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Influence of climate-resilient conservation technologies on yield and economics of sugarcane cultivation in semi-arid region of Maharashtra

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Abstract
The field experiment was conducted at Mahatma Phule Krishi Vidyapeeth (MPKV), Rahuri during 2020-21 and 2021-22 on medium black soil with moderately alkaline in soil reaction (8.22), low organic carbon (0.39%), low available nitrogen (245.64 kg/ha), medium in phosphorus (22.25 kg/ha) and high in potassium (454.40 kg/ha) to study the influence of climate-resilient conservation technologies on yield and economics of sugarcane cultivation in semi-arid region of Maharashtra. The experiment comprising of three levels of thrash management practices and four levels of irrigation was laid out in strip-plot design with three replications. Trash management with shredder machine (TMSM) has recorded significantly higher number of millable canes/clump (10.34), number of millable canes/ha (103412), weight of single cane (1.99 kg), number of internodes/cane (19.59), length of internodes (15.99 cm), girth of internodes (3.38 cm), cane yield (229.18 t/ha) as compared to farmer's practice. Among different irrigation method, surface drip irrigation with inverted micro-sprinkler irrigation recorded significantly higher number of millable canes/clump (10.78), number of millable canes/ha (107800), weight of single cane (2.06 kg), number of internodes/ cane (21.16), length of internodes (16.87) and girth of internodes (3.49 cm) as compared to furrow irrigation practice. The interaction effect between trash management and irrigation methods were found to be non-significant.

Keywords: Climate-resilient, trash-management, shredder machine, trash burning and drip-irrigation

1. Introduction

Sugarcane (*Saccharum officinarum* L.) is a versatile crop that provides sugar, biofuel, fiber and manure besides many byproducts. The crop is grown mainly to manufacture sugar and for making guru and khandasari. It is one of the important commercial crops of sugar in the world. Globally sugarcane is cultivated over an area of 26 Mha with a production of 1870 MT, with Brazil producing 40 percent of the world total, India with 20 percent, and China producing 6 percent and the average worldwide yield of sugarcane crops 71 tonnes per hectare, led by Peru with 123 tonnes per hectare (Anon., 2022) [41]. India is being the second-largest producer of sugar after Brazil and the world's biggest consumer of sweeteners (22.50 MT). In India, sugarcane is grown under diverse agro-climatic situations covering an area of 5.30 m ha producing 366 MT of sugarcane with productivity of 69.02 t ha^{-1} (Anon., 2017) [41] accounting for over one-fifth of the total area under cane in the world. Uttar Pradesh accounts for nearly half of the total cane area in the Nation followed by Maharashtra (13%), Tamil Nadu (12% each), Karnataka (9%) and Andhra Pradesh (6%). Sugarcane is an important cash crop of Maharashtra state and is influencing its economy, having a 1.054 M ha area under sugarcane with a production of 89.42 MT and average productivity of 84.26 t ha^{-1} (Anonymous, 2015a) [6]. The state has established its supreme position in the Indian sugar industry by contributing 104.37 lakh tons to total sugar production (3483.8 lakh tons). There are 172 sugar factories in Maharashtra state out of a total of 532 in India (Anonymous, 2015b) [7] highlights the importance of sugarcane cultivation and the sugar industry in Maharashtra. In the state, 80 to 84 percent of the agriculture is rainfed and one-third of the state falls under the semi-arid climatic zone. It has been reported that deficient rainfall once in every 5 years and drought conditions once every 8-9 years and also the irrigation level is only 16 percent as compared to the national average of 42 percent (Kelkar, 2014) [17] which is due to the lack of assured water supply. Hence it is very difficult to cultivate high water-consuming crops like sugarcane with the use of conventional methods of irrigation methods in the state as in the surface method, 19-23 percent of water is lost due to percolation, 30-35 percent losses are in conveyance.

