

**ASSESSMENT OF DROUGHT TOLERANCE AND RED ROT
RESISTANCE AMONG ELITE SUGARCANE (*Saccharum*
spp. Complex) VARIETIES AND ISH CLONES**

Thesis

**Submitted to the Punjab Agricultural University
in partial fulfilment of the requirements
for the degree of**

**MASTER OF SCIENCE
in
PLANT BREEDING AND GENETICS
(Minor Subject: Plant Pathology)**

By

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(L-2015-A-103-M)**

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2017

CERTIFICATE - I

This is to certify that the thesis entitled, “**Assessment of drought tolerance and red rot resistance among elite sugarcane (*Saccharum* spp. complex) varieties and ISH clones**” submitted for the degree of **Master of Science**, in the subject of **Plant Breeding and Genetics (Minor subject: Plant Pathology)** of the Punjab Agricultural University, Ludhiana, is a bonafide research work carried out by **Harmandeep Singh (L-2015-A-103-M)** under my supervision and that no part of this thesis/dissertation has been submitted for any other degree.

The assistance and help received during the course of investigation have been fully acknowledged.

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CERTIFICATE II

This is to certify that the thesis entitled, “**Assessment of drought tolerance and red rot resistance among elite sugarcane (*Saccharum* spp. complex) varieties and ISH clones**” submitted by **Harmandeep Singh (L-2015-A-103-M)** to the Punjab Agricultural University, Ludhiana, in partial fulfillment of the requirements for the degree of **Master of Science** in the subject of **Plant Breeding and Genetics (Minor subject: Plant Pathology)** has been approved by the Student’s Advisory Committee along with External Examiner after an oral examination on the same.

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Title of the Thesis	: Assessment of drought tolerance and red rot resistance among elite sugarcane (<i>Saccharum</i> spp. complex) varieties and ISH clones
Name of the Student and Admission No.	: Harmandeep Singh L-2015-A-103-M
Major Subject	: Plant Breeding & Genetics
Minor Subject	: Plant Pathology
Name and Designation of Major Advisor	: Dr. Gulzar Singh Sanghera Sugarcane Breeder
Degree to be Awarded	: M.Sc.
Year of award of Degree	: 2017
Total Pages in Thesis	: 115 + Annexure + VITA
Name of University	: Punjab Agricultural University, Ludhiana – 141004, Punjab, India.

ABSTRACT

Thirty diverse varieties/clones of sugarcane were evaluated for drought tolerance and red rot resistance in present study. All the 30 clones were planted in a randomized complete block design with two replications in normal (E_1) and water stress (E_2) environments. Under water stress (E_2) environment, irrigation was suspended for 2-3 weeks interval at critical growth stages viz. germination, tillering and grand growth stage. The observations on 8 cane yield and components, 4 physiological and 13 quality traits were recorded. Analysis of variance revealed significant differences among clones/varieties for all the traits under both environments. High magnitude of PCV, GCV, heritability and genetic advance were recorded for germination, single cane weight, number of shoots at 120 days, cane yield and CCS (t/ha) under water stress (E_2) environments. Association studies between agro-physiological traits revealed that cane yield had significant and positive association with stalk length, stalk diameter, single cane weight and chlorophyll content under both normal (E_1) and water stress (E_2) environments. Among quality traits, CCS (t/ha) at harvest exhibited significant positive association with pol (%) in juice, purity (%), CCS (%) at 10 months, brix (%), CCS (%) at 12 months and pol (%) in cane under both environments. Path analysis revealed that number of tillers at 240 days had maximum positive direct effect on cane yield followed by RWC at 60 days, stalk length, RWC at 120 days, number of shoots at 120 days and single cane weight and among quality traits pol (%) in juice at 12 months had maximum direct effect on CCS (t/ha) followed by brix (%) at 10 months, purity (%) at 10 months, pol (%) in juice at 10 months, fibre (%) at harvest, pol (%) cane percentage and juice extraction (%) at 10 months under water stress (E_2) environment. Based on low DSI (<0.75) and per cent reduction under E_2 , clones KV2012-2, KV2012-3, KV2012-4, KV2012-5, ISH148, ISH07 and ISH135 were found to withstand stress conditions. Results on disease screening showed that five varieties (Co238, CoS8436, Co118, CoPb92 and CoPb93) and 8 elite clones (ISH07, ISH135, CoPb14211, CoPb14212, CoPb13182, CoPb11214, CoPb12211, CoPb12212) were categorized as moderately resistance (score 2.1-4.0) to both CF 08 and CF 09 pathotypes of red rot. The varieties/clones having high yield, sugar, moderate resistance to red rot and low DSI (<0.75) can be utilized for future evaluation on large scale under water limited conditions across multilocations for their wider adaptability.

Keywords: Water stress, cane yield, physiological traits, DSI, red rot, resistance.

Signature of Major Advisor

Signature of the Student

ਖੋਜ ਗ੍ਰੰਥ ਦਾ ਸਿਰਲੇਖ	: ਗੰਨੇ (ਸੈਕਰਮ ਸਪੀਸ਼ੀਜ਼ ਕੰਪਲੈਕਸ) ਦੀਆਂ ਨਵੀਆਂ ਕਿਸਮਾਂ ਅਤੇ ਆਈ.ਐਸ.ਐਚ. ਕਲੋਨਾਂ ਵਿੱਚ ਸੋਕੇ ਪ੍ਰਤੀ ਸਹਿਣਸ਼ੀਲਤਾ ਅਤੇ ਅਤੇ ਰੱਤਾ ਰੋਗ ਵਿਰੁੱਧ ਪ੍ਰਤੀਰੋਧਕਤਾ ਦਾ ਮੁਲਾਂਕਣ
ਵਿਦਿਆਰਥੀ ਦਾ ਨਾਮ ਅਤੇ ਦਾਖਲਾ ਕ੍ਰਮਾਂਕ	: ਹਰਮਨਦੀਪ ਸਿੰਘ ਐਲ-2015-ਏ-103-ਐਮ
ਪ੍ਰਮੁੱਖ ਵਿਸ਼ਾ	: ਪਲਾਂਟ ਬ੍ਰੀਡਿੰਗ ਅਤੇ ਜੈਨੇਟਿਕਸ
ਸਹਿਯੋਗੀ ਵਿਸ਼ਾ	: ਪੌਦਾ ਰੋਗ ਵਿਗਿਆਨ
ਮੁੱਖ ਸਲਾਹਕਾਰ ਦਾ ਨਾਮ ਅਤੇ ਅਹੁਦਾ	: ਡਾ. ਗੁਲਜ਼ਾਰ ਸਿੰਘ ਸੰਗੇਤਾ ਗੰਨਾ ਬ੍ਰੀਡਰ
ਡਿਗਰੀ	: ਐਮ.ਐਸ.ਸੀ.
ਡਿਗਰੀ ਮਿਲਣ ਦਾ ਸਾਲ	: 2017
ਖੋਜ ਪੱਤਰ ਵਿੱਚ ਕੁੱਲ ਪੰਨੇ	: 115 + ਅੰਤਿਕਾ + ਵੀਟਾ
ਯੂਨੀਵਰਸਿਟੀ ਦਾ ਨਾਮ	: ਪੰਜਾਬ ਖੇਤੀਬਾੜੀ ਯੂਨੀਵਰਸਿਟੀ, ਲੁਧਿਆਣਾ - 141 004, ਪੰਜਾਬ, ਭਾਰਤ

ਸਾਰ ਅੰਸ਼

ਮੌਜੂਦਾ ਅਧਿਐਨ ਦੌਰਾਨ ਸੋਕੇ ਪ੍ਰਤੀ ਸਹਿਣਸ਼ੀਲ ਅਤੇ ਰੱਤਾ ਰੋਗ ਨੂੰ ਪ੍ਰਤੀਰੋਧਕ ਗੰਨੇ ਦੀਆਂ ਤੀਹ ਵਿਭਿੰਨ ਕਿਸਮਾਂ/ਕਲੋਨਾਂ ਦਾ ਮੁਲਾਂਕਣ ਕੀਤਾ ਗਿਆ। ਸਾਰੀਆਂ ਕਿਸਮਾਂ ਨੂੰ ਰੈਂਡੋਮਾਇਜ਼ਡ ਕੰਪਲੀਟ ਬਲਾਕ ਡਿਜ਼ਾਈਨ ਵਿਧੀ ਤਹਿਤ ਸਾਧਾਰਣ (E_1) ਅਤੇ ਪਾਣੀ ਦੀ ਕਮੀ (E_2) ਵਾਲੇ ਹਾਲਾਤਾਂ ਅਧੀਨ ਬੀਜਿਆ ਗਿਆ। ਪਾਣੀ ਦੀ ਕਮੀ (E_2) ਵਾਲੇ ਹਾਲਾਤ ਅਧੀਨ, ਫਸਲ ਦੇ ਵਿਕਾਸ ਦੇ ਪ੍ਰਮੁੱਖ ਪੜਾਵਾਂ ਜਿਵੇਂ ਕਿ ਪੁੰਗਰਨ ਸਮੇਂ, ਟਿਲਰਿੰਗ ਸਮੇਂ ਅਤੇ ਫਸਲ ਦੇ ਵਾਧੇ ਦੇ ਸਿਖਰ ਸਮੇਂ 'ਤੇ ਸਿੰਚਾਈ ਵਿੱਚ 2-3 ਹਫ਼ਤਿਆਂ ਦੀ ਦੇਰੀ ਕੀਤੀ ਗਈ। 8 ਗੰਨਿਆਂ ਦੇ ਝਾੜ ਅਤੇ ਸੰਘਟਕਾਂ, 4 ਫਿਜ਼ੀਓਲਾਜੀਕਲ ਅਤੇ ਗੁਣਵੱਤਾ ਨਾਲ ਸਬੰਧਤ 13 ਗੁਣਾਂ ਸਬੰਧੀ ਆਂਕੜੇ ਦਰਜ ਕੀਤੇ ਗਏ। ਵਿਭਿੰਨਤਾ ਮੁਲਾਂਕਣ ਤੋਂ ਇਹ ਤੱਥ ਸਾਹਮਣੇ ਆਏ ਕਿ ਦੋਨਾਂ ਹਾਲਾਤਾਂ ਅਧੀਨ ਸਾਰੇ ਦੇ ਸਾਰੇ ਗੁਣਾਂ ਲਈ ਗੰਨੇ ਦੇ ਕਲੋਨਾਂ/ਕਿਸਮਾਂ ਵਿੱਚ ਅਰਥਪੂਰਨ ਵਿਭਿੰਨਤਾ ਸੀ। ਪਾਣੀ ਦੀ ਘਾਟ (E_2) ਵਾਲੇ ਹਾਲਾਤ ਅਧੀਨ ਪੁੰਗਰਨ, ਇੱਕਹਿਰੇ ਗੰਨੇ ਦਾ ਭਾਰ, 120 ਦਿਨਾਂ ਮਗਰੋਂ ਸ਼ਾਖਾਵਾਂ ਦੀ ਗਿਣਤੀ, ਝਾੜ ਅਤੇ CCS (t/ha) ਲਈ PCV, GCV, ਹੈਰਿਟੇਬਿਲਿਟੀ ਅਤੇ ਅਨੁਵੰਸ਼ਿਕੀ ਵਿਕਾਸ ਮਿਕਦਾਰ ਵਧੇਰੇ ਦਰਜ ਕੀਤੀ ਗਈ। ਐਗਰੋ-ਫਿਜ਼ੀਓਲਾਜੀਕਲ ਗੁਣਾਂ ਦੇ ਸਹਿ-ਸਬੰਧਨ ਅਧਿਐਨ ਤੋਂ ਇਹ ਤੱਥ ਸਾਹਮਣੇ ਆਏ ਕਿ ਸਾਧਾਰਣ (E_1) ਅਤੇ ਪਾਣੀ ਦੀ ਕਮੀ (E_2) ਵਾਲੇ ਦੋਨਾਂ ਹਾਲਾਤਾਂ ਅਧੀਨ ਗੰਨੇ ਦੀ ਲੰਬਾਈ, ਵਿਆਸ, ਇਕਹਿਰੇ ਗੰਨੇ ਦਾ ਭਾਰ ਅਤੇ ਕਲੋਰੋਫਿਲ ਦੀ ਮਿਕਦਾਰ ਨਾਲ ਗੰਨੇ ਦੇ ਝਾੜ ਦਾ ਸਬੰਧ ਅਰਥਪੂਰਨ ਅਤੇ ਧਨਾਤਮਕ ਸੀ। ਦੋਨਾਂ ਹਾਲਾਤਾਂ ਅਧੀਨ, ਗੁਣਵੱਤਾ ਦੇ ਮਾਪਦੰਡਾਂ ਵਿੱਚੋਂ, ਕਟਾਈ ਸਮੇਂ CCS (t/ha), ਰਸ ਵਿੱਚ ਪੌਲ (%), ਸ਼ੁੱਧਤਾ (%), 10 ਮਹੀਨਿਆਂ 'ਤੇ CCS (%), ਬ੍ਰਿਕਸ (%), 12 ਮਹੀਨਿਆਂ 'ਤੇ CCS (%) ਅਤੇ ਪੌਲ (%) ਨਾਲ ਅਰਥਪੂਰਨ ਅਤੇ ਧਨਾਤਮਕ ਸਬੰਧ ਵੇਖਣ ਨੂੰ ਮਿਲਿਆ। ਪਾਥ ਮੁਲਾਂਕਣ ਤੋਂ ਪਤਾ ਚੱਲਿਆ ਕਿ ਪਾਣੀ ਦੀ ਕਮੀ ਵਾਲੇ ਹਾਲਾਤਾਂ (E_2) ਅਧੀਨ 240 ਦਿਨਾਂ ਉੱਪਰ ਟਿੱਲਰਾਂ ਦੀ ਗਿਣਤੀ ਦਾ ਗੰਨੇ ਦੇ ਝਾੜ ਅਤੇ ਇਸ ਉਪਰੰਤ 60 ਦਿਨਾਂ ਮਗਰੋਂ RWC, ਗੰਨੇ ਦੀ ਲੰਬਾਈ, 120 ਦਿਨਾਂ ਮਗਰੋਂ RWC, 120 ਦਿਨਾਂ ਮਗਰੋਂ ਸ਼ਾਖਾਵਾਂ ਦੀ ਗਿਣਤੀ ਅਤੇ ਇਕਹਿਰੇ ਗੰਨੇ ਦੇ ਭਾਰ ਉੱਪਰ ਸਭ ਤੋਂ ਵਧੇਰੇ ਧਨਾਤਮਕ ਅਤੇ ਸਿੱਧਾ ਪ੍ਰਭਾਵ ਪਿਆ ਅਤੇ ਗੁਣਵੱਤਾ ਨਾਲ ਸਬੰਧਤ ਗੁਣਾਂ ਵਿੱਚੋਂ 12 ਮਹੀਨਿਆਂ ਉੱਪਰ ਜੂਸ ਵਿੱਚ ਪੌਲ (%) ਦਾ CCS (t/ha) ਅਤੇ ਇਸ ਉਪਰੰਤ 10 ਮਹੀਨਿਆਂ ਉੱਪਰ ਜੂਸ ਵਿੱਚ ਬ੍ਰਿਕਸ (%), 10 ਮਹੀਨਿਆਂ ਉੱਪਰ ਸ਼ੁੱਧਤਾ (%), 10 ਮਹੀਨਿਆਂ ਉੱਪਰ ਪੌਲ (%), ਕਟਾਈ ਸਮੇਂ ਰੇਸ਼ੇ (%), 10 ਮਹੀਨਿਆਂ ਉੱਪਰ ਪੌਲ (%) ਅਤੇ ਰਸ ਦੇ ਨਿਸ਼ਕਰਸ਼ਣ ਦੀ ਪ੍ਰਤੀਸ਼ਤਤਾ (%) ਉੱਪਰ ਸਭ ਤੋਂ ਵਧੇਰੇ ਸਿੱਧਾ ਪ੍ਰਭਾਵ ਪਿਆ। ਘੱਟ DSI (<0.75) ਅਤੇ E_2 ਅਧੀਨ ਕਮੀ ਵਿੱਚ ਆਈ ਪ੍ਰਤੀਸ਼ਤਤਾ ਦੇ ਅਧਾਰ ਤੇ KV2012-2, KV2012-3, KV2012-4, KV2012-5, ISH148, ISH07 ਅਤੇ ISH135 ਕਲੋਨ ਪਾਣੀ ਦੀ ਘਾਟ ਨੂੰ ਸਹਾਰਣ ਦੇ ਸਮਰੱਥ ਸਨ। ਰੋਗ ਸਬੰਧੀ ਕੀਤੀ ਗਈ ਜਾਂਚ ਦੇ ਨਤੀਜਿਆਂ ਤੋਂ ਇਹ ਤੱਥ ਸਾਹਮਣੇ ਆਏ ਕਿ ਰੱਤਾ ਰੋਗ ਦੇ CF 08 ਅਤੇ CF 09 ਪੈਥੋਟਾਈਪਾਂ ਪ੍ਰਤੀ ਗੰਨੇ ਦੀਆਂ ਪੰਜ ਕਿਸਮਾਂ (Co238, CoS8436, Co118, CoPb92 ਅਤੇ CoPb93) ਅਤੇ 8 ਕਲੋਨ (ISH07, ISH135, CoPb14211, CoPb14212, CoPb13182, CoPb11214, CoPb12211 ਅਤੇ CoPb12212) ਪ੍ਰਤੀਰੋਧਕ ਸਨ। ਗੰਨੇ ਦੀਆਂ ਵਧੇਰੇ ਝਾੜ, ਸ਼ੂਗਰ, ਰੱਤਾ ਰੋਗ ਪ੍ਰਤੀ ਦਰਮਿਆਨੇ ਪੱਧਰ ਤੱਕ ਪ੍ਰਤੀਰੋਧਕ ਅਤੇ ਘੱਟ DSI (<0.75) ਵਾਲੀਆਂ ਕਿਸਮਾਂ/ਕਲੋਨਾਂ ਨੂੰ ਜ਼ਿਆਦਾ ਥਾਵਾਂ 'ਤੇ ਪਾਣੀ ਦੀ ਘਾਟ ਵਾਲੇ ਹਾਲਾਤਾਂ ਅਧੀਨ ਵੱਡੇ ਪੱਧਰ ਉੱਪਰ ਉਗਾਇਆ ਜਾ ਸਕਦਾ ਹੈ।

ਮੁੱਖ ਸ਼ਬਦ: ਪਾਣੀ ਦੀ ਘਾਟ, ਗੰਨੇ ਦਾ ਝਾੜ, ਫਿਜ਼ੀਓਲਾਜੀਕਲ ਗੁਣ, DSI, ਰੱਤਾ ਰੋਗ, ਪ੍ਰਤੀਰੋਧਕਤਾ

ACKNOWLEDGEMENT

Foremost, with folded hands, I bow with all humility and reverence to the Almighty God, the merciful and compassionate, for bestowing me with confidence, patience and courage in odd critical times for the successful completion of my degree and blessing me with skills so as to be all what I am today.

I feel privileged to express my deepest sense of gratitude, obligation and thanks to my esteemed Major Advisor **Dr. Gulzar Singh Sanghera**, Sugarcane Breeder, RRS Kapurthala, Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana, for his meticulous and constructive guidance, invaluable criticism, thoughtful suggestions and polite dealing which enabled me to complete my research work successfully. I learned the most important quality of dedication and honesty towards research from him. I consider myself fortunate to be his disciple.

It is my prerogative to thank worthy members of my Advisory committee, **Dr. R.S. Gill**, Senior Plant Breeder (Rice); **Dr.(Mrs.) Jyoti Jain**, Assistant Plant Pathologist; **Dr. S.K. Dhillon** (Dean PGS Nominee) for their able guidance, prudent suggestions and ever willing help during the course of study and meticulously scrutinizing this manuscript.

Special thanks are due to **Dr. Rupinderpal Singh**, Assistant Plant Breeder; **Dr. Vikrant Tyagi**, Research Assistant, **Dr. Lenika Kashyap**, Assistant Biochemist and **Dr. Anuradha Sharma**, Assistant Plant Pathologist for their constant cooperation and their good wishes during the tenure of research.

Words at my command are inadequate, in the present lexicon to convey my sublime obeisance to my revered grandparents, my respected father **S. Jaswinder Singh Ghuman** and mother **Smt. Sukhjot Kaur Ghuman**, my brother **Arshdeep Singh Ghuman**, and my sister **Nimrat Kaur Ghuman** whose infinite love, silent prayers, positive attitude and encouragement enabled me to put this tireless venture to a fruitful result.

I take this opportunity to extend my gratitude to my lab staff **Hazara Singh** and **Harjit Singh** for their ever willing help and support for the research work as well as the data analysis. Without them, it would be hard to complete this whole investigation.

Pleasant company, ever willing help, regular encouragement and sweet memories of my best friends **Harjit Singh Brar**, **Inderpal Singh**, **Jagmeet Singh**, **Roopkamal Kaur**, **Jashanjit Kaur**, **Rajpreet Singh Bajwa**, **Hardeep Singh**, **Amanbir Singh Pannu**, **Arshdeep Singh Gill**, **Yograj Singh Brar**, **Prabhjot Kaur** and **Gurdarshanpal Singh** will always remain as a precious asset with me. I express my cheerful acknowledgement towards them for providing me few moments of refreshment in between the exhausting hours to shed the workload which kept me energetic during this period and made my degree time memorable.

I may not have mentioned all but none is forgotten. Heart-felt thanks to all for providing me even a miniscule of help during this period of investigation. It's my honest conviction and sincerest prayer that the Almighty God blesses you all abundantly.

Place:

Date:

Harmandeep Singh

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CHAPTER I

INTRODUCTION

Sugarcane (*Saccharum* spp. hybrid complex) is the most important cash crop of India which is produced for making sugar, jaggery and khandsari. It is grown in over 110 countries and about 50 per cent of world sugarcane production occurs in Brazil and India (FAO 2016). It is indigenous to tropical South Asia and Southeast Asia (Daniels *et al* 1975; Sharpe and Peter 1998). India has emerged as the largest producer of sugar in the world. Sugar industry is the second largest agro processing industry in the country with significant contribution to the income, employment and tax revenue of the rural area (Priya *et al* 2015). In India, it is grown for jaggery, and also refined into sugar, primarily for consumption in tea and sweets, and for the production of alcoholic beverages. It is cultivated in most of the states of India (tropical and sub-tropical regions of the country) with total area coverage of 5.03 million hectare (M ha). It is the second most important agro-industrial crop of the country, next only to cotton. India is the largest sugar consuming country in the world with annual consumption of about 23 MT (Metric Tons) and the second largest producer of sugar after Brazil, with production of sugar crossing 25 million (Anonymous 2014). In India, the states of Uttar Pradesh (38.57 %), Maharashtra (17.76 %) and Karnataka (12.20 %) lead the nation in sugarcane production (Anonymous 2014). However, in Punjab it is cultivated in 94 thousand hectare area with an average cane yield of 73.4 tons per hectare.

It is a highly heterozygous and complex polyploid ($2n=80$ to 205) crop. It being a C₄, long duration, clonally propagated crop, is one of the most efficient quantum converters of solar energy. Worldwide, it is cultivated in both tropical and sub-tropical climate and acts as a source of energy, food and fuel and contributes about 75 per cent of the total world's sugar production (Kumar *et al* 2013). It is highly valuable mainly because it is able to store high of sugar or sucrose concentrations in the stem and has been used for ethanol production recently, which is an important renewable source of bio fuel. In contrast to other plants, sugarcane stores sucrose rather than polymeric compounds such as proteins, starch or lipids as the primary carbon and energy reserve. So, sugarcane by-products have received greater attention due to their multiple uses. Beside sugar, ethanol an important renewable bio fuel source is also produced from Sugarcane. Moreover, the bagasse of sugarcane has been largely used for energy cogeneration at distilleries, production of animal feed and also for paper production.

With an increase in adversaries of climate change, soil water deficit emerges as one of the principal challenges, not only for potential crop output but also for vegetation diversity. Abiotic stresses are the main causes of productivity losses in crops that cause adverse impacts on crop adaptation and competence. If a single abiotic stress is to be identified as the most common in limiting the growth of crops worldwide, it is limited water supply. In the face of a

global scarcity of water resources and the increased salinization of soil and water, water-deficit and salinity are widespread in many regions of world, and are expected to cause serious problem of more than 50% of all arable lands by the year 2050 (Vinocur and Altman, 2005). In this scenario, drought figures as the most significant stress and is considered an extremely important factor when it comes of losses in the productivity of sugarcane. Drought often sets in as a result of both inadequate rainfall and scarcely available soil water during the crop growing season (Sekhon *et al* 2010). Future projections show an increase in erratic and intense rainfall and at the same time reduction in the number of rain days that would result in an enhanced risk of drought in crops (Trenberth, 2011). Therefore, under rainfed conditions water scarcity is one of the most widespread limitations to crop production.

Sugarcane produces a large amount of biomass and because it is a water-loving crop, its requirements for water and fertilizers is equally very high. It consumes about one ton of water to produce 454 g of sugar (Scott 1972). In rainfed conditions it requires a minimum rainfall of 100-1200 mm per annum (Williams *et al* 1989). Scarcity of fresh water is affecting the productivity and profitability of sugarcane growers and millers in India. Due to glycophytic nature of sugarcane, drought conditions hinder with the process of sugar formation by affecting growth rate, cane yield, cane juice, juice purity and cane sucrose content. Thus, drought may reduce cane yield up to 50 per cent or even more (Silva *et al* 2007). It is a multi-dimensional stress, which causes several physiological and biochemical effects on plants (Jamaux *et al* 1997). Under water stress, there is considerable reduction in various cane yield, its components, physiological and quality traits (Nagaraja *et al* 2017, Silva *et al* 2007 and Hemaprabha *et al* 2004). Water stress affects adversely the sugarcane from germination to maturation stage. Severe drought can lead to lower yield cane and sugar per unit area as well as low sugar recovery from net weight of cane (Moore 1987). So, there will be pressure on growers to resort to produce sugarcane with less irrigation water in the future.

Crop scientists have customarily focussed on agronomic and physiological traits of sugarcane, which could be correlated with drought tolerance and that could further be used for breeding and development of new varieties of sugarcane (Domaingue 1995, Hemaprabha *et al* 2013 and Tena *et al* 2016). The tillering and grand growth stages in sugarcane (formative phase) have been identified as the critical water demand period (Ramesh, 2000) because during this stage 70-80% of cane yield is produced (Singh and Rao, 1987). Increased yield under stress can be obtained by modifying cultural practices to overcome stress, a slower but longer term and ultimately less expensive solution is to develop stress resistant genotypes (Moore, 1987). For that purpose, cane height can be considered as an important factor which has shown significant correlation with stalk diameter, NMC and stalk weight under water stress conditions (Silva *et al* 2008). Therefore, if one of these traits shows improved

performance during drought period, then the correlated traits should also perform better thus imparting drought tolerance, making it realistic to select clones with high productivity, NMC, cane height, and cane weight under water deficit during selection process.

Physiological traits are very important under stress conditions as they impart tolerance against many biotic as well as abiotic stresses (Sanghera *et al* 2017). In sugarcane, these traits impart drought tolerance by providing the strength and conditions which directly as well as indirectly helps the genotypes to cope up with water stress conditions. Photosynthetic responses and water relations to water deficit stress during this growth stage could therefore be useful in identifying drought tolerant genotypes. Mausa *et al* (2012) have reported that there are number of morphological, physiological, biochemical responses and adaptations to effects of drought stress. So evaluation of genotypes based on physiological parameters becomes necessary and the genotypes that shows best performance with regards to physiological traits under water stress conditions can be used in further breeding programmes (Graca *et al* 2010, Medeiros *et al* 2013 and Silva *et al* 2013). So, there is an urgent need to identify sugarcane varieties adapted to moisture stress in order to sustain sugarcane production and sugar recovery in the country.

Various biotic factors are also accountable for low yield of sugarcane and diseases are a major cause of concern. About hundred diseases of sugarcane have been reported in different parts of the world. In India, among the various diseases, red rot caused by *Colletotrichum falcatum* is one of the earliest recorded diseases and has been aptly called the cancer of sugarcane (Agnihotri, 1990). Red rot is causing considerable losses both in yield and juice quality especially in subtropical India resulting in significant losses to both cane growers and sugar factories (Gill *et al* 2012). The red rot infection can cause complete depletion of sucrose in the cane (Agnihotri *et al* 1992) and around 90 per cent reduction in juice extraction with 50 per cent red rot incidence (Ahmed *et al* 1986). A number of elite varieties have been wiped out and cultivation of promising varieties like CoJ64, CoJ82, CoJ84 and CoJ86 in Punjab had to be discontinued by farmers from time to time due to their high susceptibility to this disease. CoJ64, which had been the most popular variety of sugarcane in recent past, due of its highest sugar recovery, was among those varieties which succumbed to red rot disease. The disease which was earlier confined to sugarcane growing areas of Northern India and parts of North-Western India and Andhra Pradesh for several decades, has now started diffusing to parts of southern India, especially in the east coast zone, knocking down many improved sugarcane cultivars, the most notable being CoC671 (Natarajan *et al* 1998). As a result, breeding for red rot resistance has emerged as a significant aspect of present day varietal development and evolution.

The red rot pathogen being a facultative parasite, keeps on mutating in nature resulting in formation of new races responsible for the breakdown of hitherto resistant varieties under field conditions (Kaur *et al* 2014). In view of the non-availability of effective, systemic fungicides for controlling red rot under field conditions, breeding for red rot resistance remains the most practical, economical and effective option (Meeta *et al* 2007 and Sanghera *et al* 2017). The continued efforts are being made to generate elite material possessing tolerance to the various isolates of red rot coupled with best agronomic performance from the hybridization of specifically chosen parents (Sanghera *et al* 2016).

These biotic and abiotic stresses lead to a gradual reduction in sucrose per cent in juice and enhanced reducing sugars (Singh and Reddy, 1980). This degradation in juice quality has been attributed to larger number of immature internodes and higher cane juice weight during maturity phase following the relief from moisture stress (Singh and Naidu, 1985). At present, no completely drought and red rot resistant clone has been recommended or released in the state. Therefore, the present study was designed to evaluate different elite sugarcane varieties and ISH clones against important prevailing red rot pathotypes and drought tolerance and their effects on juice quality. Keeping above points into consideration the present study was planned with the following objectives.

- a. To evaluate relative drought tolerance and juice quality among elites clones of sugarcane.
- b. Screening of elite sugarcane clones for red rot resistance under artificial field conditions.

CHAPTER II

REVIEW OF LITERATURE

Sugarcane is tall perennial grass of the genus *Saccharum* (Family Poaceae, tribe Andropogoneae), native to warm temperate to tropical regions of Asia. It has stout, erect, jointed and fibrous stalks that are rich in sugar content and they measure about two to six meters in length. All sugarcane species are inter-breed and the major commercial cultivars are complex hybrids (Mukherjee 1957). It is a 12-14 months crop. Both biotic and abiotic stresses affect sugarcane productivity adversely in one or the other way. Relevant literature on different aspects of present study entitled, “Assessment of drought tolerance and red rot resistance among elite sugarcane (*Saccharum* spp. complex) varieties and ISH clones” documented has been collected and reviewed under following heads:

2.1 Genetic variability studies in sugarcane

The studies on the magnitude and kind of variation present in the material being utilized in crop improvement program provides basic information necessary for initiating a sound breeding program. A number of studies have been conducted to assess the type and magnitude of variation in sugarcane germplasm. Rao *et al* (1979) with objective of improvement of technological traits evaluated a large number of sugarcane germplasm belonging to all the species and revealed a high level of genetic variability for sucrose, purity, fiber content and total soluble solids.

Genetic variability for number of single cane weight, cane girth, millable canes per clump, internodes per cane, brix (%), sucrose content in juice, purity coefficient, invert sugar and fiber content in various sugarcane selections were studied by Verma (1989), in which they indicated that selection may be done for brix (%), number of millable canes per clump, invert sugar, single cane weight and internodes per cane for sugarcane improvement.

Chaudhary (2001) studied variability for seven characters in 32 sugarcane clones and found that genotypic variance was higher than environmental for cane yield, number of millable canes, single cane weight, stalk diameter and stalk length. Variability parameters (PCV and GCV) were higher in the characters single cane weight, germination at 45 DAP and number of millable canes.

Singh *et al* (2002) reported that characters like cane yield, CCS, number of millable canes, number of tillers, germination percentage and single cane weight had high whereas, cane height, cane thickness had moderate and sucrose percentage had low PCV and GCV. However, high heritability was recorded for cane weight, cane yield per plot.

Heritability (broad sense) and genetic were estimated in advance 28 sugarcane genotypes (Doule and Balasundaram 2004). They found that fiber per cent recorded the

highest heritability while rind hardness and moisture content recorded moderate levels of heritability. The genetic advance for rind hardness and fiber per cent cane was relatively high compared to moisture per cent cane.

Kashif and Khan (2007) reported significant levels of variability coupled with high broad sense heritability in sugarcane for different quantitative traits viz. plant height, number of tillers per plant, intermodal length, number of leaves per plant, leaf area, cane diameter, cane weight, brix value and sucrose content.

Out of genotypic and phenotypic coefficient of variability studies, heritability and genetic advance study Das *et al* (2007) confirmed that the traits like SCW followed by NMC and sucrose per cent must be of higher priority to the sugarcane breeder while selection during varietal development.

Silva *et al* (2008) conducted comparative variability analysis in sugarcane families under two irrigation regimes and reported that NMC and cane length were influenced by water stressed conditions during the initial growth phase and for stalk diameter and Brix, water regime had no effect on the average expression of the characters during the growth phase.

Twenty five promising clones and two standards of sugarcane were evaluated for different agronomic traits (Rahman and Bhuiayn, 2009) who reported high genotypic coefficient of variation for mean number of tillers/hectare, cane yield/hectare and single cane weight. They also documented high heritability with high genetic advance (as a percentage of the mean) for number of tillers/hectare and single stalk weight in these studies.

Anbanandan and Saravanan (2010) studied the variability for eleven characters in sugarcane and recorded high phenotypic and genotypic coefficient of variability for cane weight and cane yield per plot, while low variability for cane length, cane thickness, brix percent. Further, they found that cane weight and sugar cane yield per plot exhibited high heritability coupled with high genetic advance and traits like internode length, brix percent, sucrose percent and commercial cane sugar percent showed high heritability with moderate genetic advance. Also the traits like cane length, cane thickness and purity coefficient exhibited high heritability with low genetic advance.

Study conducted by Mali *et al* (2010) exposed highly significant differences among all the genotypes for all the characters evaluated, each character showing ample amount of variation. High heritability coupled with high genetic advance observed for number of tillers and single cane weight specified the presence of additive gene action and direct selection may be practised for high selection efficiency.

In study conducted by Khan *et al* (2012), ANOVA showed significant differences among sugarcane genotypes for all the plant characters. Highest cane yield (144 t/ha) was

recorded in clone NIA82-1026P5 and highest Pol % (20.82) and CCS % (16.45) were observed in CP84-1198.

Arora *et al* (2014) evaluated seventy two sugarcane genotypes to assess the kind and magnitude of variation for agronomically desirable traits and revealed that significant level of variability was present for traits germination count, tiller count, number of millable canes, cane length, number of internodes, cane girth, single cane weight, cane yield, total soluble solids, sucrose content in juice, purity coefficient, commercial cane sugar and ethanol potential. They also observed high genotypic coefficient of variation coupled with high heritability and high genetic advance for traits like cane yield, commercial cane sugar, number of tillers, number of millable canes, single cane weight and commercial cane sugar. They reported that differences between phenotypic coefficient of variation and genotypic coefficient of variation were very small for these traits and suggested that these traits should be given due weightage at the time of selection for achieving the desired improvements in sugarcane.

Sugarcane being genetically a complex crop in nature highly influenced by environmental conditions led to variation among different genotypes/varieties for cane yield and quality traits. Sanghera *et al* (2014a) collected data on cane yield and quality traits from 13 clones and analyzed components of genetic variability and revealed moderate estimates of GCV, PCV coupled with high heritability and genetic advance for CCS% 8 months, sucrose % at 8 months and CCS% at 10 months.

Studies on genetic variability, correlations and path coefficients of thirteen phenotypically diverse early maturing sugarcane clones were conducted by Sanghera *et al* (2015). The study exhibited highly significant differences among all the clones for all the traits studied, indicating the plentiful variation present among them. High phenotypic and genotypic coefficients of variation were observed for number of shoots at 240 days followed by cane girth and number of tillers at 120 days and single cane weight. High heritability estimates were recorded for stalk diameter (80.69%) while moderate for cane yield (74.42%) and number of millable canes (NMC) at 10 months (72.49%). It implied that simple selection for these traits would be effective and beneficial. However, moderate heritability together with high genetic advance observed for number of shoots and cane length directed towards the operative mechanism of additive gene action.

Basnayake *et al* (2015) obtained a large number of stomatal conductance (gs) measurements across varying moisture environments, locations and crop cycles with a diverse sugarcane germplasm which was comprised of introgression lines and commercial clones and indicated that there was a high genetic variation for stomatal conductance that could be exploited in future breeding prospects. Regardless of the environmental impacts on the

expression of this trait, moderate heritability was observed across 51 sets of individual measurements made on replicated trials over 3 years. The clone $\times$ water status interaction (G $\times$ E) variation was smaller than the clone (G) variation on many occasions.

In another study conducted by Kaur *et al* (2016), twelve hundred single bud setts of variety CoJ64 were irradiated with gamma rays. Analysis of variance revealed that mutagenic treatments generated significant differences for germination, number of tillers per clump, number of millable canes per clump, cane height, HR Brix, leaf length and single cane weight in M1V1 generation indicated the potential of mutagenic treatments for creating genetic variability for different traits in sugarcane. Cane weight an important trait in sugar cane ranged from 720.00 to 961.66 g. Maximum single cane weight was recorded for control followed by 10 Gy and 20 Gy treatments.

Tena *et al* (2016) conducted an experiment to assess heritability (broad sense) among yield components of sugarcane and detected high heritability (h^2 bs) for stalk diameter, single cane weight, millable cane number, stalk height and pol %. It was indicated that these traits would help in direct selection. The genetic gain of the yield components was worked out and was found to range from moderate to high. They recorded high GCV, heritability and expected genetic advance for stalk diameter, single cane weight and millable cane number.

Mehareb *et al* (2017) showed high genetic variance relative to environmental variance for different traits. They found moderate values of GCV and PCV coupled with high heritability for brix, sucrose, richness, sugar recovery and sugar yield. The highest values of PCV and GCV (%) across seasons were observed for reducing sugar followed by sugar yield. Heritability estimates across seasons exceeded 80% for all studied traits, except for purity (75.728%) and reducing sugar (75.596%).

2.2 Correlation and path analysis

Information about the nature of associations between cane yield and related characters is very necessary for effective selection towards cane yield improvement in sugarcane. An investigation was carried out by Thippeswamy *et al* (2003) to detect the association of characters and path coefficient analysis in sugarcane. They reported that out of 20 characters studied, characters like single cane weight, number of millable canes per plot, leaf area and germination per cent had positive and highly significant correlation with cane yield as well as with commercial cane sugar yield. However, path coefficient analysis revealed that commercial cane sugar per plot and commercial cane sugar per cent at harvest along with number of internodes were the major contributors to cane yield per plot, whereas sugar yield was largely depended on both cane yield and sucrose per cent.

Singh *et al* (2005) studied association and path analysis for different agronomic and quality characters of sugarcane with ratoon cane yield. Their results indicated that quality parameters like brix (%) in juice; sucrose per cent in juice and commercial cane sugar (%) had highly positive and significant correlation genotypically with Pol per cent in cane. Similarly, number of millable canes (NMC), single cane weight and cane height showed significant positive correlation with ratoon cane yield and sugar (t/ha). However, there was a weak negative correlation between NMC and single cane weight. Path analysis revealed that NMC and single cane weight showed significant positive direct contribution towards ratoon cane yield. It was suggested that for selection of high ratoon yield in early maturing genotypes, characters like NMC and single cane weight are of high significance.

Das *et al* (2007) reported that cane length, single cane weight (SCW), cane diameter and purity percentage had highly positive genetic association with both cane and sugar yield. Genetic correlation coefficient among quality parameters of juice showed that sucrose per cent is comparatively more reliable indicator of juice quality than brix per cent. For path analysis it was found that cane yield was effected to maximum extent directly by number of millable canes (NMC) while SCW had the maximum direct effect on sugar yield. However, both cane and sugar yield were influenced directly mainly by traits like SCW, NMC and sucrose per cent.

Mali *et al* (2010) reported in their study that cane yield was found to be significantly and positively correlated with number of internodes, cane diameter, single cane weight, CCS (kg/plot) at 360 DAP and NMC/plot. Path coefficient analysis indicated the highest positive direct effect of sucrose (%) at 360 DAP on cane yield.

