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Influence of moisture stress management practices on growth, yield and quality of sugarcane

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ABSTRACT

An experiment was conducted at Main Sugarcane Research Station, Junagadh Agricultural University, Kodinar, Gujarat (India), during 2014-15, 2015-16, and 2016-17 to identify cost-effective agro-techniques to improve sugarcane growth, yield, and quality under water-deficit conditions, particularly during the formative stage. The experiment followed a randomized block design with four replications. Treatments included two mulching levels (no mulch and trash mulch at 5 t/ha) and four agrochemical foliar spray levels (Control, KCl @ 2.5%, urea @ 2.5%, and urea + KCl @ 2.5% each). Sugarcane variety CoN 91132 was planted in rows, spaced 90 cm apart. The water-deficit condition was imposed from 60 to 150 days after planting. Pooled data from three years showed that trash mulch @ 5 t/ha produced significantly higher cane yield (100.05 t/ha) than no mulch (88.10 t/ha). Similar improvements were observed in the number of millable canes, commercial cane sugar, millable cane height, stalk diameter and single cane weight. Foliar application of urea and KCl, each @ 2.5%, produced significantly higher cane yield (105.53 t/ha), number of millable canes, commercial cane sugar, millable cane height, and single cane weight than the control. Among the treatment combinations, $M_2 \times S_4$ (trash mulching @ 5 t/ha and foliar spray of urea + KCl each @ 2.5 %) produced the highest cane yield (109.68 t/ha). It was significantly superior to the other combinations. Trash mulching @ 5 t/ha and foliar application of urea and KCl, each @ 2.5%, also significantly increased relative leaf water content compared with the control. However, juice-quality parameters, including brix, sucrose, purity, and sugar recovery, were not significantly affected by either mulching or foliar agrochemical application.

Keywords: Sugarcane, Moisture stress, Mulching, Urea, KCl, Formative stage, Cane yield, Foliar spray

Introduction

Sugarcane (*Saccharum officinarum* L.) is an important commercial crop, and the sugar industry is the second-largest agro-based industry in the country. Sugarcane is a backbone of the Indian agricultural economy and supports around 50 million cane growers. Specifically, the crop plays a pivotal role in South Gujarat's agrarian economy, where it remains a primary cash crop for thousands of farmers (Shah, 2026) [1]. Beyond its direct contribution to farm income, sugarcane production is deeply woven into the region's socio-political fabric, with Gujarat producing approximately 13.3 million tonnes of cane annually (Chauhan et al., 2025) [2]. Despite its economic significance, the crop often faces severe moisture stress during its formative growth stage, particularly when soil moisture deficits coincide with the intense heat of the summer season (Pooja et al., 2019) [3]. This vulnerability during the initial establishment phase often leads to poor germination and tiller suppression, which are key determinants of final stalk population and overall crop yield.

The sugarcane crop faces a major setback due to unpredictable monsoon behaviour and climate change—moisture stress coupled with high temperatures results in poor germination, reduced tillering, and higher tiller mortality. In the South Saurashtra region of Gujarat, the sugarcane crop faces water-deficit conditions due to a declining groundwater table and reduced availability of irrigation water from seasonal rivers and canals during the summer season. When this crop is sown during January-February, it experiences moisture stress during the formative phase of crop growth, which coincides with the summer months. Sugarcane is most vulnerable to moisture stress during the formative stage, which affects tillering, reduces stalk population, and limits initial stalk growth. Low atmospheric humidity during the formative stage (April-June) adversely affects the crop. A dry spell during the formative phase affects cane population and consequently reduces cane yield (Singh et al., 1980) [4]. Singh et al. (1997) [5] also reported that soil moisture stress during the formative phase significantly increased stomatal diffusive resistance, thereby decreasing transpiration rate, sucrose per cent in juice, and cane yield. Sugarcane is adaptable to a wide range of agricultural conditions, but abiotic stresses generally limit its productivity. Drought combined with high temperatures during the summer months is known to reduce cane yields in both tropical and subtropical climates. To counter these limitations, implementing advanced agro-techniques—such as optimized irrigation scheduling, mulching, and strategic row spacing—is essential to preserve soil moisture and stabilize crop performance. Overcoming the adverse effects of moisture stress requires moisture-conservation techniques and other agro-

