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Comparative evaluation of growth, yield and yield attributing traits in sugarcane (*Saccharum officinarum*) under different soil moisture regimes

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ABSTRACT

A field experiment was conducted during spring season of 2014–15 and 2015–16 at CCS HAU, RRS, Karnal to evaluate the response of four sugarcane (*Saccharum officinarum* L.) varieties differing in their maturity i.e. CoS 767 (Mid late), CoH128 (Mid late), CoJ 64 (Early) and Co 0238 (Early) to deficit irrigation. The experiment was conducted in split plot design with three replications. Based on available soil moisture (ASM), three treatments i.e. irrigation at 50% ASM (control), 40% ASM (mild stress) and 30% ASM (severe stress) were imposed in main plot and sugarcane varieties in sub-plot. Under deficit irrigation, leaf area, leaf area index (LAI), crop grown rate (CGR), relative growth rate (RGR) and net assimilation rate (NAR), significantly, reduced at 30–60 and 60–90 DAP in all the varieties and the varieties Co 0238 and CoS 767 showed least reduction. The yield parameters, viz. number of millable canes, cane length, internodal length and single cane weight reduced significantly under water limited conditions and proved to be the most sensitive yield components responsible for decrease in cane and sugar yield. Cane yield and sugar yield reduced by 36.18% and 40.47%, and 27.5% and 31.09% at 30% and 40% ASM level, respectively. Co 0238 produced highest average cane yield and sugar yield (83.05 and 10.17 t/ha) followed by CoS 767 (68.23 and 8.28 t/ha). Moreover, after stress revival Co 0238 and CoS 767 were able to recover faster which qualified these varieties to face short periods of drought without major losses in the initial phase of development.

Keywords: Available Soil Moisture (ASM), Growth analysis, Sugarcane, Yield

In India, sugarcane (*Saccharum officinarum* L.) is being cultivated over an area of 5.14 mha in tropical and sub-tropical region with an average productivity of 69.9 t/ha and sugar production of 28.31 MT. In subtropics, Haryana stands first (73 t/ha) followed by Punjab (71 t/ha). Sugarcane is a relatively high water-demanding crop and its growth is highly sensitive to water deficit (Pooja *et al*. 2017). The low productivity in sub-tropical region may be attributed to unfavourable climatic conditions prevailing during the crop growth period (Pooja *et al*. 2019a, b). Water deficit is the single largest abiotic stress affecting sugarcane productivity thus the development of water use efficient/drought tolerant cultivars is vital (Ferreira *et al*. 2017, Pooja *et al*. 2020). Out of four distinct growth stages (i.e. germination, tillering, grand growth and maturity), tillering and grand growth stages (sugarcane formative phase), have been identified as the critical water demanding stages. Water stress during formative phase (tillering phase) has a negative impact on growth and yield because 70–80% of cane yield is produced during this phase. This emphasizes the need to evolve drought tolerant varieties to sustain sugarcane production. Plants have evolved various tolerance strategies, such as changes in life cycle, modulation of growth, regulation of whole plant functions to balance resource allocation for growth and stress adaptation, and evolution of stress signal perception for rapid and long term expression of stress tolerance (Kumar *et al*. 2017). The increasing incidence, duration and intensity of severe water deficit, has prompted many large sugarcane crop improvement programs to invest in water use-efficient crop production systems. It is, therefore, important to understand the plant processes in water deficit stress condition for adopting traits to select drought tolerant varieties. Keeping above points in view, the present study was carried out to evaluate the response of four sugarcane varieties differing in their maturity to deficit irrigation.

