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# Field Screening of Sugarcane (*Saccharum* spp.) Mutant and Commercial Genotypes for Salt Tolerance

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**Abstract**

Growth and physiological attributes and sugar quality parameters are considered key criteria for screening sugarcane cultivars for salt tolerance. Maximum cane growth and yield were found in a positive check ('K88-92') as well as in cv. '(A3)AE1-18' when subjected to salt affected soil. Percent reduction in $F_v/F_m$, quantum efficiency of PSII ($\Phi_{PSII}$) and water use efficiency (WUE) due to salt stress was considerably low in 'K88-92', '(A3)AE1-18' and 'KK3' which was associated with very low salt-induced reduction in net photosynthetic rate and growth characters such as shoot length, number of internodes, and internodal length as well as yield traits. In addition, brix, polarlization, fiber, purity and commercial cane sugar (CCS) in '(A18)AE2-15' and '(A3)AE1-18' were well maintained under saline stress. By subjecting the data for various physiological, growth, yield and sugar quality parameters to the Ward's cluster analysis 'K88-92' (positive check), '(A3)AE1-18' and 'KK3' were identified as salt tolerant, whereas '(A11)AE1-114' and 'K97-32' as salt sensitive.

***Keywords:*** cluster analysis, net photosynthetic rate, sugar qualities, water use efficiency, yield traits

## Introduction

Sugarcane (*Saccharum* sp.) is one of the key commercial crops of the tropical and subtropical zones of the world. However, its yield is reduced to about 50% when the crop is grown on salt affected soils (Wiedenfeld, 2008). Plant physiological and biochemical responses in sugarcane grown under salt stress have been well documented. For examples, negative effects of saline stress on a number of sugarcane growth and physiological characteristics such as water potential, membrane integrity, nutritional balance, photosynthetic pigments, chlorophyll fluorescence, net photosynthetic rate, growth and yield have been reported (Cha-um and Kirdmanee, 2009; Gomathi and Thandapani, 2004, 2005). However, a great magnitude of intercultivar variation for salt tolerance is reported to occur in the sugarcane germplasm. For example, 'Co 85019', 'Co 94012', 'Co 94008', 'Co 86032', 'Co 92038', 'Co 85004', 'CPF-213', 'BO91', 'Co 1158', 'CoSe 92423', 'CP-4333', 'S-86-US-699', 'CP66-346' and 'H69-8235' (commercial cultivars and breeding lines) have been categorized as salt tolerant and 'CP-71-3002', 'H65-7052', 'HSF-240', 'L-116', 'Si 940-50', 'Co 85036', 'Co 97010', 'Co 95007', 'Co 97009' and 'Co 95016' as salt sensitive based on a variety of phenotypic indices (Gandonou *et al.*, 2011; Gomathi and Thandapani, 2004; Plaut *et al.*, 2000). However, most of the screening studies have been carried out under laboratory or greenhouse conditions. Thus, it is not sure whether degree of salt tolerance of different cultivars observed under controlled or semi-controlled conditions would be maintained under natural field conditions as the latter growth habitat is embraced with a variety of atmospheric and edaphic factors which in combination may enhance the adverse effects of a single stress. Thus, the principal aim of the present investigation was to classify some elite sugarcane genotypes in terms of their tolerance to salt stress imposed by a natural salt affected field, using some key physiological, growth, yield and quality attributes.

## Materials and methods

*Plant materials and salt affected treatment*

Six mutant cultivars of sugarcane, '(A3)AE1-17', '(A9) AE1-103', '(A11)AE1-114', '(A13)AE1-126', '(A18) AE2-15' and 'D14' derived from γ-irradiation and ethyl methane sulfonate (EMS), and 8 commercial cultivars, i.e., 'LK92-11' (wild type), 'K95-84', 'K93-219', 'K84-200', 'K97-32', 'Mitr Phol 3', 'KK3' including a positive check ('K88-92') were propagated in MS (Murashige and Skoog, 1962) supplemented with 8.88 μM benzyl ad-

