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Indian Journal of Sugarcane Technology **29(01)**: 1-12, June 2014 **REVIEW PAPER**

Importance and progresses of microsatellite markers in Sugarcane (*Saccharum* spp. hybrids)

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ABSTRACT

To strengthen the sugarcane (*Saccharum* spp. hybrids) molecular breeding programmes, exploration of microsatellites or simple sequence repeats (SSRs) markers are valuable technique in among the available molecular marker tools. These are functional markers having tandem repeats of 2-6 bp long DNA motifs and used for genotyping of plant population. Modern sugarcane hybrids are highly poly-enuploidy, low fertility, huge genome size and fluctuating environmental interactions. During past two decades, enormous efforts have been made to develop microsatellite (SSRs) based principals, techniques, methods, and applications in cereal crops. Unfortunately, the genomic studies in sugarcane are very limited because of its larger and genome instability. Present review focuses recent developments and future prospects of microsatellite markers in general and special reference regarding the improvement of sugarcane and sugar productivity through marker assisted selection (MAS).

Key words: Microsatellite markers, *Saccharum* spp. hybrids, Cross transferability, Genomic/cDNA library.

Sugarcane Genome complexity and Taxonomy

Sugarcane (*Saccharum* spp. hybrids) is an economically important agricultural crop in many tropical and subtropical countries for production of sugar and biofuels. It belongs to the genus *Saccharum* L., a complex polyaneuploid and highly heterozygous crop belonging to the family *Poaceae* in the tribe Andropogoneae. Commercial cultivars are hybrids, derived from *Saccharum officinarum* (Noble clones; 2n = 80, octoploid), and *S. spontaneum* (a wild species with no sugar and thin culms; 2n = 40-128) with minor contribution of *S. sinense* Roxb (Chinese clones; 2n = 80-124) and *S. barberi* Jesw (North Indian clones; 2n = 111-120). The segregating progenies were repeatedly backcrossed with *S. officinarum* clones to recover the favorable alleles for sugar content and to transfer disease resistance genes from the wild *S. spontaneum*. This process is referred as ''introgression/ nobilization'' (Roach 1972). Because of its multi specific origin, sugarcane is thought to have one of the most complex plant genomes, carrying variable chromosome numbers (generally 2n = 100-130) with a commensurately large DNA content (Lu *et al.* 1994). The basic genome size ranges from 760 to 926 Mbp, which is twice the size of the rice genome (389 Mbp) and similar to sorghum (760 Mbp) (D'Hont & Glaszman 2001).

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In sugarcane conventional breeding programs, few hybrids were extensively used for the hybridization events. Thus, genetic base of modern sugarcane has become very narrow and this has been revealed as one of the critical factors responsible for the sluggish progress currently being experienced by various sugarcane improvement programs (Singh *et al.* 2011). Characterization of such large genome is greatly facilitated by the use of molecular markers. In the present review article, authors have tried to explain all about the microsatellite (SSR) makers based genetic studies in sugarcane i.e. principles, techniques, procedures and their worldwide applications in sugarcane molecular studies.

Sugarcane Conventional versus Molecular Breeding

In spite of its immense economic importance, sugarcane genetics has received relatively little attention as compared to other crops, mainly due to its heterozygous nature, complex genome, poor fertility, and the long breeding/selection cycle. Conventional plant breeding is principally based on the phenotypic selection of superior individuals among segregating progenies generating from hybridization process. The significant difficulties (genotype-environment interactions) are often encountered during the process of phenotypic selection for agronomically important traits (Babu *et al.* 2002). In conventional sugarcane variety improvement programs one cycle takes an average, ten years from hybridization to the release of varieties. This is the main cause of slow rate of

developing high sugar, high yielding and pest tolerant varieties. Improvement in sugar content is more desirable because much amount of sucrose in less biomass can be produced which would result the less cost of sugarcane production (Singh *et al.* 2005). The complexity of the sugarcane genome inhibited large efforts and investments in the development of biotechnology and genetic tools for this crop. Hence, insufficient efforts are being made at molecular level to improve sugarcane biomass production and sugar yields. Previously varietal improvement relied on crossing and long selection, but now PCR based molecular techniques are being used in concert with those more conventional approaches to increase sugarcane and sugar yields. Use of an efficient molecular marker system is essential for sugarcane genome for understanding the genetic and taxonomic complexity, and broadening the genetic base of sugarcane cultivars, thereby improving sugar yield and its stabilization against abiotic and biotic stresses. There is still great interest among sugarcane breeders in broadening the genetic base of the crop and also in taping into the gene pool of the wild relatives to improve stress-resistance and sucrose content (Tai and Miller 2002). Breeding gains in sugarcane, even when substantial (Edme *et al.* 2005), have been slow in recent years, possibly as a result of a founder and/or genetic bottleneck effect. Classical genetics has been unreliable at ascertaining the introgression of beneficial alleles from the wild into the cultivated background and at eliminating linkage drag. Molecular approaches have improved the tracking of species-specific alleles in inter specific hybrid backgrounds and the investigation of co-linearity and recombination of chromosomal segments between the parents. Recombination is crucial in the transfer of genes/ alleles from wild species to the cultivated background and for this strategy to have an impact in plant breeding.

Microsatellites markers

Microsatellites (Litt & Luty 1989), are generally known as short tandem repeats (STRs, Edwards *et al.* 1991), simple sequence repeats (SSRs, Jacob *et al.*1991) or simple sequence length polymorphism (SSLP, Tautz 1989). Due to presence of several genetic attributes like multi-allelic nature, hyper variability, co-dominant inheritance, high reproducibility, chromosome specific location they show significant value in sugarcane genetics, breeding and assessed through (Thiel *et al.* 2003) PCR based genotyping methods.

Based on short tandem repeats microsatellite markers are 2-6 bp long DNA sequences, broadly dispersed in the eukaryotic genomes ranging from yeasts to vertebrates (Hamada *et al.*1982). These microsatellites also have been abundantly confirmed in plants and differed from animals in terms of nucleotides repeats (Tauz *et al.*1984). Genome of plants showed rich in AT sequences whereas animals have AC repeats abundantly (Powell *et al.*1996). A high degree of allelic variation by these markers showed the differences in the number of repeat units caused by slippage of DNA polymerase during replication (Jame and Lagoda, 1996) or unequal crossing-over during meiosis (Goldstein and Schlotterer 1999).

Moreover, SSRs are categorized in various ways on the basis of (A) number of nucleotides per repeat unit, as mono, do, tri, tetra, penta or hexanucleotides (Table1) and (B) arrangement of nucleotides in the repeat motifs, they are divided in to perfect, imperfect, compound microsatellites and region of cryptic simplicity (Wang *et al.* 2009). Perfect repeats are tandem arrays of a single repeat motif, whereas, in imperfect repeat; perfect repeats are interrupted by non-repeat motifs at some locations. In compound microsatellites, two basic repeat motifs are present together in various configurations. Most of the microsatellites (SSRs) are nuclear SSRs; however, microsatellites are also distributed in

Table 1 Classification of microsatellites (Kalia *et al.* 2011)

(A) Based on the number of nucleotides per repeat	
Mononucleotide $(A)_{11}$	-
Dinucleotide $(CT)_6$	CTCTCTCTCTCT
Trinucleotide $(CTG)_4$	CTGCTGCTGCTG
Tetranucleotide $(CAGA)_4$	CAGACAGACAGACAGA
Pentanucleotide $(AAATT)_5$	AAATTAAATTAAATTAAATT
Hexanucleotide $(CTTTAA)_6$	CTTTAACTTTAACTTTAACTTTAA
(B) Based on the arrangement of nucleotides in the repeat motifs (Wang *et al.* 2009)	
Perfect repeat (when repeat tract pure for one motif)	CTCTCTCTCTCT
Compound SSR (when repeat tract pure for two motifs)	CTCTCTCACACA
Imperfect SSR (if single base substitution)	CTCTCTACTCTCT
Region of cryptic simplicity (if complex but repetitive structure)	GTGTCACACAGT
(C) Based on location of SSRs in the genome	
Nuclear (nuSSRs)	
Chloroplastic (cpSSRs)	
Mitochondrial (mtSSRs)	

mitochondrial and chloroplast's genomes.

A. Chloroplast microsatellites

The study of the chloroplast provides information on the population dynamics of plants that is corresponding to that obtained from the nuclear genome. Chloroplast microsatellites consisting of relatively short and many mononucleotide stretches such as (dA)n 9 (dT)n, they are ubiquitous and polymorphic components of chloroplast genome (Powell *et al.*1995). Chloroplast genome based markers uncover genetic discontinuities and distinctiveness among or between taxa with slight morphological variation, which sometimes cannot be revealed by nuclear SSR markers as inter-breeding and genetic exchange has obscured the evidence of past demographic patterns (Wolfe *et al.*1987). Chloroplast SSRs (cpSSRs) markers loci, containing both microsatellites (cpSSRs) and single nucleotide polymorphisms (SNPs) have been identified for *Miscanthus*, *Saccharum* and related grasses (Mariateresa *et al.* 2010).

B. Mitochondrial microsatellites

Plant mitochondrial genome (mtDNA) is more complex than animal mitochondrial (mtDNA) genome. In maize mitochondrial genome has been estimated to be 320 MDa (Sederoff *et al.*1981). In addition to larger size, plant mtDNA is characterized by molecular heterogeneity observed as classes of circular chromosomes that vary in size and relative abundance. In plants, mitochondrial genomes are not usually used for phylogenetic analysis due to a high rate of sequence reorganization. However, mitochondrial haplotype diversity related to sequence rearrangement proved useful in population differentiation of pine and fir taxa (Sperisen *et al.* 2001).

Microsatellite evolution: mutational mechanism of SSR variation

Microsatellite (SSRs) variations in the form of increase or decrease in number of repeats due to mutation is known as microsatellite (SSR) evolution. Microsatellite genesis is an evolutionarily dynamic process and has proven to be much complex (Pearson *et al.* 2005). The mechanism for microsatellite origin includes single-stranded slippage of DNA polymerase during replication (Ellegren *et al.* 2002), unequal crossing over & gene conversion, mismatch/double strand break repair and retro-transposition. During DNA replication, slipping of DNA polymerase III on the DNA template strand at the repeat region may cause the newly created DNA strand to expand or contract in the repeat region if the mismatches are not repaired (Wang *et al.* 2009).

Distribution of microsatellites (SSRs) within the genome

Despite their ubiquitous occurrence, microsatellite density and distribution vary markedly across genomes and randomly distributed throughout the organism's genome i.e. coding as well as non-coding regions but many lines of evidences have demonstrated that SSRs also constitute a large fraction of non-coding DNA (Dieringer *et al.* 2003). Many reports have been revealed that SSRs of coding regions are located in protein coding genes and expressed tags (ESTs), however repeats of these regions are comparatively low (Li *et al.* 2004). In cereals (maize, wheat, barley, sorghum, and rice) 1.5%-7.5% of ESTs consist of SSRs (Thiel *et al.* 2003). These ESTs have a range of functions such as metabolic enzymes, structural and storage proteins, disease signaling, and transcription factors suggesting some roles of SSRs in plant metabolism and gene evolution.

Development of microsatellite markers

Conventionally, microsatellites (SSRs) loci have isolated from partial genomic libraries of the plant of interest by screening thousands of clones using colony hybridization method with repeat containing probes. This way of microsatellite (SSR) isolation is relatively simple in case of microsatellite rich genomes, but can be extremely inefficient for the species having low microsatellite frequencies (Zane *et al.* 2002). Conventional genomic library construction and subsequent screening is time intensive, tedious and costly process which requires high level of scientific skill. AT dinucleotide repeats, which are the most abundant type of SSR in plants genomes, are much difficult to isolate from genomic libraries because they are palindromic (Powell *et al.*1996). The updates of microsatellite development for sugarcane are given in Table 2.

Development of microsatellites from EST sequences (genic or EST-SSRs)

Expressed sequence tags (ESTs), obtained by partial random sequencing of cDNA libraries, are 300-500 nucleotide long single read mRNA sequences from any of the genes expressed in a sample from an organism and they represent a snapshot of gene expression in a specific organ or tissue at a specific developmental stage. A wealth of sequence data of ESTs has been generated as a result of sequencing projects for gene discovery from several plant species, giving scientists the flexibility to access many full-length cDNA clones and characterized genes. These sequences are usually available in online databases in public domain, and can be downloaded and scanned for identification of SSRs. These identified SSRs are usually referred to as EST-SSRs or genic microsatellites. For the development of microsatellites (SSRs), more sophisticated, user-friendly microsatellite-specific software tools are used to screen the sequence data of ESTs (Varshney *et al.* 2007) as; MISA (MIcroSAtellite), SSR finder, Sputnik, SSRIT (SSR Identification Tool), SSR SEARCH and TRF (Tandem Repeat Finder) etc.

Cross transferability of microsatellite (SSR) markers

A regular use of SSR markers for molecular breeding and other applied research in crop plants depend on the development of a large number of SSRs primers for the species of interest. The first constraint of SSRs as molecular markers is the cost and research efforts required to develop by means of cloning and sequencing SSRs containing DNA fragments.

Table 2 Some reports on identification and development of SSRs through EST database, unigenes and genomic library in sugarcane

Application	Description	References
Genomic-SSRs Development	Large set of microsatellite markers had developed and designated as Sugarcane Enriched Genomic Microsatellite (SEGMS) with 6,318 clones from genomic libraries of two hybrid sugarcane cultivars ('Co7201' and 'Co86011') enriched with 18 different microsatellite repeat-motifs.	(Parida *et al.* 2009)
	Unigene microsatellite markers were developed and utilize in diversity and mapping of sugarcane	(Parida *et al.* 2006)
	The protocol of the development of enriched microsatellite libraries in *Saccharum* was optimized and modified for better performance of the procedure.	(Cordeiro *et al.* 1999b)
	Microsatellite markers for genome analysis in *Saccharum* spp. was identified from an enriched genomic DNA library constructed from *Saccharum* sp. cv Q124.Z	(Cordeiro *et al.* 2000)
EST-SSRs Development	EaCIR1, a 371-bp *Erianthus* specific satellite DNA sequence, was cloned from TaqI restricted genomic DNA. PCR primers defined in the conserved regions of the repetitive sequences were used to isolate other satellite DNAs in different representatives of the *Saccharum* complex.	(Alix *et al.* 1998)
	Expressed sequence tags (ESTs) in the *Saccharum* spp. database (SUCEST) were electronically searched and 402 SSRs identified and SSR primers were designed.	(Da Silva *et al.* 2001)
	A survey was carried out in the publically available SUCEST (sugarcane EST) database that revealed a total of 2005 clusters out of 43 141 containing SSRs including, 8.2% dinucleotide, 30.5% trinucleotide, and 61.3% tetranucleotide repeats.	(Pinto *et al.* 2004)
	Total 2,60,000 independent clones were sequenced from the 5' end in the Sugarcane Expressed Sequence Tag (SUCEST) database, that was obtained from 37 cDNA libraries prepared from different tissues.	(Figueiredo *et al.* 2001)
	An EST database was developed for sugarcane and obtained some potentially useful information on sugarcane gene sequences.	(Deborah *et al.* 2002)
	An EST survey was carried out of the sugarcane transcriptome	(Ma *et al.* 2004)
Unigene SSRs development	Microsatellites were developed from unigene sequences assessed their functional significance in silico, determinate the allelic diversity and for evaluated their utility in large-scale genotyping applications in sugarcane.	(Parida *et al.* 2010)

Some comparative genetic studies of the genomes have exposed that gene content and order are usually conserved among the grasses which has been a icon of a "single genetic system" (Devos 1997, Bennetzen and Freeling 1993). Sequence data obtained from a number of crop plants show enough homology existing between genomes in the flanking regions of the SSRs loci (Saha *et al.*2004). Such homology in the flanking regions of SSR loci has extended the utility of these markers to related species and genera where no information on SSRs has existed. Thus primers designed on the basis of the sequence obtained from one crop could be used to amplify SSRs in related species (Kuleung *et al.* 2004). SSRs cross transferability informations are summarized in Table 4.

Microsatellites (SSRs) based fingerprinting techniques

1. Sequence-tagged microsatellite site markers (STMS)

This method explores DNA polymorphism using specific primers designed from the flanking sequence of microsatellite motifs are known as sequence tagged microsatellites sites (STMS) markers (Beckmann and Soller 1990). These microsatellite motifs are conserved within the particular species and often across the species within a genus and even across related genera (Gupta and Varshney 2000). Primers complementary to the flanking regions of the simple sequence repeat loci (Weber *et al.*1989) yield highly polymorphic amplification products. These markers show polymorphism due to variation in lengths of the microsatellites at individual microsatellite loci.