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techniques to increase sugarcane productivity. Many workers have advocated several low-cost agro-techniques, such as trash mulching and foliar nutrient sprays, to use available soil moisture efficiently. Trash mulching is a useful technique for conserving soil moisture and reducing the adverse effects of moisture stress. It also moderates soil temperature and improves germination, tiller survival, and growth. Sundra (1985) [6] reported that trash mulching soon after planting, combined with urea spray @ 2.5%, gave higher cane and sugar yields. Singh *et al.* (2008) [7] concluded that combined use of lime soaking of setts, FYM, trash mulch, foliar spray of urea and KCl and an additional dose of potassium at 170 DAP produced significantly higher yield and improved juice quality. Patil *et al.* (2009) [8] obtained maximum cane yield with the foliar spray of kaolin (6%) followed by soil application of K₂O and foliar spray of KCl. By integrating these agronomic interventions, farmers can effectively mitigate evaporative water losses and maintain soil fertility, thereby fostering sustainable yield improvements in water-limiting environments (Singh *et al.*, 2025) [9]. Furthermore, adopting water-efficient irrigation management strategies and selecting drought-resilient genotypes are vital for sustaining productivity. The tillering phase is the most moisture-sensitive stage in sugarcane (Mahadevaiah *et al.*, 2021) [10]. In this context, the present investigation was conducted to identify suitable agro-techniques to mitigate the adverse effects of water-deficit conditions during the formative stage of crop growth and improve sugarcane growth, yield, and quality.

Materials and Methods

The field experiment was conducted at Main Sugarcane Research Station, Junagadh Agricultural University, Kodinar, Gujarat (India) to determine the suitable agro-techniques for improving growth, yield and yield components and quality of sugarcane (*Saccharum officinarum* L.) under moisture stress conditions, particularly during the formative stage during 2014-15, 2015-16 and 2016-17. The research station is located at 20.82° N latitude and 70.68° E longitude, at an elevation of 15 m above mean sea level. The experimental site soil was clayey, with pH 7.77, EC 0.55 dSm⁻¹, organic carbon 0.66%, available P₂O₅ 24.75 kg/ha, and K₂O 455.33 kg/ha. The experiment was laid out in randomized block design with four replications. The treatments comprised two mulching levels (M₁-Without mulch and M₂-Trash mulch @ 5 t/ha) and four chemical spray treatments (S₁-Control, S₂-KCl @ 2.5%, S₃-Urea @ 2.5%, and S₄-Urea + KCl each @ 2.5%). The recommended dose of fertilizers, viz. 250, 125 and 125 kg/ha N, P₂O₅ and K₂O, respectively, was applied to the crop. Sugarcane variety CoN 91132 was planted during the first week of February in each year and harvested during the first fortnight of February of the following year.

Trash mulching was applied four to six days after planting and incorporated into the soil during earthing up. The water-deficit condition was imposed from 60 to 150 days after planting by applying irrigation once every 15-20 days. The crop was treated as a normal crop for irrigation before 60 and after 150 days after planting. The chemical