enine (BA), 3% sucrose and 0.25% Phytagel® for 6 weeks. Single shoots were excised and roots induced on the MS medium supplemented with 2.46 µM indole butyric acid (IBA) for 2 weeks. Plantlets were cultured *in vitro* under 25±2°C ambient temperature, 60±5% relative humidity (RH), and 60±5 µmol $m^{-2}$ $s^{-1}$ photosynthetic photon flux density (PPFD) provided by fluorescent lamps with a 16 h $d^{-1}$ photoperiod. Then, the sugarcane plantlets were transferred to MS sugar-free liquid medium using vermiculite as supporting material. The number of air exchanges in the plastic chamber was adjusted to 5.13 µmol $CO_2$ $h^{-1}$ by punching 32 holes on sideward of the plastic chamber (∅ 1 cm) and covering the holes with microporous filters (0.2 µm of pore size). For acclimatization, the plantlets were subsequently cultured in a plant growth incubator under 25±2°C ambient temperature, 60±5% RH, and 120±5 µmol $m^{-2}$ $s^{-1}$ PPFD provided by fluorescent lamps with a 16 h $d^{-1}$ photoperiod and $CO_2$ enrichment at 1,000±100 µmol $mol^{-1}$ (Cha-um *et al.*, 2003). Plantlets of 14 sugarcane cultivars were directly transferred to plastic bags containing clay soil (EC = 2.687 dS $m^{-1}$; pH = 5.5; organic matter = 10.36%; total nitrogen = 0.17%; total phosphorus = 0.07%; total potassium = 1.19%) in 50% light intensity in a greenhouse for 1 month. Irrigation was applied as water spray. The acclimatized plants were directly transplanted to a field (30 cm plant to plant and 150 cm row to row distance) at two sites including clay soil (control) and salt affected soil (Tab. 1) at Chaiyaphum province, Northeast of Thailand (Latitude 16° 35'N and Longitude 101° 55'E) for 10 months. Chemical fertilizer (16:16:16; nitrogen: phosphorus: potassium) was applied three times, i.e., February, May and August at 0.0156 kg $m^{-2}$ prior to stalk harvesting in November 2011. Data for plant height, stalk weight, number of stalks per plot, and total stalk weight per plot of sugarcane cultivars were recorded. Photosynthetic abilities, water use efficiency, growth characters, yield attributes, and sugar qualities were measured at the harvesting stage.

*Data collection*

Chlorophyll fluorescence parameters such as maximum quantum yield of PSII ($F_v/F_m$), photon yield of PSII, ($\Phi_{PSII}$), photochemical quenching (qP), and non-photochemical quenching (NPQ) from the youngest fully grown leaf (adaxial surface) from each plant were appraised using a fluorescence meter (FMS2, Hansatech Instrument Ltd., Norfolk, UK) following Loggini *et al.* (1999). Initial ($F_0$) and maximum ($F_m$) fluorescence were measured on a leaf adapted to dark conditions for 30 min. The variable fluorescence yield ($F_v$) was calculated using an equation ($F_m$-$F_0$) following Maxwell and Johnson (2000).

Net photosynthetic rate ($P_n$; µmol $m^{-2}$ $s^{-1}$), transpiration rate (E; mmol $H_2O$ $m^{-2}$ $s^{-1}$) and water use efficiency (WUE; µmol $CO_2$ $mmol^{-1}$ $H_2O$) were measured using a Portable Photosynthesis System (Model LI 6400, LI-COR® Inc, Lincoln, Nebraska, USA) with an Infra-red Gas Analyser following Cha-um *et al.* (2007). Photosynthetic WUE was calculated using the equation: WUE = $P_n$/E.

Shoot height, number of internodes, intermodal length, single stalk weight, and stalk yield were measured at the harvesting stage (10 months after planting). Brix percentage was measured using a hand-held refractrometer (model H-50, ATAGO, Tokyo, Japan). Polarization percentage and fiber percentage were also assayed. Purity percentage was calculated according to equation: Purity (%) = [Sucrose percentage/Brix percentage] × 100. In addition, commercial cane sugar (CCS) was calculated following the equation: CCS (%) = [1.05×Sucrose percentage] – [0.292×Brix percentage] (Meade and Chen, 1977).

*Experiment design and statistical analysis*

The experiment was arranged as 14 × 2 factorials in a Completely Randomized Block Design (CRBD) with eight replicates ($n$ = 8). Significant differences among the mean values were worked out using the Duncan's New DMRT and analyzed with the SPSS software. Data for all variables were subjected to the Ward's method of Hierarchical cluster analysis in SPSS software to classify the cultivars into salt tolerant and salt sensitive categories.

**Results and discussion**

*Growth performances and yield traits*

Almost all growth attributes measured in the sugarcane cultivars examined in the present investigation were severely affected by salt stress. There was a marked reduction shoot length in all cultivars, but the cultivars differed significantly in this attribute. Salt-induced reduction in shoot length was significantly lower in the positive check 'K88-92' (4.90% reduction) than that in the other cultivars, e.g., 14.55% in 'K95-84' and 41.41% in '(A11)AE1-114' (Tab. 2 and Fig. 1A). The cultivars also differed significantly for

