PAKISTAN SUGAR JOURNAL

Subscription
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Subscription Rate

Pakistan	PKR 1,000/-
OVERSEAS	US$ 50/-

Recognized by
Higher Education Commission (HEC) Pakistan

Cited by
Asia Net Pakistan (Factiva International)
Commonwealth Agriculture & Biology International (CABI-UK)

ISSN 1028-1193

CONTENTS

ADOPTION OF ENERGY SAVING EQUIPMENTS AT RAMZAN SUGAR MILLS

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ABSTRACT

In sugar industry energy conservation means to increase the earning of the organization, decrease in energy consumption for processing reduces the cost of production and give saving of fuel. Keeping in view these aspects and future vision of our honorable Managing Director, the management of Ramzan Sugar Mills is continuously working on energy saving program since last 5 years. Some bold steps have been taken in this respect; modern technologies and efficient energy saving equipments are adopted such as:

Falling Film Evaporators
Evaporator Arrangement
Vapor Line Heaters
Direct Contact Heaters
Flash Heat Recovery
Molasses Conditioning With Low Temperature Vapor
Use of Hot Condensate for Sugar Drying
Auto Condensing and Spray system

Installation of VFDs

The whole team of RSML is committed to optimal use of energy to ensure cost effective operations and conservation of energy resources. By grace of ALLAH it is the hour of satisfaction that we have achieved a goal of remarkable decrease in steam consumption and bagasse saving. This is the reason why RSML is travelling efficiently and successfully towards power co-generation with available resources in the existing setup of project.

Introduction

Any attempt at Energy Conservation in a steam generation system is constituted of two basic aspects,

a- Installation of suitable energy efficient equipment in the factory.

b-Energy efficient operation of the factory.

The presentation deals essentially with the first.

1. Falling film Evaporator

In this popular type of evaporator, juice travels from top to the bottom and as it descends, it takes the entrained vapour along with it to a lower chamber, where the vapour and liquid are separated.

The falling film evaporators have many advantages over the conventional evapora-tors:

Effective juice distribution and short contact time between juice and steam.

The falling film evaporator offers an excellent heat transfer.

The design of the evaporators is such that, the juice is in contact with the heating surface in a thin layer over the length of the heating surface.

In Ramzan Sugar Mills Limited, Chiniot, we got the opportunity to install a pair of falling film evaporators (3000 M2 + 3000 M2) and by the grace of ALMIGHTY ALLAH, after successful operation of 1st set of FFEs , it was decided to install more FFEs for further steam economy and enhancement in crushing, so in 2011 one more pair of FFEs (3000M2) each was installed and operated with considerable steam economy and remarkable fuel saving in season 2012-13 and 2013-14.

All these results and success encourages the management of RSML to work more in this respect. Now another FFE of 6000M2 is being installed to decrease steam consumption up to 42% on cane and to enhance crushing capacity up to 12000 TCD.

2- VAPOR LINE HEATER

The vapors exerted by the last effect of evaporators set generally goes to condenser. These vapors contain a smart amount of heat energy which is wasted in spray pond and creates extra load on spray system. We decide to use this energy for 1st stage primary heating. For this purpose in RSML tubular heaters are installed in vapor line of last effects. These heaters give a remarkable rise in temperature of raw juice, which gives considerable economy of vapors and load on condensers is also reduced which leads towards less consumption of injection water too.

The Advantages

It works as an effective entrainment catcher.

Consumes last effect evaporator effectively.

Additional amount of condensate is obtained which can be used to fulfill boiling house needs.

Steam economy due to usage of vapors going to condenser and less consumption of injection water.

3- Direct Contact Heaters

This invention is more efficient in respect of transmission of heat because of direct contact of heating media with juice. No heat loss occurs in shape of condensate because total heat content of vapors is transmitted to juice.

In R.S.M.L three D.C heaters were installed in year 2010. Direct Contact (DC) Heaters have high heat transfer coefficient due to absence of resistances like liquid film resistance, condensing vapor resistance, resistance of scale and tube material.

Main benefits of DC heaters:

Eliminate juice heater cleaning

Economical system as no standby vessel is required for cleaning

Low maintenance

Easy to operate and control

High heat transfer efficiency

Can be operated at low pressure vapor

Heating of juice in counter current manner that removes dissolved gases very efficiently and enhances clarification efficiencies

FLASH CIGAR:

In 2010 at the start of energy saving program at RSML when it was decided to install a set of 1st two FFEs, it was also considered to install centralized control management system of condensate.

Condensate from all evaporators of quintuple effect except steam condensate enters in different chambers accordingly, flash is taken out from each chamber and condensate travels towards next chamber and at the end, from last chamber after taking out maximum flash it is pumped towards over head service tank.

Flash Cigar improves water management of the plant by reducing the final condensate temperature to level required for process use.

The basic principle is to recover the flash from the condensate coming out from

the heaters, evaporators and pans.
It gives steam economy about = 1.76 %on cane

Advantages
Eliminates the installation of no. of condensate tanks along with its Pumping System. This in turn saves electrical energy and also reduces cost of maintenance
Elimination of sealing tanks and piping removes congestion at the Process House
Trouble free operation and easy to maintain
No air leakage in the vacuum system
Improves the water management of the plant

Stainless steel siphons are provided to transfer the condensate to lower pressure chambers making its operation trouble free and fool proof.

5- Plate Heat Exchanger
It is a simple plate heat exchanger in which from one end condensate of 1st effect FFE (steam condensate) enters having temperature about 120 °C, from the other end a part of condensate of about 84°C from last chamber of cigar enters as counter current flow, here heat transfer takes place and steam condensate of about 110 °C pumped for boilers storage tanks, and from the other end temperature of circulated condensate of last chamber rises up to 112 °C enters again in first chamber of cigar tank for flash recovery.

6- Molasses Conditioners
Previously for molasses conditioning at RSML traditional method of dilution, stirring and heating with washing steam was implemented, but in 2010-2011 imported molasses conditioner were installed and operated successfully. This type of conditioners gives some benefits leading towards energy savings, and works without additional water for dilution.
Direct contact molasses conditioners ensure perfect dissolution of crystals by using heat content of low pressure vapor for savings in steam.

Advantages
Direct heating of molasses under vacuum helps perfect dissolution of crystals
Avoids addition of water but also improves the quality of conditioned molasses which is very good for the process
High heat transfer efficiency.
Efficient operation on low pressure vapors.
No stirrer required thus no troubles associated with using mechanical stirring.

7- Hot Water Radiators
We all are well aware that extra moisture content in finished product creates huge problems and leaves bad effect over packed sugar. So drying of sugar is an important matter of sugar manufacturing. Traditionally steam radiators are used in sugar industry to get hot air for sugar drying.
At R.S.M.L, in energy saving struggles these steam radiators also replaced with hot water radiators. For this purpose hot water of about 80 - 85°C from overhead service tank is used. The temperature of hot air gained is 60 to 65 °C, while the dried sugar temperature is 38 – 42 °C.

8- Efficient Condencing & Spray System
In the year 2009 decision was taken by management to replace the old multi jet condensers and spray system with more efficient automated condensers and spray system.
All multi jet condensers were replaced with automated condensers.
Old injection pumps of 3200 M3/hr replaced with 2200 M3/hr.
Similarly on spray side pumps of 3200 M3/hr were replaced.
At spray pond old nozzles were replaced with more effective clusters. Each cluster consists of 5 nos. of nozzles
As a result of modification at spray pond remarkable drop in temperature was achieved.

Previously the temperature difference was 5°C to 6°C. After installation of new clusters it becomes 10°C to 12°C positively. As a result of all these changes, consumption of injection water reduced to give us huge saving of electrical energy.

It is computerized control system. The main aim of which is to reduce the power consumption and number of pumps required for injection water and spray pond water by monitoring the vacuum and temperature at various locations.

Power consumption at injection and spray with old and new pumps is given below.

Injection Pumps

Without Auto Condensing Running Load 1033 KW

With Auto Condensing Running Load 576 KW

Energy Saving 457 KW 1033 KW - 576 KW =

Spray Pumps

Without Auto Condensing Running Load 549 KW

With Auto Condensing Running Load 202 KW

Energy Saving 347 KW549 KW - 202 KW =

Total Saving on Auto Condensing System

Without Auto Condensing
With Auto Condensing

Injection Pumps 1033KW 576KW
Spray Pumps 549KW 202KW
Total 1582KW 778KW

Difference 1582KW - 778KW = 804 KW

9- Installation of VFDs

For saving of electrical energy VFDs are installed at Feed tables, Cane carriers, Cane cutters and boilers.

Total Saving on Feed Tables

Without VFD With VFD
Feed Table-1. 20 KW10 KW
Feed Table-2. 24 KW 12 KW
Feed Table-3. 17 KW 7 KW
Feed Table-4. 30 KW 15 KW
Total 82 KW 47 KW
Difference 82KW - 47KW = 35KW

Total Saving on Cane Carriers

Without VFD With VFD
Cane Carrier-1 43KW 25KW
Cane Carrier-2 80KW 60KW
Cane Carrier-3 60KW 40KW
Total 183KW 125KW
Difference
183KW - 125KW = 58KW

Total Saving on Boilers

Without VFD With VFD
Boiler-2. 366KW 260KW
Boiler-3. 370KW 263KW
Total 736KW 523KW
Difference
736KW - 523KW = 213KW

GRAND TOTAL
BOILERS 213KW
CANE CARRIERS 58KW
FEED TABLES 35KW
G. TOTAL 306KW

CONCLUSIONS:

Although the falling film evaporators are the main source of energy saving endeavor in Ramzan Sugar Mills Limited and since installation of vapor line heaters, they are also giving considerable energy saving, but “Many Small Drops Make a River” Spray system, Flash Cigar, D.C Heaters, P.H.E, Molasses Conditioners, Hot Water Radiators and VFDs etc all these equipments jointly contributed in energy saving and shared a reasonable amount of saved fuel.

This saving of fuel is encouraging the management for power co-generation in the light of vision of our honorable Managing Director. So work on 60 MW power plant installations has been started and in future we are planning for complete electrification of the project.


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RATOON PERFORMANCE OF ELITE SUGARCANE CLONES UNDER SOUTHERN PUNJAB CONDITIONS

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ABSTRACT

A field experiment to investigate ratooning potential of ten sugarcane clones was carried during 2013-2014 at Sugarcane Research Station, Khanpur under hot dry conditions of Southern Punjab. The genotypes under investigation were S2003US.114, S2003US.165, S2003US.824, S2006SP.18, S2006SP.25, S2006US.469, S2006US.658, S2006US.832, S2006US.834 and CPF.246 (Standard). The results revealed that new promising sugarcane clone S2006US.658 on account of best stubble sprouting plant^{-1} (2.79), highest 100-cane weight (103.67 kg) coupled with good millable cane count (104.64 thousand ha^{-1}) gave maximum stripped cane yield of 107.63 tons ha^{-1}. It was matchingly followed by S2003US.114 and CPF.246. The top yielder is also good in quality and as such it fetched maximum sugar yield of 12.86 tons ha^{-1} followed by S2003US.114 (12.05 tons ha^{-1}). The promising sugarcane clone S2006US.658 owing to 7.45 and 0.96 % more ratoon cane and sugar yield, respectively over standard variety is capable of replacing it and can make gigantic strides in sugarcane production for sweet revolution. However, its wide scale testing in various agro ecological zones is invited for regional adoptability.

Keywords: Sugarcane, Clones, Ratoon, Sugar, Millable Canes.

