GENETIC VARIABILITY AND CORRELATION STUDIES IN SWEET SORGHUM (*Sorghum bicolar* (L.) Moench)

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DISSERTATION

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Dedicated to
My Beloved
Parents,
pushpa and
Research Guide

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CERTIFICATE – I

This is to certify that the dissertation entitled "GENETIC VARIABILITY AND CORRELATION STUDIES IN SWEET SORGHUM (Sorghum bicolar (L.)Moench.) **submitted by Shri.** ZADE SANDEEP BHAGWANRAO **to the Marathwada Krishi Vidyapeeth, Parbhani in partial fulfillment of the requirements for the degree of** MASTER OF SCIENCE (Agriculture) **in the subject of** GENETICS AND PLANT BREEDING **is record of original and bonafied research work carried out by him under my guidance and supervision. It is of sufficiently high standard to warrant its presentation for the award of the said degree.**

I also certify that the dissertation or part there of has not been previously submitted by him for a degree of any university.

Place: Parbhani
Date: 16/05/2012.

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Advisory committee

CERTIFICATE- II

This is to certify that, dissertation entitled **"GENETIC VARIABILITY AND CORRELATION STUDIES IN SWEET SORGHUM (Sorghum bicolar (L.) Moench)"** submitted by Shri. **ZADE SANDEEP BANGWANRAO** to the Marathwada Krishi Vidyapeeth, Parbhani in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (Agriculture)** in the subject of **"AGRICULTURAL BOTANY"** has been approved by the student's advisory committee after viva-voce examination in collaboration with the external examiner.

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........Gratitude is the memory of heart!

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(ZADE SANDEEP)

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ABBREVIATIONS

R	=	residual effect
r	=	correlation coefficient
Σ	=	summation
MSS	=	mean sum of square
mm	=	millimeter(s)
b.s.	=	broad sense
EMS	=	error mean sum of square
etc.	=	etceteras
h^2	=	heritability (narrow sence)
d.f.	=	degree of freedom
cm	=	centimeter(s)
m	=	meter(s)
mg	=	milligram
viz.,	=	videlicet (namely)
6^2	=	variance
EGA	=	Expected genetic advance
et al.	=	and other
Fig.	=	Figure
g	=	gram (s)
GCV	=	genotypic coefficient of variation
GM	=	General mean
%	=	per cent
kg	=	kilogram(s)
ha	=	hectare(s)
/	=	per
SE	=	Standard error

CD	=	Critical difference
CV	=	Coefficient of variation
pp	=	pages
P	=	phenotypic correlation
PCV	=	phenotypic coefficient of variation
No.	=	number
DSR	=	Directorate of Sorghum Research
GA	=	Genetic advance
$H^2_{(bs)}$	=	Heritability in broad sense
i.e.	=	that is
RBD	=	Randomized Block Design

Introduction

Chapter - I

INTRODUCTION

Sorghum (*Sorghum bicolar* (L) Moench) (2n=20) is the fifth most important cereal crop in world after wheat, rice, maize and barly. Major producer of sorghum in the world are Nigeria, USA, India, Mexico, Argentina, Sudan, Ethiopia, Brazil, China and Austrelia. It has been classified under family Gramineae, subfamily Poaceae, tribe Andropogonae and genus Sorghum. Sorghum is the principal dry land coarse cereal grown in India and it covers an area of 7.2 m ha, with productivity of 6.7 m t and a productivity of 1000 kg ha^{-1} in the year 2010 [United states Department of Agriculture Report 2011].

Sweet sorghum is a special type of sorghum that can be grown for food, fuel, fodder and fiber (a crop of 4 FFFF' s),and it has (10-20 %) having ability to accumulate sugar (10-20%) in its stalk, it can be used for production of fuel, alcohol, jaggary and syrup. Thus, it is called as multipurpose crop. The sugar is composed of sacchrose (70 – 80 %), fructose and glucose similar to sugar beat. The sugar can be easily fermented to produce ethanol which can be used to blend with petrol. So far sweet sorghum has become a energy plant in world. It has the potential to improve the rural livelihoods in India due to its potential industrial use for bio-ethanol production .However, its high biomass potential has been receiving attention of late in India. In recent years, there is increased interest in the utilization of sweet sorghum for ethanol production because of its shorter growing period (about four month), and low water requirement (8,000 cu m) for raising two crops, unlike sugarcane which has a growing period of 12 to 18 months and a water requirement of 36,000 cu m per crop. Besides this national bio-fuel policy of 2009 aims at promoting bio-fuels to meet India's energy need in an environmentally sustainable manner, which reducing its import dependence on fossil fuels. The policy also proposed an indicative target of 20 per cent blending of ethanol by 2017 from the current 10 per cent ethanol blending with petrol.

The traditional route of ethanol production through sugarcane molasses would not be meeting this huge demand because of the difficulties in increasing the sugarcane area beyond the current 4.4 million ha in the country. Therefore, the renewable source of energy in the form of other would be promising optimum view of the emerging trends in international energy market as well as indigenous strengths.

The really significant advantage of sweet sorghum stalk as a source of bio-fuel is that it is not prone to the food-versus-fuel debate and the ethanol is produced from that non-molasses route which is environment friendly in the absence of any sulphurs and has high octane rating. Research results and pilot studies on ethanol production from the juice of sweet sorghum stalk have affirmed its cost effectively vis-à-vis other feed stocks .Dayakar Rao *et al* (2004), suggested sweet sorghum as the best alternative feedstock for bio-ethanol production, continuous supply of feed stock to the industries is one major constraint in sweet sorghum ethanol production. To encourage the distilleries to make sweet sorghum a major in ethanol production, there is an urgent need to arrange for the supply of sweet sorghum stalk to the distilleries all round the years.

The sweet sorghum cultivars in Maharashtra showed wide range of stalk juice quality parameters such as brix (18.31-22.24 %), sucrose (12.50-16.67%), and reducing sugar (0.73-1.99%).These values are quite comparable with those of sugarcane juice (Bapat *et al* 1986).

Selection of divers parents is of paramount important in any breeding programmes, so as to get maximum heterosis and wide spectrum of variability in segregating generation. Average cane yield and juice quality needs to be increased by using the existing germplasm resources of the sweet sorghum. Further direct selection for yield may be unfruitful because yield is a complex trait with low heritability and is determined by genetic association that exists between helpful to any breeder, during selection. However, simple correlation does not take in to consideration, the complex relationship among various dependent variable, in such situation path analysis (Dewey ana Lu, 1959.) provide an effective means of findings out the direct and indirect effects as such association.

The use of advanced nobles techniques of plant improvements will be certainly helpful in twenty first century, however, the conventional plant breeding tools such as characters association path analysis and genetic variability will also play an important role in crop improvement.

Thus, the present investigation entitled "Genetic variability and correlation studies in sweet sorghum (*sorghum bicolar* (L) Moench)" was therefore undertaken with following objectives.

1) To study the variability for cane yield, sugar content and grain yield in Sweet sorghum.
2) To study the association and direct, indirect effect of stalk yield, sugar content and its attributing traits.

Review of Literature

Chapter – II

REVIEW OF LITERATURE

An attempt is made on the collection of literature published on genetic variability and correlation and path analysis in sweet sorghum and reviewed in the present chapter.

2.1 Genetic variability :

Rao *et al* (1971) observed that the total solids contributed 10.5 to 19.2% of the juice of the sweet sorghum cultivar at harvest. The TSS increased from the 50^{th} days of growth to harvest. The greatest increase was found to be occur between the 80^{th} day of growth and harvest.

Ricaud R (1971) reported that the sugar yields were significantly higher in plants harvested at seed maturity than those harvested an anthesis.

Bapat and Chaudhari (1986) based on their study on several sweet sorghum genotypes reported that in general, the sugar per cent increased from flowering to harvesting stage.

Blume (1977) did not find any difference in cane yield, brix, polarization or purity, when sweet sorghum Cv. Rio was harvested at 30 or 40 days after heading. Further, they reported that delayed processing of sweet sorghum stalks after their harvest resulted in stem weight loss which lead to lowering juice yield and significantly lowering sugar yield. However, TSS in juice sucrose and purity were not significantly affected by delayed processing. Sucrose content and aconitic acid content increased and starch content decreased with the delay in processing.

Ferraris and Stewart (1979) had thrown light on new options for sweet sorghum. They have suggested potential use of sweet sorghum (*Sorghum bicolor* (L.) Monech) as a source of sugar particularly for fuel alcohol. Total sugar content of sorghum stalk juice was lower than of sugarcane juice, with a lower proportion of sucrose and higher reducing sugar. The major potential use for sorghum was believd to lie with fermentation products i.e. alcohol, vinegar, cirtric acid and lactic acid.

Smith and Feevas (1979) analyzed the sorghum stalk juice and reported that there are varietal differences in sucrose, dextrose, lavulose, starch, protein and fiber content.

Ayala *et al.* (1980) studied sweet sorghum Cv. Rio and Rama. They were harvested at the flowering, milk, dough and maturity stages. Sugar yields were not significantly different. The best quality juice was obtained at maturity.

Sindhu & Mahendriratta (1980), Alikhan (1995), Nguyen *et al.* (1998) and Manonmani (2002) for plant in Sorghum reported high PCV and GCV values along with high variability.

Ferreia *et al.* (1982) studied in a field trial 16 sweet sorghum cultivars and hybrids. It was observed that in different genotypes sucrose content varied between 5.12 to 13.5%, brix number between 12.41 to 21.60, reducing sugar content between 1.03 to 4.05%

Rajvanshi and Jorapur (1987) reported that sweet sorghum a dual purpose crop provides grain from its earhead and sugar from its stalks. This sugar juice can be converted into alcohol by fermentation and distillation.

Nimbalkar *et al.* (1998), Cheralu and Rao (1989), Biradar *et al.* (1996), Sankarapandian *et al.* (1996), Narkhed *et al.* (2000), Prabhakar (2001), Veerabadhiran and Kennedy (2001), Prabhakar (2003), Arunkumar *et al.* (2004) for grain yield noticed high values of PCV and GCV for grain yield in their studies.

Copani *et al.* (1989) in a field trail in 1987 at catania of 9 sweet sorghum cultivars, highest total sugar (> 15t/ha) and ethanol yields (> 9000 lit/ha) were obtained from the cultivars with the longest biological cycle. Cv. Dale, This, M 81-E and foralco. These cultivars were characterized rate of sugar accumulation than the less productive cultivars.

Krishnavani *et al.* (1990) reported data on juice and sugar content of 38 cultivars of sweet sorghum, collected at dead ripe stage, arc tabulated. Sugar contents in extractable juice were maximum (> 7 g/100 ml) in cultivars IS 6962, IS 9889, PR 4579 and IS 707, total amount of sugar in extractable juice were maximum (> 200 kg/ha) in IS 715, IS 724, IS 6962 and IS 9901. The sugar content was higher in the upper internodes (nos. 7-11) than in the lower ones, being maximum in internodes 7. There was a high correlation between the total sugar and sucrose content of internodes. Fermentation of juice from Cv. IS 6962 gave ethanol in yield equivalent to 240 lit/ha.

Nain *et al.* (1992) tested 25 sweet sorghum varieties grown during *kharif* 1990 and information was recorded on 5 morphological characters and green cane yield. They revealed that highest yield of green cane was produced by variety HES 52 (32.05t/ha) and the highest volumes of juice recorded from variety HES 62 and HES 64 (1242.7 lit/ha). Varieties HES 52 and HES 54 recorded the highest ethanol yield coefficient of 0.525 and 0.526 and fermentation of 97.68 and 97.36 per cent, respectively.

Choudhari and Tattapure (1993) conducted an experiment with seven genotypes of high energy sorghum (HES2, HES3, HES4, HES 6, HES13, CHS 1 and CHS5) during *Kharif* (1989-90). The crop was harvested a week after physiological maturity. Green stem was crushed at 0, 24,48,72 and 96 hours after harvesting by storing under room temperature. The study indicated that, delay in cane crushing after harvest reduced stem weigh, juice yield per cent, whereas it increased juice brix and pH. Minimum juiced yield reduction was observed in HES3, HEs 4 and HES 13 and maximum in HES2 , CSH5, and CSH 1. An interaction between genotype x times of crushing was significant in stem weight, juice yield, brix and pH. Hence, there is a scope for selection of genotype for required character.

