Research Article

Effect of Land Configurations and Integrated Nutrient Management Practices on Productivity, Evapotranspiration and Water Use Efficiency of Bt Cotton

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Abstract

A field experiment was conducted during *kharif* 2015-16 and 2016-17 at College farm, College of Agriculture, Rajendranagar, Professor Jayashankar Telangana State Agricultural University, Hyderabad in strip-plot design with three replications to study the effect of moisture conservation practices (flat bed sowing, ridge and furrow, broad bed and furrow (BBF) and poly mulch on BBF) and integrated nutrient management treatments (Farmer's practice, 100% RDF of 150:60:60 NPK kg ha^{-1}, 125% RDF, 100% RDF along with 25% N through FYM or press mud) and their integration effect on yield, evapotranspiration and Crop water use efficiency (CWUE) of Bt cotton. Throughout cropping period poly mulch on broad bed (M_4) was recorded high ET_C and yield. Crop water use efficiency (CWUE) was significantly higher with poly mulch on broad bed and application of 100% RDF + 25 % RDN through FYM (M_4S_4) and was at par with application of 100 % RDF + 25 % RDN equivalent to pressmud (M_4S_5).

Keywords: Bt cotton, poly mulch, ridge and furrow, broad bed and furrow, FYM and press mud, evapotranspiration, INM, crop water use efficiency

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Introduction

Cotton (*Gossypium hirsutum* L.), the "*white gold or the king of fibres*" is one of the most important commercial crops in India. The productivity of cotton in India is significantly lower (568 kg ha^{-1}) as compared to the four major cotton growing countries *i.e* China (1300 kg ha^{-1}), USA (900 kg ha^{-1}), Pakistan (700 kg ha^{-1}) and Brazil (2027 kg ha^{-1}) though India ranks first in area with 11.88 m ha^{-1}, accounting 30 per cent of world coverage and 22 per cent (351 lakh bales of lint) of the world cotton production (second rank) with a productivity of 568 kg ha^{-1} [1].

More than 65% of the cotton in India is cultivated in red soils although cotton is recommended for black soils. Under rainfed conditions, proper land configuration as per the soil type aids in efficient soil moisture conservation, apart from ensuring better stand, establishment, uniform growth, nutrient use efficiency and yield [2]. Under dryland agriculture, not only the insufficient amount of rainfall but its distribution also fails to synchronise with evapotranspiration requirements of crops. The major problem of dry land agriculture is conservation of moisture. Therefore, there is a need for in situ conservation of rain water. Effective rain water management as in-situ moisture conservation comprising of opening of furrow, intercropping, mulching etc prove to be vital for attaining sustainable yields [3]. Mulch particularly restricted the transport of water vapour from soil surface to microclimate, which decreased the direct evaporation loss of soil water [4] and increased the availability of soil water to the crops [5]. Use of plastic mulch has confirmed water saving to about 40-50 percent in cotton [6].

The other factor for reduced cotton yield is imbalanced use of fertilizers that results in micronutrient deficiencies and making the soil unproductive. Integrated use of chemical fertilizers and organic manures is essential for achieving higher yields and to maintain soil health. Although FYM is commonly recommended organic manure, its availability is becoming scarce on account of low or negligible maintenance of cattle population in the farm. In this context, alternate organic sources like pressmud, byproduct of sugarcane industry is one of the sound option on account of its rich nutrient content [7]. Keeping in view the above facts, the present study was initiated to maximize the yield of Bt cotton under different soil moisture conservation techniques and integrated nutrient management practices in red soils.