2. Inter simple sequence repeat markers (ISSR)

The inter simple sequence repeats (ISSRs) are a type of molecular marker they involve in PCR amplification of DNA by a single primer 16-18 bp long composed of a repeated sequence anchored at the 3' or 5' end by 2-4 arbitrary nucleotides (Zietkiewicz *et al.*1994). ISSRs are easy to handle, highly informative and repeatable. Since repeated sequences are abundant throughout the genome, SSR primers anneal in

Table 3. Applications of the SSR markers for fingerprinting and phylogenetic analysis in *Saccharum* spp.

Application	Description	Reference
DNA fingerprinting	Data analysis showed the potential of SSR markers viz; they can identify co-dominance, polymorphism and inheritance in sugarcane.	(Cordeiro *et al.* 1999a)
	Forty eight sugarcane varieties and breeding lines from the USDA Louisiana collection were fingerprinted by SSR markers, SMC334BS, SMC336BS.	(Pan *et al.* 2009a)
	This is the patent related to *Saccharum* spp. SSRs and their flanking region sequences, method of SSRs isolation, and methods applicable for fingerprinting.	(Matsuoka *et al.* 2010)
	Forty genotypes of sugarcane, as elite lines, commercial cultivars of *Saccharum officinarum* and clones of *S. barberi* were fingerprinted with 50 SSR markers.	(Nawaz *et al.* 2010)
Genetic diversity	Genetic diversity among members of the genera *Saccharum* (*S. officinarum, S. spontaneum, S. sinense*), Old World *Erianthus Michx*. sect. *Ripidium*, North American *E. giganteus* (*S. giganteum*), *Sorghum* and *Miscanthus* were assessed.	(Cordeiro et al. 2003)
	Genetic relationship were established among five *Saccharum* species	(Brown *et al.* 2007)
	Genetic diversity of five *S. officinarum* clones and sugarcane cultivars was assessed.	(Riascos *et al.* 2003)
	Genetic diversity was established among a selection of sugarcane varieties used in the breeding programs of Florida, Louisiana and Texas.	(Glynn *et al.* 2009)
	The utility of sugarcane SCM markers, genomic microsatellites and SEGMS markers was evaluated to assess the genetic diversity among sugarcane germplasm collection.	(Singh *et al.* 2010)
	Genetic diversity was analyzed among Chinese and U.S. sugarcane varieties and six vegetative clones of related wild species from Guangxi, China and India using capillary electrophoresis (CE).	(Liang *et al.* 2010)
	Genetic diversity was assessed among red rot resistant/susceptible genotypes and among the clones of *Saccharum spontaneum.*	(Singh *et al.* 2012, 2013)
Molecular genotyping	Genotyping was done on a fluorescence-capillary electrophoresis detection platform using 21 SSR markers	(Pan YB, 2010a)
	Capillary electrophoresis based molecular genotyping was completed of sugarcane clones using polymorphic SSR markers.	(Pan *et al.* 2003)

several regions typically giving a complex amplification pattern in which fragments are often polymorphic between different individuals. A range of microsatellites anchored at the 3' end to amplify genomic DNA and increase of their specificity. These are mostly dominant markers, though occasionally a few of them exhibit co-dominance. An unlimited number of primers can be synthesized for various combinations like di-, tri-, tetra- and penta- nucleotides etc. with an anchor made up of a few bases and exploited for a broad range of applications.

3. Randomly amplified microsatellite polymorphism (RAMP)

Microsatellite-based markers are highly polymorphic and co-dominant but their development is time taking and labor-intensive process. However, RAPD marker techniques are inexpensive but show a lower level of polymorphism. To recompense for the shortcomings of these two molecular analysis techniques, another molecular approach have been evolved and termed as random amplified microsatellite polymorphisms (RAMP). It was introduced by Wu *et al.*1994. This technique exploits a radio labeled primer to amplify genomic DNA in the presence or absence of RAPD primers. The banding profiles of PCR products are observed using denaturing polyacrylamide gel electrophoresis (PAGE), derived from the anchored primers. Most of the fragments obtained with RAMP primers alone not amplified when RAPD primers are included. Unique patterns are obtained with the same RAMP primer and different RAPD experiments, reveals that RAPD primers compete with RAMP primer during the low annealing temperature PCR cycles.

4. Retrotransposon-microsatellite amplified polymorphism (REMAP)

REMAP determines the polymorphism in retrotransposon insertion sites, between retrotransposons and microsatellites (SSRs). The REMAP method exploits an outward-facing LTR primer and a second primer from a microsatellites motif. REMAP primers are designed to the (GA), (CT), (CA), (CAC), (GTG) and (CAC) microsatellites and anchored to the microsatellite 3^1 terminus by the addition of a single selective base at the 3^1 end (Kalendar *et al.* 1999). The polymorphism is detected at about 30 bands by the presence or absence of

Table 4 Some reports of the applications of the SSR markers for paternity, fidelity analysis and cross transferability in *Saccharum* spp.

Application	Description	Reference
Parental Screening	Ten SSRs were used to analyze 13 potential parent cultivars and investigated the assertion of mislabeling at planting and in a restricted manner that of mislabeling at seed collection using SSR primers that generated 75 markers.	(Hack *et al.* 2002)
	Genetic identity of sugarcane clones were validated using SSR markers by producing molecular fingerprints.	(Pan Y, 2007)
Hybrid Validation	Intergeneric hybrids of *Erianthus rockii* and *Saccharum* were characterized using SSR markers.	(Aitken *et al.*2007b)
	Polymorphic SSR markers were identified and used with 5S rDNA PCR to screen intergeneric (F1) clones from *S. officinarum* × *E. arundinaceus* crosses, and two *Saccharum* backcross populations.	(Cai *et al*. 2005)
Genetic Fidelity	Cross fidelity was assessed of progeny within the crosses that inherited SSR DNA fingerprints from both parents using SSR molecular markers strategy.	(Tew *et al.* 2005)
Paternity Analysis & varietal Testing	Paternity of offspring was identified on a seven parent poly cross by using SSR markers technique.	(Tew *et al.* 2010)
	Varietal identification was carried out of the five varieties by particular SSR markers, which showing polymorphism information content ranging from 56% to 80%.	(Pan *et al.* 2006)
Cross Transferability	Polymorphism of *Saccharum* SSRs was tested in sugarcane cultivars that was found to be low (0.23) and significantly higher level of polymorphism was detected when these markers were applied to offspring and related genera (*Erianthu*s sp. and *Sorghum* sp.)	(Cordeiro *et al.* 2001)
	Rice and sugarcane SSR markers was used to phylogenetic and diversity analysis in bamboo.	(Sharma *et al.* 2007)
	Maize microsatellite markers were exploited to genetic diversity and fingerprinting study in sugarcane.	(Selvi *et al.* 2003)
	Parallel results were found to characterize the sugarcane clones by using SSR markers from rice and it showed that SSR markers from other cereals can be utilized for sugarcane study.	(Banumathi *et al.* 2010)
	High polymorphism level was detected among sugarcane species, genera, and varieties with high cross transferability rate within *Saccharum* complex and cereals.	(Parida *et al.* 2009)
	Unigene Sugarcane microsatellite markers were identified and used in the study of cross transferability across the wide range of *Saccharum* complex and related/ divergent genera.	(Singh *et al.* 2011)

the PCR product and lack of amplification indicates the absence of the retrotransposon at the particular locus. Since, the REMAP marker technique was highly polymorphic and it could prove useful for estimating intra-specific relationships.

5. Selectively Amplified Microsatellite Polymorphic Locus (SAMPL)

SAMPL is a method for amplifying microsatellite loci using general PCR primers. SAMPL analysis carried out by one AFLP primer in combination with a primer complementary to microsatellite sequences. This technique amplifies microsatellites loci which do not require prior cloning and characterization.

6. Fast isolation by AFLP of sequences containing repeats (FIASCO)

FIASCO protocol relies on the extremely efficient digestion-ligation reaction of the amplified fragment length polymorphism polymorphism (Vos *et al.*1995). DNA is simultaneously digested with MseI and ligated to MseI AFLP adaptor (5¹-TACTCAGGACTCAT-3¹/5¹-GACGATGAGTCCTGAG-3¹). In FIASCO protocol the amplification is carried out by mixing primers carrying all four possible selective bases (MseI-N), thus allowing amplification of all fragments flanked by MseI sites, providing only that they have an appropriate size for PCR. Amplified PCR product hybridized with a biotinylated probe and hybridized fragments are selectively captured by streptavidin coated beads. The beads-probe-DNA complex is separated by a magnetic field from the hybridization buffer, which is then discarded. The DNA separated from the beads-probe complex was reprecipitated which provides the best candidates for producing a highly enriched microsatellite library.

Table 5 Some applications of microsatellite (SSR) for genome mapping/gene identification in *Saccharum* spp.

Mapping trait/gene	Application	Reference
Comparative mapping	The study investigated a *S. officinarum* × *S. spontaneum* interspecific cross using linkage mapping strategy. Segregation of 193 microsatellite (SSR) loci was evaluated in the F1 progeny of 169 full-sibs of the cross.	(Edme *et al*. 2006)
	Comparative mapping was investigated for QTL validation and genetic map enhancement in sugarcane. Almost 1000 SSR and AFLP markers were scored in a biparental population of Australian sugarcane that was segregated widely for sugar content related traits.	(Piperidis *et al.* 2008)
	Two genetic maps were constructed using a population of 198 progeny derived from a cross between R570, and MQ76-53, an Australian clone. Total 1,666 polymorphic markers were generated by 37 AFLP, 46 SSRs primer combinations and 9 RFLP probes.	(Raboin *et al*. 2006)
Linkage mapping	A genetic linkage map was constructed for *S. officinarum* (clone IJ76-514) using a segregating population developed from a cross of Q165 and IJ76-514.	(Aitken *et al*. 2007a)
	Sugarcane EST project was access to 261,609 EST sequences from sugarcane, and they were assembled into 81,223 clusters. Among these 88 resistance gene analogs (RGAs) based on their homology to typical pathogen resistance genes were identified.	(Rossi *et al*. 2003)
	In total 149 EST-SSRs and 10 EST-RFLPs were screened in the SP80-180×SP80-4966 mapping population to enhance the resolution of an existing linkage map and to identify putative functional polymorphic gene loci in a sugarcane commercial cross	(Oliveira *et al*. 2007)
	A genetic linkage map of Louisiana's cultivar LCP 85-384 was constructed using the selfed progeny and based on polymorphism generated from 64 AFLP, 19 SSR and 12 TRAP primer pairs	(Andru *et al*. 2011)
	Genetic linkage map was constructed of sugarcane cultivar LCP 85-384 using microsatellite (SSR) DNA markers.	(Pan *et al.* 2010b)
	A genetic linkage map was developed using 300 genetically verified selfed progeny of a commercial cultivar LCP 85-384 based on AFLP and SSR markers were used to fingerprint of the population	(Pan *et al*. 2009b)
	A single integrated genetic map was developed using a population developed from a cross between two pre-commercial cultivars (SP80-180×SP80-4966) by a novel approach based on the simultaneous maximum-likelihood estimation of linkage and linkage phases method.	(Garcia *et al*. 2006)
Homo(eo) logous linkage mapping	A linkage map was constructed in Q165 an Australian cultivar, from a segregating F1 population, using 40 AFLP primer combinations, 5 randomly amplified DNA fingerprints (RAF) primers and72 SSR primers.	(Aitken *et al*. 2005)

Applications of microsatellites (SSR) marker technique

1. In DNA fingerprinting

DNA fingerprinting is one of the simplest and most invasive applications of microsatellite (SSRs) markers in plants (Soller & Beckmann, 1983). This is generally used to identify and monitor germplasm/variety after its release for commercial cultivation (Table 3).

2. In diversity and phylogeny analysis

Microsatellites (SSRs) markers are being frequently used to assess genetic variations at molecular level. The measurement of genetic similarity or differences among plant species is important information in crop conservation and varietal development (Romero *et al.* 2009). Moreover, these informations are very useful for characterization of accessions in plant germplasm collections and taxonomic studies. From one decade, microsatellite markers have proved to be a potential tool for estimation of sugarcane genetic diversity (variation in nucleotide sequence, gene structure, chromosomes and whole genomes) and phylogenetic relationships of species. Several recent studies of SSRs analysis and its applications regarding to fingerprinting, diversity and phylogenetic are summarized in Table 3.

3. In Paternity analysis

SSRs markers have been used to paternity analysis progeny derived from small poly-crosses of sugarcane, preliminary report was provided on in analyzing a polycross involving seven parents using two microsatellite markers and fidelity testing (Tew *et al.* 2010). . Recent studies related to parental

screening, hybrid validation, Genetic fidelity and cross transferability are given in Table 4.

4. Genetic mapping and QTL analysis

Genome mapping is another field where microsatellites are being extensively used. It consists of genetic mapping, comparative mapping, physical mapping, and association mapping. Generally, significant association of a molecular marker with a phenotypic trait is particularly useful for implement marker-assisted selection (MAS) for quantitative traits in plant breeding programs which is refers association mapping (Breseghello *et al.* 2006). Quantitative trait loci (QTL) mapping generally uses a population generated from a bi-parental cross, whereas association mapping exploits a collection of individuals frequently with varying ancestry. In recent years, genetic maps have been prepared in several plant species including sugarcane, rice, wheat, barley, cotton, ryegrass, white clover, raspberry, potato, sorghum, etc. A list of SSR's applications utilized for genome mapping and QTL mapping is listed in Table 5 & Table 6.

CONCLUDING REMARKS

With the advent of microsatellite markers, it has been possible to make direct presumption about genetic variability and phylogenetic relationships among organisms at the DNA level without the perplexing effects of the environmental factors or faulty analysis of pedigree records. Approximately, from last two decades the development, isolation and characterization of microsatellite markers are constantly being running not only in sugarcane but also in a wide range of plant genomes including cereals, oilseeds, legumes, vegetables, spices plants, beverage crops, fruit plants, conifers, forest trees, and other economically important plant species. Microsatellite markers are exploiting not only in genetic analyses of plant and animal populations/species, evolutionary, ecological studies, genetic diversity, paternity analysis, hybrid testing, but also being used in fundamental research like genome analysis, gene mapping QTL analysis and molecular breeding (MAS) etc.

Table 6 Some reports of the applications of the SSR markers for QTL analysis and marker identification & validation in *Saccharum* spp.

QTL Trait/ Marker/Gene	Description	Reference
QTL analysis for yellow spot disease resistance	AFLP and SSR markers were used to identify major quantitative trait loci (QTL) for yellow spot disease resistance in sugarcane.	(Aljanabi *et al.* 2007)
QTL analysis for yield related stalk traits	A cross between an Australian sugarcane variety Q165, and a *Saccharum officinarum* clone, IJ76-514, was developed to dissect the inheritance of yield related traits in the complex polyploid sugarcane.	(Aitken *et al.* 2008)
QTL analysis for sugar related traits	Progeny from a cross between a high sucrose producing cultivar and a *S. officinarum* clone, IJ76-514 were produced.	(Aitken *et al.* 2006)
Genes for rust resistance	54 different sugarcane resistance gene analogue sequences were isolated, characterized and used to identify molecular markers linked to major disease-resistance loci in sugarcane.	(McIntyre *et al*. 2005a)
QTL analysis for sugar yield and related traits	Two sugarcane mapping populations were used to QTL analysis for sugar yield, pol%, stalk weight; stalk number, fiber content and ash content.	(Ming *et al*. 2002)
Markers for downy mildew resistance	Molecular markers were identified associated with for downy mildew resistance by linkage map based approach.	(Manigbas *et al*. 2007)
Markers for multiple disease resistance	Molecular markers were investigated associated with pachymetra root rot, leaf scal, Fiji leaf gall, and other diseases.	(Wei *et al*. 2006)
Genes related to stress resistance	Two hundred and seventy one stress resistance related ESTs were discovered, of which 29 were found having SSRs and used for primer development.	(Da Silva *et al*. 2006)
Comparative mapping	A combined pedigree and QTL mapping approach was used to understand the genetic contribution of Mandalay to Australian varieties and elite parental material.	(Reffay *et al.* 2005)
Genes to drought & red rot resistance	Sequencing was carried out to generate more than 35,000 ESTs from healthy as well as red-rot infected tissues of sugarcane and by clustering with existing sugarcane ESTs in public databases identified 4,087 clusters.	(Gupta *et al.* 2009)
Pachymetra root rot and brown rust resistance gene	Pachymetra root rot and brown rust resistance ratings were obtained of a cross derived from elite sugarcane clones, Q117 and 74C42 using SSR, AFLP and RFLP markers.	(McIntyre *et al.* 2005b)

Future directions of microsatellite marker research in plant sciences

A large DNA sequence data being generated day to day, the trend is towards cross-referencing genes and genomes using sequence and map-based research tools. Since, the polymorphism is a major limitation for most of the species, microsatellite markers are a precious tool for plant molecular genetics and molecular breeding. Evidently, the most important application of SSRs is for comparative genome mapping, with good examples in graminaceous and leguminous species. A database of EST-SSR primer pairs that would amplify orthologous loci across species/genera and that are uniformly distributed over the sugarcane, maize, rice, tall fescue, *Sorghum* and *Arabidopsis* genomes would be very useful to plant breeders and geneticists. In the broader term, the development of allele-specific microsatellite markers for the genes governing economic traits would be important for advancing the molecular technology of plant breeding. Thus, in this perspective, genic (EST) microsatellites are the one class of choice marker that can be organizes along with single nucleotide polymorphisms (SNP) and other types of microsatellite based markers that target functional polymorphisms within the genes.