Tab. 1. Soil electrical conductivity ($EC_e$), pH, organic matter (OM), available phosphorus (P), potassium (K), sodium (Na) and chloride (Cl) in the non-saline (control) and salt affected soils at two depths, 0-30 cm and 30-60 cm

| Site | Depth (cm) | $EC_e$ (dS $m^{-1}$) | pH | OM (%) | P (ppm) | K (ppm) | Na (ppm) | Cl (ppm) |
|---|---|---|---|---|---|---|---|---|
| Control | 0-30 | 9.37 | 8.07 | 3.05 | 1884 | 279 | 594 | 778 |
| | 30-60 | 6.18 | 8.23 | 1.14 | 504 | 167 | 530 | 725 |
| Salt affected soil | 0-30 | 37.43 | 6.27 | 0.97 | 460 | 116 | 1348 | 4134 |
| | 30-60 | 25.20 | 5.99 | 1.03 | 312 | 98 | 1061 | 3221 |

number of internodes under saline stress, e.g. number of internodes reduced to 1.19% in 'K95-84' and 24.53% in '(A18)AE2-15' under saline regime (Tab. 2). Internodal length in the salt stressed plants of all cultivars decreased significantly when compared to that in controlled plants varying from 29.41% reduction in '(A11)AE1-114' to 57.97% in 'K84-200' (Tab. 2 and Fig. 1B). Single stalk weight in each cultivar decreased significantly due to salt stress, however, there had been considerable variation for salt tolerance in the sugarcane germplasm examined in the present study in terms of single stalk weight (Tab. 2 and Fig. 1C). Yield of sugarcane per sprout in salt stressed plants of all cultivars decreased significantly varying from 22.62% reduction in 'K95-84' to 75.64% in 'K97-32' (Tab. 2 and Fig. 1D). Growth parameters are simple, rapid and sensitive method to assay when sugarcane exposed to salt stress. For example, shoot height parameter of sugarcane pot culture was reduced for 8.8% in salt stressed 'CoS 03261' (8 dS $m^{-1}$ $EC_e$) for 150 days. Leaf area reduction in 'CoS 95-255' and 'CoSe 96436' was 5.9% and 8.6% respectively. In addition, the lowest reduction percentage of dry matter in 'CoS 07250' was identified as salt tolerant variety (Saxena *et al.*, 2010). From this it is evident that only one parameter may not be suitable to classify sugarcane cultivars/lines with regard to degree of salt tolerance. For example, stalk girth, internodal length, and yield of salt tolerant sugarcane cultivars 'CP43-33' and 'CPF-213' were higher than those in salt susceptible cv. 'L116' when subjected to varying levels of saline stress for 280 days (Akhtar *et al.*, 2001). In the same study, reduction in stalk yield and brix percentage in salt tolerant cv. 'CP43-33' was reported to be significantly lower (1.88% and 20.9% reduction) than that in salt sensitive 'CP-71-3002' (75.30% and 38.75%) under 120 mM NaCl. Thus, variation in salt tolerance in sugarcane germplasm in terms of different growth parameters exists and is variable to a great extent depending on the type of cultivars.

*Alteration in physiological characteristics*

Maximum quantum yield of PSII ($F_v/F_m$) in the salt stressed plants of all sugarcane cultivars decreased significantly except in the positive check ('K88-92') and '(A3)

Tab. 2. Shoot length, number of internodes, internodal length, single stalk weight and stalk yield traits in 14 sugarcane genotypes grown under non-saline (control) and salt-affected soils for 10 months

| Genotypes | Soil | Shoot length (cm) | Number of internodes | Internodal length (cm) | Single stalk weight (kg $cane^{-1}$) | Stalk yield (kg $sprout^{-1}$) |
|---|---|---|---|---|---|---|
| 'LK92-11' | Control | 228.3ab | 23.0a | 9.85b | 1.75bc | 24.23d |
| | salt-affected | 186.5ghi | 16.0bc | 7.63c | 1.30d | 16.71fg |
| 'K95-84' | control | 226.8abc | 21.0a | 10.08b | 2.15ab | 33.68ab |
| | salt-affected | 193.8efg | 20.8ab | 6.40d | 1.85b | 26.06cd |
| 'K93-219' | control | 169.3ijk | 17.0b | 15.69a | 1.05e | 13.26ghi |
| | salt-affected | 125.0o | 9.5d | 9.50b | 0.85f | 10.60ij |
| 'D14' | control | 213.5bcd | 24.8a | 10.62b | 2.05b | 36.37a |
| | salt-affected | 165.3jkl | 14.8c | 10.11b | 1.75bc | 24.51d |
| 'K84-200' | control | 161.8jkl | 16.0bc | 14.75a | 0.93f | 12.90fgh |
| | salt-affected | 131.0o | 10.0d | 6.20d | 0.55g | 8.08i |
| 'A9' | control | 171.0hij | 25.8a | 13.18ab | 1.35d | 14.28fgh |
| | salt-affected | 142.0mno | 13.3cd | 10.16b | 0.90f | 8.80i |
| 'K97-32' | control | 224.3abc | 24.0a | 10.56b | 2.50a | 36.62a |
| | salt-affected | 138.0no | 15.0bc | 7.31c | 0.90f | 8.92i |
| 'A18' | control | 179.3ghi | 13.3cd | 11.53b | 1.05e | 11.83ghi |
| | salt-affected | 132.3o | 10.0d | 7.25c | 0.95f | 7.96i |
| 'A13' | control | 231.5a | 25.3a | 8.56bc | 2.10ab | 26.80cd |
| | salt-affected | 193.3efg | 20.0ab | 6.58d | 1.70bc | 18.18ef |
| 'Mitr Phol 3' | control | 206.0def | 18.3b | 13.13ab | 1.80bc | 25.04cd |
| | salt-affected | 154.8klm | 11.8cd | 6.75d | 1.05e | 17.85ef |
| 'A11' | control | 225.3abc | 17.5b | 10.93b | 1.90b | 23.71d |
| | salt-affected | 131.8o | 9.8d | 7.71c | 0.70f | 7.72i |
| 'K88-92' | control | 214.3bcd | 20.3ab | 9.13b | 2.08b | 29.85bc |
| | salt-affected | 203.8def | 16.8b | 6.35d | 1.80bc | 22.54d |
| 'KK3' | control | 184.5fgh | 15.5bc | 13.89ab | 1.90b | 23.30d |
| | salt-affected | 147.0mno | 10.5d | 10.29b | 0.90f | 16.42fg |
| 'A3' | control | 205.3def | 18.7b | 11.96b | 1.40cd | 17.67ef |
| | salt-affected | 173.8ghi | 12.8c | 8.63bc | 1.15e | 12.94ghi |