The depleting soil health and crop productivity in the sugarcane cultivating area of Ahmednagar district of Maharashtra is a major concern because of reduced yields. It is strongly influenced by human management practices like burning trash after the harvest of sugarcane and faulty irrigation water management. In recent years sugarcane is facing serious problems in terms of sustainability and it is affected by multiple factors like climate change (trash burning), scarcity of water, unavailability of Labour and declining soil health and quality etc. Sugarcane being a long-duration crop, its normal irrigation water requirement is relatively higher as compared to other crops, which ranges from 2000-2500 mm depending on crop yield, soil and climate (Arulkar *et al.*, 2004; Rajegowda *et al.*, 2004) [10, 30]. It has been worked out that to produce one tonnes of cane, about 200-250 tonnes of water are required. The availability of water for sugarcane crops is almost static and has even decreased in some cane-growing areas over the years. There is an imperative need to optimize the production of sugarcane by efficiently managing water resources and their reliability (Afghan, 2003) [1]. There is a linear relationship between the growth rate of sugarcane and the optimum soil moisture regimes because vegetative growth is of economic importance in this crop (Aguilera *et al.*, 1999) [2].

Providing optimum soil moisture conditions throughout its growing period is of paramount importance to realize a higher yield. Water is a prime resource and at the same time, it is overexploited resource due to the rapid commercialization of agriculture and urbanization. The groundwater in the country has been exploited to the tune of 80-85 percent of its potential. The conventional irrigation and fertilizer application methods in sugarcane lead to considerable loss of water and leaching of mobile nutrients (50 percent loss is quite typical) resulting in lower productivity. Subsurface drip irrigation (SDI) system is still more ideal for a wide range of crops and can be defined as the application of water below the soil surface through the emitters, with discharge rates generally in the same range as surface drip irrigation (Anon., 1999) [42] as it has got many advantages like reduced evaporation losses results in higher water use efficiency, uniform water application, better growth and crop yield. Most recently inverted sprinkler irrigation system was introduced in the agriculture system which is similar to a micro-sprinkler irrigation system scheduled to apply water near the soil surface during the warmest period of plant growth can be used to enhance evaporative cooling (Evans, 2004 [14]; Caravia *et al.*, 2017 [11]; Deligios *et al.*, 2019) [12]. The amounts of water applied can be small as it is not intended to wet the rooting zone but to increase evaporative cooling and reduce the vapors pressure deficit of the microclimate around crops. Keeping these things in view, the present study on Influence of Climate-Resilient Conservation Technologies on Yield and Economics of Sugarcane Cultivation in Semi-arid region of Maharashtra was undertaken.

2. Material and Methods

2.1 Study location

The field experiment was conducted at centre for advanced agricultural science and technology-climate smart agriculture and Water Management (CAAST-CSAWM) Research Farm, Mahatma Phule Krishi Vidyapeeth (MPKV), Rahuri District, Ahmednagar. Geographically the research farm lies between latitude 19º 19' 26" N and longitude 74° 39' 25" E, at an elevation of 465 m above MSL in the scarcity zone of Western Maharashtra which comes under the Western Plateau and Hilly Region of India.

2.2 Experimental design and field management

The experiment was laid out in a strip plot design comprised of three main plot treatments, four sub-plot treatments and replicated thrice. There were 12 treatment combinations involving three thrash management practices (T1: Farmers Practice, T2: Keeping Trash as it is in the field, T3: Trash Management with Shredder Machine) and four irrigation methods (I1: Surface Irrigation, I2: Surface Drip Irrigation, I3: Sub-Surface Drip Irrigation, I4: Surface Drip Irrigation + Inverted Micro Sprinkler).

2.3 Weather of experimental site

Climatologically, the study area belongs to semi-arid tropics with annual rainfall ranging from 307 to 619 mm. The average annual rainfall of 586.15 mm was mostly concentrated during the monsoon months from June to September. The rainfall distribution is found to be erratic and uncertain. The number of rainy days varied from 19 to 43. The mean annual maximum temperature was 32.4 ℃ and it ranged from 32.0 ℃ to 43.0 ℃ the mean annual minimum temperature is 17.5 ℃ and it ranged from 6.1 ℃ to 24.0 ℃. The mean morning (RH I) and evening (RH II) relative humidity is 77.36 percent and 39.93 percent, respectively, which ranged from 28.9 to 92.9 percent.