Mummigatti *et al.* (1994) in a field trial in *Kharif* (monsoon) 1991 at Dharwad, Karnataka, 10 sweet sorghum cultivars were compared. Grain yield was higher in Cv. SSV -96 T, whereas cane yield was highest in

SSV-74. Juice yield and extractable juice were highest in SSV-53T, although grain yields in this cultivar were low.

Jadhav *et al.* (1994) tested 15 sweet sorghum verities sown in *Kharif* season on 1989 and observed that significant varietal differences at growth stages. Brix was positively correlated with sucrose content. They observed SSV 108, SSV 74, SSV53, SSV 133,SSV 96 and SSV 7073 varieties with superior juice quality.

Girgis *et al.* (1996) reported that the state of maturity had an impact on the sugar yield of sweet sorghum. Further the brix (TSS) value was higher in dough to ripe state and had significant influence on syrup yield of sweet sorghum.

Patil *et al.* (1996) in forage sorghum, observed high variability and heritability in sorghum genotype for days to 50 per cent flowering. Prabhakar (2001) estimated variability parameters in 48 rabi sorghum genotype sand reported higher PCV and GCV values for this trait.

Sankarapandin et al. (1996), Latha Chaudhary *et at.* (2001), Mallinath *et al.* (2004) and Kenga *et al.* (2006) reported high genetic variability, heritability and genetic advance for plant height in sweet sorghum. High genetic variability and high heritability coupled with low genetic advance for total soluble solids. High genetic variability and heritability coupled with moderate genetic advance for fresh stalk yield in sweet sorghum main and ratoon crops.

Rao and Patil (1996), Latha Chaudhary *et al.* (2001) and Veerabadhiran *et al.* (2001) reported high genetic variability, heritability coupled with high genetic advance in sorghum for grain yield.

Mallikarjun *et al.* (1997) conducted field trials of sweet sorghum genotype viz. SSV 83, SSV 84, SSV 12611 and Rio at four crop densities 2.2, 3.3, 4.4, 6.6 lakh plants /ha under irrigated conditions at Dharwad during summer 1992-93. Rai recorded the highest calculated sugar yield (2.36 t/ha) followed by SSV 84 (1.98 t/ha), which was gave highest grain yield (2.46 t/ha). Rao gave the highest juice yield (12303 lit/ha) which was attributed significantly to fresh millable stalk yield and juice extractability. At lower crop densities mean grain yield were higher (2.44 t/ha at 3.3 lakh plant/ha and 2.37 t/ha at 2.2 lakh plants/ha) which was due to increased 1000 grain weight. SSV 84 is recommended for dual purpose (grain and sugar) cultivation and Rio consider suitable for sugar production (both at a cop density 2.2 and 3.3 lakh plants/ha)

Narkhede *et al.* (1997) observed that seventeen sweet sorghum genotype were evaluated for total soluble sugar (TSS), green cane weight and grain yield performance over six location in India (Rahuri, Akola, Surat, Parbhani, Dharwad and Coimbatore) in *Kharif* 1995. And estimate of stability was calculated. They found that RM 48 and GSSV 235 showed stable performance with high means for green cane weight, GSSV 219, and GSSV 235 and GSSV 236 were responsive to better environment for TSS content was recorded for RSSV-9, whereas the highest non-reducing sugar content was registered for keller.

Latha Chaudhary *et al.* (2001) observed high genetic variability, high heritability coupled with high genetic advance for this character whereas Veerabadhiran *et al.* (2001) and Warkead *et al.* (2008) reported low genetic variability, high heritability with low genetic advance. Prabhakar (2001) observed low PCV and GCV values for days to maturity trait in 48 rabi sorghum genotypes.

Veerabadhiran *et al.* (2001) noticed low genetic variability, high heritability and low genetic advance in sorghum. Reddy (2003) and Rani (2004) estimated variability parameters in sorghum and reported low range of variability and low GCV and PCV values for the days to 50 percent flowering.

Ritu Thakare *et al.* (2002) the bagasse of 12 cultivators of sweet sorghum (HES-4, NSS-4, AKSSV-16, BJ-248, Wray, Keller, IS 8007, SSV-84, Madhura, RSSV-9, NSSV-104 and IS-20962) was analysed for hemicelluloses, cellulose, lignin and sugar contents. The highest hemicelluloses content was recorded for Wray, followed by IS -8007 and NSS-104, the lowest reducing sugar content was observed in BJ-248, whereas the highest non-reducing sugar content was observed in RSSV-9. Stalk juice analysis for sugars revealed that the lowest reducing sugar content was recorded for RSSV-9, where the highest non-reducing sugar content was registered for keller.

Mallinath *et al.* (2004) reported moderate genetic variability and high heritability with low genetic advance in pop sorghum. Warkad *et al.* (2008) in sorghum mentioned moderate variability, high heritability and low genetic advance for the days to 50 percent flowering.

Mallinath *et al.* (2004) in pop sorghum opined high genetic variability and heritability with low genetic advance but Kenga *et al.* (2006) reported high variability and low heritability In hybrid sorghum for grain yield.

Kachapur (2007) in sweet sorghum observed high heritability coupled with high genetic advance for juice yield indicating the variability was due to additive gene effects.

Unche *et al.* (2008b) reported considerable amount of genetic variability for total biomass, green cane weight, days to flowering, plant height, total sugar index, juice yield and juice extraction per cent in a study of variability involving 16 genotype of sweet sorghum.

Sandeep *et al.* (2009) recorded highest GCV and PCV for nodes per plant, cane height, juice volume and ethanol yield. High broad sense heritability coupled with high genetic advance was extraction per cent, brix % and ethanol yield indicating major role of additive gene action in genetic control of these traits.

2.2 Correlation and path analysis

Ferraris (1981) noticed that sugar and soluble yield were negatively correlated with grain yield and positively correlated with time to maturity and stem juice extraction rates.

Selvi *et al.* (1987) studied twenty eight hybrid obtained by crossing 7 high-juice, high sugar lines with 4 high yielding grains lines in a line x tester design. Data were collected on percentage of extractable juice. Total soluble solid (Brix), total sugar, reducing sugars, green stalk yield and sucrose percentage all characters except percentage of extractable juice and birx were significantly and positively associated with sucrose content at both the genotypic and phenotypic levels. Brix was positive and significantly associated with both extractable juice and green stalk yield at the genotypic level.

Hoda *et al.* (1988) reported significant positive correlation of cane height, internodes per cane, cane thickness and single cane weight with cane yield, while significant positive correlation was noticed between cane height and cane weight in a study of 34 sugar cane genotypes. Association studies in 35 genotypes of sugarcane by Verma *et al.*(1988) indicated significant positive association for internodes per cane, stalk weight, Brix% and commercial cane sugar per cane (CCS) with each other, while stalk weight, Brix % and CCS exhibited significant positive association with stalk girth.

Selvi and alanisamy (1989) ascertained that there was a strong relationship between green stalk yield and brix in desired direction.

Parvatikar and Munjunath (1991) studied eleven sweet sorghum genotypes and concluded that total sugar content in the juice was maximum at physiological maturity stage, and determined positive correlation between brix reading and total sugar content of juice.

Jayamani and Dorairaj (1993) studied genetic association between five sweet sorghum varieties and found that green biomass yield had significant positive correlation with plant height, leaf breadth, number of leaves, tillers per plant and stem diameter, whereas it showed significant negative correlation with days to 50 per cent flowering and leaf stem ratio.

Patel *et al.* (1994) studied six parent and their 15 Fi's resulting from dialed crossing without reciprocals during *rabi* 1990. The results on interrelationship indicated that juice yield per cent, number of primaries, secondaries and test weight were related strongly with grain yield whereas, days to 50 per cent flowering and brix at 50 per cent flowering were negatively correlated with grain yield. In general the relationship of character under study except days for 50 per cent flowering was significant and positive. The path analysis showed that, the leaf area at harvest, juice secondaries both at genotypic and phenotypic levels were having maximum direct effect on grain yield through leaf area at harvest. Therefore, the component like juice yield per cent, number of primaries and secondaries, test weight, and leaf area at harvest were the major component influencing grain yield in sorghum.

Ganesh *et al.* (1995) studied the forty two hybrids from diallel cross involving sweet sorghum and grain sorghum were raised in summer 1992 and evaluated for yield component related alcohol (ethanol) production form fermented juice. Alcohol yield was positively and significantly associated with total sugar content, sucrose percentage, brix juice yield, stem yield and stem girth. It was associated with low reducing sugar content. Among parents alcohol yield was highest form SSV74 (14.2ml/plant), while among hybrids was highest from SSV84 HE 54 (35.1ml)

Patil *et al.* (1995) reported juice yield, panicle length and number of secondaries and test weight were yield at both genotypic and phenotypic levels, a significant positive correlation between days to 50 per cent flowering, green stalk yield and fodder yield. The interrelationship among brix and leaf area at physiological maturity, green stalk and test weight was highly significant and positive, juice yield per cent, panicle length, number of primaries and secondaries had high direct and indirect contribution to grain yield sugar content. Among parents, alcohol yield was highest from SSV 74 (14.2 ml/plant), while among hybrid was highest from SSV 84 x HE 54 (32.1 ml).

Mallikarjun *et al.* (1998) observed highly significant and positive association between available sugar per cent with pol per cent, Brix%, reducing sugars, non reducing sugars, pH and specific gravity in four sweet sorghum genotypes.

Yang Wei Gung (1995) reported that number of branches, hardening duration, plant height, stalk diameter, number of nodes and spike length were significantly and positively correlated with cane yield. The plant height was significantly correlated with other traits including sugar content.

Mallikarjun *et al.* (1998) and Kachapur (2007) in their investigation on sweet sorghum declared maximum positive direct effect of stalk yield, juice yield and brix per cent on sugar yield. Further, the other traits also exhibited high positive indirect effect via stalk yield, juice yield and Brix per cent on sugar yield.

Krishnakumar *et al.* (2004) cane yield was significantly and positively correlated with number of milliable canes, cane height, cane girth and single cane weight in an association study involving 27 subtropical sugarcane cultivars.

Kadian and Mehta (2006) observed in a study on 32 sugarcane genotypes significant positive correlation of cane yield with single cane weight and cane thickness, while four juice quality parameters viz, Brix%, pol%, purity and CCS showed highly significant and positive association among themselves in an association study involving 40 diverse sugarcane genotypes,

Unche *et al* (2008a) in correlation studied in 16 genotypes of sweet sorghum and revealed significant positive association of green cane yield with total biomass followed by plant height, while juice extraction per cent and total sugar index. In a study of 20 sweet sorghum germplasm by Sandeep et al (2010), stem girth, cane weight and juice yield were significantly and positively associated with cane height, cane weight, juice yield and Brix% were significantly and positively associated with stem girth, while juice yield was significantly and positively associated with cane weight.

Ganesh *et al.* (1995) studied character association for alcohol yield in sweet sorghum and found that there was a positive significant correlation of alcohol yield with brix percentage, juice yield, cane yield and stem girth. Selection for high total sugars, sucrose and brix percentage will lead to high alcohol production.

Sankarapandin *et al.* (1996) in their study declared that plant height had negative correlation with total soluble solids and positive correlation with juice yield.

Singh and Khan (2004), Kadian and Mehta (2006), Kachapur (2007), Unche *et al.* (2008a) and Sandeep *et al.* (2010) noticed that among ethanol yield contributing characters, significant and positive association of height with stem girth, cane weight, juice volume and brix per cent; cane weight with juice volume and juice volume with brix per cent was noticed. They also reported that ethanol yield could be enhanced by selecting genotypes with long canes, thick stem, higher cane weight which increases the juice volume reveled that more emphasis should be given brix , percentage of extractable juice, green stem yield and total sugar content.

Sandeep *et al.* (2010) In study observed maximum positive direct effect of juice yield and fresh stalk yield on ethanol yield and also reported that improvement in ethanol yield could be brought about by the selection for component characters like cane weight, cane height and juice volume. Hence, indirect selection via these traits will help in identifying the superior plants with high ethanol yield.

Sandeep *et al.* (2010) studied association of sugar yield with its attributing traits indicated importance of stalk yield, juice yield and Brix in improving sugar yield as these traits had direct relation with sugar yield. Therefore , improvement in these traits automatically improves sugar yield.