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Minimum number of seedlings for evaluation of cross performance in sugarcane

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ABSTRACT

An experiment was conducted to study the sample size for estimating mean and variance of cane weight, number of stalks, cane height, brix, and internode length and cane diameter in seven families of sugarcane seedlings. Random samples of various sizes were drawn from the family showing highest variability. The absolute difference between sample estimate and population parameter was expressed relative to population parameter for each trait. Margin of error dropped from sample size of 30 to 150 sharply at desired level It was concluded that minimum size of seedlings to be grown for evaluating cross was 150 with maximum 5% margin of error in mean and 10-12% in variance in case of cane weight .

Key words: Seedling evaluation, sugarcane

In sugarcane selection programme, breeder's objective is to search families with high mean performance and sufficient genetic variance so as to make effective selection.

The real approach is to study the minimum number of seedlings from large number of diverse families and then exploit intensively those giving evidence of above average performance. In Australia, Skinner (1971) suggested to raise 75 seedlings of experimental cross to make selection among the crosses. In a study conducted in Hawaii, Wu *et al*. (1978) estimated that minimum sample size of 40 seedlings was sufficient for estimation of progeny mean and variance. A sample of 60 seedlings was found suitable for evaluating cross performance (Tripathi *et al* 1986).

Such information is scanty in respect of subtropical India. The present study is an attempt to find out suitable sample size from open pollinated families grown at Lucknow .

METHODOLOGY

Sugarcane seedlings were grown from open pollinated fluff of important varieties. Data on cane length, number of millable canes, cane weight, cane diameter, internodes length and HR Brix % on all seedlings were recorded.

A computer program has been prepared for obtaining margin of error associated with large number of samples of various sizes. The program generates desired number of samples (100) of required sizes.

The computer program was used for selection of large number of samples and calculation of various statistics . For each variable minimum hundred samples were drawn randomly by the Computer program, for each of the following sizes, 30,60,90...300 seedlings . Mean and variances were estimated from each of the sample. The absolute difference between sample estimate and population parameter was expressed relative to population parameter according to equation (Wu *et al*. 1977).

$$\Delta\bar{x} = \frac{\bar{x}\text{-}\mu}{\mu} \text{ I- } \Delta s^2 = \frac{s^2 - \sigma 2}{\sigma 2}$$

$\bar{x}$ and $\Delta s2$ are sample mean and variance, μ and σ2_are cross (population) mean and variance

$\Delta\bar{x}$ and Δs^2 decrease as the sample size increases.

RESULTS AND DISCUSSION

Table 1 shows the coefficient of variation (cv %) in different traits.

Maximum variability (coefficient of variation) was observed in SCW (57.52%) followed by NMC (56.19%), Cane height

Table 1 Coefficient of variation (%) in different traits

CROSS	COUNT	*NMC*	*SCW*	*I N LEN*	*DIA*	*HR BRIX*	*Cane Height*
'Co 87263' x 'Co 1148'	348.00	54.56	57.52	17.93	17.41	22.43	23.01
'CP 61-23' x 'Co 775'	253.00	52.73	34.83	15.34	16.50	19.56	18.76
'CoH 56' x 'Co 8347'	127.00	44.04	44.37	16.36	16.82	17.18	24.49
'CoPant 90223' x 'Co 775'	324.00	45.67	37.28	16.64	14.19	19.36	21.13
'CoS 90265' x 'Co 89003'	97.00	56.19	51.40	18.512	14.35	16.34	22.99
'Co 87263' x 'Co 775'	214.00	51.17	49.20	19.56	17.65	24.71	25.76
'CP 61-23' x 'Co 775'	55.00	54.41	52.23	17.76	15.92	16.55	28.51

Table 2 Average margin of error and number of samples lying between different margin of errors for mean and variance

Cane weight

		Mean					Variance			
		Number of points (%) lying between margin of error					Number of points(%) lying between margin of error			
Sample size	Average error	0-5	5-10	10-15	15-20	Average error	0-5	5-10	10-15	15-20
30	7.30	40	33	17	8	33.54	8	6	5	13
60	5.44	54	34	9	3	26.40	7	10	11	11
90	3.97	69	26	5	0	17.18	13	22	14	12
120	3.05	85	15	0	0	15.26	19	17	16	17
150	2.60	90	10	0	0	11.02	23	29	20	16
180	2.28	94	6	0	0	8.68	39	25	18	12
210	1.78	98	2	0	0	7.52	39	35	16	10
240	1.44	100	0	0	0	5.42	53	31	14	1
270	1.20	100	0	0	0	5.05	53	39	8	0
300	0.86	100	0	0	0	3.77	68	29	3	0

Cane height

		Mean					Variance			
Sample size	Average error	0-5	5-10	10-15	15-20	Average error	0-5	5-10	10-15	15-20
30	8.26	61	31	5	0	218.64	0	0	0	0
60	5.33	74	20	2	0	150.04	0	0	0	0
90	7.32	66	21	1	0	206.67	0	0	0	0
120	5.67	74	14	1	3	154.25	0	0	0	0
150	5.26	63	27	3	1	144.26	0	0	0	0
180	5.98	64	18	7	5	168.09	0	0	0	0
210	5.47	70	19	0	10	151.32	0	0	0	0
240	4.58	71	21	4	4	127.94	0	0	0	0
270	4.80	71	18	10	0	133.06	0	0	0	0
300	4.31	77	14	9	0	120.53	0	0	0	0

Cane internode length

		Mean					Variance			
Sample size	Average error	0-5	5-10	10-15	15-20	Average error	0-5	5-10	10-15	15-20
30	2.51	88	12	0	0	22.03	12	14	13	13
60	2.13	96	4	0	0	13.39	29	18	16	13
90	1.71	98	2	0	0	14.01	21	19	18	19
120	1.28	100	0	0	0	10.53	22	36	22	9
150	1.00	100	0	0	0	10.28	23	33	24	9
180	1.21	100	0	0	0	8.81	36	26	22	8
210	1.02	100	0	0	0	7.67	36	35	17	8
240	0.92	100	0	0	0	7.61	43	27	19	6
270	0.86	100	0	0	0	7.33	43	27	19	10
300	0.88	100	0	0	0	6.57	43	31	21	5

Number of millable canes

		Mean					Variance			
Sample size	Average error	0-5	5-10	10-15	15-20	Average error	0-5	5-10	10-15	15-20
30	9.07	36	27	17	9	27.24	10	17	11	8
60	4.54	64	24	11	1	15.55	19	21	15	16
90	4.91	62	27	10	1	13.91	20	17	22	18
120	4.09	64	30	6	0	12.79	22	27	19	10
150	3.68	70	29	1	0	11.40	30	25	16	11
180	3.15	77	23	0	0	10.05	27	27	25	13
210	2.94	79	21	0	0	8.11	38	30	18	9
240	2.88	84	15	1	0	7.71	42	27	17	12
270	2.59	87	12	1	-	6.60	47	32	13	6
300	2.11	96	4	-	-	6.28	43	36	15	5

Brix

	Mean					Variance				
Sample size	Average error	0-5	5-10	10-15	15-20	Average error	0-5	5-10	10-15	15-20
30	2.90	82	16	2	-	22.21	10	18	11	12
60	2.11	95	-	-	-	15.86	20	20	18	9
90	1.53	100	-	-	-	13.36	23	21	18	11
120	1.29	100	-	-	-	12.34	23	23	22	11
150	1.15	100	-	-	-	8.89	36	26	14	17
180	0.95	100	-	-	-	10.16	28	24	23	15
210	0.86	100	-	-	-	7.74	40	27	21	10
240	0.97	100	-	-	-	8.44	40	26	16	12
270	0.81	100	-	-	-	7.75	34	41	13	8
300	0.85	100	-	-	-	6.43	49	32	11	6

Cane diameter

	Mean					Variance				
Sample size	Average error	0-5	5-10	10-15	15-20	Average error	0-5	5-10	10-15	15-20
30	2.75	85	15	-	-	36.50	9	12	9	5
60	1.73	96	4	-	-	37.28	10	13	10	14
90	1.54	98	2	-	-	37.12	7	14	19	10
120	1.33	99	1	-	-	35.73	11	13	13	12
150	1.04	100	-	-	-	29.09	14	16	14	19
180	1.07	100	-	-	-	31.91	8	8	20	17
210	1.01	100	-	-	-	33.83	10	10	4	21
240	0.98	100	-	-	-	29.27	7	16	16	22
270	0.79	100	-	-	-	28.98	9	18	12	12
300	0.79	100	-	-	-	25.13	8	11	17	20

Table 3 Absolute difference (%) between sample mean ($\bar{x}$)and population mean(μ)

Sample size	Weight	Height	ILength	NMC	Brix	Diameter
30	7.30	8.26	2.52	9.07	2.90	2.75
60	5.44	5.33	2.13	4.54	2.11	1.73
90	3.97	7.32	1.71	4.91	1.53	1.54
120	3.05	5.67	1.28	4.09	1.29	1.33
150	2.60	5.26	1.00	3.68	1.15	1.04
180	2.28	5.98	1.21	3.15	0.95	1.07
210	1.78	5.47	1.02	2.94	0.86	1.01
240	1.44	5.58	.92	2.88	0.97	0.98
270	1.20	4.80	.86	2.59	0.81	0.79
300	0.86	4.31	.88	2.11	0.75	0.79

Table 4 Absolute difference (%) between sample variance (s^2) and population variance ($\sigma 2$)

Sample size	Weight	Height	ILength	NMC	Brix	Diameter
30	33.54	218.64	22.03	27.24	22.21	36.50
60	26.40	150.04	13.39	15.55	15.86	37.28
90	17.18	206.67	14.01	13.91	13.36	37.12
120	15.26	154.25	10.53	12.79	12.34	35.73
150	11.02	144.26	10.28	11.40	8.89	29.09
180	8.68	168.09	8.81	10.05	10.16	31.01
210	7.52	151.32	7.67	8.11	7.74	33.83
240	5.42	127.94	7.61	7.71	8.44	29.27
270	5.05	133.06	7.33	6.60	7.75	28.98
300	3.77	120.53	6.57	6.28	6.43	25.13

(28.51%), HR Brix (24.71%), Internode length (19.56%) and Diameter (17.65%). A computer program has been developed for drawing random samples of various sizes and calculating margin of error in different sample size.

Table 2 shows average margin of error and number of samples lying between different margin of errors for mean and variance for different sample sizes i.e. 30 to 300. Mean value was of greater importance than within cross variability in determining the importance of the cross (Hogarth, 1971). Number of points (%) lying between margin of error 0-5,5-10,10-15,15-20 are also shown in the table. Margin of error decreases as the sample size increases from 30 to 300. As the sample size increases, more number of points (%) is lying between margins of error 0-5.

As the sample size increases absolute difference (%) between sample variance (s^2) and population variance (S^2) decreases incase of weight, I length,and brix upto about 7 % but in case of height and diameter decrease is not sufficient and a larger sample is required. Margin of error dropped from sample size of 30 to 150 sharply after that it dropped slowly.

It was concluded that minimum size of seedlings to be grown for evaluating progeny mean and variance is 150 with about 5% margin of error for mean and 10-12% for variance.

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Seedling blight and mortality diseases of sugarcane and their management

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ABSTRACT

Losses of valuable seedlings in nursery beds after germination from the true seeds due to seedling diseases have resulted poor stand of seedlings. Diseased seedlings showing the characteristics symptoms of seedling blight and mortality yielded *H. halodes* and *A. alternata*. On inoculation these fungi produced symptoms of both the diseases indicating that both fungi were Pathogenic to sugarcane seedlings. However, the extent of diseases varied according to the levels of virulence of the test fungi and degree of resistance of seedlings of different crosses. Seedlings of 'CoPant 01215' x 'BO 17' got least infection of seedling blight and seedling mortality diseases caused by the test fungi. In case of *H. halodes*, blight and mortality varied from 30 to 100 % and 42.5 to 84.5 % respectively, while it ranged from 28 to 100% and 38.5 to 82.5% respectively with *A. alternata*. Bavistin and Saaf were found the most efficacious in arresting the growth of both the fungi in vitro and reducing the incidence of seedling blight and mortality when they were tested either as soil drench or spray. Two sprayings were found superior than one spray in relation to suppressing the disease incidence.

Key words: Sugarcane, Seedling blight, Mortality, Disease, Management.

Propagation of sugarcane seedlings from true seeds (fuzz) is an essential step in the development of new commercial clones. Approximately 40000 to 50000 seedlings are raised each year at Sugarcane Research Institute, Pusa, Bihar. At the early stage of development, losses of valuable seedlings in nurseries after germination from the seeds due to seedling diseases are important. A severe seedling mortality was observed at SRI, Pusa, Bihar, during February-March, 1986 in seedlings raised from the seeds procured from SBI, Coimbatore. The incidence of infection varied from 48.65 to 95.00 per cent and the mortality among the diseased seedlings ranged from 29.35 to 69.15 percent causing poor stand of seedlings. Fungal infection of the inflorescence leads to the production of diseased seeds, thus constituting a serious menace in hybridization and nursery raising (Kumar *et al.* 1986). A perusal of literature on seed pathology revealed that no attempts have been made to study the seedling mortality of sugarcane and its management in Bihar. Hence, to start with, diseased samples showing the characteristic symptoms of seedling mortality disease were collected from seed bed nursery of SRI, Pusa. Repeated isolations from the affected seedlings yielded *H. halodes* and *A. alternata*. On inoculation, these fungi produced two distinct types of disease symptoms which were usually observed simultaneously on the infected plants in nature as well. Since, the seedling mortality caused considerable damage to the seedlings, it was considered desirable to study disease and its management in detail.

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MATERIALS AND METHODS

To test the pathogenic behaviour of *H. halodes* and *A. alternata* 100 seeds were taken from each cross and were inoculated with spores of test fungi separately. Inoculated seeds were sown in earthen pots having steam sterilized soil and then covered with polythene sheets to provide them optimum environmental conditions. After 25 days of sowing symptom and incidence of seedling blight & mortality were recorded. To mitigate the losses caused by seedling mortality, five fungicides, (Bavistin, Indofil M-45, Saaf, Bordeaux mixture and Blue copper) were tested both *in vitro* and *in vivo*.

In vitro evaluation

To prepare the fungicidal solution of 0.1%, 0.15%, 0.2%, 0.25%, 0.3% concentrations, the required amount of each fungicide was added in Petridishes containing 25 ml. oat meal agar medium. The Petridishes were shaken well to mixed the fungicides properly and were allowed to solidify. 7 days old inoculum of *H. halodes* and *A. alternata* were put into the centre of Petridishes by the help of 5 mm sterilized cork borer. The Petridishes were incubated at 28 ± 1^0C for 7 days. Petridishes were replicated thrice in each treatment. After incubation period, the radial growth of each fungus was measured.

In vivo evaluation

To confirm the laboratory results, the fungicides and their concentrations were also evaluated by adopting soil drenching and spraying methods.