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MATERIALS AND METHODS

The study was carried out on four sugarcane varieties of different maturity group. The experiment was conducted during spring season of the year 2014–15 and 2015–16 in the field conditions at Regional Research Station, CCS HAU, RRS, Karnal. Average rainfall ranges around 600 mm and 70–80% of it is received from July to September. Maximum temperature during summer months of May and June rises up to 46°C while minimum temperature during winter months of December and January goes down to 3°C. The experiment was conducted in split plot design with three replications to study the effect of irrigation at different available soil moisture (ASM) levels on four sugarcane varieties. Two budded setts of four sugarcane varieties, two under mid late group, viz. CoH 128, CoS 767 and two under early group, viz. Co 0238, and CoJ 64 were planted by half ridge irrigation method in spring season. After complete germination (40 days after planting) three levels of ASM regimes were created based on irrigation i.e. 50% ASM level (control), 40% ASM level (mild stress) and 30% ASM level (severe stress). These ASM levels were created only during pre-monsoon (in the month of April, May and June) period by withholding irrigation while during monsoon as well as post monsoon period (in the month of July), the crop was irrigated for stress revival. Planting was done by half ridge irrigation method i.e. planting of two budded setts (seed rate 87.5 q/ha) in dry furrows followed by irrigation up to half of the ridge and then planking after 3–4 days of planting. Different growth parameters were recorded at timely intervals and yield attributes at the harvest. All the data were subjected to variance analysis using the SAS (Version 9.3, SAS Institute Inc., Cary, NC, USA). Least significant difference test was applied at 5% probability level to compare the mean differences.

RESULTS AND DISCUSSION

In sub tropical zone of India, sugarcane faces severe water scarcity with high rate of evaporation along with high temperature and dry winds during the formative phase. It is known as critical stage of drought-sensitivity due to the high need of water for growth. The adverse effects of water stress lead to high mortality of tillers, reduction in growth, cane yield and its contributing traits.

Growth parameters: Data revealed maximum reduction in LA at 30% ASM level (27.69% and 29.66%) followed by 40% ASM level (21.14% and 24.02%) as compared to 50% ASM level at 60 and 90 DAP, respectively (Fig 1). After stress revival (at 120 DAP), LA significantly increased in all the ASM levels with average values 29.31 dm^2/clump, 31.33 dm^2/clump and 38.27 dm^2/clump at 30%, 40% and 50% ASM level, respectively (Fig 1). Leaf area index (LAI) also significantly reduced at 60 and 90 DAP and the maximum reduction was recorded at 30% ASM level (27.51% and 29.90%) followed by 40% ASM level (22.68% and 23.79%) as compared to 50% ASM level, respectively (Table 1). Among the varieties, maximum reduction in LAI was recorded in CoJ 64 followed by CoH 128 and the lowest in CoS 767 and Co 0238 at 60 and 90 DAP. Leaf area gives a fairly good idea of the photosynthetic capacity of the plant while LAI is an assimilatory system of any crop and plays an important role in deciding the plant growth and yield. Ability to maintain higher leaf area and leaf area index is associated with drought tolerance mechanism through the maintenance of high RWC, water potential and photosynthetic rate (Gomathi *et al*. 2011, Farooq *et al*. 2015). Vanketramana *et al*. (1986) reported that moisture stress had severe effect on cell-tissue elongation compared to cell division and thereby reduced leaf area production in sugarcane.

Data revealed that crop growth rate (CGR) significantly decreased at 30% ASM level (16.07% and 21.95%) followed by 40% ASM level (11.9% and 17.38%) as compared to 50% ASM level at 30–60 and 60–90 DAP, respectively. Among the varieties, highest reduction was recorded in CoJ 64 followed by CoH 128 whereas the lowest in varieties Co 0238 and CoS 767 at 60–90 DAP (Table 1). However, after stress revival (at 120 DAP), CGR significantly increased in all the ASM levels to 6.02, 6.58 and 7.12 g/m^2/day at 30%, 40% and 50% ASM levels, respectively. The maximum reduction in relative growth rate (RGR) was recorded at 30% ASM level (22.34% and 21.68%) at 30–60 DAP and 60–90 DAP, respectively. Varieties Co 0238 and CoS 767 were at par and significantly maintained higher RGR as compared to varieties CoH 128 and CoJ 64 at 30–60 and 60–90 DAP, respectively (Table 1). On stress revival (at 90–120 DAP), a significant increase in RGR was recorded up to 30.34% and 29.34% at 30% and 40% ASM levels as compared to their respective values at 90 DAP (Table 1). Net assimilation rate (NAR) is the net gain of photosynthetic assimilates per unit of leaf area and time. Varieties Co 0238 (0.79 and 0.90 g/m^2/day) and CoS 767 (0.78 and 0.86 g/m^2/day) were at par and significantly maintained higher NAR as compared to varieties CoH 128 (0.73 and 0.79 g/