2.3 Quality aspect in sweet sorghum

2.3.1 Brix

Bapat and Choudhari (1976) observed that the brix percentage increased from flowering to the harvest stage and highest brix was recorded in genotypes IS – 4465 (23.95 per cent)

Brix is an indication of the soluble carbohydrate content in the stalk. The brix value of whole stem juice of sweet sorghum at harvest ranged from 16.0 to 22.5 (Choudhari *et al.* 1987)

Nimbkar *et al.* (1987) reported the brix range of 23 cultivars ranged from 10 to 22.5 per cent. The brix value had a direct relationship with flowering.

2.3.2 Non reducing sugars (Sucrose)

Ferrais (1982) examined the maturity factors in sweet sorghum the juice characteristics, sucrose yield in stem were highest at grain maturity.

Bapat *et al.* (1986) tested 12 cultivars for juice quality in sweet sorghum and recorded the highest sucrose percentage in juice (16.65 per cent) in the SSV 1333 cultivar. The sucrose content of sweet sorghum juice of 8 cultivars varies from 5.46 to 12.77 per cent.

2.3.3 Reducing sugars and total soluble sugars

Figueiredo *et al.* (1982) Studied that total sugar content increased up to 106 days and then stabilized, reducing sugar content decreased initially an subsequently increased to maximum at 126 days of age.

Bapat *et al.* (1986) tested twelve cultivars in sweet sorghum for juice quality and reported sugar content varies from 0.73 to 1.99 per cent. The Cv. SSV 1333 had minimum reducing sugar content 0.73 per cent. The total reducing sugar content of juice of Cv. CMS x 623 and BR 505 was 17.8and 16.4 per cent respectively.

In the study of 70 cultivars held at ICRISAT, Vaidyanathan *et al.* (1987) found that the total sugar content in stalk harvested after physiological maturity ranged from 17.8 to 40.3 per cent on dry weight basis and the total sugar content of juice ranged from 7.0 to 15.9 per cent.

Material & Methodes

Chapter - III

MATERIAL AND METHODS

The present investigation on " Genetic variability and correlation studies in sweet sorghum (*Sorghum bicolar* (L.) Moench) " was undertaken at Sorghum Research Station farm, Marathawada Agriculture University, Parbhani, during *kharif* 2011.The details of material used, methods adopted and statistical analysis conducted during the course of investigation as described below.

3.1 Experimental materials

The materials used for the present study includes twenty three genotypes avaible at Sorghum Research Station, M.K.V. Parbhani, which are collected from various sources (Table 1).

Table 1. Genotypes of sweet sorghum used in study.

Sr.No.	Genotypes	Source
1)	PMS 71 B	M.A.U.Parbhani
2)	PMS 74 B	M.A.U.Parbhani
3)	PMS 90 B	M.A.U.Parbhani
4)	PMS 42 B	M.A.U.Parbhani
5)	SSPV-2	D.S.R. Hyderabad.
6)	PVR-652	M.A.U.Parbhani
7)	PVK-453	M.A.U.Parbhani
8)	PVK-400	M.A.U.Parbhani
9)	SPV-422	ICRISAT.Hyderabad.
10)	SUS-8-4	D.S.R. Hyderabad.
11)	SSPV-1	D.S.R. Hyderabad.
12)	ICSV-93046	ICRISAT.Hyderabad.
13)	SSV-8	D.S.R. Hyderabad.

14)	ICSV-25074	ICRISAT.Hyderabad.
15)	SSART-1002	ICRISAT.Hyderabad.
16)	SSARVT-1003	ICRISAT.Hyderabad.
17)	SSPV-1005	ICRISAT.Hyderabad.
18)	SSART-1013	ICRISAT.Hyderabad.
19)	SSART-1015	ICRISAT.Hyderabad.
20)	SSART-1024	ICRISAT.Hyderabad.
21)	SSART-1026	ICRISAT.Hyderabad.
22)	KR-133	M.A.U.Parbhani
23)	SSV-84	M.P.K.V.Rahuri.

3.1 Experimental method.

The genotypes were sown during *khari* 2011 in Randamized block desigh (RBD) with two replications.

a) Experimental Desigh : R.B.D.
b) Number of genotypes : 23.
c) Replications : 02.
d) Specing i) Row to row : 60 cm.
ii) Plant to plant : 15 cm.

Plot size

Gross : 5.0 m x 3.6 m : 18.0 m^2
Number of rows : 6
Row length : 5 m.
Net : 4.4 m x 2.4 m : 10.56m^2
Number of rows : 4
Row length : 5 m

e) Fertilizer dose NPK (kg/ha) : 100:50:50

3.3. Cultural practices.

The soil was medium black which was brought to fine tilth. Sowing was done on 28th of June 2011.The crop was fertilized at rate of 100 : 50: 50 NPK kg/ha. Half quantity of nitrogen and full quantity of phosphorus and potash was given at the time of sowing and remaining quantity of nitrogen was given after 30 days of sowing. The crop was protected from insect pest like Jawar shoot fly (*Alterigoha soccata* .) by seed treatment with Thymahexam 75 EC along with spray of endosulphan @17 ml per 10 lit of water.

3.4 Observations recorded

The observations were recorded on randomly selected five plants for the following characters.

3.4.1 Morphological Traits

3.4.1.1 Days to 50 per cent flowering

The number of days from date of sowing to the date on which 50 per cent heads in plot had exuded anathers half way down the head was taken as days to fifty percent flowering.

3.4.1.2 Days to physiological maturity

Number of days required from sowing till to the date when 50 per cent plants showed physiological maturity were calculated.

3.4.1.3 Plant height at physiological maturity

Height was recorded from the base of plant to the tip of the panicle at physiological maturity stage, on five randomly selected plants.

3.4.2 Biomass traits at physiological maturity.

3.4.2.1 Total fresh biomass

Total fresh biomass includes leaves, stem and panicles. Total fresh biomass per plant was calculated by taking average from randomly selected five plants.(kg/plant).

3.4.2.2 Millable cane yield (cane weight)/plant.

For millable cane yield average was taken for 1 plant from five randomly selected plants, from net plot at physiological maturity carefully excluding the border rows. Removed all the leaves, sheath and panicles for fresh stalk (cane) yield/plant.

3.4.2.3 Grain yield.

Grain yield per plant was calculated from average of randomly selected five plants at physiological maturity.

3.4.3 Quality traits

3.4.3.1 Juice brix.

At the physiological maturity, juice brix was recorded on the five random selected plants with a hand refractometer (Brix meter). Brix reading was taken in field condition by taking 'v' shape cut from the middle internode or 5^{th} node from the bottom of stem. A drop of juice was taken on refractometer which directly indicates sweetness reading. (i.e. brix reading) of the juice.

3.4.3.2 Juice extraction percentage.

It was calculated by using following formula.

$$\text{Juice extraction per cent} = \frac{\text{Ml of juice from five canes}}{\text{Weight of five plant}} \times 100$$

3.4.4 Juice yield.

Juice yield was calculated by taking average juice yield from five randomly selected plants.

3.4.4 Component of total sugar.

3.4.4.1 Total soluble soluids (%)

It is the total fermentable sugars such as glucose, fructose, and sucrose *etc.* including starch in the juice. For predicting the total soluble soluids by using juice Brix%, the following regression equation given by Corletd and Cazzato as reported by Reddy *et al.* (2005) was used.

Total Soluable Sugars (TSS)=0.1516+(Brix % x 0.8746)

3.4.4.2 Reducing sugar

Reducing sugar was calculated by Benidict's methods which is given by Jayaraman (1932).

Principle: The cupric copper in alkaline solution is reduced by glucose, fructose and maltose. The cuprous oxide was formed, combines with potassium suiphocyanide (KCNS) in the solution to form a bulky white cuprous thiocyanate. This prevents the formation of red or yellow precipitate. On complete reduction, whole of $CuSO_4$ disappears and the solution shows no blue colour.

Reagents:

1. Benedict's quantitative reagent : Dissolve 200 g of sodium citrate, 75 g of anhydrous sodium carbonate and 125 g of potassium thiocynate in about 600 ml of water gentle heating. Filter and cool.

Dissolve 18 g of copper sulphate ($CuSO_4.5H_2O$) in about 100 ml water .Add this to the potassium thiocynate solution with stirring. Add 5 ml of 5 % potassium ferrocyanide solution and make up the volume to 1 liter with distilled water. If the solution is not clear, filter. (The reagent is also available commercially).

2. Anhydrous sodium carbonate.
3. Standrad solution of glucose : Weigh out accurately 0.5 of reagent grade glucose, dissolved in water and made up to 100 ml (5 gm /ml).
4. Solution of glucose or any of the reducing sugar: Fructose , lactose, maltose of unknown concentration.

Procedure:

1. Standradization of benedicts quantitative reagent in 100 ml. flask with a long narrow neck. Add 2 to 3 g of anhydrous sodium carbonate and a few pieces of porcelain. Heat the flask on a burner. Keep the content of the flask boiling through out the titration period. Take the standard glucose solution (0.5/100 ml) in a bottle and slowly run this solution in to the boiling reagent. A bulky white precipitate of cuprous thiocynate was formed. Add the glucose solution drop wise until the last trace of the blue colour due to $CuSO_4$ disappears.

   Allow the titration mixture to cool . The white precipitate settles down. Sulpernatant liquid exhibited light green colour. If the fluid shows a bluish colour, boil the content and add more glucose solution until the end point is reached. If the sulpernatant liquid show green tinge then excess glucose has been added. Then titrate until constant reading are obtained.

2. Determination of reducing sugar:

Take the test solution into the burette and repeat the titration as in the standardization experiment. End point of titration is reached when the supernatant liquid because greenish. Repeat the titration to obtain constant reading. Record the readings in a table

Reducing sugar per 100 ml (%) = $\frac{5 \times X \times 100}{Y \times 1000} = \frac{5 \times X}{10 \times Y} = \frac{X}{2Y}$

Where,

1. 25 ml Benedict' solution = X ml standard glucose solution.

25 ml Benedict's The standard glucose solution contains 5 mg glucose/ml.

2. solution = Y ml sample solution.

3.4.4.3 Non-reducing sugar.

Non-reducing sugar was also calculated by Benidicts method which is given by Jayaraman in 1932.

Principle : The sucrose is inverted by boiling with mineral acid to obtain invert sugar solution. It was titrated against Benedict's quantitative reagent as in the estimation of glucose.

Procedure :

Pipette 25 ml. of the sucrose solution in a beaker. Add 12 ml of 1N HCL. Stir well and heat on flame. Heat to boiling. Allow the content to boil for two minutes. Cool under running tap water. Add with stirring 12 ml of 1 N NaOH (alkali equivalent to acid). It should become blue. Transfer the contents of the beaker to a 250 ml volumetric flask. Make up the volume to 250 ml. Mix thoroughly by ivverting the flask several times. The hydrolysed solution of sucrose, thus formed, is called "Invert sugar solution'.

Fill this solution in the burette and titrate it with 25 ml. Benedict's quantitative reagent as described in the determination of glucose. The end point is obtained in the same manner as described for glucose estimated. Repeat the titration until constant reading is obtained.

Calculation

Invert sugar (g/100 ml) =: $\frac{X\ x\ 5\ x100}{Y\ X\ 1000}$ X $\frac{250}{25}$

$= \frac{5\ x\ X}{5}$

= z gms

Non- reducing sugar g/100ml, sucrose = glucose + fructose

MW 342 = 180 + 180

= 360

If 360 g of invert sugar = 342 of non-reducing sugar

Hence, for Z g = $\frac{342}{360}$ x z

Where.,

1.Standard glucose solution contents 5 mg glucose/ml

2.25 ml of Benedict's solution = X x 5 mg glucose (Earlier Expt.)

3. Hence Y ml of Invert sugar solution = X x 5 mg glucose.

3.4.4.4 Total sugar content

Total sugar content was calculated by addition of reducing sugar and non reducing sugar.

3.4.4.5 Ethanol yield.

Ethanol was produced in following manner as described by the Praj.industries. Ltd.