Different letters in each column show significant difference at $p \leq 0.01$ by the Duncan's New Multiple Range Test (DMRT)

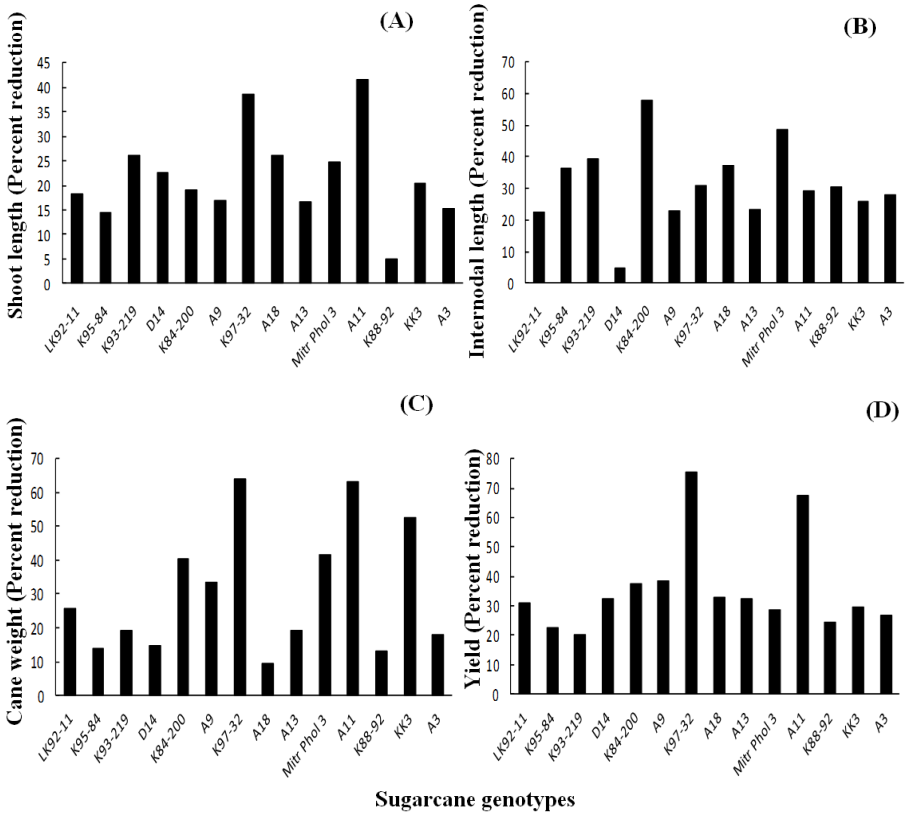


Fig. 1. Percent reduction in shoot length(A), internodal length (B), cane weight (C), and yield (D) in 14 sugarcane genotypes grown under non-saline (control) and salt-affected soils for 10 months

