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THE RESPONSE OF DOMESTIC AND FOREIGN SUGARCANE CULTIVARS TO DIFFERENT IRRIGATION REGIMES UNDER AGRICULTURAL CLIMATIC CONDITIONS IN SOUTHERN IRAN

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Abstract. The experiment was implemented to assess the reaction of domestic and foreign sugar cane varieties to various irrigation regimes under the climatic conditions of agriculture in Southern Iran during the agricultural years 2012-21, 2021-22 and 2022-23. A strip plot design with three replications was used. The treatments evaluated in the study included eight sugarcane digits and two irrigation regimens (0.6 and 2.0 IW/CPE). The impact of moisture stress on various morphological characters such as plant height, leaf area, leaf area index and tiller count was recorded at 0.6 and 2.0 IW/CPE moisture regime. Drought treatment caused an average reduction of 26.49% in leaf area index, 19.95% in specific leaf weight, 14.08% in dry matter, 23.72% in root dry matter and 30.20 % in cane yield at 120 DAP, respectively. Yield and its parameters showed remarkable changes due to inadequate water availability during the formative phase. Water stress led to an average reduction in cane and sugar yield to the tune of 30.19% and 7.01%, respectively. On the basis of results obtained from investigation it can be concluded that, for maintaining high crop performance (plant population, improved growth attributes, physiological attributes) and securing maximum cane productivity, irrigation should be given at 2.0 IW/CPE ratio and with respect to varieties BR00-01, CP57-614, Cp48-103 & IRC99-01 showed elevated performance under irrigated as well as water deficit Condition.

Keywords: *Sugarcane, irrigation regimes, cane yield.*

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1. Introduction

Sugarcane is one of the most important industrial plants (Kalantar Hormozi *et al.*, 2021). Today sugarcane (Saccharum spp.) it is grown in more than 120 countries around the world and plays an important role in the agricultural economy. Sugar cane provides nearly 70% of the world's sugar (Gallo-Meagher *et al.*, 2000; Zhou *et al.*, 2016). Sugar cane cultivation in Iran and Khuzestan province is carried out on a surface of more than 120 thousand hectares for the production of sugar (FAOSTAT, 2020), the average production of sugar cane per unit level in Iran is higher than the global average (Abdollahi, 2015), which in addition to the annual production of 7 million tons of stems and the

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production of more than 30 percent of the country's total sugar needs, various ancillary industries including livestock feed, semi-industrial board and it also feeds alcohol (Karmollachaab *et al*., 2015; Azadeh *et al*., 2024). One of the plants that is the most complete photosynthetic-plant in itself is sugarcane (Sage *et al*., 2013). It is a C4 plant and has twice the growth efficiency and water consumption compared to C3 plants. In each growth period, it requires 2000 mm of water for 150 t ha^{-1}, equivalent to 12,000 m^3 per hectare per of water if there is a precise irrigation plan (Akbari Chamani *et al*., 2013). Sugar cane function is significantly affected by non-biological stresses such as drought, salinity and drowning. Drowning stress is a global phenomenon that severely affects the growth and survival of sugarcane and can lead to a decrease in plant yield between 15 and 45 percent (Gomathi *et al*., 2015). The stress of excess water in agricultural plants can be examined in two parts: first, the condition in which only the root of the plant is in a drowning or permanent condition and the second, in which, in addition to the root, parts of the aerial organs or entire aerial organs of the plant are also submerged (Fukao *et al*., 2019). The total water requirement of sugarcane is estimated to be between 1850 and 2500 mm. Sugarcane crop consumes about 250 tons of water per ton of sugarcane produced. This is while more than 60% of the sugarcane cultivation area suffers from water stress. Water stress especially during summer months coincides with the formative phase of the crop which affects the final yield through reduction in tiller productivity, number of millable canes, individual cane weight, cane height, cane girth and finally the cane yield and juice quality (Naidu & Venkataramana, 1989). In view of the increasing demand of sugar production and the scope for further increase in area under sugarcane cultivation being limited and the evolution of drought resistant varieties has become a major research priority.

Morpho-physiological responses lead to some adaptations to drought stress and it is possible to differ significantly among different varieties (Souza *et al*., 2004; Tippayawat *et al*., 2023). Since humans have realized the importance of irrigation in increasing the yield of crops, it has always been incorrect to believe that with more water consumption, it will have more yield. To compensate for the cost of irrigation, it is necessary to achieve good performance (Yadav *et al*., 2022).