Soil drenching method

Fungicidal solution of each fungicide of different concentrations were drenched in soil before sowing. After 24 hours, soil was inoculated with spore suspension of *Alternaria alternata* and *Helminthosporium halodes* separately. Then 100 seeds of cross 'BO 926' × 'BO 17' were sown in each pot. After 10 days of emergence of sugarcane seedlings, the severity of the seedling mortality and blight disease was recorded.

Spraying method

Earthen pots having one week old sugarcane seedling of cross 'BO 926' × 'BO 17' were properly sprayed with solution of Bavistin, Saaf, Indofil M-45, Bordeaux mixture and Blue copper with an atomizer. After 24 hours of spray, the seedlings were inoculated by spraying with spore suspension of *A. alternata* and *H. halodes* separately. Each inoculated pot was again sprayed with each fungicide at an interval of 5 days. One pot inoculated with test fungi was kept as control for each treatment. All the pots were kept under moist condition by covering them with polythene sheet for 48 hours after inoculation and then allowed to grow under the same normal conditions. The observation on the severity of seedling mortality and blight was recorded after 10 days of last spraying.

Effect of number of fungicidal sprays on seedling mortality and blight.

To determine the minimum number of sprays of different fungicides, earthen pots having one week old seedlings of cross 'BO 92' × 'BO 17' were properly sprayed with the solution of Bavistin, Indofil-M-45, Saaf, Bordeaux mixture, Blue copper with an atomizer. After 24 hours of spray, the seedlings were inoculated by spraying with a mixture of spore suspension of *A. alternata* and *H. halodes* in the ratio of 1:1 by volume. Each inoculated pot was again sprayed with each fungicide after 5 days of inoculation except control. 5 pots were again sprayed with each fungicide after 10 days of last spraying. During the first observation, only completely dried leaves were counted and clipped off. During the second observation, each leaf was carefully examined and data on severity of disease were recorded.

RESULTS AND DISCUSSION

Pathogencity test

To find out the pathogenic behavior of *Helminthosporium halodes* and *Alternaria alternata* on sugarcane seedlings of different crosses, an experiment was conducted.

It is clear from the Table 1 that *Helminthosporium halodes* and *Alternaria alternata* were pathogenic on the seedlings of all the crosses. However, the extent of seedling blight and mortality varied according to the levels of virulence of the test fungi and degree of resistance of different crosses. The seedlings of different crosses got severe infection with *Helminthosporium halodes* and *Alternaria alternata*. Seedlings of 'CoPant 0215' × 'BO 17' got least infection of seedling blight and seedling mortality disease caused by the test fungi. In case of *Helminthosporium halodes,* blight and mortality varied from 30.0 to 100.0 % and 42.5 to 84.5 % respectively depending upon the degree of resistance of crosses while it ranged from 28.0 to 100.0 % and 38.5 to 82.5 % respectively with *Alternaria alternata*. It can thus be concluded that *Helminthosporium halodes* was more virulent than *Alternaria alternata*. This finding supports the results of Subramanian (1935), Kumar *et al.* (1986); Kumari (2002).

Symptomatology

Both the fungi produced different types of characteristics symptoms on sugarcane seedlings. The symptoms produced by *Helminthosporium halodes* were characterized by the appearance of hydrangea red to mineral red, elongated broken stripes or oval spots which often turned Vandyke brown in colour in later stage. These lesions coalesced to form a larger lesion. It resulted into blighting of foliage, wilting and finally mortality of seedlings. The symptom usually appeared in the

Table 1 Pathogencity test of *Helminthosporium halodes* and *Alternaria alternata* on different crosses of sugarcane seedlings.

Crosses	*Helminthosporium halodes*		*Alternaria alternata*	
	Blight (%)	Mortality (%)	Blight (%)	Mortality (%)
'BO 146' × 'CoP 02181'	97.0	61.0	94.5	58.5
'ISH 100' × 'CoP 9301'	94.5	58.5	91.5	57.0
'CoPant 84212' × 'Co 775'	98.5	66.5	96.5	64.5
'BO 108' × 'BO 130'	95.5	58.0	85.0	56.5
'BO 109' × 'Co 62198'	92.0	52.5	92.0	66.0
'CoP 02182' × 'Co 62198'	100.0	69.0	90.5	56.5
'CoS 90265' × 'CoP 04182'	96.0	62.5	93.5	55.0
'Co 86011' × 'BO 92'	98.5	79.0	97.5	75.5
'BO 92' × 'BO 17'	100.0	84.5	100.0	82.5
'CoPant 01215' × 'BO 17'	30.0	42.5	28.0	38.5
Mean	90.2	63.3	87.1	61.1
CD at 5%	6.54s	5.57	8.88	4.71
SEm ±	2.04	1.75	2.78	1.47

early stages of growth of seedlings as small, narrow, reddish stripes. At the later stages they were bright or dark brown in colour. The leaf-sheath became dark brown to olivaceous in colour owing to the formation of numerous conidiophores and conidia. Symptoms produced by *H. halodes* are more or less similar to symptoms by Subramamian (1928), Singh and Singh (1968); Kumari (2002).

The symptoms produced by *Alternaria alternata* appeared as minute water soaked spots which were later developed in avellaneous to wood brown in colour elongated, elliptical or irregular lesions usually with the dark livid brown or blackish brown margin. Under favorable conditions, these lesions coalesced to form larger lesions which ultimately covered the entire leaf area. It resulted into the blighting, wilting and finally mortality of seedlings. In some seedlings, the disease also started from the tips of the lamina. In these cases, the leaves began to dry from their tips assuming a wood brown colour with a dark livid brown or blackish brown band of affected tissues adjoining the healthy portions of the leaves. As the disease advanced, entire lamina was dried leading to the mortality of seedlings. The dark brown conidiophores and conidia of the fungus also appeared on the avellaneous to wood brown margins of the lesions or on the dried tissues of the affected leaves. Similar symptoms were also described by Singh and Singh (1968); Kumari (2002).

Morphology

In morphological studies, colony characters, size, shape and colour of conidia and condiophores of both the test fungi were recorded. Colony of *H. halodes* was defused dark and hairy. Mycelium was immersed, septate, subhyline both inter and intracellular and 2-4 µ in breadth. Stromata were usually present. Conidiophores were determinate, growth was ceased when apical conidia are produced, often in fascicles, errect, brown to dark olivaceous in colour, un-branched, 2-5 septate, 40-130 µ in breadth. Conidia were relatively short and simple developed laterally, born singly at the tip of the conidiophores measuring 19-142.5 µ × 10-16.8 µ in size with average 60.5× 13.7 µ. However there were some variations in morphological structures from those reported by Subramanian (1935), Chidambaran *et al*. (1973) and Kumari (2002) due to occurrence of different isolates on seedlings of different crosses growing in different locations.

Colonies of *A. alternata* were amphigenous, effused, pale-olive and hairy. Mycelium was immersed, hyphae branched, septate, hyaline, smooth, 4-8 µ thick. Conidiophores arising in groups of 2-10 or more from the hyphae, emerging through stomata, usually simple, errect or ascending, straight or flexuous, frequently geniculate, more or less cylindrical but often slightly swollen at the base, septate, mild-pale to grayish-olive in colour, smooth, up to 176 µ long and 6.5-1.6 µ thick, bearing one to several small but distinct conidial scars. Conidia solitary or occasionally in chains of up-to 4, acropleurogenous, arising through small pores in the conidiophores wall, straight or slightly curved, obcalvate, rostrate, with 16-19 transverse septa and 0-8 longitudinal or oblique septa, pale or very pale-olive or grayish-olive, smooth or rarely very inconspicuously warted. It posses a shorter beak. The conidia measures 72-118× 13-19 µ. More or less similar results in relation to shape, size and colour of morphological structures were also observed by Srinath and Sarwar (1965), Mishra and Prakash (1974); Kumari (2002).

Management of diseases

In vitro evaluation

In order to find out the efficacy of different fungicides and their concentrations on radial growth of *Helminthosporium halodes* and *Alternaria alternata*, experiments were conducted in vitro by employing poison food technique.

It is evident (Table 2) that there was an increase in the extent of inhibition in radial growth of *H. halodes* with an increase in the fungicidal concentrations. Bavistin was found to be the most efficacious in arresting the growth of *H. halodes*. No fungal growth was observed even at the lowest concentration (0.1 %). Whereas, Indofil M-45 and Saaf produced the same effect at 0.2 % concentration. Blue copper inhibited the fungal growth completely at 0.25 % concentration while Bordeaux mixture inhibited the fungal growth completely at 0.3 % concentration.

Average of three replications

However, complete inhibition of growth of *A. alternata* was observed in medium containg 0.15% Bavistin and Saaf completely checked the growth at 0.2 % while Indofil M-45

Table 2 Effect of fungicides and their concentrations on radial growth of *Helminthosporium halodes.*

Fungicides	Radial growth (mm) after 7 days at concentration (%)				
	0.1	0.15	0.2	0.25	0.3
Bavistin	0	0	0	0	0
Indofil M-45	18.1	13.2	0	0	0
Saaf	14.9	5.6	0	0	0
Bordeaux mixture	22.8	20.2	11.6	5.5	0
Blue copper	18.3	15.3	10.6	0	0
Control			68.8		
CD at 5 %	1.41	1.45	0.81		
SEm ±	0.45	0.48	0.26		

and Blue copper completely arrested the growth of the fungus at 0.25 %. Bordeaux mixture inhibited the fungal growth completely at 0.3 % (Table 3). Dubey *et. al.* (2000) also observed more or less similar results with Copper oxichloride, Indofil M-45, Kavach and Bavistin.

Field evaluation of fungicides

Fungicides and their concentrations found promising *in vitro* were then evaluated under field condition by adopting soil drenching and spraying methods.

Fungicides exhibited significant effect on seedling blight caused by *Helminthosporium halodes* and *Alternania alternata*. An adequate control of disease was obtained when fungicides were either soil drenched at the time of sowing or sprayed after 5 days of emergence. However, application of fungicides after 10 days of emergence of seedlings, the control of disease was not upto the mark. Among the fungicides evaluated, Bavistin (0.1 %) and Saaf (0.2 %) were found to be significantly superior in arresting the seedling blight due to *H. halodes* disease when it was either soil drenched at the time of sowing or sprayed after 5 days of emergence (Table 4). But in case of A. *alternata,* good control of seedling blight was obtained when Bavistin 0.15 % and Saaf 0.2% were applied as soil drenching at the time of sowing and sprayed after 5 days of emergence. Maximum control of seedling blight disease was recorded when fungicides were applied as soil drenching at the time of sowing. Indofil M-45, Blue copper

Table 3 Effect of fungicides and their concentrations on radial growth of *Alternaria alternata*

	Radial growth (mm) after 7 days at concentration (%)				
Fungicides	0.1	0.15	0.2	0.25	0.3
Bavistin	8.9	0	0	0	0
Indofil M-45	25.2	17.6	8.3	0	0
Saaf	13.4	9.1	0	0	0
Bordeaux mixture	28.3	24.7	19.4	8.3	0
Blue copper	20.8	16.2	7.3	0	0
Control			71.2		
CD at 5 %	2.26	1.61	1.34		
SEm ±	0.72	0.53	0.43		

Table 4 Effect of fungicides on seedling blight caused by *Helminthosporium halodes*

		Severity of blight disease after 10 days of emergence	Severity of blight disease after 10 days of last spraying				
			Spraying				
Fungicides	Concentr-ation (%)	Soil drenching at the time of sowing.	5th day	10th day	15th day	20th day	Mean
Bavistin	0.1	8.5	9.4	13.2	25.7	40.8	22.2
Indofil M-45	0.2	12.3	16.5	20.8	28.6	36.2	25.5
Saaf	0.2	9.2	12	20.3	31.5	41.3	26.2
Bordeaux mixture	0.3	21.6	24.2	31	45.8	55.2	39.05
Blue copper	0.25	15.8	20.2	27.3	40.6	47.4	33.8
Control		84.5	86	89.5	90.5	92	89.5
CD at 5 % treatment = 1.55			SEm ± = 0.57				
CD at 5 % Days = 1.42			SEm ± = 0.50				
CD at 5 % Interaction (Treatment × Days) = 3.47			SEm ± = 1.22				

Table 5 Effect of fungicides on seedling blight caused by *Alternaria alternata*

		Severity of blight disease after 10 days of emergence	Severity of blight disease after 10 days of last spraying				
			Spraying				
Fungicides	Concentra-tion (%)	Soil drenching at the time of sowing.	5th day	10th day	15th day	20th day	Mean
Bavistin	0.15	6.5	8.5	12.8	26.4	35.5	20.8
Indofil M-45	0.25	15.2	20.1	28.5	44.2	63.5	39.1
Saaf	0.2	8.5	11.5	16.5	32.6	48.4	27.2
Bordeaux mixture	0.3	20.5	26.5	34.6	52.6	73.8	46.9
Blue copper	0.25	16.2	24.8	30.3	46.5	66.4	42
Control		78.5	81.5	85.5	88	92.5	86.9
CD at 5 % treatment = 1.17			SEm ± = 0.41				
CD at 5 % Days = 1.07			SEm ± = 0.37				
CD at 5 % Interaction (Treatment × Days) = 2.61			SEm ± = 0.92				

and Bordeaux mixture were also able to control significantly the seedling blight (Table 5). Kumar (1989) also observed more or less similar results with Thiram, Captan, Topsin-M, Rondin and Kitazin in relation to control of seedling diseases of sugarcane.

In order to find out optimum number of fungicidal spray for the maximum control of the seedling blight disease, an experiment was also conducted in glass house. The data as shown in Table-6 indicate that two sprayings with each fungicides proved to be better than one spraying. Among the fungicides tested, Bavistin and Saaf were more or less equally efficacious in controlling the seedling disease followed by Indofil M-45, blue copper and Bordeaux mixture. Singh and Singh (1968) and Kumar (1989) also found two sprayings better than one.

Table 6 Effect of number of fungicidal spray on seedling blight diseases of sugarcane

Fungicides	Number of spray	Disease severity (%)	% of disease control
Bavistin (0.15 %)	1	10.2	84.4
	2	6.8	89.6
Indofil-M 45 (0.25 %)	1	17.2	73.7
	2	13.5	78.3
Saaf (0.20 %)	1	11.5	82.4
	2	8.5	87.0
Bordeaux mixture (0.3 %)	1	28.2	56.8
	2	21.5	67.1
Blue copper (0.25 %)	1	22.8	65.1
	2	15.6	76.1
Control		65.4	

CONCLUSION

Seedling blight and mortality of seedlings due to *H. halodes* and *A. alternata* resulted poor stand of seedlings in seed nursery. The extent of diseases varied according to the levels of virulence of both the fungi and degree of resistance seedlings of different crosses. Bavistin and saaf were found the most efficacious in arresting the growth of both the fungi in vitro and in reducing the incidence of seedling diseases when they were either soil drenched or sprayed twice.

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Effect of levels of irrigation and crop geometry on growth and yield of sugarcane under drip irrigation

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ABSTRACT

A field experiment was conducted in Gang Canal Command area at 3" O" village, Srikaranpur, Sriganganagar during 2005-06, 2006-07 and 2007-08 to find out optimum plant geometry of sugarcane through drip irrigation and to compare water use and water use efficiency in both the methods of irrigation. The higher cane yield and tillers per square meter were recorded with single row planting than paired row planting; however, cane yield at 90x60 cm paired planting was at par with single row planting. The different irrigation levels significantly influenced cane yield, tillers per square meter, cane length and internode length. The highest cane yield and yield attributes were recorded with drip irrigation at 100% PE treatment, followed by 80 and 60 % PE treatments. The lowest cane yield, tillers per square metre and internode's length was recorded with surface irrigation treatment. In surface irrigation treatment, total 1790, 1572.9 and 1884.2 mm water was applied during 2005-06, 2006-07 and 2007-08, respectively. Water use efficiency was the highest with 75 cm row spacing during 2005-06 and 2006-07, whereas, during 2007-08 it was highest with 90 cm row spacing. The lowest WUE was recorded with 120cm x 60 cm paired row spacing during all the three years. In drip irrigation treatment, 1477.4, 1294.9 and 1575.2 mm average water was applied during 2005-06, 2006-07 and 2007 08, respectively. The WUE was the highest in 75 cm row spacing during 2005-06 and 2007-08, whereas, during 2006-07 it was highest with 90 cm row spacing. In paired row crop WUE was lower as compared to single row crop. There was considerable difference in water use and water use efficiency in different irrigation treatments. The water use in surface irrigation and 100% PE treatment was almost equal but water use efficiency in 100% PE treatment was about 1.5 times higher than surface irrigation treatment in all the years. Water use decreased constantly in 80 and 60 % PE treatments and accordingly water use efficiency increased. All the drip irrigation levels recorded higher WUE than surface irrigation treatment. The highest WUE of was recorded with 60% PE treatment during all the three years. The mean data revealed that drip irrigation at 60, 80 & 100 % PE increased cane yield by 14.4, 26.4 & 44.6 per cent, respectively over the cane yield obtained with border strip irrigation. In addition to yield increase, the respective water saving was 32.9, 17.1 & 1.4 per cent.