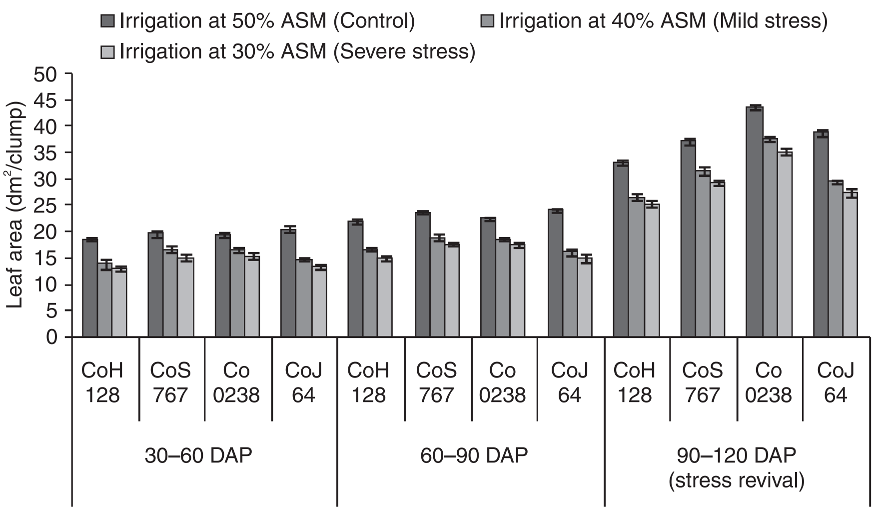

Fig 1 Effect of different soil moisture regimes on leaf area in sugarcane varieties.

Table 1 Effect of different soil moisture regimes on leaf area index, CGR, RGR and NAR in sugarcane varieties

Treatment/trait	Leaf area index			Crop growth rate ($g/m^2/day$)			Relative growth rate (mg/g/day)			Net assimilation rate ($g/m^2/day$)		
	After 30–60 DAP	After 60–90 DAP	After 90–120 DAP	After 30–60 DAP	After 60–90 DAP	After 90–120 DAP	After 30–60 DAP	After 60–90 DAP	After 90–120 DAP	After 30–60 DAP	After 60–90 DAP	After 90–120 DAP
Water deficit stress (T)												
50% ASM (Control)	2.69^{A}	3.11^{A}	5.13^{A}	5.04^{A}	6.56^{A}	7.12^{A}	6.49^{A}	7.24^{A}	8.35^{A}	0.93^{A}	1.01^{A}	1.11^{A}
40% ASM (Mild stress)	2.08^{B}	2.37^{B}	4.23^{B}	4.44^{B}	5.42^{B}	6.58^{B}	5.51^{B}	5.93^{B}	7.67^{B}	0.74^{B}	0.79^{B}	0.99^{B}
30% ASM (Severe stress)	1.95^{C}	2.18^{C}	3.96^{C}	4.23^{B}	5.12^{C}	6.02^{C}	5.04^{C}	5.67^{C}	7.39^{C}	0.61^{C}	0.7^{C}	0.93^{C}
LSD (P=0.05)	0.09	0.16	0.15	0.45	0.28	0.70	0.21	0.22	0.19	0.01	0.10	0.07
Varieties (V)												
CoH 128	2.07^{C}	2.39^{D}	3.84^{C}	4.57	5.56^{B}	6.28^{B}	5.46^{C}	6.11^{C}	7.57^{C}	0.73^{D}	0.79^{C}	0.89^{C}
CoS 767	2.35^{A}	2.72^{A}	4.39^{B}	4.56	5.94^{A}	6.76^{A}	6.05^{A}	6.58^{A}	7.81^{B}	0.78^{B}	0.86^{B}	0.98^{B}
Co 0238	2.33^{A}	2.61^{B}	5.24^{A}	4.59	5.82^{A}	6.82^{A}	5.65^{B}	6.4^{B}	8.07^{A}	0.79^{A}	0.9^{A}	1.18^{A}
CoJ 64	2.2^{B}	2.49^{C}	4.29^{B}	4.55	5.49^{B}	6.44^{B}	5.56^{BC}	6.03^{C}	7.76^{B}	0.75^{C}	0.79^{C}	0.98^{B}
LSD (P=0.05)	0.17	0.14	0.17	NS	0.28	0.28	0.23	0.2	0.20	0.02	0.04	0.09
LSD (P=0.05) (V × T)	0.29	0.24	0.29	NS	0.49	NS	0.4	0.35	NS	0.04	0.06	NS