INTRODUCTION

Ratoon keeping is a very common practice among sugarcane growers as is cheaper to grow by about 30-40% due to saving in soaking irrigation, land preparation, cost of seed and sowing operations (Akhtar *et al.,* 2003).Ratoons have an additional advantage in giving better juice quality and sugar recovery in comparison to the plant crop of same variety under similar conditions (Yadava, 1991). Ratoon occupies 35-50 % of the total sugarcane area in Pakistan (Malik and Gurmani, 2005).Afzal et al., 1990 studied the ratoon performance of six sugarcane varieties and recorded maximum average cane yield of 75.55 tons ha^{-1} for CP 43-33. The same variety surpassed in sugar yield. El-Geddawy *et al.,* 2002 elucidated that sugarcane variety GIT.54-9 significantly superseded the other sugarcane varieties in respect of stalk height, diameter and weight in both ratoon crops. Rafique *et al.,* 2005 carried out two years field experiment to investigate ratooning potential of 10 sugarcane varieties and concluded that CPF-234 and HSF-240 gave significantly more ratoon yield during both years of study primarily due to better sprouting of subterranean buds and cane formation. Bashir *et al.,* 2007 undertook a field study on ratooning ability of spring planted sugarcane varieties and observed that maximum cane yield was produced by CPF.237 and HSF.242 of ratoon crop. Jamil et al, 200evaluated the ratooning behavior of 22 candidate sugarcane varieties under NUYT programme. Findings of theier study revealed that promising sugarcane varieties S95HS.185, S97US.183, S96SP.302, CPHS.35, NSG.311 and Malakand-16 were better ratooners. Khan *et al.,* 2007 indicated that sugarcane variety S96SP.302 produced significantly maximum ratoon cane yield of 79.39 tons ha^{-1} against the lowest cane yield of 41.94 tons ha^{-1} recorded for NSG.311.The higher cane yield was mainly associated with high number of millable canes, cane height and cane girth. Aslam *et al.*, 2011 studied the ratoon performance of 13 sugarcane varieties and found that CPF.246 on account of higher number of sprouts/plant (1.57), significantly higher 100-cane weight of 95.67 kg, highest millable cane count of 112.69 thousand ha^{-1}, maximum cane yield of 107.90 tons ha^{-1} and comparable CSS of 12.74% against the check variety SPF-234, produced the highest sugar yield of 13.74 tons ha^{-1}. Aslam *et al.,* 2013 conducted a field study to explore ratooning potential of eight sugarcane varieties and disclosed that S2003US.114 gave significantly higher cane yield of 108.05 tons ha^{-1} owing to good stubbles sprouting, higher cane weight and reasonably good millable cane count. The top yielder was also good in quality and produced highest sugar yield of 13.41 tons ha^{-1}. Therefore, the present study was planned to assess the ratooning performance of nine elite sugarcane clones in comparison to commercial sugarcane variety CPF.246 under southern Punjab agro climatic conditions.

MATERIALS AND METHODS

The field experiment was conducted under irrigated conditions during spring season to evaluate the ratooning potential of ten elite sugarcane genomes during 2013-2014 at Sugarcane Research Station, Khanpur. The experiment was started during 2013 when the spring crop was harvested in the first week of February and kept as ratoon. The varieties included in the study were S2003US.114, S2003US.165, S2003US.824, S2006SP.18, S2006SP.25, S2006US.469, S2006US.658, S2006US.832, S2006US.834 and CPF.246 (Standard). The experiment was laid out in Randomized Complete Block Design with three replications. The sugarcane genotypes were sown by dry method in 120cm apart trenches with a net plot size of 3.6 × 10 m using a seed rate of 75000 double budded setts per hectare. The ratoon crop was fertilized at the rate of 218-146-146 kg NPK per hectare, respectively. After harvesting the plant crop, uneven stubbles were cut manually with the help of hand chopper. Then interculture was given to control weeds, loosen the soil to help root development and thus facilitate sprouting. Afterwards, whole of P, K and 1/3 of N was applied to the crop followed by irrigation. The remaining 2/3 N was given in two equal splits, 1/3 at completing sprouts (60 days after harvesting of plant crop) and 1/3 during the second fortnight of May when crop was earthed up. Meanwhile data on number of sprouts per plant were recorded. The data on cane density, weight, yield and quality were recorded at the harvest during the last week of December 2013. The data thus recorded were analysed using Analysis of Variance techniques and Least Significance Difference test was applied to compare the treatment means at five percent level of probability (Steel and Torrie, 1984).

Sprouts per plant

The sprouting of underground buds predicts the final millable cane stand of ratoon sugarcane crop to a large extent. The sprouting of subterrain stubble eyes is mainly affected by climatic conditions, soil moisture, plant stand and vigor of previous sugarcane crop. The data presented in table- 1 depict that there were significant differences in the number of sprouts per plant given out by the tested sugarcane clones. The promising sugarcane genotype S2003US.658 produced the highest number of sprouts $plant^{-1}$ (2.79). It was matchingly followed by S2003US.469.The lowest number of sprouts has been recorded for S2006US.832 in this study. These differences in the number of sprouts $plant^{-1}$ may be attributed to the varied inherent ratooning potential of the sugarcane varieties (Rafique *et al.,* 2005).

Cane Weight

Cane weight is one of the most important yield determining characters which directly affects the final sweep of sugarcane and is very much genetic in nature. However, the management practices also affect cane girth and weight. It is evident from the respective data embodied in table- 1 that the tested sugarcane clones behaved differently with respect to individual stalk weight. The new emerging sugarcane genome S2006US.658 produced the heaviest canes (103.67 kg per 100 canes). It was non-significantly followed by S2006US.114 and CPF.246.The lowest 100-cane weight of 77.67 kg was recorded for S2006US.832 preceded by S2006SP.18.These differences in the stalk weight were probably due to the differences in the genetic potential of tested sugarcane genotypes. The results are quite in line with the findings of Aslam *et al.,* 2011 and Aslam *et al.,* 2013.

Cane Density

Plant population per unit area is a vital yield component and directly affects the final harvest of the crop. The establishment of millable canes is a reflection of stubbles sprouts in ratoon crop of sugarcane. The data compiled in table-1 evince that the final cane stand established by tested varieties varied significantly. The highest number of millable canes were produced by S2006US.832 (112.70 thousand ha^{-1}) closely followed by S2006SP.25 (109.60 thousand ha^{-1}) and S2006US.658 (104.64 thousand ha^{-1}).The thinnest stand of 82.21 thousand canes ha^{-1} was recorded for S2006US.834.The differential behaviour of sugarcane genotypes for the production of variable number of millable canes may be attributed to the varying inherent potential of different genotypes to explore environmental resources. Similar results have also been reported by Aslam *et al.,* 2011 and Aslam *et al.,* 2013.

Stripped cane Yield

High cane yield is the ultimate target of every grower which is the happy blend of the ecosystem and the genetic potential of a variety. Different varietal traits like stubble sprouting, cane formation, cane height, girth and per cane weight have direct effect on the final ratoon cane yield. It is evident from the data presented in table- 1 that the tested strains differed substantially in final ratoon cane yield. The promising sugarcane variety S2006US.658 gave significantly highest ratoon cane yield of 107.63 tons ha^{-1}. It was comparably followed by S2003US.114 and CPF.246 with a final tonnage of 101.37 and 100.17 per hectare, respectively. The lowest cane yield of 74.66 tons ha^{-1} has been recorded for S2006US.834 preceded by S2006SP.18.These differences in the final cane yield of different sugarcane genotypes may probably be due to their varied genetic makeup. Rafique *et al.,* 2005, Jamil *et al.,* 2007, Khan *et al.,* 2007 and Aslam *et al.,* 2011 have also reported the varied tonnage of ratoon stripped canes for different genotypes in their investigations.

Sugar Yield

The ultimate aim of all the efforts being carried out by a researcher, grower or miller is the attainment of higher tonnage of sweet sugar which is actually produced in the field and extracted in the factory. The scientific data embodied in table- 1 indicated that all the sugarcane clones under study behaved differently from one another for the production of sugar yield per unit area. The highest sugar yield of 12.86 tons ha^{-1} was produced by the promising strain S2006US.658 closely followed by S2003US.114 (12.05 tons ha^{-1}). The least amount of white sugar (8.35 tons ha^{-1}) was recorded for S2006US.834.This differential behaviour of Sugarcane varieties/clones to produce sugar yield may be attributed to the variability in their genetic makeup to explore the environment to which they were exposed. Bashir *et al.,* 2007, Aslam *et al.,* 2011 and Aslam *et al.,* 2013 have also reported the similar results.

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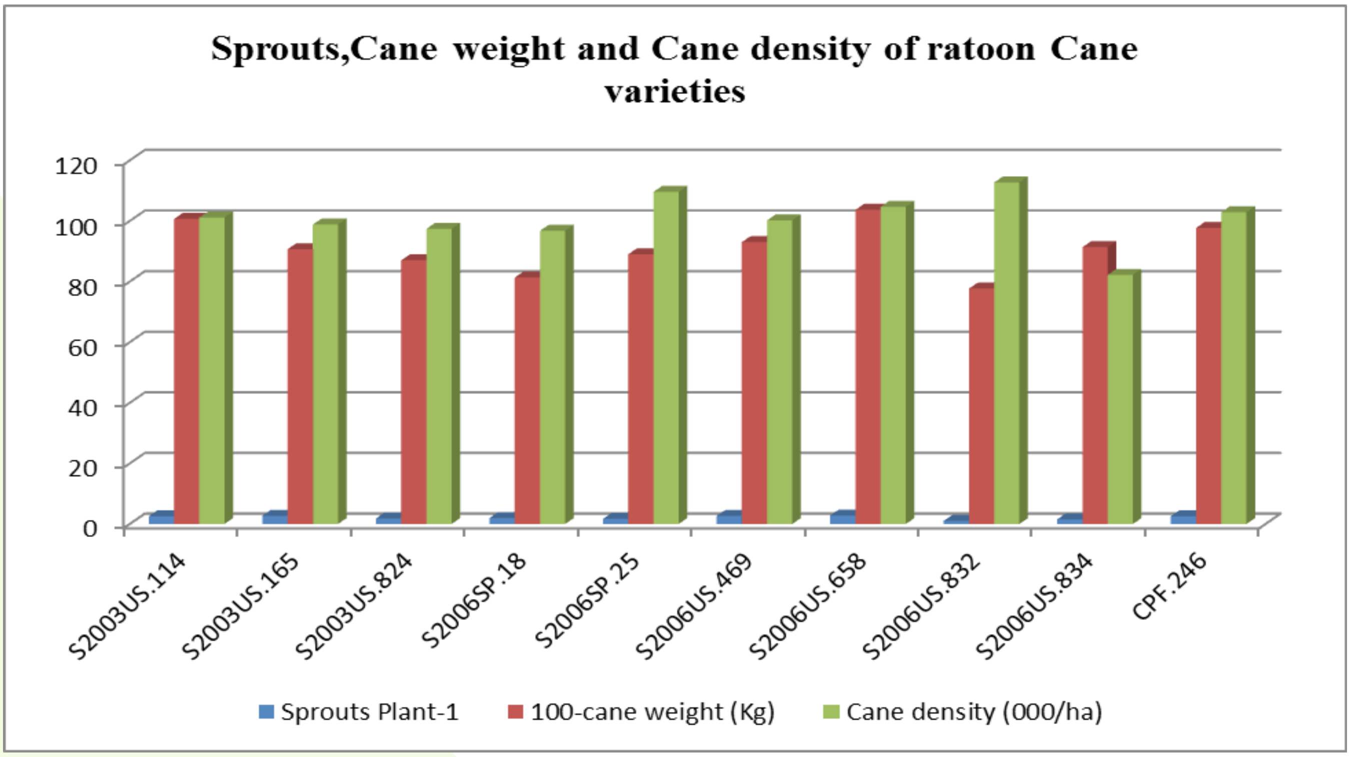
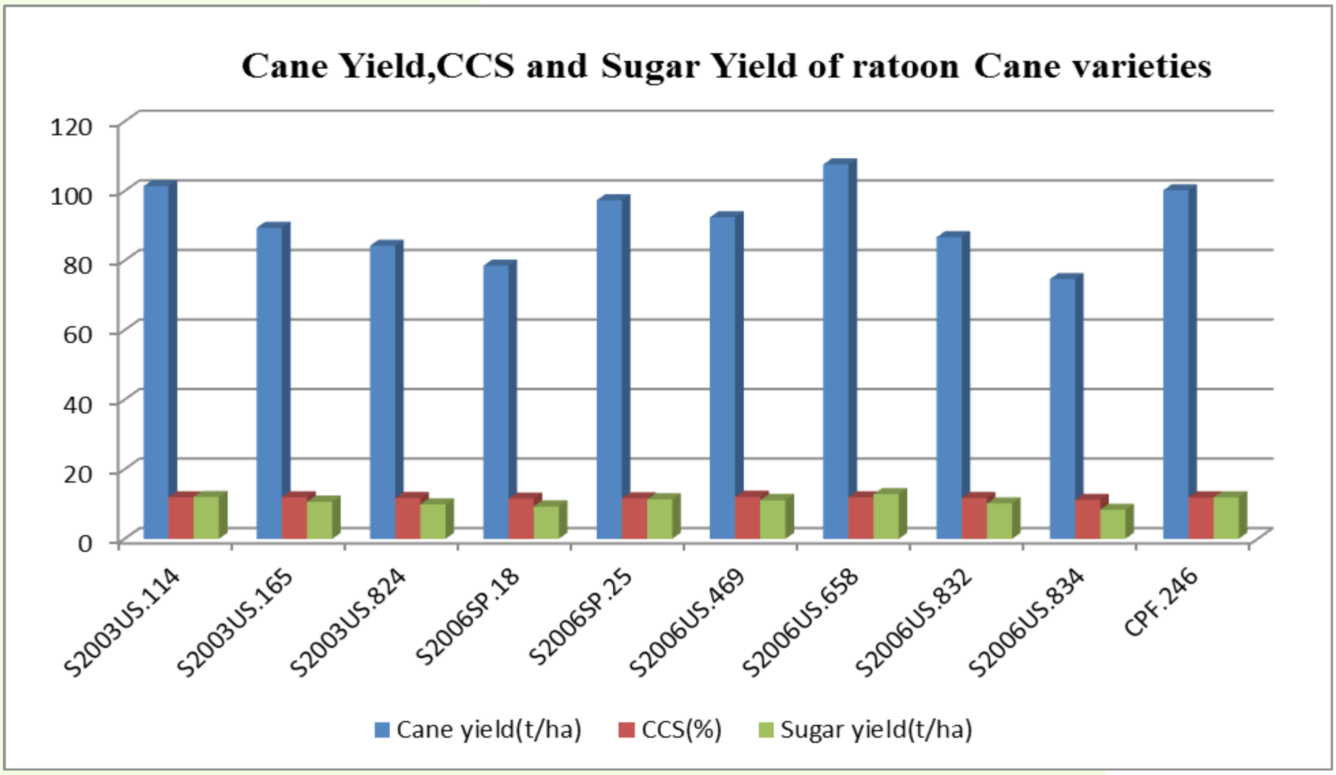
Table-1 Ratoon performance of sugarcane varieties under southern Punjab conditions