Key words: Sugarcane, Crop geometry, Drip irrigation, Growth and Yield

India is one of the largest sugarcane producers in the world after Brazil. Sugarcane being an important cash crop, it ranks third in the list of most cultivated crops after paddy and wheat. Sugarcane is planted in both tropical and sub- tropical region of India with total production of 294.6 million tonnes and productivity of 66.8 tonnes per hectare (Singh *et al*. 2013).About 80% percent of the total rainfall is received during three monsoon months (July-September) which too is highly unreliable and erratic. During rest of the period the crop performance is depend on irrigation. In irrigation northwest plain zone of Rajasthan sugarcane is a commercial crop. The most common practice of irrigation is border strip. Sugarcane requires 15-20 irrigation per annum for optimum growth and yield. Drip irrigation is high frequency irrigation method of supplying water directly to the root zone. The micro irrigation techniques have a major role to play in mitigating the water scarcity situation by enhancing the productivity of water in sugarcane in effective and scientific way (Ridge *et al*. 2000 and Shinde and Jadhav 2001). Through adoption of drip farmers can get higher yield by providing congenial environment to the plant through maintaining optimum moisture regime throughout the growing period.

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MATERIALS AND METHODS

Field experiment was conducted in Gang Canal Command area at 3 "O", Srikaranpur, Sriganganagar during 2005-06, 2006-07 and 2007-08 in randomized block design with 3 replications. The treatments comprising of 4 crop geometries (single row planting 75cm, single row planting 90 cm, paired row planting 60 cm x 90 cm, paired row planting 60 cm x 120 cm) and 4 irrigation levels (60, 80 and 100% of PE by drip system on alternate day, and border strip irrigation at IW/CPE 1.0 & irrigation water depth 7.5 cm). The soil was sandy loam in texture, low in organic carbon (0.35%), medium in available P_2O_5 (42 kg/ha) and high in available K_2O (410 kg/ha). The pH (1:2) and EC (1:2) of the soil were 8.05 and 0.21 dS/m, respectively. A uniform basal dose of 50 kg N, 40 kg P_2O_5 and

40 kg K_2O/ha was applied at planting. Rest N (100 kg/ha) was applied in 2 splits, one half each in May and June as top dressing. Sugarcane cv. 'Co 6617' was selected as the test crop.

RESULTS AND DISCUSSION

Water use and water use efficiency

The data of total water use and water use efficiency (WUE) as influenced by different treatments have been presented in table 1.

Crop geometry (surface irrigation)

In surface irrigation treatment, total 1790, 1572.9 and 1884.2 mm water was applied during 2005-06, 2006-07 and 2007-08, respectively. Water use efficiency was the highest with 75 cm row spacing during 2005-06 and 2006-07, whereas, during 2007-08 it was highest with 90 cm row spacing. A row spacing of 90 cm under timely planting condition is also recommended by Verma (2004). The lowest WUE was recorded with 120cm x 60 cm paired row spacing during all the three years.

Crop geometry (drip irrigation)

In drip irrigation treatment, 1477.4, 1294.9 and 1575.2 mm water was applied during 2005-06, 2006-07 and 2007-08, respectively. The WUE was the highest in 75 cm row spacing during 2005-06 and 2007-08, whereas, during 2006-07 it was highest with 90 cm row spacing. In paired row crop WUE was lower as compared to single row crop.

Irrigation

There was considerable difference in water use and water use efficiency in different irrigation treatments. The water use in surface irrigation and 100% PE treatment was almost equal but water use efficiency in 100% PE treatment was almost 1.5 times higher than surface irrigation treatment in all the years. Water use decreased constantly in 80 and 60 % PE treatments and accordingly water use efficiency increased. These results suggest that in case of limited water availability, drip irrigation in sugarcane is beneficial in achieving higher returns per unit of water and proves to be an economical method of irrigation as compare to surface methods. All the drip irrigation levels recorded higher WUE than surface irrigation treatment. The results are in conformity with the findings of Raskar and Bhoi 2001. The highest WUE of was recorded with 60% PE treatment during all the three years.

Yield and yield attributes

Crop geometry in surface irrigation

Cane yield and yield attributes with respect to different crop geometries were found at par under surface irrigation during all the three years except cane length which was found more at 75 cm single row spacing in comparison to 90 cm single row spacing and paired rows during 2006-07(Table 2, 3 & 4). The pooled data of three years also revealed that the cane yield and yield attributes were not influenced by different crop geometries in surface irrigation (Table 5).

Crop geometry in drip irrigation

Crop geometry in drip irrigation had significant effect on cane yield and tillers/m^2 during 2005-06. The highest cane yield of 130.64 t/ha was recorded with 75 cm row spacing followed by 90 cm spacing (126.13 t/ha). Paired row spacing gave significantly lower cane yield than single row spacing. Tillers/m^2 also followed the similar trend. Cane length, inter node length and cane diameter were not affected by crop geometry, However 75 cm row spacing recorded highest tillers/

Table 1 Effect of crop geometry and drip irrigation on water use and water use efficiency

Treatment	Water use (mm)			Water use efficiency (kg/ha mm)		
	2005-06	2006-07	2007-08	2005-06	2006-07	2007-08
Crop geometry (Surface irrigation)						
75 cm row spacing	1790.0	1572.9	1884.2	55.20	67.89	36.10
90 cm row spacing	1790.0	1572.9	1884.2	54.02	65.99	37.83
90 cm X 60 cm paired row	1790.0	1572.9	1884.2	52.65	66.61	33.44
120 cm X 60 cm paired row	1790.0	1572.9	1884.2	51.96	64.75	33.31
Crop geometry (Drip irrigation)						
75 cm row spacing	1477.4	1294.9	1575.2	88.43	110.87	54.08
90 cm row spacing	1477.4	1294.9	1575.2	85.37	114.12	53.62
90 cm X 60 cm paired row	1477.4	1294.9	1575.2	81.30	107.40	50.98
120 cm X 60 cm paired row	1477.4	1294.9	1575.2	76.18	88.49	53.15
Surface & drip irrigation						
IW/CPE 1.0 (surface)	1790.0	1572.9	1884.2	53.46	66.14	35.17
100% PE(drip)	1793.0	1544.9	1835.4	79.05	97.79	50.16
80% PE(drip)	1477.4	1295.9	1575.2	83.49	100.61	52.62
60% PE(drip)	1161.8	1043.9	1315.0	87.79	121.93	57.28

Including pre-sowing irrigation of 100 mm and rainfall of 115 mm during 2005-06
Including pre-sowing irrigation of 100 mm and rainfall of 197.9 mm during 2006-07
Including pre-sowing irrigation of 100 mm and rainfall of 434.2 mm during 2007-08

Table 2 Effect of crop geometry and drip irrigation on cane yield and yield attributes (2005-06)

Treatment	Cane yield (t/ha)	Germination (%)*	Tillers / sq. m	Cane length (m)	Internode length (cm)	Cane diameter (cm)
Crop geometry (surface)						
75 cm row spacing	98.80	12.40	13.53	2.62	17.40	2.43
90 cm row spacing	96.70	11.83	13.13	2.60	17.36	2.57
90 cm X 60 cm paired row	94.24	12.73	13.16	2.61	17.33	2.47
120 cm X 60 cm paired row	93.00	12.30	13.07	2.59	17.33	2.47
S. Em.±	3.32	0.77	0.30	0.05	0.38	0.05
CD at 5%	NS	NS	NS	NS	NS	NS
Crop geometry (drip)						
75 cm row spacing	130.64	11.74	16.38	2.83	18.72	2.39
90 cm row spacing	126.13	11.88	15.41	2.76	18.55	2.44
90 cm X 60 cm paired row	120.12	12.39	14.78	2.75	18.54	2.35
120 cm X 60 cm paired row	112.55	12.41	14.27	2.73	18.30	2.40
S. Em.±	1.91	0.44	0.17	0.03	0.22	0.04
CD at 5%	5.52	NS	0.49	NS	NS	NS
Irrigation levels						
IW/CPE 1.0	95.69	12.32	13.22	2.61	17.36	2.39
100% PE (drip)	141.73	12.20	17.26	2.89	19.37	2.44
80% PE (drip)	123.35	11.91	15.13	2.78	18.72	2.38
60% PE (drip)	102.00	12.20	13.23	2.64	17.51	2.33
S. Em.±	1.65	0.39	0.15	0.03	0.19	0.04
CD at 5%	4.78	NS	0.43	0.08	0.55	NS

* Germination (%) per meter row length

Table 3 Effect of crop geometry and drip irrigation on cane yield and yield attributes (2006-07)

Treatment	Cane yield (t/ha)	Germination (%)	Tillers / sq. m	Cane length (m)	Inter node length (cm)	Cane diameter (cm)
Crop geometry (surface)						
75 cm row spacing	106.79	46.50	22.33	2.20	13.00	2.27
90 cm row spacing	103.79	48.78	18.66	2.08	12.42	2.25
90 cm X 60 cm paired row	104.77	51.56	20.00	1.63	11.76	2.24
120 cm X 60 cm paired row	101.85	49.37	18.00	1.87	11.27	2.06
S. Em.±	10.83	2.28	1.95	0.09	0.68	0.08
CD at 5%	NS	NS	NS	0.27	NS	NS
Crop geometry (drip)						
75 cm row spacing	143.57	50.13	34.33	1.83	11.48	2.23
90 cm row spacing	147.78	50.58	35.77	1.90	12.97	2.49
90 cm X 60 cm paired row	139.07	50.81	26.22	2.06	11.64	2.37
120 cm X 60 cm paired row	114.58	49.23	24.22	1.96	11.49	2.26
S. Em.±	6.25	1.31	1.13	0.05	0.39	0.05
CD at 5%	18.05	NS	3.26	0.16	1.14	0.14
Irrigation levels						
IW/CPE 1.0	104.30	49.05	19.75	1.95	12.11	2.21
100% PE (drip)	151.08	49.91	32.08	2.02	12.78	2.40
80% PE (drip)	130.38	50.48	29.33	1.91	11.26	2.34
60% PE (drip)	127.28	51.17	29.00	1.87	11.65	2.28
S. Em.±	8.27	1.74	1.49	0.07	0.52	0.06
CD at 5%	16.88	NS	3.05	0.15	1.07	0.13

Table 4 Effect of crop geometry and drip irrigation on cane yield and yield attributes (2007-08)

Treatment	Cane yield (t/ha)	Germination (%)	Tillers / sq. m	Cane length (m)	Inter node length (cm)	Cane diameter (cm)
Crop geometry (surface)						
75 cm row spacing	68.02	46.59	24.33	2.12	11.21	2.26
90 cm row spacing	71.28	47.09	26.33	2.14	11.55	2.27
90 cm X 60 cm paired row	63.00	48.05	24.00	2.09	12.39	2.26
120 cm X 60 cm paired row	62.76	51.73	23.33	2.07	12.25	2.28
S. Em.±	3.34	2.76	1.89	0.09	0.57	0.05
CD at 5%	NS	NS	NS	NS	NS	NS
Crop geometry (drip)						
75 cm row spacing	85.19	51.52	26.33	2.24	13.25	2.27
90 cm row spacing	84.47	51.07	26.67	2.32	13.38	2.33
90 cm X 60 cm paired row	80.30	51.46	25.78	2.13	12.71	2.29
120 cm X 60 cm paired row	83.72	49.04	26.11	2.13	12.77	2.34
S. Em.±	1.93	1.59	1.09	0.05	0.33	0.03
CD at 5%	NS	NS	NS	0.14	NS	NS
Irrigation levels						
IW/CPE 1.0	66.27	48.36	24.50	2.11	11.85	2.27
100% PE (drip)	92.06	50.95	28.42	2.27	13.67	2.32
80% PE (drip)	82.88	50.77	25.92	2.21	12.98	2.31
60% PE (drip)	75.32	50.60	24.33	2.13	12.44	2.30
S. Em.±	2.55	2.11	1.44	0.07	0.43	0.04
CD at 5%	5.20	NS	2.94	0.14	0.88	NS

m^2 and more internodes length. Row spacing of 90 cm recorded the highest (2.44 cm) cane diameter.

Crop geometry in drip irrigation had significant effect on tillers/m^2, cane length, internodes length, cane diameter and cane yield during 2006-07. The highest cane yield of 147.78 t/ha was recorded with 90 cm row spacing, which was at par with that obtained at 75 cm spacing (143.57 t/ha) and at paired row of 90x60 cm spacing (139.07 t/ha). The minimum cane yield was obtained with paired planting of 120x60 cm. The tillers per square metre were more in single row planting than paired row planting, whereas, cane length was more in paired planting than single row planting. The effect of crop geometry in drip irrigation on yield and yield attributes was found non-significant during 2007-08 except on cane length which was found more in 90 cm single row spacing.

The pooled data of three years revealed that tillers per square metre and cane yield were significantly influenced by crop geometry in drip irrigation. The higher cane yield and tillers per square metre were recorded with single row planting than paired row planting; however, cane yield at 90x60 cm paired planting was at par with single row planting.

Irrigation levels: Irrigation levels influenced the cane yield and most of the yield attributes significantly during all the three years. Drip irrigation at 100% PE gave significantly the highest cane yield (141.73 t/ha) followed by 80% PE (123.35 t/ha) and 60 % PE (102.00 t/ha) during 2005-06. The lowest yield of 95.69 t/ha was recorded in surface irrigation at IW/CPE 1.0. Tillers/m^2, cane length and internode length were affected significantly by irrigation levels. All the drip irrigation levels gave higher values of tillers, cane length and internode length than surface irrigation treatment. Among the drip irrigation levels 100 % PE recorded higher values of yield attributes followed by 80 % and 60 % PE.

Drip irrigation at 100% PE also gave significantly the highest cane yield (151.08 t/ha) followed by 80% PE (130.38 t/ha) and 60 % PE (127.28 t/ha) during 2006-07. The lowest cane yield of 104.30 t/ha was recorded in surface irrigation at IW/CPE 1.0. Irrigation levels affected tillers/m^2, cane length, intersnode length and cane diameter significantly. All the drip irrigation levels gave higher values of tillers and cane diameter than surface irrigation treatment. Among the drip irrigation levels 100 % PE recorded higher values of tillers per square metre, cane length, internode length and cane diameter followed by 80 and 60 % PE.

The effect of irrigation schedule on cane yield, tillers per square metre, cane length and internode length was found significant during 2007-08. The highest yield and yield attributes were recorded with drip irrigation at 100 % PE. The minimum values of these parameters were found with flood irrigation.

The pooled data of three years (Table 5) revealed that different irrigation levels influenced cane yield, tillers per square metre, cane length and internode length significantly. The highest cane yield and yield attributes were recorded with drip irrigation at 100% PE treatment followed by 80 and 60 % PE treatments. The lowest cane yield, tillers per square meters and internode length were recorded with surface irrigation treatment.