Material and Methods

A field experiment was conducted during *kharif*, 2015 and 2016 at College farm, College of Agriculture, Rajendranagar, Professor Jayashankar Telangana State Agricultural University, Hyderabad situated at an altitude of 542 m above mean sea level at 17°19' N latitude, 78°23' E longitude under rainfed conditions. The soil of the experimental site was sandy loam with soil pH of 7.33, low available N (182 kg ha^{-1}), medium in P_2O_5 (46.8 kg ha^{-1}) and high in K_2O (432 kg ha^{-1}). The experiment was laid out in strip plot design with three replications. The size of gross and net plots was 7.2 m x 5.4 m and 5.4 m x 4.2 m respectively. There were twenty treatments with combinations of four *in-situ* moisture conservation practices (main plots) *viz.*, flat method (M_1), ridge and furrow (M_2), BBF (M_3) and poly mulch on BBF (M_4) as main plots and five integrated nutrient management (INM) practices as sub plots i.e., Farmer's practice (S_1), 100% recommended dose of fertilisers (RDF, S_2), 125% RDF (S_3), 100% RDF along with 25% N through FYM (S_4) and 100% RDF along with 25% RDN through press mud (S_5). Bt hybrid Neeraja BT-II seeds were dibbled @ 1 seed $hill^{-1}$ on 7th July during 2015 and 2nd July during 2016. The recommended dose of fertilizers to cotton in Telangana state was 150:60:60 NPK kg ha^{-1}. Entire P fertilizer was applied as basal and N and K applied at 20, 40, 60 and 80 days after sowing (DAS) in equal splits. In integrated nutrient management treatments (S_4 & S_5), 25 per cent nitrogen was applied through organic manures as basal and remaining as that of recommended dose of fertilizers (100 % RDF). Farmers practice of nutrient management was decided after survey of nutrient management in 30 cotton growing farmers fields in Telangana. Farmers are applying 50 kg of DAP at 20-25 DAS, 50 kg of 14-35-14 at 40-45 DAS, 50 kg of urea and 25 kg of muriate of potash at 60-65 DAS, 75 kg urea and 25 kg potash at 80-100 DAS. Based on the above, farmers practice of nutrient management was 3.75 t FYM ha^{-1}, 184-101-92 kg N, P_2O_5 and K_2O ha^{-1} followed.

Pressmud and FYM were analysed for nitrogen content. Pressmud contains 1.92% nitrogen during 2015 and 2.24% during 2016. FYM contains 0.49% during 2015 and 0.72% during 2016. After laying land configurations, during 2015, 1953 kgs of pressmud and 7653 kgs of FYM were applied in S_5 and S_4 treatment plots. During 2016, 1674 kgs of pressmud and 5208 kgs of FYM were applied in S_5 and S_4 treatments. In M_1 treatment, simple flat bed method of sowing was imposed without any soil moisture conservation treatments as check. In M_2 treatment, ridges and furrows were laid at 90 cm apart respectively. While in M_3 & M_4 broad bed and furrow treatment, beds of 120 cm width and furrows of 60 cm were laid. In M_4 treatment**,** polythene mulch with black (upper) and grey (bottom) having 25 µ thickness was laid before sowing of the crop on the raised (broad) beds (120cm). Before laying the film, small circular holes were made as per the intra row spacing (60 cm) of the crop and the sheet was spread on the raised bed. After that, the sides of the polythene film were covered within the soil. Under all the treatments, sowing was done by adopting intra row spacing of 60 cm, thus maintained uniform plant population (18,519 plants ha^{-1}). A total rainfall of 375.3 mm was received in 27 rainy days during 2015-16 and 741.1 mm in 37 rainy days during 2016-17 (Table 2), against the decennial average of 616 mm received in 37 rainy days. The crop was sprayed with monocrotophos @ 1 ml l^{-1} against aphids and bollworms and drenching of carbendazim @ 1g l^{-1} of water against wilt. The crop was finally terminated on 10th December during 2015 and 6th December during 2016. The seed cotton in the net plot was harvested separately. The total seed cotton yield was obtained by adding the weight from each picking and expressed as kg ha^{-1}. Statistical analysis of the data of various growth, yield and yield attributes were carried out through analysis of variance technique as described by Panse and Sukhatme [8].

Soil moisture parameters

Moisture retention capacity of the experimental field was estimated at -0.1 M Pa and -1.5 M Pa using pressure plate apparatus [9] and the bulk density of the experimental soil was estimated for each 15 cm soil depth up to 60 cm by following the standard procedures given below [10] and the resultant data was presented in **Table 1**.

$$\text{BD (g cc}^{-1}) = \frac{\text{Weight of oven dry soil}}{\text{Volume of soil}}$$

$$\text{Amount of moisture in soil (cm)} = \text{moisture content of soil (\%) x BD x depth of soil (cm)}$$

The amount of moisture storage in 0-60 cm soil profile was computed by adding the quantity of each layer. The total available soil moisture *i.e.*, the difference between -0.1 M Pa and -1.5 M Pa in 0-60 cm soil depth was amounted to 104.86 mm.