The good performance of the sugarcane product has almost a linear relationship with the absorption of nutrients (Garrity, 1982). On the other hand, because Iran's water and soil resources are limited, efforts should be made to make good use of these resources and provide a sustainable and balanced agriculture (Karimi, 2009). So, irrigation regimes in sugarcane cultivation can have a significant impact on water consumption efficiency and crop performance, with attention to water like age (Haghayeghimoghadam *et al*., 2015). This study goals to the experiment was implemented to assess the reaction of domestic and foreign sugar cane varieties to various irrigation regimes under the climatic conditions of Agriculture in southern Iran

2. Materials and Methods

The experiment was implemented to assess the reaction of domestic and foreign sugar cane varieties to various irrigation regimes under the climatic conditions of agriculture in Southern Iran during the agricultural years 2020-21, 2021-22 and 2022-23. A strip plot design with three replications was used. The treatments evaluated in the study included eight sugarcane digits (V1: BR00-01; V2: Cp57-614; V3:Cp48-103; V4:IRC99-01; V5: BR00-01; V6: CP65-315; V7: Cp69-1062; V8: TUC66-107) and two irrigation regimens (0.6 and 2.0 IW/CPE). Each variety had plot size 10.00 m (L) X 6.5 m having 4 rows at 1.5 meters row to row distance. The varieties were planted first week of September by adopting all recommended agronomic practices. Recommended dose of season sugarcane crop were applied i.e., 250: 115: 115 Kg N, P_2O_5 and K_2O/ha. The application nitrogen in four splits & P_2O_5 and K_2O application - 50% at planting and 50% at final earthing up. The nutrient status of soil tested before planting of crop which gives 7.60 pH (slightly saline), 0.31 EC, high organic carbon (0.88), low nitrogen (252.80) and very high phosphorus (52.81) and potassium (631.06) having medium deep black in nature. In this study, the Traits of No. Tiller, leaf area Index (LAI), specific leaf weight, dry matter, dry root weight, No. of internodes, Length of internodes (cm), Girth of internodes (cm), Total cane height (cm), Single cane wt. (kg), Cane yield (t/ha), CCS yield (t/ha), Juice extraction percentage, Brix (%), Sucrose (%) and CCS (%) were evaluated.

The data on cane yield and yield components were analyzed statistically using analysis of variance and LSD test was applied to discriminate the superiority of the means of different varieties as suggested by Gomez and Gomez (1984).

3. Results and Discussions

3.1. *The effect of irrigation levels on growth, quantitative and qualitative yield of sugarcane*

Reduction in evaluated traits due to drought was found to be significant among irrigation regimes (Tables 1 and 2). Perusal of data revealed that significantly highest No. Tiller (0.38, 0.5 plant/mm) at 30 & 60 and higher value (1.55 plant/mm) of tiller was found at 90 in treatment application of irrigation at 2.0 IW/CPE ratio. While, any of the treatment does not exert any significant effect on No. Tiller at 30. It indicated that a different irrigation levels manifest their significant effect on leaf area index at 70 and 120, but it was non-significant at 30. Among the treatments irrigation at 2.0 IW/CPE ratio recorded significantly highest (0.7 and 1.51) leaf area index at 70 & 120, respectively. The leaf area is smaller in stressed plants and this is one of the effective characteristics in improving stress tolerance in sugarcane (Gaber *et al*., 2021). The result showed that a different irrigation levels manifest their significant effect on sp. Leaf wt. at 70 and 120, but it was non-significant at 30. Among the treatments irrigation at 2.0 IW/CPE ratio recorded significantly highest (78.22, 135.22 g/m^2) sp. Leaf wt. at 70 & 120, respectively. The first morphological adaptations of sugarcane exposed to water deficit stress include reduced stem and leaf growth and increased deep root growth (Anjum *et al*., 2017). An examination of data given in Tables 1 and 2 regarding tiller count, leaf area index, specific leaf weight, dry matter and root dry matter showed significant differences among the varieties. Variety Cp48-103 registered significantly higher No. Tiller (0.55, 0.69 & 1.78 plant/mm) at 60, 90 & 120, but more or less at par with BR00-01, CP57-614, IRC99-01 & VSI 12003. Whereas, significantly minimum tiller Count (0.32, 0.35 & 1.08 plant/mm) registered by TUC66-107 during 60, 90 & 120, respectively.