Silva *et al* (2012) carried out path analysis in sugarcane genotypes to evaluate their physiological components under two different water conditions, with photosynthesis as the basic variable and reported that stomatal conductance, transpiration and the SPAD index could be considered as a priority in selection in sugarcane breeding programs for aiming to get more productive and tolerant genotypes to water stress.

Khan *et al* (2012) revealed that cane yield was positively associated with cane girth, clump weight, sugar yield, number of tillers and purity % whereas Pol % and CCS % showed negative correlation with cane yield.

Brasileiro *et al* (2013) evaluated the consistency of path analyses in sugarcane for enumerating the direct and indirect effects of contributing traits like stalk height, stalk diameter and number of stalks on sugarcane weight and reported that number of stalks had the greatest direct effect on sugarcane weight with the use of genetic and phenotypic correlations. Stalk diameter had a high direct effect on sugarcane weight, while stalk height had the lowest direct effect on sugarcane weight in most of the results obtained.

Sanghera *et al* (2014a) studied associations and their portioning in to direct and indirect effects using path analysis for cane yield and quality traits in sugarcane. They reported that CCS (t/ha) had positive and significant association with brix (%) 10 months, sucrose (%) 10 months, purity (%) 10 months and CCS (%) 10 months, brix (%) 8 months and cane yield (t/ha) indicating the importance of these traits. Also revealed highest direct effect of purity (%) 8 month followed by sucrose (%) 10 months, CCS (%) 10 months, brix (%) 10 months on CCS (t/ha) which concluded that due consideration be given to these traits for development of high sugar and cane yield varieties.

Kumar *et al* (2014) studied the associations among 15 characters in sugarcane and revealed that the cane yield was positively and significantly correlated with traits like germination (%), number of shoots, number of millable canes, number of green leaves, stalk diameter, stalk length, length of internodes, number of internodes and cane weight. Cane yield was found to be negatively correlated with brix in juice during all the phases of record.

Using correlation studies, Sanghera *et al* (2015) revealed that cane yield was found to be significantly and positively associated with germination percentage at 45 days, stalk length, NMC at 10 months, single cane weight and cane diameter. It was also reported that the highest positive direct effect on cane yield was exercised by sugarcane growth characters like no. of shoots 240 days, NMC, single cane weight and stalk diameter.

Basnayake *et al* (2015) reported a wide range of genetic correlations ($r_g = -0.29$ to 0.94) between stomatal conductance (g_s) and cane yield across test environments in sugarcane. They observed that canopy conductance (g_c) based on g_s and leaf area index (LAI) showed a stronger genetic correlation than the g_s with cane yield at 12 months and confirmed that the canopy conductance could have potential as a criterion for early-stage selection of clones in sugarcane breeding programmes.

Tena *et al* (2016) studied the inter-relationship status of morphological and sugar quality characters with sugarcane yield and reported that cane yield showed positive and highly significant correlation with NMC ($r = 0.832$), single cane weight ($r = 0.528$), stalk length ($r = 0.517$) and sugar yield ($r = 0.987$). They found positive and significant correlation of number of tillers and cane diameter with cane yield. Results obtained from path analysis revealed the highest positive direct effect of NMC (0.812) on cane yield followed by single cane weight (0.682) and pol per cent (0.550). However, stalk diameter and brix per cent had considerable negative direct effects and indirect positive effects through single cane weight on cane yield. They suggested that genotypes should be selected on the basis of high correlation and high positive direct effects like NMC, single cane weight and pol per cent to select for higher cane and sugar yield.

However, Barbosa *et al* (2017) reported that stalk diameter was the trait, best correlated with stalk dry matter yield. This demonstrated the possibility of obtaining significant gains via indirect selection for stalk dry matter yield via stalk diameter or via stalk diameter and number of tillers. They observed that technological variables viz. degrees brix and juice pol were the traits that best correlated with total recoverable sugar production and could be used to indirectly select for total recoverable sugar.

2.3 Studies on water stress in sugarcane

Water limitation is a major production constraint for sugarcane worldwide. However, to date, there has been little investigation of patterns of genetic variation in the response to water stress in sugarcane. According to Singh and Rao (1987) formative phase is the period when 70-80 % of cane yield is produced and drought during this period affected cane yield adversely (Venkataramana *et al* 1986). The tillering and grand growth stages of sugarcane crop, known as the sugarcane formative phase, have been identified and illustrated as the critical water demanding period in sugarcane (Ramesh 2000). Water relations in crop physiological processes and photosynthetic responses to water deficit stress during these growth stages could therefore be convenient in identifying drought tolerant genotypes (Silva *et al* 2007). Though breeding programmes in sugarcane with increased yield under normal conditions were attempted to improve drought tolerance, such studies have shown that varieties susceptible to drought wilted and showed reduced cane production early during drought, while tolerant varieties remained turgid and maintained near- optimum growth for longer time (Moore 1987), that necessitates identification of drought tolerant genotypes with desirable agro-morpho physiological traits.

2.3.1 Impact of water stress on cane yield, its components and quality traits

Inman-Bamber *et al* (1988) evaluated three varieties NC0376, N12 and N14 of sugarcane under two water regimes and found that stalk growth responded rapidly to both the onset and respite from water stress. Dry matter and sucrose contents of the stalk were reported to increase substantially during the stress periods and it appeared that moderate amounts of stress can lead to a substantial increase in sucrose yield. The dry matter and sucrose that were accumulated during the period of water stress in these sugarcane varieties were not noticeably affected when stress was relieved.

Wagih *et al* (2001) screened 26 sugarcane varieties under greenhouse conditions for their performance under water stress conditions at the formative growth stage by applying two water treatments. They reported that water stress significantly reduced the cane height, number of tillers, cane height and girth, root volume, root dry weight, leaf length and number of green leaves. Sheath moisture were positively correlated with cane height, cane girth, root volume, number of green leaves, leaf width, leaf length, root dry weight and number of green

leaves and negatively correlated with root bulk density. They identified three tolerant varieties, namely Co 997, Q77N1232 and Q127 based on this criteria.

Hemaprabha *et al* (2004) evaluated 97 genotypes containing high sugar content under water deficit condition and reported that reduction in single cane weight (64.16%) mainly through reduction in cane height (48.79%) affected cane yield under drought conditions, while juice quality traits were less affected. A wide range in sucrose content in the high sugared clones under drought was obtained which indicated the need to select stable clones among the high sugared clones. Six clones performed better for sucrose content under water deficit conditions and showed steady performance under both the normal and drought conditions. Seven clones possessing better yield and quality were recognised as potential sources for breeding for drought tolerance in future.

In order to ascertain parents for drought resistance breeding, Hemaprabha *et al* (2006) again assessed the performance of 645 Coimbatore selected sugarcane clones derived from different cross combinations grown under water deficit conditions. CoC 671 and Co 740 with better mean performance of juice quality traits were reported to serve as useful parents for quality improvement under drought situations. Significantly better performance of derivatives of CoC 671, both for cane yield and juice quality, revealed the high parental value of this clone. Other useful parents recognised were Co 740, Co 775, Co 6304, Co 6806, Co 7201 and Co 775. They concluded that utilization of these potential parents could lead to evolving drought tolerant varieties for improving sugarcane productivity in the drought prone regions of India.

Silva *et al* (2007) reported that some sugarcane families had high values for stalk diameter, stalk number and stalk height under water stress conditions. Silva *et al* (2008) also evaluated 80 genotypes including two controls (one drought-tolerant and one drought-sensitive) under a moderate water deficit condition in the field. Under stressed conditions, the tolerant control (TCP93-4245) showed higher productivity, stalk number, stalk height and stalk weight than the susceptible one (TCP87-3388). However, the susceptible control showed higher stalk diameter. There was found a linear association between cane productivity and its yield components, but stalk diameter was reported to be fairly unstable among the genotypes. Cane length showed significant correlation with NMC, stalk diameter and single cane weight. Stalk diameter also showed positive correlation with single cane weight. Therefore, during the selection procedure, when one of these traits is boosted by drought tolerance, the associated trait should also show improved performance, making it feasible to select genotypes with high productivity attributes under water deficit conditions.

Pawar *et al* (2011) conducted a study to analyse the performance of four sugarcane genotypes along with two check varieties under moisture stress. Among the four genotypes,

CoM0265 recorded minimum reduction (16.00%) in cane yield under moisture stress as compared to the irrigated crop, maintained maximum number of millable canes (96.26 thousands/ha) and had higher single cane weight (1.62 kg) over other genotypes and check varieties under moisture stress conditions thus, proved its ability to withstand moisture stress.

Basnayake *et al* (2012) conducted field experiments over 3 years under fully irrigated and managed water stress conditions at two locations. They reported that water stress treatments reduced cane yield and total dry matter to the extent of 17–52% and 20–56%, respectively, as compared to irrigated environment. However, there was little variation in genotype $\times$ environment interaction for traits like total dry matter and commercial cane sugar (CCS).

Hemaprabha *et al* (2013) evaluated 28 elite sugarcane hybrids and 165 progenies from a proven commercial cross (Co 740 $\times$ Co 775) for sugar yield traits and other contributory biochemical attributes under normal and drought conditions. In the genotypes, higher reduction under drought conditions were observed for internode length (45.76 %), single cane weight (25.5 %), NMC (22.8 %), cane length (20.10 %) and sucrose content (18.73 %), while cane diameter (2.92 %), internode number (3.58 %) and Brix (-6.99 %) showed marginal variation under normal and drought environments. Decrease in cane height and internode length indicated that cane length was most adversely affected by drought. Further, they reported that activity of nitrate reductase enzyme showed decline to the tune of 39.11 % and 44.95 % in the genotypes and progenies, respectively under drought stressed conditions. Also, proline accumulation and activities of superoxide dismutase and peroxidase almost doubled in the genotypes and progenies under stress. Based on all these findings, they categorized the population of 165 progenies into five classes of different levels of drought tolerance which followed a normal distribution curve.

Misra *et al* (2016) investigated the effect of drought on post-harvest quality of sugarcane crop for biochemical parameters (brix, commercial cane sugars (%), sucrose (%), purity coefficient, reducing sugars, titrable acidity index, pH, soluble acid invertase and dextran) and reported that CCS (%) in canes grown under normal conditions and the ones grown in drought condition after 10 days of harvest was decreased by 5.6 units and 4.04 units, respectively, in November harvest while in March harvest, 2.14 units and 5.38 units, respectively. A decline in sucrose (%) in juice and purity (%) by 0.58 units and 34.68 units, respectively, in month of November but in March, it was 3.55 units and 26.19 units, respectively, in canes grown under drought conditions. A noticeable increase in reducing sugars, titrable acidity index, soluble acid invertase, dextran and total microbial load was observed in canes grown in drought conditions than in the normal ones after 10 days of harvest.

2.3.2 Effect of water stress on physiological parameters in sugarcane

Morpho-physiological attributes which impart resistance/tolerance or susceptibility to a particular biotic and abiotic stress are important from crop production point of view. In case, a sugarcane variety possesses characteristic(s) divulging resistance/tolerance to a particular abiotic/biotic stress, with suboptimal cane and sugar yield, could be utilized as a parent for contributing the respective trait to the offspring. The adverse effects of water deficit on morphological, physiological and biochemical processes can be confirmed in all plant parts. In condition of water stress, common physiological alterations included reduced leaf water potential and the relative water content (Nogueira *et al* 2000), gaseous exchange as well as photosynthesis (Silva *et al* 2007). As a consequence, metabolic changes such as enhanced osmoregulation (Medeiros *et al* 2012) may occur along with significant changes on the plant growth, in response to the lower cellular turgor pressure (Hessini *et al* 2009). Thus, physiological studies on sugarcane may identify clones more tolerant to water stress and ultimately improve crop productivity.

In reply to drought conditions, proline contents tend to increase in sugarcane leaf tissues (Ho *et al* 1987). Under such conditions, drought resistant/tolerant varieties accumulate more proline content than the susceptible ones (Rao and Asokan, 1978). In drought tolerant sugarcane clones, proline was reported to accumulate rapidly and then it also rapidly declined during restoration of irrigation as compared to moderately tolerant and susceptible ones, depicting the tolerance mechanism in operation in tolerant sugarcane clones (Anonymous 1984).

Ho *et al* (1987) also elucidated the fact of emphasising on the accumulation of free proline that could be used as an index for selection towards drought tolerance in crop plants. A relatively more reduction in nitrate reductase activity during drought conditions in a drought tolerant variety than in the susceptible variety was ascertained as an indication for drought tolerance in plants (Gomez *et al* 1985). Another concrete physiological evidence was the accumulation of abscissic acid (ABA) which was also associated with water stress resistance (Grantz *et al* 1988).

Silva *et al* (2007) evaluated sugarcane clones for four physiological parameters viz. variable-to-maximum chlorophyll *a* fluorescence ratio (F_v/F_m), leaf chlorophyll content, leaf temperature (LT) and relative water content in leaf (RWC) to distinguish between drought tolerant and susceptible sugarcane genotypes subjected to a 90 days drought cycle. They reported that after 45 days of planting, the F_v/F_m , SPAD index and RWC of drought-stressed plants had declined significantly in all genotypes as compared to irrigated plants. However, the reductions were more severe in leaves of susceptible genotypes. Under drought stress condition, the tolerant genotypes maintained higher F_v/F_m , SPAD index (15%) and RWC

(16%) than the susceptible genotypes. In general, LT of drought-stressed plants was higher ($\sim 4^{\circ}\text{C}$) than that of well-watered plants. They suggested that these physiological tools could be used as reliable criteria in screening for drought tolerance in sugarcane.

To investigate the processes involved in the susceptibility of sugarcane clones to water deficit, Graca *et al* (2010) evaluated several physiological parameters in drought tolerant (SP83-2847 and CTC15) and sensitive (SP86-155) cultivars. They found that water stress affected the photosynthetic network of all the plants in different ways, within and among cultivars. The photosynthetic rate and stomatal conductance decreased significantly in all cultivars under water deficit conditions. As a whole, the tolerant cultivars exhibited a better photosynthetic performance than the sensitive cultivar under water stressed conditions.

Zhao *et al* (2010) evaluated the physiological processes and growth responses of sugarcane to water-deficit stress during formative growth stage. They reported that water stress reduced stomatal conductance, Photosystem II, Photochemical Efficiency (ΦPSII), leaf photosynthesis rate (Pn) and the number of tillers, resulting in reduced shoot biomass and total dry matter reduction. They also concluded that the measurement of physiological traits viz. stomatal conductance, photochemical efficiency and leaf photosynthesis rate during the formative stage may be useful for early detection of water stress in sugarcane.

Begum *et al* (2012) investigated the relationships among different physiological traits like total chlorophyll content, chlorophyll stability index, leaf area index and relative water content with juice quality in sugarcane under water stress condition during the grand growth period of sugarcane. They reported that physiological parameters viz., total chlorophyll, chlorophyll stability index, leaf area index and relative water content and biochemical parameters viz., brix, pol, purity and reducing sugar were reduced under drought treatments. The rates of reduction for most of the characters were higher in susceptible genotypes, while 36 genotypes were found in respect of physiological adaptation associated with juice quality under water deficit conditions.

Zhao *et al* (2013) identified effects of water deficit stress during sugarcane early growth on leaf photosynthetic components, plant growth, and dry matter accumulation under greenhouse. They found that water stress reduced leaf relative chlorophyll level (SPAD), stomatal conductance (gs), leaf net photosynthetic rate (Pn), transpiration rate (Tr), transpiration use efficiency (TUE) of photosynthesis and GLA, resulting in reduced shoot biomass. They concluded that physiological and growth traits, such as SPAD, gs , Pn , Tr , TUE, GLA, tillering, and stalk length may be useful for early detection of water stress and for evaluation of sugarcane genotypes in the stress tolerance.

Harmful effects of drought on the physiology of sugarcane during the initial development were evaluated by Medeiros *et al* (2013) who reported significant reduction on

stomatal conductance, transpiration, and net photosynthesis. They observed that a faster stomatal closure slowed the effects of drought on the gas exchanges parameters with a faster recovering after re-watering. Ashraf and Foolad *et al* (2007) showed that only solute accumulation does not favour the tolerance to drought *per se*, but the pathway that leads to the mechanism of drought tolerance is strongly influenced by this factor (Medeiros *et al* 2012).

Silva *et al* (2013) performed an experiment in green house using two sugarcane genotypes namely: HoCP93-776 (drought susceptible) and TCP02-4587 (drought tolerant) under different water regimes. Sixty days after planting, two different water treatments were applied (i.e., with or without water deficit). The SPAD index, photosynthetic pigments, water potential and relative water content in the leaves were also analysed. The genotype which was more tolerant to water deficit during the initial phase of development, was attributed to its high capacity to retain water in its leaves, higher water potential in leaves, better stomatal conductance efficiency, better water use efficiency and a higher photosynthetic capacity.

Abbas *et al* (2014) examined sugarcane varieties that exhibited significant difference in their contents of total phenolics as well as their scavenging capacities against free radicals, proline, glycine betaine and MDA production. They reported certain sugarcane varieties, demonstrated higher antioxidant activities due to their high phenolic contents.

Sales *et al* (2015) also conducted physiological evaluation of sugarcane genotypes under water stress conditions, and found that the tolerant variety was less affected by water deficit and could maintain photosynthesis for a longer period and thus displaying a faster recovery after rehydration as compared to the sensitive ones. It was also revealed that ferric superoxide dismutase isoforms were strongly enhanced under drought conditions, playing an important role in chloroplast redox homeostasis in drought tolerant sugarcane genotypes.

2.4 Screening of sugarcane against red rot disease

Biotic stresses, mainly diseases are the major concern for the sugarcane, resulting in its lower yield and quality. Among the diseases of sugarcane red rot of sugarcane is the most threatening disease of sugarcane, appropriately attributed as ‘Cancer’ of sugarcane. It causes severe loss in yield and quality of the sugarcane. Pathogen *Colletotrichum falcatum* responsible for this disease is highly variable in nature; hence, it causes the frequent breakdown of resistant sugarcane varieties due to its ongoing evolution (Kaur *et al* 2014, Sharma and Tamta, 2015). In spite of the best efforts of sugarcane improvement scientists, red rot is still posing challenges and threats in stabilizing cane and sugar production. Through the concerted efforts of breeders and pathologists, the disease has been contained to a manageable level and thus, the frequency and magnitude of red rot epidemic has been reduced to a great extent in recent decade (Duttamajumder 2008). In fact, entire sugarcane breeding in India is

now geared around red rot and no sugarcane variety is released for general cultivation without resistance to the prevalent pathotypes of red rot.

Abbott (1938) studied the nature of resistance to red rot among sugarcane varieties and revealed that resistance may be related to the resistance of the host to invasion of the parasite through the root primordial and to the development of the fungus within the host tissues after invasion had occurred. The first type of resistance is illustrated by C P 807, which is resistant to invasion through the root primordia under average field conditions, but which may be invaded under environmental conditions unfavourable to the host and favorable to the parasite, such as prolonged low temperatures accompanied by excessive soil moisture. Resistance of the host tissues to the spread of the parasite after invasion, therefore, was considered of greater importance.

The effect of drought conditions at planting time on sugarcane red rot was evaluated by Yin *et al* (1997) under controlled conditions and in the field. Disease severity, assessed as the number of nodes beyond which rot symptoms extended in the cane, number of nodes rotted and internode rot severity was increased in the cultivars by exposure to desiccation. However, response of individual cultivars varied for some disease traits assessed. In field experiments, *C. falcatum* inoculation along with exposure to desiccation produced the lowest shoot populations in plantings of inoculated stalks. These results demonstrated that red rot severity could be enhanced by the occurrence of drought conditions during the initial growth processes of sugarcane.

An experiment was conducted by Babu *et al* (2010) to generate diverse genetic stocks for resistance to red rot disease and other important economic traits. Study was carried out on progenies obtained from 39 crosses involving 45 parental clones of interspecific and inter-varietal origin. The progenies were evaluated for resistance to red rot disease and economic traits such as cane yield and quality. Parent progeny regression analysis suggested that about 50% of the variation in the population could be attributed to additive genetic variance. Two crosses involving susceptible parents viz. 971235 (S) x Co 1148 (S) and Co 88028 (S) x Co 775 (S) contributed 28-30% resistant progenies. These transgressive segregants were likely to be stable in resistance they provided due to additive gene action and could be used as donor parents in red rot resistance breeding programmes for imparting race non-specific red rot resistance.

Gill *et al* (2012) screened sugarcane genotypes belonging to twenty three diverse cross combinations for their reaction against two red rot pathotypes CF 08 and CF 03. A total of thirty genotypes belonging to eleven cross combination were found to have moderately resistant reaction to both the pathotypes. Three cross combination namely; CoS96869 GC, CoS92263 GC and Co 1148 GC were found to be promising, yielding higher number of

resistant clones as compared to other cross combinations. Overall, various cross combinations were found to give 65.70 and 49.25 per cent moderately resistant progenies to red rot pathotypes CF 03 and CF 08, respectively which indicated that the choice of parents is fairly appropriate for the generation of elite clones possessing tolerance to red rot disease

Bharathi *et al* (2012) screened sugarcane cultivars for their resistance to red rot pathogen and reported that out of fifty five early and mid-late genotypes, twenty six were found moderately resistant to red rot. Sixteen genotypes were found to be resistant and three were moderately susceptible. Four early and three mid late entries showed susceptible reaction while the 2000 R 551 was found highly susceptible to red rot pathogen.

Mahmud *et al* (2015) conducted an experiment to find out red rot causing pathogenic reactions of somaclones (R0) and their respective parents. 24 sugarcane genotypes including 4 sugarcane varieties were inoculated to screen red rot resistant after 7 months of planting. Some somaclones showed different reaction from their source varieties. It was revealed that induced somaclones showed variation with their source varieties for reaction against red rot pathogen.

Kaur *et al* (2016) irradiated twelve hundred single bud setts of cv. Co J 64 with gamma rays at 0, 10, 20, 25 and 30 Grays (Gy). The experimental material of M1V1 generation was assessed for reaction to red rot disease against two pathotypes viz. CF 08 and CF 09. Artificial evaluation of irradiated sub-clones against two red rot pathotypes CF 08 and CF 09 using plug method revealed moderate resistance for all the mutagenic treatments to variable extent. It was inferred that genetic variability could be induced in sugarcane using gamma rays for disease tolerance. The lower doses of gamma ray (10 and 20 Gy) were more effective to induce variation while higher doses have detrimental effects.

Effective control of red rot has been mainly through the use of resistant/tolerant sugarcane varieties. Even though the genetics of inheritance of red rot resistance is not well established, considerable progress has been made in the production of red rot resistant varieties of sugarcane. In India, the prime focus of sugarcane breeding work is on developing red rot resistant varieties. But as the pathogen is highly variable and continuously evolving in nature, therefore, even if a disease resistant variety is released for cultivation, it gets knocked down due to red rot disease within 8–10 years because of the development of a new and more virulent race of the pathogen.

CHAPTER III

MATERIAL AND METHODS

The present investigation entitled “Assessment of drought tolerance and red rot resistance among elite sugarcane (*Saccharum* spp. complex) varieties and ISH clones” was carried out at experimental area of PAU, Regional Research Station (RRS) Kapurthala. The Experimental site is located at of 31.38°N longitude and 75.38°E latitude at an elevation of 225 m above mean sea level (amsl) having clay loam soils with pH of 8.3-8.7. Experimental materials and methodologies used in different experiments are presented in this chapter.

3.1 Experiment No. 1

Evaluation of sugarcane varieties/clones for water stress tolerance.

3.2 Experimental plant material

The experimental material consisted of 30 diverse clones of sugarcane comprising nine commercial varieties released from Punjab state, twelve elite selections, five introductions procured from RS Anakapalli & four ISH clones collected from SBI, Coimbatore as listed in Table 3.1. The experiment was conducted during spring season 2016-17.

Table 3.1: The list of genotypes included in study

Sr. No.	Genotypes	Source	Sr. No.	Genotypes	Source
1	Co238	RRS, Kapurthala	16	CoPb13181	RS, Faridkot
2	CoJ88	-do-	17	CoPb13182	-do-
3	CoS8436	-do-	18	CoPb13183	-do-
4	CoPb91	-do-	19	CoPb10181	-do-
5	Co118	-do-	20	CoPb12181	-do-
6	CoJ85	-do-	21	CoPb12182	-do-
7	CoJ64	-do-	22	KV2012- 1	RS, Anakapalli
8	CoPb92	-do-	23	KV2012- 2	-do-
9	CoPb11214	-do-	24	KV2012- 3	-do-
10	CoPb14212	-do-	25	KV2012- 4	-do-
11	CoPb14211	-do-	26	KV2012- 5	-do-
12	CoPb12212	-do-	27	ISH 148	SBI, Coimbatore
13	L 818/07	-do-	28	ISH 07	-do-
14	CoPb11211	-do-	29	ISH 135	-do-
15	CoPb93	-do-	30	ISH 159	-do-

3.3 Field layout

All the 30 clones were planted during spring 2016-17 in the first week of March at RRS, Kapurthala in a randomized complete block design with two replications in normal (E₁) and water stress (E₂) environments. Under water stressed (E₂) environment irrigation was suspended for 2-3 weeks interval at critical growth stages of sugarcane viz. germination, tillering and grand growth stage (as shown in Plate 3.1). Each genotype was represented by a plot of four rows of 6m length each. The inter row spacing was maintained at 90 cm. The seed rate in both the environment was 12 buds per running 1 metre row. The standard agronomic practices as per package of practices of the PAU for kharif field crops were followed to raise the ideal crop stand.

3.4 Observations recorded

The observations on different cane yield and component traits, physiological and quality traits were recorded at appropriate stages for each clone in each replication under both the E₁ and E₂ environments as described follow:

3.4.1 Cane yield and component traits

3.4.1.1 Germination (%)

The germination (%) of conventional three budded sets was recorded for each genotype in each replication on plot basis at 60 days after planting and expressed as percent germination.

$$\text{Germination (\%)} = \frac{\text{Number of buds germinated per plot}}{\text{Total number of buds planted per plot}} \times 100$$

3.4.1.2 Number of shoots at 120 days (000/ha)

The number of shoots at 120 days after planting was recorded by counting all the shoots in each clump of each genotype in each of the replication. The mean of two replications was calculated and number of shoots expressed as thousand per hectare.

3.4.1.3 Number of tillers at 240 days (000/ha)

The number of tillers at 240 days after planting of each genotype in each replication was counted. Mean values from both the replications were taken and number of tillers expressed in thousand per hectare.

3.4.1.4 Number of millable canes at maturity (NMC) (000/ha)

The number of millable canes (NMC) pertains to the fully developed canes formed at the time of maturity which can be milled. Number of millable canes were counted at maturity by counting fully developed canes from each plot under each replication and expressed as thousand per hectare.



E1– Normal Irrigated Environment



E2– Restricted Irrigation Environment

Plate 3.1: Field view of Irrigated and Restricted irrigation environments for evaluation of Sugarcane clones

3.4.1.5 Stalk length (cm)

Stalk length was measured at the time of harvest. Five canes of each genotype in each replication were taken randomly by removing top and trash. Length of each cane was measured by measuring tape. Mean of both replications was taken and stalk length was expressed in centimetre.

3.4.1.6 Stalk diameter (cm)

Thickness of canes was measured in centimetres with the help of vernier calliper by using 5 canes from each genotype randomly selected from each replication. Each cane was measured at three places i.e. top, middle and bottom and their mean thickness was taken as the stalk diameter and expressed in centimetre.

3.4.1.7 Single cane weight (Kg)

The single cane weight was also recorded at the time of harvest by weighing five canes per plot selected randomly for each clone in each replication using digital weighing balance. The mean weight of single cane was taken and expressed in kilogram.

3.4.1.8 Cane yield (ton/ha)

Total cane yield was recorded at the time of harvest for each genotype in each replication by weighing of all the canes harvested, and expressed in tons per hectare.

3.4.2 Physiological Traits:

3.4.2.1 Relative water content at 60 DAP (%)

Fresh leaves were collected from five randomly selected plants from each clone in each replication in early morning hours and brought to lab. 10g leaf discs (fresh weight) from each genotype from each plot were submerged in distilled water in test tubes till saturation. After 6 hrs the leaf discs were removed from test tubes. Surface water of the discs was blotted off without putting any pressure and then they were weighed to obtain saturated weight. After drying the discs at 70°C for 72 hr their dry weight was determined. From these data RWC at 60 DAP was calculated (Turner 1981) as follows:

$$RLWC = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Saturated weight} - \text{Dry weight}} \times 100$$

3.4.2.2 Relative water content at 120 DAP (%)

Relative water content at 120 DAP (%) was measured as described above for RWC at 60 days and presented as percent.

3.4.2.3 Chlorophyll content (mg/l)

Chlorophyll content was estimated by following dimethyl sulphoxide (DMSO) method (Hiscox and Israelstam, 1979) and readings were taken using spectrophotometer.

Procedure: It is the easiest approach in which leaf discs of known area were cut and used for analysis. Five leaves were collected from five randomly selected seven month old plants from each clone in each replication in early morning hours and brought to lab. 0.1 g of leaf tissue of each sugarcane clone were cut into smaller pieces and placed in test tubes which contains 10 ml of solvent (DMSO). Test tubes were incubated in a water bath at 60-65°C for an hour and cooled at room temperature for 30 min followed by filtration and absorption measured at 665 nm and 648 nm with a spectrophotometer. Blank determination was carried out with DMSO. The absorbance of the blank sample was subtracted from the absorbance readings of each sample before calculations.

Calculations:

Chlorophyll concentration (a, b and total) was calculated as mg /g fresh weight by the following formulae (Barnes *et al* 1992) and expressed as mg/l.

$$\text{Chlorophyll a (mg/g F.W)} = (14.85 A_{665} - 5.14 A_{648})$$

$$\text{Chlorophyll b (mg/g F.W)} = (25.48 A_{665} - 7.36 A_{648})$$

$$\text{Total chlorophyll (mg/g F.W)} = (7.49 A_{665} + 20.34 A_{648}) \quad \backslash$$

Where: A_{665} = absorption value at 665 nm, A_{648} = absorption value at 648 nm.

3.4.2.4 Stomatal frequency (no.)

Five leaves from five randomly selected plants of a clone from each replication were taken and brought to lab. The leaf membrane from the lower side of each leaf was peeled off by applying thinner on it followed by removal of leaf membrane by using sellotape. The sellotape containing the leaf membrane was placed on a glass slide and observed under compound microscope. Stomatal frequency was calculated by counting the number of stomata per microscopic field of the compound microscope. The mean of four microscopic fields considered as stomatal frequency of the genotype under study in both the environments and expressed as number of stomata per microscopic field.

3.4.2.5 Specific Leaf weight (SLW) (g)

For this all the leaves of a genotype from each plot under each replication at 120 days after planting were counted in field and carried to lab where they were kept in oven at 50°C for 24 hours. The dry weight of oven dried leaves was taken and specific leaf weight (SLW) was calculated using the following formula:

$$\text{Specific leaf weight (g)} = \frac{\text{Dry weight of total leaves per plant (g)}}{\text{Total no. of leaves per plant}}$$

3.4.3 Quality Traits

Five healthy canes of each genotype in each plot under each replication in both the environments were taken randomly at harvest and crushed with the help of crusher for juice

extraction. The juice so collected was purified by adding lead acetate (1mg) to it and was thoroughly mixed by manual shaking. After having the precipitation, the juice was filtered to collect purified juice which was further used to estimate quality characters as follow:

3.4.3.1 Extraction at 10 and 12 months (%)

The weight of randomly selected five healthy canes of each genotype under each replication was recorded. After crushing of these selected canes, the weight of cane juice was also recorded. The mean of both cane weight and juice weight of five canes was calculated. Extraction at 10 and 12 months expressed in percentage was calculated as the ratio of mean juice weight calculated under each replication and mean weight of cane calculated under each replication.

$$\text{Extraction (\%)} = (\text{Juice weight (kg)} / \text{Cane weight (kg)}) \times 100$$

3.4.3.2 Brix at 10 and 12 months (%)

The prism face of the refractometer was cleaned and dried. A drop of distilled water was put on the refractometer prism to standardize it the zero reading. A drop of the purified juice was put on the prism and the reading was recorded and brix percentage in cane juice was calculated and expressed as percent.

3.4.3.3 Pol in juice at 10 and 12 months (%)

One hundred ml of the filtered juice was transferred to 250 ml conical flask to which one gram of basic lead acetate was added, stirred well and allowed to stand for about an hour until clear supernatant obtained. This supernatant filtered through Whatman No. 40 filter paper. The filtrate was collected, and its polarization was recorded digital automatic polarimeter (Chen and Chou 1993).

3.4.3.4 Purity at 10 and 12 months (%)

The pol percent and brix percent calculated above were taken and purity at 10 and 12 months for juice of each genotype in each plot under each replication was calculated by using following formula and expressed as percent.

$$\text{Purity (\%)} = \frac{\text{Pol \%}}{\text{Brix \%}} \times 100$$

3.4.3.5 Commercial Cane Sugar (CCS) at 10 and 12 months (%)

Commercial cane sugar (%) was calculated from the pol (%) and purity (%) at 10 and 12 months in juice using following formula:

$$\text{CCS (\%)} = \frac{0.292 * \text{Pol \%} ((0.035 * \text{Purity \%}) - 1))}{\text{Purity \%}} \times 100$$

3.4.3.6 Fibre content at harvest (%)

Fibre content in cane was estimated by Rapipol extraction method and calculations were made as per the formula (Thangavelu and Rao, 1982)

Estimation of fibre per cent of cane by Rapipol Extraction Method

From 5 canes, top, middle and bottom portion (top from first cane, middle from second cane and bottom from third cane) was chopped into small bits. Later, 250gms of chopped cane bits are taken by mixing and sampling and placed in the cup of the Rapipol extractor. Two litres of water was added and disintegrated in Rapipol extractor for five minutes. After decantation, two litre of water is added and mixed well for two to three minutes and decanted without any loss of fibre. The above procedure is repeated once again, filtered quantitatively through a fine mesh filter and finally transferred quantitatively to a bag of known weight. It was dried at 110°C to constant weight. The Fibre content (%) at harvest was calculated by following formula:

$$\text{Fibre per cent} = \{(A-B)/C\} \times 100$$

Where,

A = Dry weight of bag + bagasse after drying (g)

B = Dry weight of bag alone (g)

C = Fresh weight of cane (g)

3.4.3.7 Pol in cane at harvest (%)

Pol in cane (%) at harvest represents the total pol present in the cane. It is calculated by adding the pol percent in juice and pol percent in bagasse. For pol percent in bagasse 250 gm bagasse dipped in 2 litres distilled water was processed in Rapipol extractor for 15 minutes. The water containing bagasse juice was cleared with basic lead acetate and was thoroughly mixed by manual shaking. After having the precipitation, the juice was filtered to collect purified juice. The filtrate was collected, and its polarization was recorded digital automatic polarimeter which gives the value of pol percent in bagasse. Pol in cane at harvest (%) was calculated by following formula:

$$\text{Pol in cane (\%)} = \text{Pol in juice (\%)} + \text{Pol in bagasse (\%)}$$

3.4.3.8 Commercial cane Sugar (CCS) at harvest (t/ha)

Commercial cane sugar (CCS) at harvest was calculated using cane yield (t/ha) and commercial cane sugar percent (CCS %) as recorded earlier by using following formula:

$$\text{CCS (t/ha)} = [\text{Yield (t/ha)} \times \text{CCS\%}]$$

3.4.5 Drought susceptible index (DSI)

Drought susceptibility index (DSI) was calculated by the formula given by Fischer and Maurer (1978).

$$S = \frac{1 - Y/Y_p}{D}$$

Where,

Y is the performance of a trait of a given genotype under drought,

Y_p is the performance of a trait of the same genotype under irrigation,

D is the drought intensity which is calculated as

$$D = 1 - \frac{X_d}{X_p}$$

X_d is the mean performance of a trait for all genotypes under drought, and

X_p is the mean performance of a trait for all genotypes under irrigation.

The drought intensity ranged from 0 to 1.

3.5 Statistical Analysis

The mean values of all the traits from each genotype in each replication were used for analysis of variance as per Fisher (1935). The analysis of the experimental design was based on the linear model with the help of software CPCS1 (Cheema and Singh 1990). The mathematical notations and their expectations for the estimation of analysis of variance carried out for all possible pairs of combinations of the characters is given below:

3.5.1 Analysis of variance

For the analysis, two environments namely normal (E_1) and water stress (E_2) were considered for all the genotypes and traits used in the study. The analysis of variance was carried out for randomized block design (RBD) for each character separately in each environment suggested by Fisher (1935).

$$Y_{ij} = \mu + g_i + r_j + e_{ij}$$

Where,

Y_{ij} = phenotypic observations of i^{th} genotype and j^{th} replication

$i = 1, 2, \dots, n$

$J = 1, 2, \dots, r$

μ = general population mean

g_i = the effect of the i^{th} genotype

r_j = the effect of the j^{th} replication, and

e_{ij} = error associated with i^{th} genotype in the j^{th} replication

On the basis of this linear model the analysis of variance was done as follows:

Table 3.2: Analysis of variance for RBD

Source of variation	d.f.	MS	Expected MS	F (cal)
Replications	(r-1)	MS _r	$\sigma^2_e + g \sigma^2_r$	MS _r /MS _e
Genotypes	(g-1)	MS _g	$\sigma^2_e + r \sigma^2_g$	MS _g /MS _e
Error	(r-1) (g-1)	MS _e	σ^2_e	
Total	(rg-1)			

Where,

r = number of replications

g = number of genotypes

σ^2_g = variance due to genotypes

σ^2_r = variance due to replications

σ^2_e = error variance

MS_r, MS_g, MS_e stands for the mean squares due to replications, genotypes and error, respectively.

The standard error of mean SE (m) was computed as follows:

$$SE(m) = \sqrt{\frac{MS_e}{r}}$$

$$SE(d) = \sqrt{\frac{2MS_e}{r}}$$

The critical differences (CD) for comparing the mean of any two genotypes were computed as follows:

Critical difference (C.D.) = SE (d) x 't' (5%) value at error degree of freedom

3.5.2 Estimations of parameters of genetic variability

The genotypic and phenotypic coefficients of variation, heritability in broad sense and expected genetic advance were calculated as suggested by Burton and Devane (1953) and Johnson *et al* (1955) as under:

3.5.2.1 Genotypic Coefficient of Variation:

$$\text{Genotypic coefficient of variation (GCV \%)} = \frac{\sigma_g}{\bar{X}} \times 100$$

3.5.2.2 Phenotypic Coefficient of Variation:

$$\text{Phenotypic coefficient of variation (PCV \%)} = \frac{\sigma_p}{\bar{X}} \times 100$$

Where,

σ_g = genotypic standard deviation

σ_p = phenotypic standard deviation

$\bar{X}$ = population mean of the trait under study

Interpretation for PCV and GCV:

Both the coefficients of variation (PCV and GCV) were categorized as high, moderate and low as follow:

>20 per cent	High
10-20 per cent	Moderate
<10 per cent	Low

3.5.2.3 Heritability [h^2_{bs}] (%)

Heritability (%) in broad sense was calculated by formula given by Allard (1960).

$$h^2_{bs} = \frac{\sigma_g^2}{\sigma_p^2} \times 100$$

Where,

σ_g^2 = Genotypic Variance

σ_p^2 = Phenotypic Variance

Interpretation for heritability (h^2_{bs})

Heritability (%) in broad sense was categorized as high, moderate and low as follows:

>80 per cent	High
50-80 per cent	Moderate
<50 per cent	Low

3.5.2.4 Genetic Advance (GA)

Genetic Advance for each trait was calculated by formula given by Miller *et al* (1958). Thus

$$GA = h^2_{bs} \cdot k \cdot \sigma_p$$

where,

h^2_{bs} = heritability (%) in broad sense

k = selection differential (at 20% selection intensity, k=1.40)

σ_p = square root of phenotypic variance

3.5.2.4.1 Genetic advance (mean):

Genetic advance percent mean for all the traits was calculated as follow:

$$GA (\% \text{ of mean}) = \frac{GA}{\bar{X}} \times 100$$

Interpretation for genetic advance (%):

Genetic advance percent mean was categorized as high, moderate and low as follows:

>30 per cent	High
20-30 per cent	Moderate
<20 per cent	Low

3.5.3 Correlation coefficient

Phenotypic and genotypic correlation coefficients were worked out by the formulae suggested by Al-Jibouri *et al* (1958).