2.4 Soil characteristics

The soil of the experimental field was medium black Vertic Haplustept (Inceptisol) and clay in texture. The average depth of soil was 70 cm which was sufficient for the better stand of the crop as most of the active roots of sugarcane lie within this particular depth. The bulk density of the soil was 1.32 cm^{-3} and the percent moisture held at FC, PWP and available water holding capacity of the soil was 40.24, 18.27 and 21.97 percent, respectively. All these physical properties of soil indicated that the soil was physically sound to support the satisfactory growth of sugarcane. The soil was moderately alkaline in reaction with pH 8.22 and EC ($0.27 dSm^{-1}$). It was low in available N (245.64 kg ha^{-1}), available P was medium (22.25 kg ha^{-1}) and very high in available K (454.40 kg ha^{-1}).

2.6 Cane yield: All the canes in the net plot were cut close to the ground level. The green tops and trash were removed and cane yield per plot was recorded at harvest and expressed as tonnes per hectare.

2.5 Profitability

Profitability parameters viz. cost of cultivation, gross returns, net returns and B: C were calculated by using standard formulas and methodology. The price of inputs that were prevailing at the time of their use was considered to work out the cost of cultivation. The following items were considered for working out the treatment wise cost of cultivation by considering the material input like the seed, manure, fertilizers, plant protection chemicals, *etc.* and the labour input for all the operations. The net returns per hectare was calculated by deducting the cost of cultivation from the gross returns. B: C was worked out by using the following formula.

$$\text{Benefit: Cost ratio} = \frac{\text{Gross returns (₹ ha}^{-1})}{\text{Total cost of cultivation (₹ ha}^{-1})}$$

2.6 Statistical analysis

The experimental data collected were subjected to statistical analysis using Fisher's method of analysis of variance as outlined by Gomez and Gomez (1984) [43]. The level of significance used in 'F' and 't' tests was p = 0.05. Critical difference values were calculated, wherever 'F' test was found significant.

3. Results and Discussion

3.1 Yield attributing characters

Trash management with shredder machine (TMSM) has recorded significantly higher number of millable canes clump^{-1} (10.34), number of millable canes ha^{-1} (103412), weight of single cane (1.99 kg), number of internodes cane^{-1} (19.59), length of internodes (15.99 cm), girth of internodes (3.38 cm) followed by, treatment T_2. The lowest number of millable canes clump^{-1} (9.57), number of millable canes ha^{-1} (94921), weight of single cane (1.85 kg), number of internodes cane^{-1} (16.83), length of internodes (14.80 cm), girth of internodes (3.14 cm) recorded with treatment T_1 i.e., trash removal (farmer practice) at harvest (Table 1). The trash mulching significantly reduced the direct heating of plant and soil, therefore, improving moisture regime and nutrient uptake which in turn resulted into a greater number of millable canes per clump (Ahmed *et al.*, 2014) [35]. Appropriate moisture in the root zone increased nutrient availability which resulted into the increase in yield parameters. It might be due to conservation of more soil moisture, maintenance of low soil temperature and suppression of weed growth under trash mulching (Tiwari, 2006) [38]. The mulch also helps in reserving the moisture by reducing the evaporation from the soil (Ahmed *et al.*, 2014) [35].