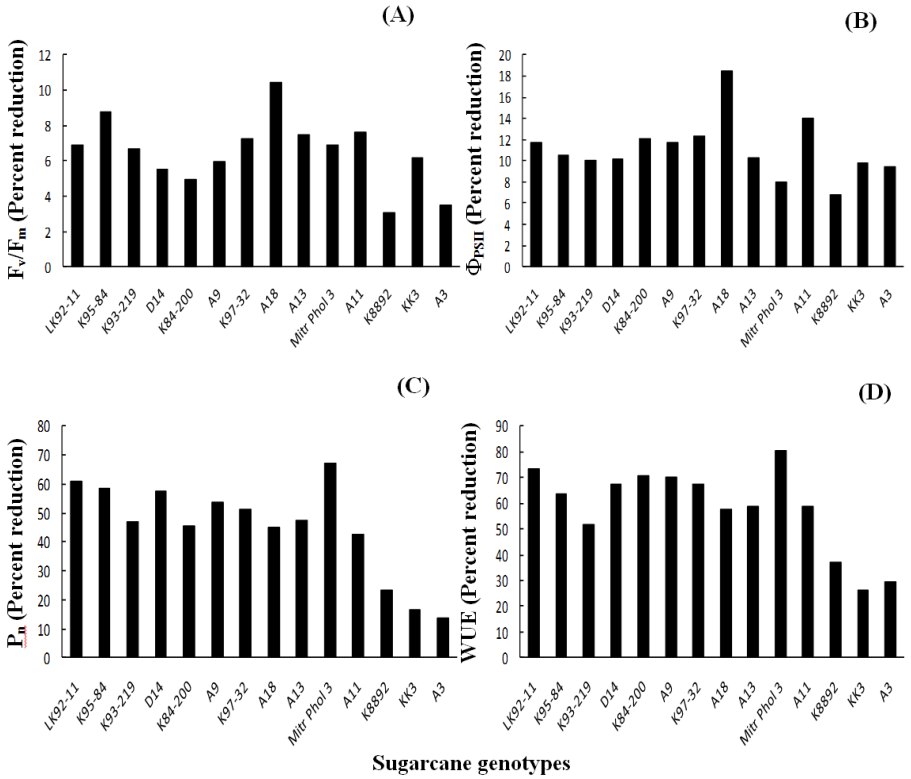


Fig. 2. Percent reduction in $F_v/F_m$ (A), $\Phi_{PSII}$ (B), $P_n$ (C), and WUE (D) in 14 sugarcane genotypes grown under non-saline (control) and salt-affected soils for 10 months

Tab. 3. Maximum quantum yield of PSII ($F_v/F_m$), photon yield of PSII ($\Phi_{PSII}$), net photosynthetic rate ($P_n$) and water use efficiency (WUE) in 14 sugarcane genotypes grown under non-saline (control) and salt-affected soils for 10 months

| Genotypes | Soil | $F_v/F_m$ | $\Phi_{PSII}$ | $P_n$ ($\mu mol\ m^{-2}\ s^{-1}$) | WUE ($\mu mol\ CO_2\ mmol^{-1}\ H_2O$) |
|---|---|---|---|---|---|
| 'LK92-11' | control | 0.893ab | 0.829a | 74.1a | 123.5cde |
| | salt-affected | 0.832efg | 0.732bc | 29.0hi | 32.6kl |
| 'K95-84' | control | 0.891ab | 0.806a | 74.7a | 107.4fgh |
| | salt-affected | 0.813fg | 0.721bc | 31.2gh | 39.3jkl |
| 'K93-219' | control | 0.899ab | 0.823a | 74.2a | 108.7fgh |
| | salt-affected | 0.839def | 0.741bc | 39.5de | 52.8j |
| 'D14' | control | 0.905a | 0.808a | 71.8a | 113.0fgh |
| | salt-affected | 0.855cde | 0.726bc | 30.7gh | 36.6jkl |
| 'K84-200' | control | 0.882abc | 0.814a | 75.0a | 145.8a |
| | salt-affected | 0.839def | 0.716bcd | 41.0d | 42.6jkl |
| 'A9' | control | 0.891ab | 0.816a | 74.6a | 135.8abc |
| | salt-affected | 0.838def | 0.720bc | 34.6fg | 40.4jkl |
| 'K97-32' | control | 0.905a | 0.840a | 74.0a | 130.6abc |
| | salt-affected | 0.839def | 0.736bc | 36.0ef | 42.9jkl |
| 'A18' | control | 0.896ab | 0.830a | 72.1a | 103.0gh |
| | salt-affected | 0.802f | 0.677d | 39.7de | 43.6jkl |
| 'A13' | control | 0.893ab | 0.804a | 75.4a | 116.6efg |
| | salt-affected | 0.826efg | 0.721bc | 39.6de | 48.1jk |
| 'Mitr Phol 3' | control | 0.897ab | 0.817a | 75.0a | 144.9a |
| | salt-affected | 0.835efg | 0.751b | 24.6i | 28.4l |
| 'A11' | control | 0.897ab | 0.811a | 75.4a | 125.9cde |
| | salt-affected | 0.829efg | 0.697cd | 43.2d | 51.9j |
| 'K88-92' | control | 0.893ab | 0.817a | 71.3a | 116.9efg |
| | salt-affected | 0.866bcd | 0.761b | 58.4c | 73.4i |
| 'KK3' | control | 0.903ab | 0.823a | 74.9a | 141.6ab |
| | salt-affected | 0.847def | 0.743b | 62.5b | 104.8gh |
| 'A3' | control | 0.886abc | 0.823a | 74.2a | 138.2abc |
| | salt-affected | 0.855cde | 0.746b | 64.0b | 97.4h |