3.5.3.1 Phenotypic correlation coefficient (r_p)

$$r_p = \frac{\sigma_{pxy}}{\sqrt{\sigma_{px}^2 \times \sigma_{py}^2}}$$

Where,

σ_{pxy} = Phenotypic covariance between two characters

σ_{px}^2 = Phenotypic variance of the x character

σ_{py}^2 = Phenotypic variance of the y character

3.5.3.2 Genotypic correlation coefficient (r_g)

$$r_g = \frac{\sigma_{gxy}}{\sqrt{\sigma_{gx}^2 \times \sigma_{gy}^2}}$$

Where,

σ_{gxy} = genotypic covariance between two characters

σ_{gx}^2 = genotypic variance of the x character

σ_{gy}^2 = genotypic variance of the y character

3.5.3.3 Test of significance:

The simplest formula for computing the appropriate t value to test significance of a correlation coefficient employs the t distribution:

$$t = r\sqrt{(n-2)/(1-r^2)}$$

Where r = correlation between the two variables

The degrees of freedom for entering the t-distribution is $n - 2$, where n is the number of genotypes among the traits of which correlation being tested.

3.5.4 Path Coefficient Analysis

Path coefficient analysis was done following Dewey and Lu (1959). The path coefficients were calculated by abbreviated 'Do little' techniques.

$$Py_1 + Py_2.r_{12} + Py_3.r_{13} + \dots + Pyn.r_{1n} = ry_1$$

$$Py_1.r_{12} + Py_2 + Py_3.r_{23} + \dots + Pyn.r_{2n} = ry_2$$

$$Py_1.r_{13} + Py_2.r_{23} + Py_3 + \dots + Pyn.r_{3n} = ry_3$$

$$Py_1.r_{1n} + Py_2 + Py_3.r_{n3} + \dots + Pyn = ry_n$$

Where, $Py_1, Py_2, Py_3, \dots, Pyn$ are the direct path effects of 1, 2, 3... n variables on the dependent variable 'y'. $r_{12}, r_{13}, \dots, r_{1n}, \dots, r_{(n-1)n}$ are the possible coefficients of correlation between various independent variables, and ry_1, ry_2, ry_n are the coefficients of correlation of independent variables with dependent variable 'y'.

The variation in the dependent variable which remained undetermined by including the given variables was assumed to be due to variable not included in the present investigation. The degree of determination of such variables was calculated as follows:

$$\text{Residual Effect} = \sqrt{1-R^2}$$

Where, $R^2 = Py_1.ry_1 + Py_2.ry_2 + \dots + Pyn.ryn$.

R^2 is the squared multiple correlation coefficient and is the amount of variation in yield that can be accounted for by the yield component traits included in the study.

3.5.4 Name of the experiment: Evaluation of sugarcane varieties/clones against CF 08 and CF 09 red rot Pathotypes.

3.6.1 Experimental plant material

The experimental material consisted of 30 diverse recommended Varieties, elite sugarcane selections and ISH clones comprising nine commercial varieties, twelve local selections, five KV lines & four ISH clones as listed in table 3.1.

3.6.2 Experimental location and layout

The experimental material was planted at PAU, Regional Research Station Kapurthala in a randomized block design with a plot size of $2R \times 6m \times 0.90m$ with under two replications in normal (E_1) and water stress (E_2) environments.

3.6.3 Preparation of pathological cultures

The pathological cultures were taken from RRS, Kapurthala and they were freshly revived by sub culturing in laboratory and used for inoculation in sugarcane plants under field conditions.

3.6.4 Disease inoculation:

Freshly cultured inoculum of both the isolates viz. Cf08 and Cf09 was inoculated to all the experimental material by plug method as detailed below:

Plug method: Red rot pathotypes CF 08 (from CoJ84) and CF 09 (from CoS767) were multiplied on oat meal agar medium in Petri dishes at $25 \pm 1^\circ C$. Fresh sporulating 7-10 days old cultures were used for inoculations. The spores were washed with sterile distilled water

and homogenized by shaking and spore suspensions with concentration of 2×10^4 conidia ml⁻¹ was maintained. Using single bud setts, experimental plant materials were planted in the field area. Ten canes per treatment were selected and inoculated by a suspension of two pathotypes viz. CF 08 and CF 09 by artificial inoculation under field conditions using plug method (Srinivasan and Bhatt, 1961). The inoculations were done in the third internode from the base of the standing canes with the help of hypodermic syringe by injecting 1.0 ml of spore suspension (2×10^4 conidia ml⁻¹). The core was then replaced and the openings were sealed with modeling clay. Disease data were recorded after 60 days of inoculation. For disease screening, the condition of the top was recorded and the canes splitted longitudinally and observations were recorded on the number of internodes transgressed by the pathogen.

3.6.5 Observations recorded:

Disease score was recorded at 60 days after inoculation for pathogenicity parameters (Table 3.3) and disease reaction following 0-9 scale given in (Table 3.4) as per Srinivasan and Bhatt (1961). The clones were categorized as resistant (R), moderately resistant (MR), moderately susceptible (MS), susceptible (S) and highly susceptible (HS) accordingly.

Table 3.3: Pathogenecity parameters for screening of sugarcane against red rot disease (Srinivasan and Bhatt, 1961).

Symptoms	Numerical scale	Severity of symptoms
Conditions of tops	0	Green.
	1	Yellow or drying.
Nodal transgression	0	No lesion spread. Lesion restricted to the inoculated node.
	1	Lesion transgression of one node above the inoculated node.
	2	Lesion transgression of 2 nodes above the inoculated node.
	3	Lesion transgression of more than 2 nodes above the inoculated node.
Lesion width	0	No lesion spread.
	1	Lesion spread to about 25% of the width of the stalk.
	2	Lesion spread to about half the cane width.
	3	Lesion spread to more than half the width of the cane.
White spots	0	No white spots.
	1	Sparse presence of white spots.
	2	Moderate to profuse presence of white spots.

Table 3.4: Screening of sugarcane varieties against red rot and their reaction (0-9 scale)

Sr. No	Sore on 0-9 scale	Reaction category
1	0.0-2.0	Resistant (R)
2	2.1-4.0	Moderately resistance (MR)
3	4.1-6.0	Moderately susceptible (MS)
4	6.1-8.0	Susceptible (S)
5	8.1-9.0	Highly susceptible (HS)

CHAPTER IV

RESULTS AND DISCUSSION

Experimental results of present study entitled “Assessment of drought tolerance and red rot resistance among elite sugarcane (*Saccharum* spp. complex) varieties and ISH clones” are presented in this chapter. The elucidations of each experiment covered under different heads and sub heads are presented.

4.1. Meteorological conditions of experimental site

The minimum and maximum mean weekly temperature ranged from 2.00°C to 36.00°C and from 7.00°C to 46.00°C, respectively (Appendix Table 1.1). The total annual rainfall during crop season (Feb 2016-Jan 2017) was 110.5mm. Rainfall was not evenly distributed throughout the cropping season which resulted in moisture stress conditions during the critical crop growth stages. In the present investigation, the moisture stress was experienced during germination, tillering and grand growth stage (formative stage).

Data recorded for different parameters of cane yield and component traits, physiology, quality and disease screening were subjected to statistical analysis following standard procedures. The results of the study obtained on the analysis of variance, genetic variability parameters, association and path analysis of various traits in normal (E_1) and water stress (E_2) environments, drought susceptibility index and disease screening are presented below in the light of relevant literature.

4.2 Analysis of variance

The analysis of variance under normal (E_1) and water stressed (E_2) conditions was carried out for eight cane yield and component traits, seven physiological and thirteen quality parameters (Table 4.1). Mean sum of squares for genotypes were found significant for all cane yield and component traits recorded in this study under both the environments, except for stalk length under normal (E_1) environment. Analysis of variance revealed significant difference among clones and varieties used in the study for the cane yield and component traits. Significant variability for cane and component traits has also been documented by Nair *et al* (1999). Sanghera *et al* (2015) reported highly significant differences among the 13 sugarcane clones for the characters (germination % at 45 days, number of tillers at 120 days, stalk length, stalk diameter, NMC and cane yield) under normal environment. Similarly, Khan *et al* (2012) reported that the mean performance of the genotypes for cane yield and its components showed significant ($p \leq 0.05$) differences among the clones. Significant differences have also been observed among the sugarcane genotypes for single stalk weight and cane yield under prolonged drought stress (Ishaq *et al* 2009).

For physiological traits, RWC at 120 DAP, total chlorophyll and specific leaf weight were significant under both the environments (E_1 and E_2), while RWC at 60 DAP and

chlorophyll b were found to be significant under water stressed (E_2) environment. Begum *et al* (2012) showed significant difference among the sugarcane genotypes for total chlorophyll content under water stress (E_2) conditions. The results given by Graca *et al* (2010) showed a significant difference in relative water content (RWC) in the stressed plants compared to the irrigated plants.

Similarly, of the 13 quality traits studied at 10 months and harvest, clones behaved significantly and differentially for all the traits in both the environments except for purity (%) at 10 months under normal (E_1) conditions. Tena *et al* (2016) reported significant difference for all the quality traits of sugarcane under normal water conditions. The significant variances for different cane yield and component traits, physiological and quality traits in both the environments revealed that there exists sufficient genetic variability in the experimental material used for the present study. It will help to isolate specific clones suitable for water stress and non stress conditions.

4.3 Genetic Variability Parameters

Genetic variability is the pre requisite for the improvement of any experiment. The range of mean values based on phenotypic expression could represent only a rough estimate of the variation or magnitude of divergence present among different genotypes. The estimates of genotypic and phenotypic coefficients of variation are more reliable estimates of extent of variability present within the experimental material. Similarly, knowledge of the heritability of character is important to the breeders since it indicates the possibility and extent of improvement that can be achieved through selection. So these genetic variability parameters like mean, range, phenotypic coefficient of variation, genotypic coefficient of variation, heritability and genetic advance for cane yield and component traits, physiological and quality traits studied in the present study under both normal (E_1) and water stress (E_2) environments are discussed below:

4.3.1 Cane yield and Component Traits:

Cane yield and its component traits are most important traits for improvement of sugarcane. Genetic improvement in cane yield may be achieved by targeting traits closely associated with cane yield. So, the genetic variability for different cane and component traits studied under normal (E_1) and water stress (E_2) environments are presented below along with relevant literature.

4.3.1.1 Germination (%)

The germination percentage among the different clones ranged from 27.36 to 67.91 percent with mean value of 43.53% under normal (E_1) conditions and from 17.50 to 45.00 percent with a mean of 28.44 (%) under water stressed (E_2) conditions. The highest germination was recorded for

Table 4.1: Analysis of variance for different cane yield, its component, physiological and quality traits in sugarcane under normal (E₁) and water stress (E₂) environments

S. No.	Traits	Mean Squares						
		S.V.	Replications		Varieties/Clones		Error	
		Df	1		29		29	
		Env.	E ₁	E ₂	E ₁	E ₂	E ₁	E ₂
Cane yield and component traits								
1	Germination (%)		2.59	60.11	220.15*	100.64*	45.23	17.30
2	No. of shoots at 120 days (000/ha)		232.04	1401.66	680.36*	442.61*	178.58	47.12
3	No. of tillers at 240 days (000/ha)		248.07	3226.65	738.14*	368.78*	206.48	68.32
4	No. of millable canes (000/ha)		1075.27	170.02	628.00*	357.33*	166.27	107.02
5	Stalk length (cm)		400.53	11070.36	1417.5	1485.66*	482.93	186.59
6	Stalk diameter (cm)		0.01	0.81	0.17*	0.10*	0.04	0.02
7	Single cane weight (kg)		0.16	0.03	0.30*	0.22*	0.05	0.02
8	Cane yield (t/ha)		32.27	240	433.6*	238.45*	50.47	10.76
Physiological traits								
1	Relative water content (%) at 60 DAP		0.49	2.14	26.34	131.02*	12.38	66.77
2	Relative water content (%) at 120 DAP		0.04	136.68	110.32*	136.01*	30.57	69.65
3	Chlorophyll a (mg/l)		0.84	0.12	0.26	0.25	0.21	0.17
4	Chlorophyll b (mg/l)		2.21	2.04	0.65	0.52*	0.56	0.22
5	Total chlorophyll (mg/l)		0.99	1.11	1.78*	1.45*	0.84	0.57
6	Stomatal frequency (no.)		0.27	35.27	25.12	22.92	5.68	4.44
7	Specific leaf weight (g)		0.25	2.74	2.25*	1.76*	1.19	0.28
Quality traits at 10 and 12 months								
1	Brix at 10 months (%)		0.03	0.14	5.39*	5.58*	0.54	0.32
2	Pol in juice at 10 months (%)		0.16	0.02	4.39*	4.29*	0.40	0.29
3	Extraction at 10 months (%)		108.72	24.34	29.52*	41.72*	9.52	6.71
4	Purity at 10 months (%)		1.77	1.39	22.87	23.96*	13.98	5.71
5	CCS at 10 months (%)		0.12	0.11	2.33*	2.21*	0.31	0.19
6	Brix at 12 months (%)		0.64	0.10	1.99*	2.37*	0.38	0.28
7	Pol in juice at 12 months (%)		0.02	0.10	2.25*	3.02*	0.40	0.16
8	Extraction at 12 months (%)		0.05	19.78	41.64*	34.54*	16.29	8.72
9	Purity at 12 months (%)		10.27	0.15	20.58*	21.34*	8.07	3.98
10	CCS at 12 months (%)		0.01	0.05	1.48*	1.93*	0.32	0.10
11	Fibre content at harvest (%)		4.75	0.06	2.28*	1.56*	0.61	0.60
12	Pol in cane at harvest (%)		0.03	0.09	1.48*	1.56*	0.32	0.42
13	CCS at harvest (t/ha)		0.24	2.49	8.29*	4.31*	0.93	0.16

* Significant at 5% level of significance

sugarcane variety CoJ64 (67.91%) closely followed by clone CoPb13183 (65.00%). Clones CoPb10181, CoPb13181, CoPb11214, KV2012-5 and CoPb92 recorded germination more than 50 % under normal (E_1) conditions. Similarly, under water stressed (E_2) conditions, variety CoJ64 exhibited maximum germination percentage (45.00%) followed by CoPb13183. However, four clones viz; KV2012-5, ISH135, ISH159 and ISH07 exhibited germination more than 30 % under water stressed environment. Overall, 14 clones were found to have germination percentage higher than the mean value under normal conditions (43.53%) and water stressed conditions (28.44%), respectively (Table 4.2).

Variability studies revealed that under normal (E_1) conditions, the phenotypic and genotypic coefficients of variation for germination percentage were found to be 26.46% and 21.48%, whereas under water stressed (E_2) conditions, the corresponding values were 27.00% and 22.69%, respectively. Heritability (broad sense) for germination percentage was moderate under normal (E_1) conditions and water stressed (E_2) conditions to the tune of 65.91% and 70.66%, respectively. Genetic advance (percent of mean) was found to be high under both normal (E_1) and water stressed (E_2) environments 35.93% and 39.30%, respectively (Table 4.5). High genotypic and phenotypic coefficient of variation for germination % under irrigated conditions was reported by Chaudhary (2001), while Singh *et al* (2002) reported moderate coefficient of variation for germination percentage. Moderate to high heritability and genetic advance for germination (%) has been documented in earlier studies (Singh *et al* 2010). Therefore, this trait should be considered while making selection for higher cane yield.

4.3.1.2 Number of shoots at 120 days (000/ha)

The number of shoots at 120 days in the study ranged from 91.00 to 163.00 (000/ha) with a mean value of 127.00 (000/ha) under normal (E_1) conditions. In E_1 , maximum number of shoots at 120 days were recorded for variety CoJ64 (163000/ha) followed by CoPb12212, CoPb92, ISH148, L818/07, CoPb13183 and CoPb11214. Minimum number of shoots recorded for CoPb11211, CoPb91, KV2012-4 and KV2012-2. However, under water stressed (E_2) conditions, the number of shoots at 120 days ranged from 53.00 to 118.00 (000/ha) with overall mean value of 84.00 (000/ha). Clone ISH148 exhibited maximum number of shoots at 120 days (118000/ha) followed by CoJ64, CoPb13183, ISH135, KV2012-5 under water stressed (E_2) environment. Clones CoPb11211, CoJ88, CoPb91, CoS8436, Co118 and CoJ85 in order, could manage to produce fewer number of shoots at 120 days owing to their susceptibility towards water stressed environment (Table 4.2).

The number of shoots at 120 days exhibited moderate magnitude of PCV (16.33 and 18.67%, respectively) and GCV (12.48 and 16.78%, respectively) under both E_1 and E_2 environments (Table 4.5). The heritability estimates for this trait were moderate (58.42%) under normal (E_1) conditions and high (80.76%) under water stressed (E_2) conditions whereas

the genetic advance (percent of mean) was low (19.65%) under normal (E_1) and high (31.06%) under water stressed (E_2) environments.

4.3.1.3 Number of tillers at 240 days (000/ha)

The number of tillers at 240 days is an important character contributing towards cane yield and ratooning ability. Under normal conditions (E_1), the number of tillers at 240 days ranged from 83.00 to 161.00 (000/ha) with a mean value of 122.00. The number of tillers under water stress conditions (E_2) ranged from 51.00 to 104.00 with mean value of 80.00. Maximum number of tillers were recorded in variety CoJ64 (161.00) under normal (E_1) conditions followed by CoPb92, CoPb12212 and L818/07. Similarly, under water stress (E_2) conditions, variety CoJ64 produced maximum number of tillers at 240 days (104.00) followed by ISH148, ISH135, KV2012-5, KV2012-3, CoPb92 and CoPb13183.

Number of tillers at 240 days exhibited moderate magnitude of all the variability parameters like PCV (17.87%), GCV (13.40%), heritability (56.28) and genetic advance (percent of mean) (20.72%) under normal (E_1) environment and the corresponding figures in water stress (E_2) environment were PCV (18.53%) and GCV (15.37%), heritability (68.74%) and genetic advance (percent of mean) (26.24%), respectively (Table 4.5). Moderate heritability in sugarcane for number of tillers at 240 days was recorded by Sanghera *et al* (2015) under irrigated conditions.

4.3.1.4 Number of millable canes (NMC) (000/ha)

The number of millable canes (NMC) pertains to the fully developed canes formed at maturity which can be milled. NMC were recorded at maturity of the crop and ranged from 77.00 to 146.00 (000/ha) with a mean value of 112.13 (000/ha) under normal (E_1) conditions. In water stress (E_2) conditions, NMC ranged from 47.00 to 94.00 with a mean of 72.88. Maximum NMC were recorded for the varieties CoJ64 (146.00) and CoPb92 (146.00) closely followed by L818/07, CoPb12212, CoPb13182 and KV2012-3 under normal (E_1) conditions whereas under water stressed (E_2) conditions, maximum NMC were recorded in CoJ64 (94.00) and ISH148 (94.00). The minimum NMC were recorded in clone CoPb11211 in both normal and water stress conditions with a mean value of 77.00 and 47.00 respectively (Table 4.2).

The PCV and GCV values for NMC were moderate (17.77 and 13.55%, respectively) under E_1 environment while high PCV (20.91%) and moderate GCV (15.35%) under E_2 environment. The heritability (58.13 and 53.91, respectively) and genetic advance (21.28 and 23.22, respectively) for NMC were found to be moderate under both the environments (Table 4.5). Sanghera *et al* (2015) reported moderate heritability (72.49%) and moderate genetic advance for number of millable canes (NMC). This trait is an important component of cane

yield and should given emphasis while selecting for higher cane yield in combination with other traits.

4.3.1.5 Stalk length (cm)

Stalk length is a significant trait that directly contributes towards cane yield. Under normal (E_1) conditions, it ranged from 192.50 to 308.33 cm with a mean of 267.48 cm and under water stressed (E_1) conditions it was recorded to have range of 120.00 to 240.00 cm with a mean of 178.65 cm. Maximum stalk length was recorded for clone KV2012-5 (308.33 cm) followed by CoPb13182, KV2012-1, CoPb13181 and CoPb92 under normal (E_1) conditions whereas under water stress (E_2) conditions, maximum stalk length was exhibited by the clone KV2012-5 (240.00 cm) followed by KV2012-1, ISH07, KV2012-4 and KV2012-2. Under normal (E_1) conditions, CoS8436 and under water stressed (E_2) conditions, CoJ88 were minimum scoring varieties for stalk length. Overall, clones KV2012-1 and KV2012-5 were least affected by water stress and performed well under both the environments (Table 4.2).

Variability studies revealed that under normal (E_1) environment, stalk length exhibited moderate PCV (11.52%), low GCV (8.08%), low heritability (49.48%) and low genetic advance (11.67%). While, under water stress (E_2) environment, moderate PCV (16.19%), GCV (14.27%), heritability (77.68%) and genetic advance (25.90%) were recorded for this trait (Table 4.5). The results under normal water conditions are in accordance with studies conducted by Anbanandan and Saravanan (2010), who also reported low coefficient of variability and genetic advance for cane length.

4.3.1.6 Stalk diameter (cm)

In the present study, the stalk diameter ranged from 1.83 to 3.10 cm with a mean value of 2.41 cm under normal (E_1) conditions. In this environment, maximum value was recorded for clone CoPb91 (3.10 cm) followed by CoPb10181, CoJ85 and KV2012-2 and minimum stalk diameter was recorded in clone ISH135 (1.83 cm). Stalk diameter under E_2 environment ranged from 1.02 to 1.96 cm with a mean value of 1.61cm and maximum stalk diameter was recorded for clones KV2012-2 and KV2012-4 (1.96 cm). While minimum stalk diameter under water stress (E_2) conditions was recorded in L818/07 (1.02 cm). About 18 genotypes exhibited stalk diameter above the mean under normal (E_1) conditions and 14 genotypes under water stress (E_2) conditions had more stalk diameter than the mean value (Table 4.2) depicting their adaptability and suitability for diverse growth conditions.

In context of variability studies, moderate PCV, GCV and heritability were recorded for stalk diameter under both normal (E_1) and water stress (E_2) conditions (Table 4.5). The genetic advance was recorded low (17.59%) under normal (E_1) and moderate (21.61%) under

water stress (E_2) conditions. Since stalk diameter is a trait which directly affect the cane yield, moderate heritability and genetic advance for this trait would not give significant breeding advantage in successive selection cycles in different generations. The results under normal (E_1) conditions are in corroboration with earlier study conducted by Singh *et al* (2010).

4.3.1.7 Cane yield (t/ha)

Cane yield is the most important and economical trait for any crop including sugarcane. In present study, the cane yield of different genotypes under normal (E_1) conditions ranged between 48.78 to 110.00 t/ha with a mean value of 76.40 t/ha. Clone CoPb10181 had maximum cane yield of 110.00 t/ha under normal (E_1) conditions followed by clones KV2012-3 (100.69), CoPb91 (97.43), L818/07 (96.18) and CoPb93 (94.33), however, minimum cane yield of 48.78 t/ha was recorded in clone CoPb11211. Under water stress (E_2) conditions, the cane yield was generally lower where it ranged from 25.42 to 76.39 t/ha with a mean value of 51.40 t/ha. In E_2 environment, highest cane yield was recorded for the clone KV2012-3 (76.39 t/ha) followed by clones CoPb93 (68.25), KV2012-1 (65.97), CoPb10181 (64.31) and KV2012-5 (64.24) while lowest cane yield was recorded for the genotype CoPb11211 (25.42 t/ha). Clones KV2012-1 and KV2012-5 performed high with respect to cane yield under water stressed (E_2) conditions. Under water stressed (E_2) conditions, 14 genotypes had more cane yield than the overall mean cane yield (Table 4.2).

The magnitude of PCV for cane yield was high (20.36 and 21.69, respectively) under both E_1 and E_2 environments while moderate GCV was recorded (18.12%) under normal (E_1) and high (20.73%) under water stressed (E_2) conditions. The heritability (broad sense) for this trait was recorded to be moderate (79.15%) under E_1 and high (85.37%) under E_2 environment. The genetic advance was higher under both the environments (Table 4.5) which proposes an opportunity for the breeder to get selection advantage for cane yield in different conditions. Kumar *et al* (2001) also reported high heritability and genetic advance as per cent of mean for cane yield under moisture stress environment. For normal water conditions, similar results were revealed by Chaudhary (2001) and Arora *et al* (2014) who reported high genetic advance and high to moderate variability coefficients for cane yield under irrigated conditions. This suggests that a large proportion of the total variance is heritable and selection of this trait would be effective under both normal (E_1) and water stress (E_2) environments.

4.3.1.8 Single cane weight (SCW) (kg)

The single cane weight (SCW) is also an important parameter contributing towards the cane yield. In the present study, under normal (E_1) conditions, it ranged from 0.75 to 2.24 kg with a mean value of 1.47 kg. Maximum SCW was recorded for clone CoPb91 (2.24 kg) followed by clones CoPb10181 (2.02 kg), KV2012-3 (1.99 kg) and KV2012-1 (1.84 kg) while the minimum SCW was recorded by clone CoPb14212 (0.75 kg) under normal (E_1)

conditions. SCW under water stress (E_2) conditions ranged from 0.48 to 1.52 kg with mean value of 1.00 kg and the maximum and minimum SCW were recorded for the clones KV2012-3 (1.52) and L818/07 (0.48), respectively. About 18 clones/varieties under E_1 conditions and 15 clones under E_2 conditions had more SCW than their respective mean values (Table 4.2).

The SCW exhibited high PCV, GCV and genetic advance and moderate heritability under both normal (E_1) as well as water stress (E_2) conditions (Table 4.5). Moderate heritability value was reported by Kumar *et al* (2001) for single cane weight under water stress conditions. High PCV, GCV and genetic advance for single cane weight has also been reported in studies (Arora *et al* 2014 and Tena *et al* 2016). This trait is an important component of cane yield and should given emphasis while selecting for higher cane yield in combination with other traits.

4.3.2 Physiological Traits

The degree of limitation of yield by environmental stressed varies among genotypes within a species (Aguilera *et al* 1999). The ability to maintain key physiological processes, such as photosynthesis during moderate drought stress, is indicative of the potential to sustain productivity under water shortage. Use of physiological parameters as a tool to access water stress tolerance in sugarcane has been documented (Silva *et al*, 2007). Identifying suitable screening tools and quantifiable traits would facilitate crop improvement process for drought stress. The results on different physiological traits studied are presented below:

4.3.2.1 Relative water content (RWC) (%) at 60 days after planting

The relative water content (RWC) in leaf at 60 days after planting was recorded and it ranged from 62.90 to 80.25 (%) and 34.00 to 65.00 (%) under normal (E_1) and water stress (E_2) environments, respectively (Table 4.3). The clone CoPb12182 had the highest RWC (80.25%), followed by clones KV2012-1 (78.67), CoPb10181 (76.76), CoPb11211 (76.37) and CoPb13181 (76.12) while CoPb12212 had the lowest RWC value (62.90) under normal (E_1) conditions. Highest value for RWC under water stress (E_2) environment was observed for clone CoPb12182 (65.00%) followed by clones KV2012-1 (62.00), ISH135 (59.00), ISH07 (58.00) and ISH148 (56.00). Clone CoPb12212 (34.00%) had the lowest RWC under water stress (E_2) environment (Table 4.3). Relative water content in leaf is an indicator of degree of tolerance of plants towards adverse conditions like water stress. These results were found in accordance with already reported findings in literature which state that drought-tolerant sugarcane genotypes exhibited high relative water content as compared to the drought-sensitive genotypes (Silva *et al* 2007 and Venkataramana *et al* 1986).

For variability parameters studied, RWC at 60 days after planting exhibited low magnitude of PCV and GCV (6.11 and 3.67%) under normal (E_1) environment whereas under water stress (E_2) environment, a high magnitude of PCV and moderate GCV (20.37 and 11.61%) was recorded, respectively. However, the heritability and genetic advance was observed to be low under both the environments (Table 4.5).

4.3.2.2 Relative water content (RWC) (%) at 120 days after planting

RWC was also recorded at 120 days after planting to assess the water stress tolerance level of the clones under study. The mean values for RWC at 120 DAP among clones ranged from 47.35 to 77.30 % with an average of 65.20 % in the normal (E_1) and 29.00 to 58.00 % with an average of 42.61 % in the water stress (E_2) environment (Table 4.3). Clone CoPb11211 recorded the highest value for RWC at 120 days after planting under normal (E_1) conditions (77.30%), followed by clones KV2012-2 (77.19) and Co118 (76.67). In water stress (E_2) environment, clone KV2012-2 (58.00%) exhibited the highest RWC, followed by clones ISH135 (55.00) and KV3 (55.00).

For parameters of variability studied, this trait had moderate PCV, low GCV, moderate heritability and low genetic advance under normal (E_1) conditions whereas high PCV, moderate GCV, low heritability and genetic advance under water stress (E_2) conditions (Table 4.5).

4.3.2.3 Chlorophyll a (mg/l)

Total chlorophyll content estimated in the study was further partitioned into its components like chlorophyll a and chlorophyll b content and each was estimated individually in the study. The chlorophyll a (mg/l) was found to vary from 2.54 to 3.88 mg/l with a mean of 3.31 mg/l under normal (E_1) conditions while under water stress (E_2) conditions, it ranged from 1.39 to 2.95 mg/l with a mean of 2.25 mg/l. The value of chlorophyll a was highest for the clone Co238 (3.88 mg/l), followed by clones KV2012-4 (3.84), CoS8436 (3.84) and CoPb93 (3.81) under normal (E_1) conditions. Clone KV2012-4 had the maximum value (2.95 mg/l) of chlorophyll a, followed by clones KV2012-3 (2.86) and ISH148 (2.84) under water stress (E_2) conditions. Minimum value of chlorophyll a was recorded for variety CoJ88 (2.54 mg/l) and clone CoPb11214 (1.39 mg/l) under normal (E_1) and water stressed (E_2) conditions, respectively. Jangpromma *et al* (2010) found that the drought tolerant sugarcane cultivars have higher level of chlorophyll than drought susceptible cultivars.

4.3.2.4 Chlorophyll b (mg/l)

The chlorophyll b content ranged from 2.68 to 4.89 mg/l in normal (E_1) and from 1.56 to 3.63 mg/l under water stress (E_2) conditions. The maximum value of chlorophyll b was recorded in variety Co238 (4.89 mg/l) under normal (E_1) and in clone KV2012-4 (3.63 mg/l)

under water stress (E_2) environment. The clones Co238, CoPb92, CoPb93, KV2012-3 and ISH148 had high value of chlorophyll b under normal (E_1) conditions while clones KV2012-4, KV2012-3 and ISH148 recorded maximum chlorophyll b content under water stress (E_2) conditions.

4.3.2.5 Total Chlorophyll (mg/l)

In the present study, the total chlorophyll content ranged from 5.22 to 8.87 mg/l with a mean of 7.23 mg/l under normal (E_1) water conditions while under water stress (E_2) conditions it ranged from 3.12 to 6.50 mg/l with overall mean of 4.81 mg/l (Table 4.3). The maximum chlorophyll content under normal (E_1) water conditions was recorded for variety CoPb92 (8.87 mg/l), followed by clones Co238 (8.77) and KV2012-4 (8.62). The clone KV2012-4 (6.50 mg/l) was found to possess highest total chlorophyll content under water stress (E_2) conditions followed by clones ISH148 (6.38) and KV2012-3 (6.18). However, variety CoJ88 (5.22 mg/l) was found to have minimum total chlorophyll content under normal (E_1) water conditions while under water stress (E_2) conditions clone CoPb11214 (3.22 mg/l) had minimum total chlorophyll content. About 16 genotypes had higher total chlorophyll content than overall mean under normal (E_1) water conditions and about 15 genotypes under water stressed (E_2) conditions possessed higher total chlorophyll content value than the overall mean. These findings are in agreement with the studies of Silva *et al* (2007) who also reported that drought caused a decline in sugarcane leaf chlorophyll level, but this reduction varied among genotypes. Begum *et al* (2012) and Jangpromma *et al* (2010) reported that drought tolerant sugarcane cultivars were found to possess higher level of chlorophyll than drought susceptible cultivars.

Variability parameters worked out for total chlorophyll content revealed moderate PCV (15.80%), low GCV (9.46%), heritability (35.88) and genetic advance (11.68%) under normal (E_1) conditions whereas high PCV (20.88), moderate GCV (13.80%), low heritability (43.66) and genetic advance (18.78%) under water stress (E_2) conditions (Table 4.5).

4.3.2.6 Stomatal frequency (no.)

Stomatal frequency of leaves was worked out by counting the number of stomata per microscopic field. It gave an indication of the mitigating mechanisms being used by the plants internally to counter water stress conditions. The number of stomata per microscopic field ranged from 37.00 to 52.00 under normal (E_1) and from 22.00 to 35.00 under water stressed (E_2) conditions (Table 4.3). Mean stomatal frequency was recorded to be 44.00 under normal (E_1) conditions and about 14 genotypes including clones ISH135, ISH148 and CoPb11211 had higher stomatal frequency than the overall mean. Under water stress (E_2) conditions, the mean stomatal frequency was 28.30 and clone CoPb11211 (35.00) possessed highest number of stomata followed by clones CoPb12182, CoPb92 and CoJ88. However, clones CoPb14212

(37.00) and ISH159 (22.00) recorded lowest number of stomata under normal (E_1) and water stress (E_2) conditions, respectively. The stomatal frequency under E_1 and E_2 are shown in Plate 4.1).

Variability study for this trait showed low PCV (8.94%), GCV (7.10%), genetic advance (11.62%) and moderate heritability values (63.11) under normal (E_1) conditions whereas moderate PCV (13.07%), GCV (10.74%) and heritability (67.55) coupled with low genetic advance values (18.18%) under water stress (E_2) conditions (Table 4.5).

4.3.2.7 Specific leaf weight (g)

The specific leaf weight in the study varied from 3.23 to 7.48 g averaging 5.02 g under normal (E_1) and 2.10 to 5.60 g under water stress (E_2) conditions with a mean of 3.42 g. The clone CoPb11214 (7.48 g) recorded the highest specific leaf weight whereas the clone CoPb14212 (3.23 g) recorded lowest specific leaf weight under normal (E_1) conditions (Table 4.3). Under water stress (E_2) conditions, the clone CoPb11214 (5.60 g) recorded maximum specific leaf weight whereas variety CoJ88 (2.10 g) had minimum specific leaf weight. Overall, the clone KV2012-4 had maximum specific leaf weight under both normal (E_1) as well as water stressed (E_2) conditions.

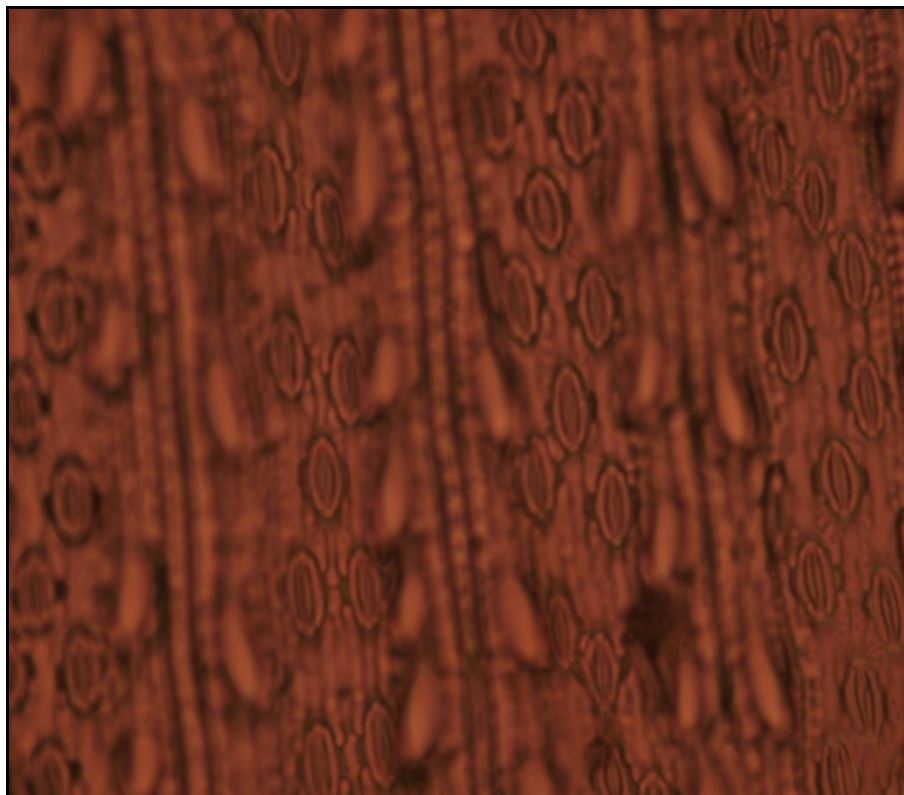
The specific leaf weight exhibited high PCV (29.44%), GCV (25.14%) and genetic advance (44.21%) values with moderate heritability value (72.90) under water stress (E_2) conditions whereas under normal (E_1) conditions high PCV (26.07%), Moderate GCV (14.48%), low heritability (30.87) and genetic advance values (16.57%) were recorded (Table 4.5).

4.3.3 Quality Traits

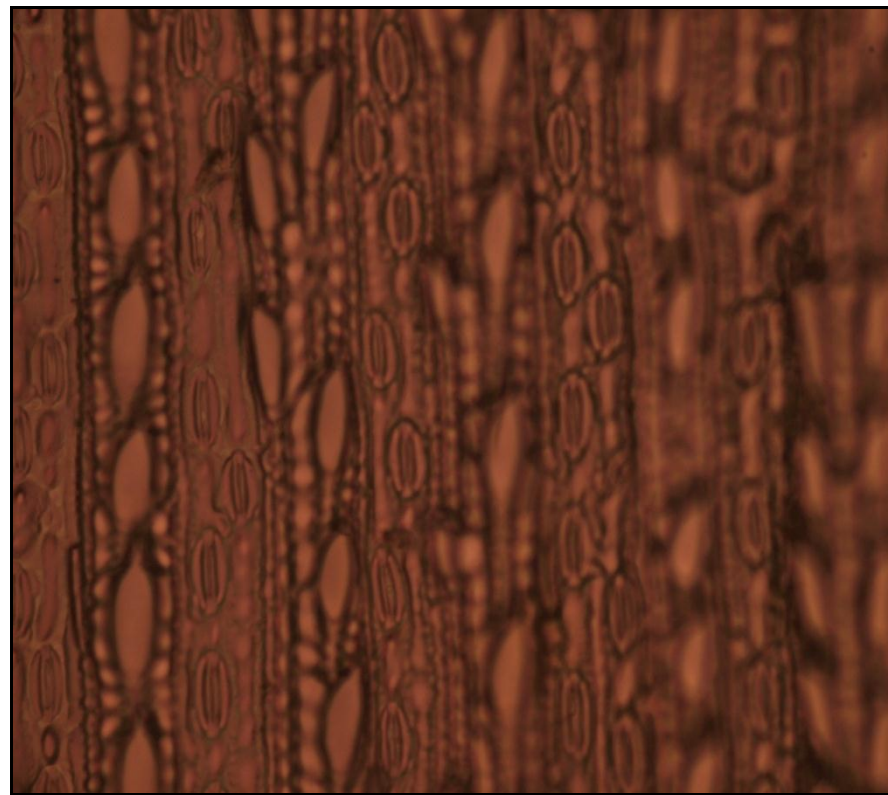
Sugar is the end product of the sugarcane. The quality and quantity of the sugar depends upon the quality traits of sugarcane. As drought conditions interfere with sugar production by affecting growth rate, yield of the cane, juices of lower sucrose contents, purity, higher acidity and the sucrose content of the stalk. So it becomes necessary to select those quality traits which lead to high sugar recovery from sugarcane under water stress conditions. The results of genetic variability of quality traits under both normal (E_1) as well as water stress (E_2) environments are discussed below along with relevant literature.

4.3.3.1 Brix at 10 months (%)

Brix value is an indication of total soluble sugars in juice based on which sucrose accumulation in juice can be estimated. Brix at 10 months (%) ranged from 12.92 to 18.87 % with a mean value of 16.20 % under normal (E_1) conditions. The maximum brix % was recorded for the clone KV2012-2 (18.87%) followed by clones KV2012-1 (18.37 %), KV2012-5 (18.30%) and KV2012-3 (18.02%) under normal (E_1) environment (Table 4.4).



Number of stomata in KV 2012-2 in E₁
(Normal Irrigated Environment)



Reduced number of stomata in KV 2012-2 in E₂
(Restricted Irrigation Environment)

Plate 4.1: Microscopic field view of stomatal frequency of sugarcane clone under irrigated and restricted irrigation environments

However, minimum brix % was recorded for variety CoPb91 (12.92%) followed by varieties CoPb8436 (13.37%) and CoJ88 (13.49%) under normal (E_1) environment. Under water stress (E_2) conditions, brix at 10 months (%) varied from 10.97 to 16.63 % with a mean of 14.22 %. Highest and lowest brix at 10 months (%) was recorded for clone KV2012-4 (16.63%) and variety CoPb91 (10.97%), respectively. Low brix (%) in sugarcane juice under water stress conditions was also reported by Begum *et al* (2012).