1 Harvesting and cane preparation
2 Milling and processing
3 Milling (Tandem/diffusion)
4 Juice extraction
5 Condensate (through evaporation, clearification)
6 Bagass for boilers
7 Juice concentration
8 Syrup
9 Fermentation
10 Distillation ? CO_2 to atmosphere.
11 Restified spirit
12 Fuel ethanol.

3.5 Statistical Analysis

The mean values of all traits under consideration were used for statistical analysis.

3.5.1 Analysis of variance

The data collected on individual characters were subjected to the randomization Block Design (Panse and Sukhatme, 1967).

Genotypic mean square (GMS) were tested for their significance against error mean square (EMS) BY 'F' test for nl = (g-1)and n2= (r-1)(g-1) degrees of freedom.

3.5.2 Variability

a) **Estimation of mean and range**

The mean values for each character were worked out by dividing the total by corresponding of observation.

$$\bar{X} = \frac{1}{n}\left(\sum_{i=0}^{n} Xi\right)$$

Where,

$\bar{X}$ = mean of character

$\sum Xi$ = total of all observation for character and

N = number of observations

The lowest and highest value of each character represented the range.

b) **Estimation of components of variation**

The analysis of phenotypic and genotypic variances were calculated by using the respective mean squares form variance table as below.

Environmental variance $\sigma^2 e = EMS$

Genotypic variance $\sigma^2 g = \frac{GMS - EMs}{r}$

Phenotypic variance $\sigma^2 p = \sigma^2 g + \sigma^2 e$

Where,

GMS = genotypic mean sum of squares

EMS = error means sum of squares

r = number of replications.

c) **Estimation of coefficient of variation**

The genotypic and phenotypic coefficient of variation were calculated by using the following formula given by Burton (1952).

i) **Genotypic coefficient of variation (GCV)**

$$GCV = \frac{\sqrt{\sigma^2 p}}{\bar{X}} \times 100$$

Where,

$\sigma^2 p$ = phenotypic variance

$\bar{X}$ = mean of character

d) Estimation of heritability (h^2)

heritability in broad sense was estimated for various characters suggested by Hanson *et al.* (1956).

$$h^2 = \frac{\sigma^2 g}{\sigma^2 p} \times 100$$

Where,

$\sigma^2 g$ = genotypic variance

$\sigma^2 p$ = phenotypic variance

The high, medium and low heritability estimates were classified as per Robinson (1996) as,

Low = below 10 per cent

Medium = 10-30 per cent

High = Above 30 per cent .

e) Genetic advance (GA)

Genetic advance (at 5 per cent selection intensity) was calculated using the formula cited by Allard (1960)

i) $$GA = K\frac{\sigma^2 g}{\sigma^2 p} \times \sqrt{\sigma^2 p}$$

Where,

$\sigma^2 p$ = Phenotypic variance

$\sigma^2 g$ = Genotypic variance

$\sqrt{\sigma^2 p}$ = Standard deviation due to phenotype

K = Selection differential (At 5 per cent selection intensity, the value of K = 2.06)

Where,

GA = genetic advance

$\bar{X}$ = character mean

3.5.3 Correlation

Covariance analysis between all the pairs of character under study was carried out as per the analysis of variance and covariance as described by Singh and Choudhari (1977).

Environmental covariance = $[e^{cov} 1.2] = EMP$

Genotypic variance = $[g^{cov} 1.2] = \frac{(GMP - EMP)}{r}$

Phenotypic covariance = $[p^{cov} 1.2] = [e^{cov} 1.2] + [g^{cov} 1.2]$

The appropriate variance and covariance were used for calculation of phenotypic and genotypic correlation coefficient (Johnson *et al.*, 1955). The phenotypic correlation coefficient (rp) was calculated.

$$rp_{1.2} = \frac{(p^{cov} 1.2)}{\sqrt{(\sigma^2 p_1).\sigma^2 p_2}}$$

Where,

rp 1.2 = phenotypic correlation coefficient between character 1 & 2.

$P^{cov} 1.2$ = phenotypic covariance between character 1 and 2.

$\sigma^2 p_1$ and $\sigma^2 p_2$ =phenotypic variance of character 1 & 2 respectively.

Significance of the phenotypic correlation coefficient was tested by referring to Fisher and Yates (1943) table.

The genotypic correlation coefficient (rg) calculated as :

$$rp_{1.2} = \frac{(g^{cov}1.2)}{\sqrt{(\sigma^2 g_1).\sigma^2 g_2}}$$

Where,

$rg_{1.2}$ = genotypic correlation coefficient between character 1 and 2.

$G^{cov}1.2$= genotypic covariance between character 1 and 2.

$\sigma^2 g_1$ and $\sigma^2 g_2$ = genotypic variance of character 1 and 2 respectively.

The significance of the various correlation coefficient were tested by 't' test.

3.5.4 Path analysis

To establish the cause and effect relationship between genotypic and phenotypic correlation coefficient were partitioned into direct and indirect effects by path analysis as suggested by Dewey and Lu (1959).

The first step in the path analysis is to prepare a path diagram based on cause and effect relationship. In present investigation, path diagram was prepared by taking green cane yield as effect and various green cane yield contributing characters as causal factors.

Path coefficients were obtained by solving a set of simultaneous equation in the form.

$r_{ny} = P_{ny} + r_{n2}.P_{2y} + r_{n3}.P_{3y}$

Where,

r_{ny} = respected correlation between one component and green cane yield.

P_{ny} = represent path coefficient between the character and green cane yield.

R_{n2} = represent correlation between that character and each of the green cane yield components in turn.

Matrix A   Matrix B

$$\begin{pmatrix} r_{1y} \\ \vdots \\ r_{2y} \\ \vdots \\ r_{ny} \end{pmatrix} \qquad \begin{pmatrix} r_{11} & r_{12} & r_{13} \cdots & r_{1n} \\ r_{21} & r_{22} & r_{23} \cdots & r_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ r_{n1} & r_{n2} & r_{n3} \cdots & r_{nn} \end{pmatrix}$$

Where,

$r_{12} = r_{21}$ and so on and r_{1y} represent correlation between one component character and green cane yield.

The matrix B was inversed $(B)^{-1}$ and path coefficient (P_{ij}) were obtained as : $(P_{ij}) = A \times (B)^{-1}$

The indirect effect of particular character through other character was obtained by multiplication of direct path and particular correlation coefficients, between these characters respectively thus,

Indirect effect = $r_{ij} \times P_{ij}$

Where,

i = 1………20

j = 1………20

P_{ij} = $P_{1y}, P_{2y}\ldots\ldots P_{ny}$

Path coefficient (Pij) correlation coefficient (rij) and residudal factors (R) were diagrammatically presented. The residual factors i.e. variation in green cane yield unaccounted by these associations was calculated from following formula.

$$\text{Residual effect (R)} = \sqrt{(1 - R^2)}$$

Where,

$R^2 = P_{1y}R_{1y} + P_{2y}.r_{2y}S + \ldots\ldots\ldots\ldots P_{ny}.r_{ny}$

$P_{1y}, P_{2y}\ldots\ldots\ldots\ldots P_{ny}$ = Path values

$R_{1y}, r_{2y}\ldots\ldots\ldots\ldots r_{ny}$ = Correlation coefficient

Results

Chapter - IV

RESULTS

The success of any crop improvement is mainly depends on extent of variability present in the crop ,relationship knowledge from evalution point of view and major objective is to improves yield and yield contributing traits.Many agronomic and quality traits are quantitative in nature and are complex in inheritance and often involve several unrelated characters. For this reason knowledge of the degree of association and relationship between different characters may indicate a cause and effect relationship, pleiotropy or linkage and can therefore assist in the identification of promising materials. Thus the present investigation entitled 'Genetic variability and correlation studies in sweet sorghum (*sorghum bicolar* (L) Moench) are presented below under suitable subheadings

A) GROWTH CHARACTERS

4.1 Analysis of variance

For six growth characters studied in sweet sorghum analysis of variance is presented in Table 2. Mean sum of squares due to treatments were significant for all the traits indicating genotypes under study differed significantly for all the traits.

Table. 2. Analysis of variance of six growth character in sweet sorghum.

Sr. No.	Character	Mean sum of squares	
		Treatment	Error
1	Days to 50 % flowering	83.48**	8.30
2	Days to physiological maturity	93.43**	20.99
3	Plant height at physiological maturity (cm)	7321.61**	252.48
5	Total fresh biomass (kg/plant)	0.12**	0.00
6	Millable cane yield (kg/plant)	0.12**	0.00
7	Grain yield (g/plant)	398.03**	6.37

**,* - significant at 1% and 5% levels respectively.

4.1.1 Mean performance and variability parameters

The mean performance and variability parameters are presented in table 3 and 4, respectively. In general, the estimates of PCV were higher than those of GCV. High estimates of GCV were recorded for the characters millable cane(35.07), grain yield (33.95), total biomass (25.94) and plant height at physiological maturity (20.86), medium estimates of GCV were observed. Low estimates of GCV were observed for two characters namely days to physiological maturity (5.11), and days to 50% flowering (7.58).

Similar trend was observed for phenotypic coefficient of variation that was higher for millable cane yield (36.01), and grain yield (34.53) while medium for total fresh biomass (26.46), plant height at physiological maturity (21.60), and low for days to physiological maturity (6.43), and days to 50% flowering (8.38).

As heritability in broad sense includes both additive and epistemic gene effects, it will be reliable only if accompanied by high genetic

Table 3. Mean performances of six growth characters studied in sweet sorghum

Sr.No.	Genotypes	Days to 50% flowering	Days to physiological maturity	Plant height at physiological maturity (cm)	Total fresh biomassc (kg/plant)	Millable cane yield (kg/plant)	Grainyield (g/plant)
1	PMS 71 B	72.00	104.50	214.50	0.57	0.28	65.00
2	PMS 74 B	77.50	116.00	199.00	0.78	0.34	64.00
3	PMS 90 B	77.50	113.00	204.00	0.62	0.33	59.50
4	PMS 42 B	66.50	102.00	184.00	0.63	0.34	57.00
5	SSPV - 2	70.00	108.00	263.50	0.97	0.60	64.00
6	PVR - 652	84.00	123.50	304.00	0.80	0.67	33.50
7	PVK - 453	86.50	127.00	285.50	0.88	0.72	23.50
8	PVK - 400	86.00	115.50	267.00	0.76	0.57	32.00
9	SPV - 422	85.00	124.50	330.50	1.16	0.88	19.50
10	SUS - 8-4	74.50	111.50	152.50	0.71	0.49	44.50
11	SSPV - 1	74.50	113.00	365.50	1.37	0.93	50.50
12	ICSV - 25074	84.00	122.00	281.00	0.82	0.65	42.50
13	SSV - 8	82.00	120.50	269.50	0.89	0.68	44.50
14	ICSV - 93046	80.50	118.50	342.00	1.00	0.77	26.00
15	SSART - 1002	84.50	120.50	326.50	1.17	0.98	23.00
16	SSARVT - 1003	86.50	123.00	313.00	0.96	0.79	26.50
17	SSPV - 1005	75.50	111.00	313.50	1.29	1.02	27.50
18	SSART - 1013	83.00	122.50	370.50	1.39	1.17	36.00
19	SSART - 1015	84.50	123.00	281.50	1.30	1.08	36.50
20	SSART - 1024	87.00	126.50	274.00	0.81	0.60	39.00
21	SSART - 1026	81.50	121.00	373.00	1.12	0.94	52.50
22	KR - 133	81.00	120.50	278.00	0.73	0.58	40.00
23	SSV - 84	94.50	117.00	319.00	0.87	0.74	40.50
	Mean	**80.80**	**117.58**	**283.00**	**0.93**	**0.70**	**41.19**
	CD at 5%	**5.96**	**9.48**	**32.89**	**0.10**	**0.11**	**5.38**

Table 4. Variability Parameters for six growth characters in sweet sorghum

Sr.No.	Parameters	Days to 50% flowering	Days to physiological maturity	Plant height at physiological maturity (cm)	Total fresh biomass (Kg/plant)	Milable cane yield (kg/plant)	Grain yield (gm/plant)
1	Range	66.50 - 94.50	102.00-127.00	152.50-365.50	0.57-1.39	0.28-1.17	19.50-65.00
2	GCV	7.58	5.11	20.86	25.94	35.07	33.95
3	PCV	8.38	6.43	21.60	26.46	36.01	34.53
4	H^2 (bs) (%)	81.90	63.23	93.25	96.14	94.86	96.65
5	Genetic advance as % mean	14.14	8.38	41.50	52.41	70.37	68.76

Table 5. Genotypic Correlation coefficient for Six Growth characters in sweet sorghum.