sprays were applied at 60, 80, and 100 days after planting. Other agronomic practices and disease and pest management were followed as per the recommendations. Growth parameters, including germination, millable cane height and stalk diameter, were recorded at the respective stages of crop growth. At harvest, five millable canes were selected randomly from each plot to assess yield attributes and juice-quality parameters. Cane juice was extracted with a sugar cane crusher, and juice quality was evaluated according to the method described by Spencer *et al.* (1955) [11]. Sugar yield was calculated as: Sugar yield (t/ha) = CCS % × cane yield (t/ha)/100. Juice extraction per cent was calculated as: Juice extraction (%) = $\frac{\text{Weight of juice (kg)}}{\text{Weight of cane (kg)}} \times 100$. The relative leaf water content was estimated by the method prescribed by Barrs *et al.* (1962) [12]. Benefit-cost ratio (B: C) was calculated by dividing the gross returns by the total cost of cultivation and was used to compare treatment profitability. Data collected over the three consecutive years were statistically analyzed using standard statistical procedures (Gomez *et al.*, 1984) [13]. The critical difference (CD) was computed to determine statistically significant differences between treatments. Year-to-year variation was minimal and not statistically significant for most parameters; therefore, data from the three years were combined and presented as pooled means.

Results and Discussion

Growth parameters

The pooled data from the three-year study (Table 1) indicated that germination percentage was not significantly influenced by either mulching or foliar application of agrochemicals. However, trash mulch @ 5 t/ha significantly increased millable cane height, stalk diameter, and single cane weight compared with no mulch. This response may be attributed to improved soil-moisture conservation and moderation of soil temperature in the mulched plots. These effects are particularly important during the formative stage, when moisture stress can restrict stalk elongation, cane weight, and the number of millable canes. These results conform to the findings of Rana *et al.* (2003) [14], who also observed improvements in shoot height, shoot dry matter, cane length, cane girth, and cane yield with trash mulching over no mulching. Further review of pooled data (Table 1) indicated that foliar spray of urea + KCl each @ 2.5% significantly increased millable cane height and single cane weight over the control. However, millable cane height remained on par with KCl spray @ 2.5%. The favourable response to potassium under moisture stress may relate to its role in stomatal regulation and plant-water relations, which could help to maintain tissue hydration and physiological activity when soil-water availability was limited. These results are in agreement with the findings of Hunshal *et al.* (1996) [15], who reported that foliar application of muriate of potash spray (2.5%) and foliar spray of muriate of potash (2.0%) + urea (2.0%) recorded maximum single cane weight. However, foliar application of the agrochemicals did not significantly affect stalk diameter.

Table 1. Effect of mulching and chemical spraying on growth, yield attributes and yield of sugarcane (Pooled data)

Treatments	Germination % (45 DAP)	Millable cane height (cm)	Stalk diame- ter (cm)	SCW (kg)	NMC (000/ha)	Cane yield (t/ha)	CCS (t/ha)
Mulching							
Without mulch	59.52	201.19	2.21	0.804	97.80	88.10	10.08
Trash mulch @ 5 t/ha	57.84	210.65	2.30	0.884	106.29	100.05	11.65
SEm+	0.72	2.41	0.02	0.012	1.33	1.41	0.17
C D ($P = 0.05$)	NS	6.82	0.06	0.034	3.75	3.98	0.47
Chemical spraying							
Control	58.84	191.88	2.21	0.775	91.76	82.80	9.40
KCl (2.5 %)	58.66	208.81	2.28	0.849	103.80	95.97	11.08
Urea (2.5 %)	58.12	206.05	2.24	0.842	101.01	92.01	10.63
Urea + KCl each (2.5 %)	59.10	216.92	2.29	0.911	111.61	105.53	12.34
SEm+	1.02	3.41	0.03	0.017	1.88	1.99	0.24
C D ($P = 0.05$)	NS	9.65	NS	0.049	5.31	5.63	0.67

DAP- Days after planting; SCW- Single cane weight; NMC- Number of millable canes; CCS- Commercial cane sugar

Yield attributes and yield

Perusal of the three-year pooled data presented in Table 1 revealed that trash mulching influenced cane yield and yield attributes at the level of significance. Application of trash mulch @ 5 t/ha recorded significantly higher cane yield (100.05 t/ha) as compared to no mulch (88.10 t/ha), increasing yield by 13.56%. This improvement may be attributed to the more favourable soil micro environment created by the mulch. Trash mulching reduces direct soil-water evaporation, suppresses weed growth, and moderates fluctuations in soil temperature, improving soil moisture availability during periods of water deficit. Rana *et al.* (2002) [16], Dahiya *et al.* (2008) [17], and Kumar *et al.* (2015) [18] also reported a positive influence of trash mulching on cane yield. Such conservation measures are recognized as important components of sustainable sugarcane production under water-limiting conditions. The improved moisture regime may have supported tiller survival, stalk elongation, and final millable cane production.