Studies on variability parameters for this trait revealed moderate PCV, low GCV and genetic advance with high heritability values under normal (E_1) environment whereas under water stress (E_2) conditions moderate PCV and GCV, high heritability and moderate genetic advance were recorded (Table 4.5). Moderate values of genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) coupled with high heritability for brix percentage has been reported by Mehareb *et al* (2017) and Sanghera *et al* (2014a) in sugarcane.

4.3.3.2 Pol in juice at 10 months (%)

Pol (%) in juice depicts the sucrose percentage in juice. At 10 months after planting it ranged from 11.92 to 16.77 % with a mean value of 14.10 % under normal (E_1) water conditions. Under same environment (E_1) the maximum value for Pol (%) in juice at 10 months was recorded in clone KV2012-5 (16.77%) while the minimum value was recorded for variety CoPb91 (11.92%). The Pol % varied from 8.76 to 14.08 % under water stress (E_2) conditions with a mean of 11.61 % and maximum and minimum value for Pol % in juice were recorded in clone KV2012-2 (14.08%) and variety CoPb91 (8.76%), respectively (Table 4.4).

Pol (%) in juice at 10 months recorded moderate PCV and high heritability under both the environments, whereas low GCV and genetic advance under normal (E_1) and moderate GCV and genetic advance under water stress (E_2) environment (Table 4.5). The results on variability parameters obtained in this study under normal (E_1) environment were in accordance with the results reported by Anbanandan and Saravanan (2010), Tena *et al* (2016) and Mehareb *et al* (2017). High heritability and genetic advance for pol (%) has been reported by Sanghera *et al* (2014a) in early maturing varieties of sugarcane under irrigated conditions. Contrary, low variability in sucrose percent has been reported by Hapase and Repale (1999).

4.3.3.3 Juice extraction at 10 months (%)

In the present study, under normal (E_1) environment, juice extraction at 10 months (%) varied from 41.56 to 59.51 % with a mean value of 53.59 %. Maximum extraction % was recorded for clone CoPb12212 (59.51%) followed by varieties CoPb91 (58.23%) and Co118 (57.92) and minimum extraction (%) was recorded for clone CoPb13181 (41.56%) under normal (E_1) conditions. The value of extraction (%) under water stress (E_2) conditions varied

from 35.28 to 52.36 % with a mean of 45.81 % and maximum and minimum extraction (%) value was recorded for the clones CoPb12212 (52.36%) and CoPb13181 (35.28%), respectively (Table 4.4).

This trait recorded low GCV, low genetic advance and moderate heritability under both environmental conditions. The PCV was low under E_1 and moderate under E_2 environments (Table 4.5). Sanghera *et al* (2014b) also reported low PCV, GCV and genetic advance for this trait under irrigated conditions in early maturing genotypes of sugarcane.

4.3.3.4 Purity at 10 months (%)

The purity at 10 months ranged from 80.16 to 92.32 (%) with a mean value of 87.42 % under normal (E_1) conditions and the highest value for purity (%) was recorded in the clone KV2012-3 (92.32%) followed by variety CoPb91 (92.21%). The lowest purity at 10 months (%) was recorded for the clone CoPb14212 (80.16%) under E_1 environment (Table 4.4). Under water stress (E_2) conditions, purity at 10 months varied from 74.94 to 90.52 (%) with overall mean of 81.62 %. The maximum and minimum values of purity (%) at 10 months were recorded for the clones Co 238 (90.52%) and CoPb14212 (74.94%), respectively.

The purity (%) at 10 months had low PCV, GCV and genetic advance under both the environments whereas it had low heritability under normal (E_1) and moderate heritability under water stress (E_2) conditions (Table 4.5). The results on variability parameters obtained in this study are in harmony with the results reported by Anbanandan and Saravanan (2010), Sanghera *et al* (2014b), Tena *et al* (2016) and Mehareb *et al* (2017).

4.3.3.5 Commercial cane sugar (CCS) at 10 months (%)

The commercial cane sugar (CCS %) at 10 months among the tested clones ranged from 8.04 to 11.80 % with a mean value of 9.73 % under normal (E_1) conditions and from 5.75 to 9.73 % with a mean value of 7.71 % under water stressed (E_2) conditions (Table 4.4). The minimum and maximum CCS (%) was recorded for clones KV2012-5 (11.80%) and CoPb12181 (8.04%), respectively under normal (E_1) conditions. Under water stress (E_2) environment, the highest CCS (%) was recorded for the clone KV2012-3 (9.73%) and lowest for variety CoPb91 (5.75%).

This trait exhibited moderate PCV (11.81% and 14.20%, respectively) and GCV (10.35% and 13.02%, respectively) under both the environments. The genetic advance was found low (18.68%) under E_1 and moderate (24.59%) under E_2 whereas as heritability was moderate (76.81) under E_1 and high (84.06) under E_2 environment (Table 4.5). High amount of variability in sugar yield has been reported by Hapase and Repale (1999). Moderate estimates of GCV, PCV coupled with high heritability has been reported by Sanghera *et al* (2014a) for CCS (%) in early maturing sugarcane clones under irrigated conditions. Therefore, this trait should be considered while making selection for higher sugar yield.

4.3.3.6 Brix at 12 months (%)

The brix among clones at 12 months (%) harvested in of February varied from 16.50 to 20.69 % with a mean value of 18.98 % under normal (E_1) conditions with maximum brix (%) for the clone KV2012-4 (20.69%) closely followed by clones KV2012-2 (20.45%), CoPb13182 (20.43%) and CoPb11214 (20.15%) and minimum brix (%) for the clone CoPb14212 (16.50%) (Table 4.4). Under water stress (E_2) conditions, it ranged from 14.86 to 18.81%. The mean value of brix (%) under stress environment was 17.37 % and highest and lowest brix were recorded for the clones KV2012-1 (18.81%) and CoPb14212 (14.86%), respectively. Overall, the clones KV2012-1, KV2012-2, KV2012-3, KV2012-4 and KV2012-5 possessed high brix at 12 months (%) under water stress (E_2) conditions. Deleterious effects of drought on the sugarcane quality particularly brix and sucrose of juice was reported by Mukunda *et al* (2000).

Variability parameter studies revealed that PCV, GCV and genetic advance for this trait were low under both E_1 and E_2 environments while the heritability was moderate under both the environments (Table 4.5). Similar results i.e. low coefficient of variation for brix (%) were reported by Rahman and Bhuiayn (2009) and Anbanandan and Saravanan (2010) in mid-late maturing clones of sugarcane under irrigated conditions.

4.3.3.7 Pol in juice at 12 months (%)

The Pol or sucrose in juice (%) at 12 months ranged from 14.53 to 18.84 % with average value of 17.12 % under normal (E_1) conditions whereas under water stress (E_2) conditions, it varied from 12.59 to 17.38 % with a mean of 14.96 % (Table 4.4). The highest and lowest pol (%) at 12 months (%) were recorded for clones KV2012-2 (18.84%) and CoPb14212 (14.53%), respectively, under normal (E_1) conditions while under water stress (E_2) conditions maximum pol (%) was recorded in KV2012-2 (17.38%) and minimum value was recorded for clone CoPb12212 (12.59%).

This trait exhibited low PCV, GCV and genetic advance and moderate heritability under normal (E_1) as well as water stress (E_2) conditions (Table 4.5). These findings are in concordance with earlier studies reported by Sanghera *et al* (2014b) and Singh *et al* (2002).

4.3.3.8 Juice extraction at 12 months (%)

It ranged from 39.39 to 63.54 % with mean value of 55.29 % under normal (E_1) conditions. The maximum juice extraction (%) at 12 months was recorded for the variety Co118 (63.54%) followed by clones CoPb13182 (60.80%) and CoPb10181 (60.46%) while minimum extraction (%) was observed for clone ISH135 (39.39) under normal (E_1) conditions (Table 4.4). The value of extraction (%) under water stress (E_2) conditions varied from 35.12 to 56.22 % with population mean of 47.54 %. The highest extraction (%) was

observed in variety Co118 (56.22%) and the lowest for clone ISH135 (35.12%) under water stress (E_2) environment.

The PCV, GCV and genetic advance were low for this trait under both environments while the heritability was moderate under normal (E_1) as well as water stress (E_2) environment (Table 4.5). Sanghera *et al* (2014b) also reported moderate heritability for this trait among mid-late maturing clones.

4.3.3.9 Purity at 12 months (%)

In the present study, the purity (%) at 12 months under normal (E_1) environment varied from 84.60 to 96.90 % with average value of 90.23 % (Table 4.4). The maximum and minimum purity (%) under this environment was recorded for varieties CoPb92 (96.90%) and CoJ85 (84.60%), respectively. Under water stress (E_2) environment, the maximum purity (%) was recorded for the clone KV2012-2 (93.74%) followed by clone KV2012-3 (89.82%) and variety Co238 (89.78%). Under E_2 , the population mean for purity (%) was recorded to be 86.06 % and the minimum purity (%) was recorded for clone CoPb11214 (74.84%) followed by CoPb14211 (80.11%) and CoPb11211 (80.34%).

For this trait, low PCV, GCV and genetic advance and moderate heritability were obtained under normal (E_1) as well as water stress (E_2) environment (Table 4.5). Low estimates of GCV, PCV genetic advance and moderate heritability for purity (%) in sugarcane were also reported by Sanghera *et al* (2014b).

4.3.3.10 Commercial cane sugar (CCS) at 12 months (%)

The CCS (%) at 12 months was recorded in the range of 10.03 to 13.47 % with an average value of 11.96 % under normal (E_1) environment. Maximum CCS (%) was exhibited by variety CoPb92 (13.47%) and minimum was recorded for clone CoPb14212 (10.03%) under normal (E_1) conditions (Table 4.4). Range of CCS (%) under water stress (E_2) conditions was 8.42 to 12.35 % with mean value of 10.21 %. The highest CCS (%) was exhibited by clone KV2012-2 (12.35%) followed by clones KV2012-3 (11.59%) and KV2012-1 (11.55%). The lowest CCS % under stress environment was recorded for clone CoPb12182 (8.42%).

This trait also exhibited low PCV, GCV and genetic advance under both the environments while the heritability was moderate under normal water (E_1) conditions and high under water stress (E_2) conditions (Table 4.5). Moderate heritability, low PCV, GCV and genetic advance for CCS (%) in sugarcane were also reported by Sanghera *et al* (2014b).

4.3.3.11 Fibre content at harvest (%)

Fibre content (%) at harvest under normal (E_1) conditions was recorded in the range of 11.36 to 14.97 % with overall mean value of 13.12 %, however, under water stress (E_2) conditions; it varied from 8.50 to 12.24 % with population mean value of 10.60 % (Table

4.4). Maximum fibre (%) was recorded for variety CoJ88 (14.97%) under normal (E_1) conditions while under water stress (E_2) conditions, the highest fibre (%) was exhibited by clone KV2012-4 (12.24%). Fifteen genotypes under normal (E_1) environment had more fibre (%) value than overall mean and 17 genotypes had more fibre (%) value than population mean under stress (E_2) environment.

Fibre content at harvest (%) recorded low PCV, GCV and genetic advance under both E_1 and E_2 environments while moderate heritability under E_1 and low heritability under E_2 were obtained (Table 4.5). Contradictory results for genetic variability for fibre (%) were reported by and Doule and Balasundaram (2004) and Rao *et al* (1979) in sugarcane.

4.3.3.1 Pol in cane at harvest (%)

Under normal (E_1) water conditions, the pol (%) in cane at harvest ranged from 15.05 to 19.36 (%) with overall mean of 17.65 (%) while under water stress (E_2) conditions pol (%) cane at harvest varied from 13.11 to 17.90 (%) with a mean value of 15.49 (Table 4.4). The maximum and minimum pol % cane value under normal (E_1) conditions was recorded for clones KV2012-2 (19.36%) and CoPb14212 (15.05%), respectively and, for clones KV2012-2 (17.90%) and CoPb12212 (13.11%) under water stressed (E_2) conditions, respectively.

PCV, GCV and genetic advance values were low for this trait under both normal (E_1) as well as water stressed (E_2) conditions (Table 4.5).

4.3.3.13 Commercial cane sugar (CCS) (t/ha) at harvest

Commercial cane sugar (t/ha) is an important industrial parameter representing the sugar yield which takes into account the cane yield and quality. In present study, CCS (t/ha) ranged from 5.70 to 13.09 (t/ha) with overall mean of value of 9.18 (t/ha) under normal (E_1) conditions (Table 4.4). It was found maximum for variety CoPb10181 (13.09) closely followed by clones KV2012-3 (13.05) and KV2012-1 (12.08) and it was recorded minimum for the clone CoPb14212 (5.70) under normal (E_1) conditions. CCS (t/ha) under water stress (E_2) conditions ranged from 2.27 to 8.85 (t/ha) with population mean value of 5.32 (t/ha). The highest value of CCS (t/ha) was recorded for clone KV2012-3 (8.85) followed by clones KV2012-1 (7.62) and KV2012-2 (7.32) and the lowest was recorded for clone CoPb11211 (2.27) under water stress (E_2) conditions. Overall, clones KV2012-3, KV2012-1 and KV2012-2 yielded high CCS (t/ha) under water stressed (E_2) environment.

This trait recorded high PCV (23.38% and 28.11%), GCV (20.89% and 27.06%) and genetic advance (38.43% and 53.66%) under both normal (E_1) as well as water stress (E_2) conditions, respectively (Table 4.5). The heritability was moderate (79.78) under normal (E_1) and high (92.65) under water stressed (E_2) environment. Singh *et al* (2002), Anbanandan and Saravanan (2010) and Arora *et al* (2014) also reported high PCV, GCV and genetic advance for CCS tons per hectare.

The conclusive findings of the study pertaining to genetic variability parameters for cane yield, its components, physiological and quality traits are further summarized below with relevant supportive literature.

High heritability values for major economic traits like cane yield, commercial cane sugar tons per hectare, number of shoots thousand per hectare, brix and pol percentage at 10 months and commercial cane sugar % under water stress (E_2) conditions indicates that substantial improvement can be expected by giving emphasis on the selection of these traits. The relative water content (%) at 120 days (32.27) had the lowest h^2 values followed by relative water content (%) at 60 days (32.48) under water stressed (E_2) conditions and under normal (E_1) conditions the lowest h^2 value was recorded for purity in percentage at 10 months (24.14) followed by specific leaf weight in grams (30.87). This could be due to the environmental influence on the expression of these traits as is also indicated by the differences in phenotypic coefficient of variation and genotypic coefficient of variation values.

Arora *et al* (2014) estimated the coefficient of variations of different traits like cane yield, commercial cane sugar, number of tillers, number of millable canes, single cane weight and commercial cane sugar which indicated that these traits had high genotypic coefficient of variation coupled with high heritability and high genetic advance. High levels of genotypic variations for cane yield and yield associated traits like number of millable canes, cane weight, cane length and cane thickness have been reported in several earlier reports (Bhide 1971, Khairwal and Babu 1976). Ram (1994) had also reported high coefficient of variation for cane weight, cane yield per plot and sugar cane yield. High amount of variability in cane weight, cane yield, and sugar yield and low variability in brix and sucrose percent has also been reported by Hapase and Repale (1999).

The low variability for cane length and cane thickness has been reported by Khan *et al* (1991) although cane length has been found to exhibit moderate range of variability in present studies. Kashif and Khan (2007) also reported significant variability for twelve agronomic traits in a set of fourteen sugarcane genotypes. In the studies made by Rahman and Bhuiayn (2009) and Anbanandan and Saravanan (2010) high coefficient of variation have been reported for traits like cane yield, cane weight, sugar yield and low coefficient of variation for cane length, cane thickness, internode length, brix %, purity coefficient and number of millable canes.

The results of genetic advance (GA) indicated that the traits namely cane yield tons per hectare, commercial cane sugar tons per hectare, single cane weight were having high genetic advance values under both the environments (E_1 and E_2) and substantial improvement can be expected by practicing selection for these traits. The number of shoots at 120 days in

thousand per hectare and number of tillers at 240 days in thousand per hectare recorded high and moderate genetic advance under water stressed (E_2) conditions, so improvement can be expected by practicing selection for these traits under water stressed (E_2) conditions. The low to moderate values of h^2 and GA for traits like relative water content at 60 and 120 days in percentage, chlorophyll content in milligrams per litre and some quality traits indicates that direct selection could not be much effective for these traits.

The low levels of GA obtained for some agronomic and quality traits could be attributed to low levels of genotypic coefficient of variation. Balasundaram and Bhagyalakshmi (1978) also obtained low level of GA for cane thickness and quality characters which attributed the low level of variability.

Several reports indicating high heritability and high GA for cane yield and cane yield components like single cane weight, cane length, numbers of millable canes have been reported in literature (Punia 1981 and Nair *et al* 1984). Further, Singh *et al* (1994) also reported that millable canes per hectare, stalk weight, and brix per cent had high heritability. In general the results of the present studies are in agreement with the above studies.

Jain *et al* (2001) and Chaudhary (2001) had also emphasized on the importance of single cane weight, number of millable canes and cane yield at the time of selection as these were found to have high heritability coupled with high genetic advance. In the recent studies conducted by Rahman and Bhuiayn (2009) high heritability coupled with high genetic advance has been reported for number of tillers thousand per hectare and single stalk weight. Anbanandan and Saravanan (2010) also reported high heritability and high genetic advance for cane weight, cane yield per plot and sugar yield per plot. The cane length, cane thickness, and purity coefficient were reported to have high heritability but low genetic advance values. Similar results have also been reported in the present studies, but contrary to this the estimates of heritability for cane length and cane girth were of moderate type under both environments. Tena *et al* (2016) has reported moderate broad sense heritability (h^2_{bs}) for stalk diameter, single cane weight, millable cane number, stalk height, and pol (%) indicating that selection for these traits could be. The results suggested that selection should be practiced on the basis of stalk diameter, single cane weight and millable cane number for higher cane and sugar yield.

Based on the results of genetic variability, heritability and genetic advance, it can be concluded that cane yield, number of tillers, number of millable canes, single cane weight and commercial cane sugar are the traits which should be given due weightage at the time of selection under water stress conditions for achieving the improvements in a crop breeding.

4.4 Association studies under normal (E_1) and water stress (E_2) environments

In plant breeding, the degree of association of plant characters has always been useful for selection especially in the case of yield which is the multiplicative end product of many

Table 4.2: Mean performance of 30 sugarcane genotypes for different cane yield and component traits under normal (E₁) and water stress (E₂) environments

Sr. No.	Genotype	Germination (%)		No. of shoots at 120 days (000/ha)		No. of tillers at 240 days (000/ha)		SCW (kg)		NMC (000/ha)		Stalk length (cm)		Stalk diameter (cm)		Cane yield (ton/ha)	
		E ₁	E ₂	E ₁	E ₂	E ₁	E ₂	E ₁	E ₂	E ₁	E ₂	E ₁	E ₂	E ₁	E ₂	E ₁	E ₂
1	CoPb10181	58.00	30.00	135.00	93.00	132.00	91.00	2.02	1.23	119.00	69.00	283.33	150.00	2.90	1.64	110.00	64.31
2	CoPb13181	55.00	33.74	131.00	87.00	120.00	81.00	1.71	1.12	111.00	69.00	296.67	193.17	2.43	1.64	83.33	57.10
3	CoPb13182	27.36	17.62	137.00	77.00	134.00	74.00	1.52	0.98	128.00	65.00	303.33	176.20	2.50	1.60	79.69	51.39
4	CoPb13183	65.00	40.50	143.00	102.00	141.00	94.00	1.26	0.80	122.00	73.00	283.33	173.59	2.33	1.61	72.05	41.67
5	CoPb11214	54.67	32.00	142.00	85.00	139.00	80.00	0.99	0.52	116.00	65.00	246.67	140.00	2.17	1.21	68.75	36.46
6	CoPb11211	38.25	21.00	91.00	53.00	83.00	51.00	1.57	0.89	77.00	47.00	263.33	156.00	2.63	1.59	48.78	25.42
7	CoPb12181	32.22	22.32	119.00	78.00	113.00	72.00	1.07	0.67	100.00	68.00	259.17	174.90	2.25	1.57	54.51	38.19
8	CoPb12182	29.03	19.97	125.00	86.00	120.00	79.00	1.24	0.92	104.00	69.00	277.50	180.12	2.38	1.66	65.97	43.40
9	CoPb14212	33.00	23.00	117.00	76.00	111.00	72.00	0.75	0.51	107.00	69.00	240.83	176.20	2.08	1.50	57.12	38.19
10	CoPb14211	40.55	27.80	122.00	85.00	116.00	85.00	0.91	0.60	114.00	75.00	263.33	189.26	2.17	1.39	63.72	41.88
11	CoPb12212	38.06	22.19	157.00	81.00	150.00	80.00	1.54	1.01	131.00	67.00	292.50	180.12	2.52	1.54	82.64	53.84
12	L 818/07	51.80	26.43	153.00	79.00	148.00	76.00	0.92	0.48	144.00	72.00	255.50	140.00	2.00	1.02	96.18	52.08
13	KV2012- 1	28.33	21.00	109.00	76.00	107.00	74.00	1.84	1.40	97.00	69.00	296.83	220.00	2.67	1.93	91.49	65.97
14	KV2012-2	36.39	28.00	102.00	76.00	95.00	72.00	1.74	1.35	88.00	69.00	278.33	210.00	2.75	1.96	76.39	59.03
15	KV2012- 3	39.44	29.00	134.00	96.00	131.00	94.00	1.99	1.52	127.00	93.00	253.50	190.00	2.43	1.85	100.69	76.39
16	KV2012- 4	37.64	28.00	100.00	72.00	92.00	65.00	1.55	1.16	86.00	65.00	266.67	212.00	2.58	1.96	77.43	60.76
17	KV2012-5	52.08	39.00	136.00	101.00	129.00	96.00	1.65	1.25	120.00	91.00	308.33	240.00	2.53	1.89	86.63	64.24
18	ISH148	41.00	33.00	154.00	118.00	124.00	99.00	1.68	1.36	114.00	94.00	237.00	195.00	1.88	1.53	58.33	48.61
19	ISH07	43.91	34.00	121.00	90.00	108.00	86.00	1.78	1.42	106.00	83.00	269.17	216.00	2.23	1.72	61.63	50.35

Sr. No.	Genotype	Germination (%)		No. of shoots at 120 days (000/ha)		No. of tillers at 240 days (000/ha)		SCW (kg)		NMC (000/ha)		Stalk length (cm)		Stalk diameter (cm)		Cane yield (ton/ha)	
		E ₁	E ₂	E ₁	E ₂	E ₁	E ₂	E ₁	E ₂	E ₁	E ₂	E ₁	E ₂	E ₁	E ₂	E ₁	E ₂
20	ISH135	46.97	38.00	125.00	102.00	121.00	96.00	1.79	1.46	116.00	93.00	251.67	195.00	1.83	1.48	63.02	49.65
21	ISH159	45.14	35.00	123.00	96.00	120.00	93.00	1.64	1.32	112.00	91.00	242.50	185.00	2.45	1.95	61.28	47.57
22	Co238	42.78	31.00	132.00	95.00	129.00	92.00	1.71	1.25	125.00	88.00	283.33	193.17	2.53	1.82	85.29	61.58
23	CoJ88	32.64	17.50	111.00	61.00	110.00	58.00	1.02	0.59	109.00	56.00	206.67	120.00	2.43	1.40	81.21	51.26
24	CoS8436	47.02	28.00	124.00	67.00	118.00	65.00	0.96	0.54	108.00	63.00	192.50	126.00	2.63	1.58	72.69	46.52
25	CoPb91	39.53	21.00	100.00	65.00	99.00	62.00	2.24	1.31	81.00	48.00	290.00	160.00	3.10	1.72	97.43	59.00
26	Co118	50.97	28.00	123.00	71.00	121.00	69.00	1.63	0.98	120.00	67.00	271.67	168.37	2.67	1.56	77.00	48.61
27	CoJ85	32.78	19.36	112.00	72.00	106.00	70.00	1.76	1.15	94.00	58.00	282.50	170.00	2.82	1.77	73.82	48.00
28	CoJ64	67.91	45.00	163.00	106.00	161.00	104.00	1.03	0.68	146.00	94.00	260.83	165.00	2.25	1.57	72.65	42.00
29	CoPb92	51.80	28.60	155.00	97.00	152.00	94.00	1.25	0.72	146.00	89.00	293.33	180.00	2.17	1.32	80.56	55.00
30	CoPb93	46.86	33.28	111.00	72.00	106.00	69.00	1.36	0.96	100.00	67.00	278.33	185.00	2.22	1.50	94.33	68.25
	CD (0.05%)	13.75	8.50	27.32	14.03	29.37	16.89	0.46	0.32	26.36	21.15	44.92	27.92	0.40	0.27	14.52	9.30
	CV(%)	15.45	14.62	10.53	8.19	11.81	10.36	15.5	15.67	11.50	14.19	8.22	7.65	8.11	8.23	6.70	6.37
	GM	43.53	28.44	127.00	84.00	122.00	80.00	1.47	1.00	112.13	72.88	267.48	178.65	2.41	1.61	76.40	51.40
	Range	27.36-67.91	17.50-45.00	91.00-163.00	53.00-118.00	83.00-161.00	51.00-104.00	0.75-2.24	0.48-1.52	77.00-146.00	47.00-94.00	192.50-308.33	120-240	1.83-3.10	1.02-1.96	48.78-110.00	25.42-76.39

Table 4.3: Mean performance of 30 sugarcane genotypes for different physiological traits under normal (E₁) and water stress (E₂) environments

Sr. No.	Genotype	Relative water content at 60 DAP (%)		Relative water content at 120 DAP (%)		Chlorophyll a (mg/l)		Chlorophyll b (mg/l)		Total chlorophyll (mg/l)		Stomatal frequency (no.)		Specific leaf wt (g)	
		E ₁	E ₂	E ₁	E ₂	E ₁	E ₂	E ₁	E ₂	E ₁	E ₂	E ₁	E ₂	E ₁	E ₂
1	CoPb10181	76.76	48.00	65.00	34.00	3.47	1.96	3.99	2.13	7.46	4.20	45.00	27.00	4.64	2.69
2	CoPb13181	76.12	52.00	73.96	45.41	3.31	2.19	4.03	3.05	7.34	5.06	44.00	28.00	5.28	3.13
3	CoPb13182	70.12	46.99	65.00	40.17	3.20	2.16	3.98	2.93	7.18	4.48	44.00	28.00	6.96	4.20
4	CoPb13183	73.53	49.34	53.29	29.00	3.31	2.23	3.75	2.36	6.95	4.23	47.00	32.00	4.48	2.98
5	CoPb11214	72.69	39.00	67.25	35.00	2.68	1.39	2.91	1.56	5.59	3.12	47.00	32.00	7.48	5.60
6	CoPb11211	76.37	52.82	77.30	43.00	3.16	1.93	3.56	2.40	6.71	4.02	48.00	35.00	5.83	3.40
7	CoPb12181	71.93	46.99	57.32	40.68	3.63	2.39	4.25	3.02	7.87	4.98	45.00	31.00	4.36	2.88
8	CoPb12182	80.25	65.00	64.58	46.50	3.01	1.98	3.29	2.03	6.30	4.19	47.00	35.00	4.94	3.34
9	CoPb14212	68.50	46.99	76.38	49.00	3.52	2.16	4.08	2.74	7.60	4.95	37.00	25.00	3.23	2.15
10	CoPb14211	72.99	53.59	60.13	30.00	2.95	1.83	3.41	2.36	6.36	4.32	41.00	29.00	4.25	2.75
11	CoPb12212	62.90	34.00	67.51	34.00	3.41	2.09	3.98	2.39	7.39	4.65	39.00	29.00	3.81	2.19
12	L 818/07	70.71	35.00	66.25	34.00	2.94	1.63	3.35	1.86	6.29	3.50	47.00	27.00	4.64	2.83
13	KV2012- 1	78.67	62.00	47.35	34.18	3.04	2.19	3.79	2.68	6.82	4.97	42.00.	24.00	6.61	4.86
14	KV2012-2	74.80	56.00	77.19	58.00	3.38	2.65	3.78	2.96	7.16	5.36	43.00	28.00	5.69	4.29
15	KV2012- 3	72.33	52.47	73.33	55.00	3.76	2.86	4.59	3.47	8.35	6.18	38.00	24.00	6.65	4.89
16	KV2012- 4	75.32	54.82	55.58	41.11	3.84	2.95	4.79	3.63	8.62	6.50	45.00	23.00	6.75	5.10
17	KV2012-5	72.32	53.25	61.67	48.00	3.40	2.46	4.06	3.09	7.46	5.54	41.00	25.00	5.39	4.28

Sr. No.	Genotype	Relative water content at 60 DAP (%)		Relative water content at 120 DAP (%)		Chlorophyll a (mg/l)		Chlorophyll b (mg/l)		Total chlorophyll (mg/l)		Stomatal frequency (no.)		Specific leaf wt (g)	
		E ₁	E ₂	E ₁	E ₂	E ₁	E ₂	E ₁	E ₂	E ₁	E ₂	E ₁	E ₂	E ₁	E ₂
18	ISH148	69.92	56.00	63.14	52.00	3.67	2.84	4.51	3.62	8.18	6.38	51.00	30.00	5.25	4.12
19	ISH07	70.35	58.00	64.10	53.00	2.99	2.43	3.55	2.79	6.54	5.26	42.00	24.00	4.68	3.73
20	ISH135	72.19	59.00	67.55	55.00	3.09	2.59	3.30	2.83	6.38	5.29	52.00	31.00	4.98	3.98
21	ISH159	69.02	54.00	61.89	51.00	2.76	2.19	3.33	2.76	6.09	4.90	41.00	22.00	4.64	3.69
22	Co238	69.85	51.00	63.10	45.00	3.88	2.75	4.89	3.21	8.77	6.10	44.00	31.00	5.00	3.80
23	CoJ88	66.70	34.00	62.50	34.00	2.54	1.95	2.68	2.05	5.22	3.20	46.00	32.00	3.81	2.10
24	CoS8436	67.08	42.00	57.50	35.00	3.84	2.19	4.63	2.83	8.47	4.71	45.00	28.00	4.33	2.80
25	CoPb91	70.94	38.00	55.36	32.00	3.40	2.35	3.88	2.35	7.27	4.48	45.00	29.00	3.89	2.15
26	Co118	71.58	44.00	76.67	46.63	3.55	2.21	3.93	2.32	7.98	4.69	43.00	26.00	5.00	3.02
27	CoJ85	73.70	50.32	70.00	45.52	3.44	2.18	3.63	2.35	7.07	4.38	38.00	27.00	5.35	3.26
28	CoJ64	69.93	43.86	68.81	46.33	2.99	2.21	3.06	2.16	6.55	4.11	41.00	28.00	3.54	2.39
29	CoPb92	73.45	41.00	67.26	37.00	3.59	2.19	4.74	2.75	8.87	5.05	47.00	33.00	5.42	3.31
30	CoPb93	69.97	45.42	69.18	49.00	3.81	2.65	4.47	3.21	8.27	5.60	42.00	28.00	4.01	2.80
	CD (0.05%)	7.19	16.70	11.30	17.06	NS	NS	NS	0.96	1.87	1.54	4.87	4.30	2.22	1.07
	CV (%)	4.88	16.74	8.48	19.58	13.94	18.67	19.39	17.82	12.65	15.67	5.43	7.44	21.67	15.33
	GM	72.03	48.82	65.20	42.61	3.31	2.25	3.87	2.66	7.23	4.81	44.00	28.3	5.02	3.42
	Range	62.90-80.25	34.00-65.00	47.35-77.30	29.00-58.00	2.54-3.88	1.39-2.95	2.68-4.89	1.56-3.63	5.22-8.87	3.12-6.50	37.00-52.00	22.00-35.00	3.23-7.48	2.10-5.60

Table 4.4: Mean performance of 30 sugarcane genotypes for different quality traits under normal (E₁) and water stress (E₂) environments

Sr. No.	Genotype	Brix at 10 months (%)		Pol in juice at 10 months (%)		Extraction at 10 months (%)		Purity at 10 months (%)		CCS at 10 months (%)		Brix at 12 months (%)		Pol in juice at 12 months (%)	
		E ₁	E ₂	E ₁	E ₂	E ₁	E ₂	E ₁	E ₂	E ₁	E ₂	E ₁	E ₂	E ₁	E ₂
1	CoPb10181	16.75	14.17	14.43	11.64	56.75	48.32	86.28	82.11	9.86	7.75	18.83	17.86	17.09	15.27
2	CoPb13181	17.89	15.53	15.56	12.84	41.56	35.28	87.04	82.71	10.67	8.58	18.58	17.85	17.68	15.90
3	CoPb13182	14.15	13.38	12.38	11.49	54.24	43.25	87.50	85.83	8.52	7.83	20.43	16.59	18.16	14.60
4	CoPb13183	14.90	12.73	13.25	10.75	51.73	40.28	88.92	84.46	9.19	7.27	18.94	17.62	16.80	14.97
5	CoPb11214	17.49	15.53	14.88	12.18	55.77	47.34	85.09	78.43	10.10	7.91	20.15	17.42	18.24	13.91
6	CoPb11211	15.88	13.38	13.54	10.41	50.98	39.65	85.29	77.77	9.20	6.73	19.26	17.05	17.61	13.69
7	CoPb12181	14.32	11.72	11.96	9.17	48.46	38.54	83.51	78.24	8.04	5.94	18.81	16.44	16.77	13.90
8	CoPb12182	16.42	15.58	13.28	12.38	57.04	52.01	80.77	79.46	8.78	8.10	17.80	15.42	15.30	12.65
9	CoPb14212	15.56	12.53	12.47	9.39	50.75	38.69	80.16	74.94	8.20	5.93	16.50	14.86	14.53	13.04
10	CoPb14211	15.99	14.24	13.12	11.29	54.95	41.28	81.99	79.25	8.73	7.38	18.77	16.11	16.23	12.90
11	CoPb12212	15.31	12.73	13.13	10.27	59.51	52.36	85.81	80.58	8.95	6.78	17.30	14.93	15.11	12.59
12	L 818/07	17.55	13.38	15.05	10.47	56.10	48.59	85.72	78.23	10.26	6.79	18.96	17.80	16.81	14.97
13	KV2012- 1	18.37	15.84	15.80	13.17	55.83	50.29	85.97	83.27	10.78	8.84	20.06	18.81	18.63	16.67
14	KV2012-2	18.87	16.30	16.60	14.08	49.45	47.58	88.03	86.35	11.45	9.63	20.45	18.54	18.84	17.38
15	KV2012- 3	18.02	15.73	16.62	14.01	53.11	49.09	92.32	88.98	11.72	9.73	19.50	18.51	18.24	16.63
16	KV2012- 4	17.22	16.63	15.07	12.75	44.81	41.26	87.84	76.61	10.37	8.17	20.69	18.73	18.30	16.29
17	KV2012-5	18.30	16.41	16.77	13.44	48.69	45.39	91.77	81.89	11.80	8.94	20.10	18.66	17.42	16.02

Sr. No.	Genotype	Brix at 10 months (%)		Pol in juice at 10 months (%)		Extraction at 10 months (%)		Purity at 10 months (%)		CCS at 10 months (%)		Brix at 12 months (%)		Pol in juice at 12 months (%)	
		E ₁	E ₂	E ₁	E ₂	E ₁	E ₂	E ₁	E ₂	E ₁	E ₂	E ₁	E ₂	E ₁	E ₂
18	ISH148	17.40	15.66	14.73	12.42	55.23	48.68	84.63	79.33	9.97	8.12	18.11	17.39	16.05	14.71
19	ISH07	16.96	15.85	14.49	12.60	50.35	45.21	85.42	79.46	9.86	8.24	18.10	17.52	16.17	15.10
20	ISH135	16.21	15.53	13.65	12.35	51.30	46.21	84.25	79.53	9.21	8.09	19.45	17.94	17.36	15.27
21	ISH159	17.05	15.51	15.60	12.56	55.58	49.65	91.49	81.02	10.96	8.31	19.02	17.26	17.61	15.23
22	Co238	14.21	13.62	12.92	12.31	53.54	49.00	90.97	90.52	9.06	8.61	18.39	17.47	16.76	15.69
23	CoJ88	13.49	11.56	12.31	9.65	55.20	45.00	91.25	83.50	8.64	6.49	19.88	18.34	17.40	15.53
24	CoS8436	13.37	11.63	12.17	9.53	53.89	46.00	91.18	81.98	8.54		18.62	17.89	17.41	16.06
25	CoPb91	12.92	10.97	11.92	8.76	58.23	49.50	92.21	79.86	8.41	5.75	17.47	16.53	16.64	14.83
26	Co118	17.10	14.82	15.31	12.27	57.92	50.40	89.58	82.64	10.65	8.21	19.47	18.30	17.12	15.81
27	CoJ85	16.22	14.79	14.46	12.29	55.35	51.00	89.15	83.23	10.04	8.24	19.00	17.99	16.08	15.00
28	CoJ64	17.14	14.53	15.16	11.84	47.26	42.00	88.57	81.43	10.49	7.85	18.05	17.36	17.45	15.23
29	CoPb92	14.02	11.71	12.61	9.79	56.20	42.39	90.01	83.52	8.79	6.58	19.61	15.99	17.37	13.57
30	CoPb93	17.12	14.71	15.41	12.29	56.22	50.28	90.02	83.63	10.75	8.26	19.30	17.59	18.70	15.59
	CD (0.05%)	1.50	1.16	1.29	1.10	6.30	5.29	NS	4.88	1.13	0.89	1.25	1.08	1.30	0.81
	CV (%)	4.54	4.00	4.47	4.67	5.76	5.65	4.28	2.93	5.69	5.67	3.23	3.05	3.71	2.66
	GM	16.20	14.22	14.10	11.61	53.59	45.81	87.42	81.62	9.73	7.71	18.98	17.37	17.12	14.96
	Range	12.92-18.87	10.97-16.63	11.92-16.77	8.76-14.08	41.56-59.51	35.28-52.36	80.16-92.32	74.94-90.52	8.04-11.80	5.75-9.73	16.50-20.69	14.86-18.81	14.53-18.84	12.59-17.38

Table 4.4: contd.