Table 5 Effect of crop geometry and drip irrigation on cane yield and yield attributes (Pooled data of three years)

Treatment	Cane yield (t/ha)	Germination (%)	Tillers / sq. m	Cane length (m)	Inter node length (cm)	Cane diameter (cm)
Crop geometry (surface)						
75 cm row spacing	91.21	46.54	20.06	2.31	13.87	2.32
90 cm row spacing	89.75	47.93	19.37	2.27	13.78	2.36
90 cm X 60 cm paired row	88.15	49.80	19.05	2.11	13.83	2.32
120 cm X 60 cm paired row	85.87	50.55	18.13	2.18	13.62	2.27
S. Em.±	5.53	2.52	1.38	0.07	0.54	0.06
CD at 5%	NS	NS	NS	0.27	NS	NS
Crop geometry (drip)						
75 cm row spacing	119.80	50.82	25.68	2.30	14.48	2.30
90 cm row spacing	117.46	50.82	25.95	2.33	14.97	2.40
90 cm X 60 cm paired row	115.18	51.13	22.26	2.31	14.30	2.34
120 cm X 60 cm paired row	103.62	49.13	21.53	2.27	14.19	2.33
S. Em.±	3.19	1.45	0.80	0.04	0.31	0.04
CD at 5%	9.21	NS	2.28	0.14	NS	NS
Irrigation levels						
IW/CPE 1.0	88.74	48.70	19.16	2.22	13.77	2.29
100% PE (drip)	128.29	50.43	25.92	2.39	15.27	2.39
80% PE (drip)	112.21	50.62	23.46	2.30	14.32	2.34
60% PE (drip)	101.54	50.88	22.19	2.21	13.87	2.30
S. Em.±	2.98	1.36	0.73	0.04	0.27	0.04
CD at 5%	8.62	NS	2.14	0.12	0.83	NS

The mean data revealed that drip irrigation at 60, 80 & 100 % PE increased cane yield by 14.4, 26.4 & 44.6 per cent, respectively over the cane yield obtained with border strip irrigation. In addition to yield increase, the respective water saving was 32.9, 17.1 & 1.4 per cent. The results are in conformity with the findings of Ramesh *et al.* (1994) and Waykar *et al.* (2003).

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Response of soil test based integrated nutrient management under sugarcane cultivation

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ABSTRACT

Field experiments were conducted for two consecutive crop cycles during 2011-12 and 2012-13 in spring planting season at the farms of U.P. Council of Sugarcane Research, Shahjahanpur under recent alluvium soil to study the effect of soil test fertilizer recommendation (STFR) alongwith organic manure on growth, yield, quality and soil health under sugarcane cultivation. Application of fertilizers on the basis of soil test (100% NPK) was found effective in comparison to farmers' practice (either nitrogen 150 kg/ha alone or NPK 150, 40, 20 kg/ha). When 100% NPK (STFR) was applied through chemical fertilizer and organic manure both along with dual biofertilizers (*Azotobacter* and PSB), it further enhanced the shoot, NMC and cane yield significantly. Under this treatment, the sucrose percent in juice increased from 16.49 to 17.06 at 10 month crop age and from 18.41 to 18.92 at 12 month crop age as compared to farmers' practice. This treatment fetched the highest net income and B:C ratio (2.56) as compared to control (2.20). The organic carbon (0.36%) at the experimental field was improved with the application of organic manure alongwith dual biofertilizer indicating that the treatment could maintain the level of available nitrogen in the soil.

Key words : Sugarcane, Cane yield, STFR, Fertilizer recommendation, NPK, Soil fertility

Imbalanced fertilizer use is one of the major abiotic constraints causing the stagnation of cane productivity. The last decades have witnessed the increasing use of high analysis fertilizer resulting in the poor physical, chemical and biological properties of soil. A number of reports exhibited that the organic carbon in soil has gone below the critical levels under north Indian condition (Sharma *et al*. 2010). The microorganisms found in the soil are dependent on organic matter for energy and nutrient but continuous application of only high analysis fertilizer has considerably reduced organic matter in the soil and restoration mechanism of soil organic matter is fairly checked. Once the organic carbon content has reached a critical level, restoring the organic matter to its original level would be requiring so that the original vegetation can be reestablished. Incorporation of farm waste and organic manures in to such soils improves its physical and chemical properties (Lal *et al*. 2012). It is therefore, expected that nutrient management may be achieved by involvement of organic sources, biofertilizers, chemical fertilizers and micro nutrients. Consideration of above fact, the present study was undertaken to manage the fertilizer on the basis of soil testing through integrated nutrient management for improving physical and chemical properties of soil, yield and quality of sugarcane grown in soil of an Entisol order.

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MATERIALS AND METHODS

The field experiments were conducted at the research farms of U.P. Council of Sugarcane Research, Shahjahanpur (U.P.) using sugarcane variety 'CoS 07250' during spring planting season of 2011-12 and 2012-13. The soil was classified as alluvial belonging to Entisol order with pH 7.2, EC (ds/m) 0.15, organic carbon (gm/kg) 3.9, available N (kg/ha) 218.0, available P (kg/ha) 17.94, available K (kg/ha) 148.0, available S (mg/kg) 12.4, DTPA Zinc (mg/kg) 0.41, DTPA Fe (mg/kg) 8.0, DTPA manganese (mg/kg) 15.2, and DTPA copper (mg/kg) 1.0. Six treatments *viz* T_1 - (conventional or farmers practice fertilizer recommendation as nitrogen @ 150 kg/ha), T_2 - (conventional fertilizer or general farmers practice recommendation as NPK @ 150, 40, 20 kg/ha, T_3 - (75% NPK, STFR, soil test fertilizer recommendation); T_4 - (100% NPK (STFR), T_5 -100% NPK+ Zn+Cu (STFR); T_6 – 100% NPK (STFR) through chemical fertilizer and organic manure + *Azotobacter* + PSB with three replications were tested in randomized block design. All the sources of computed chemical fertilizer, organic manure, biofertilizer were added in furrow before planting of cane. Only 1/3 dose of N was applied at the time of planting and remaining 2/3 doses of nitrogen was top dressed in two equal splits before the onset of monsoon. All the agronomical practices were followed as per recommendations. The sucrose per cent in Juice was analyzed by the method described by Meade and Chen (1977) at 10^{th} and 12^{th} month of crop age. Yield and yield attributes

viz. shoots, millable canes were also recorded timely. Soil samples were procured from 0-23 cm depth before planting and after harvest of cane. The physico-chemical properties of soil were analyzed by standard procedures using CHNS analyzer (CE 440), AAS (ECIL 4141) flame photo meter (Chemito-1020) etc.

RESULTS AND DISCUSSION

Effect on shoots, NMC and cane yield

It is apparent from data presented in Table 1 that the application of conventional fertilizer recommendation or general farmers practice as N, P, K @ 150, 40, 20 kg/ha (T_2) to the soil enhanced the number of shoots, millable canes and cane yield in comparison to conventional fertilizer recommendation as only nitrogen @ 150kg/ha (T_1). This response was possibly observed due to addition of phosphorus and potash in the soil. However, application of fertilizer on the basis of soil testing (100 % NPK @ 190, 60 and 50 kg/ha) (T_4), further increased the shoots, number of millable canes and cane yield in comparison to T_1 treatment and the results were at par with general farmers practice as T_2 treatment. Superiority of number of shoots, millable canes and cane yield was observed possibly due to the balance fertilization for the standard of cane cultivation which increased the utilization of major nutrient for proper development of plant. Similar results were reported by Singh *et al*. (2000) as well. The treatment T_3 as 75% NPK (STRF) was declined by 8.20 per cent cane yield. The application of fertilizer 100% NPK (STFR) through integrated nutrient management (T_6) gave significantly higher shoots, NMC and cane yield as compared to those planted under T_2, T_3 and T_4 treatments. The magnitude of response under T_6 was higher upto 22.20% possibly due to the contribution of organic manure and biofertilizer which increased the efficiency of fertilizer as organic manure is also known to maintain the adequate supply of different nutrients and microbial activities of soil. Similar results have been reported by Srivastava (1990) and Bokhtiar and Sakwai (2005). The inclusion of organic manure in combination with inorganic fertilizer possibly increases the absorption of NPK in leaf tissue as compared with chemical fertilizer alone.

Effect on sucrose percent in juice

Data presented in Table 1 indicated that significant increase in sucrose per cent in juice was observed under T_3 (100% NPK; STFR) as compared to T_1 treatment (Conventional fertilizer).

Table 1 Effect of fertilizer application on the basis of soil testing on yield and quality of sugarcane

Treatments	Shoots/ha (000)	NMC/ha (000)	Yield (t/ha)	Sucrose %		B:C ratio
				10^{th} month	12^{th} month	
T_1- Conventional fertilizer or farmers practice recommendation (150 kg N/ha)	107	92	65.74	16.49	18.41	2.20
T_2- Conventional fertilizer or general farmers practice recommendation (NPK 150,60, 20 kg/ha)	116	101	71.39	16.64	18.78	2.36
T_3- 75% NPK (STFR)	113	99	67.90	16.73	18.72	2.35
T_4- 100% NPK (STFR)	118	103	73.97	16.84	18.85	2.41
T_5- 100% NPK ZnCu (STFR)	122	105	75.30	16.94	18.92	2.45
T_6- 100% NPK (STFR) through chemical fertilizers and organic manure + *Azotobacter* + PSB	126	112	80.34	17.06	18.92	2.52
SE±	7.47	8.16	4.98	0.047	0.10	
CD at 5%	16.64	18.19	7.35	0.105	0.20	

Table 2 Residual effect on soil after the harvest of the crop

Treatments	Organic carbon (g/kg)	N (kg/ha)	P (kg/ha)	K (kg/ha)
Initial status	3.9	218	17.90	148.0
T_1- Conventional fertilizer or farmers practice recommendation (150 kg N/ha)	3.2	196	12.0	133.0
T_2- Conventional fertilizer or general farmers practice recommendation (NPK 150,60, 20 kg/ha)	3.5	207	14.0	139.0
T_3- 75% NPK (STFR)	3.4	204	13.2	142.0
T_4- 100% NPK (STFR)	3.6	215	15.6	145.0
T_5- 100% NPK ZnCu (STFR)	3.6	214	16.0	151.0
T_6- 100% NPK (STFR) through chemical fertilizers and organic manure + *Azotobacter* + PSB	4.5	227	21.2	161.0

The application of 100% NPK (STFR) in combination with organic manure and biofertilizer (T_6) further significantly increased in sucrose per cent in juice upto 0.57 units as compared to T_1 treatment. This increase was obtained possibly due to presence of secondary and micronutrients in organic manure which are responsible for increasing sucrose content in juice. An increase in sucrose per cent in juice after application of sulphur and micronutrients have been reported earlier (Rakkiyappan *et al*. 2002; Singh *et al*. 2000). Similar trends were observed in case of 12th month crop age.

Soil fertility status

The soil analysis done after the harvest of cane (Table 2) revealed that the restoration mechanism of soil organic matter is checked under T_1 treatment (150 kgN/ha). Though, it slightly increased after addition of phosphorus and potash as chemical fertilizers (under 100% NPK; STFR), it did not reach to initial status of soil. This indicated that plant crop utilized majority of the nutrient applied through chemical fertilizers. Moreover, the application of 100% NPK (STFR) alongwith organic manure and biofertilizer (T_6) increased the organic carbon in comparison to T_1, T_2 and T_3 treatments and also maintained the initial status of soil. Build up of organic carbon in T_1 treatment, organic carbon content was 3.2 g kg^{-1} which increased to 4.5 g kg^{-1} with the application of 100% NPK (STFR) along with organic manure and bio fertilizer. Balance fertilization improved the available N over its initial value. Integrated use of inorganic fertilizer and organic manure + biofertilizer was more effective in increasing the soil available N. Similar results were reported by Bhale Rao *et al*. (2006).

Effect on C:B ratio

Cost benefit ratio was also computed on the basis of net returns as per existing market prices in all the treatments (Table 1). The results clearly showed that the application of 100% NPK (STFR) along with organic manure and Biofertilizer (T_6) fetched the highest B:C ratio (2.52) followed by T_1 (2.20), T_2 (2.36) and T_3 (2.35) treatments indicating that the application of 100% NPK (STFR) through integrated nutrient management was found more profitable.

Conclusively, the application of 100% NPK (STFR) along with organic manure and biofertilizer showed significant increase in yield and quality of sugarcane and also improved the fertility status of soil. It is therefore advisable that the use of integrated nutrient management on the basis of soil test may be adopted in place of conventional farmers' practice for improved cane and sugar productivity under sugarcane cultivation.

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Sustainable sugarcane production through intercropping of mungbean (*Vigna radiata* L.) in relation to nitrogen management in trench planted sugarcane

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ABSTRACT

Field experiments were carried out for three consecutive years (2011-12 to 2013-14) during spring season at U.P. Council of Sugarcane Research farm, Shahjahanpur. The main objective of the study was to find the suitable method of mungbean residue management and appropriate dose of N in light of NPK application and its effects on productivity and profitability of trench planted sugarcane. The experimental soil was sandy loam in texture, low in organic carbon (0.36%) and available phosphorus (11.43kg/ha) and medium in potassium (124 kg/ha) with 7.7 pH. Experiment was laid out in a randomized block design with eight treatments and three replications with the variety 'CoS 07250' (mid late maturing). The mean data of three years revealed that sugarcane (trench method) with 100% NPK + mungbean and residue incorporation with organodecomposer @ 10 kg/ha followed by sugarcane (trench method) with 100% NPK + mungbean and legume residue incorporation gave higher cane yield 96.37 t/ha and 94.95 t/ha with B:C ratios of 2.07 and 2.06, respectively.

Key words: Sustainable, Nitrogen management, Trench planted sugarcane, organodecomposer, residue incorporation.

Increasing demand of chemical fertilizers and their adverse effects on soil physical, chemical and microbial properties and changing agro-ecosystem environment has initiated the scientists to evolve the other safer means for plant nutrient. Integrated nutrient management helps to restore and sustain the soil fertility and crop productivity by supplementing not only the primary and secondary nutrients but also micronutrients, microbial population and thus improves the physical, chemical and biological environment of the soil for sustained agriculture production (Gaur and Singh 1982). nonjudicious use of inputs such as fertilizer, water and organic manures and inability of practice integrated nutrient management about 174 million hectares of land in India has so for degraded. The nitrogen use efficiency is as low as 20% and hardly exceeds 50%. This may lead to environmental pollution to increase nitrate concentration in ground water. It is therefore, urgent need to promote integrated nutrient supply system involving organic manures, green manuring of legume crops and bio-fertilizer for biological nitrogen fixation with rational use of chemical fertilizers. A number of scientists have reported the beneficial effects of organic manures (SPMC/FYM) on soil properties, crop productivity including sugarcane (Raman *et al.* 1966) and also microbial activity in soil (Jauhari 1990). As sufficient experimental data were not available on the effect of FYM and green manuring of legume crop with bio-fertilizers. Keeping above points in view, a field experiment was conducted.

MATERIALS AND METHOD

Field experiments were carried out during spring season for three consecutive years (2012-13 and 2013-14) at Sugarcane Research Institute Farm, Shahjahanpur. The experimental soil was sandy loam in texture, low in organic carbon and available phosphorus and medium in potassium with 7.7 pH. The experiment was laid out in randomized block design with eight treatments replicated thrice. Sugarcane variety 'CoS 07250' (mid late maturing) was planted in February and harvested in March. 30 cm wide and 20-25 cm deep trench opened at 120 cm and followed by two lines of mungbean were taken between two trenches. Mungbean crop was turned off in soil after last picking of pods and organodecomposer @ 10kg/ha was applied as per treatment. Observations on germination, number of shoots, millable canes, cane yield, CCS yield were recorded at the respective growth and harvesting stages. All the recommended package of practices was followed for raising the experimental crop. The details of treatments were as follows:

T_1- Sugarcane (trench method) with 100% NPK

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Table 1 Effect of treatments on germination, shoots, number of millable canes, cane yield, CCS % and B : C ratio of trench planted sugarcane (Pooled data of 2011-12 to 2013-14)

Treatments	Germi. %	Shoots (000/ha)	NMC (000/ha)	Cane yield (t/ha)	CCS (%)	B : C ratio
T_1- Sugarcane (trench method) with 100% NPK	64.88	145.910	115.316	91.17	10.89	1.99
T_2- Sugarcane (trench method) with 125% N+ 100% P & K	65.63	152.431	119.097	94.83	10.88	1.98
T_3- Sugarcane (trench method) with 100% NPK+ mungbean without residue management.	63.08	146.296	114.660	89.16	10.92	2.03
T_4- Sugarcane (trench method) with 100% NPK+ mungbean and residue incorporation.	66.71	150.309	118.171	94.95	11.18	2.06
T_5- Sugarcane (trench method) with 100% NPK+ mungbean and residue incorporation with organodecomposer.	63.80	153.819	121.103	96.37	11.14	2.07
T_6- Sugarcane (trench method) with 75 % N and 100% P & K+ mungbean and residue removal.	67.64	141.550	109.182	88.04	11.37	1.98
T_7- Sugarcane (trench method) with 75 % N and 100% P & K+ mungbean and residue incorporation.	67.06	144.637	110.648	93.29	11.27	2.05
T_8- Sugarcane (trench method) with 75 % N and 100% P & K+ mungbean and residue incorporation with organodecomposer.	68.66	148.727	116.011	93.67	11.29	2.03
SE±	0.76	1.264	3.523	1.29	0.24	
CD 5%	NS	2.533	7.060	2.58	N.S.	

