2nd July 2015. Scheduling of

irrigation was done at three days frequency based on ETc levels. The volume of water was calculated as: $V = Ep \times Kp$ (0.7) $Kc \times S_1 \times S_2$ where, V, volume of water to be given/dripper (litres); Ep, pan evaporation (mm); Kp, pan co-efficient (0.7); Kc, crop co-efficient; S_1, lateral spacing (0.9 m) and S_2, dripper spacing (0.6 m). In cotton Kc values considered were 0.45, 0.75, 1.15 and 0.70 for initial (0–25 DAS), development stage (26–70 DAS), boll development (71–120 DAS) and maturity stage (121-harvest) respectively as per FAO Irrigation Water Management Training Manual No. 3 (1986). Time of irrigation was as per the discharge of water per dripper. In control six cm depth of irrigation was given on the basis of cumulative pan evaporation (100 mm CPE). The annual rainfall received during the year 2015 was 582.9 mm with of 392.2 mm during the cropping period from 2nd July to 28th February.

Growth and yield parameters and seed cotton yield were recorded as per standard procedures. Soil analysis were carried out using standard procedures. The data collected from the experimental field were analyzed statistically following the procedure as described by Gomez and Gomez (1984). The level of significance used in 'F' and 't' test was P=0.05. The mean values were separately subjected to Duncan's Multiple Range Test (DMRT) using the corresponding error mean sum of squares and degrees of freedom values. The control treatment was compared with the treatment combinations of main and sub plots by using Randomized Block Design.

Results and discussion

The data on growth parameters of Bt cotton are summarized in Table 1. Surface drip and sub surface drip method of irrigation did not make any significant difference with respect to plant height, number of sympodia and number of monopodia at all stages. However sub surface drip irrigation recorded higher plant height of 72.20 cm at 60 DAS and increased gradually to 94.94 cm at 120 DAS. Number of sympodia (8.14 & 17.23) recorded higher value in sub surface drip irrigation at 60 and 120 DAS, respectively.

Scheduling irrigation based on ETc levels was found to be non significant with respect to plant height. Irrigation scheduled at 1.0 ETc recorded higher plant height (71.92 & 94.98 cm, respectively) at 60 and 120 DAS. Number of sympodia was significantly influenced by ETc levels at 60 DAS. At 60 DAS higher number of sympodia was obtained in irrigation scheduled at 1.0 ETc (8.16) and was found on par with 0.6 ETc (8.06). No significant difference was observed with respect to number of sympodia in ETc levels at 120 DAS.

Interaction effect in method of irrigation and ETc levels was found significant. Among different treatment combinations sub surface drip irrigation with 1.0 ETc recorded significantly higher plant height at 60 DAS (73.03 cm) and was on par with surface drip irrigation at 0.6 ETc (72.63 cm) and sub surface drip irrigation with 0.8 ETc (72.38 cm). At 120 DAS, sub surface drip irrigation with 1.0 ETc recorded significantly higher plant height (98.08 cm) compared to all other treatments. The number of monopodia and sympodia was significantly influenced by interaction effect of irrigation method and ETc levels. At 60 DAS sub surface drip irrigation with 1.0 ETc recorded significantly higher number of monopodia (2.58) over other treatments. At 120 DAS sub surface drip irrigation with 1.0 ETc recorded significantly higher number of monopodia (3.58) and it was on par with surface drip irrigation with 0.6 ETc (3.43) and sub surface drip irrigation with 0.8 ETc (3.43). At 60 DAS sub surface drip irrigation with 1.0 ETc recorded significantly higher number of sympodia (8.45), which was followed by surface drip irrigation with 0.6 ETc (8.25). At 120 DAS significantly higher number of sympodia was obtained in sub surface drip irrigation with irrigation scheduled at 1.0 ETc (17.68) and was on par with surface drip irrigation at 0.6 ETc (17.33). Higher growth parameters in sub surface drip irrigation with 1.0 ETc may be attributed to availability of higher moisture content in sub surface drip irrigation during crop growth and development.

At 60 DAS surface irrigation at 0.6 IW/CPE ratio recorded a plant height of 72.93 cm, which was on par with rest of treatments except surface drip irrigation with 1.0 and 0.8 ETc. At 120 DAS surface irrigation at 0.6 IW/CPE ratio recorded plant height of 97.0 cm and was on par with rest of the treatments except surface drip irrigation with 1.0 and 0.8 ETc. Significantly higher number of sympodia (8.43) was recorded in surface irrigation at 0.6 IW/CPE ratio at 60 DAS compared to other treatments and was on par with sub surface drip irrigation at 1.0 ETc (8.45). At 120 DAS surface irrigation recorded higher number of sympodia (17.53) and was on par with sub surface drip irrigation at 1.0 ETc (17.68) and surface drip irrigation at 0.6 ETc (17.33).