Further perusal of pooled data indicated that trash mulching produced significantly higher commercial cane sugar (11.65 t/ha) than no mulching (10.08 t/ha). A similar trend was observed for the number of millable canes. Mathew *et al.* (2003) [19] stated that mulching significantly enhanced cane length, cane weight, cane girth, number of millable canes and cane yield.

Pooled data (Table 1) showed that foliar application of urea + KCl, each @ 2.5%, recorded significantly higher cane yield (105.53 t/ha) than the control (82.80 t/ha). The combined spray of urea + KCl increased cane yield by 27.45, 9.61, and 14.69% compared with the control, KCl, and urea sprays alone, respectively. Jaybal *et al.* (1990) [20], Manickam *et al.* (2009) [21], and Patil *et al.* (2009) [8] have earlier reported the favourable effect of urea + KCl sprays in enhancing cane yield under moisture stress. Cane yield results from additive and complementary effects of plant growth and yield-attributing characters. The combined spray of agrochemicals favourably influenced all growth- and yield-attributing characters; therefore, their cumulative effect also increased cane yield. Adequate potassium availability appears to contribute significantly to growth and yield improvement under drought conditions. Potassium regulates stomatal opening and closure and supports osmotic adjustment, thereby helping plants main-

tain water balance under moisture stress. Foliar spray of urea may have complemented this response by supplying nitrogen directly to the foliage and supporting chlorophyll formation, photosynthetic activity, and biomass production. The combined availability of nitrogen and potassium may therefore have improved canopy development and sustained assimilate production during the stress period. Urea enhances potassium absorption in leaf tissue, thereby positively influencing shoot population and final cane production (Manoharan *et al.*, 1992) [22]. Mohan Naidu *et al.* (1983) [23] also reported that foliar-applied potash was more effective when combined with urea. In another study, it was found that spraying urea (2.5%) + KCl (2.5%) enhanced the leaf area, and this increased leaf area was maintained during water stress, which ultimately helped in increased cane yield (Rao *et al.*, 2002) [24]. The highest commercial cane sugar was obtained with foliar spray of urea + KCl each @ 2.5% (12.34 t/ha) over control (9.40 t/ha), KCl @ 2.5% (11.08 t/ha) and urea @ 2.5% (10.63 t/ha). The highest number of millable canes was obtained under foliar spray of urea + KCl each @ 2.5% over the control, followed by KCl @ 2.5%. These results indicated that the treatment improved both cane productivity and sugar recovery primarily through its positive effects on stalk population and individual cane growth.

Quality parameters

The pooled data of three years presented in Table 2 indicated that trash mulching did not significantly affect quality parameters, including brix, sucrose, purity, commercial cane sugar, and juice-extraction percentage. Rana *et al.* (2002) [16] reported similar results, noting that trash mulching did not significantly affect any sugarcane quality parameters. The absence of a significant quality response suggested that trash mulching primarily improved cane productivity through moisture conservation and growth enhancement rather than through changes in juice composition.

Further reference to data (Table 2) showed that different foliar agrochemical treatments had no significant effect on juice quality parameters. Thus, the higher cane yield obtained with the combined urea + KCl spray was not accompanied by a significant alteration in brix, sucrose, purity, or juice-extraction percentage. This is important under water-deficit conditions because moisture stress can affect both cane growth and quality, depending on its timing and intensity.