Sr. No	Variety	Sprouts Plant $^{-1}$	100-cane weight (Kg)	Cane density 000/ha	Cane yield (t/ha)	CCS %	Sugar yield (t/ha)
1	S2003US.114	2.53a	100.67ab	101.09ab	101.37ab	11.89	12.05
2	S2003US.165	2.68a	90.67abc	98.81ab	89.45cdef	11.95	10.68
3	S2003US.824	1.84b	87.00abc	97.40ab	84.29efg	11.73	9.89
4	S2006SP.18	1.94b	81.33bc	96.74ab	78.51fg	11.58	9.30
5	S2006SP.25	1.67b	89.00abc	109.60a	97.34abcd	11.66	11.35
6	S2006US.469	2.61a	93.00abc	100.20ab	92.44bcde	12.07	11.15
7	S2006US.658	2.79a	103.67a	104.64ab	107.63a	11.95	12.86
8	S2006US.832	1.04c	77.67c	112.70a	86.71def	11.72	10.16
9	S2006US.834	1.56b	91.33abc	82.21b	74.66g	11.19	8.35
10	CPF.246	2.59a	97.67abc	102.89ab	100.17abc	11.88	11.90
LSD 0.05		0.39	21.54	22.97	11.07	--	--

Values with different letter(s) differ significantly (P=0.05)


Sprouts,Cane weight and Cane density of ratoon Cane varieties
120
100
80
60
40
20
0
S2003US.114
S2003US.165
S2003US.824
S2006SP.18
S2006SP.25
S2006US.469
S2006US.658
S2006US.832
S2006US.834
CPF.246
Sprouts Plant-1
100-cane weight (Kg)
Cane density (000/ha)


Cane Yield,CCS and Sugar Yield of ratoon Cane varieties
120
100
80
60
40
20
0
S2003US.114
S2003US.165
S2003US.824
S2006SP.18
S2006SP.25
S2006US.469
S2006US.658
S2006US.832
S2006US.834
CPF.246
Cane yield(t/ha)
CCS(%)
Sugar yield(t/ha)

CHARACTER ASSOCIATION AND PATH ANALYSIS OF THE PHYSIOLOGICAL RESPONSES UNDER MOISTURE STRESS IN SUGARCANE VARIETIES

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ABSTRACT

Fifty two commercial varieties of sugarcane (*Saccharum* sp.) were evaluated based on the morpho-physiological responses to moisture stress. All the varieties were planted in pots under green house conditions and two replications were subjected to moisture stress by withholding irrigation after two months of growth. The appearance of the wilting symptoms of each variety under stress condition were recorded and analysis of moisture stress related physiological traits such as proline, electrical conductivity (EC), relative water content (RWC) and chlorophyll content were done 8 days after stress induction under stress and unstressed conditions. RWC (stress), chlorophyll content (stress) and EC (unstressed) showed positive correlation and total contribution effect on moisture stress tolerance which measured in terms of the days taken for appearance of wilting symptoms. Therefore, improvement in moisture stress tolerance in sugarcane could be achieved by selecting breeding materials with high EC (unstressed), RWC (stress) and chlorophyll content (stress).

Key words: Heritability, Correlation, Path coefficient, Moisture stress, Physiological traits, Sugarcane

INTRODUCTION

Sugarcane is the world's largest crop by production and cultivated on an about 26.0 million hectares, in more than 90 countries (FAO, 2014). As the major contributor of sucrose to the world, it is being cultivated in tropical and subtropical regions in the world. Due to the increasing population, demand for the sucrose is increasing day by day. The expansion of cultivation area and introduction of the high yielding varieties are the well recommended solutions to meet the increasing demand. As a highly water demanding crop at the initial stages of the plant growth and development, expanding the area under cultivation has become a problem to the sugarcane farmers. Hence, development of high yielding moisture stress tolerant cultivars is the best solution to meet the increasing demand (Silva *et al*., 2007).

The performance of a genotype in terms of productivity is the net result of genotype into environment interaction. Morphological, physiological changes and biochemical modifications are responsible for moisture stress tolerance (Yordanov *et al*., 2003). Therefore, plant scientists are making concerted efforts in identifying genotypes with higher yield coupled with relatively better moistures stress tolerance. But the progress in breeding for moisture stress tolerance is slow due to the quantitative and temporal variability of available moisture across years, the low genotypic variance in yield under these conditions and inherent methodological difficulties in evaluating component traits together with the highly complex genetic basis of this character (Turner *et al.,* 2001). Studying the traits which contribute to moisture stress tolerance in different varieties and their genetic basis is, therefore, fundamental to enable breeders and molecular biologist to develop new varieties with improved moisture stress tolerance. Further, an understanding of the physiological processes in relation to stress tolerance is essential for identifying physiological criteria for screening the abiotic stress tolerant varieties (Rao, 1994). The knowledge of the relative contribution of individual traits to moisture stress tolerance may be accomplished by correlation studies but the idea of direct and indirect contribution of each trait towards tolerance cannot be traced through correlation studies (Allard, 1960; Chaubey and Singh, 1994). Therefore, the path coefficient analysis is utilized to have an idea of direct, indirect and total contribution of the traits towards moisture stress tolerance (Dewey and Lu, 1959). Therefore, this study was conducted to gather information on heritability, correlation and path coefficient of physiological traits related to moisture stress tolerance in 52 sugarcane varieties.

MATERIALS AND METHODS

Fifty two commercial sugarcane varieties were planted in the pots filled with soil (one single bud sett per pot) in four replications. All pots were irrigated once in two days and maintained under green house condition. After 2 months of planting, water stress was induced by withholding the irrigation (stress) for two replications of each variety and remaining were irrigated as usual (unstressed). Treated plants were subjected for increasing water deficiency and date of appearance of wilting symptoms were recorded during the moisture stress period. Leaf samples were collected 8 days after moisture stress induction for analysis of moisture stress related physiological traits such as RWC (Silva *et al.* 2008), chlorophyll content using SPAD meter (502 Plus, Spectrum Technologies, Plainfield, IL, USA), free proline content (Bates *et al.* 1973) and electrical conductivity using the electrical conductivity-meter. The data were analyzed statistically using standard protocols (Panse and Sukhatme 1954). The simple correlation coefficients were calculated to determine the direction and magnitude of associations among different characters and tested against table‘t’ values (Fisher and Yates, 1963). Path coefficient analysis was made on the basis of correlation coefficients taking moisture stress tolerance as effect and the physiological traits related to moisture stress as causes. Direct and indirect effects of component traits on moisture stress tolerance were worked out using path coefficient analysis (Dewey and Lu, 1959).

RESULTS

Appearance of wilting symptoms

Different varieties differed for the number of days taken for the appearance of wilting symptoms after withholding irrigation (Table 1). Of the 52, three varieties namely Co 94008, CoT 8201 and ISH 100 showed wilting symptoms after 12 days of moisture stress induction and Co 775 and Co 99010 varieties showed early (4 days) wilting symptoms. Rest of the varieties showed the wilting symptoms 6 (11 varieties), 8 (27 varieties) and 10 days (9 varieties) after stress induction (Table 1).

Physiological traits

ANOVA indicated the significant differences in the responses of varieties to moisture stress in all the physiological traits studied (Table 2). The genetic parameters such as genotypic variance (Vg), phenotypic variance (Vp), genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability (broad sense) (Hbs), for various moisture stress related traits under control and moisture stress were calculated and presented in Table 3.

The highest genotypic (128.95) and phenotypic (130.51) variability were observed for RWC (stress) and minimum genotypic (0.02856) and phenotypic (0.02860) variability observed for free proline content (unstressed) of the varieties. Proline content (stress) showed the maximum GCV (125.70) and PCV (125.77) and RWC (unstressed) showed the minimum values for GCV (4.93) and PCV (5.92). Heritability for all traits were high (> 60%) and ranged from 69.34 (RWC under control) to 99.89 (proline content under stressed condition).

Correlation among the different moisture stress related traits.
Correlation coefficients were determined to know the nature and magnitude of relationship existing between moisture stress related traits and the degrees of association of different characters are presented in Table 4. Correlation among the data of appearance of wilting symptoms and other physiological traits related to moisture stress were observed. EC (unstressed (0.352)), RWC (stress, (0.648)) and chlorophyll content (stress, (0.427)) showed positive correlation with the date of appearance of wilting symptom and the percent reduction of RWC (-0.628) and chlorophyll content (-0.675) showed negatively correlations.

The moisture stress related traits also showed the significant correlations among the traits. Proline content under moisture stress condition correlated significantly and positively (0.435) with electrical conductivity under moisture stressed condition. Further, RWC under stressed condition were positively and significantly (0.422) correlated with the chlorophyll content under stressed condition.

Path coefficient analysis
In the path analysis, correlation coefficients were partitioned into direct and indirect effects (Tables 5) and results showed that RWC (stress) had highest total contribution effect (0.633) including indirect effects (0.772) on time taken for appearance of wilting symptoms. Chlorophyll content (stress) showed maximum direct contribution effect (0.429) towards moisture stress tolerance. EC (unstressed) showed positive indirect (0.127), direct (0.235) and total contribution effect towards the time taken for the appearance of wilting symptoms. Free proline content showed low total contribution effect (0.012) due to high negative indirect effect (-0.154) though it had positive direct effect (0.167) on appearance of wilting symptoms.

DISCUSSION

Moisture stress is a complex process connected with almost all aspects of biology (Bayoumi *et al*. 2008). Genetic improvement in moisture stress tolerance may be achieved by targeting traits closely associated with moisture stress tolerance. A number of characteristics have been proposed as indirect selection criteria for genetic improvement of moisture stress tolerance in breeding programmes (Skinner et al., 1987; Rebettzke et al., 2002).

Understanding the associations between traits is of great importance in breeding and selection studies especially for traits with low heritability or difficult to measure traits (Bakhsh et al., 2006; Silva et al., 2007). Consideration of genetic relationships between important attributes in exploiting genetic populations through breeding and directed selection is essential, primarily to understand how changes made by selecting one character may cause changes in others (Jackson, 1994; Tyagi and Khan, 2010). This knowledge can be used when devising appropriate selection strategies for particular traits in a sugarcane breeding programme (de Sousa-Vieira and Milligan, 2005). Changes in physiological parameters under moisture deficit stress were observed (Levitt, 1972) and the analyses of changes of physiological parameters were considered as reliable criteria for the selection of cultivars (Silva *et al*., 2007).

