Pak. J. Agri. Sci., Vol. 51(4), 789-795; 2014
ISSN (Print) 0552-9034, ISSN (Online) 2076-0906
http://www.pakjas.com.pk

EFFECT OF SOWING METHODS AND DIFFERENT IRRIGATION REGIMES ON COTTON GROWTH AND YIELD

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A field experiment was conducted for comparative examination of three sowing methods i.e., bed sowing, ridge sowing and flat sowing and two irrigation levels 75% and 50% field capacity during summer 2010 and 2011. Object of the study was to find out the best planting method having higher water use efficiency (WUE) and water productivity (WP). Randomized Complete Block Design (Split Plot arrangement) was employed with three replicates. Total dry matter accumulation (TDM), cotton yield and economic analysis were recorded. Higher WUE and WP was noted in bed sowing. Furthermore, at 75% FC yield was higher than 50% FC level, which was mild stress to the crop. Bed sowing at 75% FC exhibited higher TDM than other sowing methods. The highest BCR (1.28) was observed in 75% FC level in bed sown cotton which was followed by ridge planted cotton giving 1.21 BCR. Minimum benefit cost ratio of 1.10 was observed in flat sown cotton at 75% FC level, while at 50% FC the highest BCR (1.00) was obtained in bed sown cotton. Conclusively, bed sowing proved to be more beneficial for higher water use efficiency as compared to ridge and flat sowing of cotton
Keywords: Cotton, bed sowing, water use efficiency, water productivity

INTRODUCTION

Cotton occupies a vital position in Pakistan's economy (Ibrahim *et al*., 2007). Planting method is an important factor which distresses crop growth and development and finally the crop yield. Various planting methods such as flat sowing, ridge planting and bed planting for cotton crop are being practiced in Pakistan. The ridge tillage (RT) planting system gave higher lint yield and more earliness than conventional planting system (CT) and cotton grown on beds produced more seed cotton yield as compared to ridge and flat sowing (Ali *et al*., 2012). Cotton (*Gossypium* spp.) is a crop of warm climate and requires regular supply of water. Nonetheless, irrigation requirement in relation to sowing methods is an important factor that affects greatly crop productivity. The good management of these variables may increase production of cotton (Anwar, 2003).

Irrigated agriculture is facing dire need for low cost and high quality water and world is searching for water saving agriculture, which mentions to maximum benefit of accessible irrigation facilities (Howell, 2001; Xi-ping *et al.,* 2004). Water saving agriculture proposes to raise water consumption rate and efficiency for obtaining more cost-effective yield on irrigated farm with lowest input of water at both public and private levels. Water saving is an ample exercise using every conceivable actions in farm production, as well as full use of natural precipitation in addition to effective management of an irrigation system through appropriate planting methods. With amassed apprehension about utilization of limited water resources, there is an improved interest in enhancing the water use efficiency in cotton (Tennakoon and Milroy, 2003; Tang *et al.,* 2005). Better water use efficiency can be achieved through the adoption of best irrigation management practices (Goyne and McIntyre, 2001). Benefits associated with permanent raised beds included better irrigation management which saved 25-30% of irrigation water with increased water productivity and improved nutrient availability (Sayre and Hobbs, 2004). Maximum water saving and the highest water use efficiency were recorded in bed and furrow method in cotton (Nasrullah *et al.,* 2011). Ali and Ehsanullah (2007) reported that flat planting with alternate row earthing up produced maximum water use efficiency and highest seed cotton yield compared with ridge and bed planting. Therefore, this study was conducted: to attain efficient irrigation water utilization and saving without affecting crop yield or quality and to quantify the amount of irrigation water required for cotton crop sown under different planting methods.

MATERIALS AND METHODS

The study was conducted at the Agronomic Research Area, University of Agriculture Faisalabad, Pakistan in 2010 and 2011. Geographical location of the site was Latitude 31°.25' N and Longitude 73°.09' E. The soil type belongs to Lyallpur soil series and was sandy loam. A Randomized Complete Block Design with Split-Plot arrangement was

used with three replications. The irrigation levels of 75% and 50% field capacity level were randomized in main plots and sowing methods including flat, ridge and bed sowing in sub plots.