Table 1 Available soil moisture of the experimental soil

Soil depth (cm)	Soil moisture content (%) at		Bulk density (g cc^{-1})	Available soil moisture (mm)
	Field capacity (-0.1 M Pa)	Permanent wilting point (-1.5 M Pa)		
0-15	20.5	9.5	1.57	25.9
15-30	21.0	10.0	1.58	26.07
30-45	21.5	10.6	1.61	26.32
45-60	21.7	10.9	1.64	26.57
			Total	104.86

Soil moisture estimation

The soil moisture was determined gravimetrically by taking soil samples at 30,60,90,120 DAS and at harvest at different depths (0-15, 15-30, 30-45 and 45-60) and as and when irrigation was given up to 60 cm depth in 15 cm increment of soil layer.

The moisture percentage was calculated by using the following formula.

$$\text{Gravimetric soil moisture (\%)} = \frac{\text{Fresh weight of soil- Dry weight of soil}}{\text{Dry weight of soil}} \times 100$$

Crop evapotranspiration (ET_c)

The evapotranspiration of crop is calculated by subtracting the soil moisture from the maximum available soil moisture and presented in **Table 2** for two consecutive years 2015 and 2016 respectively.

Table 2 Applied water (mm) (Rainfall + irrigation) at different stages of *Bt* cotton during 2015 and 2016

Days after sowing	Rainfall (mm)	Effective rainfall (mm)	Irrigation(mm)	Total (mm)
2015				
0-30 DAS	25.0	21.2	50.0	71.2
30 - 60 DAS	98.2	72.0		72.0
60 - 90 DAS	194.8	137.0		137.0
90 - 120 DAS	36.6	32.0	50.0	82.0
120 - 150 DAS	18.3	16.0	50.0	66.0
150 - 180 DAS	2.2	2.0		2.2
Total	375.3	280.4	150.0	430.4
2016				
0-30 DAS	92.2	78.0		78.0
30 - 60 DAS	82.7	72.4		72.4
60 - 90 DAS	461.2	320.6		320.6
90 - 120 DAS	102.8	81.0		81.0
120 - 150 DAS	0	0.0	50.0	50.0
150 - 180 DAS	2.2	2.2	50	52.2
Total	741.1	554.2	100	654.2

*Effective rainfall is calculated based on USDA method

Crop Water Use Efficiency (CWUE)

Crop Water Use Efficiency (CWUE): It is the ratio between seed yield to the amount of water used in evapotranspiration by the crop. It was worked out by using the following formula and expressed as kg ha mm^{-1}.

$$\text{CWUE} = \frac{\text{Seed yield (kg ha}^{-1}\text{)}}{\text{Evapotranspiration (mm)}}$$

The applied water (Rainfall + Irrigation) at different stages of *Bt* cotton (**Table 3**) was 430.4 mm and 654.2 mm respectively during 2015 and 2016. The effect of moisture conservation practices on soil moisture, evapotranspiration and water use efficiency were presenting for supporting evidence of higher seed cotton yield in respective treatments.

Three and two irrigations were given during 2015 and 2016 quantifying to 150 mm and 100 mm at different stages of *Bt* cotton. Effective rainfall was calculated based on USDA method and it was 280.4 and 554.2 mm during 2015 and 2016 respectively (Table 3). It is clearly evident that the rainfall is higher and uniformly distributed during the year 2016 compared to 2015 year.