Different letters in each column show significant difference at $p \leq 0.01$ by the Duncan's New Multiple Range Test (DMRT)

AE1-17' in which reduction in this trait had been only 3.02% and 3.50%, respectively. In contrast, percent reduction in $F_v/F_m$ in the other sugarcane cultivars ranged from 4.95% in'K84-200') to 10.46% in '(A18)AE2-15' (Fig. 2A). Photon yield of PSII ($\Phi_{PSII}$), net photosynthetic rate ($P_n$) and water use efficiency (WUE = $P_n/E$) in all sugarcane cultivars declined significantly under saline stress (Tab. 3). Leaf $P_n$ and WUE were found to be very sensitive parameters in sugarcane cultivars subjected to salt affected soil, especially in salt sensitive cultivars. The $\Phi_{PSII}$ in the salt stressed sugarcane plants decreased significantly, e.g., 8.04% reduction in 'Mitr Phol 3', 6.78% in 'K88-92' (6.78%), 9.76% in 'KK3' (9.76%) and 9.39% in '(A3)AE1-17' (Fig. 1B). Similarly, percent reduction in $P_n$ salt stressed plants of 'K88-92', 'KK3' and '(A3)AE1-17' was 23.13%, 16.53% and 13.71%, respectively (Fig. 1C). Also, WUE in the salt stressed plants of 'K88-92' (37.20%), 'KK3' (26.01%) and '(A3)AE1-17' (29.51%) was 37.2%, 26.01%, and 29.51%, respectively (Fig. 1D). In the present study, $P_n$ (42.69-67.23%) and WUE (51.43-80.43%) in salt sensitive cultivars were also sensitive than $F_v/F_m$ (4.95-10.46%) and $\Phi_{PSII}$ (10.06-18.51%). *In vitro* salt tolerant screening, $F_v/F_m$, $\Phi_{PSII}$, quantum efficiency of PSII (qP) and $P_n$ in salt stressed plantlets (200 mM NaCl) were sharply decreased. Only $\Phi_{PSII}$ and qP in salt stressed 'K88-1' or 'K88-92' cultivar were maintained at <10% diminishing (Cha-um *et al.*, 2012). Also, the salt tolerant cultivar, 'K88-92' was applied as positive check in the field trial. The photosynthetic abilities in salt stressed plants have been potentially classified the salt tolerance in sugarcane. For example, diminishing of $F_v/F_m$ in salt tolerant genotypes, 'C 92038' (9.28%) and 'Co 85004' (6.85%) of sugarcane in mature and reproductive stage was lower than that in salt sensitive, 'Si 94050' (17.35%) and 'Co 85036' (22.46%) when subjected to 1% NaCl ($EC_e$ 7 dS $m^{-1}$) (Gomathi *et al.*, 2010; Gomathi and Rakkiyapan, 2011). Vasantha *et al.* (2010) reported that the $P_n$ in 8 sugarcane cultivars declined significantly but to a varying extent when treated with salt stress of $EC_e$ 8 dS $m^{-1}$. Percent reduction in $P_n$ cvs. 'Co 94012' and 'Co 94008' had been 4.57% and 4.56%, respectively, whereas that in other cultivars had been from 11.57% in 'Co 86032') to 46.25% in 'Co 97009' (Vasantha *et al.*, 2010). It has been reported

that the decline in $P_n$ depends on salt tolerance abilities, level of salt stress and period of salt treatment.

*Quality of sugarcane and cluster analysis*

Brix percentage of five sugarcane cultivars, 'K93-219', 'K84-200', '(A9)AE1-103', 'K97-32' and 'KK3' significantly decreased when plants were subjected to salt affected soil, i.e., varying from 17.49% in 'K84-200' to 26.58% in 'KK3', whereas that of other cultivars remained almost unchanged (Tab. 4 and Fig. 3). Polarization, fiber, purity and commercial cane sugar (CCS) percentages in salt stressed plants of all sugarcane cultivars also decreased significantly, especially in '(A13)AE1-126' (34.53%, 16.26%, 11.56% and 38.0% reduction, respectively), and 'KK3' (36.79%, 35.12%, 16.42% and 41.19%, respectively (Tab. 4 and Fig. 3). In contrast, the reduction in these quality parameters in the positive salt tolerant check 'K88-92' was relatively lower, i.e., 13.57%, 10.14%, 3.88% and 14.33% reduction, respectively. The data for physiological attributes, plant growth, yield potential and quality traits of sugarcane genotypes were subjected to the multivariate cluster analysis, through which it was possible to identify salt tolerant cluster as '(A3)AE1-11' and 'KK3' where in the positive check 'K88-92' was also present (Fig. 4). Also, '(A11)AE1-114' was classified as salt susceptible where in the negative check 'K97-32' was presented. Lingle and Wiegand (1997) have reported that brix, polarization and purity percentage of sugarcane cultivar 'CP 70-321' declined depending on soil salinity of a salt affected field (2-10 dS $m^{-1}$ $EC_e$). Also, brix, sucrose, purity and CCS in salt tolerant cultivars, 'C 92038' and 'Co 85004', have been reported to be maintained better than those in salt susceptible cultivars, 'Si 94050' and 'Co 85036' (Gomathi and Thandapani, 2005). In a previous study, the multivariate cluster analysis (Ward's method) has been found to be very effective in screening some commercial sugarcane cultivars for salt tolerance under controlled conditions (Cha-um *et al.*, 2012). However, in the recent report, changes in physiological and growth characters, yield attributes and quality of sugarcane were evaluated in a salt affected field.