***Meteorological data*:** Meteorological data such as daily maximum and minimum air temperature (°C), rainfall (mm) and humidity were collected from the nearby observatory of the Department of Crop Physiology, University of Agriculture, Faisalabad, Pakistan and presented in Fig.1.

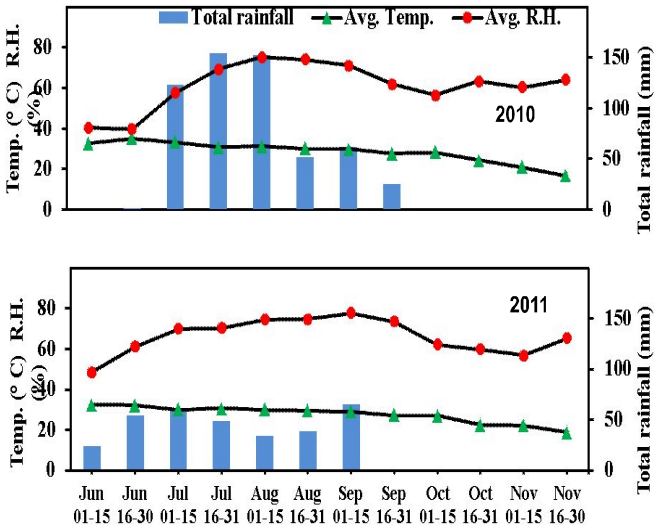

Figure 1. Summary of climatic data during 2010 and 2011

Tensiometers were used for measuring 50% and 75% field capacities. The tensiometers were installed in the soil at 40 cm depth. It was calibrated according to the soil and two readings on the gauge were set, i.e., 30 centibars indicating 75% field capacity (means 25% moisture was depleted and 75 % was remaining) while at 50 centibars showing 50% field capacity level (means 50% moisture is depleted and 50% is remaining) when the tensiometers gauges showed the described readings, the field was irrigated. Interval of irrigations was adjusted keeping in view the gauge reading of tensiometers. Total amount of water was expressed in terms of number of irrigations. As all treatments were in open field at the same site so the amount of rainfall was considered same. Sowing was done on 28th and 26th May, 2010 and 2011. Cotton yield traits such as, number of opened bolls, 100-seed weight, seed cotton yield and total dry matter were recorded. However, water use efficiency (WUE) and water productivity (WP) were computed using the following formulas:-

WUE = Crop yield (Economic yield) /Water (I+R) used to produce the yield (described by Viets 1962)

Where I= Irrigation and R= Rainfall

Water productivity = Yield / Total water applied

***Economic analysis*:** Net return was determined by subtracting the total cost of production from the gross income of each treatment (CIMMYT, 1988).

Net income = Gross income – Cost of production

Benefit-cost ratio (BCR) was calculated by dividing gross income to the total cost of production.

BCR = Gross income / Total cost

RESULTS AND DISCUSSION

***Number of opened bolls per plant*:** Significant effects of both irrigation levels and sowing methods were noted on number of opened bolls per plant during both years while the interactive effect of both factors showed non-significant variation (Table 1). Maximum number of opened bolls per plant (25.63) was recorded in 75% FC level compared with 50% FC levels which produced lesser number of opened bolls per plant (19.47) during 2010 and similar trend was observed during 2011. These results were confirmed with the finding of Hussein *et al.* (2003) who reported more number of bolls at higher irrigation rates. They also described that as the irrigation rate decreased, number of bolls was decreased and this decrease led to reduction in yield ultimately. Bed sowing produced more number of opened bolls per plant (24.78) and statistically similar (22.58) to ridge sown cotton, while significantly minimum number of opened bolls (20.30) was recorded in cotton planted under

Table 1. Effect of irrigation levels and sowing methods on number of opened bolls of cotton