Yield parameters also differed significantly among irrigation methods. Among irrigation method treatment received I_4 i.e., surface drip irrigation with inverted micro-sprinkler irrigation recorded significantly higher number of millable canes clump^{-1}, number of millable canes ha^{-1}, weight of single cane, number of internodes per cane, length of internodes and girth of internodes at harvest (10.78, 107800, 2.06 kg, 21.16, 16.87 cm and 3.49 cm) followed by, treatment I_3 however, treatment I_2 and I_3 are on far with each other. The lowest (8.82, 88166, 1.82 kg, 15.15, 15.37 cm and 3.09 cm in plant crop and 8.58, 85277, 1.80 kg, 14.70, 14.78 cm and 3.04 cm in ration) recorded with treatment I_1 i.e., surface irrigation (furrow). The interaction effect between trash management and irrigation method did not differ significantly with respect to yield parameters. Elongation of cane by increasing internodes number and enhancing girth of cane need to be focused. Cane weight is function of both these biometric parameters. Controlling canopy temperature by using inverted modular sprinklers can help reduce microclimatic stress and more accumulation of photosynthetic sugars in cane plant leading positive effect on cane weight and yield. Sugarcane with surface drip fertigation with inverted sprinkler has recorded higher number of millable canes clump^{-1}, number of millable canes ha^{-1}, weight of single cane, number of internodes per cane, length of internodes and girth of internodes compared to furrow irrigation wherein nutrients were applied directly to soil. Increased photosynthetic activities leading to faster cell division increasing the girth of internodes. Frequent irrigations increased number of millable canes as it increased the number of tillers. These results are in agreement with Hossain *et al.* (2009) [16] and Rahman *et al.* (2012) [28]. Appropriate moisture in the root zone increased nutrient availability which resulted into better and early conversion of tillers to millable canes otherwise have resulted in excess production of tillers in the early stages and would have diverted the plant nutrients unnecessarily for unproductive purpose. These results are in line of findings of Gurusamy *et al.* (2011) [15] and Seema *et al.* (2014) [35]. The characteristic effect of water stress on sugarcane in the form of reduced cane girth was earlier reported by Rao *et al.* (2000) [32]. He noted that the reduction in girth of cane was due to water stress at germination and tillering stages.

Table 1: Yield contributing characters of sugarcane as influenced by Climate Resilient Conservation Technologies (Pooled data)

Treatments	Number of millable canes clump^{-1}	Average cane weight (kg)	Number of millable canes ha^{-1}	Number of internodes plant^{-1}	Length of internode plant^{-1} (cm)	Girth internodes plant-1 (cm)
Trash management (T)						
T_1 : Trash removal	9.57	1.85	94921.33	16.83	15.24	3.14
T_2 : Keeping trash	10.24	1.96	102412.50	19.08	15.96	3.31
T_3:TM with SM	10.34	1.99	103412.50	19.59	16.31	3.38
S.Em±	0.16	0.02	882.12	0.55	0.24	0.01
CD at 5%	0.62	0.09	3463.63	2.17	NS	0.05
Irrigation methods (I)						
I_1 : SI	8.70	1.81	85995.11	14.93	15.07	3.07
I_2 : SDI	10.31	1.92	103133.33	18.75	15.59	3.26
I_3 : SSDI	10.41	1.94	104066.67	19.17	15.82	3.29
I_4 : SDI+IMS	10.78	2.06	107800.00	21.16	16.87	3.49
S.Em±	0.19	0.03	1102.94	0.33	0.20	0.02
CD at 5%	0.65	0.09	3816.68	1.15	0.68	0.05
Interaction (T×I)						
T_1I_1	8.35	1.68	80535.33	13.37	14.67	2.85
T_1I_2	9.56	1.89	95600.00	16.98	15.05	3.21
T_1I_3	9.68	1.91	96800.00	17.45	15.08	3.23
T_1I_4	10.68	1.93	106750.00	19.52	16.15	3.27
T_2I_1	8.76	1.87	87550.00	15.45	15.11	3.16
T_2I_2	10.65	1.93	106500.00	19.44	15.41	3.26
T_2I_3	10.74	1.94	107400.00	19.76	16.13	3.29
T_2I_4	10.82	2.09	108200.00	21.69	17.21	3.54
T_3I_1	8.99	1.88	89900.00	15.96	15.45	3.19
T_3I_2	10.73	1.95	107300.00	19.85	16.31	3.31