Table 3 Effect of moisture conservation practices and INM on kapas and stalk yield of Bt cotton (Pooled mean, 2015 & 2016)

Treatments	Kapas yield (kg ha^{-1})					
	S_1	S_2	S_3	S_4	S_5	Mean
M_1 - Flat bed (control)	1566	1447	1695	1758	1843	1662
M_2 - Ridge & furrow	1871	1779	2076	2125	2195	2009
M_3 - BBF	1687	1590	1898	1938	2004	1823
M_4 - Poly mulch on BBF	2018	1888	2293	2346	2370	2183
Mean	1785	1676	1990	2042	2103	1919
		Main	**Sub**	**MXS**	**SXM**	
S.Em±		26	21	18	29	
C.D at 5%		89	68	53	100	
CV		7.2				

Sub treatments (S) S_1: Farmers practice, S_2 : 100% RDF, S_3 : 125% RDF, S_4 : 100% RDF + FYM equivalent to 25% RDN, S_5: 100% RDF + Press mud equivalent to 25% RDN

Results and Discussion

Productivity

Treatment combination involving poly mulch on broad bed and application of RDF along with 25% RDN through press mud (M_4S_5) recorded significantly higher mean seed cotton yield (2370 kgha^{-1}) than rest of the treatment combinations. This treatment was comparable with (M_4S_4) poly mulch on broad bed and application of RDF along with 25% RDN through FYM (2346 kgha^{-1}). M_4S_5 and M_4S_4 treatments were in turn on par with poly mulch on broad bed and application of 125% RDF (M_4S_3) indicating that poly mulch was more effective when RDF was applied either with press mud or FYM equivalent to 25% RDN or with 125% RDF alone (Table 3). Increased seed cotton yield under broad bed and furrow with poly mulch was due to the sufficient soil moisture in the root zone and the extended retention of moisture lead to higher uptake of nutrients for proper growth and development of plant which resulted in higher yield. These results are in accordance with those of Patel *et al*. [11], who reported improved yield on treatments consisting of positive effect of press mud and FYM on seed cotton yield. Higher fertilizer (125% RDF) might have increased growth parameters and higher drymatter accumulation in reproductive parts there by leads to higher productivity.

Evapotranspiration (ETc) (mm) of Bt cotton

Effect of moisture conservation practices

Soil moisture at different stages of crop in different moisture conservation and INM treatments was estimated at 30 (Seedling stage), 60 (flower initiation), 90 (flowering stage), 120 (boll development) and 150 DAS (harvest). ET of crop was low at seedling stage, increased at flower initiation and flowering stages and reached a peak at boll development stages and reduced at harvest (150 DAS) irrespective of treatments. Cumulative evapotranspiration was higher during 2015 compared to 2016. This might be attributed to the presence of higher soil moisture content in the soil layers due to higher rainfall and resulted in higher evapotranspiration of crop during 2016. In addition, optimum plant population and favourable soil moisture range helped in higher plant growth (plant height, leaf area, and number of branches plant^{-1}) and reflected in higher ETc. Similar results were reported by Bhaskar *et al.* [12] and Ravinder *et al* [13]. Throughout cropping period, poly mulch on broad bed (M_4) was recorded high cumulative ET_C (Figure 4) 338.79 mm (2015) and 350.52 mm (2016) whereas the lowest ET_C was recorded with flat bed 303.68 mm (2015) and 312.70 mm (2016). Soil moisture storage is less in flat bed method resulting in relatively lower crop ET (**Figure 1**). As the cotton crop is a long duration crop and need for soil moisture conservation, flat bed method of sowing need to be discouraged. Ridge and furrow method (M_2) and broad bed method of sowing (M_3) observed comparable ETc values (**Figures 2** and **3**) during 2015 (322.24 mm, 320.17 mm) and during 2016 (335.90 mm, 330.31 mm) respectively (**Table 4** and **5**). This was supported by Ambika *et al* [14] who stated that both these methods are effective for *in situ* moisture conservation.