	2010			2011		
	50% Field capacity	75% Field capacity	Mean	50% Field capacity	75% Field capacity	Mean
Flat Sowing	17.50	23.11	20.30 B	22.88	23.66	23.27 B
Ridge Sowing	19.66	25.50	22.58 A	22.22	24.11	23.16 B
Bed Sowing	21.26	28.30	24.78 A	23.89	26.39	25.14 A
Mean	19.47 B	25.63 A		23.0 B	24.72 A	
LSD	FC levels: 4.43	Sowing methods: 2.20		FC levels: 0.63	Sowing methods: 1.42	

Any two means not sharing a letter in a common differ significantly at $P \leq 0.05$.

flat planting method during 2010. During 2011 trend was changed as cotton grown on beds produced significantly maximum number of opened bolls per plant (25.14) and it was followed by number opened bolls in flat sowing (23.27) whereas flat sowing was at par with opened bolls resulted in ridge sowing (23.16). This increase was most probably due to better water availability, maximum water utilization at fruit bearing stage, better maturity and ultimately better opening of bolls. During 2010 environment was unfavourable during the whole crop period due to un-timely rainfall and stunted growth of the crop which ultimately resulted in less boll opening. These results were in line with findings obtained by Goyne and Mclntyre (2001).

***Boll weight (g)*:** Boll weight is one of the major yield contributing attributes. Experimental results pertaining to boll weight manifested a significant effect of irrigation levels and various sowing methods (Table 2). The interaction between these factors showed non -significant variation. At 75% FC, significantly greater boll weight (2.55 g) appeared as compared to 50% FC level (2.15g) during 2010; while during 2011 boll weight of 2.93 and 2.42 g, respectively. These results were found similar with those reported by Hussein *et al.* (2003) who stated that with decrease in irrigation boll weight decreased significantly. Nevertheless, sowing methods significantly enhanced boll weight (2.53 g) in cotton grown on beds. Minimum boll weight (2.19 g) was produced by cotton planted under flat plating method. Same trend was found during 2011. The interaction of irrigation levels and sowing methods was non-significant. The increase in boll weight was due to higher moisture retention in bed sowing and more aeration to the plant.

***100-Seed weight (g)*:** Seed index (100-seed weight) is a key factor which contributes integral share in ginning out turn (GOT) in cotton. It was observed that irrigation levels had significant effect on 100-seed weight during both years 2010 and 2011, respectively. Maximum 100-seed weight (7.49 g) was recorded in 75% FC level during 2010 and same trend was observed during 2011 (Table 3).

Sowing methods also influenced seed index significantly during both growing seasons. During 2010, significantly higher 100-seed weight (7.69 g) was recorded in cotton grown on beds and it was at par with 100-seed weight (7.45 g) in cotton planted on ridges; while minimum 100-seed weight (6.91 g) was observed in flat sown cotton. During 2011, maximum 100-seed weight (7.66 g) was recorded in cotton grown on beds and it was followed by 100-seed weight (7.37 g) obtained in ridge planted cotton while minimum 100-seed weight (6.98 g) was found in flat sown cotton. The interactive effect of irrigation levels and sowing methods on seed index (100- seed weight) was non-significant during both years of the study. Higher 100- seed weight at 75% FC and bed sowing might be ascribed to better growth, more water availability and more water consumed. These results were found contradictory in relation with findings of Ali and Ehsanullah (2007) who found non-significant effect on 100-seed weight of cotton planted under different sowing methods.

Table 2. Effect of irrigation levels and sowing methods on boll weight of cotton

	2010			2011		
	50% Field capacity	**75% Field capacity**	**Mean**	**50% Field capacity**	**75% Field capacity**	**Mean**
Flat Sowing	2.03	2.35	2.19 C	2.23	2.70	2.46 C
Ridge Sowing	2.15	2.53	2.34 B	2.40	2.96	2.68 B
Bed Sowing	2.28	2.78	2.53 A	2.64	3.14	2.89 A
Mean	2.15 B	2.55 A		2.42 B	2.93 A	
LSD	FC levels: 0.23	Sowing methods: 0.13		FC levels: 0.41	Sowing methods: 0.16	

Any two means not sharing a letter in a common differ significantly at $P \leq 0.05$.