In conclusion, salinity-induced decline in chlorophyll fluorescence, $P_n$, growth, yield and quality in salt stressed

Tab. 4. Brix percentage, polarization percentage, fiber percentage, purity and commercial cane sugar (CCS) traits in 14 sugarcane genotypes grown under non-saline (control) and salt-affected soils for 10 months

| Genotypes | Soil | Brix (%) | Polarization (%) | Fiber (%) | Purity (%) | CCS (%) |
|---|---|---|---|---|---|---|
| 'LK92-11' | Control | 21.85a | 13.21bc | 12.45b | 80.86bc | 9.69bc |
| | salt-affected | 20.30a | 9.41d | 10.39c | 71.84c | 6.12cd |
| 'K95-84' | Control | 19.20ab | 16.70b | 14.72a | 85.89a | 12.11a |
| | salt-affected | 16.45bc | 15.25b | 11.85b | 84.45a | 11.33ab |
| 'K93-219' | Control | 18.45b | 13.67bc | 11.96b | 80.23bc | 9.87bc |
| | salt-affected | 14.40c | 10.87cd | 11.26bc | 74.99c | 7.38c |
| 'D14' | Control | 20.75a | 14.97bc | 12.69b | 83.07a | 10.91b |
| | salt-affected | 17.75bc | 12.06c | 12.52b | 77.49bc | 8.33c |
| 'K84-200' | Control | 19.15ab | 10.56cd | 12.05b | 75.31c | 7.33c |
| | salt-affected | 15.80c | 8.77d | 10.33c | 70.23c | 5.61d |
| 'A9' | Control | 21.10a | 15.28b | 12.45b | 86.30a | 11.32ab |
| | salt-affected | 16.65bc | 12.82c | 12.03b | 84.30a | 9.59bc |
| 'K97-32' | Control | 18.20b | 12.76c | 11.29bc | 81.00b | 9.29bc |
| | salt-affected | 13.90c | 9.84d | 11.19bc | 71.65c | 6.47cd |
| 'A18' | Control | 19.00ab | 13.42bc | 11.55bc | 81.35b | 9.80bc |
| | salt-affected | 16.75bc | 12.01c | 11.13bc | 77.11bc | 8.38c |
| 'A13' | Control | 21.10a | 18.45a | 14.76a | 89.30a | 13.71a |
| | salt-affected | 19.40ab | 12.08c | 12.36b | 78.98bc | 8.50c |
| 'Mitr Phol 3' | Control | 19.10ab | 15.55b | 10.87bc | 85.84a | 11.94a |
| | salt-affected | 16.55bc | 13.37bc | 10.06c | 81.34b | 9.80bc |
| 'A11' | Control | 18.55b | 13.65bc | 10.62bc | 81.24b | 10.02b |
| | salt-affected | 16.60bc | 10.92cd | 10.35c | 75.96c | 7.64c |
| 'K88-92' | Control | 16.35bc | 16.88b | 13.31ab | 87.74a | 12.63a |
| | salt-affected | 14.65c | 14.59bc | 11.99b | 84.34a | 10.82b |
| 'KK3' | Control | 18.25b | 14.65bc | 15.86a | 84.95a | 10.39b |
| | salt-affected | 13.40c | 9.26d | 10.29c | 71.00c | 6.11cd |
| 'A3' | Control | 22.50a | 14.51bc | 13.68ab | 83.67ab | 10.61b |
| | salt-affected | 19.50ab | 14.01bc | 12.67b | 82.87ab | 10.04b |

Different letters in each column show significant difference at $p \leq 0.01$ by the Duncan's New Multiple Range Test (DMRT)