Sr. No	Genotype	Extraction at 12 months (%)		Purity at 12 months (%)		CCS at 12 months (%)		Fibre content at harvest (%)		Pol in cane at harvest (%)		CCS) at harvest (ton/ha)	
		E ₁	E ₂	E ₁	E ₂	E ₁	E ₂	E ₁	E ₂	E ₁	E ₂	E ₁	E ₂
1	CoPb10181	60.46	48.21	90.85	85.56	11.97	10.39	14.56	10.84	17.61	15.79	13.09	6.67
2	CoPb13181	58.88	51.21	95.17	89.10	12.64	11.03	11.66	9.45	18.20	16.42	10.54	6.25
3	CoPb13182	60.80	49.63	88.92	88.00	12.60	10.08	13.78	11.88	18.68	15.12	10.04	5.18
4	CoPb13183	56.76	47.29	88.69	84.98	11.64	10.16	11.44	9.36	17.32	15.49	8.36	4.24
5	CoPb11214	51.06	43.28	90.75	79.84	12.76	9.13	12.83	11.07	18.76	14.43	8.74	3.31
6	CoPb11211	59.87	46.58	91.43	80.34	12.37	9.01	12.54	8.50	18.13	14.21	6.06	2.27
7	CoPb12181	59.27	52.24	89.19	84.67	11.65	9.40	13.25	10.39	17.29	14.42	6.34	3.61
8	CoPb12182	58.27	44.86	85.93	82.01	10.43	8.42	11.59	9.12	15.82	13.17	6.92	3.63
9	CoPb14212	53.72	47.68	88.01	87.77	10.03	8.98	12.25	9.68	15.05	13.56	5.70	3.45
10	CoPb14211	54.05	42.18	86.49	80.11	11.10	8.48	14.39	10.35	16.75	13.42	7.13	3.53
11	CoPb12212	53.52	41.29	87.29	84.38	10.39	8.50	14.25	11.36	15.63	13.11	8.55	4.56
12	L 818/07	51.22	43.68	88.59	84.13	11.64	10.10	11.96	10.36	17.33	15.49	11.18	5.28
13	KV2012- 1	50.99	45.63	92.87	88.66	13.18	11.55	12.98	11.23	19.15	17.19	12.08	7.62
14	KV2012-2	58.03	49.68	92.10	93.74	13.28	12.35	13.58	11.54	19.36	17.90	10.15	7.32
15	KV2012- 3	54.56	48.21	93.50	89.82	12.94	11.59	11.36	10.05	18.76	17.15	13.05	8.85
16	KV2012- 4	57.88	50.31	88.53	86.95	12.66	11.18	14.21	12.24	18.82	16.81	9.78	6.79
17	KV2012-5	56.47	47.65	86.67	85.88	11.93	10.93	12.36	10.84	17.94	16.54	10.41	7.03
18	ISH148	47.79	43.25	88.59	84.56	11.11	9.95	12.32	10.85	16.57	15.23	6.50	4.84

Sr. No	Genotype	Extraction at 12 months (%)		Purity at 12 months (%)		CCS at 12 months (%)		Fibre content at harvest (%)		Pol in cane at harvest (%)		CCS) at harvest (ton/ha)	
		E ₁	E ₂	E ₁	E ₂	E ₁	E ₂	E ₁	E ₂	E ₁	E ₂	E ₁	E ₂
19	ISH07	53.18	46.49	89.36	82.94	11.24	10.11	13.28	11.21	16.69	15.62	6.97	5.10
20	ISH135	39.39	35.12	89.23	85.12	12.06	10.36	12.96	10.63	17.88	15.79	7.59	5.11
21	ISH159	54.25	46.39	92.62	88.23	12.45	10.52	13.27	11.20	18.13	15.75	7.59	5.02
22	Co238	53.88	51.23	91.17	89.78	11.76	10.93	12.42	10.83	17.28	16.21	9.98	6.77
23	CoJ88	56.11	51.36	87.48	84.64	11.98	10.51	14.97	10.24	17.92	16.05	9.73	5.33
24	CoS8436	54.33	49.54	93.57	89.79	12.36	11.19	13.60	10.86	17.93	16.58	9.00	5.20
25	CoPb91	55.57	50.32	95.33	89.74	11.90	10.33	12.96	10.21	17.16	15.35	11.47	6.04
26	Co118	63.54	56.22	87.96	86.51	11.81	10.81	13.65	11.02	17.64	16.33	9.09	5.26
27	CoJ85	58.69	47.21	84.60	83.36	10.88	10.07	13.96	10.25	16.60	15.52	8.08	4.78
28	CoJ64	57.91	54.23	96.65	87.78	12.56	10.50	14.91	11.25	17.97	15.75	9.19	4.39
29	CoPb92	55.24	49.17	96.90	88.66	13.47	10.80	14.58	11.96	17.89	14.09	10.86	5.94
30	CoPb93	53.09	48.32	88.57	84.77	12.03	9.19	11.85	9.35	19.22	16.11	11.25	6.22
	CD (0.05%) (0.05%)	8.25	6.03	5.80	4.07	1.15	0.65	1.60	1.58	1.15	1.31	1.97	0.82
	CV (%)	7.30	6.21	3.15	2.32	4.70	3.14	5.97	7.30	4.21	5.62	10.52	7.62
	GM	55.29	47.54	90.23	86.06	11.96	10.21	13.12	10.60	17.65	15.49	9.18	5.32
	Range	39.39-63.54	35.12-56.22	84.60-96.90	79.84-93.74	10.03-13.47	8.42-12.35	11.36-14.97	8.50-12.24	15.05-19.36	13.11-17.90	5.70-13.09	2.27-8.85

Table 4.5: Genetic variability parameters for cane yield, its components, physiological and quality traits in sugarcane under normal (E₁) and water stress (E₂) environments

Traits	PCV (%)		GCV (%)		GA (%)		h^2_{bs}	
	E ₁	E ₂	E ₁	E ₂	E ₁	E ₂	E ₁	E ₂
Cane yield and component traits								
Germination (%)	26.46	27.00	21.48	22.69	35.93	39.30	65.91	70.66
No. of shoots at 120 days (000/ha)	16.33	18.67	12.48	16.78	19.65	31.06	58.42	80.76
No. of tillers at 240 days (000/ha)	17.87	18.53	13.40	15.37	20.72	26.24	56.28	68.74
No. of millable canes (000/ha)	17.77	20.91	13.55	15.35	21.28	23.22	58.13	53.91
Stalk length (cm)	11.52	16.19	8.08	14.27	11.67	25.90	49.18	77.68
Stalk diameter (cm)	13.43	15.01	10.71	12.55	17.59	21.61	63.56	69.91
Single cane weight (kg)	28.36	34.62	23.75	30.88	40.97	56.72	70.12	79.53
Cane yield (t/ha)	20.36	21.69	18.12	20.73	33.20	40.82	79.15	85.37
Physiological traits								
Relative water content (%) at 60 DAP	6.11	20.37	3.67	11.61	4.54	13.63	36.06	32.48
Relative water content (%) at 120 DAP	12.87	23.79	9.68	13.52	15.01	15.82	56.60	32.27
Total Chlorophyll content (mg/litre)	15.80	20.88	9.46	13.80	11.68	18.78	35.88	43.66
Stomatal frequency (no.)	8.94	13.07	7.10	10.74	11.62	18.18	63.11	67.55
Specific leaf weight (g)	26.07	29.44	14.48	25.14	16.57	44.21	30.87	72.90
Quality traits								
Brix at 10 months (%)	10.63	12.08	9.61	11.40	17.90	22.16	81.77	89.06
Pol in juice at 10 months (%)	10.94	13.04	9.98	12.17	18.77	23.42	83.32	87.17
Extraction at 10 months (%)	8.94	10.74	5.90	9.13	8.70	7.59	51.21	72.30
Purity at 10 months (%)	4.91	4.72	2.41	3.70	2.44	5.98	24.14	61.51
CCS at 10 months (%)	11.81	14.20	10.35	13.02	18.68	24.59	76.81	84.06
Brix at 12 months (%)	5.73	6.62	4.73	5.88	8.05	10.75	68.20	78.81
Pol in juice at 12 months (%)	6.73	8.42	5.62	7.99	9.65	15.63	69.58	90.05
Extraction at 12 months (%)	9.73	9.78	6.44	7.56	8.77	12.03	43.76	59.69
Purity at 12 months (%)	4.19	4.13	2.77	3.42	3.77	5.84	43.69	68.59
CCS at 12 months (%)	7.92	9.86	6.38	9.34	10.57	18.24	64.76	89.83
Fibre content at harvest (%)	9.17	9.80	6.97	6.53	10.90	8.98	57.69	44.46
Pol in cane at harvest (%)	7.09	8.67	5.17	6.60	9.46	10.35	64.76	57.94
CCS at harvest (t/ha)	23.38	28.11	20.89	27.06	38.43	53.66	79.78	92.65

factors which jointly or singly influence it and the environment in which the crop has been grown. Therefore, for complex characters like yield, selection based on highly correlated component character is more effective than the direct selection (Grafius 1964). The existence of association between different characters is usually determined by studying correlations existing between them. A plant breeder has to be concerned with more than one character for improving merely a single character. For this purpose, it is important to know the genetic correlation among different characters, as this would provide breeder the valuable information regarding the correlated response to selection. Besides this, once the significant genetic correlations are established between easily measureable characters and yield, it would facilitate the selection process. Therefore, the correlation studies between characters play an important role in determining the most efficient breeding procedure. Stronger the association of trait with the yield, the more will be the chances of success in selection programme

From correlation matrix of cane yield and its component traits, agro-physiological and quality traits under study at phenotypic level (Table 4.6 and 4.7) and at genotypic level (Table 4.8 and 4.9) it was evident that genotypic correlation coefficients, in general under both the environments, were higher in magnitude than the corresponding phenotypic correlation coefficients. This indicated that there was an inherent association among various characters under study, which was depressed due to environmental influence and ultimately resulted in low phenotypic expression of the correlation. Khan *et al* (2012) also reported that lower estimates of phenotypic correlation indicated that the relationships were affected by environment at phenotypic level.

At phenotypic level, cane yield had significant positive correlation with stalk length (0.254 and 0.378), stalk diameter (0.329 and 0.373) and single cane weight (0.301 and 0.541) under normal (E_1) as well as water stressed (E_2) environments, respectively. However, in the water stressed environment, cane yield also had highly significant positive correlation with chlorophyll content (0.413) and significant negative correlation with number of stomata (-0.447). Kumar *et al* (2001) reported close association of cane yield with number of tillers, number of millable canes per plot, germination per cent, length of internodes and single cane weight under moisture deficient conditions. Sanghera *et al* (2015) also reported that cane yield was significantly and positively correlated with NMC at 10 months, stalk length, single cane weight, stalk diameter and germination percentage at 45 days under irrigated conditions.

At genotypic level, normal (E_1) and water stress (E_2) environments cane yield was significantly and positively associated with stalk length (0.558 and 0.463), stalk diameter (0.565 and 0.488), single cane weight (0.512 and 0.652) and chlorophyll content, respectively (0.289 and 0.757). However, it had negative significant correlation with number of stomata (-0.556) under water stress (E_2) environment. Thippeswamy *et al* (2003) and Tyagi *et al* (2012)

found positive and highly significant genotypic associations of cane yield with single cane weight, number of millable cane per plot and germination percent. Highly significant and positive genotypic associations of cane yield with germination (%), number of tillers at 120 days, number of shoots at 240 days, stalk diameter and NMC were also reported by Sanghera *et al* (2015).

Germination in percentage was highly significant positively correlated with number of shoots at 120 days and number of tillers at 240 days in thousand per hectare under both the environment at both phenotypic as well as genotypic level. Similarly, number of millable canes was highly positively associated with germination in percentage, number of shoots at 120 days in thousand per hectare and number of tillers at 240 days in thousand per hectare under both the environments at both phenotypic and genotypic level.

At phenotypic level, stalk length was positively correlated with number of tillers at 240 days (0.339) and number of millable canes (0.429) and at genotypic level it was positively correlated with germination percent (0.398), number of shoots at 120 DAP (0.348), number of tillers at 240 DAP (0.416) and number of millable canes (0.568) under water stress (E_2) environment. The stalk diameter was positively correlated with stalk length under both the environments but was negatively correlated with germination percent, number of shoots at 120 days, number of tillers at 240 days and number of millable canes at maturity under water stress environment (E_2) at genotypic level. Earlier correlation study for characters under normal and drought conditions by Hemaprabha *et al* (2013) also reported significant association for NMC, cane length and internode length confirming the importance of quantifying NMC, cane length and single cane weight as important parameters to be considered in drought screening.

Physiological traits like relative water content (RWC) at 60days after planting had a positive correlation with stalk length (0.332 and 0.553) under both E_1 and E_2 environments, respectively whereas it was positively correlated with stalk diameter (0.463) and single cane weight (0.447) under water stress (E_2) environment at phenotypic level. At genotypic level RWC had positive significant correlation with stalk length and single cane weight under both the environments but it was negative and significantly correlated with number of shoots at 120 days, number of tillers at 240 days and number of millable canes under normal water (E_1) conditions and positive significantly correlated with these characters under water stress (E_2) conditions.

At phenotypic level, under E_2 environment total chlorophyll content had significant positive correlation with stalk length, stalk diameter and single cane weight while at genotypic level it was significant and positively correlated with germination percentage, number of shoots at 120 days, number of tillers at 240 days, number of millable canes at

maturity, stalk length, stalk diameter, single cane weight and RWC at 60 and 120 days after planting. Under E_1 conditions, it had significant positive correlation with stalk length and negative significant correlation with RWC at 60 days after planting. Similar results were exposed by Silva *et al* (2007) who found positive significant correlation among total chlorophyll content and RWC under water stress conditions.

Number of stomata was significant and negatively correlated with stalk length, stalk diameter and single cane weight under water stress (E_2) conditions at phenotypic level while at genotypic level; it had significant negative association with stalk length, stalk diameter, single cane weight and RWC at 120 days after planting. Under normal E_1 conditions, it was negatively associated with stalk length, stalk diameter, and RWC at 120 days after planting at genotypic level.

At phenotypic level, specific leaf weight had significant positive correlation with stalk length (0.395), single cane weight (0.385), single cane weight (0.385) and RWC at 60 days after planting (0.349) under water stressed (E_2) conditions and at genotypic level it had significant positive correlation with number of millable canes, stalk length, stalk diameter, single cane weight RWC at 60 and 120 days after planting and total chlorophyll content under same environment.

For quality traits, at genotypic level commercial cane sugar (CCS) tons per hectare at harvest which is a function of cane yield and CCS per cent at 12 months exhibited significant positive association with other quality traits like pol per cent in juice at 10 months (0.385 and 0.532), purity percent at 10 months (0.875 and 0.712), CCS percent at 10 months (0.465 and 0.608), brix percent at 12 months (0.390 and 0.611), pol (%) at 12 months (0.559 and 0.776), purity (%) at 12 months (0.490 and 0.752), CCS percent at 12 months (0.586 and 0.803) and pol (%) in cane (0.586 and 0.817) under both E_1 and E_2 environments, respectively and with brix percent at 10 months (0.335) and fibre percent at harvest (0.414) under water stress (E_2) conditions. Sreekumar *et al* (1994) and Thippeswamy *et al* (2003) reported that sugar quality parameters show highly significant positive genetic correlations with each other and with sugar yield revealing that any of these juice quality traits could be considered for selection leading to the simultaneous improvement in the remaining quality traits and sugar yield. Results shown by Tena *et al* (2016) indicated that cane yield had a strong positive and highly significant correlation with millable cane number, single cane weight, stalk height and sugar yield (Table 4.8).

At phenotypic level sugar yield (t/ha) had significant positive correlation with pol (%), purity (%), CCS (%) at 10 months and brix (%), pol (%), purity (%), CCS (%) and pol (%) in cane at harvest under both normal (E_1) as well as water stressed (E_2) conditions (Table 4.9).

Table 4.6: Phenotypic correlation coefficients among different agro-physiological traits of sugarcane under normal (E₁) and water stressed (E₂) environments.

Traits	En v.	Germination (%)	No. of shoots at 120days (000/ha)	No. of tillers at 240 days (000/ha)	NMC at maturity (000/ha)	Stalk length (cm)	Stalk diameter (cm)	SCW (kg)	RWC at 60 DAP (%)	RWC at 120 DAP (%)	Total Chlorophyll (mg/l)	Stomatal frequency (no.)	Specific leaf wt (g)	Cane yield (t/ha)
Germination (%)	E ₁													
	E ₂													
No. of shoots at 120days (000/ha)	E ₁	0.541**												
	E ₂	0.619**												
No. of tillers at 240 days (000/ha)	E ₁	0.556**	0.940**											
	E ₂	0.673**	0.898**											
NMC at maturity (000/ha)	E ₁	0.469**	0.880**	0.930**										
	E ₂	0.509**	0.774**	0.743**										
Stalk length (cm)	E ₁	0.100	0.133	0.182	0.115*									
	E ₂	0.215	0.432	0.339**	0.429**									
Stalk diameter (cm)	E ₁	-0.118	-0.404	-0.287*	-0.348**	0.294**								
	E ₂	0.033	0.026	0.026	0.093	0.514**								
SCW (kg)	E ₁	-0.194	-0.154	-0.153	-0.173	0.460**	0.561**							
	E ₂	0.111	0.247	0.236	0.291*	0.567**	0.606**							
RWC at 60 DAP (%)	E ₁	-0.008	-0.142	-0.135	-0.147	0.331**	0.184	0.213						
	E ₂	0.039	0.245	0.152	0.275*	0.553**	0.463**	0.447**						
RWC at 120 DAP (%)	E ₁	0.088	0.023	0.041	0.108	-0.017	-0.005	0.041	-0.015					
	E ₂	0.157	0.272*	0.128	0.466**	0.436**	0.255*	0.378**	0.410**					
Total Chlorophyll (mg/l)	E ₁	0.039	0.116	0.069	0.088	0.112	0.112	0.215	0.046	0.034				
	E ₂	0.208	0.306*	0.144	0.320*	0.602**	0.415**	0.477**	0.285*	0.443**				
Stomatal frequency (no.)	E ₁	0.135	0.115	0.036	0.004	-0.103	-0.251	0.018	0.130	-0.099	-0.089			
	E ₂	-0.146	-0.044	-0.119	-0.203	-0.350**	-0.394**	-0.348**	-0.058	-0.159	-0.260*			
Specific leaf wt (g)	E ₁	-0.077	-0.041	-0.047	-0.059	0.175	0.162	0.300*	0.214	0.056	0.014	0.159		
	E ₂	0.151	0.175	0.145	0.195	0.395**	0.304*	0.385**	0.349**	0.160	0.241	-0.149		
Cane yield (t/ha)	E ₁	0.156	0.159	0.222	0.250	0.254*	0.329*	0.301*	0.100	-0.099	0.202	0.184	0.782**	
	E ₂	0.078	0.147	0.207	0.228	0.378**	0.373**	0.541**	0.096	0.137	0.413**	- 0.447**	0.225	

Critical value of 'r' at 5%=0.2541 and at 1%=0.3301

Table 4.7: Phenotypic correlation coefficients among different quality traits of sugarcane under normal (E₁) and water stress (E₂) environments

Traits	Env.	Brix at 10 months (%)	Pol in juice at 10 months (%)	Extraction at 10 months (%)	Purity at 10 months (%)	CCS at 10 months (%)	Brix at 12 months (%)	Pol in juice at 12 months (%)	Extraction at 12 months (%)	Purity at 12 months (%)	CCS at 12 months (%)	Fibre content at harvest (%)	Pol cane at harvest (%)	CCS at harvest (t/ha)
Brix at 10 months (%)	E ₁													
	E ₂													
Pol in juice at 10 months (%)	E ₁	0.901**												
	E ₂	0.931**												
Extraction at 10 months (%)	E ₁	-0.226	-0.211											
	E ₂	0.147	0.227											
Purity at 10 months (%)	E ₁	-0.189	0.250	0.036										
	E ₂	0.027	0.387**	0.245										
CCS at 10 months (%)	E ₁	0.803**	0.981**	-0.192	0.428**									
	E ₂	0.857**	0.986**	0.253	0.535**									
Brix at 12 months (%)	E ₁	0.228	0.344**	-0.173	0.261*	0.374**								
	E ₂	0.452**	0.517**	0.104	0.289*	0.523**								
Pol in juice at 12 months (%)	E ₁	0.273*	0.435**	-0.141	0.380**	0.479**	0.791**							
	E ₂	0.379**	0.508**	0.143	0.434**	0.545**	0.875**							
Extraction at 12 months (%)	E ₁	-0.058	-0.006	0.022	0.100	0.017	0.039	0.028						
	E ₂	-0.235	-0.125	-0.175	0.248	-0.070	0.215	0.322*						
Purity at 12 months (%)	E ₁	0.117	0.227	0.009	0.278*	0.262*	-0.082	0.543**	-0.004					
	E ₂	0.030	0.187	0.120	0.406**	0.250	0.185	0.636**	0.322*					
CCS at 12 months (%)	E ₁	0.263*	0.424**	-0.117	0.385**	0.469**	0.648**	0.978**	0.021	0.704**				
	E ₂	0.334**	0.478**	0.148	0.458**	0.522**	0.786**	0.986**	0.340**	0.752**				
Fibre content at harvest (%)	E ₁	-0.092	-0.060	0.243	0.077	-0.042	0.075	0.098	0.153	0.062	0.097			
	E ₂	0.276*	0.272*	0.325**	0.064	0.258*	0.261*	0.365**	-0.002	0.330**	0.381**			
Pol in cane at harvest (%)	E ₁	0.263*	0.424**	-0.117	0.385**	0.469**	0.648**	0.978**	0.021	0.704**	0.951**	0.097		
	E ₂	0.320*	0.433**	0.155	0.387**	0.465**	0.632**	0.786**	0.228	0.596**	0.795**	0.310*		
CCS at harvest (t/ha)	E ₁	0.118	0.325**	0.074	0.483**	0.396**	0.386**	0.548**	0.079	0.367**	0.552**	0.013	0.552**	
	E ₂	0.293*	0.477**	0.271*	0.559**	0.539**	0.561**	0.757**	0.188	0.635**	0.781**	0.327*	0.637**	

Critical value of 'r' at 5%=0.2541 and at 1%=0.3301

Table 4.8: Genotypic correlation coefficients among different agro-physiological traits under normal (E₁) and water stressed (E₂) environments

Traits	Env.	Germination (%)	No. of shoots at 120days (000/ha)	No. of tillers at 240 days (000/ha)	NMC at maturity (000/ha)	Stalk length (cm)	Stalk diameter (cm)	SCW (kg)	RWC at 60 DAP (%)	RWC at 120 DAP (%)	Total Chlorophyll (mg/l)	Stomatal frequency (no.)	Specific leaf wt (g)	Cane yield (t/ha)
Germination (%)	E ₁													
	E ₂													
No. of shoots at 120days (000/ha)	E ₁	0.542**												
	E ₂	0.851**												
No. of tillers at 240 days (000/ha)	E ₁	0.604**	0.985**											
	E ₂	0.816**	0.912**											
NMC at maturity (000/ha)	E ₁	0.580**	0.959**	0.963**										
	E ₂	0.991**	0.932**	0.953**										
Stalk length (cm)	E ₁	-0.084	-0.025	-0.026	-0.051									
	E ₂	0.398**	0.348**	0.416**	0.568**									
Stalk diameter (cm)	E ₁	-0.261*	-0.560**	-0.485**	-0.610**	0.358**								
	E ₂	0.067	0.059	0.048	0.135	0.744**								
SCW (kg)	E ₁	-0.204	-0.372**	-0.480**	-0.465**	0.508**	0.491**							
	E ₂	0.220	0.348**	0.316	0.367**	0.759**	0.883**							
RWC at 60 DAP (%)	E ₁	-0.095	-0.659**	-0.652**	-0.754**	0.580**	0.252	0.372**						
	E ₂	0.442**	0.437**	0.486**	0.476**	0.932**	0.886**	0.887**						
RWC at 120 DAP (%)	E ₁	0.062	0.027	-0.032	0.068	-0.004	-0.265*	-0.093	-0.135					
	E ₂	0.592**	0.332**	0.526**	0.505**	0.647**	0.739**	0.875**	0.866**					
Total Chlorophyll (mg/l)	E ₁	-0.070	-0.091	-0.197	-0.068	0.369**	0.204	0.240	-0.337**	0.008				
	E ₂	0.349**	0.429**	0.551**	0.838**	0.952**	0.869**	0.910**	0.905**	0.917**				
Stomatal frequency (no.)	E ₁	0.271*	0.074	-0.040	-0.013	-0.353**	-0.412**	-0.067	0.329*	-0.281**	-0.150			
	E ₂	-0.161	-0.064	-0.067	-0.264*	-0.446**	-0.571**	-0.421**	-0.303*	-0.506**	-0.616**			
Specific leaf wt (g)	E ₁	-0.414**	-0.184	-0.287*	-0.236	0.416**	-0.001	0.322*	0.956**	-0.166	0.228	0.127		
	E ₂	0.144	0.324*	0.245	0.419**	0.586**	0.428**	0.524**	0.830**	0.664**	0.651**	-0.281*		
Cane yield (t/ha)	E ₁	0.245	0.144	0.267*	0.251	0.558**	0.565**	0.512**	-0.031	-0.147	0.289*	-0.180	0.114	
	E ₂	0.101	0.182	0.199	0.328*	0.463**	0.488**	0.652**	0.071	0.248	0.757**	-0.556**	0.299*	

Critical value of 'r' at 5%=0.2541 and at 1%=0.3301

Table 4.9: Genotypic correlation coefficients among different quality traits of sugarcane genotypes under normal (E₁) and water stress (E₂) environments

Traits	Env.	Brix at 10 months (%)	Pol in juice at 10 months (%)	Extraction at 10 months (%)	Purity at 10 months (%)	CCS at 10 months (%)	Brix at 12 months (%)	Pol in juice at 12 months (%)	Extraction at 12 months (%)	Purity at 12 months (%)	CCS at 12 months (%)	Fibre content at harvest (%)	Pol in cane at harvest (%)	CCS at harvest (t/ha)
Brix at 10 months (%)	E ₁													
	E ₂													
Pol in juice at 10 months (%)	E ₁	0.972**												
	E ₂	0.952**												
Extraction at 10 months (%)	E ₁	-0.253	-0.180											
	E ₂	0.281*	0.357**											
Purity at 10 months (%)	E ₁	-0.063	0.173	0.298*										
	E ₂	0.071	0.370**	0.320*										
CCS at 10 months (%)	E ₁	0.941**	0.994**	-0.144	0.277*									
	E ₂	0.899**	0.989**	0.381**	0.498**									
Brix at 12 months (%)	E ₁	0.370**	0.489**	-0.228	0.557**	0.533**								
	E ₂	0.549**	0.642**	0.136	0.444**	0.665**								
Pol in juice at 12 months (%)	E ₁	0.373**	0.552**	-0.307*	0.801**	0.622**	0.877**							
	E ₂	0.427**	0.593**	0.130	0.637**	0.652**	0.921**							
Extraction at 12 months (%)	E ₁	-0.153	-0.029	-0.309*	0.486**	0.027	0.209	0.120						
	E ₂	-0.224	-0.079	-0.335**	0.416**	-0.008	0.149	0.368**						
Purity at 12 months (%)	E ₁	0.107	0.275*	-0.242	0.710**	0.346**	0.082	0.549**	-0.090					
	E ₂	0.038	0.263*	0.056	0.713**	0.361**	0.437**	0.751**	0.616**					
CCS at 12 months (%)	E ₁	0.353**	0.542**	-0.317*	0.841**	0.617**	0.786**	0.986**	0.080	0.680**				
	E ₂	0.375**	0.559**	0.125	0.676**	0.627**	0.867**	0.992**	0.424**	0.822**				
Fibre content at harvest (%)	E ₁	-0.133	-0.092	0.383**	0.166	-0.071	0.233	0.222	0.211	0.069	0.206			
	E ₂	0.482**	0.517**	0.371**	0.248	0.516**	0.475**	0.529**	0.181	0.423**	0.528**			
Pol in cane at harvest (%)	E ₁	0.353**	0.542**	-0.317*	0.841**	0.617**	0.786**	0.986**	0.080	0.680**	0.924**	0.206		
	E ₂	0.451**	0.637**	0.203	0.714**	0.704**	0.937**	0.921**	0.303*	0.810**	0.935**	0.599**		
CCS at harvest (t/ha)	E ₁	0.191	0.385**	0.265*	0.875**	0.465**	0.390**	0.559**	0.198	0.490**	0.586**	0.042	0.586**	
	E ₂	0.335**	0.532**	0.318*	0.712 **	0.608**	0.611**	0.776**	0.244	0.752**	0.803**	0.414**	0.817**	

Critical value of 'r' at 5%=0.2541 and at 1%=0.3301

On the basis of correlation studies, cane yield, stalk length, stalk diameter, number of millable canes, number of tillers at 240 days and CCS (t/ha) were identified as important traits which can be selected for yield improvement under both the environments. While the number of stomata, chlorophyll content, specific leaf weight and RWC at 60 and 120 days are identified as important physiological traits for cane yield as well as sugar content under water stress (E_2) environment.

4.5 Path analysis

Efficiency of selection in any breeding programme mainly depends upon the knowledge of association of characters. Although correlation coefficient indicates the nature of association among the traits but path coefficient analysis splits the correlation values into direct and indirect effects so as to measure the relative importance of causal factors involved. Correlation studies reveal only the general relationship between any two variables without unfolding the underlying cause of such association. As many variables are included in correlation studies, the indirect effects of other variable become confounded. In such a situation, path coefficient analysis is useful in finding out direct and indirect causes of associations and allows a precise perception of specific forces acting to produce a given correlation. The relative importance of each causal factor also becomes evident.

4.5.1 Estimates of direct and indirect effects at the phenotypic level

In present investigation, the direct and indirect effects of different traits on cane yield at phenotypic level were worked out both under normal (E_1) and water stressed (E_2) conditions and presented in Table 4.10 and 4.11.

Maximum positive direct effect among agro-physiological traits on cane yield was of number of millable canes at maturity (0.669) followed by stalk diameter (0.329), single cane weight (0.153), germination percentage (0.096), chlorophyll content (0.084) and RWC at 60 days (0.065) at phenotypic level under normal (E_1) water conditions (Table 4.10). Under same environment among quality traits commercial cane sugar at 10 months (CCS %) (17.944) had the highest direct effect on commercial cane sugar (CCS t/ha) followed by pol (%) in juice at 12 months (11.480), brix (%) at 10 months (8.735), commercial cane sugar (%) at 12 months (4.669), purity (%) at 10 months (0.683), juice extraction percent at 10 months (0.163). These results were similar to as reported by Thippeswamy *et al* (2003), Singh *et al* (2005), Mali *et al* (2010), Sanghera *et al* (2014a) and Tena *et al* (2016). Number of shoots at 120 days (-0.048 and -0.359, respectively), RWC at 120 days (-0.189 and -0.093, respectively) had negative direct effect on cane yield at phenotypic level under both E_1 and E_2 environments and number of stomata had negative direct effect in E_2 environment.

Under water stress (E_2) environment, among agro-physiological traits, number of tillers at 240 days after planting (0.445) had maximum direct effect on cane yield at

phenotypic level followed by single cane weight (0.377), chlorophyll content (0.288), and number of millable canes (0.079), specific leaf weight (0.042) and stalk length (0.029) while among quality traits CCS (%) (11.922) had maximum direct effect on CCS (t/ha) followed by pol (%) in juice at 10 months (1.351), brix (%) at 12 months (1.010), juice extraction (%) at 10 months (0.084) and pol (%) cane at harvest (0.049).

Among indirect effects, germination percentage had positive indirect effect via NMC, chlorophyll content and specific leaf weight under both E_1 and E_2 environments and via number of tillers at 240 days, single cane weight, stalk length and number of stomata under water stress (E_2) conditions. However, this trait exhibited negative indirect effect via number of shoots at 120 days, number of tillers at 240 days, stalk diameter, single cane weight, RWC at 60 and 120 days and number of stomata under normal (E_1) conditions, while under water stress conditions (E_2) this trait exhibited negative indirect effect via number of shoots at 120 days and RWC at 60 and 120 days.

Number of shoots at 120 days had positive indirect effects on cane yield via germination percentage, NMC, stalk length and chlorophyll content under E_1 environment and it had negative indirect effect via remaining agro-physiological traits. Under E_2 environment it had positive indirect effect via number of tillers at 240 days, number of millable canes, stalk length, stalk diameter, single cane weight, chlorophyll content, number of stomata and specific leaf weight and negative indirect effect via germination percentage, number of shoots and RWC at 60 and 120 days after planting.

Number of millable canes had negative indirect effect on cane yield via germination percentage, stalk length and chlorophyll content and negative indirect effect via remaining agro-physiological traits at phenotypic level under normal (E_2) water conditions. Under E_2 environment, NMC had negative indirect effect via germination percentage, number of shoots at 120 days and RWC at 60 and 120 days. However, this trait exhibited positive indirect effect via number of tillers at 240 days, stalk length, stalk diameter, SCW, chlorophyll content, number of stomata and specific leaf weight.

Stalk length had negative indirect effect via number of shoots at 120 days and number of tillers at 240 days but a positive indirect effect via other remaining traits under normal (E_1) conditions whereas under water stress (E_2) conditions it had negative indirect effect on yield via number of shoots at 120 days and positive indirect effect via single cane weight. Stalk diameter had negative direct effect via NMC and positive direct effect via single cane weight under E_1 whereas under E_2 it had positive indirect effect via single cane weight and negative indirect effect via number of shoots at 120 days. Single cane weight had positive indirect effect on cane yield via stalk diameter and negative indirect effect via NMC under normal water conditions whereas it had negative indirect effect via number of shoots at 120 days and

positive indirect effect via stalk length under water stressed conditions. The results were similar to earlier reported by Sanghera *et al* (2015), Kumar and Singh (2005), Thippeswamy *et al* (2009) and Madhavi *et al* (1990) for cane yield and component traits under irrigated conditions.

In case of physiological traits under water stress (E_2) environment, RWC at 60 and 120 days after planting had negative direct effect but it shows positive indirect effect on cane yield via single cane weight and number of tillers at 240 days. The chlorophyll content had negative indirect effect via number of shoots at 120 days and positive direct effect via single cane weight. The number of stomata had negative direct effect on yield but it had positive indirect effect via number of shoots at 120 days. In case of normal (E_1) conditions RWC at 60 days had positive indirect effect via stalk diameter and single cane weight and negative indirect effect via number of millable canes. The chlorophyll content had negative indirect effect via number of tillers at 240 days and positive indirect effect via stalk diameter and number of millable canes.

In case of quality traits, under water stress (E_2) conditions, brix (%) at 10 months had negative direct affect on commercial cane sugar (t/ha) but it had a positive indirect effect via pol (%) at 10 months. Pol (%) at 10 months had a negative indirect effect via pol (%) at 12 months; juice extraction (%) at 10 months had negative indirect effect via pol (%) at 12 months. CCS (%) at 10 months had negative direct effect but had positive indirect effect via CCS (%) at 12 months. Similarly, brix (%) at 12 months, pol (%) at 12 months, juice extraction (%) at 12 months, purity (%), fibre (%) at harvest and pol (%) cane at harvest had a positive indirect effect on commercial cane sugar (CCS t/h) via commercial cane sugar percentage (CCS %) at 12 months after planting.

The residual (unexplained) variation in the path analysis came out to be 0.14 under E_1 and 0.16 under E_2 on phenotypic correlations among the agro-physiological and 0.15 under E_1 and 0.17 under E_2 among quality characters studied for all the genotypes. This residual variation signified that there was still unexplained and unaccounted variation left among the genotypes which could not be explained by the above traits studied. To explain the same, some more agro-physiological and quality characters are required.

4.5.2 Estimates of direct and indirect effects at genotypic level

A perusal of direct and indirect effects at genotypic level (Table 4.12 and 4.13) delineate that under normal (E_1) conditions, number of millable canes (7.487) exhibited highest positive direct effect on cane yield followed by stalk diameter (3.189), number of stomata (1.217), RWC at 120 days (0.445), specific leaf weight (0.423) and stalk length (0.356). The character with negative direct effects on cane yield were number of tillers at 240 days, number of shoots at 120 days, germination percentage, RWC at 60 days and chlorophyll

content. However, under water stressed (E_2) conditions number of tillers at 240 days (3.177) had maximum positive direct effect on cane yield followed by relative water content at 60 days (1.930), stalk length (1.741), RWC at 120 days (1.525), number of shoots (0.768) and single cane weight (0.453). The above results are in accordance with the earlier studies of Das *et al* (2007), Khan *et al* (2012) and Kumar *et al* (2014).

Among indirect effects, germination percentage had positive indirect effects on cane yield via NMC, single cane weight, chlorophyll content under E_1 and via number of tillers at 120 days, number of tillers at 240 days, stalk length and RWC at 60 days after planting under E_2 environment. Number of shoots at 120 days had positive indirect effect via NMC, SCW and chlorophyll content and had negative effects via number of tillers at 240 days and stalk diameter under normal water conditions whereas under water stressed conditions it had positive indirect effect via number of tillers at 240 days, SCW, stalk length, RWC at 60 and 120 days and number of stomata and negative indirect effect via germination percentage, NMC, stalk diameter and chlorophyll content. The genotypic correlation coefficients indicated that NMC, stalk weight, and stalk height had significant and positive association with cane yield as well as sugar yield (Rishipal *et al* 1998 and Thippeswamy *et al* 2003) so these traits have high direct and indirect effects.

Under water stressed (E_2) conditions, number of tillers at 240 days had a positive indirect effect via RWC at 60 and 120 days and number of shoots at 120 days whereas it had negative indirect effect on cane yield via NMC, germination percentage and stalk diameter.

Number of millable canes (NMC) had positive indirect effect under normal water (E_1) conditions via single cane weight and chlorophyll content and it had negative indirect effect via stalk diameter and number of tillers at 240 days. Under water stressed (E_2) conditions, it had a positive direct effect on cane yield and had positive indirect effect on cane yield via number of tillers at 240 days, stalk length, RWC at 60 and 240 days and number of stomata. Stalk length had negative indirect effect via NMC, chlorophyll content under both the environments however; it had positive indirect effect via number of tillers at 240 days and number of shoots at 120 days. Singh *et al* (2005) reported that two characters namely NMC and single cane weight showed significant positive direct contribution towards cane yield. Sanghera *et al* (2015) studied the partitioning of association into their direct and indirect effects and reported that highest positive direct effect on cane yield is exerted by growth characters like number of shoots 240 days, number millable canes, single cane weight and stalk diameter.

Under both the environments, stalk diameter had positive indirect effect via stalk length, number of shoots at 120 days and number of tillers at 240 days however, under water stress (E_2) conditions, it had positive indirect effect on cane yield via single cane weight,

RWC at 60 and 120 days and number of stomata. Under E_2 environment SCW and RWC at 60 and 120 days had negative indirect effect on cane yield via germination percentage and positive indirect effect via number of shoots at 120 days, number of tillers at 240 days, stalk length and number of stomata.

Among quality traits CCS (%) at 12 months (13.043) had maximum positive direct effect on CCS (t/ha) under normal (E_1) conditions followed by pol (%) cane at harvest (11.389), pol (%) in juice at 12 months (4.030), juice extraction (%) at 10 months and 12 months (0.383 and 0.126, respectively) and fibre (%) at harvest had negative direct effect. Under water stress (E_2) conditions, pol (%) in juice at 12 months (5.361) had maximum direct effect on CCS (t/ha) followed by brix (%) at 10 months (2.938), purity (%) at 10 months (1.584), pol (%) in juice at 10 months (1.262), fibre (%) at harvest (0.259), pol (%) cane percentage at harvest (0.259) and juice extraction (%) at 10 months (0.204).

In case of indirect effects, under E_2 environment brix (%) at 10 months had positive indirect effect on CCS (t/ha) via all quality traits. Similarly pol (%) in juice at 10 months had also positive indirect effect via all the quality. Shahzad *et al* (2017) reported that highest direct effect on sugar recovery was shown by purity, followed by brix% which confirms that these traits could contribute more towards an increase of sugar recovery.

. The residual (unexplained) variation in the path analysis came out to be 0.16 under E_1 and 0.20 under E_2 on genotypic correlations among the morpho- physiological and 0.18 under E_1 and 0.19 under E_2 among quality characters studied for all the genotypes.