Table 3. Effect of irrigation levels and sowing methods on 100-seed weight of cotton

	2010			2011		
	50% Field capacity	**75% Field capacity**	**Mean**	**50% Field capacity**	**75% Field capacity**	**Mean**
Flat Sowing	6.56	7.26	6.91 B	6.66	7.31	6.98 C
Ridge Sowing	7.35	7.54	7.45 A	7.25	7.49	7.37 B
Bed Sowing	7.71	7.66	7.69 A	7.66	7.65	7.66 A
Mean	7.21 B	7.49 A		7.19 B	7.48 A	
LSD	FC levels: 0.15	Sowing methods: 0.30		FC levels: 0.16	Sowing methods: 0.25	

Any two means not sharing a letter in a common differ significantly at $P \leq 0.05$.

***Seed cotton yield (kg ha^{-1})*:** Significant influence of irrigation levels as well as sowing methods on seed cotton yield was observed during both the growing seasons (Table 4). However, interactive effects of these two factors were found non-significant. Cotton grown under 75% FC level produced maximum seed cotton yield of 2019 kg ha^{-1} which was significantly higher as compared to 50% FC level (1462 kg ha^{-1}) during 2010 while almost similar trend was recorded during 2011 where highest seed cotton yield of 2152 kg ha^{-1}was obtained in 75% FC compared with 50% FC (1649 kg ha^{-1}).

Similarly, cotton grown on beds gave more yield of 1912 kg ha^{-1} which was followed by ridge sowing (1704 kg ha^{-1}); whereas, flat planting produced minimum seed cotton yield of 1606 kg ha^{-1} during 2010. While in the next year both bed and ridge sowing remained statistically same with the seed cotton yield of 2051 and 1933 kg ha^{-1}, respectively, whereas flat sown cotton produced the minimum yield of 1717 kg ha^{-1}. Yield of cotton in bed sowing was increased due to early germination and emergence of crop as compared to flat sowing. Yield contributing parameters such as number of opened bolls per plant, boll weight and seed cotton yield was higher. The results are similar as reported by Ali *et al.* (2012) who also found significantly higher seed cotton yield in cotton grown on beds comparing three sowing methods viz. flat sowing, ridge sowing and bed sowing. These results also correlate with findings of Chauhan (2007) who found 35% higher seed cotton yield in cotton-wheat rotation in bed sowing method and it was superior to flat sowing.

***Total dry matter accumulation (TDM)*:** Pronounced differences among the TDM means were recorded under the influence of different field capacity levels and sowing methods (Fig. 1). Higher TDM (911.73 g and 983.27 g) was recorded in both growing seasons, respectively, in case of 75% field capacity level. Similarly, response of TDM varied to different sowing methods; bed sowing of cotton accumulated higher TDM. Bed sowing and 75% field capacity level proved the best combination regarding TDM in both the years.

(a)