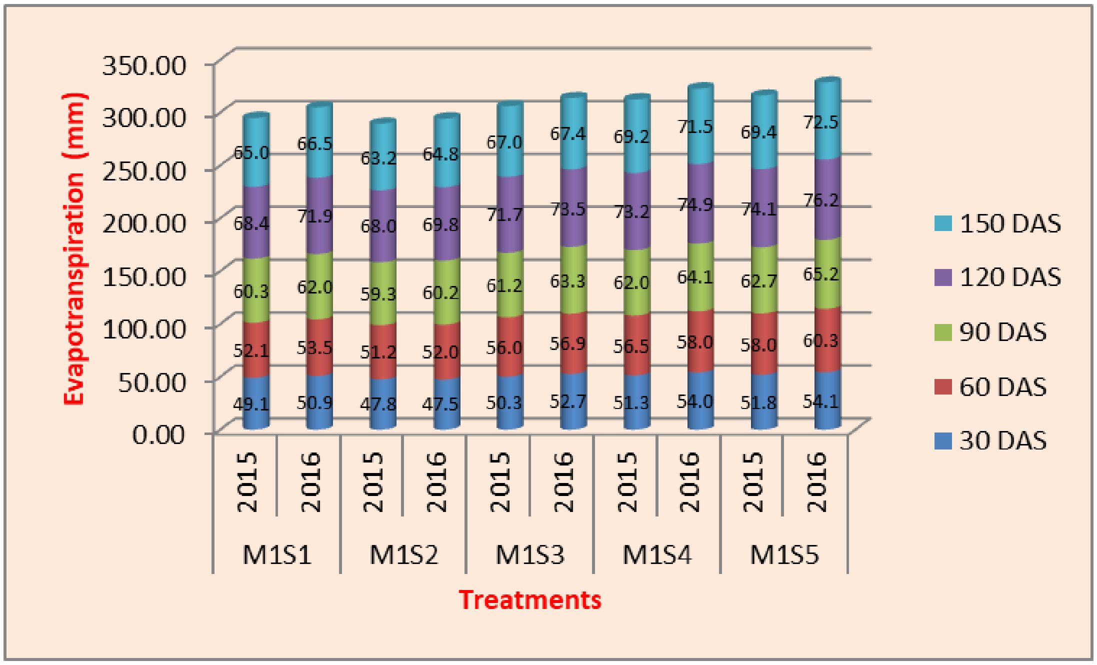

Figure 1 Evapotranspiration (ETc) (mm) of Bt cotton at different stages of crop growth during 2015 and 2016 under flat bed method

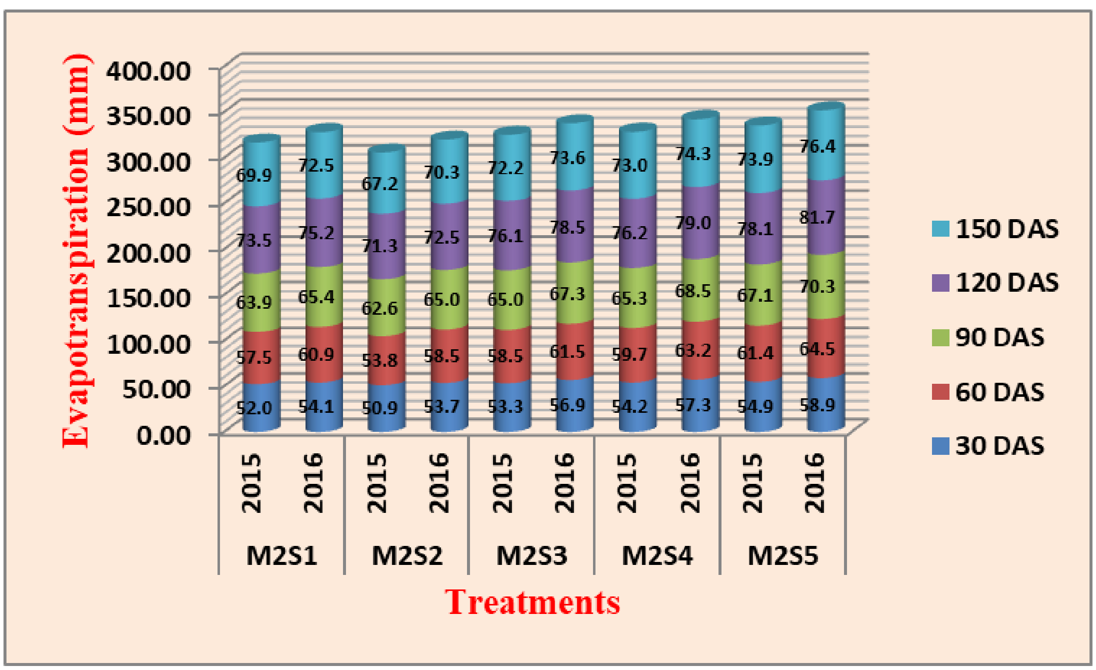

Figure 2 Evapotranspiration (ETc) (mm) of Bt cotton at different stages of crop growth during 2015 and 2016 under ridge and furrow method