In this study, moisture stress tolerance was measured in terms of days taken to appear the wilting symptoms. The varieties showed wilting symptoms 12 days after stress induction were grouped as highly tolerant and the varieties which showed witling symptoms 4 days after stress induction were grouped as highly susceptible (Table 1). Analysis of variance for all the traits showed significant genotyping effects indicating genetic variability among the varieties and the possibility of genetic improvement in most of the traits studied through selection (Punia, 1982; Khan et al., 2004). Significant water regime x varieties interactions for all the traits revealed that mean performances of the varieties were influenced by the water level.

The GCV and PCV were high under stress than unstressed condition for all the characters except EC. Bayoumi *et al.* (2008) also reported higher GCV and PCV under stress than unstressed condition for RWC and proline content in wheat in the experiment carried out in field. Among the four moisture stress related traits studied, proline content (stress and unstressed) and EC (stress and unstressed) and RWC (stress) showed high values of PCV and GCV indicating that these traits contributed markedly to the total variability and possibility for further improvement for these traits. Though, PCV and GCV for chlorophyll content (stress and unstressed) were moderate and it is amenable for further improvement. RWC (unstressed) showed low values for PCV and GCV which suggest that negligible contribution of this trait to total variability. Further, it indicated that there is a little scope to improve further for moisture stress tolerance. Less PCV and GCV values in RWC was recorded by Praveen and Patil (1997) in the experiment conducted to study the genetic parameters of twelve Ber cultivars. Difference between GCV and PCV were also found to be less for all the traits indicating that these traits were less affected by environmental fluctuations and real effect of the genotype (Johnson *et al.,* 1955).

Presence of variability in the population is prerequisite for selection. However, coefficient of variation reveals only the extent of variability for different characters in the population. The effectiveness of selection for a trait depends on the relative level of genetic and non genetic variation. Hence heritability is a useful parameter, which considers the role of heredity and environment in the expression of a character (Allard, 1960). Effective selection can be achieved only when additive effects are substantial and environmental effects are small.

In this study, the estimated broad sense heritability values for all the traits under stressed and unstressed conditions were high and ranged from 69.34 to 99.89. In general, high heritability for any traits indicates that the traits are less subjected to environmental influence and suitable for phenotypic selection. Since, the present experiment was conducted under green house condition, environment influence was low and high heritability values (>60) for all the traits were observed. Among the observed heritability values, RWC under control condition showed lowest heritability value (69.34). Similar result for RWC was recorded by Praveen and Patil (1997) in Ber.

Correlations among phenotypic traits may reflect biological processes that are of considerable evolutionary interest and can be the result of genetic, functional and physiological or developmental nature (Soomro et al., 2006; Ulloa, 2006). In this study, correlation study was made to establish the extent of association between morphological and physiological data. Percent increase in EC and EC (stress) were not shown any relation with the date of appearance of witling symptoms. Due to positive direct, indirect and total contribution effects, EC of a variety (EC control) was significantly and positively correlated with the date of appearance of wilting symptoms. Hence, selection of genotypes with comparatively high EC may improve the tolerance moisture stress.

RWC is a key indicator of the degree of cell and tissue hydration, which is crucial for optimum physiological functioning and growth processes. Among the physiological parameters, estimating RWC to represent the plant water balance is considered as a fast and cheap tool (González and González-Vilar, 2001). In this study, RWC (stress) was positively correlated (0.648) with the date of appearance of wilting symptoms and percent reduction in RWC was negatively correlated (-0.628) to the date of appearance of wilting symptoms. Therefore, RWC can be suggested as a good indicator of stress tolerance in sugarcane. Numerous studies have shown that maintenance of relatively high RWC during mild moisture stress is indicative of moisture stress tolerance (Jamaux *et al.*, 1997, Altinkut *et al.*, 2001, Colom and Vazzana, 2003). RWC was used as a tool to distinguish moisture stress tolerance sugarcane varieties by Silva *et al.* (2007) and Graça et al., (2010) and reported that varieties with higher percentage in RWC as moisture stress tolerant and *vice versa*. Further, path analysis revealed that RWC (stress) showed high positive total contribution effect (0.633) on the time taken for appearance of wilting symptoms due to the high indirect effects (0.772).

Decrease in leaf photosynthetic pigments under moisture stress as has been shown by Chaves *et al*. (2002) in *Quercus ilex*, by Manivannan *et al*. (2008) in sunflower and by Silva *et al*. (2007, 2011) and O'Neill *et al*. (2006) in sugarcane. Chlorophyll content (unstressed (-0.424)) and percent reduction (-0.675) of chlorophyll content showed significant and negative correlation with the date of appearance of wilting symptoms. The chlorophyll content (stress) was positively correlated (0.427) to the date of appearance of wilting symptoms. Hence, chlorophyll content also can be used as a good indicator of stress tolerance. This result is in accordance with the earlier reports (Jangpromma *et al*., 2010; Silva *et al*., 2007; 2011), which reported that the moisture stress tolerant sugarcane cultivars have higher level of chlorophyll under moisture stress than drought susceptible cultivars. Further, path coefficient analysis showed that chlorophyll content (stress) showed high positive total effect (0.429) including high direct effect (0.434) on time taken for appearance of witling symptoms. But chlorophyll content (unstressed) have negative total effect on time taken for appearance of witling symptom due to high negative direct effect (-0.399).

Proline is known to be involved in plant response to various environmental stresses, including moisture stress. Proline accumulation under moisture stress has been found in plant (Johari-Pireivatlou, 2010, Mafakheri *et al*., 2010, Vajrabhaya *et al*., 2001, Parida *et al*., 2008, Munawarti *et al*., 2013). In the present study also all the varieties showed increase in proline content under moisture stress condition compared to normal condition. The appearance of wilting symptoms and the proline content of the varieties under control and stressed conditions did not show any significant relation. Hence, the proline content may not be a good indicator of stress tolerance in the sugarcane varieties included in this study. Hanson *et al*. (1979) working with *Hordeum vulgare* L., also suggested that proline accumulation was of no practical use in breeding, even though they found a heritable component to this trait. Further, Ceh *et al*. (2009) also found no correlation between proline content and moisture stress-resistance in Hops (*Humulus lupulus* L.) and Ilahi and Dorffling (1982) found that moisture stress-susceptible cultivars of *Zea mays* had higher proline content than moisture stress-resistant ones. On the contrary, Ma *et al*. (2004), Bayoumi *et al*. (2008) and Naser *et al*. (2010) suggested that proline accumulation could be used as a marker for moisture stress tolerance. Differences in the role of proline with respect to moisture stress tolerance in sugarcane have also been reported. Rao and Asokan (1978) found that moisture stress resistant varieties of sugarcane accumulated more proline than susceptible ones and suggested that proline accumulation could be used as an index of moisture stress tolerance, whereas Zhao *et al*. (2010) suggested that proline was not a sensitive water stress indicator in sugarcane. Path coefficient analysis for proline also revealed low total effects on time taken to appearance of wilting symptoms. Therefore, proline content may not be a good indicator of stress tolerance.

This study revealed that moisture stress tolerance is associated with its various components genetically and phenotypically in various magnitudes. Further, the study has indicated the contribution and magnitude of the correlations among moisture stress tolerance related physiological traits, their heritability and genotype × environment interactions that could be encountered within the sugarcane breeding programme and demonstrated differential responses of different sugarcane varieties to moisture stress conditions.

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Table 1: The varieties and the number of days taken for appearance of wilting symptoms under moisture stress

Days after withholding irrigation	No of varieties showed wilting	Name of the variety	Tolerance group
4	2	Co 775, Co 99010	Susceptible
6	11	CoM 88121, Co 98013, Co 720, Co 7804, Co 99012, Co 86011, CoC 92061, Co 8371, Co 7527, Co 92020, Co 85246	Moderately susceptible
8	27	Co 1163, Co 419, CoJn 94-8, Co 7704, Madumathii, CoJ 83, Co 8213, Co 86002, Co 7602, CoSNK 03044, CoSNK 03632, Co 403, Co 86250, CoM265, Co 94012, Cp 5268, CoSNK 05104, Co 85002, Co 62175, CoSNK 05103, Co 92005, Co 85004, Co 740, Co 99008, Co 1148, Co 86032, CoC 671	Moderately tolerant
10	9	Co 7405, Co 88025, Ms 68 47, Co 7424, Madhuri, Co 86249, Co 2001-15, Co 93009, Co 99004	Tolerant
12	3	CoT 8201, ISH 100, Co 94008	Highly tolerant

Table 2: ANOVA for few moisture stress related parameters among 52 sugarcane varieties

Source of Variance	DF	MSS			
		Proline	EC	RWC	Chlorophyll
Replication	1	0.01	0.00	0.51	6.78
Water regimes	1	136.85**	9.99**	71476.89**	3546.07**
Error(a)	1	0.002	0.00	55.47	3.25
Variety	51	5.06**	0.090**	166.79**	71.49**
Water regimes X varieties	51	12.75**	0.36**	1705.92**	186.96**
Error (b)	102	0.0027	0.0004	4.8481	0.9457
SEM		0.026	0.010	1.101	0.486

** - Significant at 0.01%

Table 3: Estimates of genetic parameters for moisture stress related traits among 52 sugarcane varieties

Vg = genotypic variance, **Vp =** phenotypic variance, **GCV =** genotypic coefficient of variation, **PCV =** phenotypic coefficient of variation, H **(bs) =** heritability (broad sense)

Trait	Treatment	Variance		Coefficient of variation (%)		H(bs)
		Vg	Vp	GCV	PCV	
Proline	**Unstressed**	0.02856	0.0286	107.62	107.69	99.87
	Stress	5.0	5.01	125.70	125.77	99.89
EC	**Unstressed**	0.022	0.023	26.71	26.94	98.31
	Stress	0.0637	0.0641	25.29	25.39	98.25
RWC	**Unstressed**	18.41	26.54	4.93	5.92	69.34
	Stress	128.95	130.51	22.75	22.89	98.81
Chlorophyll	**Unstressed**	27.89	29.01	13.48	13.75	96.15
	Stress	29.88	30.66	17.69	17.91	97.47

Table 4: Correlation coefficients values for date of wilting and moisture stress related parameters

C – Unstressed condition

	C proline	D proline	Inc/ proline	C EC	D EC	Inc. EC	C RWC	D RWC	Redu-ction RWC	C SPAD	D SPAD	Reduction SPAD	Wilting date
C proline	1												
D proline	0.035	1											
Increase proline	-0.358**	0.438**	1										
C EC	0.134	-0.109	-0.152	1									
D EC	-0.03	0.435**	0.465**	0.06	1								
Increase EC	-0.146	0.385**	0.537**	-0.676**	0.653**	1							
C RWC	-0.09	0.074	0.114	0.046	0.156	0.051	1						
D RWC	0.158	-0.208	-0.043	0.357**	0.113	-0.225	0.135	1					
Reduction RWC	-0.176	0.224	0.071	-0.344*	-0.079	0.235	0.101	-0.971**	1				
C SPAD	0.184	-0.052	-0.162	-0.318*	-0.036	0.208	0.04	-0.287*	0.296*	1			
D SPAD	0.255	-0.157	-0.178	0.131	0.016	-0.129	0.038	0.422**	-0.403**	0.219	1		
Reduction SPAD	-0.097	0.139	0.049	-0.333*	-0.033	0.256	-0.017	-0.584**	0.572**	0.446**	-0.763**	1	
Wilting date	0.025	-0.02	-0.01	0.352*	0.152	-0.182	0.073	0.648**	-0.628**	-0.424**	0.427**	-0.675**	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

D - Moisture stress condition
EC – Electrical conductivity
RWC – Relative water content
SPAD – Chlorophyll content in SPAD units

Table 5: Path coefficients of physiological traits related to moisture stress tolerance.