Sr.No.	Genotypes	Days to 50% flowering	Days to physiological maturity	Plant height at physiological maturity (cm)	Total fresh biomass (Kg/plant)	Grain yield (g/plant)	Milable cane yield (kg/plant)
1	Days to 50% flowering	1.000	0.951**	0.470**	0.172	-0.670**	0.410**
2	Days to physiological maturity		1.000	0.626**	0.379*	-0.742**	0.585**
3	Plant height at physiological maturity (cm)			1.000	0.783**	-0.542**	0.854**
4	Total fresh biomass (Kg/plant)				1.000	-0.432**	0.939**
5	Grain yield (gm/Plant)					1.000	-0.628**
6	Milable cane yield (kg/plant)						1.000

**,* Significant at 1% and 5% Level respectively.

Table 6. Genotypic path analysis of Five components on fresh stalk (cane) yield in sweet sorghum.

Sr.No.	Genotypes	Days to 50% flowering	Days to physiological maturity	Plant height at physiological maturity (cm)	Total fresh biomass (Kg/plant)	Grain yield (gm/Plant)	Genotypic correlation coefficient
1.	Days to 50% flowering	**0.224**	-0.122	0.063	0.133	0.111	0.409**
2.	Days to physiological maturity	0.213	**-0.128**	0.083	0.292	0.123	0.585**
3.	Plant height at physiological maturity (cm)	0.105	-0.080	**0.134**	0.605	0.090	0.854**
4.	Total fresh biomass (Kg/plant)	0.038	-0.048	0.105	**0.772**	0.072	0.939**
5.	Grain yield (gm/Plant)	-0.504	0.095	-0.072	-0.334	**-0.166**	-0.628**

**, * - Significant at 1% and 5% Level respectively

Bold figure indicate direct effect : **Residual effect = 0.5795**

X = Genotypes of sweet sorghum
Y = Millable cane yield (Kg/Plant)

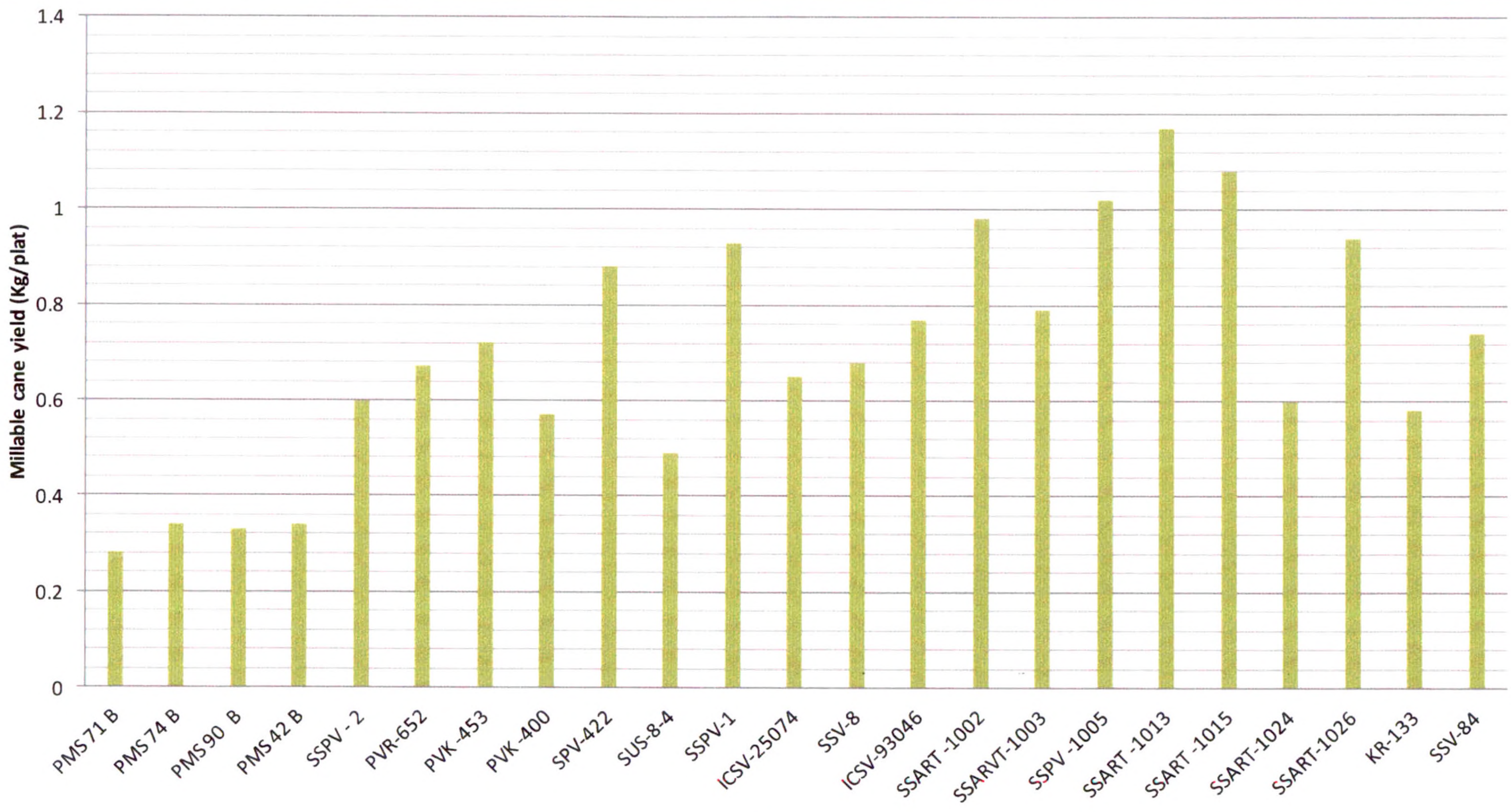


Fig.1. millable cane yield (Kg/plant) for different genotypes

X = Different growth characters of sweet sorghum
Y = GCV and PCV Values

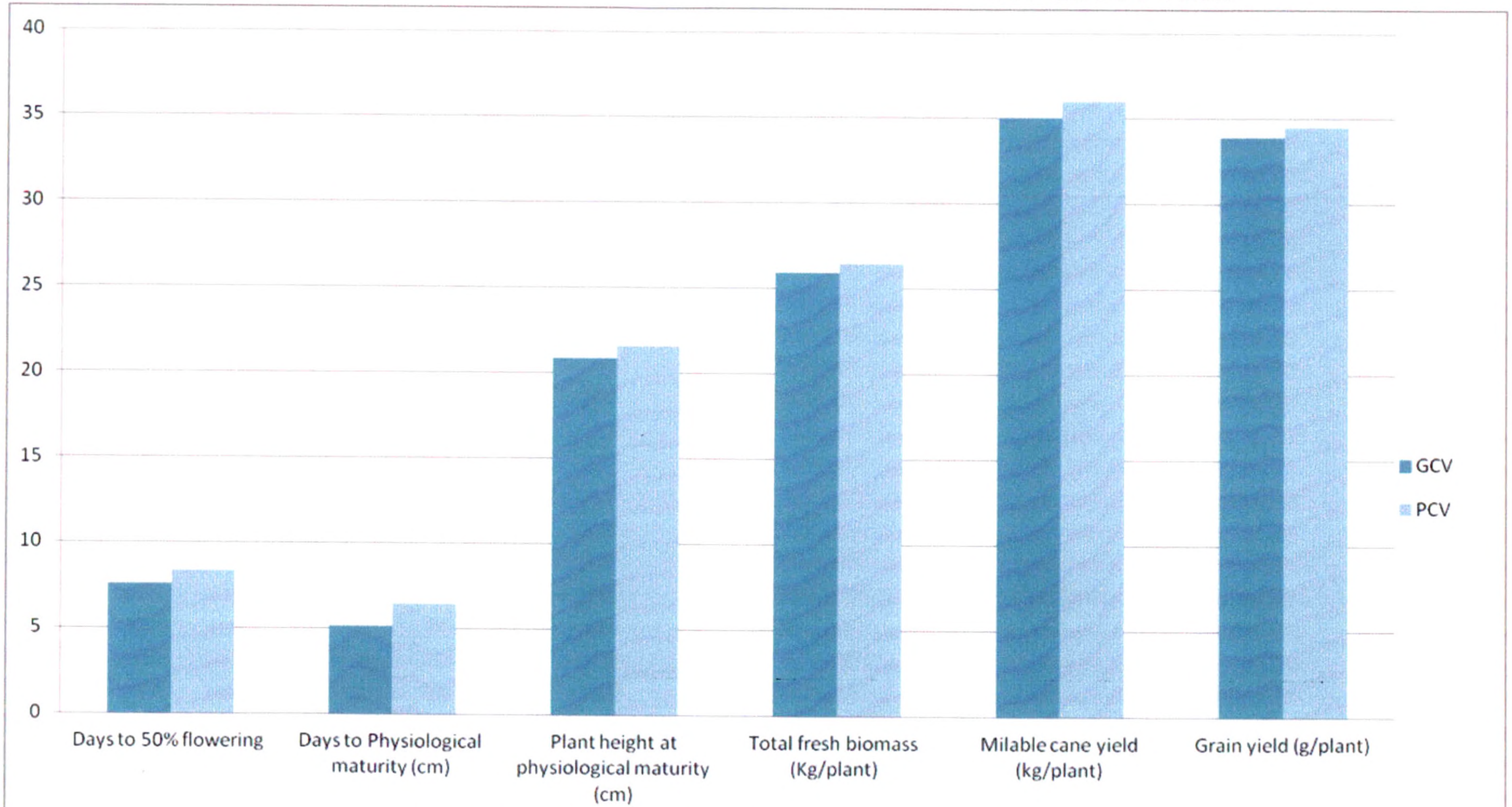
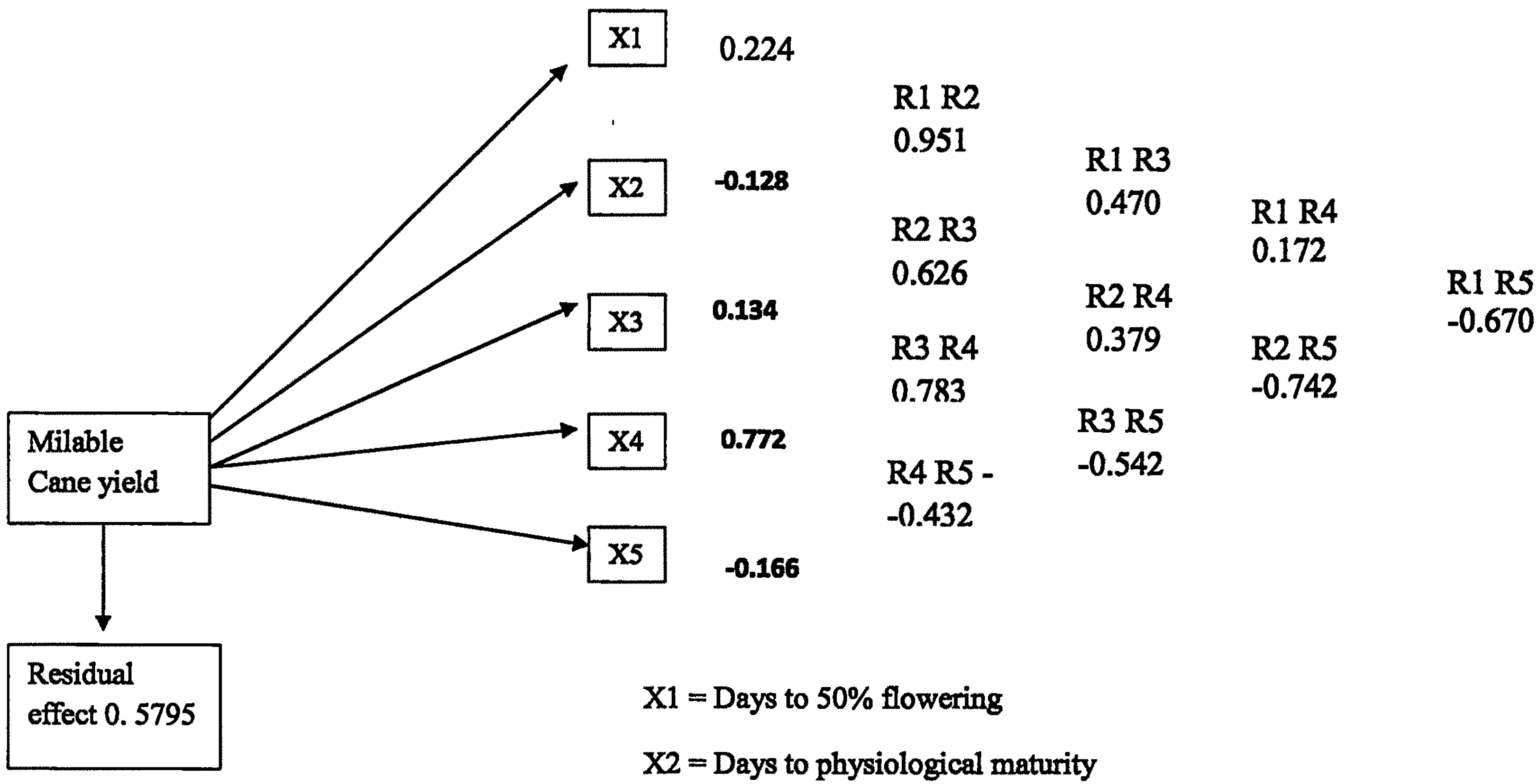


Fig. 2. GCV and PCV of different growth characters in sweet sorghum



X1 = Days to 50% flowering

X2 = Days to physiological maturity

X3 = Plant height at physiological maturity

X4 = Total fresh biomass.