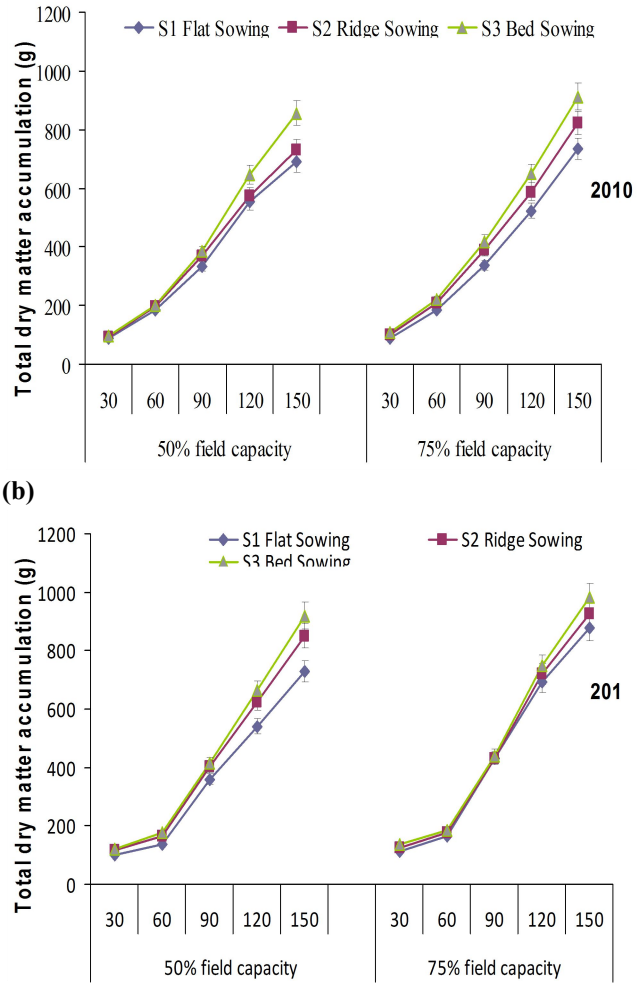

Figure 2. Effect of irrigation levels and sowing methods on total dry matter (TDM) during 2010 (a) and during 2011(b)

***Water use efficiency (WUE) (kg ha^{-1} mm^{-1})*:** Significant effect of irrigation levels and sowing methods were found on WUE in cotton plants during both the growing seasons (Fig. 3). Maximum WUE (2.50) was recorded at 50% FC level during 2010 and similar trend was observed during

Table 4. Effect of irrigation levels and sowing methods on seed cotton yield

	2010			2011		
	50% Field capacity	**75% Field capacity**	**Mean**	**50% Field capacity**	**75% Field capacity**	**Mean**
Flat Sowing	1370	1843	1606 B	1507	1926	1717 B
Ridge Sowing	1443	1966	1704 B	1677	2190	1933 AB
Bed Sowing	1574	2250	1912 A	1763	2339	2051 A
Mean	1462 B	2019 A		1649 B	2152A	
LSD	FC levels: 270.65	Sowing methods: 131.56		FC levels: 389.82	Sowing methods: 234.58	

Any two means not sharing a letter in a common differ significantly at $P \leq 0.05$.

2011. These results were contradictory with those reported by Hussein *et al*. (2003) who substantiated that irrigation at 80% gave maximum WUE. As far as, sowing methods are concerned, bed sowing gave the highest WUE (2.35 and 2.50) than other sowing methods (ridge and flat sowing) during both years of experimentation. Higher WUE in bed sowing was attributed to efficient utilization of applied water in beds with more water holding capacity and ultimately produced higher seed cotton yield than rest of the sowing methods under study. However, these results are in contradiction with the findings of Ali and Ehsanullah (2007) who observed the highest WUE in flat planting with alternate earthing up resulted in higher seed cotton yield.

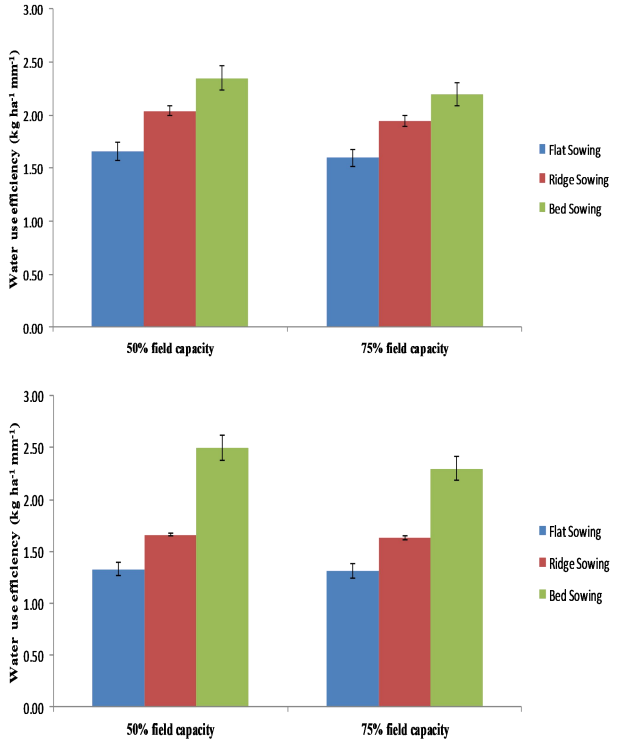

Figure 3. Effect of irrigation levels and sowing methods on water use efficiency during 2010 (a) and during 2011(b)