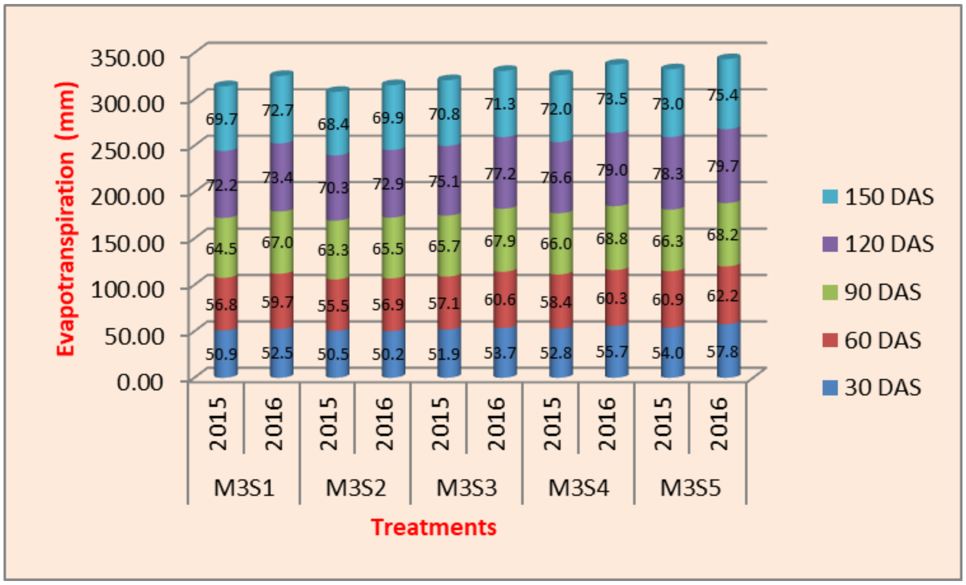

Figure 3 Evapotranspiration (ETc) (mm) of Bt cotton at different stages of crop growth during 2015 and 2016 under broad bed and furrow method

Table 4 Effect of moisture conservation practices and INM on Crop evapotranspiration (mm) of Bt cotton (Pooled mean, 2015).

Treatments	**Cumulative evapotranspiration (Etc) (mm)**					
	S_1	**S_2**	**S_3**	**S_4**	**S_5**	**Mean**
M_1 - Flat bed (control)	294.86	289.41	305.96	312.24	315.95	303.68
M_2 - Ridge & furrow	316.74	305.76	325.07	328.39	335.26	322.24
M_3 - Broad bed	314.04	308.00	320.60	325.84	332.39	320.17
M_4 - Poly mulch on broad bed	332.68	324.35	339.64	344.50	352.79	338.79
MEAN	314.58	306.88	322.82	327.74	334.10	321.22

Sub treatments (S) S_1: Farmers practice, S_2 : 100% RDF, S_3 : 125% RDF, S_4 : 100% RDF + FYM equivalent to 25% RDN, S_5: 100% RDF + Press mud equivalent to 25% RDN

Table 5 Effect of moisture conservation practices and INM on Crop evapotranspiration (mm) of Bt cotton (Pooled mean, 2016).