Character	Total indirect effect	Direct effect	Total effect
C proline	0.151	-0.115	0.036
D proline	-0.154	0.167	0.012
C EC	0.127	0.235	0.362
D EC	0.232	-0.088	0.144
C RWC	-0.068	0.121	0.052
D RWC	0.772	-0.139	0.633
C Chlorophyll content	0.098	-0.399	-0.301
D Chlorophyll content	-0.005	0.434	0.429

C – Under unstressed condition
D – Under moisture stress condition

CORRELATION OF SOIL PROPERTIES WITH WEED OCCURRENCE IN SUGARCANE FIELDS

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ABSTRACT

The study was established on three sugarcane growing fields with known cropping history, located in the southern Guinea savanna ecological zone (Latitude 9^0 29' N and Longitude 4^0 35' E) of Nigeria during the 2012/2013 and 2014 growing seasons to determine the relationship between weed seedling emergence and soil properties. Soil seedbank was sampled from sugarcane fields to a depth of 0-10cm, 11-20cm, 21-30cm and was estimated using the direct seedling germination method, and the emerged weed seedlings were monitored over a period of 8 months concurrently with a floristic survey conducted on same fields. Data collected on weed seedling emergence were transformed and subjected to analysis of variance, regression and correlation analyses. The results of the study demonstrated that soil properties exert significant influence on the occurrence and distribution of specific weed species in the sugarcane cultivated fields and there was a strong positive correlation ($r=0.86$, $p\leq0.003$) between seedling emergence in the seedbank and field emergence. *Paspalum scrobiculatum,* dominant weed species, correlated positively with soil particle sizes and all the chemical properties except Na, K and acidity. This implies that predictable estimate of the sugarcane fields' weed flora can be made from the soil seedbank and soil properties, with such information, it would be possible to schedule a more appropriate weed management strategy.

Keywords: Soil properties, seedbank, weed emergence, floristic survey, sugarcane

INTRODUCTION

Sugarcane (*Saccharum officinarum* L.) is one of the most important crops in the world because of its strategic position in the search for renewable and cleaner energy sources and its immense uses in the daily life of a nation as well as for industrial uses aimed at nutritional and economic sustenance (Girei and Giroh, 2012). The production of sugarcane in Nigeria is still far below the world average and one of the contributing factors is weed interference. Weeds are considered major constraints to higher yields in sugarcane production because it can reduce potential sugar yield by 24 to 93% as well as a loss of significant quantities of nutrients (Anon., 2013).

Weed infestation dynamics depend on quantity (Forcella, 1992) and horizontal distribution of the seedbank (Wiles and Brodahl, 2004), as well as seedbank allotments in various soil layers (Grundy *et al*., 1996). Seedbank distribution depends on depth of seed burial (Yenish *et al*., 1992). Differences in seed burial depth can have important implications for relative time of weed emergence, survival of weed seeds, and distribution of weed species.

Weed is not distributed uniformly along the ground, and the spatial variability of the infestation is observed, with stains or thick woods formations (Iwara *et al*., 2011). Soil physical, chemical and biological properties also present spatial variability, assuming similar values to short distances and different values as the distance between observations increases. The spatial variability of soil properties and weed present occur due to several factors, among which are: topography, structure and type of soil, groundwater characteristics, microclimate and management practices (Silva *et al*., 2008).

The dynamics and the development of weed soil seedbank vary according to time of year, the crop stage and edaphic conditions. Taking these into consideration, it is necessary to know which factors may be related, directly or indirectly, and determining the occurrence of some weed species, since, with such information, it would be possible to schedule a more appropriate management. This study is therefore designed to determine the relationship between weed seedling emergence and soil chemical/ physical properties in a sugarcane ecology.

MATERIALS AND METHODS

Description of study area

This study was conducted at the University of Ilorin Sugar Research Institute's Farm between 2012/2013 - 2014 growing seasons in the southern Guinea savanna ecological zone (Latitude 9^0 29' N and Longitude 4^0 35' E) of Nigeria, which is 307 m above sea level.

The study was established on three sugarcane growing fields with different cultivation periods (20 years of continuous cropping, less than 5 years of cropping after 10 years of fallow and one year of cropping after 15 years of fallow). The fields had similar tillage operations (ploughing, harrowing and ridging) and the use of broad spectrum pre-emergence herbicides, supplemented with post-emergence (directed spray) application of paraquat, ametryn or hand hoeing in each cropping cycle. The soil was classified as Plinthustaffs, having sandy texture in the first 30 cm of the surface (Ogunwale, 1991).

Soil sampling

The experimental field on each of the 3 sugarcane monoculture was divided into eight (8) cardinal points. One quadrat ($0.5m^2$) was placed on each of the cardinal points. Nine core sample were collected from each of the cardinal points using a precision auger (7.4cm in diameter) to a depth of 0-10cm, 11-20cm, 21 -30cm and replicated three times for each experimental field. The soil samples were air dried and passed through a 2mm diameter sieve. The sieved samples were used for the estimation of the soil weed seedbank using the direct seedling germination method which is mainly used to determine the density of the viable weed seeds in the seedbank (Swanton *et al*., 2000).

One hundred grams of the sieved soil samples was used to fill each plastic bowl (replicated three times) and were arranged in the screen house for germination. Each of the bowls had four perforations at the base to facilitate the drainage of excess water in the soil samples. The soil samples were watered on alternate days and monitored for weed seed germination/seedling emergence at monthly intervals. Emerging weed seedlings were enumerated either as broadleaves, grasses and sedges; identified to species level, counted and then pulled out. Identification of weed seedlings was done with the aid of weed handbook, Akobundu and Agyakwa (1998). Soil samples were stirred using a spatula after each assessment to stimulate germination by bringing to the surface other weed seeds that might have been deeply buried in them.

The experiment was terminated when emergence ceased after a period of 8 months.

Soil analysis

The composite soil samples at depths 0-10 cm, 11-20 cm and 21-30 cm were air dried, crushed with mortar and pestle and sieved with a 2 mm diameter sieve. Particle size analyses were performed to obtain sand, silt and clay content while chemical analyses were also performed to obtain total available N, P, exchangeable bases (Na, K, Mg), Ca, total acidity, soil pH, effective cation exchange capacity, organic carbon and organic matter.

Floristic survey

Floristic survey was conducted with the aid of quadrat (0.5 x 0.5 m), launched randomly on the three fields. The emerging weed seedlings were observed, counted, pulled for identification. The weeds were separated into broadleaves, grasses and sedges.

Data analysis

The absolute and relative frequencies, densities and dominances of weed species were recorded. The importance value index (IVI) was evaluated, which numerically expresses the importance of a particular species in a community (Curtes & McIntosh, 1950).

Sorensen similarities (Wolda, 1981) and Simpson diversity (Anon., 2008) indices were used to determine and compare the weed species diversity of each field and the indices were computed as follows: Sorensen similarity index = (a/a+ b+ c) x 100.

Where a = number of weed species common to both fields, b= number of weed species in first field, c= number of weed species in second field.

Simpson's diversity index= ∑t-1 [ni (ni -1)] / [N (N-1)].

Where n =total number of each species, N = total frequency of all species.

The possible relation between weed densities found through floristic survey and through seedbank estimate with the physical and chemical properties were evaluated by correlation and regression analyses.

RESULTS

A total of 43 weed species belonging to 37 genera and 14 families were enumerated across the sugarcane cultivated fields (Table 1). About 72 % of all the genera enumerated belonged to the Poaceae (13), Asteraceae (5), Cyperaceae (5), Euphorbiaceae (5) and Amaranthaceae (3) families. About 58 % of the genera were broadleaved species, 30 % grasses and 12 % sedge weed species. Annual weed species accounted for 65 %, 28 % perennials and about 7 % were annuals or perennials.

Twenty-five weed species within 22 genera which comprised of 15 broadleaves, 6 grasses and 4 sedge weed seedlings were enumerated from the soil weed seedbank. Weed species with the highest percent occurrence includes: *Portulaca oleracea* (9.63%), *Euphorbia hirta* (6.33%), *Tridax procumbens* (6.04 %) and so on (Table 2).

In the floristic survey performed, 45 weed species were identified across the three fields while only 25 weed species emerged from the soil seedbank across soil sampling depths and 24 of such were encountered during the survey except *Euphorbia hirta*. There was significant ($p \leq 0.05$) positive correlation (R^2= 0.7373, R= 0.8587) between floristic and seedbank emergence (Table 3).

The regression analyses for soil physical and chemical properties did not show any significant ($p \leq 0.05$) relationship with population of emerged weed seedlings from the soil seedbank (Table 4). Thus, in the correlations shown, soil physical properties indicated negative relationship with emerged weed seedlings except % sand (R^2 = 0.011 and R = 0.103) while the soil chemical properties were positively related with weed seedling emergence except total acidity (R^2 =0.170 and R = - 0.872), exchangeable Na (R^2 = 0.536 and R = - 0.662), exchangeable K (R^2 = 0.438 and R = - 0.732) and total N (R^2 = 0.005 and R = - 0.408). High positive relationships were observed with exchangeable Mg (78.8%), available P (66.2%) while organic matter was 41.3% related to the emergence of weed seedlings from the soil seedbank.

The effect of soil properties on weed morphological groups was inconsistent. Soil physical properties shown on Table 5 indicated that sand positively correlated with all the morphological groups except broadleaved seedlings. The percent silt was only related positively with broadleaved seedlings while clay correlated positively (47.5%) with grass weed seedlings, showed a negative relationship with other weed morphological groups.

The relationship between soil chemical properties and weed morphological group differed across soil parameters (Table 6). Cation exchange capacity, Mg and P positively correlated with broadleaved and sedges but negatively with grass weed seedlings. Acidity, pH, Na, K and N had an opposite trend while organic matter and Ca correlated negatively with all the groups except sedges.

Selected weed species from each morphological groups that had highest importance value index were correlated with soil properties (Table 7) and the analyses indicated that, all weed species identified related positively with % sand and organic carbon except *Brachiaria deflexa* and *Cyperus difformis Paspalum scrobiculatum* (grass weed species), the dominant weed species correlated positively with all soil properties except Na, K and acidity.

DISCUSSION

Weed seedling composition was similar across the three sugarcane fields. The relative proportion of weed species showed that about 29 % of the encountered weeds were members of Poaceae family, Asteraceae, Cyperaceae, Euphorbiaceae each had 11 % relative occurrence, Amaranthaceae had 6.7 % while other weed species belonging to the other families had about 2 % occurrence each. The result showed that, grass weed seedlings dominated the sugarcane weed community while broadleaves had higher diversity in species. This agreed with the findings of Ndarubu and Fadayomi (2006) who observed that broadleaves had higher diversity while density of grasses was higher across the sugarcane fields of Nigerian Sugar Company, Bacita while Takim and Amodu (2013) also reported similar observation in a survey conducted on the farms of Unilorin Sugar Research Institute during 2011and 2012 growing seasons.

This also shows the presence of weeds particular to sugarcane monoculture and agrees with Derksen *et al*., (1993) that morphological similarity of crops and weeds influenced the type of weed species present. Liebman and Dyck (1993) demonstrated that monoculture can lead to a less diverse and more intractable weed flora than crop rotation. Owen (1998) concluded that adaptation of weed populations to continuous cropping is due to a consistently hospitable environment for weeds that have phenological and physiological similarities to the crop. Therefore, the structure of the current weed species in a seedbank of sugarcane ecology is influenced by the sugarcane and the cropping system.

Significantly higher density of weed seedlings were found to emerge in newly open fields compared to field characterized by continuous sugarcane cultivation. In other words, the increase in the period of cultivation reduces the diversity of weed seedlings and induced dominance of certain weed species were created while a gradual shift from the natural vegetation with predominant annual broadleaves to an induced vegetation of perennial grasses was associated with the fallow fields (Takim and Amodu, 2013). The higher density of weed seedlings in the newly open fields could be as a result of weed seed dormancy breaking point which invariable means a condition in which weed seed regains its viability after long period of being dormant and also the presence of conducive environment. It is understandable as reported by Szott *et al.* (1991) and later confirmed by Ekeleme *et al*. (2004) that weed seedbank is usually low in the season after opening field that has been under long fallow and this could translate into low weed density in that season while increase in weed density will be observed in the presiding season.