Yield parameters

Method of irrigation was found non significant with respect to good opened bolls per plant, total number of bolls per plant and mean boll weight (Table 1). However numerically higher number of good opened bolls per plant (33.73), total number of bolls per plant (37.34) and mean boll weight (6.04 g) was recorded in sub surface drip irrigation.

Yield parameters *viz.,* good opened bolls per plant and mean boll weight was found non significant with respect to ETc levels. Whereas irrigation scheduled at 1.0 ETc recorded numerically higher good opened bolls per plant (33.61) and mean boll weight (6.08 g). Total number of bolls was significantly influenced by ETc levels. Irrigation scheduled at 1.0 ETc recorded significantly higher total number of bolls per plant (37.24) compared to 0.8 ETc (36.25) and 0.6 ETc (36.78).

Interaction effect of method of irrigation and ETc levels indicated that irrigation scheduled at 1.0 ETc with sub surface drip irrigation produced significantly higher number of good opened bolls per plant (35.23) compared to other treatment combinations. Significantly lower number of good opened bolls per plant was obtained in surface drip irrigation at 1.0 ETc (32.0). Irrigation scheduled at 1.0 ETc with sub surface drip irrigation produced significantly higher number of bolls per plant (39.03) as compared to other treatment combinations. The next best treatment was surface drip irrigation at 0.6 ETc (37.21). Significantly, higher mean boll weight was produced by irrigation

Table 1. Growth and yield parameters of Bt cotton as influenced by method of irrigation and ETc levels

Treatment	Plant height (cm)		No. of monopodia		No. of sympodia		Good opened bolls/plant	Total no. of bolls/plant	Mean boll wt (g)
	60 DAS	120 DAS	60 DAS	120 DAS	60 DAS	120 DAS			
Method of Irrigation (M)									
M_1: Surface drip	71.36	92.79	2.11	3.10	8.03	16.84	32.63	36.17	5.83
M_2: Sub surface drip	72.20	94.94	2.25	3.38	8.14	17.23	33.73	37.34	6.04
S.Em±	0.25	0.72	0.04	0.06	0.03	0.12	0.25	0.27	0.16
C.D. (P= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
ETc levels (I)									
I_1: 1.0 ETc	71.92	94.98	2.26a	3.20	8.16a	17.11	33.61	37.24	6.08
I_2: 0.8 ETc	71.56	93.08	2.13b	3.21	8.03b	16.85	32.75	36.25	5.82
I_3: 0.6 ETc	71.86	93.55	2.15b	3.29	8.06ab	17.14	33.19	36.78	5.91
S.Em±	0.32	0.58	0.04	0.06	0.04	0.10	0.28	0.29	0.09
C.D. (P= 0.05)	NS	NS	0.11	NS	0.10	NS	NS	0.89	NS
Interaction (MxI)									
M_1I_1	70.70^{c}	91.88^{b}	1.95^{b}	2.88^{b}	7.88^{d}	16.55^{d}	32.00^{c}	35.45^{c}	5.72^{b}
M_1I_2	70.75^{c}	92.30^{b}	2.13^{b}	3.00^{b}	7.96^{cd}	16.65^{cd}	32.43^{bc}	35.85^{c}	5.75$_{b}$
M_1I_3	72.63^{ab}	94.20^{b}	2.25^{b}	3.43^{a}	8.25^{b}	17.33^{ab}	33.48^{b}	37.21^{b}	6.01^{b}
M_2I_1	73.03^{a}	98.08^{a}	2.58^{a}	3.58^{a}	8.45^{a}	17.68^{a}	35.23^{a}	39.03^{a}	6.44^{a}
M_2I_2	72.38^{ab}	93.85^{b}	2.13^{b}	3.43^{a}	8.10^{bc}	17.05^{bc}	33.08^{bc}	36.65^{bc}	5.88^{b}
M_2I_3	71.21^{bc}	92.90^{b}	2.05^{b}	3.15^{b}	7.88^{d}	16.95^{bcd}	32.90^{bc}	36.35^{bc}	5.80^{b}
S.Em±	0.46	0.82	0.06	0.07	0.05	0.14	0.40	0.41	0.13
C.D. (P= 0.05)	1.41	2.52	0.19	0.22	0.15	0.43	1.22	1.26	0.41
Control									
C_1	72.93	97.00	2.58	3.50	8.43	17.53	34.08	38.13	6.25
S.Em±	0.44	0.94	0.07	0.08	0.05	0.15	0.46	0.48	0.16
C.D. (P= 0.05)	1.31	2.79	0.21	0.23	0.16	0.45	1.36	1.43	0.49

Control (C_1): Surface irrigation (AAFI) at 0.6 IW/CPE ratio; values followed by different letters in a column significantly differ as per DMRT.