X5 = Grain yield

Fig. 3. Genotypic path diagram for Six growth characters.

advance. The heritability in broad sense varied to 63.23 (lowest) for days to physiological maturity to 96.65 (highest) for grain yield. The estimates of heritability were observed high for all characters studied. High estimates of genetic advance were observed for millable cane yield (70.37), grain yield (68.76), and total fresh biomass(52.41). Medium estimates of genetic advance present of mean were observed for plant height at physiological maturity (41.50). While for characters days to 50 % flowering (14.14) and days to physiological maturity (8.38) low estimates of genetic advance were noticed.

4.1.2 Correlation studies

4.1.2.1 Association of millable cane yield with its components

Millable cane yield was significantly and positively correlated with total fresh biomass (0.939), followed by plant height at physiological maturity (0.854) days to physiological maturity (0.585), and days to 50 % flowering (0.410).

4.1.2.2 Association among the components.

Days to 50 % flowering had significant and positive association with days to physiological maturity (0.951), plant height at physiological maturity (0.470), millable cane yield (0.410), and days to physiological maturity. While significantly but negatively associated with grain yield (-0.670). Days to physiological maturity had significant and positive association with plant height at physiological maturity (0.379) and millable cane yield(0.585). While, it having significant and negative association with grain yield (-0.742). Plant height at physiological maturity had significant and positive association with total fresh biomass (0.783) and millable cane yield (0.854) and significant and negative association with grain yield (-0.542). Total fresh biomass had significant and positive association with plant height at physiological maturity (0.379). Grain yield had significant and negative association with days to 50 % flowering (-0.670) and days to physiological maturity (-0.742).

4.1.3 Genotypic path coefficient analysis

The genotypic correlation coefficient were further partitioned in to direct and indirect path coefficient which are presented in Table 6 and fig 3.

4.1.3.1 Days to 50 per cent flowering

Days to 50 per cent flowering had high and positive (0.224), direct effect on millable cane yield. Its indirect effect via remaining characters were positive expect days to physiological maturity (-0.122), which had medium negative indirect effect.

4.1.3.2. Days to physiological maturity

Days to physiological maturity had medium negative (-0.128) direct effect on fresh stalk (cane) yield. Its indirect effect via days to 50 per cent flowering and total fresh biomass were high and positive, while, plant height, physiological maturity and grain yield were having medium and positive indirect effect.

4.1.3.3 Plant height at physiological maturity

Plant height at physiological maturity had medium positive direct effect (0.134) on millable cane yield. Their indirect effect via days to 50 per cent flowering had medium and positive indirect effect and via total fresh biomass and grain yield had high and positive indirect effect while days to physiological maturity had negative and indirect effect on millable cane yield.

4.1.3.4 Total fresh biomass (Kg/plant)

Total fresh biomass had high and positive direct effect (0.772) on millable cane yield had medium and positive indirect effect on days to 50 per cent flowering, plant height at physiological maturity and grain yield,while days to physiological maturity had medium and negative indirect effect.

B) QUALITY CHARACTERS

4.2 Analysis variance

For eight quality characters studied in sweet sorghum the analysis of variance is given in Table No.7. The mean sum of square due to treatment was significant for all characters excluding non reducing sugar non significant indicating that the genotypes studied different significantly for concerned characters.

Table.7.Analysis of variance of eight quality characters in sweet sorghum.

Sr. No.	Characters	Mean sum of squares	
		Treatment	Error
1.	Juice brix	4.02**	1.44
2.	Juice extraction (%)	120.23**	4.50
3.	Juice yield (ml/plant)	12276.35**	296.98
4.	Total soluble soluid (TSS) (%)	3.07**	1.24
5.	Reducing sugar (%)	0.08*	0.03
6.	Non –reducing sugar (%)	1.35	0.56
7.	Total sugar yield	2.06*	0.91
8.	Ethanol yield (ml/lit of juice)	48.38**	14.34

**, * significant at 1% and 5% levels respectively.

4.2.1 Mean performance and variability parameters.

The mean performance and variability parameters of eight quality characters studied in twenty three genotypes of sweet sorghum are presented in Table No. 8 and 9, respectively.

In general estimates of PCV were higher than GCV. High estimates of GCV and PCV were observed for juice yield (33.25 -34.06) and juice extraction (%) (22.19-23.04). Low estimates of GCV and PCV were observed of juice brix (6.50-9.46), total soluble soluid TSS (6.21-9.52), reducing sugar (6.13-9.25), non –reducing sugar (3.90 -6.07), total sugar content (4.04-6.49) and for ethanol yield (5.76-7.83).

High estimates of heritability was observed for juice yield (95.28), and juice extraction (92.78) whereas, medium estimate of heritability was observed for ethanol yield (54.26), juice brix (47.32), total soluble soluid (42.28), and total sugar content (38.83).

High estimate of genetic advance as percent of mean were observed for juice extraction percent (44.03) and juice yield (66.85). Low estimate of genetic advance as per cent of mean were observed for juice brix (9.22), ethanol yield (8.75), total soluble soluid (TSS) (8.33), reducing sugar (8.37), non-reducing sugar (5.16) and total sugar content (5.19).

4.2.2 Correlation studies

4.2.2.1 Association of sugar content with its components.

Total sugar content was highly significant and positively correlated with ethanol yield (0.903), reducing sugar (0.872), total soluble soluid (0.832), juice brix and non reducing sugar (0.810) and negative but highly significant correlation with juice yield (-0.394).

4.2.2.2 Association among the components

Juice brix had positive and highly significant association with reducing sugar (0.880), ethanol yield (0.842) non reducing sugar (0.723) and total

Table 8. Mean performances of eight quality characters studied in sweet sorghum.

Sr.No.	Genotypes	Juice brix	Juice extraction (%)	Juice yield (ML/Plant)	TSS (%)	Reducing sugar (%)	Non-Reducing sugar	Total Sugar Content (%)	Ethanol Yield (ml/Lit of Juice
1	PMS 71 B	20.00	31.41	88.50	17.64	2.93	17.02	20.13	76.50
2	PMS 74 B	19.25	45.66	156.00	16.98	2.93	17.32	20.33	74.00
3	PMS 90 B	16.00	41.19	137.50	14.14	2.62	16.30	18.91	68.00
4	PMS 42 B	17.00	37.90	129.00	15.01	2.50	15.80	18.30	73.00
5	SSPV - 2	18.00	31.01	185.00	15.89	2.85	17.21	20.06	76.50
6	PVR - 652	16.25	24.80	166.00	14.36	2.40	15.11	17.51	70.00
7	PVK - 453	16.00	22.76	165.00	14.14	2.46	15.23	17.69	68.50
8	PVK - 400	18.25	31.05	177.50	16.11	2.49	16.02	18.51	74.00
9	SPV - 422	18.00	28.98	256.00	15.89	2.68	16.71	19.39	70.50
10	SUS - 8-4	17.00	45.32	223.00	15.01	2.61	16.27	18.82	72.00
11	SSPV - 1	19.00	38.01	354.50	16.76	2.80	17.04	19.85	70.50
12	ICSV - 25074	17.00	47.02	305.50	15.01	2.64	16.48	19.17	72.50
13	SSV - 8	16.00	41.31	282.00	14.14	2.46	15.61	18.07	69.50
14	ICSV - 93046	17.00	30.45	233.50	15.01	2.62	16.37	18.97	71.00
15	SSART - 1002	16.00	30.99	302.00	14.14	2.51	16.04	18.55	68.50
16	SSARVT - 1003	16.00	32.22	254.50	14.14	2.30	14.68	17.28	59.00
17	SSPV - 1005	16.00	26.83	272.00	14.14	2.34	15.02	17.36	70.00
18	SSART - 1013	18.00	29.60	344.50	15.89	2.70	16.55	19.22	71.00
19	SSART - 1015	16.75	29.27	315.00	14.80	2.44	15.31	17.75	68.00
20	SSART - 1024	17.00	50.87	305.50	15.01	2.59	16.29	18.88	72.50
21	SSART - 1026	17.25	36.26	341.00	15.23	2.34	14.84	17.17	67.00
22	KR - 133	19.00	26.02	145.00	16.76	2.81	17.08	19.89	76.50
23	SSV - 84	21.00	29.28	215.50	18.51	3.02	17.23	20.24	86.00
	Mean	**17.46**	**34.27**	**232.76**	**15.42**	**2.61**	**16.15**	**18.78**	**71.52**
	CD at 5%	**2.48**	**4.39**	**35.67**	**2.24**	**0.31**	**1.55**	**1.97**	**7.84**

Table 9. Variability parameters for eight quality characters studied in sweet sorghum.

Sr.No.	Genotypes	Juice brix	Juice extraction (%)	Juice yield (ml/Plant)	TSS (%)	Reducing Sugar (%)	Non-Reducing Sugar	Total Sugars Content (%)	Ethanol Yield (ml/Lit of Juice
1	Range	16.00-21.00	22.76-50.87	88.50-354.00	14.14-18.51	2.30-3.02	14.68-17.23	17.17-20.24	67.00-86.00
2	GCV	6.50	22.19	33.25	6.21	6.13	3.90	4.04	5.76
3	PCV	9.46	23.04	34.06	9.52	9.25	6.07	6.49	7.83
4	H^2 (bs) (%)	47.32	92.78	95.28	42.48	43.93	41.28	38.83	54.26
5	Genetic advance as % mean.	9.22	44.03	66.85	8.33	8.37	5.16	5.19	8.75

Table 10. Genotypic correlation coefficient for eight quality characters in sweet sorghum.

Sr.No.	Genotypes	Juice brix	Juice extraction (%)	Juice yield (ml/Plant)	Total soluble sugar (%) (TSS)	Reducing Sugar (%)	Non-Reducing Sugar	Ethanol Yield (ml/Lit of Juice	Total Sugar Content (%)
1	Juice brix	1.000	-0.189	-0.280	0.760**	0.880**	0.723**	0.842**	0.810**
2	Juice extraction (%)		1.000	0.204	-0.053	0.120	0.271	0.000	0.263
3	Juice yield (ml/Plant)			1.000	-0.307	-0.360*	-0.339*	-0.455**	0.394**
4	Total soluble sugar (%) (TSS)				1.000	0.683**	0.897**	0.797**	0.832**
5	Reducing Sugar (%)					1.000	0.721**	0.698**	0.872**
6	Non-Reducing Sugar						1.000	0.658**	0.810**
7	Ethanol Yield (ML/Lit of Juice							1.000	0.903**
8	Total Sugar Content (%)								1.000

Table 11. Genotypic path analysis of seven components on total sugar content in sweet sorghum.