4.6 Screening for drought tolerance

Thirty sugarcane genotypes/clones were evaluated for different cane yield, its components, physiological and quality traits under 2 environments viz. Normal (E_1) and water stress (E_2). Based on the mean performance of different traits under study drought susceptibility index (DSI) as per given by fisher and Maurer (1978) was calculated for all the traits. Based on the value of DSI given under table (4.14 to 4.16) the sugarcane genotypes/clones were categorized as drought tolerant ($S < 0.75$), intermediate ($S = 0.75-1.00$) and sensitive ($S > 1.00$). Trait-wise results of different genotypes under both the environments, percentage reduction in mean under E_2 and corresponding DSI values are described below:

4.6.1 Drought susceptibility index for different cane yield and component traits

The cane yield and its components traits are the most important characters to evaluate the performance of sugarcane clones. The mean germination percentage was 43.53 % under normal (E_1) environment and 28.44 % under water stress (E_2) environment. The % decrease in germination in E_2 environment was 34.19 % with maximum reduction for the L818/07 (48.98%) and minimum for the genotype ISH135 (19.10%). The DSI values worked out for

Table 4.10: Estimates of direct and indirect effects of different agro-physiological traits of sugarcane genotypes on cane yield (t/ha) at phenotypic level under normal (E₁) and water stressed (E₂) environments

Traits	Env.	Germination (%)	No. of shoots at 120days (000/ha)	No. of tillers at 240 days (000/ha)	NMC at maturity (000/ha)	Stalk length (cm)	Stalk diameter (cm)	SCW (kg)	RWC at 60 DAP (%)	RWC at 120 DAP (%)	Total Chlorophyll (mg/l)	Stomatal frequency (no.)	Specific leaf wt (g)	Correlation with cane yield (t/ha)
Germination (%)	E ₁	0.096	-0.026	-0.153	0.314	0.0004	-0.039	-0.003	-0.0006	-0.016	0.003	-0.021	0.002	0.157
	E ₂	-0.164	-0.222	0.299	0.04	0.006	0.0001	0.042	-0.006	-0.012	0.059	0.031	0.006	0.079
No. of shoots at 120days (000/ha)	E ₁	0.052	-0.048	-0.258	0.589	0.0006	-0.133	-0.023	-0.009	-0.004	0.009	-0.014	-0.003	0.159
	E ₂	-0.102	-0.359	0.400	0.061	0.012	0.0001	0.093	-0.038	-0.023	0.088	0.009	0.007	0.148
No. of tillers at 240 days (000/ha)	E ₁	0.053	-0.045	-0.274	0.622	0.0008	-0.094	-0.023	-0.008	-0.007	0.005	-0.004	-0.003	0.223
	E ₂	-0.11	-0.323	0.445	0.058	0.009	0.0001	0.089	-0.023	-0.011	0.04	0.026	0.007	0.207
NMC at maturity (000/ha)	E ₁	0.045	-0.042	-0.255	0.669	0.005	-0.114	-0.026	-0.009	-0.02	0.007	-0.004	-0.005	0.251
	E ₂	-0.083	-0.278	0.331	0.079	0.012	0.0003	0.11	-0.043	-0.043	0.092	0.044	0.008	0.229
Stalk length (cm)	E ₁	0.009	-0.006	-0.05	0.077	0.004	0.096	0.07	0.021	0.003	0.009	0.014	0.007	0.254
	E ₂	-0.035	-0.155	0.151	0.033	0.029	0.014	0.214	-0.086	-0.041	0.173	0.076	0.005	0.378
Stalk diameter (cm)	E ₁	-0.011	0.019	0.078	-0.233	0.001	0.329	0.085	0.012	0.001	0.009	0.033	0.006	0.329
	E ₂	-0.005	-0.009	0.011	0.007	0.015	0.002	0.229	-0.072	-0.024	0.119	0.086	0.014	0.373
SCW (kg)	E ₁	-0.001	0.007	0.042	-0.115	0.002	0.184	0.153	0.014	-0.007	0.018	-0.003	0.007	0.301
	E ₂	-0.018	-0.089	0.105	0.023	0.016	0.001	0.377	-0.069	-0.035	0.137	0.076	0.017	0.541
RWC at 60 DAP (%)	E ₁	-0.0009	0.006	0.037	-0.098	0.001	0.06	0.032	0.065	0.003	0.003	-0.01	0.003	0.101
	E ₂	-0.019	-0.088	0.068	0.021	0.016	0.001	0.135	-0.156	0.038	0.072	0.008	0.001	0.097
RWC at 120 DAP (%)	E ₁	0.008	-0.001	-0.011	0.072	-0.0001	-0.002	0.006	-0.001	-0.189	0.002	0.015	0.001	-0.100
	E ₂	-0.026	-0.098	0.057	0.036	0.012	0.0007	0.142	-0.064	-0.093	0.128	0.034	0.009	0.138
Total Chlorophyll (mg/l)	E ₁	0.003	-0.005	-0.019	0.059	0.0005	0.037	0.033	0.003	-0.006	0.084	0.011	0.001	0.202
	E ₂	0.034	-0.11	0.064	0.025	0.017	0.001	0.17	-0.054	-0.071	0.288	0.041	0.008	0.413
Stomatal frequency (no.)	E ₁	0.013	-0.005	-0.009	0.003	-0.0004	-0.002	0.002	0.013	0.029	-0.007	0.128	0.019	0.184
	E ₂	0.024	0.015	-0.053	-0.016	-0.01	-0.011	-0.131	0.009	0.015	-0.066	-0.218	-0.006	-0.448
Specific leaf wt (g)	E ₁	-0.001	0.056	0.123	-0.003	0.028	0.053	0.277	0.045	-0.002	0.182	-0.002	0.026	0.782
	E ₂	-0.024	-0.063	0.065	0.015	0.011	0.0008	0.145	-0.054	-0.015	0.069	0.034	0.042	0.226

Unexplained variation at phenotypic level under E₁ = 0.14

Unexplained variation at phenotypic level under E₂ = 0.16

Table 4.11: Estimates of direct and indirect effects of different quality traits of sugarcane genotypes on commercial cane sugar (CCS) (t/ha) at phenotypic level under normal (E₁) and water stress (E₂) environments

Traits	Env.	Brix at 10 months (%)	Pol in juice at 10 months (%)	Extraction at 10 months (%)	Purity at 10 months (%)	CCS at 10 months (%)	Brix at 12 months (%)	Pol in juice at 12 months (%)	Extraction at 12 months (%)	Purity at 12 months (%)	CCS at 12 months (%)	Fibre content at harvest (%)	Pol in cane at harvest (%)	Correlation with CCS (t/ha)
Brix at 10 months (%)	E ₁	8.735	-23.010	-0.036	-0.129	14.076	-0.798	3.143	-0.003	-0.432	-1.229	0.002	-0.201	0.118
	E ₂	-0.783	1.259	0.012	0.000	-0.456	0.457	-4.165	0.013	-0.051	3.984	0.009	0.015	0.294
Pol in juice at 10 months (%)	E ₁	7.878	-25.512	-0.034	0.171	17.619	-1.205	4.993	0.000	-0.113	-1.982	0.006	-1.495	0.326
	E ₂	-0.730	1.351	0.019	0.000	-0.524	0.523	-5.589	0.007	-0.309	5.700	0.008	0.021	0.477
Extraction at 10 months (%)	E ₁	-1.978	5.399	0.163	0.025	-3.447	0.606	-1.629	0.001	-0.004	0.549	-0.024	0.414	0.075
	E ₂	-0.116	0.307	0.084	0.000	-0.134	0.105	-1.574	0.010	-0.199	1.771	0.009	0.008	0.271
Purity at 10 months (%)	E ₁	-1.655	-6.401	0.006	0.683	7.695	-0.913	4.368	0.005	-0.138	-1.800	-0.007	-1.360	0.483
	E ₂	-0.021	0.524	0.020	0.000	-0.284	0.292	-4.773	-0.014	-0.673	5.467	0.001	0.020	0.559
CCS at 10 months (%)	E ₁	7.021	-25.050	-0.031	0.293	17.944	-1.310	5.500	0.001	-0.130	-2.192	0.004	-1.653	0.397
	E ₂	-0.672	1.332	0.021	0.000	-0.531	0.528	-5.986	0.004	-0.414	6.226	0.007	0.025	0.540
Brix at 12 months (%)	E ₁	1.994	-8.796	-0.028	0.178	6.724	-3.496	9.081	0.002	0.042	-3.026	-0.007	-2.282	0.386
	E ₂	-0.354	0.699	0.008	0.000	-0.278	1.010	-9.614	-0.012	-0.307	9.371	0.007	0.032	0.562
Pol in juice at 12 months (%)	E ₁	2.391	-11.097	-0.023	0.260	8.597	-2.765	11.480	0.001	-0.270	-4.569	-0.009	-3.447	0.549
	E ₂	-0.297	0.687	0.012	0.000	-0.289	0.884	-10.983	-0.018	-1.053	11.766	0.010	0.039	0.758
Extraction at 12 months (%)	E ₁	-0.512	0.154	0.003	0.068	0.310	-0.138	0.330	0.056	0.002	-0.102	-0.015	-0.076	0.080
	E ₂	0.184	-0.169	-0.014	0.000	0.037	0.217	-3.545	-0.058	-0.532	4.059	0.000	0.010	0.189
Purity at 12 months (%)	E ₁	1.029	-5.808	0.001	0.190	4.702	0.290	6.235	0.000	-0.498	-3.287	-0.006	-2.481	0.367
	E ₂	-0.024	0.252	0.010	0.000	-0.133	0.187	-6.993	-0.018	-1.654	8.970	0.009	0.030	0.636
CCS at 12 months (%)	E ₁	2.299	-10.832	-2.019	0.608	8.424	-2.266	11.234	0.001	-2.035	4.669	-4.009	-5.521	0.553
	E ₂	-2.262	0.121	0.012	0.000	-2.852	0.794	0.849	-3.852	0.244	11.922	0.020	-4.214	0.782
Fibre content at harvest (%)	E ₁	-0.806	1.543	0.039	0.052	-0.762	-0.263	1.130	0.008	-0.031	-0.454	-0.100	-0.343	0.013
	E ₂	-0.217	0.367	0.027	0.000	-0.137	0.263	-4.017	0.000	-0.546	4.542	0.029	0.017	0.328
Pol in cane at harvest (%)	E ₁	2.299	-10.833	-0.019	0.263	8.424	-2.266	11.233	0.002	-0.351	-4.669	-0.009	-3.521	0.553
	E ₂	-1.251	0.585	0.013	0.000	-0.247	0.638	-1.864	-1.013	0.986	2.732	0.009	0.049	0.637

Unexplained variation at phenotypic level under E₁ = 0.15

Unexplained variation at phenotypic level under E₂ = 0.17

Table 4.12: Estimates of direct and indirect effects of different agro-physiological traits of sugarcane genotypes on cane yield (t/ha) at genotypic level under normal (E₁) and water stressed (E₂) environments

Traits	Env.	Germination (%)	No. of shoots at 120days (000/ha)	No. of tillers at 240 days (000/ha)	NMC at maturity (000/ha)	Stalk length (cm)	Stalk diameter (cm)	SCW (kg)	RWC at 60 DAP (%)	RWC at 120 DAP (%)	Total Chlorophyll (mg/l)	Stomatal frequency (no.)	Specific leaf wt (g)	Correlation with cane yield (t/ha)
Germination (%)	E ₁	-0.286	-0.178	-3.055	4.345	-0.030	-0.832	0.020	0.010	0.028	0.067	0.330	-0.175	0.245
	E ₂	-2.607	0.654	2.594	-2.302	0.693	-0.166	0.099	0.854	0.904	-0.781	0.353	-0.194	0.102
No. of shoots at 120days (000/ha)	E ₁	-0.155	-0.329	-4.983	7.185	-0.009	-1.786	0.038	0.072	0.012	0.087	0.090	-0.078	0.145
	E ₂	-2.221	0.768	3.437	-2.512	0.606	-0.146	0.158	0.844	0.506	-0.960	0.140	-0.437	0.183
No. of tillers at 240 days (000/ha)	E ₁	-0.173	-0.324	-5.055	7.254	-0.009	-1.549	0.049	0.071	-0.014	0.189	-0.048	-0.121	0.267
	E ₂	-2.129	0.831	3.177	-2.750	0.725	-0.121	0.143	0.938	0.802	-1.235	0.158	-0.340	0.199
NMC at maturity (000/ha)	E ₁	-0.166	-0.316	-4.898	7.487	-0.018	-1.947	0.047	0.082	0.030	0.065	-0.016	-0.100	0.251
	E ₂	-2.584	0.123	3.151	2.322	0.026	-1.965	0.023	0.123	0.770	-1.877	0.015	0.201	0.329
Stalk length (cm)	E ₁	0.024	0.008	0.135	-0.382	0.356	1.143	-0.052	-0.063	-0.001	-0.354	-0.430	0.174	0.558
	E ₂	-1.039	0.267	1.324	-1.320	1.741	-1.847	0.344	1.954	0.986	-2.131	0.974	-0.790	0.463
Stalk diameter (cm)	E ₁	0.074	0.184	2.455	-4.570	0.127	3.189	-0.050	-0.027	-0.118	-0.196	-0.502	-0.001	0.566
	E ₂	-0.174	0.045	0.155	-1.315	1.295	2.482	0.400	0.512	1.128	-1.946	0.211	-2.305	0.489
SCW (kg)	E ₁	0.058	0.122	2.430	-3.483	0.181	1.567	-0.102	-0.040	-0.041	-0.230	-0.082	0.132	0.513
	E ₂	-0.573	0.268	1.005	-0.852	1.322	-2.192	0.453	1.714	1.334	-2.039	0.919	-0.707	0.652
RWC at 60 DAP (%)	E ₁	0.027	0.217	3.298	-5.648	0.206	0.750	-0.038	-0.109	-0.060	0.324	0.401	0.321	-0.031
	E ₂	-1.154	0.336	1.544	-1.105	1.762	-2.201	0.402	1.930	1.322	-2.307	0.662	-1.119	0.072
RWC at 120 DAP (%)	E ₁	-0.018	-0.009	0.152	0.356	-0.001	-0.846	0.009	0.014	0.445	-0.007	0.122	-0.070	-0.147
	E ₂	-1.546	0.255	1.671	-1.173	1.126	-1.836	0.397	1.673	1.525	-2.054	1.105	-0.896	0.248
Total Chlorophyll(mg/l)	E ₁	0.020	0.030	0.997	-0.510	0.131	0.653	-0.024	0.036	0.003	-0.960	-0.183	0.096	0.290
	E ₂	-0.910	0.329	1.753	-1.947	1.657	-2.158	0.413	1.989	1.399	-2.239	1.347	-0.878	0.757
Stomatal frequency (no.)	E ₁	-0.077	-0.024	0.202	-0.098	-0.125	-1.317	0.006	-0.036	-0.125	0.144	1.217	0.053	-0.180
	E ₂	0.421	-0.049	0.213	0.614	-0.776	1.418	-0.191	0.584	-0.772	0.898	-2.184	0.380	-0.556
Specific leaf wt(g)	E ₁	0.118	0.060	1.451	-1.770	0.148	-0.005	-0.032	-0.140	-0.074	-0.219	0.154	0.423	0.115
	E ₂	-0.376	0.249	0.779	-0.974	1.021	-1.062	0.238	1.602	1.013	-1.458	0.615	-1.348	0.300

Unexplained variation at genotypic level under E₁ = - 0.16

Unexplained variation at genotypic level under E₂ =0.20

Table 4.13: Estimates of direct and indirect effects of different Quality traits of sugarcane genotypes on commercial cane sugar (CCS) (t/ha) at genotypic level under normal (E₁) and water stress (E₂) environments

Traits	Env.	Brix at 10 months (%)	Pol in juice at 10 months (%)	Extraction at 10 months (%)	Purity at 10 months (%)	CCS at 10 months (%)	Brix at 12 months (%)	Pol in juice at 12 months (%)	Extraction at 12 months (%)	Purity at 12 months (%)	CCS at 12 months (%)	Fibre content at harvest (%)	Pol in cane at harvest (%)	Correlation with CCS (t/ha)
Brix at 10 months (%)	E ₁	-8.123	-2.219	-0.097	0.166	10.183	-2.673	1.506	-0.019	-0.561	14.503	0.029	-12.503	0.192
	E ₂	2.938	1.202	0.057	0.113	-4.054	-1.643	2.290	0.219	-0.016	-0.763	-0.125	0.117	0.335
Pol in juice at 10 months (%)	E ₁	-7.896	-2.283	-0.069	-0.458	10.750	-3.529	2.225	-0.003	-1.442	22.266	0.019	-19.195	0.385
	E ₂	2.799	1.262	0.073	0.586	-4.463	-1.692	3.182	0.007	-0.116	-1.136	-0.134	0.164	0.532
Extraction at 10 months (%)	E ₁	2.055	0.412	0.383	-0.785	-1.560	1.648	-1.239	-0.039	1.271	-13.026	-0.879	12.024	0.265
	E ₂	0.829	0.450	0.204	0.507	-1.720	-0.359	0.700	0.032	-0.024	-0.254	-0.096	0.050	0.319
Purity at 10 months (%)	E ₁	0.514	-0.397	0.114	-2.635	2.997	-4.022	3.231	0.061	-3.721	34.539	-0.038	-29.767	0.876
	E ₂	0.210	0.467	0.065	1.584	-2.249	-1.170	3.415	-0.040	0.315	-1.842	-0.064	0.021	0.712
CCS at 10 months (%)	E ₁	-7.651	-2.270	-0.055	-0.730	10.811	-3.848	2.508	0.003	-1.811	25.353	0.014	-21.858	0.466
	E ₂	2.641	1.249	0.077	0.817	-4.509	-1.121	3.497	0.001	-0.160	-1.054	-1.035	0.205	0.608
Brix at 12 months (%)	E ₁	-3.010	-1.117	-0.087	-1.469	5.767	-7.215	3.538	0.026	-0.433	32.273	-0.053	-27.829	0.391
	E ₂	1.614	0.811	0.027	0.704	-3.001	-2.632	4.940	-0.014	-0.193	-1.764	-0.123	0.243	0.612
Pol in juice at 12 months (%)	E ₁	-3.034	-1.260	-0.118	-2.112	6.727	-6.333	4.030	0.015	-2.878	40.471	-0.051	-34.897	0.560
	E ₂	1.201	0.678	0.026	1.009	-2.989	-2.254	5.361	-0.036	-0.332	-2.018	-0.137	0.268	0.777
Extraction at 12 months (%)	E ₁	1.249	0.067	-0.118	-1.282	0.298	-2.302	0.484	0.126	0.473	3.334	-0.486	-1.645	0.198
	E ₂	0.659	0.100	-0.185	0.659	0.031	-0.489	1.973	-0.097	-0.585	-1.852	-0.047	0.078	0.245
Purity at 12 months (%)	E ₁	-0.872	-0.629	-0.093	-1.873	3.741	-0.597	2.358	-0.011	-5.235	27.925	-0.160	-24.064	0.491
	E ₂	0.111	0.332	0.011	1.129	-1.630	-1.151	4.030	-0.060	-0.442	-1.678	-0.109	0.210	0.753
CCS at 12 months (%)	E ₁	-2.870	-1.238	-0.121	-2.217	6.678	-5.673	3.971	0.010	-3.562	13.043	-0.047	-7.387	0.587
	E ₂	1.103	0.705	0.025	1.071	-2.829	-2.285	5.322	-0.041	-0.365	-2.033	-0.137	0.267	0.803
Fibre content at harvest (%)	E ₁	1.085	0.210	0.147	-0.438	-0.772	-1.685	0.895	0.026	-0.365	8.470	-0.229	-7.301	0.043
	E ₂	1.418	0.652	0.075	0.394	-2.329	-1.251	2.853	-0.589	-0.187	-1.075	0.259	0.195	0.415
Pol in cane at harvest (%)	E ₁	-2.870	-2.985	-0.121	-2.216	2.247	-5.674	1.989	0.010	-3.560	2.852	-0.474	11.389	0.587
	E ₂	1.327	0.804	0.041	1.132	-3.174	-2.467	5.526	-0.029	-0.358	-2.087	-0.157	0.259	0.817

Unexplained variation at genotypic level under E₁ = 0.18

Unexplained variation at genotypic level under E₂ = 0.19

different genotypes in study ranged from 0.50 to 1.41 with prevailed drought intensity ($D = 0.35$). Seven genotypes namely ISH135, ISH148, KV2012-2, ISH07, ISH159, KV2012-5, KV2012-4 were found drought tolerant ($S < 0.75$), whereas 8 genotypes KV2012-1, KV2012-3, CoJ64, CoPb93, CoPb12181, CoPb12182, CoPb14212 and CoPb14211 were intermediate ($S = 0.75-1.00$). The remaining genotypes were found to be drought susceptible ($S > 1.00$) (Table 4.14).

Number of shoots at 120 days in the present study had a mean value of 127.00 (000/ha) under normal (E_1) environment and 84.00 (000/ha) under water stress (E_2) environment. The reduction percentage under E_2 was 33.79 % for this trait. Highest DSI for it was recorded for the genotypes CoPb12212 and L818/07 (1.43) and lowest for ISH135 (0.54). About 3 genotypes were found least affected, 12 intermediate and remaining 15 were most affected by drought for this trait.

Sugarcane clones/varieties under study exhibited mean percentage decrease of 33.86% under water stress (E_2) environment for number of tillers at 240 days. DSI values were ranged from 0.59 to 1.41 with the prevailed drought intensity of 0.34. The genotype ISH148 and ISH07 (0.59) had minimum DSI value followed by ISH135 (0.60), ISH159 (0.65), KV2012-2 (0.70) and KV2012-5 (0.74). The genotypes KV2012-1, KV2012-3, KV2012-4, Co238 and CoPb14211 were intermediate in their reaction to water stress (Table 4.14). These results were similar as reported by Wagih *et al* (2001), who reported significant reduction in the number of tillers under water stress conditions among sugarcane clones.

In case of number of millable canes clone ISH148 (0.50) exhibited minimum DSI value followed by ISH159 (0.54), ISH135 (0.57), ISH07 (0.62), KV2012-2 (0.62), KV2012-5 (0.69) and KV2012-4 (0.70). The percent reduction under E_2 for this trait ranged from 17.54 to 50.00 with mean value of 34.79 %. The maximum percent reduction under E_2 was recorded for the clone L818/07 (50.00 %) followed by CoPb13182 (49.22 %), CoPb12212 (48.85 %) and CoJ88 (48.62) and minimum for the ISH148 (17.54 %) followed by ISH159 (18.75 %), ISH135 (19.83 %) and KV2012-2 (21.59 %). On the basis of DSI values and percent reduction in mean under E_2 clones ISH148, ISH135, ISH159, ISH07, KV2012-2 and KV2012-5 were categorized as drought tolerant for this trait. Pawar *et al* (2011) found high number of millable canes under moisture stress conditions and proved these genotypes to withstand moisture stress.

Stalk length is a very important trait that directly effects cane yield. Under normal (E_1) environment, this trait ranged from 192.50 to 308.33 cm and from 120 .00 to 240.00 cm under water stress (E_2) environment. Percent reduction under E_2 for this trait was ranged from 17.72 to 47.06 with, maximum value exhibited by clone CoPb10181 (47.06 %) and minimum value was recorded for the clone ISH148 (17.72 %). DSI values were ranged from 0.53 to

1.42 for this trait. Maximum DSI value was exhibited by the clone CoPb10181 (1.42) followed by clone L818/07 (1.36), CoJ88 (1.26) and CoPb13182 (1.26) while the minimum DSI values were recorded for the clone ISH148 (0.53) followed by ISH07 (0.59), KV2012-4 (0.62) and KV2012-5 (0.67). Based on minimum DSI values and minimum percent reduction under E_2 , seven clones were categorized as drought tolerant, seven clones were intermediate and rest were sensitive to drought reaction for stalk length. Higher reduction in drought in relation to the normal condition was observed for internode length and cane length by Hemaprabha *et al* (2013).

Stalk diameter under normal (E_1) environment ranged from 1.83 to 3.10 cm with a mean value of 2.41 and from 1.02 to 1.96 cm with a mean value of 1.61 under water stress (E_2) environment. The percent reduction under E_2 for this trait varied from 18.62 to 49.00 with maximum reduction exhibited by the clone L818/07 (49.00 %) followed by variety CoPb91 (44.52 %) and CoPb11214 (44.24 %). Minimum percent reduction under E_2 was recorded for the clone ISH148 (18.62 %) followed by ISH135 (19.13 %) and ISH159 (20.41 %). DSI for stalk diameter ranged from 0.56 to 1.48 with a mean value of 0.99. The highest DSI recorded for the clone L818/07 (1.48) followed by CoPb91 (1.35), CoPb11214 (1.34) and CoPb10181 (1.31) while lowest DSI exhibited by the clone ISH148 (0.56) followed by ISH135 (0.58) and ISH159 (0.62). Based on DSI clones namely ISH148, ISH07, ISH135, ISH159, KV2012-3 and KV2012-4 were categorized as drought tolerant for this trait ($S < 0.75$). These results are in accordance Singh and Reddy (1980) who revealed that thin stalked varieties with more number of millable canes in general appeared to more drought tolerant.

Single cane weight recorded percent reduction in mean under E_2 with a range of 18.44 to 47.83 % with a mean reduction of 32.64 (%). Maximum percent reduction under E_2 was exhibited by clone L818/07 (47.83%) while minimum value was recorded for the clone ISH135 (18.44%). DSI for this trait varied from 0.58 to 1.50 with highest value exhibited by clone L818/07 (1.50) and lowest by clone ISH135 (0.58). Based on DSI values, six clones were categorized as drought tolerant ($S < 0.75$), six clones were intermediate ($S = 0.75 - 1.00$) and rest were categorized as drought susceptible ($S > 1.00$) for this trait. Similar findings were reported by Pawar *et al* (2011), who also found high single cane weight among sugarcane clones under moisture stress conditions.

Sugarcane cane yield is the end product for which all selections and improvements are made. Genotypes in the present study exhibited a range of 48.78 to 110.00 (t/ha) with a mean value of 76.40 (t/ha) for cane yield under normal (E_1) environment and from 25.42 to 76.39 t/ha with a mean value of 51.40 t/ha under water stress (E_2) environment. Cane yield percent reduction under E_2 ranged from 16.66 to 47.89% with a maximum reduction percent

for the genotype CoPb11211 (47.89 %) followed by CoPb11214 (46.97), CoPb13183 (42.17) and L818/07 (45.85) and minimum for the genotype ISH148 (16.66) followed by ISH07 (18.30), ISH135 (21.22), KV2012-4 (21.53) and KV2012-2 (22.73). DSI for cane yield (t/ha) was ranged from 0.51 to 1.47 showing a differential behaviour of clones/varieties to water stress. Of the clones/varieties tested minimum DSI value was exhibited by the clone ISH148 (0.51) followed by ISH07 (0.56), ISH135 (0.35), KV2012-4 (0.66), ISH159 (0.69), KV2012-2 (0.70) and KV2012-3 (0.74) and all these clones/varieties were categorized as drought tolerant with the prevailed drought intensity ($D=0.35$). The genotypes/clones KV2012-5, CoPb93, Co238, KV2012-2, CoPb12181 and CoPb94 had DSI (0.75 -1.00) were categorized as intermediate and rest were drought susceptible in terms of cane yield (Table 4.14). Variable extent of cane yield reduction in sugarcane genotypes had been reported by earlier workers Venkataramana *et al*, 1986 (70-80%) and Pawar *et al*, 2011 (16.00%). Basnayake *et al* (2012) reported cane yield reduction (17.52%) under water stressed conditions and concluded that the genotypes with minimum cane yield reduction under water stress conditions can be considered drought tolerant.

4.6.2 DSI for different physiological traits

Physiological traits are very important under stress conditions as they impart tolerance against many biotic as well as abiotic stresses.

In present study, data on 4 physiological parameters viz. Relative water content (%) at 60 and 120 days (RWC), chlorophyll content (Chl a, Chl b and total chlorophyll) (mg/l), stomatal frequency (no.) and specific leaf weight (g) were recorded for 30 clones/varieties of sugarcane. Relative water content (RWC) at 60 and 120 days after planting ranged from 62.90 to 80.25 (%) and 47.35 to 77.30 %, respectively under normal (E_1) environment. This value varied from 34.00 to 65.00 (%) and 29.00 to 58.00 %, respectively under water stress (E_2) environment (Table 4.15). The mean percent decrease in RWC at 60 and 120 days after planting under E_2 was 32.39 and 34.58, respectively. The clones ISH148, ISH07, ISH135, ISH 159, KV2012-1 and KV2012-2 showed less decrease in this trait under E_2 environment. Mean DSI value for RWC at 60 and 120 days after planting was 1.00 with drought intensity (D) of 0.33. The genotypes ISH148, ISH07, ISH135, ISH 159, KV2012-1 and KV2012-2 were found drought tolerant ($S < 0.75$) in terms of this trait. These results are in agreement with the earlier findings of Gill and Singh (1959) who also concluded that the genotypes that maintain higher leaf sheath moisture in their leaves appeared to be more drought tolerant. Similarly, Venkataramana *et al* (1986) also documented that varieties Co 312, Co 1148 and Co 6806 maintained relatively higher leaf water potential possessed some drought tolerance. Silva *et al* (2007) also reported that the tolerant group of genotypes had relatively high RWC values compared to those in the susceptible group thus confirming their empirical

classification as drought tolerant. Maintenance of relatively high RWC during mild drought is indicative of drought tolerance (Jamaux *et al* 1997, Altinkut *et al* 2001 and Colom and Vazzana, 2003).

Chlorophyll content i.e. chlorophyll a, chlorophyll b and total chlorophyll recorded mean values of 3.31, 3.87 and 7.23 (mg/l), respectively under E₁ environment and 2.25, 2.66 and 4.81, respectively under E₂ environment. The mean percentage reduction of chlorophyll a, chlorophyll b, and total chlorophyll content under water stress (E₂) environment was 31.88, 31.22 and 31.50, respectively (Table 4.15). The clone ISH135 showed minimum percentage reduction (17.08 %) in total chlorophyll content under water stress (E₂) environment. About 7 clones/varieties in terms of chlorophyll a, 4 for chlorophyll b and 5 in terms of total chlorophyll content had a DSI value of < 0.75 that indicates all these clones/varieties have same degree of drought tolerance in terms of chlorophyll content. The above results are in accordance with Silva *et al* (2007) who reported that Chlorophyll content declined progressively with exposure to drought but the decline was more severe in genotypes from the susceptible group. Zhao *et al* (2010) concluded that the measurement physiological traits viz. stomatal conductance, photochemical efficiency and leaf photosynthesis rate during the formative stage may be useful for early detection of water stress in sugarcane.

DSI for stomatal frequency ranged from 0.70 to 1.34 that shows variation in expression of clones/varieties to water stress. Among the tested genotypes, CoPb12182 (0.70) showed minimum value of DSI followed by the genotype CoPb14211 (0.71) and CoPb11211 (0.74). These genotypes had minimum decrease percentage under E₂ environment. The clones KV2012-4 (48.89), ISH159 (46.34), ISH07 (42.86), KV2012-1 (42.86), ISH148 (41.18), KV2012-5 (39.02), KV2012-3 (36.84) and KV2012-2 (34.88) had maximum reduction percentage in terms of stomatal frequency under water stress (E₂) environment which means these genotypes had minimum number of stomata in their leaves that reduces transpiration rate from the leaves of these genotypes under water scarcity so, these genotypes performed better under water stress conditions. Graca *et al* (2010) showed the photosynthetic rate and stomatal conductance decreased significantly in all cultivars exposed to water deficit. As a whole, the tolerant cultivars exhibited a better photosynthetic performance lesser transpiration losses than the sensitive cultivar. Silva *et al* (2013) considered TCP02-4587 as a drought tolerant cultivar of sugarcane because of its high capacity to economize water in its leaves, higher leaf water potential, a higher efficiency of stomatal control and a higher photosynthetic capacity.

In case of specific leaf weight the percent reduction under water stress (E₂) varied from 20.08 to 44.88 (%) with the mean value of 32.45 (%). Maximum percent reduction under E₂ was exhibited by clone CoJ88 (44.88) while minimum was recorded for the clone ISH135

(20.08). Among the clones/varieties tested the lowest DSI was exhibited by the clones ISH07 and ISH135 (0.63) closely followed by ISH159 (0.64), KV2012-5 (0.64) and ISH148 (0.67). These clones/varieties were categorized as drought tolerant ($S < 0.75$). The clones/varieties that exhibited medium DSI values i.e. Co238, KV2012-1, KV2012-2, KV2012-3, KV2012-4, CoPb11214 and CoPb93 and these were categorized as intermediate ($S = 0.75-1.00$). Remaining all were drought susceptible ($S > 1.00$). Munamava and Riddoch (2001) reported that specific leaf weight (SLW) and specific leaf area (SLA) decreased with stress, especially when water stress was applied at booting stage in wheat. Aggarwal and Sinha (1984) and Misra (1995) revealed that specific leaf weight had been widely used as selection parameter contributing towards drought tolerance for various crop plants in addition to economic yield.

4.6.3 DSI for quality traits at 10 months

Data on quality traits viz. Brix, pol, juice extraction, purity and CCS (%) at 10 months after planting were recorded under both E_1 and E_2 environments. Reduction in brix percent at 10 months ranged from 3.43 to 23.76 (%) with a mean value of 12.27 (%) under normal (E_2) environment. The percent decrease in mean under E_2 was highest for the clone/variety L818/07 (23.76 %) followed by CoPb14212 (19.47) and CoPb12181 (18.16) and lowest for the genotype KV2012-4 (3.43). DSI for this trait ranged from 0.29 to 1.98 with a mean value of 1.02. It was lowest for the genotype KV2012-4 (0.29) followed by ISH135 (0.35), Co238 (0.35) CoPb12182 (0.43), CoPb13182 (0.45) and ISH07 (0.55) (Table 4.16). So, based on DSI these clones are categorized as drought tolerant ($S < 0.75$).

Percent reduction in mean under E_2 for pol percent in juice varied from 4.72 to 30.43 (%) with a mean value of 17.98 (%). Maximum percent reduction was recorded for the clone L818/07 (30.43 %) followed by CoPb91 (26.51), CoPb14212 (24.70) and CoPb12181 (23.33) while the minimum reduction was exhibited by the variety Co238 (4.72) followed by CoPb12182 (6.78) and CoPb13182 (7.19). DSI for this trait ranged from 0.28 to 1.79. Highest DSI was exhibited by the clone L818/07 (1.79) followed by CoPb91 (1.52) and CoPb14212 (1.45). Genotype Co238 had lowest value (0.28) of DSI followed by CoPb12182 (0.40) and CoPb13182 (0.42) so, categorized as drought tolerant. For this trait genotypes like ISH07, KV2012-1, KV2012-2, KV2012-3, KV2012-4, CoPb14211 and CoJ85 had DSI value from 0.75 to 1.00, so these genotypes were categorized as intermediate to withstand water stress. Misra *et al* (2016) recorded a decline in sucrose % in juice and purity % by 0.58 units and 34.68 units, respectively, in month of November, in canes grown under drought conditions. Hemaprabha *et al* (2013) also recorded a reduction in sucrose content (18.73 %) under water stress conditions.

For extraction percentage at 10 months the DSI ranged from 0.29 to 1.91 and percentage decrease in mean under E_2 varied from 3.78 to 24.88. Maximum percent decrease

for this trait under E_2 was recorded in clone/variety CoPb14211 (24.88 %) followed by genotype CoPb14212 (23.76) and CoPb11211 (22.22) and this value was lowest for the clone/variety KV2012-2 (3.78) followed by KV2012-5 (6.78) and KV2012-3 (7.57). Highest DSI was exhibited by the clone CoPb14211 (1.91) while lowest value of DSI was recorded for KV2012-2 (0.29) (Table 4.16).

Percent reduction in E_2 for purity (%) at 10 months ranged from 0.49 to 13.39 (%) with a mean value of 6.59 (%). Highest percent reduction in E_2 was exhibited by CoPb91 (13.39) while lowest value was recorded for the clone Co238 (0.49). DSI for this trait ranged from 0.08 to 2.23 with a mean value of 1.09. DSI for purity percent at 10 months were highest for the genotype CoPb91 (2.23) and lowest for the genotype Co238 (0.08). Of the clones/varieties tested 7 genotypes were drought tolerant, 4 were intermediate and 19 were drought susceptible for purity percent at 10 months.

In case of CCS percentage at 10 months the percent decrease under E_2 varied from 4.97 to 33.82 (%) with a mean value of 20.76 (%). DSI for this trait ranged from 0.25 to 1.69 with a mean value of 1.09. Highest percent decrease under E_2 and high DSI value were exhibited by the clone L818/07 (33.82 and 1.69, respectively) and lowest values were exhibited by the variety Co238 (4.97 and 0.25, respectively). The percentage decrease in mean under E_2 and DSI for this trait was lowest for the genotype Co238 followed by ISH159, CoPb12182, CoPb13182 and ISH135 ($S < 0.75$). Among other tested clones/varieties KV2012-1, KV2012-3, ISH148, ISH07, CoPb14211, CoJ85 and CoPb13181 were intermediate to water stress ($S = 0.75 - 1.00$). Clones/varieties like CoPb10181, CoPb13183, CoJ88, CoS8436, CoPb91 and CoJ64 were drought susceptible ($S > 1.00$).

4.6.4 DSI for quality trait at harvest

For brix (%) at 12 months, the percentage reduction under E_2 ranged from 3.82 to 18.80 with a value of 8.53. The genotype CoJ64 had minimum percentage decrease in mean under E_2 for this trait followed by CoS8436, CoPb13181 and ISH148. DSI for this trait ranged from 0.40 to 2.35 with a mean value of 1.06. It was highest for the clone/variety CoPb13182 (2.35) followed by CoPb92 (2.31) and CoPb14211 (1.77). These clones/varieties were highly drought sensitive for this trait. The drought tolerant clones/varieties based on DSI values were ISH07, ISH148, CoJ64, CoS8436, CoPb13181 and KV2012-3 which have corresponding value of 0.40, 0.50, 0.48, 0.49, 0.49 and 0.63, respectively.

Pol in juice at 12 months varied from 14.53 to 18.84 (%) under normal (E_1) and from 12.59 to 17.38 under water stress (E_2) environment. Percent decrease for this trait ranged from 6.38 to 23.74 (%) with a mean value of 12.60 (%) under E_2 environment. It was recorded maximum for the clone CoPb11214 (23.74%) followed by CoPb11211 (22.26) and CoPb92 (21.88), while minimum value was exhibited by variety Co238 (6.38) followed by ISH07

(6.62) and CoJ85 (6.72). DSI for this trait ranged from 0.53 to 1.98 with a mean value of 1.05 and a drought intensity of 0.12 (%). Clone CoPb11214 (1.98) followed by CoPb11211 (1.86) and CoPb92 (1.82) exhibited highest DSI values for this trait among different tested genotypes and categorized as drought susceptible. Similarly, clones/varieties like Co238 (0.53), ISH07 (0.55), KV2012-2 (0.65) and KV2012-5 (0.67) based on values of low values of DSI were categorized as drought tolerant in terms of pol percent at 12 months.

Juice extraction percent at 12 months exhibited percent reduction under E_2 under a range of 4.92 to 23.01 (%) with a mean value of 13.77 (%). Maximum reduction percent was recorded for the CoPb12182 (23.01) and minimum for Co238 (4.92) under E_2 environment. The DSI for this trait ranged from 0.38 to 1.77 with a mean value of 1.05 (%). Highest DSI value was exhibited by clone CoPb12182 (1.77) and lowest by variety Co238 (0.38). Among the tested varieties/clones, seven were categorized as drought tolerant ($S < 0.75$), 8 were intermediate ($s = 0.75 - 1.00$) and rest were drought sensitive ($s > 1.00$) in terms of this trait.

For purity percent at 12 months the percent reduction under E_2 ranged from 0.27 to 12.13 (%) with a mean of 4.70 (%). Maximum percent reduction was exhibited by the clone CoPb11211 (12.13) closely followed by CoPb11214 (12.02) and CoJ64 (9.18) and minimum by clone CoPb14212 (0.27) followed by KV2012-5 (0.91) and CoPb13182 (1.03) under E_2 environment. DSI for this trait varied from 0.07 to 3.03 with a mean value of 1.17. It was lowest for the genotype CoPb14212 (0.07) followed by KV2012-5 (0.23) and CoPb13182 (0.26). Of the clones/varieties tested 8 were categorized as drought tolerant and 3 were intermediate to drought reaction in terms of this trait.

For CCS (%) at 12 months, the percentage decrease under E_2 was maximum for the genotype CoPb11214 (28.45%) followed by CoPb11211 (27.16) and CoPb14211 (23.60) and the DSI values of these clones were also high ($s > 1.00$) which indicates that these clones/varieties are drought susceptible. The DSI of clones/varieties like KV2012-2, Co238, CoJ85 and KV2012-4 was low ($s < 0.75$) which means these clones/varieties were drought tolerant for this trait under prevailing drought intensity of 0.14. Out of the 30 clones/varieties tested, 7 were categorized as drought tolerant and 11 were intermediate based on DSI values. Reduction in CCS (%) in canes grown under drought condition was also reported by Misra *et al* 2016.

Fibre percent at harvest under normal (E_1) environment ranged from 11.36 to 14.97 % with overall mean value of 13.12 % and was varied from 8.50 to 12.24 % with population mean value of 10.60 % under water stress (E_2) environment. The DSI value for fibre percent ranged from 0.61 to 1.70. Minimum DSI was recorded for the genotype KV2012-3 (0.61) followed by ISH148 (0.63) and KV2012-5 (0.65). These clones/varieties were considered drought tolerant in terms of fibre percent at harvest under drought intensity

of 0.19. The percentage decrease in mean under E_2 was lowest for the genotype KV2012-3 (11.53). So, the genotypes viz. KV2012-3, ISH148, KV2012-4 and KV20112-5 with low DSI and percent decrease under E_2 for fibre percentage at harvest were categorized as drought tolerant.

DSI value for pol (%) cane percentage at harvest ranged from 0.50 to 1.88. Among tested clones/varieties, clone Co238 (0.50) exhibited lowest DSI followed by ISH07, CoJ85, CoS8436, KV2012-2, KV2012-5 and ISH148 ($S < 0.75$) showed that these were behaved as drought tolerant for pol cane (%) at harvest (Table 4.16). About 8 clones were intermediate and 10 clones were drought susceptible to water stress in terms of this trait.

Commercial cane sugar (CCS) (t/ha) at harvest is a very important industrial quality trait because it is a function of both CCS percent and cane yield. The percent decrease in E_2 for CCS (t/ha) at harvest varied from 25.54 to 62.54 with a mean value of 42.11. Genotype with maximum percent decrease in mean under E_2 environment was CoPb11211 (62.54) with a highest DSI value of 1.49 which means this genotype was most drought susceptible among the 30 tested genotypes. Similarly the genotype ISH148 (25.54) had minimum percentage decrease in mean under E_2 environment and lowest DSI (0.61) value which indicates this genotype was considered as drought tolerant. Other genotypes like ISH07, KV2012-4 and KV2012-2 had low DSI values ($S < 0.75$) so these genotypes were categorized as drought tolerant clones/varieties for commercial cane sugar (t/ha) at harvest. The genotypes like ISH135, ISH159, Co238, KV2012-5, KV2012-3, KV2012-1, CoPb14212 and CoPb13181 and CoJ85 exhibited DSI values from 0.75 to 1.00 and were categorized as intermediate to water stress. The clones/varieties like CoJ88, CoS8436, CoPb91, CoPb10181, CoPb13182 had high DSI value so these genotypes were categorized as drought susceptible ($S > 1.00$). The drought intensity for CCS tons per hectare was high ($D = 0.42$). In this study, it was conferred that cane yield and component traits were more sensitive to water stress than quality traits. These results are in supporting to earlier findings of Hemaprabha *et al* (2004) who reported that reduction in yield parameters was relatively more than quality traits showing that quality traits are less sensitive to drought planted canes.