Least significant difference test was applied at 5% probability level to compare the mean differences.

m^2/day) and CoJ 64 (0.75 and 0.79 g/m^2/day) at 30–60 and 60–90 DAP, respectively (Table 1). NAR was significantly affected at 30% ASM level (34.41% and 30.69%) and 40% ASM level (20.43% and 21.78%) as compared to 50% ASM level in all the varieties at 30–60 DAP and 60–90 DAP, respectively. On stress revival (90–120 DAP), a significant increase in NAR was recorded by 32.86% and 20.2% at 30% and 40% ASM levels than at 60–90 DAP, respectively (Table 1). It is well established fact that the plant infrastructure is decided by the growth parameters such as CGR, RGR, NAR. This concept not only involves the final crop yield and its components, but also probes into the physiological events that have occurred early in the growth stages causing variation in yield potential (Patil *et al*. 2009). Growth parameters such as CGR, RGR and NAR indicate the development of crop in a logical sequence and elucidate the causes for differences in yield through the events that have occurred earlier in the growth (Farooq *et al*. 2015).

Yield parameters: Cane length is an important parameter contributing towards final yield in sugarcane. The highest cane length was recorded in variety Co 0238 (224.16 cm) followed by CoS 767 (209.47 cm). Cane length was significantly reduced by 17.12% and 11.03% at 30% and 40% ASM levels, respectively, as compared to 50% ASM level (Table 2). At 30% ASM, significantly higher cane length was recorded in varieties Co 0238 (224.16 cm) and CoS 767 (209.47 cm) as compared to varieties CoJ 64 (193.1 cm) and CoH 128 (192.48 cm), respectively. Reduction in cane length might be associated with higher reduction in plant water status, gas exchange attributes and water use efficiency of leaves during formative phase of growth (Dhansu *et al*. 2021) as well as due to differences in genetic constitution of the varieties. Present results are in confirmatory with earlier findings in sugarcane that any stress during this critical water demanding stage (formative phase) directly affects growth, photosynthesis, dry matter accumulation and yield (Venkataramana *et al*. 1986, Hemaprabha *et al*. 2004, Silva *et al*. 2008). The maximum internode length was recorded in variety Co 0238 (12.35 cm) than CoJ 64 (10.87), CoS 767 (10.72cm) and CoH 128 (10.69 cm) and these three were at par under control conditions. Internodal length significantly reduced by 8.42% and 3.32% at 30% and 40% ASM levels, respectively, as compared to 50% ASM level (Table 2). Moisture stress has severe effect on cell-tissue elongation than on cell division in sugarcane. Under water stress, internodal length, cane girth and cane length reduced significantly, whereas the number of internodes was least affected (Hemaprabha *et al*. 2013). Water deficit stress had significant effect on number of millable canes (NMC) in all the varieties (Table 2). Highest reduction in NMC was recorded at 30% ASM level (18.88%) than 40% ASM level (14.06 %) as compared to 50% ASM level. Among the varieties, CoS 767 and CoH 128 produced significantly higher NMC as compared to varieties CoJ 64 and Co 0238. The number of millable canes is most important yield contributing parameter for final yield and it depends on number of tillers converted into economic shoots. Tillering phase is high water demanding stage and reduction of water availability to plants at this stage caused reduction in tiller population and ultimately reduced NMC (Ramesh and Mahadevaswamy 2000). Single cane weight reduced significantly by 21.84% and 16.43% at 30% and 40% ASM levels, respectively, as compared to 50% ASM level (Table 2). Co 0238 produced the highest single cane

Table 2 Effect of different soil moisture regimes on yield and yield attributing traits in sugarcane varieties