Treatments	**Cumulative Evapotranspiration (Etc) (mm)**					
	S_1	**S_2**	**S_3**	**S_4**	**S_5**	**Mean**
M_1 - Flat bed (control)	304.66	294.31	313.65	322.53	328.34	312.70
M_2 - Ridge & furrow	328.05	319.91	337.61	342.23	351.71	335.90
M_3 - Broad bed	325.12	315.26	330.54	337.38	343.25	330.31
M_4 - Poly mulch on broad bed	342.36	335.87	351.17	357.04	366.15	350.52
MEAN	325.05	316.34	333.24	339.80	347.36	332.36

Sub treatments (S) S_1: Farmers practice, S_2 : 100% RDF, S_3 : 125% RDF, S_4 : 100% RDF + FYM equivalent to 25% RDN, S_5: 100% RDF + Press mud equivalent to 25% RDN

Effect of integrated nutrient management practices

Different nutrient management practices exerted conspicuous effect on crop ETc during 2015 and 2016. The Evapotranspiration (ET_c) was relatively higher in plots applied with 100% RDF + pressmud equivalent to 25% RDN (334.10 mm, 347.36 mm) over rest of the treatments (Table 4 and 5) and closely followed by 100% RDF + FYM equivalent to 25% RDN (327.74 mm, 339.80 mm), 125% RDF (322.82 mm, 333.24 mm) and farmers practice (314.58 mm, 325.05 mm) during 2015, 2016 respectively. Application of 100% RDF (306.88mm, 316.34 mm) recorded the minimum ETc in both the years. Satyanarayana Rao and Janawade [15], who reported that combined application of FYM @ 10 t ha^{-1} with chemical fertilizers decreased bulk density and increased infiltration rate compared to application of organics and inorganics alone.

Among the treatment combinations, laying of poly mulch on broad bed along with application of 100 % RDF + 25 % RDN through pressmud (M_4S_5) or FYM (M_4S_4) or 125 % RDF (M_4S_3) showed higher ETc (**Figure 4**) during 2015 (352.79, 344.50, 339.64 mm) and during 2016 (366.15, 357.04, 351.17 mm) respectively (Table 4 and 5).

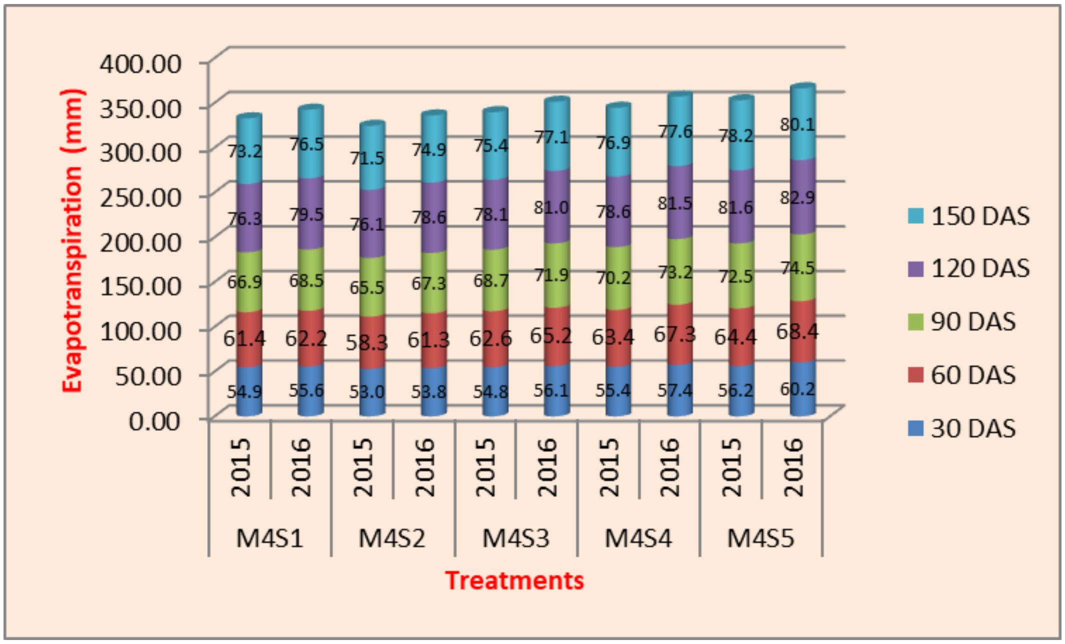

Figure 4 Evapotranspiration (ETc) (mm) of Bt cotton at different stages of crop growth during 2015 and 2016 under poly mulch on broad bed method

Crop (CWUE) water use efficiency of Bt cotton as influenced by moisture conservation and INM practices

Crop water use efficiency (CWUE) was higher during 2016 (Table 5) compared to 2015 (Table 4) as the crop enjoyed good soil moisture throughout the growth period because of well distributed rainfall and higher yield.