scheduled at 1.0 ETc with sub surface drip irrigation (6.44 g) compared to other treatments and the next best treatment was surface drip irrigation at 0.6 ETc (6.01 g). Higher yield parameters in sub surface drip irrigation with 1.0 ETc might be due to moisture supplied directly near root zone in sub surface drip irrigation which further helped in increased moisture absorption, photosynthesis and translocation of photosynthates to the developing bolls, besides producing and retaining more number of bolls per plant at later stages of crop cycle. Similar increase in the number of millable canes was found in subsurface irrigated sugarcane (1.3 lakh/ha) in comparison to sprinkler irrigation (0.93 lakhs/ha). The increase was by 90% (Shrivastava *et.al.,* 2011)

Surface irrigation at 0.6 IW/CPE ratio produced significantly higher number of good opened bolls per plant (34.08) and it was on par with all the interaction treatment except surface drip irrigation with 1.0 ETc and surface drip irrigation with 0.8 ETc. Significantly higher number of bolls per plant (38.13) and mean boll weight (6.25 g) was also recorded in surface irrigation at 0.6 IW/CPE ratio compared to all other treatments and was on par with sub surface drip irrigation at 1.0 ETc. The differences in various yield parameters of Bt cotton, which led to significant yield differences in surface irrigation at 0.6 IW/CPE ratio, could be traced back to differences in growth components such as plant height, number of monopodia and sympodia and due to better availability of irrigation water during early stages which helped to maintain the favourable microclimate for the plant growth and development.

Yield and water use efficiency

Seed cotton yield did not differ significantly due to method of irrigation (Table 2). The sub surface drip irrigation recorded numerically higher seed cotton yield 3,109 kg ha^{-1} than surface drip irrigation 2,748 kg ha^{-1}. Method of irrigation was found to be non significant as the amount of water applied in both the methods remained the same *i.e.,* 530 mm. However, sub surface drip irrigation increased the seed cotton yield by 13 per cent over surface drip irrigation. These results are in conformity with Kalfountzos *et al.* (2007). Both forms of drip irrigation performed similarly under wet year with rainfall of 173 mm in 2002. On the other hand sub surface drip irrigation was better in dry year when the rainfall was 61.8 mm in 2001. In the present investigation year 2015 at IWMRC Belavatagi, rainfall of 392.6 mm can be considered as wet year for cotton cultivation.

The spectacular yield advantage due to ETc levels also could not be realized. These contrasting results were mainly attributed to variation in the rainfall pattern during the reproductive stages of the crop (51.2 mm during developmental stage (26-70 DAS), 291.6 mm during boll development stage (76-120 DAS) and it coincided with high effective rainfall of 151 mm throughout crop growth period. Similar results were observed by Nalayini *et al.* (2006) at Central Institute for Cotton Research, Coimbatore.

Interaction effect of method of irrigation and ETc levels was found significant. Scheduling of irrigation at 1.0 ETc with

Table 2. Yield and water use efficiency of Bt cotton as influenced by method of irrigation and ETc levels

Treatment	Seed cotton yield (kg/ha)	Water use efficiency (kg/ha-mm)	Total water used (mm) Water applied through irrigation	Effective rainfall	Total	Water saving (%) over control
Method of irrigation (M)						
M_1: Surface drip	2,758	5.39	379	151	530	21.7
M_2: Sub surface drip	3,109	5.93	379	151	530	21.7
S. Em±	149.80	0.29	-	-	-	-
C.D. (P= 0.05)	NS	NS	-	-	-	-
ETc levels (I)						
I_1: 1.0 ETc	2,996	4.79[c]	474	151	625	7.6
I_2: 0.8 ETc	2,815	5.31[b]	379	151	530	21.7
I_3: 0.6 ETc	2,990	6.87[a]	284	151	435	35.7
S. Em±	99.81	0.19	-	-	-	-
C.D. (P= 0.05)	NS	0.58	-	-	-	-
Interactions (MxI)						
M_1I_1	2,521b	4.03[c]	474	151	625	7.6
M_1I_2	2,681b	5.06[b]	379	151	530	21.7
M_1I_3	3,072ab	7.06[a]	284	151	435	35.7
M_2I_1	3,471a	5.55[b]	474	151	625	7.6
M_2I_2	2,949b	5.56[b]	379	151	530	21.7
M_2I_3	2,908b	6.69[a]	284	151	435	35.7
S. Em±	141.15	0.26	-	-	-	-
C.D. (P= 0.05)	434.92	0.82	-	-	-	-
Control						
C_1	3,206	4.68	540	137	677	-
S. Em±	161.52	0.30	-	-	-	-
C.D. (P= 0.05)	479.89	0.90	-	-	-	-