The result confirmed that different varieties exert their significant effect on leaf area index at 70 and 120, but it was non-significant at 30 DAP. Significantly higher leaf area index (0.70 and 1.52) was observed under variety CP57-614 at 70 & 120 DAP respectively, but remained at par with BR00-01, Cp48-103, IRC99-01 at 70 DAP and variety BR00-01, Cp48-103, IRC99-01 & Cp69-1062 found at par at 120 DAP. Results of the correlation analysis of plant characteristics with yield also indicated that LAI were significantly and positively correlated with yield under drought stress condition. Hence, maintenance of better LAI is an indicator of drought tolerance. Water stresses that continuously affect plants cause a reduction in leaf size and area, indicating a stress measurement mechanism in stressed plants (Vasantha *et al*., 2003).

Table 1. Number of tillers at 30, 60 and 90 cm intervals, leaf area index and leaf specific weight at 30, 70 and 120 cm intervals under the influence of irrigation levels and cultivar

Treatment details	No. Tiller at 30 (plant per mm)	No. Tiller at 60 (plant per mm)	No. Tiller at 90 (plant per mm)	Leaf area index at 30	Leaf area index at 70	Leaf area index at 120	Specific leaf wt. at 30 (g/m^2)	Specific leaf wt. at 70 (g/m^2)	Specific leaf wt. at 120 (g/m^2)
Irrigation levels									
I_1: 0.6 IW/CPE	0.35	0.47	1.40	0.22	0.54	1.11	33.89	72.1	108.22
I_2: 2.0 IW/CPE	0.38	0.50	1.55	0.23	0.7	1.51	35.10	78.22	135.22
SEm±	0.005^{ns}	0.011^{*}	0.008^{*}	0.003^{ns}	0.028^{*}	0.04^{*}	0.35^{ns}	0.57^{*}	1.13^{**}
Varieties									
V_1: BR00-01	0.46	0.56	1.38	0.25	0.60	1.34	35.13	73.95	125.70
V_2: Cp57-614	0.43	0.56	1.33	0.23	0.70	1.52	33.60	78.69	132.21
V_3:Cp48-103	0.55	0.69	1.78	0.23	0.59	1.21	34.15	75.24	112.46
V_4:IRC99-01	0.46	0.62	1.36	0.26	0.62	1.27	35.41	76.91	116.68
V_5: BR00-01	0.34	0.55	1.30	0.20	0.52	1.12	31.19	74.83	117.18
V_6: CP65-315	0.39	0.43	1.16	0.17	0.53	1.11	36.86	78.32	118.02
V_7: Cp69-1062	0.34	0.44	1.16	0.19	0.50	1.14	30.49	72.42	113.67
V_8: TUC66-107	0.32	0.35	1.08	0.19	0.45	1.07	29.19	65.67	103.38
SEm±	0.03^{*}	0.04^{*}	0.039^{*}	0.020^{ns}	0.040^{*}	0.07^{*}	0.63^{*}	1.26^{**}	4.89^{**}
Interaction I×V									
SEm±	0.03^{ns}	0.07^{ns}	0.089 ns	0.021 ns	0.078 ns	0.09 ns	1.08 ns	1.25 ns	8.19^{ns}

The result furnished in Tables 1 and 2 showed that a different irrigation levels manifest their significant effect on dry matter accumulation at 70 and 120 DAP, but it was non-significant at 30 DAP. Among the treatments irrigation at 2.0 IW/CPE ratio recorded significantly highest (15.45 & 37.17 t/ha) dry matter accumulation at 70 & 120 respectively. The rate of photosynthesis and as a result, the weight loss of sugarcane stems is lower in stressed plants compared to non-stressed plants (Hoang *et al*., 2019). The different irrigation levels exert their significant effect on root dry weight at 70 and 120, but it was non-significant at 30 DAP. Among the treatments irrigation at 2.0 IW/CPE ratio recorded significantly highest (18.22 & 25.5 g) root dry weight at 70 & 120, respectively.

The result presented in table 2 showed that different varieties exert their significant effect on dry matter accumulation at 30, 70 and 120 DAP. Variety IRC99-01 recorded maximum dry matter accumulation (3.55 t/ha) at 30, while at 120 DAP variety BR00-01 received higher (35.88 t/ha) dry matter accumulation, but at 70 & 120 DAP variety CP57-614 gained significantly higher dry matter accumulation 18.33 & 34.22 t/ha, respectively which was more or less statistically on same line with BR00-01, CP57-614, Cp48-103 & IRC99-01. Whereas, significantly minimum dry matter accumulation 1.88, 10.01 & 19.88 t/ha at 30, 70 & 120 DAP, respectively was observed under variety TUC66-107. The different varieties exert their significant influence on root dry weight at 30, 70 and 120

DAP. Variety CP57-614 recorded significantly higher root dry weight (10.22, 24.85, 30.33 g) at 30, 70 & 120 DAP, respectively. Whereas, significantly minimum root dry weight 4.22, 10.18, 15.45 g at 30, 70 & 120 DAP respectively was observed under variety TUC66-107, while variety Cp69-1062 registered lower root dry weight 17.08 g at 120 DAP.