Significantly higher crop water use efficiency (**Table 6**) was recorded in poly mulch on broad bed (M_4) (6.32 kg ha mm^{-1}) compared to ridge and furrow, broad bed and furrow and flat bed methods. Improved yield under mulched treatment coupled with lower evaporation had recorded higher crop water use efficiency. Similar results were reported by Wankhade *et al* (16). It indicated that the crop under poly mulch plots utilized stored soil water more efficiently and by partitioning a greater fraction of ET toward more productive transpiration component. However, crop water use efficiency (CWUE) of poly mulch on broad bed treatment was at par with ridge & furrow (6.09 kg ha mm^{-1}) and broad bed (5.59 kg ha mm^{-1}) methods respectively. Higher WUE with ridge and furrow and broad bed and furrow might be due to presence of moisture conservation structures which acts as a barrier to run off water and harvest maximum rain water into the soil. This was supported by Nalayini *et al* [6], who reported that the water requirement of mulched cotton was lower (58.63 ha-cm) than conventionally grown cotton (84.19 ha-cm) and the water use efficiency of mulched cotton was 43.2 kg ha-cm^{-1} as against 16.6 kg ha-cm^{-1}for conventionally planted cotton crop grown without any mulch. Observations made in the present investigation are in line with the findings of Thukkaiyannan et al [17].

Table 6 Effect of moisture conservation practices and INM on Crop water use efficiency (kg ha mm^{-1}) of Bt cotton (Pooled mean, 2015 and 2016).

Treatments	**Crop water use efficiency (kg ha mm^{-1})**					
	S_1	**S_2**	**S_3**	**S_4**	**S_5**	**Mean**
M_1 - Flat bed (control)	5.21	4.96	5.47	5.53	5.71	5.38
M_2 - Ridge & furrow	5.80	5.68	6.26	6.33	6.38	6.09
M_3 - Broad bed	5.27	5.10	5.82	5.84	5.93	5.59
M_4 - Poly mulch on broad bed	5.97	5.71	6.64	6.68	6.59	6.32
Mean	5.57	5.36	6.05	6.10	6.15	5.84
		Main	Sub	MXS	SXM	
S.Em±		0.10	0.20	0.10	0.20	
CD at 5%		0.40	0.50	0.40	0.60	
CV		7.80				

Sub treatments (S) S_1: Farmers practice, S_2 : 100% RDF, S_3 : 125% RDF, S_4 : 100% RDF + FYM equivalent to 25% RDN, S_5: 100% RDF + Press mud equivalent to 25% RDN

Among the different INM practices, the crop water use efficiency of cotton was higher with application of 100% RDF + pressmud equivalent to 25% RDN (6.15 kg ha mm^{-1}, respectively) which was statistically on par with 100% RDF + FYM equivalent to 25% RDN and was followed by 125% RDF and farmers practice. Lower moisture use efficiency was noticed in 100% RDF (5.36 kg ha mm^{-1} respectively).

Among the treatment combinations, pooled crop water use efficiency (CWUE) was significantly higher (6.68 kg ha mm^{-1}) with poly mulch on broad bed and application of 100% RDF + 25 % RDN through FYM (M_4S_4) and was at par with M_4S_5. The observations made in the present investigation are in line with the findings of Kelfemariam [18] and Devarushi and Kulkarni [19] indicated that WUE of Alternate Furrow Irrigation + mulching with 125 % RDF (3.03 kg/ha mm) was 15.38 % higher than that of conventional furrow irrigation (2.62 kg/ha mm) with 125 % RDF.

Conclusion

Based on above results, it can be concluded that maximum yield from Bt. cotton can be obtained by application of pressmud or FYM equivalent to 25% RDN along with 100 % RDN or 125% RDF with *in-situ* moisture conservation practice of poly mulch on broad bed in red soils of Telangana. Crop water use efficiency (CWUE) was significantly higher with poly mulch on broad bed and application of 100% RDF + 25 % RDN through either FYM or pressmud.

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