T_2- Sugarcane (trench method) with 125% N + 100% P & K

T_3- Sugarcane (trench method) with 100% NPK + mungbean without residue management.

T_4- Sugarcane (trench method) with 100% NPK + mungbean and residue incorporation.

T_5- Sugarcane (trench method) with 100% NPK + mungbean and residue incorporation with organodecomposer.

T_6- Sugarcane (trench method) with 75% N and 100% P & K + mungbean and residue removal.

T_7- Sugarcane (trench method) with 75% N and 100% P & K + mungbean and residue incorporation.

T_8- Sugarcane (trench method) with 75% N and 100% P & K + mungbean and residue incorporation with organodecomposer.

RESULTS AND DISCUSSION

The mean data of three years (2011-12 to 2013-14) regarding germination, shoots, millable canes, cane yield, CCS % and benefit cost ratio given in table-1 clearly indicated that the germination remained unaffected by different treatments. Integration of nutrient sources and mungbean residue management practices led to increase, shoots, millable canes, cane yield. Sugarcane (trench method) with 100% NPK of RD + mungbean and residue incorpotation with organodecomposer @10 kg/ha (T_5), produced significantly higher shoots (153819/ha), number of millable canes (121103/ha) and cane yield (96.37 t/ha) followed by treatment T_4 : Sugarcane (trench method) with 100% NPK + mungbean and residue incorporation than other treatments. Cane yield (96.37 t/ha) than that of T_6 Sugarcane (trench method) with 75% N and 100% P & K + mungbean and residue removal. The perceptible increase in cane yield was attributed due to improvement in yield parameters. Similar findings were also reported by Ramalingswami 1966. Maximum benefit cost ratio (2.07) was also recorded under same treatment followed by T_4-Sugarcane (trench method) with 100% NPK + mungbean and residue incorporation and T_7-Sugarcane (trench method) with 75% N and 100% P & K + mungbean and residue incorporation as compared to others. CCS % was not affected significantly by various treatments, it was higher obtained in mungbean intercropped treatments over alone cane.

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Improving thermal efficiency of open pan jaggery furnaces - A novel concept

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ABSTRACT

Despite many improvements in open pan furnaces used for jaggery making, a lot of valuable heat energy still goes waste in the process of concentrating sugarcane/palm juice on these furnaces. Efforts are still going on but the quantum of heat loss is enormous. Non-uniform feeding of fuel (bagasse) results in improper combustion and sometimes inflammable gases, generated on thermal cracking of biomass, remain unburnt and goes with the flue gases as waste. Drifting of flames towards flue gas opening even without touching pan bottom results in poor convective heat transfer. It has also been observed that heating ability of flames increases many times if these are mixed with pressurized oxygen/air. Any improvement in furnace efficiency accrued though modification/alteration in existing system will go long way to save tremendous amount of fuel and energy. To implement this concept, a miniature model of efficiency booster (EB) using simple materials was designed and fabricated. It consisted of a web made out of G.I. nipples, bends, tees, cross tees etc. Drilling of holes was done on these components at suitable places and at certain angles. For testing of concept, the EB was designed matching with a mild steel pan of 203 mm diameter and was tested in a small jaggery furnace like structure by connecting it to a hand blower with suitable attachments. Water boiling test was performed. Cosiderable improvement in thermal efficiency and increase in evaporation per unit of fuel was observed. Improvement in furnace performance parameters would help in saving of fuel and time.

Key words: Jaggery, Furnace, Juice concentration.

Jaggery and *Khandsari* is an age-old cottage industry consuming 18.1 per cent of total sugarcane produced in India (Anon. 2014). In jaggery making, sugarcane is crushed for extraction of juice and the raw juice is subjected to filtration, clarification and finally concentration to a desired level of consistency. Unlike sugar mills, where well-designed and efficient vacuum pans and multiple-effect evaporators are used for sugarcane juice concentration, open pans are used in jaggery making industry. Design of furnaces varies from place to place as per requirement. These furnaces vary in size and capacity and are mostly location specific. Based on capacity of jaggery plant and system of jaggery making, open pan furnaces of jaggery industry may have single or multiple pans. Heat utilization efficiency of multi-pan furnaces is better. Many designs of furnaces have been described by Roy (1952). In most of the furnaces, lack of scientific awareness and know-how is root cause towards their poor design and performance. Still at many places traditional single pan furnaces are being used. It is highly inefficient and huge loss of valuable heat energy is witnessed. Due to poor heat utilization efficiency of these furnaces sometimes shortage of bagasse (main source of heating material) is experienced. However, it is generally understood and said that the bagasse obtained from cane is sufficient to boil/concentrate the juice that has been obtained from that particular quantity of cane. If it is so, then the minimum heat utilization efficiency of furnace should be 35% (Anwar 2005). Indian Institute of Sugarcane Research (IISR), Lucknow developed an improved 2-pan furnace with step grate for better combustion of fuel and rectangular gutter pan for pre-heating of juice and tested (Anon. 1956; Baboo and Anwar 1994; Singh *et al.* 2009). Later, a 3-pan furnace was developed having two circular and one rectangular pan (Singh 2009). Open pans are considered to be an integral part of these furnaces. Anwar (2010) developed modified pans having fins for jaggery furnace, which resulted in improvement in performance parameters.

The rate of fuel feeding is not uniform in furnaces and sometimes this does not match with the air being sucked in for combustion and the rate of heat transfer requird. Flame formation during combustion of fuel is actually the combustion of inflammable gases, which emerge out on thermal cracking of fuel. Sometimes, these gases are formed but in absence of sufficient oxygen/air, are not burnt properly and go waste with flue gases. Secondly, it has been observed that flames drift towards flue gas opening and many of these flames do not even touch pan bottom. Therefore, a device, which can direct flame towards pan bottom and make more turbulence for increased heat transfer may overcome this problem to some extent. A novel concept to inject forced air in a specified configuration has been used for designing a device, named 'Efficiency Booster' which is expected to increase quantum of available heat to a pan in jaggery making furnace in

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particular by directing it to the pan bottom for increased utilization. The air supplied through this would also help in complete combustion of unburnt gases, which would have otherwise gone as waste.

MATERIALS AND METHODS

For testing of the hypothesis, a model of efficiency booster was developed by using G.I. nipples, sockets, tee, cross tee and bends (Fig.1). Holes (4 mm dia.) were drilled at specified places and angles as shown in figure 2. The size of efficiency booster was kept matching with a mild pan of 203 mm diameter. This was installed in a small jaggery furnace like structure at such a height that it does not affect normal fuel feeding and was connected to a hand blower with suitable attachments. This was kept close to the pan bottom so that air coming out of holes would be able to strike pan bottom. On operaing the blower, the air, which is hot as it is coming out of heated efficiency booster and is at a increased velocity, will attract surrounding flames due to pressure difference and direct these to the pan bottom. With this phenomenon more heat transfer is expected to take place and as a result, efficiency is expected to increase.

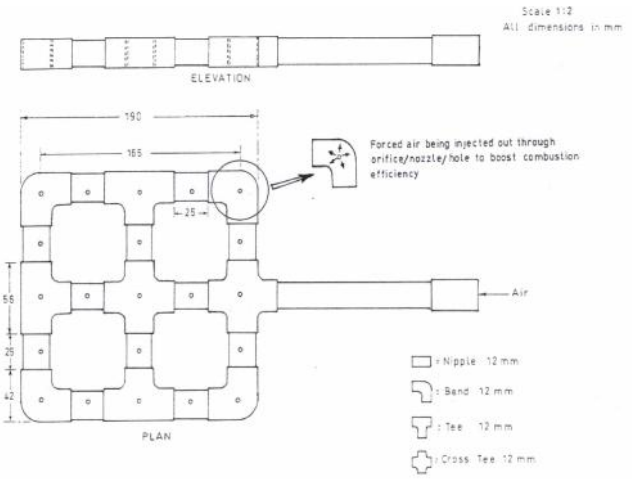

Fig.1. Miniature model of efficiency booster

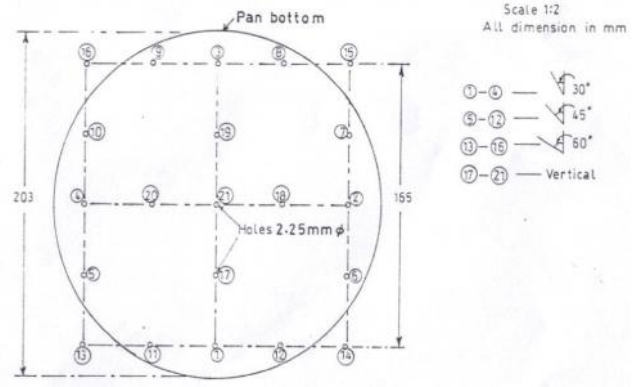

Fig.2. Position of holes in respect of pan bottom and their angle

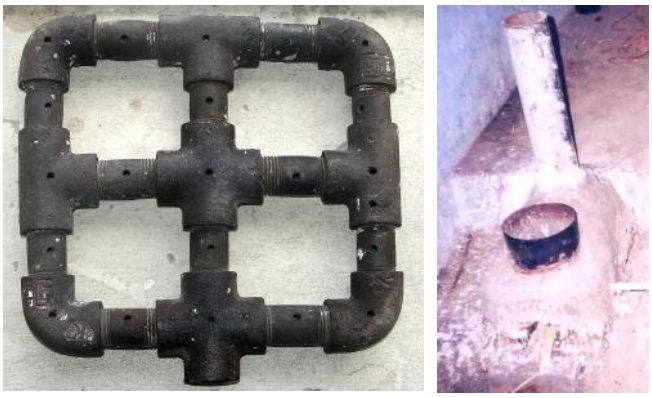

Fig.3. Efficiency booster and its installation in jaggery furnace like structure

Performance evaluation

The miniature model of efficiency booster was installed as described before in a small jaggery furnace like structure (Fig.3). Bagasse was used as fuel. 2500 ml of water was taken in the pan and the fuel was lit.

On formation of flames hand blower was operated. Fuel feeding was maintained at a constant rate and the temperature of water was noted down at regular interval till water started boiling. Fuel feeding was continued for some more time and the pan was covered with lid and water was allowed to cool down. In the last, water left in pan was measured and by initial and final weight of fuel, actual fuel consumed was calculated. The experiment was repeated thrice.

RESULTS AND DISCUSSION

The temperature profile of water with and without efficiency booster has been shown in figure 4. It is apparent from the figure that it required considerably less time for water to attain boiling point by using efficiency booster than otherwise. More turbulence and blue flames were observed in the modified system, which helped in comparatively more heat generation and heat transfer. Lesser quantity of fuel was consumed with efficiency booster. Although, extra energy was required for running the blower, but in actual conditions of jaggery making, blower can be operated by already running prime mover for cane crushing by some suitable arrangement and even larger blower can be used as per the requirement. In juice concentration for jaggery making, maximum amount of time is consumed in evaporating water from juice and it is desirable that this time is reduced as much as possible to check inversion losses. Fuel feeding is also maintained at a constant rate during this period. So efficiency booster is very much suitable for such system. On those occasions, when controlled heat is required, like while performing clarification or at final stage near striking point, the blower can be set to off position. Improvement in jaggery quality will be an added advantage and with lesser time of processing, jaggery productivity is also expected to increase. Effect on other important performance

parameters has been shown below:

Effect of efficiency booster on various performance parameters

A. Water evaporated
Without EB – 1.34 kg
With EB - 1.82 kg
Percent increase in thermal efficiency – 35

B. Evaporation/kg fuel
Without EB – 0.53 kg
With EB – 0.72 kg
0.19 kg more evaporation /kg of fuel
Per cent increase in evaporation/ kg fuel – 35

C. Fuel consumed/kg water evaporated
Without EB – 1.89 kg
With EB – 1.39 kg
Per cent saving in fuel – 26

D. Time requirement/kg water evaporation
Without EB – 0.59 hours
With EB – 0.41 hours
Per cent saving in time – 30

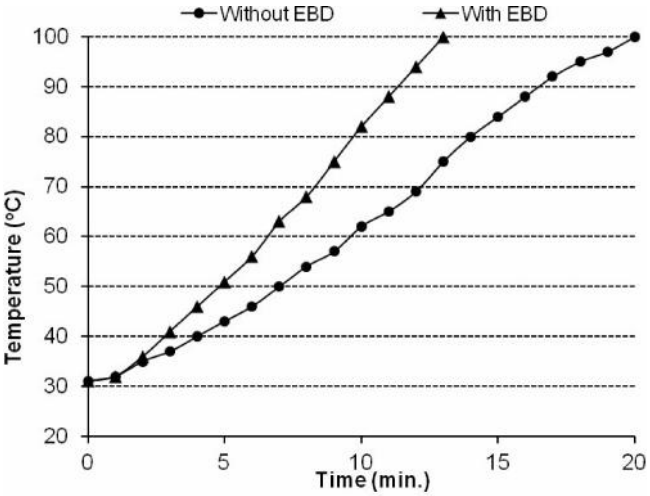

Fig. 4. Temperature profile of water with and without EB

It is evident from above figures that efficiency booster has positive effect on all the performance parameters of the furnace. Saving in fuel will save bagasse in jaggery making whereas, saving in time will lead to increase in jaggery productivity. Therefore, whole economics of jaggery production is likely to improve.

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Effect of surface and sub surface drip fertigation on yield and quality of sugarcane

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ABSTRACT

A field experiment was conducted at Regional Agricultural Research Station, Anakapalle to study the effect of water and fertilizer management practices with drip irrigation on yield and quality of sugarcane during 2012-13 and 2013-14. The study was conducted with three methods of irrigations viz., surface drip, sub surface drip and furrow irrigation under four nitrogen levels in split plot design. The test variety '97A85' (Visakha) was planted in paired rows (60/120 cm) and the surface and subsurface drip laterals were installed in the rows of each pair. Significant differences in cane yield were observed due to different methods of irrigation and application of different levels of nitrogen**.** Drip irrigation methods both sub surface (102.7 t/ha and 119.6 t/ha) and surface (101.2 t/ha and 115 t/ha) irrigation method**s** registered significantly highest cane yield as compared to furrow method of irrigation (85.5 t/ha and 99.8 t/ha) during 2012-13 and 2013-14 respectively. Among different nitrogen levels application of 200 Kg N/ha recorded significantly higher cane yield of 103.4 t/ha and 119 t/ha during two seasons.. Further increase in level of nitrogen does not resulted in significant increase in cane yield during both the years. Highest per cent juice sucrose was recorded in drip irrigation treatments as compared to furrow irrigation. Among different nitrogen levels , application of 150 Kg N/ha recorded higher sucrose per cent during two seasons. There is saving of water to the extent of 34.1% during 2012-13 and and 30.8% during 2013-14 in drip irrigation as compared to furrow irrigation. Among different methods of irrigation sub surface (1.24 and 1.33) and surface (1.21 and 1.28) methods of irrigations registered higher water use efficiency as compared to furrow method of irrigation(0.68 and 0.77) during 2012-13 and 2013-14 respectively. There is increase in cane yield to the tune of 20.1 and 18.4 per cent during first year and 19.8 and 15.2 per cent increase during second year of study in sub surface and surface drip irrigation methods respectively as compared to furrow method of irrigation.

Key words: nitrogen levels ; sub surface drip fertigation; sugarcane yield: water use efficiency

Water is most costlier and scarce input in sugarcane agriculture. It is imperative to use available water most judiciously and scientifically in order to increase land and water use efficiency. The water requirement of crop fulfilling the evapo-transpiration is met either from rainfall or reservoirs or ground water. Frequent aberrations in rainfall leading to reduced ground water availability is the major constraint of water in Agriculture. The method of using water in this sector for raising the crops is further enhancing the problem of water scarcity. Surface method of irrigation is most commonly used in India to meet the water requirement of the crop which involves heavy loss of water in conveyance and poor in application and water use efficiency. Drip fertigation, one of the potential technologies offers the great scope to increase cane productivity up to 200-220 t/ha (Senthil Kumar 2009), saves 40-50% irrigation water and enhances nutrient efficiency by 40% (Solomon 2012). Fertigation with conjunctive use of fertilizer nutrients and irrigation water offers the possibility to optimize the water and nutrient distribution over time and space (Nanda 2010). Sugarcane being a long duration crop requires considerable quantity of water to the extent of 1400 – 1500 mm in the subtropics (Solomon 2012). Keeping these facts in view the present study was carried out to study the effect of water and fertilizer management under drip irrigation on yield and quality of sugarcane.