Table 2. Effect of mulching and chemical spraying on quality parameters and relative leaf water content of sugarcane (Pooled data)

Treatments	Brix (%)	Sucrose (%)	Purity (%)	CCS (%)	Extraction (%)	Relative leaf water content (%)		
						65 DAP	95 DAP	125 DAP
Mulching								
Without mulch	19.52	16.77	84.79	11.44	49.98	81.74	80.25	79.19
Trash mulch @ 5 t/ha	19.50	16.95	85.67	11.62	50.75	84.52	83.25	81.15
SEm+	0.09	0.08	0.36	0.07	0.29	0.42	0.41	0.47
C D (<i>P</i> = 0.05)	NS	NS	NS	NS	NS	1.20	1.16	1.32
Chemical spraying								
Control	19.33	16.61	84.71	11.33	49.51	80.56	79.44	77.26
KCl (2.5 %)	19.63	16.91	85.25	11.56	50.81	83.89	82.47	81.22
Urea (2.5 %)	19.49	16.87	85.18	11.56	50.31	82.60	81.00	80.06
Urea + KCl each (2.5 %)	19.59	17.03	85.78	11.68	50.82	85.48	84.09	82.14
SEm+	0.12	0.12	0.51	0.11	0.42	0.60	0.58	0.66
C D (<i>P</i> = 0.05)	NS	NS	NS	NS	NS	1.69	1.64	1.86

Physiological parameters

Trash mulching @ 5 t/ha significantly improved relative leaf water content at 65, 95, and 125 days after planting compared with no mulching. The higher relative leaf water content indicated that trash mulching improved plant-water status during the imposed moisture-stress period. This response is scientifically consistent with the capacity of surface residues to reduce evaporative water loss and maintain greater soil-water availability in the crop root zone. Improved leaf hy-

dration would help to maintain cell turgor, stomatal function, leaf expansion, and photosynthetic activity, thereby supporting tillering and stalk development during the formative stage.

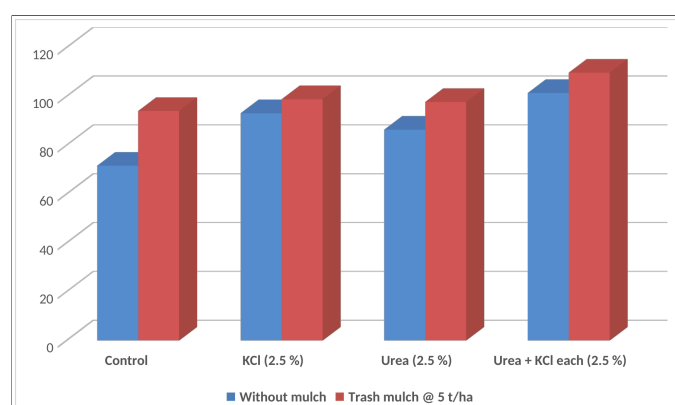
Further perusal of data indicated that significantly higher relative leaf water content was recorded under foliar spray of urea + KCl each @ 2.5 % as compared to control at 65, 95 and 125 days after planting and remained at par with the foliar spray of KCl @ 2.5 % (Table 2). These results conform to the findings of Hunshal *et al.* (1996) [15].

Table 3. Interaction effect of mulching and chemical spraying on cane yield (t/ha) of sugarcane (Pooled data)

Mulching	Chemical spraying			
	Control	KCl (2.5 %)	Urea (2.5 %)	Urea + KCl each (2.5 %)
Without mulch	71.61	93.08	86.33	101.37
Trash mulch @ 5 t/ha	93.99	98.85	97.69	109.68
SEm+	2.82			
C D ($P = 0.05$)	7.97			