Treatment/trait	Cane Length (cm)	Internode length (cm)	No.of millable canes (thousand/ha)	Single cane weight (g)	Cane yield	Sugar yield
Water deficit stress (T)						
50% ASM (Control)	226.02^{A}	11.16^{A}	101.6^{A}	875.27^{A}	88.32^{A}	10.71^{A}
40% ASM (Mild stress)	201.08^{B}	10.79^{B}	87.32^{B}	731.5^{B}	64.03^{B}	7.64^{B}
30% ASM (Severe stress)	187.32^{C}	10.22^{C}	82.42^{C}	684.05^{C}	56.37^{C}	6.72^{C}
LSD (P=0.05)	4.08	0.26	3.92	32.27	4.61	0.49
Varieties (V)						
CoH 128	192.48^{C}	10.45^{B}	92.92^{A}	712.11^{B}	66.59^{B}	7.55^{C}
CoS 767	209.47^{B}	10.48^{B}	92.99^{A}	729.31^{B}	68.23^{B}	8.28^{B}
Co 0238	224.16^{A}	11.88^{A}	86.59^{B}	947.84^{A}	83.05^{A}	10.17^{A}
CoJ 64	193.1^{C}	10.09^{C}	89.28^{B}	665.18^{C}	60.43^{C}	7.43^{C}
LSD (P=0.05)	6.35	0.34	4.63	51.92	3.85	0.71
LSD (P=0.05) (V × T)	11.0	0.59	7.41	NS	7.85	1.02

Least significant difference test was applied at 5% probability level to compare the mean differences.

weight (947.84 g) followed by CoS 767 (729.31 g) and CoH 128 (712.11 g) and lowest in case of Co J64 (665.18 g). The present observations are similar to those reported by Hemaprabha *et al*. (2004) and Silva *et al*. (2008) in sugarcane and might be due to reduction in source strength via reduced photosynthesis and decreased translocation of metabolites contributing towards yield.

Highest cane yield (83.05 t/ha) was observed in Co 0238 followed by CoS 767 (68.23 t/ha) and CoH 128 (66.59 t/ha) whereas the lowest cane yield was recorded in CoJ 64 (60.43 t/ha). Cane yield was significantly reduced by 36.18% and 27.5% at 30% and 40% ASM level, respectively, in comparison to 50% ASM level. The reduction in cane yield is largely due to reduction in growth parameters, total number of tillers, NMC, cane length and single cane weight. Similar drought stress mediated decrease in yield parameters have also been reported in sugarcane (Ramesh and Mahadevaswamy 2000, Vasantha *et al*. 2005, Hemaprabha *et al*. 2013). Sugar yield is the product of cane yield and sugar recovery. Sugar yield decreased significantly by 31.09% at 40% ASM and 40.47% at 30% ASM as compared to 50% ASM level in all varieties (Table 2). Among the varieties, Co 0238 produced significantly highest sugar yield (9.70 t/ha) followed by CoS 767 (8.05 t/ha) whereas lowest sugar yield was recorded in varieties CoH128 (7.31 t/ha) and CoJ 64 (7.06 t/ha). It might be due to the fact that water deficit during formative phase significantly reduced yield and yield contributing characters in all the four varieties. The reduction in sugar yield might be due to reduction in sugar yield contributing factors, viz. cane length, single cane weight, NMC and cane yield (Khan *et al*. 2013). Based upon the growth analysis and yield parameters it can be concluded that varieties Co 0238 and CoS 767 are relatively more tolerant because these varieties maintained growth parameters, higher dry matter production and yield. Moreover, after stress revival, Co 0238 and CoS 767 were able to recover faster, a characteristic that qualifies these varieties to face short periods of drought without major losses in the initial phase of plant development.

REFERENCES

Ferreira T H S, Tsunada M S, Bassi D, Araújo P, Mattiello L, Guidelli G V, Righetto G L, Gonçalves V R, Lakshmanan P and Menossi M. 2017. Sugarcane water stress tolerance mechanisms and its implications on developing biotechnology solutions. *Frontiers in Plant Science* **8**: 1077.

Farooq U, Mehmood S, Afghan S, Shahzad A and Asad M. 2015. Comparative study on agro-physiology of sugarcane (*Saccharum officinarum* L.) genotypes at different irrigation co-efficient values. *Pakistan Journal of Botany* **47**: 527–32.