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MATERIALS AND METHODS

A field experiment was conducted at Regional Agricultural Research Station, Anakapalle, Andhra Pradesh during 2012-13 and 2013-14. Soil of the experimental site is sandy loam. The experiment was designed in split plot design with three methods of irrigation (surface drip, sub surface drip and furrow irrigation) and four levels of nitrogen (100 Kg/ha, 150 Kg/ha, 200 Kg/ha and 250 Kg/ha), thus constituting of twelve treatments randomized in three replications. Drip was operated daily to replenish 100% evaporation losses taking into account rain fall, pan and crop co-efficients. Early maturing sugarcane variety '97A 85' (visakha) was planted in paired rows (60 cm/ 120 cm) using three budded setts @ 40,000/ha in the month of March during during both the seasons. Fertigation schedule was started at 30 days after planting (DAP) with an weekly interval and continued up to 180 days after planting. Thus the N fertilizers in different doses were applied through drip in

21 equal splits. All other agronomic practices like hand weeding, earthing up, trash twist propping etc, were carried out according to recommendations. Yield attributing parameters like number of millable canes, cane length were recorded at the time of harvest. Cane yield was recorded after stripping the leaves and de-topping. Juice quality parameters viz., sucrose%, CCS % and sugar yield were recorded at harvest by following standard procedures (Meade and Chen,1971). Data collected were statistically analyzed and the results were compared.

RESULTS AND DISCUSSION

Results pertaining to the yield, yield attributes and juice quality parameters are presented in table 1&2 and discussed below.

No. of millable canes at harvest

Sub surface drip irrigation method registered significantly higher number of millable canes (1,01,681/ha and 82,296/ha) followed by surface drip irrigation method (1,00,569/ha and 81,506/ha) during 2012-13 and 2013-14 respectively. Among different nitrogen levels, , application of 250 Kg N/ha recorded significantly higher number of millable canes as compared to other levels of nitrogen but found on par with application of 200 Kg N/ha (Table 1).

Per cent Juice Sucrose

Significant differences were observed in respect of per cent sucrose due to different treatments. Highest per cent juice sucrose was recorded in drip irrigation treatments as compared to furrow irrigation during both the years of study. Among different nitrogen levels , application of 150 Kg N/ha recorded higher sucrose per cent of 16.8 and 18.0 during 3012-13 and 2013-14 respectively.

Commercial Cane Sugar

Significant differences in CCS % were observed due to different methods of irrigation and also due to nitrogen levels. Both Surface and sub surface drip irrigation methods registered highest CCS % as compared to the furrow method of irrigation (Tabel 1). Application of 150 Kg/ha of nitrogen gave significantly higher CCS% of 12.7 during 2012-13 but significant differences in CCS were not observed due to different N levels during 2013-14.

Cane yield

Significant differences in cane yield were observed due to different methods of irrigation and application of different levels of nitrogen**.** Drip irrigation methods both sub surface (102.7 t/ha and 119.6 t/ha) and surface (101.2 t/ha and 115 t/ha) irrigation method**s** registered significantly highest cane yield as compared to furrow method of irrigation (85.5 t/ha and 99.8 t/ha) during 2012-13 and 2013-14 respectively. Among different nitrogen levels application of 200 Kg N/ha recorded significantly higher cane yield during both the years (Table 1). Higher sugarcane yield with increase in fertilizer levels was also reported by Rajanna and Patil (2003). Further increase in level of nitrogen does not resulted in significant increase in cane yield (104.5 t/ha).

Sugar yield

Highest sugar yield is recorded with sub surface and surface method of irrigations and application of 200 Kg N /ha recorded highest sugar yield (Table 1).

WUE

There is saving of water to the extent of 34.1% and 30.8 % in drip irrigation as compared to furrow irrigation (Table 2). Among different methods of irrigation sub surface (1.24 &

Table 1 Yield attributes, yield and quality of sugarcane as influenced by methods of irrigation and nitrogen levels under drip fertigation during 2012-13 and 2013-14

Treatment	NMC/ha		Cane yield (t/ha)		Sucrose %		CCS %		Sugar yield (t/ha)	
	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14
Method of Irrigation										
Sub surface irrigation	1,01,681	82,296	102.7	119.6	16.4	17.6	12.24	13.7	12.6	16.1
Surface Irrigation	1,00,569	81,506	101.2	115.0	16.4	17.4	12.33	13.7	12.5	15.6
Furrow irrigation	88,016	77,839	85.5	99.8	15.8	17.4	11.74	13.9	10.3	13.5
SEm±	180.2	225	1.90	1.54	0.07	-	0.06	-	-	-
C.D(0.05)	708.0	659	7.5	6.1	0.30	NS	0.25	NS	-	-
Nitrogen Levels										
N1:100 Kg/ha	85,185	78,518	83.1	96.6	16.5	17.8	12.4	14.1	10.3	13.5
N2: 150 kg/ha	91,671	80,691	94.7	108.6	16.8	18.0	12.7	13.2	12.0	14.2
N3: 200 kg/ha	1,04,303	82,552	103.4	114.1	16.0	17.2	11.8	14.0	12.2	15.9
N4: 250kg/ha	1,05,861	81,226	104.5	119.9	15.4	17.0	11.5	13.8	12.0	16.4
SEm±	375.0	259	1.83	1.9	0.29	-	0.32	-	-	-
C.D(0.05)	1114.0	760	5.4	5.9	0.9	NS	0.95.	NS	-	-

Table 2 Effect of drip fertigation on water use and WUE

Treatments	Quantity of irrigation water applied (ha-cm)		Water saving (%)		Cane yield (t/ha)		Increase in cane yield (%)		Water Use Efficiency (t/ha-cm)	
	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14
Sub surface irrigation	83.0	90.0	34.1	30.8	102.7	119.6	20.1	19.8	1.24	1.33
Surface irrigation	83.0	90.0	34.1	30.8	101.2	115	18.4	15.2	1.21	1.28
Furrow irrigation	126.0	130.0	-	-	85.5	99.8	-	-	0.68	0.77

1.33) and surface (1.21 & 1.28) methods of irrigations registered higher Water Use Efficiency as compared to furrow method of irrigation (0.68 &0.77) during 2012-13 and 2013-14 respectively.

CONCLUSION

Adopting of drip irrigation both sub surface and surface registered significantly higher cane yield when compared to conventional furrow irrigation. There is saving of water to the extent of 34.1% under drip irrigation as compared to furrow irrigation. Among different methods of irrigation sub surface (1.24) and surface (1.21) methods of irrigations registered higher Water Use Efficiency as compared to furrow method of irrigation (0.68).

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Evaluation of some sugarcane varieties for quality jaggery production in Uttar Pradesh

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ABSTRACT

Studies on performance of some elite early and mid-late maturing sugarcane varieties were carried out for jaggery yield and its quality at Sugarcane Research Institute, Shahjahanpur. Ten varieties namely 'CoS 767', 'CoS 95255', 'CoS 98259', 'CoS 07250', 'CoS 08272', 'CoS 08279', 'CoSe 01424', 'CoSe 01434', 'CoSe 03234' and 'CoSe 96436' were evaluated during the years 2011-12 to 2013-14. Pooled analysis of the results showed that an early variety 'CoS 08272' recorded the highest jaggery percent in juice (20.72) and jaggery percent in cane (12.25) followed by 'CoSe 01434', 'CoSe 03234', 'CoS 98259' and 'CoS 08279'. Cultivar 'CoSe 08272' gave slightly lesser jaggery yield as compared to 'CoS 08279' and 'CoSe 01434' due to their higher cane yields. Jaggery prepared from 'CoS 08272' gave the highest sucrose percent in jaggery (83.2), purity coefficient (88.42) and less invert sugar percent (3.64). The jaggery of 'CoS 08272' is light yellowish in colour, granular in texture and has a good taste. Highest jaggery yield was recorded in 'CoS 08272' (10.22 mt/ha) followed by 'CoSe 01434' (9.89), 'CoS 08272' (9.46) and 'CoS 07250' (9.42) among the cultivars studied. Varieties 'CoS 08272' and 'CoS 03234' produced jaggery of excellent quality while 'CoS 08279', 'CoSe 01434' and 'CoS 95255' produced jaggery of medium to good quality.

Key words: Jaggery, Quality

INTRODUCTION

Sugarcane is an important commercial crop of Uttar Pradesh occupying about half of the area with more than 45 percent production of sugarcane in the country which renders Uttar Pradesh to be a premier state. Jaggery is one of the oldest and most important cottage industries in India. Prior to 1902, almost all the sugarcane produced was being processed for manufacturing of jaggery and *khandsari*. Jaggery is not only used as sweetening agent but also used in several sweet food preparations owing to its low cost and ready availability. Juice quality is affected by many factors namely cane variety, climate, soil, fertilizer, irrigation and other management practices. It is well accepted that the quality of sugarcane is highly associated with the variety. Jaggery quality depends mainly on juice quality and hence factors affecting the juice quality also affect the jaggery quality. Widely with respect to juice composition, Pandiyan (1988) and Vasudha (1986) have reported that the brix, pol and purity of jaggery differed significantly among the varieties studied. According to Mishra (1992), jaggery quality depended on the chemical composition of juice irrespective of method of boiling and clarification. Good quality jaggery had high sucrose and purity with less reducing sugar. Rakkiyappan et al. (1996) evaluated some of the varieties and observed wide variation in jaggery quality due to varieties. Hence, it was thought plausible to evaluate elite sugarcane varieties developed from Sugarcane Research Institute, Shahjahanpur for jaggery production and quality indices.

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MATERIALS AND METHODS

The material for the present study consisted of 10 elite sugarcane varieties namely 'CoS 767', 'CoS 95255', 'CoS 98259', 'CoS 07250', 'CoS 08272', 'CoS 08279', 'CoSe 01424', 'CoSe 01434', 'CoSe 03234' and 'CoSe 96436' which were planted in spring season of 2012-13 and 2013-14. The recommended package of practices was followed for raising a good crop. As representative samples, 10 kg of randomly selected canes were taken from the mature crop of experimental field, trash and tops were removed and crushed. Juice thus obtained was filtered and three liters of juice was taken for jaggery preparation. The measured juice was poured into a small galvanized iron pan and then heated at low temperature (75^{o}C). Gum, colloids and other impurities floating as scum were removed and then clarified with Deola water. The juice was evaporated till the striking point. The concentrated semisolid mass was cooled and poured on the mould to get jaggery cubes. Jaggery samples were analyzed for various physico-chemical characters following standard procedures (Spencer and Meade 1945). Pol percent Jaggery was determined by the single polarization using dry sub acetate of lead. A sample of 65 g jaggery was taken and mixed with 500 ml of water to make homogeneous solution and then the brix analysis was done. An aliquot 100 ml of solution was taken

Table 1 Yield and quality parameters of jaggery obtained from ten elite varieties of sugarcane (Mean of three years, 2011-12 to 2013-14)

S. N.	Varieties	Cane yield mt/ha	Jaggery yield mt/ha	Jaggery% in Juice	Jaggery% in cane	Pol% in Jaggery	Purity% in Jaggery	Invert sugar %	Color
1	'CoS 767'(Std)	74.48	8.18	20.36	11.30	82.4	86.25	3.94	119
2	'CoS95255'(Std)	79.45	8.93	20.48	11.23	82.5	87.95	3.69	99
3	'CoS 98259'	76.50	9.12	20.53	12.06	82.4	87.32	4.14	98
4	'CoS 07250'	81.94	9.42	20.32	11.39	82.2	86.20	3.95	121
5	'CoS 08272'	77.25	9.46	20.72	12.25	83.2	88.42	3.64	92
6	'CoS 08279'	87.38	10.22	20.42	11.70	82.6	87.61	3.73	102
7	'CoSe 01424'	79.63	8.47	19.37	10.70	77.7	84.12	4.60	135
8	'CoSe 01434'	83.73	9.89	20.66	11.82	82.6	86.78	3.98	98
9	'CoSe 03234'	73.84	8.75	20.61	11.86	82.8	87.31	3.68	123
10	'CoSe 96436'	74.70	7.65	19.09	10.32	78.2	84.61	4.71	120
	CV=	2.36	5.31	5.46	4.83	0.94	0.95	4.78	5.71
	SE=	1.51	0.14	0.91	0.46	0.62	0.66	0.15	5.25
	CD=	3.17	0.29	NS	0.96	1.30	1.38	0.32	11.02

and 2.0 g of lead sub acetate was added. The solution was mixed well by shaking and filtered. The filtered solution was then polarized in a 200 mm pole tube and reading was taken by a sophisticated polarimeter "Autopol Rudolph". Double of pol reading gave the pol percent jaggery. Purity was calculated using the following formula.

$$\text{Purity \%} = \frac{\text{Pol \% x 100}}{\text{Brix of Jaggery}}$$

Invert sugar percent was determined by procedure of Chen (1985). Filtered solution of jiggery, prepared as explained above, was titrated against 5 ml each of Fehling solutions A and B. Methylene blue was used as an indicator. Invert sugar was calculated with the help of Fehling constant. Colour was estimated in Jaggery solution (1/4 normal solution) with Klett Summerson photoelectric colorimeter at 470 nm using green filter.

RESULTS AND DISCUSSION

Pooled data on quality and quantity parameters of jaggery obtained from different sugarcane varieties are presented in Table 1. The data revealed that sugarcane variety 'CoS 08272' (20.72) gave the highest Jaggery percent in juice followed by 'CoSe 01434' (20.66), 'CoSe 03234' (20.61) and 'CoS 98259' (20.53). The Jaggery percent in cane was also found to be the highest in variety 'CoS 08272' (12.25) followed by 'CoS 98259' (12.06), 'CoSe 03234' (11.86) and 'CoSe 01434' (11.82). Variety 'CoS 08279' recorded highest Jaggery yield (10.22 mt/ha) followed by 'CoSe 01434' (9.89 mt/ha), 'CoS 08272' (9.46 mt/ha), 'CoS 07250' (9.42 mt/ha) and 'CoS 98259' (9.12 mt/ha). Among the tested varieties, 'CoS 8279' (87.38 mt/ha) gave the highest cane yield followed by 'CoSe 01434' (83.73 mt/ha) and 'CoS 07250' (81.94 mt/ha). Marginally lower jaggery yield was recorded in 'CoS 08272' possibly due to lower cane yield in this variety as compared to 'CoS 08279' and 'CoS 01434'. All the varieties, except 'CoSe 96436', were found superior to the standards ('CoS 767' and 'CoS 95255') in jaggery yield.

As far as the quality is concerned, the highest sucrose content in jaggery was noticed in 'CoS 08272' (83.2) that was on par with 'CoSe 03234' (82.8), 'CoSe 01434' (82.6) and 'CoS 08279' (82.6) and also superior to the standards. Similar varietal variations were reported by other workers (Pandian, 1988; Lognathan, *et al*. 1998). Likewise, the purity of jaggery was recorded to be 88.42 percent in 'CoS 08272' followed by 'CoS 08279' (87.61), 'CoS 98259' (87.32) and 'CoS 03234' (87.31). Similar varietal variation was also observed by other investigators (Vasudha, 1986; Pandian, 1988; Patil *et al*., 1994). Observations on invert sugar revealed that varieties 'CoS 08272' (3.64), 'CoS 08279' (3.73) and 'CoSe 03234' (3.68) had lower percentage of reducing sugar than other varieties tested, the minimum being in variety 'CoS 08272'. Almost the same variation due to varieties has also been demonstrated by Pandian (1988). Value of jaggery colour was minimum (92) in variety 'CoS 08272' followed by 'CoSe 01434' (98), 'CoS 98259' (98) and 'CoS 08279' (102). The jaggery obtained from CoS 08272 was golden in colour and highly crystalline in texture while other varieties gave light golden to yellow golden jaggery that were highly to medium crystalline in texture. Light colored Jaggery is generally preferred to dark colored Jaggery for eating. Texture is also an important factor that determines the quality of Jaggery. The grading of jaggery is mainly based on the colour and texture (Khare, 1939). On the basis of observations recorded in the present study, varieties 'CoS 08272', 'CoSe 01434', 'CoS 08279' and 'CoS 98259'found suitable for production of quality jaggery.

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