All the weed species emerged from soil seedbank were identified on the field survey except *Euphorbia hirta*. The dominant weed species were similar in both enumeration which indicates that the very large size of this seedbank is probably due to both its prolific seed production and the ability of its seeds to persist more during the cultivation periods. There was a strong positive correlation (r=0.86, p≤0.003) between seedling emergence in the seedbank and field emergence. A similar study carried out by Ndarubu and Fadayomi (2006), reported non-significant (p≤0.05) linear correlation between weed species diversity based on floristic survey and estimated morphological groups, while Takim *et al*. (2013)reported a strong positive relationship (r=0.98, p≤0.003) between weed seed number in the soil and the number of emerged seedlings on the field. The authors further stated that an average of 15.8-30.6% of weed seeds in the seedbank could emerge in any given year. This study affirmed that soil seedbank data on weed density could be used to predict the floristic weed density whereas the floristic species' diversity may not be precisely predictable from the soil seedbank estimation. This implies that predictable estimate of the sugarcane fields' weed flora can be made from the soil seedbank analysis.

The soil seedbank density decreased with increase in soil depth. The pattern of depth distribution of seedbank is similar for all the weed species. In the three fields, all the weed species encountered were concentrated in the upper 0-10 cm of the soil. In Ohio, Cardina *et al*. (1992) studied three soils with different cropping history and reported that the top 0-5 cm of the soil had the highest numbers of the total weed seeds. Similarly, Zhang *et al.* (1998) observed that weed seedling emergence and seedbank depletion are greater from seeds near the soil surface than from those more deeply buried because more seeds encounter conditions favourable for germination, Rahman *et al*. (2000) who studied four cultivation treatment on the distribution of weed seeds in the soil profile at the Waikato Orchard near Hamilton found that larger seedbank and more weed seedlings were in the upper 5 cm of the soil profile and there was no difference in number of seeds between 0-5 and 5-10 cm depths. This phenomenon might be partly attributed to the fact that it takes some time for seed produced by the weed species to penetrate the lower soil layer and this agrees with the findings of Wagner *et al*.

(2003). This large surface seed stock could also be due to the considerable seed rain and lack or inadequate weed control at the end of the cropping season because most farmers have the tendency of not removing late weeds.

An equal distribution of weed seeds in the 11-20 cm and 21-30 cm soil depths were also observed and this supported the reports of Yenish *et al*. (1992). Different types of cultivation also influenced seed distribution among soil aggregates and in the soil profile. Studies of the horizontal movement of weed seeds following cultivation with different implements have shown that majority of seed moved <1 m from their source (Rew and Cussans, 1997). The vertical seed movement is of greater consequence as different types of cultivation move seeds to different depths in the soil (Dessaint *et al*., 1996). Clement *et al.* (1996) concluded that the type and frequency of land preparation influences the seed dispersion in the soil profile; the management at same depth, favour uniform distribution of the seeds in the soil profile, finding lower seed populations deeper in the soil.

The relationship between soil properties and weed seedling emergence was inconsistent. In other words, soil conditions affected the arable soil seedbank directly or indirectly. It was observed that % sand, ECEC, Mg and P had high positive influence on emergence of weed seedlings while a strongly negative effect on weed emergence were obtained with % silt, %clay, acidity and K. The ECEC and Mg had strong positive correlation with emergence of broadleaved and sedge weed seedling while grasses were highly influenced by acidity content and K. The positive correlation observed between weed seedling emergence and ECEC, Mg and P contents implies that soil fertility influence weed seedling emergence and there are more demanding than others in certain nutrients (Lousada *et al*., 2013).

The dominant species, *Paspalum scrobiculatum* was strongly (positive) influenced by the 3 soil physical properties while the chemical properties showed inconsistent results, while P, organic matter and Ca related highly positively, Na and K were highly negatively correlated with emergence of *P. scrobiculatum.* Udoh *et al.,* (2007) studying the influence of physico-chemical soil properties on the weed distribution in five different soils in Nigeria, observed that the distribution and occurrence of the dominant species, *Tridax procumbens* was strongly influenced by 21 soil properties, including C, K and high sand content. These authors concluded that this species has the greatest potential for growth and development in a variety of soils and conditions, since of the five areas observed, it was found in four while Lousada *et al*. (2013) reported that, *Cyperus rotundus* was the dominant weed species in Campos dos Goytacazes, in the northern region of the state of Rio de Janeiro in the two seasons evaluated and correlated with some soil characteristics such as P, K, C and high clay content.

Elucidating the factors that contribute to an increased occurrence and distribution of the dominant weed species are extremely important in order to elaborate an integrated and efficient management. Different plants are known to have different requirements, which demonstrate that differences in the distribution and abundance of weed flora in a scenario may indicate the variation of soil properties (Udoh *et al.,* 2007).

Soil properties at different levels can influence weed density in the area. When species are slightly favored by some soil property and slightly impaired by other properties, it means that there is a high relation of density of species in areas with different characteristics, that is, the diffusion of that species may occur in different types of soil. However, when the density of some species is strictly related to some soil characteristic, the incidence of that species in the field can be restricted to the existence of that property (Otto *et al*., 2007).The influences of soil types and soil properties on the distribution of weed species have earlier been observed by other workers. Woo *et al.* (1991), Malik and Born (1988) and Frick (1984), in their various studies observed that weed species distribution was influenced by soil properties. Similarly, Petry *et al.* (1991) observed the influence of organic matter, while Andreasen and Streibig (1990) and Sharma (1986) observed the influence of soil texture on weed occurrence. On the other hand, Aarssen *et al*. (1986) observed that five *Vicia* species were not highly specialized in their substrate requirements, although they were generally associated with sandy soils.

The positive effect of weed seedling emergence and % sand could be attributed to germination of seeds at shallow depth which was stimulated by the moist environment around seeds, thereby prevented seeds and seedlings from drying out (Benvenuti et al., 2001). However, in the silt and clay fraction with a more compact pore space, there was dormancy acquisition by weed seeds as a result of higher soil moisture, lower temperature, poor gas exchange and higher Co_2 levels Also, limiting light intensity in these two soil formation might affect seed dormancy which could almost be detected in top soil sand fraction, thus the positive effect observed in the latter.
The results of the correlation of physical and chemical soil properties with weed seedling emergence can define and explain why some species are spread throughout the area and others focus on specific points. This is because different plants are known to have different requirements, which demonstrate the differences in the distribution and abundance of weed flora in a scenario which may indicate the variation of soil properties (Udoh et al., 2007).

CONCLUSION

The study demonstrated that, there was a strong positive correlation ($r=0.86$, $p \leq 0.003$) between seedling emergence in the seedbank and field emergence and certain soil physical and chemical properties exert significant influence on the occurrences of types and distribution of specific weed species in the sugarcane cultivated fields. This implies that predictable estimate of the sugarcane fields' weed flora can be made from the soil seedbank analysis.

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Table-1Importance value index (IVI) weeds of s.cane across different period of cultivation of s.cane

				Importance Value Index		
FAMILY	WEED SPECIES	MG	LC	CSC	FW2	FW1
Aizoaceae	*Trianthema portulacastrum* L.	B	A	8.46	9.51	9.71
Amaranthaceae	*Achyranthes aspera* L.	B	A	5.51	2.10	1.27
	Celosia leptostachya Benth.	B	A	0.62	2.27	0.62
	Gomphrena celosoides Mart.	B	A/P	7.73	6.21	7.5
Asteraceae	*Agerantum conyzoides* L.	B	A	0.84	1.27	7.07
	Chromolena odorata L.	B	P	11.39	10.19	7.35
	Tridax procumbens L.	B	A	16.74	6.33	4.43
	Vernonia cinerea L.	B	A	1.92	0.99	1.10
	V. galamensis Cass.	B	A	3.87	7.00	7.2
Commelinaceae	*Commelina benghalensis* L.	B	A/P	0.31	4.55	6.92
Cyperaceae	*Cyperus diffformis* L.	S	A	9.51	13.38	12.09
	C. esculentus L.	S	P	3.43	4.99	2.21
	Fimbrystylis litoralis Gaudet	S	A	5.89	3.40	5.80
	Fuirena umbellata Rottb	S	P	3.99	5.71	5.52
	Mariscus alternifolus Vahl	S	P	11.79	7.56	5.41
Euphorbiaceae	*Croton hirtus* L'Hert	B	A	9.15	7.21	4.94
	C. lobatus L.	B	A	7.12	8.28	7.61
	Euphorbia heterophylla L.	B	A	4.03	7.98	5.64
	E. hyssopifolia L.	B	A	10.28	10.57	8.96
	Phyllantus amarus Schum	B	A	7.1	6.32	6.04
Fabaceae	*Senna obtusifolia (*L.) H.S. Iruun & Barneby	B	A/P	5.92	7.98	8.31
	Mimosa pudica L.	B	P	0.47	0.67	1.22
	Spigelia anthelmia L.	B	A	8.93	8.55	7.79
	Tephrosia bracteolate Guil.	B	A	7.09	6.59	6.16
Nyctaginaceae	*Boerhavia diffusa* L.	B	P	6.86	7.9	8.52
Onagraceae	*Ludwigia decurrens* Walt.	B	A	9.45	10.56	12.54
Poaceae	*Andropogon gayanus* Kunth	G	P	7.79	7.58	5.63
	Axonopus compresus (Sw.) P. Beauv.	G	P	7.67	8.93	9.09
	Brachiaria deflexa(Schumach) Robyns.	G	A	7.49	5.46	7.95
	B. lata (Schumach) CE Hubbard	G	A	7.94	8.42	6.09
	Cynodon dactylon L.	G	P	8.61	6.06	9.46
	Digitaria horizontalis Willd.	G	A	8.09	10.66	7.81
	Eleusine indica Gaertn.	G	A	9.53	10.39	10.64
	Imperata cylindrica L.	G	P	7.09	6.06	10.07
	Panicum repens L.	G	P	0.69	2.32	1.48
	Paspalum conjugatum Berg.	G	P	8.67	5.39	4.26
	P. scrobiculatum L.	G	P	8.65	13.81	14.88
	Rottboelia cochinchinensis (Lour.) Clayton	G	A	5.65	5.65	6.98
	Setaria barbata (Lam.) Kunth	G	A	15.93	7.58	4.56
Portulacaceae	*Portulaca oleracea* L.	B	A	8.72	10.14	8.77
Rubiaceae	*Odellandia corymbosa* L.	B	A	9.77	8.79	6.91
Solanaceae	*Physalis angulata* L.	B	A	0.53	0.61	5.18
Tiliaceae	*Corchorus olitorius* L.	B	A	1.21	5.66	6.82

LC = life cycle, MG = morphological group, P = perennial, A= annual, A/P= annual/perennial,
G = grass, B= broadleaf, S= sedge, CSC= 20 years of continuous cropping,
FW1= 2 years of cropping after 10 years of fallow, FW2= one year of cropping after 15 years of fallow

Table-2 Weed species enumerated from soil seedbank across soil sampling depths

Weed species	Percentage weed species occurrence			
	SD1	**SD2**	**SD3**	**Mean**
Portulaca oleracea	8.82	10.52	9.56	9.63
Euphorbia hirta	5.26	4.54	9.20	6.33
Tridax procumbens	6.70	5.29	6.13	6.04
Setaria barbata	5.32	7.26	5.13	5.90
Odellandia corymbosa	5.26	5.14	6.13	5.51
Phyllantus amarus	3.59	6.13	6.52	5.41
Cyperus difformis	6.80	4.69	4.28	5.26
Brachiaria lata	5.65	7.41	2.70	5.25
Euphorbia hyssopifolia	5.37	4.39	5.55	5.10
Euphorbia heterophylla	3.82	4.31	6.67	4.93
Brachiaria deflexa	5.07	4.39	4.89	4.78
Fimbrystylis litoralis	5.30	4.99	3.48	4.59
Croton lobatus	4.44	3.86	3.84	4.05
Hyptis lanceolata	5.15	3.40	3.36	3.97
Spigelia anthelmia	4.38	3.70	2.72	3.60
Chromolena odorata	4.69	2.87	2.97	3.51
Agerantum conyzoides	2.87	4.46	1.99	3.11
Digitaria horizontalis	2.69	3.78	2.53	3.01
Tephrosia bracteolate	1.98	3.70	2.53	2.74
Panicum repens	1.73	2.34	1.55	1.88
Ludwigia decurrens	1.92	0.68	2.62	1.74
Paspalum scrobiculatum	0.90	0.68	3.01	1.53
Fuirena umbellate	0.74	0.15	1.55	0.81
Mariscus alternifolus	0.74	0.68	0.87	0.76
Vernonia galamensis	0.66	0.52	0.09	0.42