Based on the DSI values and percent reduction in mean under E_2 environment for cane yield and component traits, physiological and quality traits it was concluded that varieties/clones, that exhibited low DSI values and low percent reduction in mean under E_2 environment for all the traits has more ability to withstand water stress than others. Based on present study it was concluded that clones namely KV2012-2, KV2012-3, KV2012-4, ISH148, ISH07 and ISH135 have ability to withstand water stress conditions and considered as drought tolerant so, these clones can be used in future evaluation against limited water conditions over locations.

Table 4.14: Drought Susceptibility index (DSI), mean and percent decrease in mean under E₂ of sugarcane genotypes for cane and component traits under normal (E₁) and water stress (E₂) environments

Sr. No.	Genotype	Germination (%)				No. of shoots at 120 days (000/ha)				No. of tillers at 240 days (000/ha)				NMC (000/ha)			
		Mean E ₁	Mean E ₂	% ↓ in mean under E ₂	DSI	Mean E ₁	Mean E ₂	% ↓ in mean under E ₂	DSI	Mean E ₁	Mean E ₂	% ↓ in mean under E ₂	DSI	Mean E ₁	Mean E ₂	% ↓ in mean under E ₂	DSI
1	CoPb10181	58.00	30.00	48.28	1.39	135.00	93.00	31.11	0.92	132.00	91.00	31.06	0.90	119.00	69.00	42.02	1.21
2	CoPb13181	55.00	33.74	38.65	1.12	131.00	87.00	33.59	0.99	120.00	81.00	32.50	0.94	111.00	69.00	37.84	1.09
3	CoPb13182	27.36	17.62	35.60	1.03	137.00	77.00	43.80	1.29	134.00	74.00	44.78	1.30	128.00	65.00	49.22	1.41
4	CoPb13183	65.00	40.50	37.69	1.09	143.00	102.00	28.67	0.85	141.00	94.00	33.33	0.97	122.00	73.00	40.16	1.15
5	CoPb11214	54.67	32.00	41.47	1.20	142.00	85.00	40.14	1.19	139.00	80.00	42.45	1.23	116.00	65.00	43.97	1.26
6	CoPb11211	38.25	21.00	45.10	1.30	91.00	53.00	41.76	1.23	83.00	51.00	38.55	1.12	77.00	47.00	38.96	1.12
7	CoPb12181	32.22	22.32	30.73	0.89	119.00	78.00	34.45	1.02	113.00	72.00	36.28	1.05	100.00	68.00	32.00	0.92
8	CoPb12182	29.03	19.97	31.21	0.90	125.00	86.00	31.20	0.92	120.00	79.00	34.17	0.99	104.00	69.00	33.65	0.97
9	CoPb14212	33.00	23.00	30.30	0.87	117.00	76.00	35.04	1.03	111.00	72.00	35.14	1.02	107.00	69.00	35.51	1.02
10	CoPb14211	40.55	27.80	31.44	0.91	122.00	85.00	30.33	0.90	116.00	85.00	26.72	0.78	114.00	75.00	34.21	0.98
11	CoPb12212	38.06	22.19	41.70	1.20	157.00	81.00	48.41	1.43	150.00	80.00	46.67	1.36	131.00	67.00	48.85	1.40
12	L 818/07	51.80	26.43	48.98	1.41	153.00	79.00	48.37	1.43	148.00	76.00	48.65	1.41	144.00	72.00	50.00	1.44
13	KV2012- 1	28.33	21.00	25.87	0.75	109.00	76.00	30.28	0.89	107.00	74.00	30.84	0.90	97.00	69.00	28.87	0.83
14	KV2012- 2	36.39	28.00	23.06	0.67	102.00	76.00	25.49	0.75	95.00	72.00	24.21	0.70	88.00	69.00	21.59	0.62
15	KV2012- 3	39.44	29.00	26.47	0.76	134.00	96.00	28.36	0.84	131.00	94.00	28.24	0.82	127.00	93.00	26.77	0.77
16	KV2012-4	37.64	28.00	25.61	0.74	100.00	72.00	28.00	0.83	92.00	65.00	29.35	0.85	86.00	65.00	24.42	0.70
17	KV2012- 5	52.08	39.00	25.12	0.72	136.00	101.00	25.74	0.76	129.00	96.00	25.58	0.74	120.00	91.00	24.17	0.69

Sr. No.	Genotype	Germination (%)				No. of shoots at 120 days (000/ha)				No. of tillers at 240 days (000/ha)				NMC (000/ha)			
		Mean E ₁	Mean E ₂	% ↓ in mean under E ₂	DSI	Mean E ₁	Mean E ₂	% ↓ in mean under E ₂	DSI	Mean E ₁	Mean E ₂	% ↓ in mean under E ₂	DSI	Mean E ₁	Mean E ₂	% ↓ in mean under E ₂	DSI
18	ISH 148	41.00	33.00	19.51	0.56	154.00	118.00	23.38	0.69	124.00	99.00	20.16	0.59	114.00	94.00	17.54	0.50
19	ISH 07	43.91	34.00	22.57	0.65	121.00	90.00	25.62	0.76	108.00	86.00	20.37	0.59	106.00	83.00	21.70	0.62
20	ISH 135	46.97	38.00	19.10	0.55	125.00	102.00	18.40	0.54	121.00	96.00	20.66	0.60	116.00	93.00	19.83	0.57
21	ISH 159	45.14	35.00	22.46	0.65	123.00	96.00	21.95	0.65	120.00	93.00	22.50	0.65	112.00	91.00	18.75	0.54
22	Co 238	42.78	31.00	27.54	0.79	132.00	95.00	28.03	0.83	129.00	92.00	28.68	0.83	125.00	88.00	29.60	0.85
23	CoJ88	32.64	17.50	46.38	1.34	111.00	61.00	45.05	1.33	110.00	58.00	47.27	1.37	109.00	56.00	48.62	1.40
24	CoS8436	47.02	28.00	40.45	1.17	124.00	67.00	45.97	1.36	118.00	65.00	44.92	1.30	108.00	63.00	41.67	1.20
25	CoPb91	39.53	21.00	46.88	1.35	100.00	65.00	35.00	1.03	99.00	62.00	37.37	1.09	81.00	48.00	40.74	1.17
26	Co 118	50.97	28.00	45.07	1.30	123.00	71.00	42.28	1.25	121.00	69.00	42.98	1.25	120.00	67.00	44.17	1.27
27	CoJ85	32.78	19.36	40.94	1.18	112.00	72.00	35.71	1.05	106.00	70.00	33.96	0.99	94.00	58.00	38.30	1.10
28	CoJ64	67.91	45.00	33.74	0.97	163.00	106.00	34.97	1.03	161.00	104.00	35.40	1.12	146.00	94.00	35.62	1.02
29	CoPb92	51.80	28.60	44.79	1.29	155.00	97.00	37.42	1.11	152.00	94.00	38.16	1.11	146.00	89.00	39.04	1.12
30	CoPb93	46.86	33.28	28.98	0.84	111.00	72.00	35.14	1.04	106.00	69.00	34.91	1.01	100.00	67.00	33.00	0.95
	GM	43.53	28.44	34.19	0.98	127.00	84.00	33.79	0.99	122.00	80.00	33.86	0.98	112.13	72.88	34.79	0.99
	Range	27.36-67.91	17.50-45.00	19.10-48.98	0.50-1.41	91.00-163.00	53.00-118.00	18.40-48.41	0.54-1.43	83.00-161.00	51.00-104.00	20.16-48.65	0.59-1.41	77.00-146.00	47.00-94.00	17.54-50.00	0.50-1.44
	CD (0.05%)	13.75	8.50			27.32	14.02			29.37	16.89			26.36	21.15		

Table 4.14: contd.

Sr. No.	Genotype	Stalk length (cm)				Stalk diameter (cm)				Single cane weight (kg)				Cane yield (t/ha)			
		Mean E ₁	Mean E ₂	% ↓ in mean under E ₂	DSI	Mean E ₁	Mean E ₂	% ↓ in mean under E ₂	DSI	Mean E ₁	Mean E ₂	% ↓ in mean under E ₂	DSI	Mean E ₁	Mean E ₂	% ↓ in mean under E ₂	DSI
1	CoPb10181	283.33	150.00	47.06	1.42	2.90	1.64	43.45	1.31	2.02	1.23	39.11	1.22	110.00	64.31	41.54	1.27
2	CoPb13181	296.67	193.17	34.89	1.05	2.43	1.64	32.51	0.98	1.71	1.12	34.50	1.08	83.33	57.10	31.48	0.97
3	CoPb13182	303.33	176.20	41.91	1.26	2.50	1.60	36.00	1.09	1.52	0.98	35.53	1.11	79.69	51.39	35.51	1.09
4	CoPb13183	283.33	173.59	38.73	1.17	2.33	1.61	30.90	0.93	1.26	0.80	36.51	1.14	72.05	41.67	42.17	1.29
5	CoPb11214	246.67	140.00	43.24	1.30	2.17	1.21	44.24	1.34	0.99	0.52	47.47	1.48	68.75	36.46	46.97	1.44
6	CoPb11211	263.33	156.00	40.76	1.23	2.63	1.59	39.54	1.20	1.57	0.89	43.31	1.35	48.78	25.42	47.89	1.47
7	CoPb12181	259.17	174.90	32.52	0.98	2.25	1.57	30.22	0.91	1.07	0.67	37.38	1.17	54.51	38.19	29.94	0.92
8	CoPb12182	277.50	180.12	35.09	1.06	2.38	1.66	30.25	0.92	1.24	0.92	25.81	0.81	65.97	43.40	34.21	1.05
9	CoPb14212	240.83	176.20	26.84	0.81	2.08	1.50	27.88	0.84	0.75	0.51	32.00	1.00	57.12	38.19	33.14	1.02
10	CoPb14211	263.33	189.26	28.13	0.85	2.17	1.39	35.94	1.09	0.91	0.60	34.07	1.07	63.72	41.88	34.27	1.05
11	CoPb12212	292.50	180.12	38.42	1.16	2.52	1.54	38.89	1.18	1.54	1.01	34.42	1.08	82.64	53.84	34.85	1.07
12	L 818/07	255.50	140.00	45.21	1.36	2.00	1.02	49.00	1.48	0.92	0.48	47.83	1.50	96.18	52.08	45.85	1.41
13	KV2012- 1	296.83	220.00	25.88	0.78	2.67	1.93	27.72	0.84	1.84	1.40	23.91	0.75	91.49	65.97	27.89	0.86
14	KV2012- 2	278.33	210.00	24.55	0.74	2.75	1.96	28.73	0.87	1.74	1.35	22.41	0.70	76.39	59.03	22.73	0.70
15	KV2012- 3	253.50	190.00	25.05	0.75	2.43	1.85	23.87	0.72	1.99	1.52	23.62	0.74	100.69	76.39	24.13	0.74
16	KV2012-4	266.67	212.00	20.50	0.62	2.58	1.96	24.03	0.73	1.55	1.16	25.16	0.79	77.43	60.76	21.53	0.66
17	KV2012- 5	308.33	240.00	22.16	0.67	2.53	1.89	25.30	0.77	1.65	1.25	24.24	0.76	86.63	64.24	25.85	0.79
18	ISH 148	237.00	195.00	17.72	0.53	1.88	1.53	18.62	0.56	1.68	1.36	19.05	0.60	58.33	48.61	16.66	0.51

Sr. No.	Genotype	Stalk length (cm)				Stalk diameter (cm)				Single cane weight (kg)				Cane yield (t/ha)			
		Mean E ₁	Mean E ₂	% ↓ in mean under E ₂	DSI	Mean E ₁	Mean E ₂	% ↓ in mean under E ₂	DSI	Mean E ₁	Mean E ₂	% ↓ in mean under E ₂	DSI	Mean E ₁	Mean E ₂	% ↓ in mean under E ₂	DSI
19	ISH 07	269.17	216.00	19.75	0.59	2.23	1.72	22.87	0.69	1.78	1.42	20.22	0.63	61.63	50.35	18.30	0.56
20	ISH 135	251.67	195.00	22.52	0.68	1.83	1.48	19.13	0.58	1.79	1.46	18.44	0.58	63.02	49.65	21.22	0.65
21	ISH 159	242.50	185.00	23.71	0.71	2.45	1.95	20.41	0.62	1.64	1.32	19.51	0.61	61.28	47.57	22.37	0.69
22	Co 238	283.33	193.17	31.82	0.96	2.53	1.82	28.06	0.85	1.71	1.25	26.90	0.84	85.29	61.58	27.80	0.85
23	CoJ88	206.67	120.00	41.94	1.26	2.43	1.40	42.39	1.28	1.02	0.59	42.16	1.32	81.21	51.26	36.88	1.13
24	CoS8436	192.50	126.00	34.55	1.04	2.63	1.58	39.92	1.21	0.96	0.54	43.75	1.37	72.69	46.52	36.00	1.10
25	CoPb91	290.00	160.00	44.83	1.35	3.10	1.72	44.52	1.35	2.24	1.31	41.52	1.30	97.43	59.00	39.44	1.21
26	Co 118	271.67	168.37	38.02	1.14	2.67	1.56	41.57	1.26	1.63	0.98	39.88	1.25	77.00	48.61	36.87	1.13
27	CoJ85	282.50	170.00	39.82	1.20	2.82	1.77	37.23	1.13	1.76	1.15	34.66	1.08	73.82	48.00	34.98	1.07
28	CoJ64	260.83	165.00	36.74	1.11	2.25	1.57	30.22	0.91	1.03	0.68	33.98	1.06	72.65	42.00	42.19	1.29
29	CoPb92	293.33	180.00	38.64	1.16	2.17	1.32	39.17	1.18	1.25	0.72	42.40	1.33	80.56	55.00	31.73	0.97
30	CoPb93	278.33	185.00	33.53	1.01	2.22	1.50	32.43	0.98	1.36	0.96	29.41	0.92	94.33	68.25	27.65	0.85
	GM	267.48	178.65	33.15	0.99	2.41	1.61	32.83	0.99	1.47	1.00	32.64	1.02	76.40	51.40	32.40	0.99
	Range	192.50-308.33	120-240	17.72-47.06	0.53-1.42	1.83-3.10	1.02-1.96	18.62-49.00	0.56-1.48	0.75-2.24	0.48-1.52	18.44-47.83	0.58-1.50	48.78-110.00	25.42-76.39	16.66-47.89	0.51-1.47
	CD (0.05%)	44.92	27.92			0.40	0.27			0.46	0.32			14.52	9.30		

Table 4.15: Drought Susceptibility index (DSI), mean and percent decrease in mean under E₂ of sugarcane genotypes for physiological traits under normal (E₁) and water stress (E₂) environments

Sr. No.	Genotype	RWC at 60 DAP (%)				RWC at 120 DAP (%)				Chlorophyll a (mg/l)				Chlorophyll b (mg/l)			
		Mean E ₁	Mean E ₂	% ↓ in mean under E ₂	DSI	Mean E ₁	Mean E ₂	% ↓ in mean under E ₂	DSI	Mean E ₁	Mean E ₂	% ↓ in mean under E ₂	DSI	Mean E ₁	Mean E ₂	% ↓ in mean under E ₂	DSI
1	CoPb10181	76.76	48.00	37.47	1.16	65.00	34.00	47.69	1.38	3.47	1.96	43.52	1.36	3.99	2.13	46.62	1.50
2	CoPb13181	76.12	52.00	31.69	0.98	73.96	45.41	38.60	1.11	3.31	2.19	33.84	1.06	4.03	3.05	24.32	0.78
3	CoPb13182	70.12	46.99	32.99	1.02	65.00	40.17	38.20	1.10	3.20	2.16	32.50	1.01	3.98	2.93	26.38	0.85
4	CoPb13183	73.53	49.34	32.90	1.02	53.29	29.00	45.58	1.32	3.31	2.23	32.63	1.02	3.75	2.36	37.07	1.20
5	CoPb11214	72.69	39.00	46.35	1.44	67.25	35.00	47.96	1.38	2.68	1.39	48.13	1.50	2.91	1.56	46.39	1.50
6	CoPb11211	76.37	52.82	30.84	0.96	77.30	43.00	44.37	1.28	3.16	1.93	38.92	1.22	3.56	2.40	32.58	1.05
7	CoPb12181	71.93	46.99	34.67	1.08	57.32	40.68	29.03	0.84	3.63	2.39	34.16	1.07	4.25	3.02	28.94	0.93
8	CoPb12182	80.25	65.00	19.00	0.59	64.58	46.50	28.00	0.81	3.01	1.98	34.22	1.07	3.29	2.03	38.30	1.24
9	CoPb14212	68.50	46.99	31.40	0.97	76.38	49.00	35.85	1.04	3.52	2.16	38.64	1.21	4.08	2.74	32.84	1.06
10	CoPb14211	72.99	53.59	26.58	0.83	60.13	30.00	50.11	1.45	2.95	1.83	37.97	1.19	3.41	2.36	30.79	0.99
11	CoPb12212	62.90	34.00	45.95	1.43	67.51	34.00	49.64	1.43	3.41	2.09	38.71	1.21	3.98	2.39	39.95	1.29
12	L 818/07	70.71	35.00	50.50	1.57	66.25	34.00	48.68	1.41	2.94	1.63	44.56	1.39	3.35	1.86	44.48	1.43
13	KV2012- 1	78.67	62.00	21.19	0.66	47.35	34.18	27.81	0.80	3.04	2.19	27.96	0.87	3.79	2.68	29.29	0.94
14	KV2012- 2	74.80	56.00	25.13	0.78	77.19	58.00	24.86	0.72	3.38	2.65	21.60	0.67	3.78	2.96	21.69	0.70
15	KV2012- 3	72.33	52.47	27.46	0.85	73.33	55.00	25.00	0.72	3.76	2.86	23.94	0.75	4.59	3.47	24.40	0.79
16	KV2012-4	75.32	54.82	27.22	0.85	55.58	41.11	26.03	0.75	3.84	2.95	23.18	0.72	4.79	3.63	24.22	0.78
17	KV2012- 5	72.32	53.25	26.37	0.82	61.67	48.00	22.17	0.64	3.40	2.46	27.65	0.86	4.06	3.09	23.89	0.77

Sr. No.	Genotype	RWC at 60 DAP (%)				RWC at 120 DAP (%)				Chlorophyll a (mg/l)				Chlorophyll b (mg/l)			
		Mean E ₁	Mean E ₂	% ↓ in mean under E ₂	DSI	Mean E ₁	Mean E ₂	% ↓ in mean under E ₂	DSI	Mean E ₁	Mean E ₂	% ↓ in mean under E ₂	DSI	Mean E ₁	Mean E ₂	% ↓ in mean under E ₂	DSI
18	ISH 148	69.92	56.00	19.91	0.62	63.14	52.00	17.64	0.51	3.67	2.84	22.62	0.71	4.51	3.62	19.73	0.64
19	ISH 07	70.35	58.00	17.56	0.55	64.10	53.00	17.32	0.50	2.99	2.43	18.73	0.58	3.55	2.79	21.41	0.69
20	ISH 135	72.19	59.00	18.27	0.57	67.55	55.00	18.58	0.54	3.09	2.59	16.18	0.51	3.30	2.83	14.24	0.46
21	ISH 159	69.02	54.00	21.76	0.68	61.89	51.00	17.60	0.51	2.76	2.19	20.65	0.64	3.33	2.76	17.12	0.55
22	Co 238	69.85	51.00	26.99	0.84	63.10	45.00	28.68	0.83	3.88	2.75	29.12	0.91	4.89	3.21	34.36	1.11
23	CoJ88	66.70	34.00	49.03	1.52	62.50	34.00	45.60	1.32	2.54	1.95	23.23	0.73	2.68	2.05	23.51	0.76
24	CoS8436	67.08	42.00	37.39	1.16	57.50	35.00	39.13	1.13	3.84	2.19	42.97	1.34	4.63	2.83	38.88	1.25
25	CoPb91	70.94	38.00	46.43	1.44	55.36	32.00	42.20	1.22	3.40	2.35	30.88	0.96	3.88	2.35	39.43	1.27
26	Co 118	71.58	44.00	38.53	1.20	76.67	46.63	39.18	1.13	3.55	2.21	37.75	1.18	3.93	2.32	40.97	1.32
27	CoJ85	73.70	50.32	31.72	0.98	70.00	45.52	34.97	1.01	3.44	2.18	36.63	1.14	3.63	2.35	35.26	1.14
28	CoJ64	69.93	43.86	37.28	1.16	68.81	46.33	32.67	0.94	2.99	2.21	26.09	0.81	3.06	2.16	29.41	0.95
29	CoPb92	73.45	41.00	44.18	1.37	67.26	37.00	44.99	1.30	3.59	2.19	39.00	1.22	4.74	2.75	41.98	1.35
30	CoPb93	69.97	45.42	35.09	1.09	69.18	49.00	29.17	0.84	3.81	2.65	30.45	0.95	4.47	3.21	28.19	0.91
	GM	72.03	48.82	32.39	1.00	65.20	42.61	34.58	0.99	3.31	2.25	31.88	0.99	3.87	2.66	31.22	1.00
	Range	62.90-80.25	34.00-65.00	17.56-50.50	0.55-1.57	47.35-77.30	29.00-58.00	17.32-50.11	0.50-1.45	2.54-3.88	1.39-2.95	16.18-48.13	0.51-1.50	2.68-4.89	1.56-3.63	14.24-46.62	0.46-1.50
	CD (0.05%)	7.19	16.70			11.30	17.06			NS	NS			NS	0.96		

Table 4.15: Contd.

Sr. No.	Genotype	Total chlorophyll (mg/l)				Stomatal frequency (no.)				Specific leaf weight (g)			
		Mean E ₁	Mean E ₂	% ↓ in mean under E ₂	DSI	Mean E ₁	Mean E ₂	% ↓ in mean under E ₂	DSI	Mean E ₁	Mean E ₂	% ↓ in mean under E ₂	DSI
1	CoPb10181	7.46	4.20	43.70	1.30	45.00	27.00	40.00	1.10	4.64	2.69	42.03	1.31
2	CoPb13181	7.34	5.06	31.06	0.93	44.00	28.00	36.36	1.00	5.28	3.13	40.72	1.27
3	CoPb13182	7.18	4.48	37.60	1.12	44.00	28.00	36.36	1.00	6.96	4.20	39.66	1.24
4	CoPb13183	6.95	4.23	39.14	1.17	47.00	32.00	31.91	0.88	4.48	2.98	33.48	1.05
5	CoPb11214	5.59	3.12	44.19	1.32	47.00	32.00	31.91	0.88	7.48	5.60	25.13	0.79
6	CoPb11211	6.71	4.02	40.09	1.19	48.00	35.00	27.08	0.74	5.83	3.40	41.68	1.30
7	CoPb12181	7.87	4.98	36.72	1.09	45.00	31.00	31.11	0.86	4.36	2.88	33.94	1.06
8	CoPb12182	6.30	4.19	33.49	1.00	47.00	35.00	25.53	0.70	4.94	3.34	32.39	1.01
9	CoPb14212	7.60	4.95	34.87	1.04	37.00	25.00	32.43	0.89	3.23	2.15	33.44	1.04
10	CoPb14211	6.36	4.32	32.08	0.96	41.00	29.00	29.27	0.80	4.25	2.75	35.29	1.10
11	CoPb12212	7.39	4.65	37.08	1.10	39.00	29.00	25.64	0.71	3.81	2.19	42.52	1.33
12	L 818/07	6.29	3.50	44.36	1.32	47.00	27.00	42.55	1.17	4.64	2.83	39.01	1.22
13	KV2012- 1	6.82	4.97	27.13	0.81	42.00	24.00	42.86	1.18	6.61	4.86	26.48	0.83
14	KV2012- 2	7.16	5.36	25.14	0.75	43.00	28.00	34.88	0.96	5.69	4.29	24.60	0.77
15	KV2012- 3	8.35	6.18	25.99	0.77	38.00	24.00	36.84	1.01	6.65	4.89	26.47	0.83
16	KV2012-4	8.62	6.50	24.59	0.73	45.00	23.00	48.89	1.34	6.75	5.10	24.44	0.76
17	KV2012- 5	7.46	5.54	25.74	0.77	41.00	25.00	39.02	1.07	5.39	4.28	20.59	0.64

Sr. No.	Genotype	Total chlorophyll (mg/l)				Stomatal frequency (no.)				Specific leaf weight (g)			
		Mean E ₁	Mean E ₂	% ↓ in mean under E ₂	DSI	Mean E ₁	Mean E ₂	% ↓ in mean under E ₂	DSI	Mean E ₁	Mean E ₂	% ↓ in mean under E ₂	DSI
18	ISH 148	8.18	6.38	22.00	0.66	51.00	30.00	41.18	1.13	5.25	4.12	21.52	0.67
19	ISH 07	6.54	5.26	19.57	0.58	42.00	24.00	42.86	1.18	4.68	3.73	20.30	0.63
20	ISH 135	6.38	5.29	17.08	0.51	52.00	31.00	40.38	1.11	4.98	3.98	20.08	0.63
21	ISH 159	6.09	4.90	19.54	0.58	41.00	22.00	46.34	1.27	4.64	3.69	20.47	0.64
22	Co 238	8.77	6.10	30.44	0.91	44.00	31.00	29.55	0.81	5.00	3.80	24.00	0.75
23	CoJ88	5.22	3.20	38.70	1.15	46.00	32.00	30.43	0.84	3.81	2.10	44.88	1.40
24	CoS8436	8.47	4.71	44.39	1.32	45.00	28.00	37.78	1.04	4.33	2.80	35.33	1.10
25	CoPb91	7.27	4.48	38.38	1.14	45.00	29.00	35.56	0.98	3.89	2.15	44.73	1.40
26	Co 118	7.98	4.69	41.23	1.23	43.00	26.00	39.53	1.09	5.00	3.02	39.60	1.24
27	CoJ85	7.07	4.38	38.05	1.13	38.00	27.00	28.95	0.80	5.35	3.26	39.07	1.22
28	CoJ64	6.55	4.11	37.25	1.11	41.00	28.00	31.71	0.87	3.54	2.39	32.49	1.01
29	CoPb92	8.87	5.05	43.07	1.28	47.00	33.00	29.79	0.82	5.42	3.31	38.93	1.22
30	CoPb93	8.27	5.60	32.29	0.96	42.00	28.00	33.33	0.92	4.01	2.80	30.17	0.94
	GM	7.23	4.81	33.50	0.99	44.00	28.30	35.34	0.99	5.02	3.42	32.45	1.01
	Range	5.22-8.87	3.12-6.50	17.08-34.39	0.51-1.32	37.00-52.00	22.00-35.00	25.53-48.89	0.70-1.34	3.23-7.48	2.10-5.60	20.08-44.88	0.63-1.40
	CD (0.05%)	1.87	1.54			4.87	4.30			2.22	1.07		

Table 4.16: Drought Susceptibility index (DSI), mean and percent decrease in mean under E₂ of sugarcane genotypes for quality traits under normal (E₁) and water stress (E₂) environments

Sr. No.	Genotype	Brix at 10 months (%)				Pol in juice at 10 months (%)				Extraction at 10 months (%)				Purity at 10 months (%)				CCS at 10 months (%)			
		Mean E ₁	Mean E ₂	% ↓ in mean under E ₂	DSI	Mean E ₁	Mean E ₂	% ↓ in mean under E ₂	DSI	Mean E ₁	Mean E ₂	% ↓ in mean under E ₂	DSI	Mean E ₁	Mean E ₂	% ↓ in mean under E ₂	DSI	Mean E ₁	Mean E ₂	% ↓ in mean under E ₂	DSI
1	CoPb10181	16.75	14.17	15.40	1.28	14.43	11.64	19.33	1.14	56.75	48.32	14.85	1.14	86.28	82.11	4.83	0.81	9.86	7.75	21.40	1.07
2	CoPb13181	17.89	15.53	13.19	1.10	15.56	12.84	17.48	1.03	41.56	35.28	15.11	1.16	87.04	82.71	4.97	0.83	10.67	8.58	19.59	0.98
3	CoPb13182	14.15	13.38	5.44	0.45	12.38	11.49	7.19	0.42	54.24	43.25	20.26	1.56	87.50	85.83	1.91	0.32	8.52	7.83	8.10	0.40
4	CoPb13183	14.90	12.73	14.56	1.21	13.25	10.75	18.87	1.11	51.73	40.28	22.13	1.70	88.92	84.46	5.02	0.84	9.19	7.27	20.89	1.04
5	CoPb11214	17.49	15.53	11.21	0.93	14.88	12.18	18.15	1.07	55.77	47.34	15.12	1.16	85.09	78.43	7.83	1.30	10.10	7.91	21.68	1.08
6	CoPb11211	15.88	13.38	15.74	1.31	13.54	10.41	23.12	1.36	50.98	39.65	22.22	1.71	85.29	77.77	8.82	1.47	9.20	6.73	26.85	1.34
7	CoPb12181	14.32	11.72	18.16	1.51	11.96	9.17	23.33	1.37	48.46	38.54	20.47	1.57	83.51	78.24	6.31	1.05	8.04	5.94	26.12	1.31
8	CoPb12182	16.42	15.58	5.12	0.43	13.28	12.38	6.78	0.40	57.04	52.01	8.82	0.68	80.77	79.46	1.62	0.27	8.78	8.10	7.74	0.39
9	CoPb14212	15.56	12.53	19.47	1.62	12.47	9.39	24.70	1.45	50.75	38.69	23.76	1.83	80.16	74.94	6.51	1.09	8.20	5.93	27.68	1.38
10	CoPb14211	15.99	14.24	10.94	0.91	13.12	11.29	13.95	0.82	54.95	41.28	24.88	1.91	81.99	79.25	3.34	0.56	8.73	7.38	15.46	0.77
11	CoPb12212	15.31	12.73	16.85	1.40	13.13	10.27	21.78	1.28	59.51	52.36	12.01	0.92	85.81	80.58	6.09	1.02	8.95	6.78	24.25	1.21
12	L 818/07	17.55	13.38	23.76	1.98	15.05	10.47	30.43	1.79	56.10	48.59	13.39	1.03	85.72	78.23	8.74	1.46	10.26	6.79	33.82	1.69
13	KV2012- 1	18.37	15.84	13.77	1.15	15.80	13.17	16.65	0.98	55.83	50.29	9.92	0.76	85.97	83.27	3.14	0.52	10.78	8.84	18.00	0.90
14	KV2012- 2	18.87	16.30	13.62	1.13	16.60	14.08	15.18	0.89	49.45	47.58	3.78	0.29	88.03	86.35	1.91	0.32	11.45	9.63	15.90	0.79
15	KV2012- 3	18.02	15.73	12.71	1.06	16.62	14.01	15.70	0.92	53.11	49.09	7.57	0.58	92.32	88.98	3.62	0.60	11.72	9.73	16.98	0.85
16	KV2012-4	17.22	16.63	3.43	0.29	15.07	12.75	15.39	0.91	44.81	41.26	7.92	0.61	87.84	76.61	12.78	2.13	10.37	8.17	21.22	1.06

Sr. No.	Genotype	Brix at 10 months (%)				Pol in juice at 10 months (%)				Extraction at 10 months (%)				Purity at 10 months (%)				CCS at 10 months (%)			
		Mean E ₁	Mean E ₂	% ↓ in mean under E ₂	DSI	Mean E ₁	Mean E ₂	% ↓ in mean under E ₂	DSI	Mean E ₁	Mean E ₂	% ↓ in mean under E ₂	DSI	Mean E ₁	Mean E ₂	% ↓ in mean under E ₂	DSI	Mean E ₁	Mean E ₂	% ↓ in mean under E ₂	DSI
17	KV2012- 5	18.30	16.41	10.33	0.86	16.77	13.44	19.86	1.17	48.69	45.39	6.78	0.52	91.77	81.89	10.77	1.79	11.80	8.94	24.24	1.21
18	ISH 148	17.40	15.66	10.00	0.83	14.73	12.42	15.68	0.92	55.23	48.68	11.86	0.91	84.63	79.33	6.26	1.04	9.97	8.12	18.56	0.93
19	ISH 07	16.96	15.85	6.54	0.55	14.49	12.60	13.04	0.77	50.35	45.21	10.21	0.79	85.42	79.46	6.98	1.16	9.86	8.24	16.43	0.82
20	ISH 135	16.21	15.53	4.19	0.35	13.65	12.35	9.52	0.56	51.30	46.21	9.92	0.76	84.25	79.53	5.60	0.93	9.21	8.09	12.16	0.61
21	ISH 159	17.05	15.51	9.03	0.75	15.60	12.56	19.49	1.15	55.58	49.65	10.67	0.82	91.49	81.02	11.44	1.91	10.96	8.31	24.18	1.21
22	Co 238	14.21	13.62	4.15	0.35	12.92	12.31	4.72	0.28	53.54	49.00	8.48	0.65	90.97	90.52	0.49	0.08	9.06	8.61	4.97	0.25
23	CoJ88	13.49	11.56	14.31	1.19	12.31	9.65	21.61	1.27	55.20	45.00	18.48	1.42	91.25	83.50	8.49	1.42	8.64	6.49	24.88	1.24
24	CoS8436	13.37	11.63	13.01	1.08	12.17	9.53	21.69	1.28	53.89	46.00	14.64	1.13	91.18	81.98	10.09	1.68	8.54	6.35	25.64	1.28
25	CoPb91	12.92	10.97	15.09	1.26	11.92	8.76	26.51	1.56	58.23	49.50	14.99	1.15	92.21	79.86	13.39	2.23	8.41	5.75	31.63	1.58
26	Co 118	17.10	14.82	13.33	1.11	15.31	12.27	19.86	1.17	57.92	50.40	12.98	1.00	89.58	82.64	7.75	1.29	10.65	8.21	22.91	1.15
27	CoJ85	16.22	14.79	8.82	0.73	14.46	12.29	15.01	0.88	55.35	51.00	7.86	0.60	89.15	83.23	6.64	1.11	10.04	8.24	17.93	0.90
28	CoJ64	17.14	14.53	15.23	1.27	15.16	11.84	21.90	1.29	47.26	42.00	11.13	0.86	88.57	81.43	8.06	1.34	10.49	7.85	25.17	1.26
29	CoPb92	14.02	11.71	16.48	1.37	12.61	9.79	22.36	1.32	56.20	42.39	24.57	1.89	90.01	83.52	7.21	1.20	8.79	6.58	25.14	1.26
30	CoPb93	17.12	14.71	14.08	1.17	15.41	12.29	20.25	1.19	56.22	50.28	10.57	0.81	90.02	83.63	7.10	1.18	10.75	8.26	23.16	1.16
	GM	16.20	14.22	12.27	1.02	14.10	11.61	17.98	1.05	53.59	45.81	13.85	1.06	87.42	81.62	6.59	1.09	9.73	7.71	20.76	1.09
	Range	12.92-18.87	10.97-16.63	3.43-23.76	0.29-1.98	11.92-16.77	8.76-14.08	4.72-30.43	0.28-1.79	41.56-59.51	35.28-52.36	3.78-24.88	0.29-1.91	80.16-92.32	74.94-90.52	0.49-13.39	0.08-2.23	8.04-11.80	5.75-9.73	4.97-33.82	0.25-1.69
	CD (0.05%)	1.50	1.16			1.29	1.10			6.30	5.29			NS	4.88			1.13	0.89		

Table 4.16: Contd.

Sr. No.	Genotype	Brix at 12 months (%)				Pol in juice at 12 months (%)				Extraction at 12 months (%)				Purity at 12 months (%)			
		Mean E ₁	Mean E ₂	% ↓ in mean under E ₂	DSI	Mean E ₁	Mean E ₂	% ↓ in mean under E ₂	DSI	Mean E ₁	Mean E ₂	% ↓ in mean under E ₂	DSI	Mean E ₁	Mean E ₂	% ↓ in mean under E ₂	DSI
1	CoPb10181	18.83	17.86	5.15	0.64	17.09	15.27	10.65	0.89	60.46	48.21	20.26	1.56	90.85	85.56	5.82	1.46
2	CoPb13181	18.58	17.85	3.93	0.49	17.68	15.90	10.07	0.84	58.88	51.21	13.03	1.00	95.17	89.10	6.38	1.59
3	CoPb13182	20.43	16.59	18.80	2.35	18.16	14.60	19.60	1.63	60.80	49.63	18.37	1.41	88.92	88.00	1.03	0.26
4	CoPb13183	18.94	17.62	6.97	0.87	16.80	14.97	10.89	0.91	56.76	47.29	16.68	1.28	88.69	84.98	4.18	1.05
5	CoPb11214	20.15	17.42	13.55	1.69	18.24	13.91	23.74	1.98	51.06	43.28	15.24	1.17	90.75	79.84	12.02	3.01
6	CoPb11211	19.26	17.05	11.47	1.43	17.61	13.69	22.26	1.86	59.87	46.58	22.20	1.71	91.43	80.34	12.13	3.03
7	CoPb12181	18.81	16.44	12.60	1.57	16.77	13.90	17.11	1.43	59.27	52.24	11.86	0.91	89.19	84.67	5.07	1.27
8	CoPb12182	17.80	15.42	13.37	1.67	15.30	12.65	17.32	1.44	58.27	44.86	23.01	1.77	85.93	82.01	4.56	1.14
9	CoPb14212	16.50	14.86	9.94	1.24	14.53	13.04	10.25	0.85	53.72	47.68	11.24	0.86	88.01	87.77	0.27	0.07
10	CoPb14211	18.77	16.11	14.17	1.77	16.23	12.90	20.52	1.71	54.05	42.18	21.96	1.69	86.49	80.11	7.38	1.84
11	CoPb12212	17.30	14.93	13.70	1.71	15.11	12.59	16.68	1.39	53.52	41.29	22.85	1.76	87.29	84.38	3.33	0.83
12	L 818/07	18.96	17.80	6.12	0.76	16.81	14.97	10.95	0.91	51.22	43.68	14.72	1.13	88.59	84.13	5.03	1.26
13	KV2012- 1	20.06	18.81	6.23	0.78	18.63	16.67	10.52	0.88	50.99	45.63	10.51	0.81	92.87	88.66	4.53	1.13
14	KV2012- 2	20.45	18.54	9.34	1.17	18.84	17.38	7.75	0.65	58.03	49.68	14.39	1.11	92.10	90.52	1.72	0.43
15	KV2012- 3	19.50	18.51	5.08	0.63	18.24	16.63	8.83	0.74	54.56	48.21	11.64	0.90	93.50	89.82	3.94	0.98
16	KV2012-4	20.69	18.73	9.47	1.18	18.30	16.29	10.98	0.92	57.88	50.31	13.08	1.01	88.53	86.95	1.78	0.45
17	KV2012- 5	20.10	18.66	7.16	0.90	17.42	16.02	8.04	0.67	56.47	47.65	15.62	1.20	86.67	85.88	0.91	0.23

Sr. No.	Genotype	Brix at 12 months (%)				Pol in juice at 12 months (%)				Extraction at 12 months (%)				Purity at 12 months (%)			
		Mean E ₁	Mean E ₂	% ↓ in mean under E ₂	DSI	Mean E ₁	Mean E ₂	% ↓ in mean under E ₂	DSI	Mean E ₁	Mean E ₂	% ↓ in mean under E ₂	DSI	Mean E ₁	Mean E ₂	% ↓ in mean under E ₂	DSI
18	ISH 148	18.11	17.39	3.98	0.50	16.05	14.71	8.35	0.70	47.79	43.25	9.50	0.73	88.59	84.56	4.55	1.14
19	ISH 07	18.10	17.52	9.47	0.40	16.17	15.10	6.62	0.55	53.18	46.49	12.58	0.97	89.36	82.94	7.18	1.80
20	ISH 135	19.45	17.94	7.76	0.97	17.36	15.27	12.04	1.00	39.39	35.12	10.84	0.83	89.23	85.12	4.61	1.15
21	ISH 159	19.02	17.26	9.25	1.16	17.61	15.23	13.52	1.13	54.25	46.39	14.49	1.11	92.62	88.23	4.74	1.18
22	Co 238	18.39	17.47	5.00	0.63	16.76	15.69	6.38	0.53	53.88	51.23	4.92	0.38	91.17	89.78	1.52	0.38
23	CoJ88	19.88	18.34	7.75	0.97	17.40	15.53	10.75	0.90	56.11	51.36	8.47	0.65	87.48	84.64	3.25	0.81
24	CoS8436	18.62	17.89	3.92	0.49	17.41	16.06	7.75	0.65	54.33	49.54	8.82	0.68	93.57	89.79	4.04	1.01
25	CoPb91	17.47	16.53	5.38	0.67	16.64	14.83	10.88	0.91	55.57	50.32	9.45	0.73	95.33	89.74	5.86	1.47
26	Co 118	19.47	18.30	6.01	0.75	17.12	15.81	7.65	0.64	63.54	56.22	11.52	0.89	87.96	86.51	1.65	0.41
27	CoJ85	19.00	17.99	5.32	0.66	16.08	15.00	6.72	0.56	58.69	47.21	19.56	1.50	84.60	83.36	1.47	0.37
28	CoJ64	18.05	17.36	3.82	0.48	17.45	15.23	12.72	1.06	57.91	54.23	6.35	0.49	96.65	87.78	9.18	2.29
29	CoPb92	19.61	15.99	18.46	2.31	17.37	13.57	21.88	1.82	55.24	49.17	10.99	0.85	96.90	88.66	8.50	2.13
30	CoPb93	19.30	17.59	8.86	1.11	18.70	15.59	16.63	1.39	53.09	48.32	8.98	0.69	88.57	84.77	4.29	1.07
	GM	18.98	17.37	8.53	1.06	17.12	14.96	12.60	1.05	55.29	47.54	13.77	1.05	90.23	86.06	4.70	1.17
	Range	16.50-20.69	14.86-18.81	3.82-18.80	0.40-2.35	14.53-18.84	12.59-17.38	6.38-23.74	0.53-1.98	39.39-63.54	35.12-56.22	4.92-23.01	0.38-1.77	84.60-96.90	79.84-93.74	0.27-12.13	0.07-3.03
	CD (0.05%)	1.25	1.08			1.30	0.81			8.25	6.03			5.80	4.07		

Table 4.16: contd.