Table 2. Dry matter and root dry wt., 30, 70 and 120 DAP as influenced by irrigation levels and varieties

Treatment details	Dry matter at 30 (t/ha)	Dry matter at 70 (t/ha)	Dry matter at 120 (t/ha)	Root dry weight at 30 (g)	Root dry weight at 70 (g)	Root dry weight at 120 (g)
Irrigation levels						
I_1: 0.6 IW/CPE	2.88	12.22	28.22	7.22	13.85	19.45
I_2: 2.0 IW/CPE	3.45	15.45	32.17	7.55	18.22	25.5
SEm±	0.044^{ns}	0.28^{*}	0.35^{**}	1.28^{ns}	0.51^{**}	0.60^{**}
Varieties						
V_1: BR00-01	3.23	13.73	35.88	7.68	22.12	25.97
V_2: CP57-614	3.11	18.33	34.22	10.22	24.85	30.33
V_3:Cp48-103	3.18	12.43	28.55	7.32	16.59	22.41
V_4:IRC99-01	3.21	14.00	30.11	6.24	15.12	21.17
V_5: BR00-01	2.96	13.24	28.59	7.77	13.92	19.20
V_6: CP65-315	3.55	14.76	28.67	7.74	13.29	16.82
V_7:Cp69-1062	3.07	12.62	29.56	7.34	12.93	17.08
V_8: TUC66-107	1.88	10.01	19.88	4.22	10.18	15.45
SEm±	0.064^{*}	0.28^{*}	0.34^{**}	0.86^{**}	0.92^{**}	0.87^{**}
Interaction I×V						
SEm±	0.089^{ns}	0.45^{ns}	0.49^{ns}	1.94^{ns}	1.10^{ns}	0.92^{ns}

The average data related to yield characteristics based on different irrigation levels are presented in Table 3. Among the treatments, irrigation with IW/CPE ratio of 2.0 recorded significantly highest internode length (13.55 cm), stem circumference (12.70 cm), total shoot height (297.88 cm) and single shoot weight (1.85 kg), but the number of internodes was not significant. The results showed that shoot height under drought conditions was determined by the length of internodes rather than the number of internodes. The results of juice quality parameters i.e. Brix, sucrose, CCS percentage and juice extraction percentage recorded after harvest showed that different irrigation levels failed to have a significant effect. This study showed that different irrigation levels significantly affected the sugarcane yield. Treatment (I2) using irrigation water with a ratio of 2.0 IW/CPE significantly achieved the highest sugarcane yield (140.70 t/ha) compared to the treatment with irrigation water with a ratio of 0.6 IW/CPE. It was found that different irrigation levels had a positive effect on CCS yield. Treatment (I2) using irrigation water with a ratio of 2.0 IW/CPE significantly recorded the highest CCS yield (20.70 t/ha). In the present study, the cane diameter and number of internodes did not show significant reduction due to drought. The mean data of number of internodes, length of internodes (cm), diameter of internodes (cm), total height of cane (cm), weight of single cane (kg), cane yield (ton/ha), CCS yield (ton/ha), juice extraction percentage, Brix (%), sucrose (%) and CCS (%) are presented in Table 3. It was found that number of internodes and length were not affected by cultivars, but cultivar CP57-614 recorded significantly maximum cane diameter (12.21 cm), total cane height (305.88 cm) and weight of single cane (2.18 kg), but it was not statistically different from BR00-01, Cp48-103, IRC99-01 and CoVSI 03102. While the cultivar TUC66-107 showed lower single reed weight of 1.08 kg, while lower total reed height of 227.85 cm was observed under the cultivar Cp69-1062. Drought is a major limiting factor for sucrose accumulation and stress at the formation stage affects sucrose synthesis (Venkataramana *et al*., 1986). The average data on juice quality under the influence of the varieties are presented in Table 3. It was shown that none of the varieties had a significant effect on juice quality, but the maximum juice extraction percentage (45.80%) observed in CP57-614 and Brix (24.28%), sucrose (22.80%) and CCS (16.34%) were observed under TUC66-107. Sufficient water is essential for sucrose formation and its transport to the stem. Small changes in the moisture content of green leaves affected the balance between simple sugars and sucrose percentage. This could also be due to differences in sucrose accumulation and transport to the storage tank, as water supply determines the efficiency of photosynthetic material transport. Lower juice sucrose may also be due to higher production of immature internodes and maximum juice weight during maturity after moisture stress is relieved. A similar decrease in juice quality was observed in sugarcane (Vasanta *et al*., 2005). The evaluation of data (Table 3) confirmed that CP57-614 variety recorded significantly higher sugarcane yield (144.22 t/ha), but was ranked in the same row as BR00-01 and IRC99-01. TUC66-107 variety recorded lower sugarcane yield (70.88 t/ha). However, CP57-614 and CP57-614 showed higher sugarcane and sugar yield under both stress and non-stress conditions, which may be attributed to its tolerant nature through maintaining physiological, morphological and biochemical activities even under stress. The data shown in Table 3 showed that CP57-614 variety recorded significantly higher CCS yield (28.33 t/ha), but was ranked in the same row as BR00-01, IRC99-01 and Cp48-103. The minimum CCS yield (14.20 t/ha) was recorded by variety TUC66-107.