Interaction effect

The interaction effect between sugarcane trash mulching and foliar spray of agrochemicals significantly affected cane yield. The pooled analyzed three-year data (Table 3 and Fig. 1) indicated that treatment combination $M_2 \times S_4$ (Trash mulching @ 5 t/ha and foliar spray of urea + KCl each @ 2.5 %) produced the highest cane yield (109.68 t/ha) and was significantly superior to the other treatment combinations. The second highest yield was recorded with over other treatment combinations with M_1S_4 . These findings are in agreement with Rao *et al.* (2002) [24], who observed that trash mulching coupled with spraying urea (2.5%) + KCl (2.5%) at 1:1 concentration and split application of potash significantly improved the cane yield under soil moisture stress. The superiority of $M_2 \times S_4$ on cane yield might also be attributed to the conservation of soil moisture and, as such, the nutrient uptake by the crop, which leads to the vigorous growth of the crop. Trash mulch likely maintained a more favourable root-zone moisture regime, while the combined foliar spray supported nutrient availability and physiological activity during the stress period. Improved plant-water status, nutrient uptake, tiller survival, and stalk development would collectively contribute to greater cane yield. The integrated use of conservation practices and nutrient management is therefore particularly relevant for stabilising sugarcane productivity in water-limiting environments (Singh *et al.*, 2025) [9].

**Figure 1.** Interaction effect of mulching and chemical spraying on cane yield (t/ha) of sugarcane

Economics

The three-year mean data (Table 4) showed that the cost of cultivation and net return of sugarcane were strongly influenced by various treatment combinations. Among the treatments, M_2S_4 (trash mulching @ 5 t/ha and foliar spray of urea + KCl each @ 2.5%) produced the highest net return of Rs. 182,111, with a benefit-cost ratio of 2.97. This was followed by M_1S_4 , which recorded a net return of Rs.

164,084 and a benefit–cost ratio of 2.83. The greater profitability of M_2S_4 was primarily associated with its higher cane yield and the resulting increase in gross returns. In water-limited production systems,

these technologies conserve soil moisture while improving yield, which can enhance both water productivity and economic sustainability.

Table 4. Economics of different treatments (Mean of 3 years)

Treatments	Pooled cane yield (t/ha)	Cost of cultivation (Rs/ha)	Gross return (Rs/ha)	Net return (Rs/ha)	BCR
M_1S_1	71.61	80217	179240	99023	2.23
M_1S_2	93.08	87266	232979	145713	2.67
M_1S_3	86.33	87211	216084	128873	2.48
M_1S_4	101.37	89645	253729	164084	2.83
M_2S_1	93.99	86882	235257	148375	2.71
M_2S_2	98.85	89290	247422	158132	2.77
M_2S_3	97.69	89033	244518	155485	2.75
M_2S_4	109.68	92418	274529	182111	2.97

Mean selling price of sugarcane: Rs. 2503.00/tonne.

Conclusion

Based on the results over three years, trash mulching @ 5 t/ha combined with foliar spray of urea + KCl each @ 2.5% produced the highest cane yield. Considering cane yield, net returns, and the benefit–cost ratio, application of trash mulching @ 5 t/ha and foliar spray of urea + muriate of potash each @ 2.5 % at 60, 80 and 100 days after planting was found superior over other treatment combinations. Accordingly, the treatment combination M_2S_4 (trash mulching @ 5 t/ha and foliar spray of urea + KCl each @ 2.5 %) may be recommended for farmers growing sugarcane under water-deficit conditions. Thus, trash mulching @ 5 t/ha and foliar application of urea + KCl (Muriate of potash) each @ 2.5 % (2.5 kg urea + 2.5 kg KCl in 100 liters of water) at 60, 80 and 100 days after planting can help to secure higher cane yields and net returns, particularly when moisture stress occurs during the formative stage.

Based on the study conducted over three years, it may be concluded that application of trash mulch @ 5 t/ha, four to six days after planting, combined with foliar application of urea + muriate of potash each @ 2.5 %, at 60, 80 and 100 days after planting is recommended for spring-planted sugarcane under water deficit conditions, particularly during the formative stage for securing higher cane yield and net return.

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