Gomathi R, Vasantha S, Hemaprabha G, Alarmelu S and Shanthi R M. 2011. Evaluation of elite sugarcane clones for drought tolerance. *Journal of Sugarcane Research* **1**: 55–62.

Hemaprabha G, Nagarajan R and Alarmelu S. 2004. Response of sugarcane genotypes to water deficit stress. *Sugar Tech* **6**(3): 165–68.

Hemaprabha G, Swapna S, Lavanya D L, Sajitha B and Venkataramana S. 2013. Evaluation of drought tolerance potential of elite genotypes and progenies of sugarcane (*Saccharum* sp. hybrids). *Sugar Tech* **15**(1): 9–16.

Khan I A, Bibi S, Yasmin S, Khatri A and Seema N. 2013. Phenotypic and genotypic diversity investigations in sugarcane for drought tolerance and sucrose content. *Pakistan Journal of Botany* **45**(2): 359–66.

Kumar A, Lata C, Krishnamurthy S L, Kumar A, Prasad K R K and Kulshreshtha N. 2017. Physiological and biochemical characterization of rice varieties under salt and drought stresses. *Journal of Soil Salinity and Water Quality* **9**: 167–77.

Patil R P, Chetti M B and Hiremath S M. 2009. Influence of agrochemicals on morpho-physiological characters, yield and yield components of sugarcane under moisture stress. *Karnataka Journal of Agricultural Science* **22**(4): 759–61.

Pooja, Nandwal A S, Chand M, Kumar A, Rani B, Kumari A and Kulshrestha N. 2017. Comparative evaluation of changes in protein profile of sugarcane varieties under different soil moisture regimes. *International Journal of Current Microbiology and Applied Sciences* **6**(3): 1203.

Pooja, Nandwal A S, Chand M, Kumari A, Rani B, Goel V and Singh S. 2019a. Genotypic differences in growth behavior and quality parameters of sugarcane (*Saccharum officinarum*) varieties under moisture stress conditions. *Indian Journal of Agricultural Sciences* **89**(1): 65.

Pooja, Nandwal A S, Chand M, Singh K, Mishra A K, Kumar A, Kumari A and Rani B. 2019b. Varietal variation in physiological and biochemical attributes of sugarcane varieties under different soil moisture regimes. *Indian Journal of Experimental Biology* **57**(10): 721–32.

Pooja, Nandwal A S, Chand M, Pal A, Kumari A, Rani B, Goel V and Kulshreshtha N. 2020. Soil moisture deficit induced changes in antioxidative defense mechanism of sugarcane (*Saccharum officinarum*) varieties differing in maturity. *Indian Journal of Agricultural Sciences* **90**(4): 507–12.

Dhansu P, Kulshreshtha N, Kumar R, Raja A K, Pandey S K, Goel V and Ram B. 2021. Identification of drought-tolerant co-canes based on physiological traits, yield attributes and drought tolerance indices. *Sugar Tech* **23**: 747–61.

Ramesh P and Mahadevaswamy M. 2000. Effect of formative phase drought on different classes of shoots, shoot mortality, cane attributes, yield and quality of four sugarcane cultivars. *Journal of Agronomy and Crop Science* **185**(4): 249–58.

Silva MA, da Silva JAG, Enciso J, Sharma V and Jifon J. 2008. Yield components as indicators of drought tolerance of sugarcane. *Scientia Agricola* **65**(6): 620–27.

Vasantha S, Alarmelu S, Hemprabha G and Shanthi R M. 2005. Evaluation of promising sugarcane genotypes for drought. *Sugar Tech* **7**: 82–83.

Venkataramana S, Rao PNG and Naidu K M. 1986. The effects of water stress during the formative phase on stomatal resistance and leaf water potential and its relationship with yield in ten sugarcane varieties. *Field Crops Research* **13**(4): 345–53.

Venkataramana S, Shunmugasundaram S and Naidu K M. 1984. Growth behaviour of field grown sugar-cane varieties in relation to environmental parameters and soil moisture stress. *Agriculture, Forest Meteorology* **31**: 251–60.