SD1= 0-10cm soil depth, SD2= 11-20cm soil depth, SD3= 21-30cm soil depth

Table-3 Details of diversity, similarity and regression statistic between floristic and seedbank weed seedling emergence

Indices	Floristic emergence	Seedbank emergence
Species Richness	45	25
Sorensen similarity index	51%	
Regression Equation	Y= 0.0143x + 15.148	
	0.7373	
R		
Probability	0.8587 0.003	

Table-4 Regression statistics for the total emergence from soil weed seedbank (Y) relative to soil properties (x) across land use intensities and soil sampling depth

Soil property	Regression equation	R^2	R
% clay	$Y = -3 \times 10^{-7}x + 5.921$	0.344	-0.587
% silt	$Y = -3 \times 10^{-7}x + 0.269$	0.166	-0.073
% sand	$Y = -9 \times 10^{-7}x + 81.952$	0.011	0.103
Ph	$Y = -2 \times 10^{-7}x + 6.233$	0.166	-0.408
Acidity (cmol/kg)	$Y = 4 \times 10^{-7}x + 0.271$	0.170	-0.872
Organic matter (O.M)g/kg	$Y = -1 \times 10^{-6}x + 1.083$	0.760	0.413
ECEC (cmol/kg)	$Y = 8 \times 10^{-6}x + 5.699$	0.667	0.816
Na (cmol/kg)	$Y = -6 \times 10^{-6}x + 3.375$	0.536	-0.662
K (cmol/kg)	$Y = -1 \times 10^{-5}x + 6.878$	0.438	-0.732
Mg (cmol/kg)	$Y = 7 \times 10^{-6}x + 4.402$	0.620	0.788
Ca (cmol/kg)	$Y = 2 \times 10^{-7}x + 1.297$	0.119	0.345
P (mg/kg)	$Y = 1 \times 10^{-6}x + 0.131$	0.438	0.662
N (kg/ha)	$Y = -6 \times 10^{-7}x + 12.127$	0.005	-0.408

R^2 = coefficient of determination, R = correlation coefficient of seedbank emergence

Table-5 The regression statistics for emergence of weed morphological groups (Y) relative to soil physical properties (x) across soil depths

Soil Physical Property	Regression Equation	R^2	R
	Broadleaf weed seedling		
% Sand	Y= 0.7569x + 78.875	0.1079	-0.3286
% Silt	Y= - 5.927x + 13.765	0.1278	0.3571
% Clay	Y= - 0.1641x + 6.3395	0.0352	-0.1877
	Grass weed seedling		
% Sand	Y= 0.1807x + 81.578	0.0008	0.0287
% Silt	Y= - 0.3536x + 13.229	0.0035	-0.0590
% Clay	Y= 0.1729x + 5.1932	0.2256	0.4750
	Sedge weed seedling		
% Sand	Y= 0.7569x + 78.875	0.0291	0.1705
% Silt	Y= - 0.5927x + 13.765	0.0197	-0.1405
% Clay	Y= - 0.164x + 6.3395	0.4100	-0.6403

Table-6 The regression statistics for emergence of weed morphological groups (Y) relative to soil Chemical properties (x) across soil depths

Soil chemical Properties	Regression Equation	R^2	R
	Broadleaf weed seedling		
ECEC (cmol/kg)	Y=54.092x – 222	0.9688	0.9843
pH	Y=-23539x + 16.977	0.5727	-0.7568
Organic matter (O.M)g/kg	Y=-9.4648x + 40.903	0.9946	-0.0128
Acidity (cmol/kg)	Y=-0.0687x + 0.6781	0.0002	-0.9973
N (kg/ha)	Y=-2.8247x + 12.202	0.5727	-0.7568
P (mg/kg)	Y=2.987x - 12.207	0.0793	0.2816
Mg (cmol/kg)	Y=54.33x - 224.36	0.9499	0.9746
Na (cmol/kg)	Y=-0.2387x + 2.3618	0.0074	-0.2816
K (cmol/kg)	Y=-32.246x + 140.07	0.793	-0.3738
Ca (cmol/kg)	Y=-18.779x + 81.326	0.1397	-0.0859
	Grass weed seedling		
ECEC (cmol/kg)	Y=-5.6928x + 28.888	0.7838	-0.8853
pH	Y=0.19078x + 5.467	0.2752	0.5246
Organic matter (O.M.) g/kg	Y=-0.1821x + 1.0531	0.0836	-0.2891
Acidity (cmol/kg)	Y=1.0313x - 3.1258	0.8624	0.9287
N (kg/ha)	Y=0.2291x - 0.6496	0.2752	0.5246
P (mg/kg)	Y=-0.69214x + 3.0319	0.311	-0.5577
Mg (cmol/kg)	Y=-5.6218x + 27.281	0.7429	-0.8619
Na (cmol/kg)	Y=7.4725x - 24.44	0.3109	0.5576
K (mg/kg)	Y=3.738x - 12.232	0.4043	0.6359
Ca (cmol/kg)	Y=-0.071x + 1.6066	0.0477	-0.2183
ECEC (cmol/kg)	Y=3.5114x - 2.9436	0.6011	0.7753
pH	Y=0.0884x + 6.443	0.1191	-0.345
Organic matter (O.M.)g/kg	Y=0.21x - 0.2701	0.2242	0.4735
Acidity (cmol/kg)	Y=-0.6543x + 2.6974	0.6697	-0.8365
N (kg/ha)	Y=-0.106x + 0.5216	0.1191	-0.345
P (mg/kg)	Y=0.6219x - 1.4471	0.5062	0.7115
Mg (cmol/kg)	Y=3.4079x - 3.9984	0.5536	0.744
Na (cmol/kg)	Y=0.0934x + 1.0548	-0.1663	-0.7114
K (cmol/kg)	Y=-3.2154x + 11.512	0.603	-0.7765
Ca cmol/kg	Y=-6.7147x + 23.922	0.5061	0.4078

Table-7 The regression statistics for emergence of selected weed seedling (Y) relative to soil physical and chemical properties (x) across soil depths

Weed species	**% Sand**	**% Silt**	**% Clay**	**N**	**Na**	**P**	**Organic matter**	**pH**	**K**	**Mg**	Acidity	Ca	ECEC
Broadleaves													
Euphorbia hirta	0.054	-0.084	0.452	0.546	0.536	-0.536	-0.264	0.546	0.616	-0.874	0.939	-0.193	-0.896
Portulaca oleracea	0.015	0.015	-0.513	-0.486	-0.593	0.593	0.330	-0.486	-0.669	0.838	-0.911	0.260	0.864
Tridax procumbens	0.993	-0.996	-0.801	0.918	-0.739	0.739	0.904	0.918	-0.670	-0.627	0.502	0.933	-0.589
Grasses													
Brachiaria deflexa	-0.140	0.110	0.616	0.373	0.689	-0.689	-0.446	0.373	0.756	-0.764	0.852	-0.377	-0.794
Digitaria horizontalis	0.986	0.990	-0.771	0.936	-0.706	0.706	0.883	0.936	0.634	-0.663	0.043	0.915	-0.627
Panicum repens	0.139	-0.109	0.615	-0.374	0.688	0.689	0.445	-0.374	-0.756	0.764	-0.853	0.378	0.794
Paspalum scrobiculatum	0.761	0.741	0.983	0.385	-0.996	0.996	0.927	0.335	-0.999	0.144	-0.292	0.897	0.191
Sedges													
Cyperus difformis	-0.768	0.787	0.345	-0.985	0.253	-0.253	-0.526	-0.985	0.157	0.950	-0.892	0.586	0.934
Fimbrystylis litoralis	0.827	-0.809	-0.997	0.435	-0.999	0.999	0.982	0.435	0.992	0.035	-0.186	0.940	0.084

SUGAR INDUSTRY ABSTRACTS

EFFICACY OF FLUTRIAFOL COMPARED TO OTHER TRIAZOLE FUNGICIDES FOR THE CONTROL OF SUGARCANE SMUT

Shamsu A Bhuiyan, Barry J Croft, Glen R Tucker, Rebecca James

SMUT IS AN important disease of sugarcane, caused by the fungus Sporisorium scitamineum. Two fungicides, propiconazole and triadimefon can be applied as a 5 min dip to protect the buds from smut infection. This 5 min dip of 1–2 tonne bundles of seed cane has some practical problems. The treatment requires a separate, large 5 000–10 000 L tank and disposal of the waste fungicide by an environmentally acceptable method is difficult and costly. The aim of this research was to evaluate the potential of flutriafol for control of smut by methods that will be more practical for field application. Two pot experiments were undertaken to: (i) determine whether flutriafol mixed with fertiliser can be taken up by sugarcane roots in sufficient concentration to protect plants from smut infection; and (ii) compare the efficacy of flutriafol with other triazole fungicides, propiconazole and triadimefon, when mixed with fertiliser or used as a dip. The pot trials also tested methods of inoculation with smut that could be used in larger-scale field trials of the fungicide. Results indicated that flutriafol is effective in significantly reducing sugarcane smut infection when applied at rates of 100–400 g a.i./ha mixed with fertiliser and at rates of 12.5 g a.i./100 L and above when applied as a 10-minute dip of setts. There were significant relationships between application rate of flutriafol and smut suppression when the fungicide was applied mixed with fertiliser. The 10-minute dip applications of the three triazole fungicides were more effective than the fungicide/fertiliser mix. Propiconazole and triadimefon were equally effective when applied as a dip, but they were less effective than flutriafol when mixed with fertiliser. Control was achieved when the smut was injected into the buds or applied by a dip of the setts at planting. Results suggest that flutriafol can kill smut fungus after it has established within the plant. Dipping setts in a suspension of smut spores is a practical method of inoculation that can be used for future field trials of flutriafol.

A STATISTICAL APPROACH FOR IDENTIFYING IMPORTANT CLIMATIC INFLUENCES ON SUGARCANE YIELDS

Y Everingham, J Sexton A Robson

INTERANNUAL CLIMATE VARIABILITY impacts sugarcane yields. Local climate data such as daily rainfall, temperature and radiation were used to describe yields collected from three locations–Victoria sugar mill (1951–1999), Bundaberg averaged across all mills (1951–2010) and Condong sugar mill (1965–2013). Three regression methods, which have their own inbuilt variable selection process were investigated. These methods were (i) stepwise regression, (ii) regression trees and (iii) random forests. Although there was evidence of overlap, the variables that were considered most important for explaining yields by the stepwise regressions were not always consistent with the variables considered most important by the regression trees. The stepwise regression models for Bundaberg and Condong delivered a model that was difficult to explain biophysically, whereas the regression trees offered a much more intuitive and simpler model that explained similar levels of variation in yields to the stepwise regression method. The random forest approach, which extends on the regression tree algorithm generated a variable importance list which overcomes model sensitivities caused by sampling variability, thereby making it easier to identify important variables that explain yield. The variable importance list for Victoria indicated that maximum temperature (February–April), radiation (January–March) and rainfall (July–October) were important predictors for explaining yields. For Bundaberg, emphasis clearly centred on rainfall, particularly for the period January to April. Interestingly, the random forest model did not rate rainfall highly as a predictor for Condong. Here the model favoured radiation (February to April), minimum temperature (March–April) and maximum temperature (January to April). Improved understanding of influential climate variables will help improve regional yield forecasts and decisions that rely on accurate and timely yield forecasts.

MEASURING POPULATION IMPROVEMENT IN THE SRA SUGARCANE BREEDING PROGRAM

Mc Cox, Fc Atkin, X Wei, G Piperidis, Rc Parfitt, Jk Stringer

EACH YEAR, SUGARCANE breeders in each region plant and assess new populations of clones in Clonal Assessment Trials (CAT, target 2,000–2,500) and Final Assessment Trials (FAT, target 150–250). These clonal populations are selected originally from seedling families that are derived from crosses between two parents. Breeder input annually into parent selection, cross selection, seed selection, family selection and, ultimately, clonal selection, is critical in delivering new varieties to the Australian sugar industry. It could also be assumed that, through continual improvements in all aspects of selection mentioned, the current clonal populations produced are 'better' than previous populations for the important traits under selection – i.e. cane yield (TCH), CCS and the combination of these two and other traits as the selection index called relative Economic Genetic Value (rEGV). This concept of 'Population Improvement' is important to plant breeders to achieve continual improvement in genetic gain and in the new varieties released. However, currently there are no routine methods developed to quantify this improvement. There are a number of difficulties in comparing the different populations across years. These include large year to year and site to site variation and the appearance of a new disease, such as the recent orange rust (2000) and smut (2006) epidemics. Population statistics relative to a common standard variety or set of standard varieties would be one way to overcome this problem, but the standard varieties used by breeders also change with time. This generally precludes the assessment of populations over long time periods, which would be optimal (e.g. 10 to 20 years). However, data are available to assess populations over much shorter periods. This paper examines methods to measure clonal population improvement within the SRA regional selection programs and reports on the trends in population improvement and their implications and limitations.