T_3I_3	10.80	1.98	108000.00	20.31	16.26	3.35
T_3I_4	10.85	2.16	108450.00	22.26	17.24	3.66
S.Em±	0.32	0.05	1874.89	0.74	0.38	0.03
CD at 5%	NS	NS	NS	NS	NS	0.05

3.2 Cane yield, green top yield and commercial cane sugar

Yield in any crop is dependent upon the photosynthetic source it can build up. A sound source in terms of plant height, number of tillers to support and hold the leaves are logically able to increase the total dry matter and later lead to higher yield. Dry matter production and crop growth rate are important for determination of total yield of crop (Donald, 1962) [13]. Trash management significantly differed with the cane yield, green top yield and commercial cane sugar yield under ratoon cane and pooled mean However, Plant cane is not differed significantly with trash management (Table 2).

Among trash management treatment received T_3 i.e., trash management with shredder machine (TMSM) has recorded significantly higher cane yield (ratoon cane: 225.69 t ha^{-1}; pooled 229.18 t ha^{-1}), green top yield (ratoon cane: 18.47 t ha^{-1}; pooled mean: 20.34 t ha^{-1}) and CCS yield (ratoon cane: 26.75 t ha^{-1}; pooled mean: 27.50 t ha^{-1}) followed by, treatment T_2. The lowest cane yield (ratoon cane: 192.84 t ha^{-1}; pooled 196.83 t ha^{-1}), green top yield (ratoon cane: 15.78 t ha^{-1}; pooled mean: 17.48 t ha^{-1}) and CCS yield (ratoon cane: 21.22 t ha^{-1}; pooled mean: 23.22 t ha^{-1}) recorded with treatment T_1 i.e., trash removal (farmer practice). Cane yield of ratoon crops significantly increased in plots where shredded trash retained compared to plots with trash removal/burning over that of plant cane. Improvement in soil fertility due to shredded fine particles of trash might have been responsible for such an effect (Yadav *et al.*, 1994) [39]. Commercial cane sugar yield increased with trash mulching observed by Rana *et al.* (2002) [31]; Mathew *et al.* (2003) [20]. Sugar yield improved significantly from 9.01 in no mulch to 9.68 at 5 t/ha to 11.06 t/ha at 10 t/ha of mulch application (Sanjeev Kumar *et al.*, 2015) [34]. Mulching of sugarcane trash also showed positive and significant impact on cane yield and sugar recovery (Minhas *et al.*, 2010) [22] and incorporation of residue also shows higher stalk population, higher cane yield and higher sugar yield (Kennedy and Arceneaux, 2006) [18]. The higher production of sugarcane led to the higher sugar production in mulch treatment of subsurface drip irrigation. These results are confirmed with the findings of Pires *et al.* (2014) [26] and Allen and Selim (2012) [4]. Mathew and Varughese (2005) [21] found similar results of trash mulching on cane yield. Mulching with chopped trash along with addition of 25 kg N/ha after one intercultural recorded the highest mean cane yield (72.4 t/ha) and the number of millable canes (81.3 thousand per ha) observed by Rana *et al.* (2002) [31].

Irrigation method significantly differed the cane yield, green top yield and CCS yield, among irrigation method treatment received I_4 i.e., surface drip irrigation with inverted micro-sprinkler irrigation recorded significantly higher cane yield (plant cane: 251.58 t ha^{-1} ; ratoon cane: 243.28 t ha^{-1}; pooled 247.43 t ha^{-1}), green top yield (plant cane: 24.02 t ha^{-1} ; ratoon cane: 19.91 t ha^{-1}; pooled mean: 21.96 t ha^{-1}) and CCS yield (plant cane: 31.19 t ha^{-1} ; ratoon cane: 29.84 t ha^{-1}; pooled mean: 30.51 t ha^{-1}) followed by, treatment I_3 however, treatment I2 and I3 are on far with each other. The lowest cane yield (plant cane: 177.50 t ha^{-1}; ratoon cane: 171.66 t ha^{-1}; pooled 174.58 t ha^{-1}), green top yield (plant cane: 16.94 t ha^{-1}; ratoon cane: 14.05 t ha^{-1}; pooled mean: 15.50 t ha^{-1}) and CCS yield (plant cane: 22.32 t ha^{-1}; ratoon cane: 18.62 t ha^{-1}; pooled mean: 20.47 t ha^{-1}) recorded with treatment I_1 i.e., surface irrigation (furrow).