Sr. No.	Genotype	CCS at 12 months (%)				Fibre content at harvest (%)				Pol in cane at harvest (%)				CCS at harvest (t/ha)			
		Mean E ₁	Mean E ₂	% ↓ in mean under E ₂	DSI	Mean E ₁	Mean E ₂	% ↓ in mean under E ₂	DSI	Mean E ₁	Mean E ₂	% ↓ in mean under E ₂	DSI	Mean E ₁	Mean E ₂	% ↓ in mean under E ₂	DSI
1	CoPb10181	11.97	10.39	13.20	0.94	14.56	10.84	25.55	1.34	17.61	15.79	10.34	0.84	13.09	6.67	49.05	1.17
2	CoPb13181	12.64	11.03	12.74	0.91	11.66	9.45	18.95	1.00	18.20	16.42	9.78	0.80	10.54	6.25	40.70	0.97
3	CoPb13182	12.60	10.08	20.00	1.43	13.78	11.88	13.79	0.73	18.68	15.12	19.06	1.55	10.04	5.18	48.41	1.15
4	CoPb13183	11.64	10.16	12.71	0.91	11.44	9.36	18.18	0.96	17.32	15.49	10.57	0.86	8.36	4.24	49.28	1.17
5	CoPb11214	12.76	9.13	28.45	2.03	12.83	11.07	13.72	0.72	18.76	14.43	23.08	1.88	8.74	3.31	62.13	1.48
6	CoPb11211	12.37	9.01	27.16	1.94	12.54	8.50	32.22	1.70	18.13	14.21	21.62	1.76	6.06	2.27	62.54	1.49
7	CoPb12181	11.65	9.40	19.31	1.38	13.25	10.39	21.58	1.14	17.29	14.42	16.60	1.35	6.34	3.61	43.06	1.03
8	CoPb12182	10.43	8.42	19.27	1.38	11.59	9.12	21.31	1.12	15.82	13.17	16.75	1.36	6.92	3.63	47.54	1.13
9	CoPb14212	10.03	8.98	10.47	0.75	12.25	9.68	20.98	1.10	15.05	13.56	9.90	0.81	5.70	3.45	39.47	0.94
10	CoPb14211	11.10	8.48	23.60	1.69	14.39	10.35	28.08	1.48	16.75	13.42	19.88	1.62	7.13	3.53	50.49	1.20
11	CoPb12212	10.39	8.50	18.19	1.30	14.25	11.36	20.28	1.07	15.63	13.11	16.12	1.31	8.55	4.56	46.67	1.11
12	L 818/07	11.64	10.10	13.23	0.95	11.96	10.36	13.38	0.70	17.33	15.49	10.62	0.86	11.18	5.28	52.77	1.26
13	KV2012- 1	13.18	11.55	12.37	0.88	12.98	11.23	13.48	0.71	19.15	17.19	10.23	0.83	12.08	7.62	36.92	0.88
14	KV2012- 2	13.28	12.35	7.00	0.50	13.58	11.54	15.02	0.79	19.36	17.90	7.54	0.61	10.15	7.32	27.88	0.66
15	KV2012- 3	12.94	11.59	10.43	0.75	11.36	10.05	11.53	0.61	18.76	17.15	8.58	0.70	13.05	8.85	32.18	0.77
16	KV2012-4	12.66	11.18	11.69	0.84	14.21	12.24	13.86	0.73	18.82	16.81	10.68	0.87	9.78	6.79	30.57	0.73
17	KV2012- 5	11.93	10.93	8.38	0.60	12.36	10.84	12.30	0.65	17.94	16.54	7.80	0.63	10.41	7.03	32.47	0.77

Sr. No.	Genotype	CCS at 12 months (%)				Fibre content at harvest (%)				Pol in cane at harvest (%)				CCS at harvest (t/ha)			
		Mean E ₁	Mean E ₂	% ↓ in mean under E ₂	DSI	Mean E ₁	Mean E ₂	% ↓ in mean under E ₂	DSI	Mean E ₁	Mean E ₂	% ↓ in mean under E ₂	DSI	Mean E ₁	Mean E ₂	% ↓ in mean under E ₂	DSI
18	ISH 148	11.11	9.95	10.44	0.75	12.32	10.85	11.93	0.63	16.57	15.23	8.09	0.66	6.50	4.84	25.54	0.61
19	ISH 07	11.24	10.11	10.05	0.72	13.28	11.21	15.59	0.82	16.69	15.62	6.41	0.52	6.97	5.10	26.83	0.64
20	ISH 135	12.06	10.36	14.10	1.01	12.96	10.63	17.98	0.95	17.88	15.79	11.69	0.95	7.59	5.11	32.67	0.78
21	ISH 159	12.45	10.52	15.50	1.11	13.27	11.20	15.60	0.82	18.13	15.75	13.13	1.07	7.59	5.02	33.86	0.81
22	Co 238	11.76	10.93	7.06	0.50	12.42	10.83	12.80	0.67	17.28	16.21	6.19	0.50	9.98	6.77	32.16	0.77
23	CoJ88	11.98	10.51	12.27	0.88	14.97	10.24	31.60	1.66	17.92	16.05	10.44	0.85	9.73	5.33	45.22	1.08
24	CoS8436	12.36	11.19	9.47	0.68	13.60	10.86	20.15	1.06	17.93	16.58	7.53	0.61	9.00	5.20	42.22	1.01
25	CoPb91	11.90	10.33	13.19	0.94	12.96	10.21	21.22	1.12	17.16	15.35	10.55	0.86	11.47	6.04	47.34	1.13
26	Co 118	11.81	10.81	8.47	0.60	13.65	11.02	19.27	1.01	17.64	16.33	7.43	0.60	9.09	5.26	42.13	1.00
27	CoJ85	10.88	10.07	7.44	0.53	13.96	10.25	26.58	1.40	16.60	15.52	6.51	0.53	8.08	4.78	40.84	0.97
28	CoJ64	12.56	10.50	16.40	1.17	14.91	11.25	24.55	1.29	17.97	15.75	12.35	1.00	9.19	4.39	52.23	1.24
29	CoPb92	13.47	10.80	19.82	1.42	14.58	11.96	17.97	0.95	17.89	14.09	21.24	1.73	10.86	5.94	45.30	1.08
30	CoPb93	12.03	9.19	23.61	1.69	11.85	9.35	21.10	1.11	19.22	16.11	16.18	1.32	11.25	6.22	44.71	1.06
	GM	11.96	10.21	14.53	1.03	13.12	10.60	19.02	1.00	17.65	15.49	12.23	0.99	9.18	5.32	42.11	1.00
	Range	10.03-13.47	8.42-12.35	7.00-28.45	0.50-2.03	11.36-14.97	8.50-12.24	11.53-32.22	0.61-1.70	15.05-19.36	13.11-17.90	6.19-23.08	0.50-1.88	5.70-13.09	2.27-8.85	25.54-62.54	0.61-1.49
	CD (0.05%)	1.15	0.65			1.60	1.58			1.15	1.31			1.97	0.82		

4.7 Screening against red rot disease

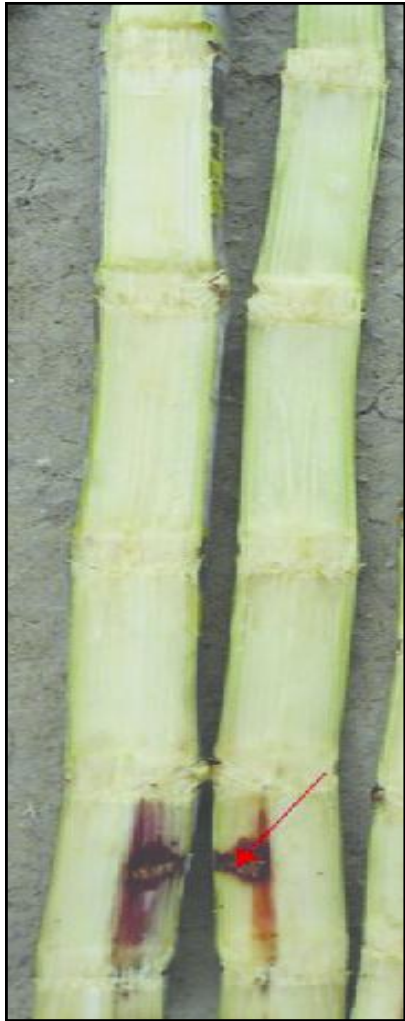
Red rot (*Colletotrichum falcatum* Went.) disease is the most dreadful disease of sugarcane. It causes great loss to growers as well as sugarcane industry. Moreover, most of the newly released cultivars to replace the susceptible ones succumb to the pathogen almost as soon as they become popular due to the frequent emergence of new variants of the pathogen. Management of the disease by the use of disease-free seed canes for planting is impractical due to the difficulty in diagnosing the dormant infections of the fungus in seed canes under field conditions (Viswanathan and Samiyappan, 2002). In view of the non-availability of effective, systemic fungicides for controlling red rot under field conditions, breeding for red rot resistance remains the most practical, economical and effective option (Meeta *et al* 2007 and Kaur *et al* 2014). The continued efforts are being made to generate elite material possessing tolerance to the various isolates of red rot coupled with best agronomic performance from the hybridization of specifically chosen parents. In the present study 30 varieties/ clones were screened against CF 08 (isolated from CoJ84) and CF 09 (isolated from CoS767) isolates of red rot pathogen using artificial inoculation by plug method under normal (E_1) and water stress (E_2) environments and the reaction of these genotypes was scored against both the red rot pathogen per Srinivasan and Bhatt (1961) and results obtained are presented in the Table 4.17.

The tested genotypes showed differential reaction against both the pathotypes ranging from moderately resistance (< 4.0) to highly susceptible (>7.0) indicating genetic variability for disease resistance in the research material used in study. Reaction to CF 08 red rot pathotype under artificial inoculation by plug method revealed that varieties/clones like Co238, CoS8436, Co118, CoPb92, CoPb93, clones like ISH07, ISH135, ISH159, KV2012-1, KV2012-3, KV2012-5, CoPb14211, Copb14212, CoPb13182, CoPb11211, CoPb12212 and CoPb10181 were found to be moderately resistance (MR) having disease score between 2.1-4.0 under both normal (E_1) as well as water stress (E_2) environments. Bharathi *et al* (2012) screened fifty five early and mid late sugarcane cultivars for their resistance to red rot pathogen out of which twenty six were found moderately resistant to red rot.

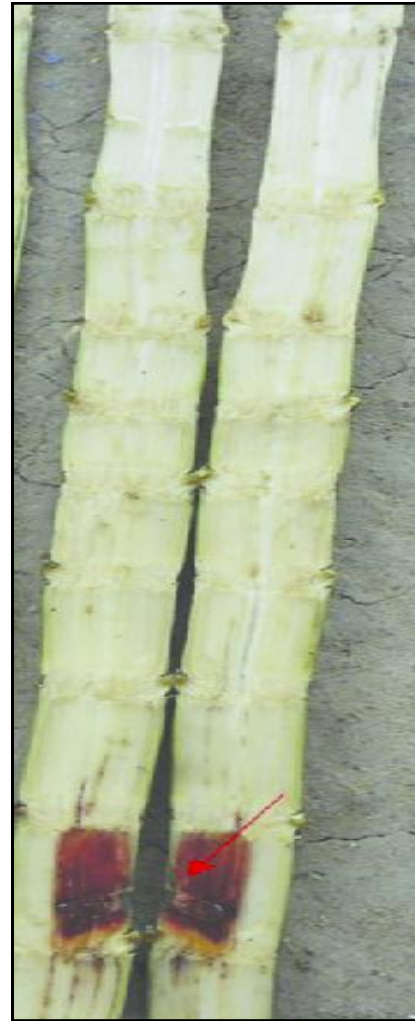
Clones like CoPb12181 and CoPb12182 were susceptible (S) to Cf08 under normal (E_1) environment while they were moderately susceptible (MS) to this pathotypes under water stress (E_2) environment. The highly susceptibility (HS) reaction was exhibited by the clone CoPb13183 (score 8.7 and 8.5, respectively) to CF 08 under both the environments followed by CoJ64 and CoJ85. The clone ISH148 was found to be highly susceptible (S) (score 8.4) under normal E_1 environment while under water stress (E_2) conditions it exhibited moderate resistance (MR) reaction (score 4.0) against CF 08. Variety CoJ88 found to be susceptible (S) (score 6.4 and 6.3, respectively) under both normal (E_1) and water stress (E_2) environment

Table 4.17: Reaction and score of 30 sugarcane clones against CF 08 and CF 09 pathotypes of red rot under normal (E₁) and water stress (E₂) environments

Genotypes	CF-08				CF-09			
	Normal(E ₁)		Water stress(E ₂)		Normal(E ₁)		Water stress(E ₂)	
	Score	Reaction	Score	Reaction	Score	Reaction	Score	Reaction
CoPb10181	3.7	MR	3.6	MR	3.8	MR	3.8	MR
CoPb11214	4.2	MS	3.9	MR	3.7	MR	3.9	MR
CoPb12181	6.6	S	5.9	MS	6.2	S	5.8	MS
CoPb12182	6.9	S	6.0	MS	6.8	S	6.7	S
CoPb11211	3.7	MR	3.7	MR	3.7	MR	3.9	MR
CoPb12212	3.7	MR	3.7	MR	3.5	MR	3.7	MR
CoPb13181	5.5	MS	5.7	MS	5.6	MS	5.7	MS
CoPb13182	3.6	MR	3.8	MR	3.8	MR	3.7	MR
CoPb13183	8.7	HS	8.5	HS	8.9	HS	8.7	HS
CoPb14211	3.6	MR	3.7	MR	3.7	MR	3.8	MR
CoPb14212	3.8	MR	3.8	MR	3.7	MR	3.5	MR
CoPb92	3.8	MR	3.7	MR	3.8	MR	3.6	MR
CoPb93	3.8	MR	3.6	MR	3.4	MR	3.6	MR
ISH 07	3.7	MR	3.5	MR	3.9	MR	3.7	MR
ISH 135	3.7	MR	3.6	MR	3.7	MR	3.6	MR
ISH 148	8.4	HS	4.0	MR	8.4	HS	3.9	MR
ISH 159	3.8	MR	3.8	MR	6.1	S	5.8	MS
L 818/07	3.7	MR	3.6	MR	3.8	MR	3.5	MR
KV2012-1	3.8	MR	3.8	MR	3.7	MR	3.7	MR
KV2012-2	4.3	MS	3.7	MR	4.4	MS	3.8	MS
KV2012-3	3.8	MR	3.8	MR	4.3	MS	3.7	MR
KV2012-4	4.7	MS	4.7	MS	4.8	MS	4.5	MS
KV2012-5	3.9	MR	3.6	MR	3.7	MR	3.6	MR
Co 238	3.7	MR	3.6	MR	3.9	MR	3.6	MR
CoJ88	6.4	S	6.3	S	3.8	MR	3.7	MR
CoS8436	3.7	MR	3.7	MR	3.7	MR	3.8	MR
CoPb91	4.5	MS	4.5	MS	4.6	MS	4.3	MS
Co 118	3.9	MR	3.5	MR	3.5	MR	3.6	MR
CoJ85	8.4	HS	8.3	HS	8.6	HS	8.3	HS
CoJ64	8.5	HS	8.3	HS	8.4	HS	8.2	HS



Red Rot Symptoms-R



Red Rot Symptoms-MR



Red Rot Symptoms-S



Red Rot Symptoms-HS

Plate 4.2: Red Rot disease reaction of different sugarcane clones

which indicates that pathogen is highly variable and resistance of cultivars breakdown frequently. Artificial evaluation of irradiated sugarcane subclones done by Kaur *et al* 2016 against two red rot pathotypes CF 08 and CF 09 using plug method has revealed moderate level of resistance for different mutagenic treatments.

Similarly, varieties like Co238, CoS8436, Co118, CoPb92 and CoPb93 and clones like ISH07, ISH135, CoPb14211, CoPb14212, CoPb13182, CoPb11214, CoPb12211, CoPb12212 and CoPb10181 showed a varied disease score from 2.1 to 4.0 and exhibited moderately resistant (MR) reaction against CF 09 red rot pathotype under normal (E_1) as well as water stress (E_2) environments. Gill *et al* (2012) also screened 23 sugarcane genotypes belonging to twenty three diverse cross combinations under irrigated conditions for their reaction against red rot pathotypes CF 08 and CF 03 and found a total of 13 genotypes belonging to eleven cross combinations as moderately resistant reaction to both the pathotypes.

Varieties CoJ85 and CoJ64 were found highly susceptible (HS) to CF 09 pathotype under both the environments. Clone KV2012-3 found to be moderately susceptible (MS) having disease score 4.3 to this pathotype under normal (E_1) environment while this clone exhibited moderately resistance (MR) reaction (score 3.7) under water stress (E_2) environment. Similarly, clone ISH148 exhibited highly susceptibility (HS) having score of 8.4 to CF 09 pathotype under normal (E_1) environment but exhibited moderately resistant score of 3.9 under water stress (E_2) environment. It was observed in the present study that there was less incidence of red rot among genotypes planted under water stress (E_2) environment than in those genotypes that were planted under normal (E_1) environment that may be attributed to more favourable conditions under irrigated conditions, so there is decline in the severity under water stress (E_2) conditions. Results reported by Yin *et al* (1997) were contradictory to present study, who revealed that red rot severity can be increased by the occurrence of drought conditions during the initial growth processes of vegetatively propagated sugarcane stalks. Similarly, Olufolaji *et al* (1989) also demonstrated increase in red rot incidence when standing cane was exposed to drought stress.

The results under present study concludes that varieties viz. Co238, CoS8436, Co118, CoPb92 and CoPb93 and 8 elite clones namely ISH07, ISH135, CoPb14211, CoPb14212, CoPb13182, CoPb11214, CoPb11211, CoPb12212 were categorized as moderately resistance to CF 08 and CF 09 pathotypes of red rot under both normal (E_1) and water stress (E_2) environments and can be used in future red rot breeding programmes. However, 2 clones like ISH148 and KV2012-3 were categorized as moderately resistance under water stress (E_2) environment, so these clones can be used in future evaluation for red rot resistance under limited water conditions over locations. The red rot infected split cane symptoms are depicted in Plate 4.2.

CHAPTER V

SUMMARY

Sugarcane (*Saccharum* spp. hybrid complex) is an important industrial crop of the country mainly because of its ability to store high concentrations of sucrose or sugar in the stem and more recently for the production of ethanol, which is an important renewable biofuel source. Abiotic and biotic stresses are the main causes of low productivity that cause negative impacts on crop adaptation and production. Among abiotic stresses, drought is severe one and may reduce sugarcane yield up to 50% or even more. It is being a multi-dimensional stress, causes various physiological and biochemical effects on plant growth and development. So, there is an urgent need to identify sugarcane varieties adapted to moisture stress in order to sustain sugarcane production and sugar recovery. At present, no completely drought and red rot resistant clone has been recommended or released. Therefore, the present study was designed to evaluate different elite sugarcane varieties and ISH clones for drought tolerance and against prevailing red rot pathotypes and their effects on cane yield and juice quality. This investigation was carried out during spring season 2016-17 using 30 diverse clones of sugarcane (comprising 9 commercial varieties released from Punjab state, 12 elite selections, 5 introductions procured from RS Anapalli & 4 ISH clones collected from SBI, Coimbatore). All the 30 clones were planted in a randomized complete block design with two replications in normal (E_1) and water stress (E_2) environments. Under water stress (E_2) environment irrigation was suspended for 2-3 weeks interval at critical growth stages of sugarcane viz. germination, tillering and grand growth stage. Standard agronomic were followed to raise the ideal crop stand. The observations on 8 cane yield and component traits, 4 physiological and 13 quality traits were recorded at appropriate stages for each clone under both the E_1 and E_2 environments. The mean values of all the traits were subjected to statistical analysis genetic variability, correlation and path analysis, DSI and disease reaction was worked out for all the traits. The results on various aspects of study are summarized below:

Analysis of variance revealed significant difference among genotypes for all the cane yield and component traits recorded in this study under both the environments, except for stalk length under normal (E_1) environment. For physiological traits, RWC at 120 DAP, total chlorophyll and specific leaf weight were significant under both (E_1 and E_2) environments, while RWC at 60 DAP and chlorophyll b were found to be significant under water stressed (E_2) environment only. Similarly, of the 13 quality traits studied at 10 months and at harvest, clones behaved significantly different for all the traits in both the environments except for purity (%) at 10 months under normal (E_1) conditions.

High magnitude of coefficient of variation i.e. PCV and GCV under cane yield and component traits was recorded for germination (%) and single cane weight (kg) under both

normal (E_1) and water stress (E_2) environments. For cane yield (t/ha) high PCV was recorded under both the environments while high GCV was recorded for this trait under E_2 only. For physiological traits high PCV was recorded for specific leaf weight (g) under both the environments while high GCV for this trait was recorded under water stress (E_2) only. For quality traits, High PCV and GCV was recorded for CCS (t/ha) under both normal (E_1) as well as water stress (E_2) environments.

High heritability values for major economic traits like cane yield, commercial cane sugar tons per hectare, number of shoots thousand per hectare, brix (%) and pol percentage at 10 months and commercial cane sugar (%) under water stress (E_2) conditions indicates that substantial improvement can be expected by giving emphasis on the selection of these traits under water stress conditions. In this study environmental influence on the expression of different traits was observed as indicated by the differences in parameters of variability. Genetic advance (GA) indicated for traits; cane yield, CCS (t/ha) and single cane weight under both the environments (E_1 and E_2) were having higher values and substantial improvement can be expected by practicing selection for these traits. High heritability coupled with high genetic advance recorded for number of shoots at 120 days (000/ha), cane yield (t/ha), CCS (t/ha) under water stress (E_2) environment indicated that direct selection of these traits under water stress conditions could be effective. Moderate values of h^2 and GA for traits like relative water content (%) at 60 and 120 days, chlorophyll content and some quality traits indicates that direct selection could not be much effective for these traits.

From correlation matrix of cane yield and its component traits, agro-physiological and quality traits at phenotypic and genotypic level revealed that genotypic correlation coefficients, in general under both the environments, were higher in magnitude than the corresponding phenotypic correlation coefficients. This indicated that there was an inherent association among various characters under study, which was depressed due to environmental influence and ultimately resulted in low phenotypic expression of the correlation. At genotypic level, under normal (E_1) and water stress (E_2) environments cane yield had significant and positive association with stalk length, stalk diameter, single cane weight and chlorophyll content. Physiological traits like RWC at 60 days after planting had a positive correlation with stalk length under both E_1 and E_2 environments whereas; with stalk diameter and single cane weight under water stress (E_2) environment at phenotypic level. At genotypic level, RWC had positive significant correlation with stalk length and single cane weight under both the environments but it was negative with number of shoots at 120 days, number of tillers at 240 days and number of millable canes under normal (E_1) conditions and significant positive correlation with these characters under water stress (E_2) conditions. For quality traits, at genotypic level CCS (%) at harvest exhibited significant positive association with pol (%)

in juice, purity (%), CCS (%) , brix (%) , CCS (%) at 12 months and pol (%) in cane at harvest under both E_1 and E_2 environments. On the basis of correlation studies, cane yield, stalk length, stalk diameter, number of millable canes, number of tillers at 240 days and CCS (t/ha) were identified as important traits which can be selected for yield improvement under both the environments. While the number of stomata, chlorophyll content, specific leaf weight and RWC at 60 and 120 days are identified as important physiological traits for cane yield as well as sugar content under water stress (E_2) environment.

A perusal of direct and indirect effects at genotypic level delineate that under normal (E_1) conditions, number of millable canes exhibited highest positive direct effect on cane yield followed by stalk diameter, number of stomata, RWC at 120 days, specific leaf weight and stalk length. The character with negative direct effects on cane yield were number of tillers at 240 days, number of shoots at 120 days, germination percentage, RWC at 60 days and chlorophyll content. However, under water stressed (E_2) conditions number of tillers at 120 days had maximum positive direct effect on cane yield followed by relative water content at 60 days, stalk length, RWC at 120 days, number of shoots and single cane weight. Among quality traits CCS (%) at 12 months had maximum positive direct effect on CCS (t/ha) under normal (E_1) conditions followed by pol (%) cane at harvest , pol (%) in juice at 12 months, juice extraction (%) at 10 months and 12 months and fibre (%) at harvest had negative direct effect. Under water stress (E_2) conditions, pol (%) in juice at 12 months had maximum direct effect on CCS (t/ha) followed by brix (%) at 10 months, purity (%) at 10 months, pol (%) in juice at 10 months, fibre (%) at harvest, pol (%) cane percentage at harvest and juice extraction (%) at 10 months.

Drought susceptibility index (DSI) based on the mean performance of different traits in normal (E_1) and water stress (E_2) environments under study was calculated. Sugarcane genotypes/clones were categorized as drought tolerant ($S < 0.75$), intermediate ($S = 0.75-1.00$) and sensitive ($S > 1.00$) as suggested by Fisher and Maurer (1978). Germination percentage was 43.53% under normal (E_1) environment and 28.44% under water stressed (E_2) environment. The DSI values were ranged from 0.55 to 1.41 with prevailed drought intensity ($D = 0.35$). The genotypes ISH135, ISH148, KV2012-2, ISH07, ISH159, KV2012-5, KV2012-4 were found promising for this trait having DSI ($S < 0.75$). DSI value ranged from 0.59 to 1.41 with the prevailed drought intensity of 0.34 and percent reduction of 33.86% under water stress for number of tillers at 240 days. The genotype ISH148, ISH07 (0.59) exhibited minimum DSI followed by ISH135, ISH159, KV2012-2 and KV2012-5 for this trait. In case of number of millable canes at maturity the genotype ISH148 (0.50) scored minimum DSI value among all the genotypes followed by ISH159 (0.54), ISH135 (0.57), ISH07 (0.62), KV2012-2 (0.62), KV2012-5 (0.69) and KV2012-4 (0.70). The percent reduction for this trait

under E₂ environment was 34.79%. Stalk length, stalk diameter and single cane weight (SCW) are very important characters in sugarcane as they directly influence the cane yield. About 7 genotypes for stalk length, 6 genotypes for stalk diameter and 6 genotypes for SCW exhibited a DSI value less than 0.75 and considered ideal for water stress conditions. Among tested varieties/clones, all ISH clones were categorized as drought tolerant for these 3 traits based on their DSI values. KV2012-4 exhibited drought tolerant reaction for stalk length and stalk diameter and intermediate for single cane weight, KV 2012-3 was good for stalk diameter, single cane weight and intermediate for stalk length, whereas KV2012-2 was found better for stalk length, single cane weight and stalk diameter based on DSI values with drought intensity (D) value of 0.33. The cane yield percent reduction in E₂ ranged from 16.66 to 47.89% with an average of 32.40 (%). Maximum reduction in cane yield was exhibited by clone CoPb11211 (47.89 %) followed by CoPb11214, CoPb13183 and L818/07 and minimum for the genotype ISH148 (16.66 %) followed by ISH07, KV2012-4, ISH135 and KV2012-2. DSI values for cane yield were ranged from 0.51 to 1.47 showing a differential behaviour of clones/varieties to water stress. Of the clones/varieties tested low DSI value ($s < 0.75$) was exhibited by the clone ISH148 followed by ISH07, ISH135, KV2012-4, ISH159, KV2012-2 and KV2012-3 and all these clones/varieties were categorized as drought tolerant with the prevailed drought intensity ($D = 0.35$) for this trait. The genotypes/clones KV2012-5 (0.79), CoPb93 (0.85), Co238 (0.85), KV2012-2 (0.86), CoPb12181 (0.92) and CoPb94 (0.97) were categorized as intermediate having DSI ($s = 0.75 - 1.00$) and rest were susceptible. In present study, observations on 4 physiological parameters revealed that relative water content (RWC) at 60 and 120 days after planting exhibited a mean percent decrease of 32.39 and 34.58, respectively under E₂ environment. The clones ISH148, ISH07, ISH135, ISH 159, KV2012-1 and KV2012-2 showed minimum decrease in this trait under E₂ environment. Based on drought intensity (D) of 0.33 and DSI ($s < 0.75$), 6 genotypes ISH148, ISH07, ISH135, ISH 159, KV2012-1 and KV2012-2 were considered drought tolerant. Clone ISH135 showed minimum percentage reduction for chlorophyll content under water stress (E₂) environment. Further seven clones/varieties in terms of chlorophyll a, 4 for chlorophyll b and 5 terms of total chlorophyll content had a DSI value of < 0.75 indicates these clones/varieties are good for drought conditions. Similarly, DSI for stomatal frequency ranged from 0.70 to 1.34 shows variation in expression of clones/varieties to water stress. Among the tested genotypes, CoPb12182 (0.70) revealed minimum value of DSI followed by the genotype CoPb14211 (0.71) and CoPb11211 (0.74). These genotypes had minimum decrease percent under E₂ environment. The clones ISH148, ISH07, ISH159, KV2012-1, KV2012-2, KV2012-3, KV2012-4 and KV2012-5 had maximum reduction percentage in terms of

stomatal frequency under water stress (E_2) environment which means these genotypes had minimum number of stomata in their leaves under water stress which helps to reduce the transpiration rate from the leaves of these genotypes under water scarcity. So, these genotypes performed better under water stress conditions. Among quality traits studied, DSI for pol percent at 10 months ranged from 0.28 to 1.79. Genotype Co238 had lowest values of DSI followed by CoPb12182 and CoPb13182. For this trait, genotypes like ISH07, KV2012-1, KV2012-2, KV2012-3, and KV2012-4. CoPb14211 and CoJ85 had DSI value from 0.75 to 1.00 rating these genotypes as intermediate to water stress tolerance. In case of CCS (%) at 10 months, the percentage reduction under E_2 and DSI was lowest for the genotype ISH159 followed by genotype CoPb12182, CoPb13182 and ISH135 ($S < 0.75$). Similarly, the genotype ISH148 (25.54) had minimum percentage decrease in mean under E_2 environment and lowest DSI (0.61) value which means this genotype was suitable for drought stress among the 30 tested genotypes for CCS (t/ha). The genotypes like ISH135, ISH159, Co238, KV2012-5, KV2012-3, KV2012-1, CoPb14212, CoPb13181 and CoJ85 exhibited DSI values from 0.75 to 1.00 and were categorized as intermediate to water stress conditions. The drought intensity for CCS (t/ha) was high ($D = 0.42$) in this study.

Results on disease screening of sugarcane clones/varieties against prevalent red rot pathotypes (CF 08 and CF 09) under artificial inoculation using plug method revealed disease score among the clones ranged from 3.7 to 8.7 under normal (E_1) and from 3.5 to 8.5 under water stress (E_2) environments for CF 08 pathotype while for CF 09 the disease score ranged from 3.4 to 8.9 under normal (E_1) and from 3.5 to 8.7 under water stress (E_2) environments showing variable degree of resistance. Reaction to CF 08 red rot pathotype revealed that varieties/clones like Co238, CoS8436, Co118, CoPb92, CoPb93, clones like ISH07, ISH135, ISH159, KV2012-1, KV2012-3, KV2012-5, CoPb14211, CoPb14212, CoPb13182, CoPb11211, CoPb12212 and CoPb10181 were found to be moderately resistance (MR) having disease score between 2.1-4.0 under both normal (E_1) as well as water stress (E_2) environments. Similarly, varieties like Co238, CoS8436, Co118, CoPb92 and CoPb93 and clones like ISH07, ISH135, CoPb14211, CoPb14212, CoPb13182, CoPb11214, CoPb11211, CoPb12212 and CoPb10181 showed a varied disease score from 2.1 to 4.0 and exhibited moderately resistant (MR) reaction against CF 09 red rot pathotype under normal (E_1) as well as water stress (E_2) environments.

The results under present study concludes that 5 of 30 varieties/clones screened for red rot disease resistance against the pathotypes CF 08 and CF 09 viz. Co238, CoS8436, Co118, CoPb92 and CoPb93 and 8 elite clones namely ISH07, ISH135, CoPb14211, CoPb14212, CoPb13182, CoPb11214, CoPb11211, CoPb12212 were categorized as

moderately to red rot under both normal (E_1) and water stress (E_2) environments. The varieties/clones found moderately resistant (MR) under water stress (E_2) environment can be used for future evaluation across locations for red rot resistance under limited water conditions.

Based on the results summarized above, the present study concludes as follow:

- Analysis of variance revealed significant difference among clones and varieties for cane yield, its components, physiological and quality traits under both E_1 and E_2 environments except for chlorophyll a and number of stomata, the stalk length, RWC at 60 DAP, chlorophyll b and purity (%) at 10 months under normal (E_1) environment.
- High magnitude of coefficient of variation (PCV and GCV) were recorded for germination, single cane weight and CCS (t/ha) under both normal (E_1) and water stress (E_2) environments while for cane yield and specific leaf weight high PCV was recorded under both E_1 and E_2 environments while high GCV for these traits were exhibited under E_2 only.
- High heritability coupled with high genetic advance was recorded for number of shoots at 120 days, cane yield, CCS (t/ha) under water stress (E_2) environment indicated that direct selection of these traits under water stress conditions could be effective.
- Association studies for agro-physiological traits revealed that cane yield had significant and positive association with stalk length, stalk diameter, single cane weight and chlorophyll content under both normal (E_1) and water stress (E_2) environments. Number of stomata, chlorophyll content, specific leaf weight and RWC at 60 and 120 days are identified as important physiological traits for cane yield as well as sugar content under water stress (E_2) environment.
- Among quality traits, CCS (t/ha) at harvest exhibited significant positive association with pol (%) in juice at 10 months, purity (%), CCS (%) at 10 months, brix (%), CCS (%) at 12 months and pol (%) in cane at harvest under both E_1 and E_2 environments.
- Path analysis revealed that under normal (E_1) conditions, number of millable canes exhibited highest positive direct effect on cane yield followed by stalk diameter, number of stomata, RWC at 120 days, specific leaf weight and stalk length. However, under water stressed (E_2) conditions number of tillers at 120 days had maximum positive direct effect on cane yield followed by relative water content at 60 days, stalk length, RWC at 120 days, number of shoots and single cane weight.
- Under water stress (E_2) conditions, pol (%) in juice at 12 months had maximum direct effect on CCS (t/ha) followed by brix (%) at 10 months, purity (%) at 10 months, pol (%)

in juice at 10 months, fibre (%) at harvest, pol (%) cane percentage at harvest and juice extraction (%) at 10 months.

- Cane yield percent reduction under E₂ ranged from 16.66 to 47.89% and DSI ranged from 0.51 to 1.47 showing a differential behaviour of clones/varieties to water stress. Minimum DSI value and percent reduction under E₂ among cane and component traits were exhibited for number of millable canes followed by germination (%), number of tillers at 240 days and stalk length. Among physiological traits, DSI and percent reduction under E₂ for total chlorophyll content was ranged from 0.51 to 1.32 and 17.08 to 34.39 (%), respectively. Maximum values of DSI and percent reduction under E₂ were recorded for RWC at 120 DAP followed by number of stomata and specific leaf weight. The clone ISH135 showed minimum percentage reduction and DSI value in total chlorophyll content under water stress (E₂) environment. Among quality traits, percent decrease in E₂ for CCS (t/ha) at harvest varied from 25.54 to 62.54 (%) with DSI value ranged from 0.61 to 1.49. The clones/varieties like CoJ88, CoS8436, CoPb91, CoPb10181, CoPb13182 had high DSI value under this trait so these genotypes were categorized as drought susceptible (S>1.00). Maximum DSI and percent reduction under E₂ was recorded for CCS (t/ha) followed by CCS (%) at 12 months and fibre content (%) at harvest. Based on DSI and percent reduction under E₂ it was concluded that clones KV2012-2, KV2012-3, KV2012-4, KV2012-5, ISH148, ISH07 and ISH135 had least affected by water stress and have ability to withstand water stress conditions. So, these clones can be considered as tolerant to water stress conditions and can be utilized in future evaluation against limited water conditions over locations.
- Results for disease screening reported that five varieties namely Co238, CoS8436, Co118, CoPb92 and CoPb93 and 8 elite clones namely ISH07, ISH135, CoPb14211, CoPb14212, CoPb13182, CoPb11214, CoPb11211, CoPb12212 were categorized as moderately resistance to both CF 08 and CF 09 pathotypes of red rot, so these clones can be used in future evaluation for red rot resistance under limited water conditions over locations.

The varieties/clones having high yield and sugar, moderately red rot resistance and low DSI were identified that can be utilized for future evaluation on large scale against water limited conditions across multilocation for their wider adaptability.

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Appendix 1 Mean Weekly meteorological data of 2016-17 at RRS, Kapurthala.

Date	Temperature (°C)		Total Rainfall (mm)
	Max	Min	
8 – 14 Jan	7.6	20.1	14.0
15 – 21	6.3	12.4	-
22- 28	4.6	13.6	3.0
			-
29- 4 Feb.	4.1	20.1	4.0
5 – 11	3.9	21.9	-
12 – 18	4.7	20.7	-
19-25	4.7	24.0	7.0
26-4 March.	9.1	28.5	-
5 – 11	10.7	30.0	7.0
12 – 18	9.9	22.3	28.0
19 – 25	10.4	29.9	-
26- 1 April.	12.1	32.0	-
2 – 8	17.0	33.6	-
9 – 15	15.9	35.4	-
16 – 22	18.7	40.4	-
23 -29	15.3	40.0	-
30 – 6 May.	20.1	39.7	-
7 – 13	23.3	40.6	-
14- 20	23.4	42.3	-
21 – 27	23.7	38.9	15.0
28 – 3 June.	25.9	40.0	8.0
4 – 10	28.3	41.3	-
11 – 17	25.0	36.6	0.5
18-24	24.7	36.3	18.0
25- 1 July.	29.4	36.6	6.0
2 – 8	26.6	32.7	-
9 – 15	27.4	37.4	-

Date	Temperature (°C)		Total Rainfall (mm)
	Max	Min	
16 – 22	26.4	31.7	-
23 – 29	26.3	33.7	-
30- 5 Aug.	27.7	35.4	-
			-
6 – 12	26.4	33.7	-
13 – 19	25.0	34.7	-
20 – 26	25.7	34.3	-
27 – 2 Sept.	23.9	31.9	-
3 – 9	25.4	33.7	-
10 – 16	24.0	33.6	-
17- 23	25.9	36.0	-
24 – 30	24.0	34.3	-
1 – 7 Oct.	23.7	36.0	-
8 – 14	20.1	34.6	-
15 – 21	16.4	35.1	-
22 – 28	14.1	33.7	-
29 – 4 Nov.	12.4	31.3	-
5 – 11	9.9	30.7	-
12 – 18	8.7	28.9	-
19 – 25	8.7	27.9	-
26 – 2 Dec.	7.7	27.6	-
3 – 9	6.6	25.1	-
10 – 16	7.3	19.7	-
17 – 23	4.3	18.7	-
24 – 31	5.0	23.1	-

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