Table 3. Number of internodes, internode length (cm), internode diameter (cm), total cane height (cm), single cane weight (kg), cane yield (tons per hectare), CCS yield (tons per hectare), extraction percentage, Brix (%), sucrose (%) and CCS (%) under the influence of irrigation levels and cultivar

Treatment details	**No. of internodes**	**Length of internodes (cm)**	**Girth of internodes (cm)**	**Total cane height (cm)**	**Single cane wt. (kg)**	**Cane yield (t/ha)**	**CCS yield (t/ha)**	**Juice extraction percentage**	**Brix (%)**	**Sucrose (%)**	**CCS (%)**
Irrigation levels (A)											
I_1: 0.6 IW/CPE	19.22	11.85	11.08	218.88	1.22	98.22	16.17	39.99	22.88	21.2	13.8
I_2: 2.0 IW/CPE	20.7	13.55	12.70	297.88	1.85	140.70	20.70	42.80	23.70	22.8	14.7
SEm±	0.37^{ns}	0.04^{*}	0.05^{*}	4.26^{**}	0.032^{*}	3.98^{**}	0.31^{*}	1.80^{ns}	0.26^{ns}	0.43^{ns}	0.36^{ns}
Varieties (B)											
V_1: BR00-01	21.04	12.31	11.16	257.33	1.94	136.45	20.73	41.04	22.10	21.13	15.27
V_2: Cp57-614	21.66	14.04	12.21	307.88	2.18	144.22	28.33	45.80	22.30	21.31	15.47
V_3:Cp48-103	22.00	12.36	11.13	264.83	1.66	104.97	18.24	42.91	23.29	21.38	15.26
V_4:IRC99-01	21.28	13.37	11.18	270.17	1.70	110.45	17.05	42.28	22.69	21.39	15.44

V_5: BR00-01	20.73	11.19	10.78	238.83	1.47	104.14	16.12	44.18	22.03	21.19	15.42
V_6: CP65-315	22.66	12.57	10.91	275.33	1.73	100.44	15.71	40.92	22.57	21.49	15.75
V_7: Cp69-1062	20.79	11.12	10.95	232.17	1.27	99.64	15.31	39.65	22.51	21.14	15.23
V_8: TUC66-107	21.16	11.89	10.28	227.85	1.08	70.88	14.20	38.81	24.28	22.80	16.34
SEm±	0.63 ns	0.72 ns	0.38*	12.16**	0.15*	10.53**	1.53**	1.84 ns	0.52 ns	0.49 ns	0.39 ns
A×B											
SEm±	1.34 ns	0.62 ns	0.56 ns	14.37 ns	0.20 ns	12.35 ns	1.89 ns	2.97 ns	0.98 ns	0.98 ns	0.74 ns

4. Conclusion

Based on the results obtained from the studies, it can be concluded that to maintain high crop yield (plant population, improved growth characteristics, physiological characteristics) and ensure maximum sugarcane productivity, irrigation should be carried out at a ratio of 2.0 IW/CPE and in this regard, the varieties BR00-01, CP57-614, Cp48-103 and IRC99-01 showed higher performance under irrigated conditions as well as water deficit.

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