Control (C_1): Surface irrigation (AAFI) at 0.6 IW/CPE ratio

Values followed by different letters in a column significantly differ as per DMRT.

sub surface drip irrigation recorded significantly higher seed cotton yield 3471 kg ha^{-1}. The treatment recorded an increase of 17.7, 19.3, 29.4 and 37.6 per cent over sub surface drip irrigation with 0.8 ETc, sub surface drip irrigation with 0.6 ETc, surface drip irrigation with 0.8 ETc and surface drip irrigation with 1.0 ETc, respectively. However it was on par with surface drip irrigation with 0.6 ETc 3,072 kg ha^{-1}. Increase in yield was due to significant increase in the number of good opened bolls per plant total number of bolls produced per plant.

The difference in seed cotton yield could be ascribed to yield parameters like sympodia per plant, number of good bolls per plant, total bolls per plant and yield per plant which were found to increase significantly with increasing ETc levels in case of sub surface drip irrigation. Patil and Rodge (1977) observed positive correlation between seed cotton yield and sympodial branches. Sympodial branches form the principal segment of super structure of cotton plant on which fruiting bodies develop. Higher number of sympodial branches at an early date indicates the formation of higher number of fruiting points at an early stage and the sites of sympodia contributed for economic yield of cotton crop. Significantly higher seed cotton yield was recorded in surface irrigation at 0.6 IW/CPE ratio (3,206 kg ha^{-1}) over surface drip irrigation with 1.0 and 0.8 ETc (an increase of 27.1 and 19.5 per cent). However this was found on par with sub surface drip irrigation with 1.0, 0.8 and 0.6 ETc along with surface drip irrigation at 0.6 ETc. This could be attributed to large amount of application of water (677 mm). The differences in yield of Bt cotton, with surface irrigation at 0.6 IW/CPE ratio, could be traced back to differences in growth and yield components such as number of sympodia (17.53), good opened bolls per plant (34.08), total number of bolls per plant (38.13) and mean boll weight (6.25 g).

Total water use and water use efficiency

The total water use by the crop was higher in furrow irrigation (677 mm) as against drip irrigation regimes under 1.0 ETc, (625 mm) under 0.8 ETc and (530 mm) under 0.6 ETc (435 mm). The amount of water required for cotton ranges from 660 to 1,145 mm for different places or different varieties, depending on duration, soil and climatic conditions. As the seed cotton yield was comparable with furrow irrigation, considerable saving in water use was possible by adopting drip irrigation. The water saving in 1.0, 0.8 and 0.6 ETc levels were 7.6, 21.7 and 35.7 per cent respectively compared to furrow irrigation. Higher saving in water use in drip irrigation might be due to decreased evaporation losses.

The data on water use efficiency is presented in Table 2. Water use efficiency did not differ significantly due to method of irrigation. Water use efficiency was found higher in sub surface drip irrigation (5.93 kg ha^{-1} mm) and increase was by 10.02 per cent over surface drip irrigation. These results are in conformity with Abdrabbo (2013) at Egypt. ETc level differed significantly as irrigation scheduled at 0.6 ETc (6.87 kg ha^{-1} mm) recorded significantly higher water use efficiency. Next best

water use efficiency was in 0.8 ETc (5.31 kg ha^{-1} mm) and was significantly higher than 1.0 ETc (4.79 kg ha^{-1} mm). This might be due to higher seed cotton yield (2,990 kg/ha) and limited quantity of water applied under 0.6 ETc (435 mm).

Amount of water applied varies based on ETc levels. In surface drip irrigation at 1.0 ETc (625 mm), 0.8 ETc (530 mm) and 0.6 ETc (435 mm) of water was applied. Same amount of water is used in sub surface drip irrigation. Among different treatment combinations significantly higher water use efficiency of 7.06 kg ha^{-1} mm was registered with surface drip irrigation with 0.6 ETc. Increase in the level of water application by drip irrigation decreased the water use efficiency, while limited quantity of water applied under lower drip irrigation regime increased seed cotton yield, due to higher moisture content at all stages. These results were in harmony with Veeraputhiran and Chinnuswamy (2009). Lower water use efficiency was recorded in surface drip irrigation with 1.0 ETc (4.03 kg ha^{-1} mm) due to lower seed cotton yield. Surface irrigation at 0.6 IW/CPE ratio recorded significantly lower water use efficiency (4.68 kg ha^{-1} mm) compared to other treatments except surface drip irrigation with 1.0 ETc (4.03 kg ha^{-1} mm).

Conclusion

From the results of the experiment it was concluded that the adoption of sub surface drip method of irrigation at 1.0 ETc was proved to be advantageous and resulted in recording higher seed cotton yield, water use efficiency and water saving in comparison surface method of irrigation under vertisols.

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