***Water productivity (WP) (kg ha^{-1} m^{-3})*:** Significant variations in WP were observed (due to what) (Fig. 4). The interactive effect of irrigation levels and sowing methods was found non-significant. Irrigation levels significantly affected WP of cotton plants. The highest WP (0.50) was recorded at 50% FC level followed by 75% FC during 2010 and 2011, might be ascribed to less availability of water at 50% FC than 75% FC and because of less chances of wastage of surplus water and maximum amount of water applied became the part of crop yield.

Furthermore, bed sowing showed the highest WP (0.50 and 0.40) followed by ridge sowing, while minimum WP (0.18 and 0.23) was noted in flat sowing during 2010 and 2011. Higher water productivity in bed sown cotton was due to more yields obtained in bed sown cotton, less wastage of water and higher water use efficiency as compared to other treatments. In bed sown cotton water holding capacity was more, total amount of water applied was less which ultimately leads to highest water productivity. These results are in line with the findings of Shukla *et al.* (2013) and Vories *et al.* (2007) who reported that significantly higher water use efficiency (WUE) and crop productivity were produced under optimum irrigation application. Basal *et al.* (2009) also reported that water stress improved the WUE and water productivity

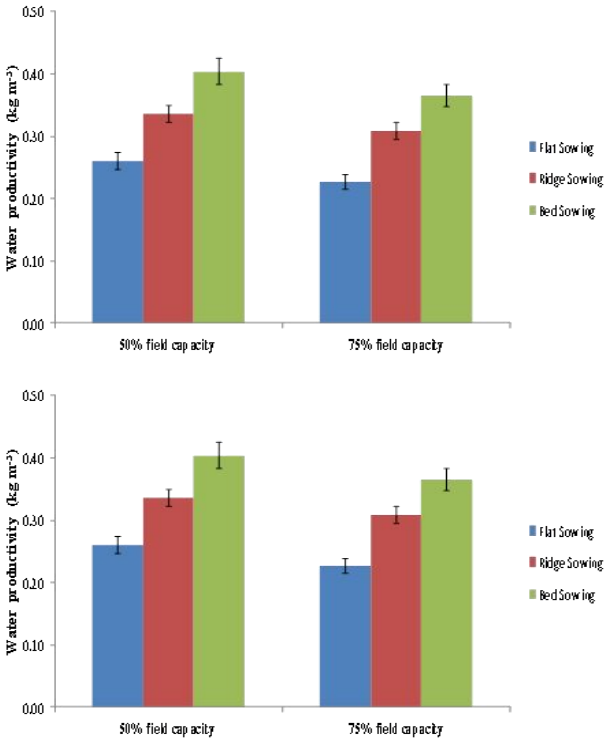

Figure 4. Effect of irrigation levels and sowing methods on water productivity during 2010 (a) and during 2011(b)

Economic analysis:

***Net return*:** In first growing season overall environment during the whole crop period was unfavourable due to heavy monsoon rainfall which ultimately affected crop yield. While during second growing season (2011) the environment was favourable. Timely rainfall at critical stages, optimum temperature and more sunny days well supported the growth of cotton that's why the overall yield in 2011 was more than 2010. During 2010 bed sowing at

75% field capacity (FC) gave maximum net return of Rs. 82574/- while during 2011 it was Rs. 43336/- in the same treatments. Although yield during 2011 was more as compared to first year yet decrease in net returns during second year was due to lower cotton market prices than first year. No doubt, the yields of bed sown plots at 75% FC level were statistically higher due to which net return was more than rest of the treatments. During 2010 overall cotton production was lower due to more rainfall and flood occurrence in the country; due to lesser availability of cotton than demand its market value was raised. During next growing season environment was favourable, overall cotton production was higher than the previous year. So, for obtaining more net returns it was recommended that cotton should be sown on beds with 75% FC levels, because it gave maximum net return of Rs. 82574/- and Rs. 43336/- during 2010 and 2011, respectively. In this way farmers can get more returns of their cost applied on cotton production.