Sr.No.	Genotypes	Juice brix	Juice extraction (%)	Juice yield (ml/Plant)	TSS(%)	Reducing Sugar (%)	Non-Reducing Sugar	Ethanol Yield (ml/Lit of Juice	Genotypic Correlation coefficient
1	Juice brix	**-0.415**	0.001	-0.205	-0.842	-0.382	0.044	0.009	0.810**
2	Juice extraction (%)	0.126	**-0.020**	0.149	0.025	-0.033	0.011	0.003	0.263
3	Juice yield (ml/Plant)	0.396	-.004	**0.733**	0.146	0.099	-0.014	-0.752	-0.394**
4	TSS (%)	-0.491	0.001	-0.225	**-0.478**	-0.339	0.056	0.108	0.831**
5	Reducing Sugar (%)	-0.953	-0.002	-0.0263	-0.585	**-0.277**	0.075	0.879	0.872**
6	Non-Reducing Sugar	-0.448	-0.005	-0.248	-0.620	-0.477	**0.043**	0.457	0.810**
7	Ethanol Yield (ml/Lit of Juice	-0.474	-0.000	-0.334	-0.334	-0.635	-0.351	**0.050**	0.902**

Bold Figurs indicates direct effects   Residual effect = 0.1173

X = Sweet Sorghum genotypes.
Y = Total sugar content (%).

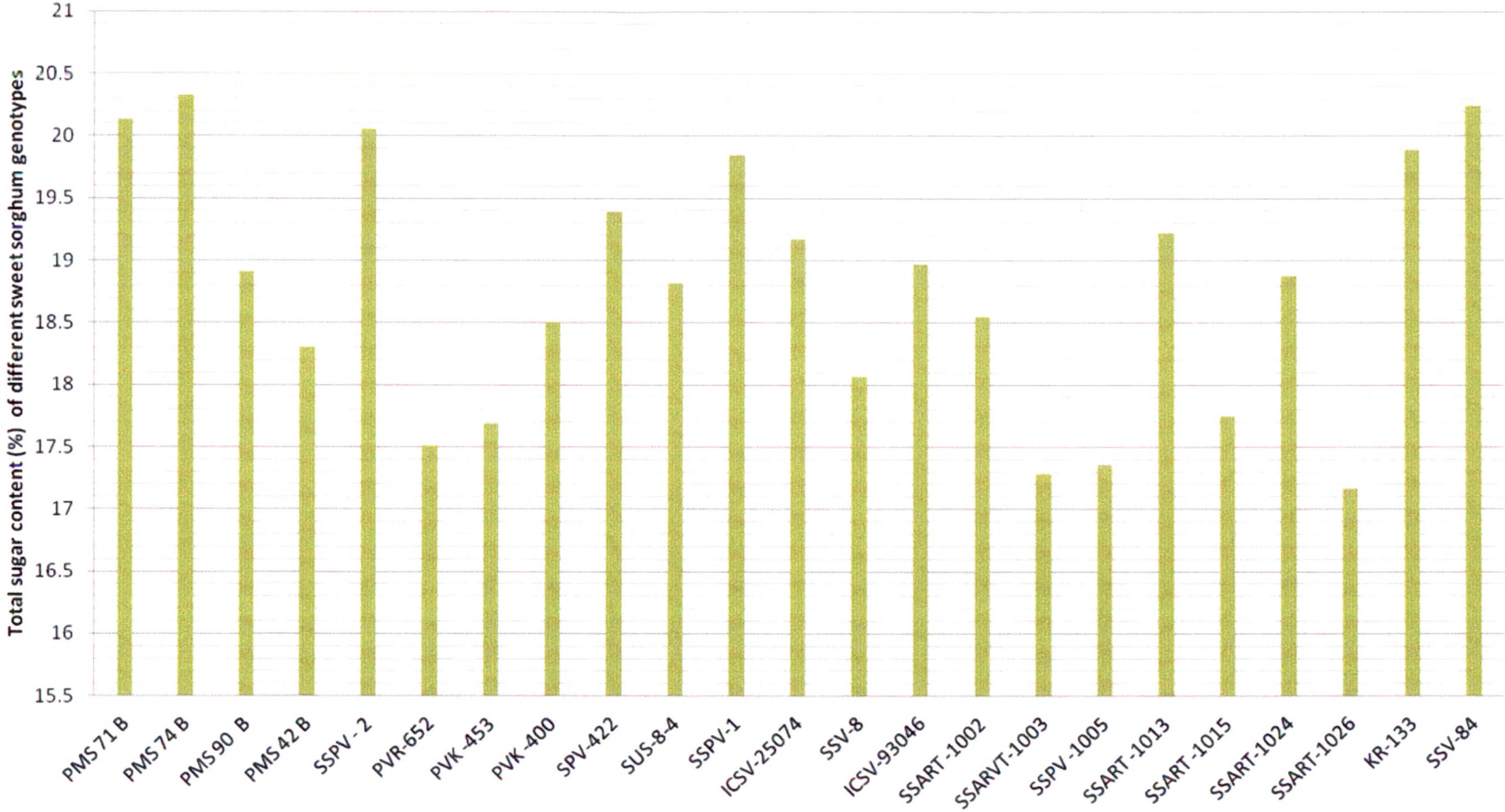


fig.4.Total sugar content (%) of different sweet sorghum genotypes

X = Different Quality Characters of sweet sorghum
Y = GCV and PCV values

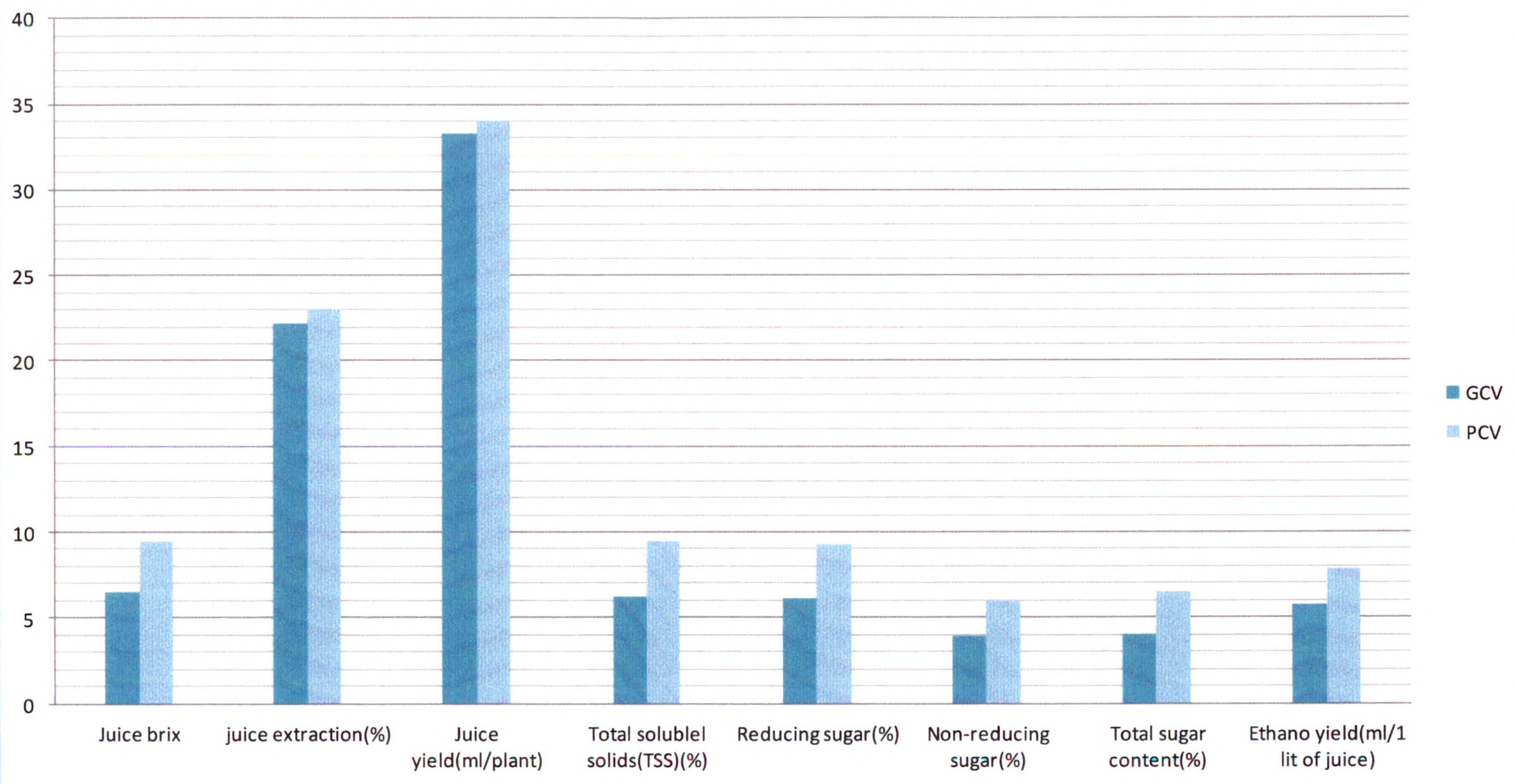
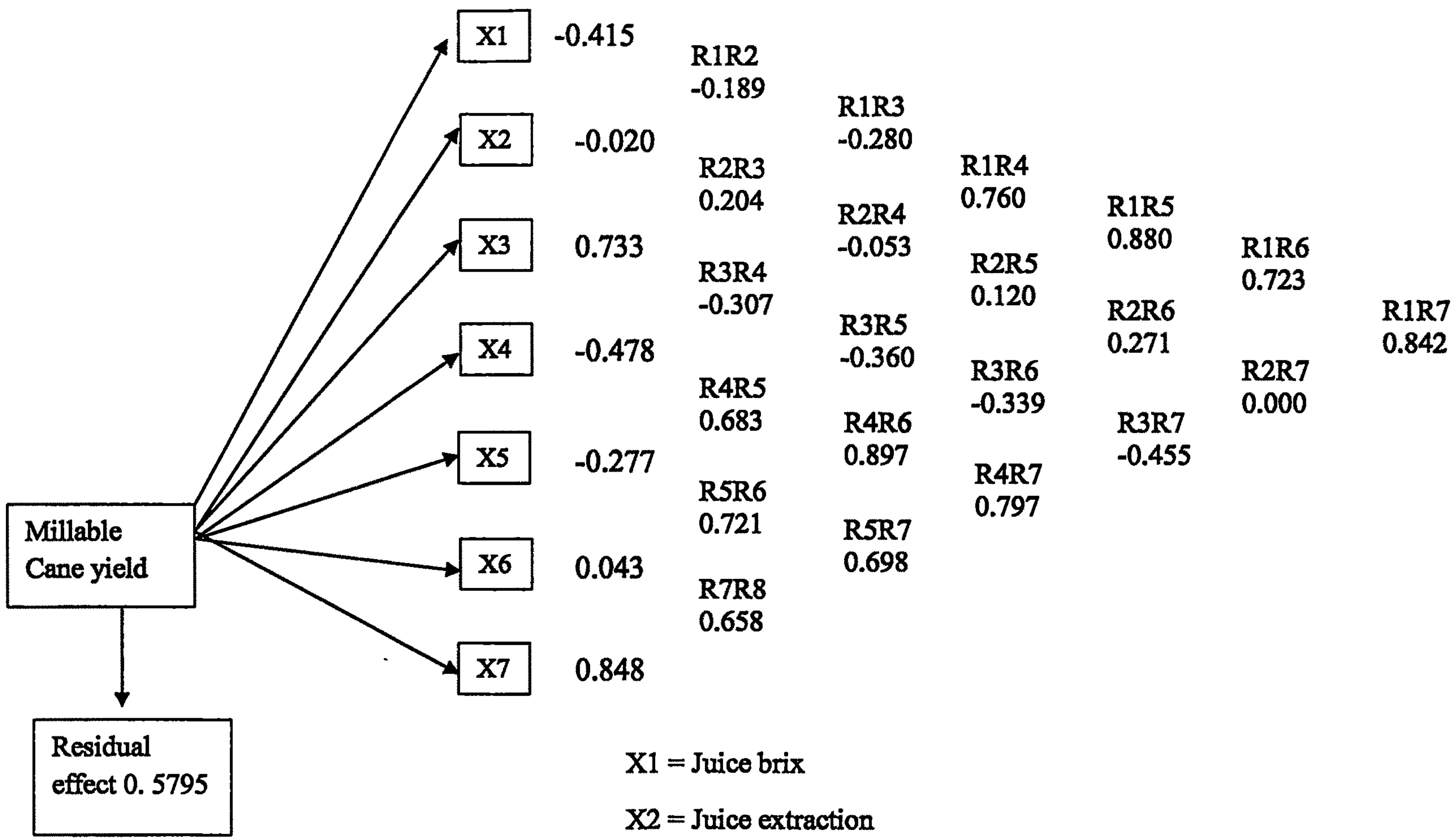


Fig 5.GCV and PCV of different quality caaracters in sweet sorghum.