EFFICACY OF NEW CHEMICALS TO CONTROL PINEAPPLE SETT ROT OF SUGARCANE

Priyanka Wickramasinghe, Shamsul A Bhuiyan, Barry J Croft

PINEAPPLE SETT ROT, caused by Ceratocystis paradoxa, is an economically important disease of sugarcane worldwide. It causes germination failures of seedcane or setts leading to poor crop establishment. Among the registered fungicides in Australia, the organomercury fungicide Shirtan® (methoxy ethyl mercuric chloride) is the most popular because it may stimulate germination of setts in addition to controlling pineapple sett rot. However, the organomercury fungicides have greater health and environmental impacts than other fungicides in use due to the presence of mercury. Two glasshouse experiments and a field experiment were undertaken at Sugar Research Australia, Woodford, aiming to assess the efficacy of fungicides Vibrance®, Dynasty® and Mirador® against pineapple sett rot of sugarcane compared to two registered chemicals, Sinker® and Shirtan®, and to assess their ability to stimulate sett germination. The results of these experiments clearly indicate that Dynasty® and Vibrance® can be effectively used to control pineapple sett rot of sugarcane in glasshouse conditions with similar effectiveness to Sinker® and either better or similar effectiveness to Shirtan®. More research is needed to further evaluate the efficacy of fludioxonil (one of the component chemicals of Dynasty®) and Vibrance® in controlling pineapple sett rot under field conditions, and for the control of other important fungal diseases such as sugarcane smut.

NEW SOURCES OF RESISTANCE TO MAJOR DISEASES FROM WILD RELATIVES OF SUGARCANE

Barry Croft, Shamsul Bhuiyan, Robert Magarey, George Piperidis, Eunice Wong, Priyanka Wickramasinghe, Judi Bull, Mike Cox, Graham Stirling, John Foreman, Phillip Jackson

THE HYBRIDISATION OF noble sugarcane, Saccharum officinarum, with its wild relative S. spontaneum in the early 1900s was responsible for greatly improved resistance to a number of diseases, increased vigour and improved ratooning. New crosses made in Australia with S. spontaneum clone Mandalay during the 1960s resulted in the important parent clone, QN66-2008, which is the parent of 25 and grandparent of 18 'Q' varieties. Introgression breeding requires many years of crossing, screening of progeny and backcrossing to retain the beneficial characteristics while reducing the negative characters associated with the wild relatives, such as low sugar and high fibre. A collaborative introgression breeding program between CSIRO, BSES/SRA and Chinese research organisations commenced in 2000. Chinese breeders made crosses with Erianthus spp. and S. spontaneum from Asia. Seed and clones from this program were imported into Australia through quarantine and have been tested for yield and disease resistance. A selection of over 600 introgression clones has been screened for resistance to pachymetra root rot, root knot nematode, root lesion nematode and smut. Some clones from the advanced backcrosses that are resistant to these diseases have been identified and are currently being further tested for potential as commercial varieties or as parents to provide new sources of resistance to the diseases and to broaden the genetic base of commercial varieties. This paper reports on the variation in resistance to diseases of the introgression crosses from sugarcane wild relatives including the disease resistance of true crosses with the genus Erianthus.

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EFFECT OF SILICON FERTILISERS ON SUGARCANE SMUT IN AUSTRALIA

Shamsul A Bhuiyan, Barry J Croft

SMUT CAUSED BY the fungus, Sporisorium scitamineum, is an important disease of sugarcane in Australia. A trial was conducted in Bundaberg on a silicon-deficient sandy soil to determine the efficacy of soil-applied silicon for control of smut in two susceptible (Q157 and Q205A), one intermediate (Q208A) and two resistant (Q151 and Q200A) varieties. Silicon was applied as air-cooled blast furnace slag (14–18% silicon) at 6 t/ha (8.1 kg/9 m row) to selected plots and incorporated using a rotary hoe. Test varieties were planted between spreader rows of smut-infected Q205A. The trial was maintained for three years until second ratoon. Disease assessments were carried out prior to harvesting, and yield data were collected only in the second ratoon. The silicon levels in leaf tissue were significantly higher in silicon-treated plots compared to untreated controls. The highly resistant variety Q151 showed no smut in either silicon or untreated plots throughout the experiment. The intermediate to resistant variety Q208 had 3% smut in the silicon treatment and 6% smut in the untreated plots in the second ratoon crop and the moderately resistant variety Q200A had 12% smut in the silicon treatment and 8% smut in the untreated. These differences were not significant. At the final inspection in the second ratoon crop there were no significant differences in smut incidence between the silicon-treated and untreated plots of the susceptible variety Q157 (99 and 100% respectively), but significance differences were observed in Q205A (86 and 93% respectively). Tonnes of cane per hectare (TCH) and tonnes of sugar per hectare (TSH) were significantly higher in the silicon-treated Q208A compared with the untreated Q208A. The highest TCH and TSH in this trial were obtained from Q208A with silicon (150 and 26 t/ha respectively). Silicon did not significantly increase TCH or TSH in the other varieties and no differences in commercial cane sugar (CCS) were observed between silicon treated and untreated varieties. This experiment showed that resistant and intermediate varieties are effective in controlling smut with no addition of silicon under very high inoculum pressure from the disease. Silicon did not control smut in highly susceptible varieties, but possibly minimised the adverse stress response in Q208A.

AN EFFECTIVE APPROACH TO DELIVERING SUGARCANE IRRIGATION EXTENSION AT BUNDABERG BASED ON REAL TIME WEB-BASED TECHNOLOGY

MG HAINES

BUNDABERG HAS A supplementary irrigation water supply capable of supplying approximately one third of the potential annual crop moisture demand and rainfall is often insufficient or inappropriately timed for the seasonal requirements of the sugarcane crop. This situation lead to the development of an extension program designed to improve scheduling techniques to maximise crop utilisation of both water sources. There are several locations across the world where field monitoring of soil moisture is practiced and data are received through web technologies (Kenana Sugar Company, Sudan, Indonesia, Murray Darling Irrigation Area, Australia) but discussions with these groups indicate that data are generally delivered to the primary user for the specific use of the company, agronomy department or the specific farming operation. A modern interpretation of the role of agricultural extension is one that enables change in individuals, communities and industries involved in the primary industry sector and in natural resource management. The concept of identifying champions with the intention that other farmers will be encouraged to adopt similar goals and practices is a long-standing extension method. However, when dealing with issues of irrigation, promoting outcomes after the event does not alert the target group to the need for timely change and therefore is unlikely to successfully achieve the desired outcome. A Bundaberg web-based extension program designed to draw all farmers in the district into a technology group of likeminded users was developed. Monitoring systems located on the farms of high performing enterprises provide a constant flow of real time information which enables the industry as a whole to react to climatic influences. The potential outcomes of this program are a sustainable increase in productivity, a reduction in irrigation input costs and a greater understanding of factors that impact on the local environment.

IMPROVING SELECTION ACCURACY IN CLONAL ASSESSMENT TRIALS BY ACCOUNTING FOR SITE VARIABILITY

X WEI, J STRINGER, B SALTER, G PIPERIDIS, B SCHROEDER

RESEARCHERS ROUTINELY USE ‘blocking’ as a technique to reduce the natural variationm within field experiments. This enables treatments to be compared without the confounding effects of differences in environmental factors such as soil type. However, it is often difficult to determine the locality of appropriate blocks within a trial when the natural variation at the site is unknown or difficult to measure. Examples are chemical and physical properties of soil. This is particularly an issue in a sugarcane breeding program, where large land areas are often required to assess the performance of >2000 clones. The assumption of homogeneity of the site within a replicate or block may not always be valid. This assumption violation could lead to inefficient selection. Apparent electrical conductivity (ECa) is an easily measured parameter that can be used toidentify differences in soil properties. In this study we demonstrated that ECa could be used in variety trials to improve the selection accuracy. In two clonal assessment trials, each site was grouped into four zones based on ECa measured for 0–90 cm of soil. The difference in average cane yield between high and low performing zones was up to 32 tonnes per hectare. If the soil variation was ignored in clonal evaluation, selection would be biased to high performing zones and clones planted in poor soil zones would be less likely to be selected.


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INTERNATIONAL EVENTS CALENDAR

February 1 -3
ASBF Annual Meetng Long Beach, CA USA ASBF

February 2-4
Louisiana Division of ASSCT, Lafayette, LA USA ASSCT

February 23 -26
ASSBT Clearwater, FL USA ASSBT

May 17-20
Sugar Industry Technologists Annual Meeting Osaka, Japan SIT

June 22 -24
Florida and Louisiana Joint Division of ASSCT New Orleans, LA USA ASSCT

October 19-24
Latin American Sugar Technologist Meeting (ATALAC), *Olinda, Pernambucco, Brazil*

STORY OF SWEETS

Leg Of Lamb Stuffed With Rice

Ingredients
For Stuffing:
- 2 tbsp. oil
- 2 tbsp. butter
- 1 medium onion, peeled anddiced
- 2 cups button mushrooms, quartered
-1/2 green bell pepper, diced
-4 whole red chilies
-1 clove garlic, minced
-2 cups boiled rice
-2 tbsp. fresh cream
-1 tbsp. fresh coriander leaves
-1 tsp. salt
-1\2 tsp. pepper

For leg of lamb:
- 3 tbsp. lemon juice
- 2 tsp. salt
- 1\2 tsp. black pepper
- 1 tbsp. garlic paste
- 1 tsp. chili powder
- 4 tbsp. oil
- 2 1\2 kg. boneless leg of lamb

1. Melt butter with oil in large nonstick skillet over medium heat.
2. Add onion, mushrooms, bell pepper, chilies and minced garlic clove and sauté until mushrooms are tender, about 5 minutes.
3. Add rice and cook until heated through, stirringconstantly. Cool. Add cream, coriander leaves, salt and pepper and mix to blend.
4. Preheat oven to 425°F. In a bowl, mix together lemon juice, salt, pepper, garlic paste, chili powder and 2 tablespoons oil.
5. Unroll lamb, pat dry and rub with marinade. Place cut side up of lamb on work surface. Spread half of stuffingevenly over lamb, press to adhere.
6. Starting at narrow end, roll up lamb tightly, enclosing filling. Place lamb in netting to hold shape.
7. Hold one end of lamb and fill the opposite end with rest of stuffing. Use kitchen string to tie ends of netting.
8. Rub outside of lamb with remaining 2 tablespoons oil, Place it on rack in roasting pan. Roast lamb to desired doneness, about 11\2 hour.
9. Remove from oven. Cover with foil and let stand 15-20minutes. Remove string and netting. Cut lamb into 1/2-inch-thick slices. Place on platter.
10. Serve it with Nan and Chutney.

Serves: 8
Note: For ease of preparation, ask the butcher to butterflythe leg of lamb for you.

Mango Ice Cream
Ingredients
-1 Peach mango (peeled, chopped)
-1 Pawpaw (peeled, chopped)
-1 tbsp. Lemon juice
-4 Egg yolks
-2/3 cup Icing sugar
-1/2 cup Thickened cream
-1/4 cup Fresh coconut milk
-1 tbsp. Ground almonds
-Garnish Fresh fruit or mint sprigs

Method
Puree the mango and pawpaw together with the lemon juice.
2. Beat the eggs and icing sugar in the top of a double boiler until the eggs are pale and thick. Remove from the heat, pour into a bowl and continue to beat until the mixture is cool. Fold the fruit puree into the egg mixture and add the cream, coconut milk and almonds.
3. Pour the mixture into a mould or freezer tray and freeze for 2-3 hours.
4. To Serve: Dip the mold into hot water for 30 seconds before turning out, or scoop out as ice cream balls. Garnish with fruit or fresh mint sprigs.

GUIDELINES FOR AUTHORS

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