The interaction effect between trash management and irrigation method did not differ significantly cane yield, green top yield and CCS yield. The treatment received T_3I_4 which is TMSM and SDI with IMS recorded highest cane yield (plant cane: 251.58 t ha^{-1} ; ratoon cane: 243.28 t ha^{-1}; pooled 247.43 t ha^{-1}), green top yield (plant cane: 24.02 t ha^{-1} ; ratoon cane: 19.91 t ha^{-1}; pooled mean: 21.96 t ha^{-1}) and CCS yield (plant cane: 31.19 t ha^{-1} ; ratoon cane: 29.84 t ha^{-1}; pooled mean: 30.51 t ha^{-1}). The lowest interaction effect recorded withT_1I_1 i.e., trash removal and surface irrigation.

Cane yield is a manifestation of yield contributing characters like number of millable canes, cane length and cane girth. The higher cane yield in drip might be due to higher number of millable canes, cane length, cane girth, cane weight and number of internodes cane^{-1}. These might have resulted in higher cane yield in drip fertigation. The results of the present study were in corroboration with results of Thimmegowda (1985) [37] and Mahesh (2009) [19]. The higher yield also might be due to higher NPK uptake due to maintenance of optimum soil moisture. The application of micro-sprinkler cooling system increased growth, yield and yield contributing character including juice quality in both seasons, which agrees with the results of Mupambi *et al.* (2017) [23], Caravia *et al.* (2017) [11] and Zhipeng *et al.* (2021) [40]. Because high temperature stress affects photosynthetic activity in source tissues, it subsequently reduces the supply of soluble sugars to sink tissues (Roth *et al.*, 2015) [33]. The two-year results here showed that microclimatic stress reduced by the micro-sprinkler irrigation, resulting in enhanced crop growth and yield. In contrast, control plots did not appear to be consistently affected by evaporative cooling. In general, the productivity and juice quality results of this study are in agreement with those reported in other studies that have positive effects on crops such as tomato (Zhang *et al.*, 2017) [44], globe artichoke (Deligios *et al.*, 2019) [12] and grape (Caravia *et al.*, 2017) [11] when applying a micro-sprinkler cooling system. The two-year results here showed that the yield significantly increased (39-42%) when compared to the control. Evaporative cooling can be effective in reducing elevated Ta stresses and ameliorating drought stresses on crops. Micro-sprinkler cooling systems scheduled to apply water near the soil surface during the warmest period of plant growth can be used to enhance evaporative cooling (Evans, 2004 [14]; Caravia *et al.*, 2017 [11]; Deligios*et al.*, 2019) [12]. The amounts of water applied can be small as it is not intended to wet the rooting zone but to increase evaporative cooling and reduce VPD of the microclimate around crops.

Higher cane yield was attributed to higher plant height, number of tillers and dry matter accumulation. Sugarcane under drip fertigation recorded higher leaf area. This might have helped in higher dry matter production and accumulation due to higher photosynthetic activity resulting in production of higher photosynthesis leading to better growth parameters. This is in conformity with Nogle and Fritz (1982) [24], Thimmegowda (1985) [37], Rajanna and Patil (2003) [29] and Prabhakar *et al.* (2014) [27]. The higher yields in drip may also be resultant of required and continuous availability of soil moisture which was held at near field capacity. Furrow irrigation, on the contrary, resulted in considerable wastage of water and plant nutrients due to deep percolation below root zone and set a chain of undesirable hazards such as poor soil aeration and imbalanced soil water-nutrient environment leading to the declined yield. Similar findings were reported by Anusha (2015) [9]. In furrow irrigation moisture availability was maximum only a day after irrigation followed by, intermittent stress caused between two irrigations. This might have affected plant growth with furrow irrigation than with drip irrigation. The above results were in conformity with the work of Pawar *et al.* (2014) [25] who have also reported that in drip irrigation soil moisture will be around field capacity throughout the crop growth period. The intermittent stress under cane with furrow irrigation might have affected cell division and cell elongation which are very sensitive to moisture stress (Nogle and Fritz, 1982) [24]. The plants having optimum moisture content and having higher turgidity led to maximum stomatal aperture opening with minimal stomatal resistance.