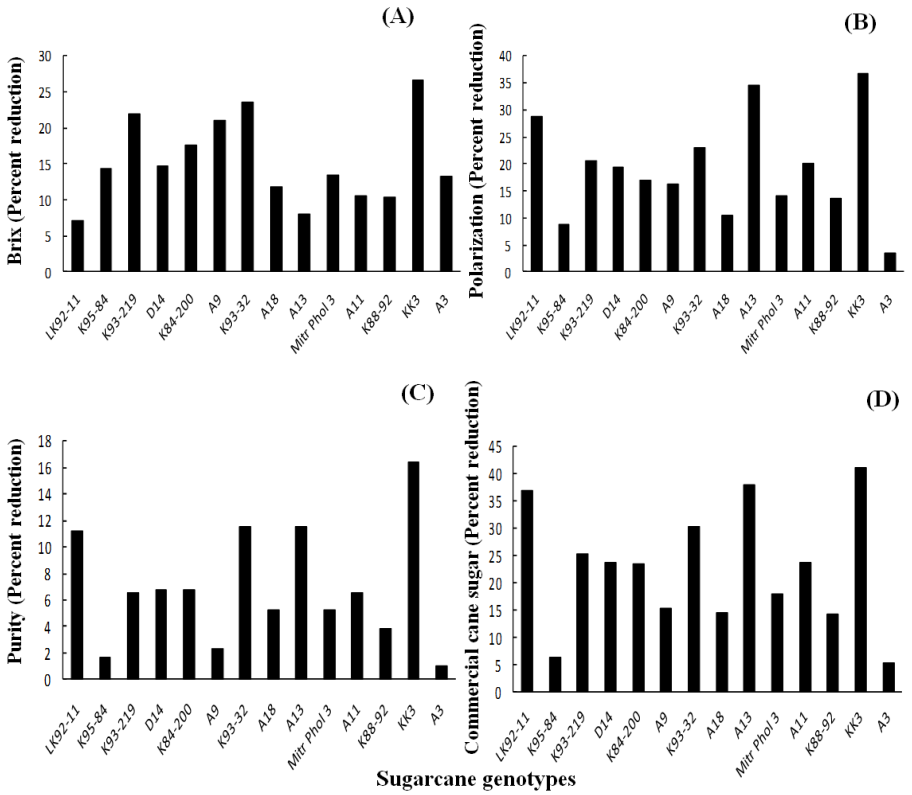


Fig. 3. Percent reduction in brix (A), polarization (B), purity (C), and commercial cane sugar (D) in 14 sugarcane genotypes grown under non-saline (control) and salt-affected soils for 10 months

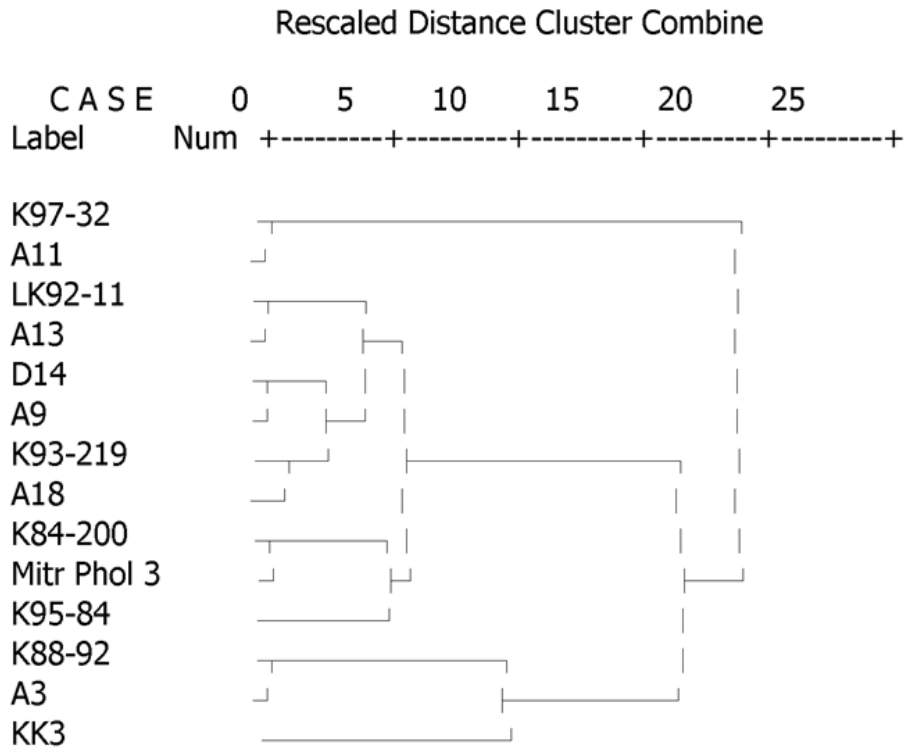


Fig. 4. Ward's dendrogram showing the classification of mutant sugarcane genotypes based on data for photosynthetic abilities, growth performances, yield and sugar quality traits (salt sensitive, 'A11' and 'K97-32', and salt tolerant, 'A3', 'KK3' and 'K88-92')

plants of sugarcane genotypes was evident. Multivariate analysis of data for all parameters allowed discriminating among the sugarcane cultivars for salt tolerance. Sugarcane cultivars '(A3)AE1-11' and 'KK3' were identified as salt tolerant using the Ward's cluster analysis as was the positive control 'K88-92'.

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