***Benefit cost ratio*:** Benefit cost ratio is another important economic parameter in which farmers are interested to see the gain in net returns with a given increase in total costs. During 2010 in bed sowing cotton at 75% FC gave maximum BCR of 1.54 which was followed by ridge planting (1.37 BCR). Whereas, flat sown cotton at 75% FC produced minimum BCR of 1.31. Similar trend was noted in case of 50% FC level. Thus, bed sowing gave the maximum BCR of 1.13; it was followed by ridge sowing method with BCR of 1.04. The minimum BCR (1.01) was found in flat sown cotton at 50% FC level (Table 6a). During 2011, similar trend was found but benefit cost ratio was low due to price differences. The highest BCR (1.28) was observed at 75% FC level in bed sown cotton. It was followed by ridge planted cotton giving 1.21 BCR. Minimum benefit cost ratio of 1.10 was observed in flat sown cotton at 75% FC level, while at 50% FC the highest BCR (1.00) was obtained in bed sown cotton. It was followed by ridge planting producing 0.96 BCR and minimum BCR of 0.89 in flat sown cotton (Table 6b). Comparison showed that during both the growing seasons' bed planting at 75% FC gave maximum benefit cost ratio compared with rest of the treatments. Higher BCR was due to greater net returns obtained in these plots.

***Conclusion*:** It is concluded from the study that higher water use efficiency and water productivity can be achieved with bed sowing maintaining field capacity of 75% . Therefore, bed sowing may be adopted to save water and obtain higher water use efficiency as compared to ridge and flat sowing of cotton. Economic analysis affirmed bed sowing as most economical and productive than the other sowing methods under study.

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Table 6a. Effect of irrigation levels and sowing methods on total cost, net return and benefit-cost ratio of cotton planted during 2010

Treatment		Yield (kg ha^{-1})	Value (Rs ha^{-1})	CSV	GI (Rs ha^{-1})	TC (Rs ha^{-1})	NR (Rs ha^{-1})	BCR
50%	Flat sowing	1370.4	137040	10000	147040	145528	1512	1.01
FC	Ridge sowing	1443.8	144380	10000	154380	147895	6485	1.04
	Bed sowing	1574.1	157410	10000	167410	148547	18863	1.13
75%	Flat sowing	1843.2	184320	10000	194320	148392	45928	1.31
FC	Ridge sowing	1966.1	196610	10000	206610	151007	55603	1.37
	Bed sowing	2250.0	225000	10000	235000	152426	82574	1.54

TC= Total cost, GI= Gross income, CSV= Cotton sticks value, NR= Net return, BCR= Benefit cost ratio, Seed cotton price = Rs. 4000 per 40 kg Cotton sticks value = Rs. 10000 per ha

Table 6b. Effect of irrigation levels and sowing methods on total cost, net return and benefit-cost ratio of cotton planted during 2011

Treatment		Yield (kg ha^{-1})	Value (Rs ha^{-1})	CSV	GI (Rs ha$^{-1)}$	TC (Rs ha^{-1})	NR (Rs ha^{-1})	BCR
50%	Flat sowing	1507.4	120592	10000	130592	146763	-16171	0.89
FC	Ridge sowing	1677.2	134176	10000	144176	150012	-5836	0.96
	Bed sowing	1763.0	141040	10000	151040	150441	599	1.00
75%	Flat sowing	1926.5	154120	10000	164120	149359	14761	1.10
FC	Ridge sowing	2190.1	175208	10000	185208	153077	32131	1.21
	Bed sowing	2339.5	187160	10000	197160	153824	43336	1.28

FC= Field Capacity, TC= Total cost, GI= Gross income, CSV= Cotton sticks value, NR= Net return, BCR= Benefit cost ratio, Seed cotton price = Rs. 3200 per 40 kg Cotton sticks value = Rs. 10000 per ha

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