Table 2: Cane yield, top yield and CCS yield of sugarcane as influenced by Climate Resilient Conservation Technologies

Treatment	Cane yield (t ha^{-1})			Green top yield (t ha^{-1})			CCS yield (t ha^{-1})		
	Plant cane	Ratoon cane	Pooled mean	Plant cane	Ratoon cane	Pooled mean	Plant cane	Ratoon cane	Pooled mean
Trash management (T)									
T_1 : Trash removal	200.82	192.84	196.83	19.17	15.78	17.48	25.22	21.22	23.22
T_2 : Keeping trash	226.57	219.77	223.17	21.63	17.99	19.81	26.83	25.75	26.29
T_3 : TM with SM	232.67	225.69	229.18	22.21	18.47	20.34	28.26	26.75	27.50
S.Em±	6.57	6.34	6.46	0.63	0.52	0.57	0.58	0.75	0.65
CD at 5%	NS	24.91	25.35	NS	2.04	2.25	NS	2.94	2.57
Irrigation methods (I)									
I_1 : SI	177.50	171.66	174.58	16.94	14.05	15.50	22.32	18.62	20.47
I_2 : SDI	223.02	215.67	219.34	21.29	17.65	19.47	26.43	24.32	25.37
I_3 : SSDI	227.98	220.46	224.22	21.76	18.04	19.90	27.14	25.51	26.33
I_4 : SDI+IMS	251.58	243.28	247.43	24.02	19.91	21.96	31.19	29.84	30.51
S.Em±	3.94	3.81	3.87	0.38	0.31	0.34	0.69	0.61	0.63
CD at 5%	13.63	13.17	13.40	1.30	1.08	1.19	2.38	2.11	2.17
Interaction (T×I)									
T_1I_1	159.54	153.21	156.37	15.23	12.54	13.88	23.67	15.78	19.72
T_1I_2	202.61	194.56	198.58	19.34	15.92	17.63	24.69	20.58	22.64
T_1I_3	208.23	199.96	204.10	19.88	16.37	18.12	24.75	22.13	23.44
T_1I_4	232.89	223.64	228.27	22.23	18.31	20.27	27.78	26.40	27.09
T_2I_1	183.40	177.90	180.65	17.51	14.56	16.03	20.58	19.75	20.16
T_2I_2	230.78	223.85	227.32	22.03	18.32	20.18	26.38	25.31	25.85
T_2I_3	234.58	227.54	231.06	22.39	18.62	20.51	27.89	26.77	27.33
T_2I_4	257.52	249.79	253.66	24.58	20.45	22.51	32.46	31.15	31.81
T_3I_1	189.56	183.87	186.72	18.10	15.05	16.57	22.73	20.32	21.52
T_3I_2	235.67	228.60	232.13	22.50	18.71	20.60	28.21	27.07	27.64
T_3I_3	241.12	233.89	237.50	23.02	19.14	21.08	28.78	27.62	28.20
T_3I_4	264.32	256.39	260.36	25.23	20.99	23.11	33.32	31.98	32.65
S.Em±	8.83	8.53	8.68	0.84	0.70	0.77	1.18	1.18	1.15
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS

3.3 Economics

Economics of sugarcane varied by trash management and irrigation methods with respect to gross returns, which was a result of prices and yield of marketable produce, cost of cultivation which varies in relation to different input used, and in turn net returns and B: C ratio. Higher cost of cultivation, gross returns, net returns and B: C ratio was observed for surface drip irrigation with inverted sprinkler in both seasons (Rs. 171677, 666930, 495253 ha^{-1} and 3.88 and Rs. 136498, 645899, 509401 ha^{-1} and 4.73 in plant and ratoon crops, respectively). Higher cost of cultivation in drip irrigation was due to initial cost on drip system installation. Higher gross returns, net returns, and B: C ratio obtained in drip irrigated sugarcane was due to higher cane yield realized (Table 3). Trash management with shredder machine has recorded higher cost of cultivation, gross returns, net returns and B: C ratio (Rs.161339, 616799, 455460 ha-1 and 3.82 and Rs. 133350, 599198, 465848 ha^{-1} and 4.48 in plant and ratoon crops, respectively). Though the drip irrigation in sugarcane involves additional investment to install drip unit, the extra cost incurred will be returned as higher profit due to increased yields to a greater extent. The highest B: C ratio was obtained by treatment combination (T_3I_3) plot of surface drip irrigation with inverted sprinkler and trash management with shredder machine (4.08 and 4.85 in plant and ratoon cane, respectively) due to highest yield. These results are in line of Tiwari 1998 [45], Kumar and Imtiyaj 2007 [46], Danawale *et al*. 2012 [47], Gururaj Kombali 2016 [48] and *et al*. 2017 [49].

Table 3: Economics of sugarcane cultivation as influenced by climate resilient conservation technologies

Treatment	Plant cane				Ratoon cane			
	Cost of cultivation (Rs./ha)	Gross returns (Rs./ha)	Net returns (Rs./ha)	B:C Ratio	Cost of cultivation (Rs./ha)	Gross returns (Rs./ha)	Net returns (Rs./ha)	B:C Ratio
Trash management (T)								
T_1 : Trash removal	161339	532365	371026	3.30	128350	512001	383652	3.98
T_2 : Keeping trash	161339	600635	439297	3.72	130350	583495	457146	4.47
T_3:TM with SM	161339	616799	455460	3.82	133350	599198	465848	4.48
Irrigation methods (I)								
I_1 : SI	161583	470553	308970	2.91	123500	455756	332256	3.69
I_2 : SDI	154761	591218	436457	3.82	127800	572607	444807	4.48
I_3 : SSDI	157333	604365	447032	3.84	129600	585331	455731	4.52
I_4 : SDI+IMS	171677	666930	495253	3.88	136498	645899	509401	4.73
Interaction (T×I)								
T_1I_1	161583	422941	261358	2.62	122500	406763	284263	3.32
T_1I_2	154761	537110	382349	3.47	126800	516565	389765	4.07
T_1I_3	157333	552016	394683	3.51	128600	530901	402301	4.13
T_1I_4	171677	617391	445714	3.60	135498	593776	458278	4.38
T_2I_1	161583	486193	324610	3.01	120500	472319	351819	3.92
T_2I_2	154761	611791	457030	3.95	124800	594333	469533	4.76
T_2I_3	157333	621872	464539	3.95	126600	604126	477526	4.77
T_2I_4	171677	682686	511009	3.98	133498	663204	529706	4.97
T_3I_1	161583	502525	340942	3.11	127500	488185	360685	3.83
T_3I_2	154761	624752	469991	4.04	131800	606924	475124	4.60
T_3I_3	157333	639206	481873	4.06	133600	620965	487365	4.65
T_3I_4	171677	700712	529035	4.08	140498	680717	540219	4.85

4. Conclusions

Growing sugarcane under drip irrigation with inverted-sprinkler irrigation has influence significantly yield of sugarcane and recorded highest B: C ratio among other treatments it is due to higher cane yield achieved. The evaporative cooling effect created by the inverted-sprinkler reduced the microclimatic stress thereby this favourable growing condition effected on sugarcane cultivation and trash management with shredder machine helps to avoid burning of trash left after the harvest of sugarcane besides improved the soil fertility status.

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