X1 = Juice brix

X2 = Juice extraction

X3 = Juice yield

X4 = TSS

X5 = Reducing sugar

X6 = Non-reducing sugar

X7 = Ethanol yield

Fig. 6. Genotypic path diagram for Eight quality characters.

soluble soluid (0.760). Juice yield had negative and significant correlation with ethanol yield (-0.455), reducing sugar (-0.360) and total soluble soluid (-0.307). Total soluble soluid had positive and significantly correlated with non-reducing sugar, (0.897), ethanol yield (0.797) and reducing sugar (0.683). Reducing sugar was also significantly positively correlated with non-reducing sugar (0.721) and ethanol yield (0.698),while Non-reducing sugar had positive and significant correlation with ethanol yield (0.658)

4.2.3 Genotypic path coefficient analysis

The genotypic correlation coefficient were further partitioned in to direct and indirect path coefficients which are presented in Table No. 11 and Fig 6.

4.2.3.1 Juice brix

Juice brix had high and negative direct effect on total sugar content (-0.415). its indirect effect via remaining characters were also negative.

4.2.3.2 Juice extraction (%)

Juice extraction (%) had low and negative direct effect on total sugar content (-0.020). Its indirect effect via remaining characters was positive except reducing sugar.

4.2.3.3 Juice yield

Juice yield had high and positive direct effect on total sugar content (0.733) and its indirect effect via juice brix were highly positive and highly negative via ethanol yield.

4.2.3.4 Total soluble soluid (TSS)

Total soluble soluid (TSS) had high and negative direct effect on total sugar content (-0.478), while its indirect effect via juice brix had also high negative.

4.2.3.5 Reducing sugar

Reducing sugar had high and negative direct effect on total sugar content (0.277). Its indirect effect was also negative via reaming characters.

4.2.3.6 Non-reducing sugar

Non-reducing sugar had low and positive direct effect on total sugar content (0.043) and its indirect effect was negative to all remaining characters except ethanol yield (0.457).

4.2.3.7 Ethanol yield

Ethanol yield had high and positive direct effect on total sugar content (0.848) Also its correlation with total sugar content was high and positive (0.902).

Discussion

Chapter - V

DISCUSSION

Management of genetic variability by plant breeder is of basic importance which can be derived from immense valuable germplasm to design a suitable selection procedure for identification of superior genotype. It is therefore, necessary to study the nature and magnitude of variability for exploitation in genetic upgradation of biological population. Selecting the genotype on the basis of pre se performance for yield trial does not give fruitful results due to yield is a very complex character. Simple correlation coefficient are of limited value in selection hence, it is important to study the cause and effect relationship between yield contributing characters.

In present investigation 23 sweet sorghum genotypes were assessed to understand the nature and magnitude of variability, correlation coefficient and path analysis based on six component of millable cane yield. Similarly genetic variability, correlation and path analysis were also worked out for juice yield and other seven independent quality traits of sugar content. The result presented and discussed under appropriate sub heads.

5.1 GROWTH CHARACTERS

5.1.1 Variability parameters

5.1.1.1 Range of variability

Wide range of variability was observed for days to 50 per cent flowering, days to physiological maturity, plant height at physiological maturity, total fresh biomass, fresh (cane) stalk yield, and grain yield. This indicated ample scope for exploitation of the above characters.

Patduke *et al.* (1993) observed similar results for days to 50 per cent flowering, plant height, number of leaves, stem girth and grain yield per plant.

Patil *et at.* (1996) reported wide range of variability for green cane, yield forage yield, and plant height.

Choudhary *et al.* (2001) observed the same results for days to maturity, earhead width, grain yield per plant and plant height.

Sankarapandian *et al* (1996) in their study noticed high genetic variability and heritability coupled with moderate genetic advance for millable cane yield in sweet sorghum.

Rao and Patil (1996) Latha Chaudhary *et al.* (2001) and Veerabadhiran *et al* (2001) reported high genetic variability, heritability coupled with high genetic advance in sorghum.

5.1.1.2 Genotypic and Phenotypic coefficient of variation

The polygenic variation present in the population is of three types viz, phenotypic, genotypic and environmental variation. Phenotypic variation is the total variation which is observable. It includes both genotypic and environmental variation and hence changes under different environmental conditions. Such variation is measured in terms of phenotypic variance. The genotypic components being the heritable part of the total variability, which remains unaltered by environmental conditions. Hence this type of variability is more useful to plant breeder for exploitation in selection or hybridization. This is measured in terms of genotypic variance. Environmental variation is uncontrolled variation, which is non-heritable and is measured in terms of error mean variance.

In present study higher estimates of genotypic and phenotypic coefficient of variance were observed for millable cane yield, grain yield indicates more variability and scope for selection in improvement. The similar results were reported by Rao and Patil *et al* (1996) for grain yield per plant. Veerbhadian and Kennedy (2001) reported high GCV and PCV for grain yield. Nimbalkar *et al.* (1988) Cheralu and Rao (1989), Biradar *et al.* (1996)

Narkhede *et al.* (2000), Prabhakar (2001), Prabhakar (2003), Arunkumar *et al.* (2004), noticed high value of PCV and GCV for grain yield.

Sankarapandian *et al.* (1996) in their study noticed high genetic variability and heritability coupled with moderate genetic advance for millable cane yield in sweet sorghum.While medium for total biomass, and plant height at physiological maturity showing less scope for selection in these characters. Similar results were reported by Patil *et al.* (1996) for green cane yield. Choudhary *et al.* (2001) observed similar results for biological yield.

The estimates of genotypic and phenotypic coefficient of variation were nearly equal to almost all traits like days to 50 per cent flowering, days to physiological maturity, plant height at physiological maturity, total biomass, millable cane yield and grain yield, indicates that the variability existing in these characters was due to influence of environmental factor in the expression of these character. Similar results was noticed by Unche et al. (2008).

5.1.2.3 Heritability (b.s.) and Genetic Advance (GA)

The genotypic coefficient of variation alone does not indicate the proportion of total heritable variation. The heritability estimates is also important in this respect. High heritability indicates the effectiveness of selection based on phenotypic performance but does not necessarily mean high genetic gain for particular character. Considering of both heritability and genetic advance, is more important for predicting effectiveness of selection than heritability alone. High heritability with high genetic advance indicates preponderance of additive gene effect, in such cases selection may be effective. High heritability with low genetic advance reveals preponderance of non additive gene action.

In present investigation high heritability was found to be associated with high genetic advance for grain yield, millable cane yield and total fresh biomass indicats that heritability of these character was most likely due to additive gene effect Rao an Patil (1996), Latha Chaudhary et al (2001) and Veerbhahdian et al. (2001) for grain yield Sankarpadian et al. (1996) for plant height, green cane (stalk) yield and juice yield reported similar results while Rajappa (2009) and Sandeep (2009) observed high genetic value for juice yield in sweet sorghum. High heritability with moderate genetic advance was observed for the traits plant height at physiological maturity indicates the role of both additive and non additive gene action, hence hybridization fallowed by selection would be effective. Sankarpandian et al.(2002) reported similar traits for days to physiological maturity. High to medium heritability estimates coupled with low genetic advance was noticed for days to 50 per cent flowering, days to physiological maturity suggested non additive gene action was played important role in inheritance of these in traits, hence simple selection would be effective for them as there is limited scope for improving these traits in their phenotypic selection. Unche et al. (2008) noticed similar finding for days to 50 per cent flowring, plant height at physiological maturity.

From the foregoing discussion on variability and genetic parameters it is evident that the character total biomass, millable cane yield and grain yield had high PCV, GCV and high heritability coupled with high genetic advance indicating variation in these characters was most likely due to additive gene effects. Hence simple direction and selection may be effective to improve these traits. The other traits with moderate to low value for these genetic parameters suggested that these consideration shall be given to them while fixing the selection criteria.

5.1.2 Correlation studies

Knowledge of relationship between characters is very important from evolution point of view and for selection purpose. In breeding programmes, major objectives is the improvement of yield and other quality characters. Yield is multiplicative product function of yield attributing plant component. Many agronomic and qualitative traits are quantitative in nature and are complex in inheritance and often involve several unrelated characters. For this reason knowledge of the degree of association and relationship between different characters may indicate a cause and effect relationship, pleiotropy of linkage can therefore assets in the identification of promising breeding material to plant breeder.

The present investigation was, therefore undertaken in sweet sorghum with a view to study the association as well as direct and indirect effects of component characters on millable cane yield. Significant and positive correlation coefficient were observed between millable cane yield and days to 50 per cent flowering, days to physiological maturity, plant height at physiological maturity, total fresh biomass.

Unche et al. (2008) observed the positive correlation of total biomass with plant height, and green cane yield which had parallelism with the present results.

The grain yield had negative and significant association with millable cane yield. Similar type of finding was noticed by Unche *et al.* (2008), Bangarwa *et al.*(1989), Jayamani and Dorairaj (1993) and Yang Weig Guang (1995).

Days to 50 per cent flowering showed significant and positive association with days to physiological maturity, plant height at physiological maturity, and millable cane yield indicating there was certain inherent relationship between these characters. Unche *et al.* (2008), Jayamani and Dorairaj (1993), and Prabhakar (2001) noticed similar findings in their studies. Veerabadgurab *et al.* (2001) also noticed similar report of significant positive association between days to 50 per cent flowering and days to physiological maturity.

SWEET SORGHUM GENOTYPS USED IN PROGRAMM

PMS 71 B

PMS 74 B

PMS 90 B

PMS 42 B

SSPV - 2

PVR - 652

PVR - 453

PVK - 400

SPV - 422

SUS - 8-4

SSPV - 1

ICSV-25074

SSV - 8

ICSV - 93046

SSART - 1002

SSARVT - 1003

SSPV - 1005

SSART - 1013

SSART - 1015

SSART - 1024

SSART - 1026

KR - 133

SSV - 84

WHOLE FIELD TRIAL

In respect of grain yield there was significant negative association between days to 50 per cent flowering, days to physiological maturity, while it significant and positive association with plant height at physiological maturity, total biomass, and millable cane yield .. Unche *et al.* (2008), Patil *et al.* (1995) reported similar results for physiological maturity.

Plant height at physiological maturity had significant association between total biomass and millable cane yield while negatively significant association with grain yield. Badwal (1971) reported significant and positive association between days to flowering and days to harvest.

Thus to summarise, characters viz., total biomass, days to physiological maturity, plant height at physiological maturity, days to 50 % flowering had positive and significant correlation with millable cane yield. Hence more imphasis should be given on more biomass yield, maximum plant height at 50 % flowering and physiological maturity for selecting genotypes for sweet sorghum purpose.

5.1.3 Path coefficient analysis

The correlation between yield and its component-character is often miss-leadings, since it is affected by the inter- relationship among the component traits. Path coefficient analysis developed by Wright (1921) helps in partitioning of correlation coefficient in to direct and indirect effects followed by assessing the relations and contribution of each component character to millable cane yield. Direct effect of any components on millable cane yield gives an idea about reliability of indirect selection to made through that character to bring about improvement in stalk yield. If both correlation and the direct effect are high and positive then correlation explains its true relationship and selection for the character will be effective, and if the correlation coefficient is positive but the direct effect is negative or negligible, in such relations the indirect causal factor are to be considered simultaneously for selection. When correlation coefficient is negative but the direct effect is positive and high in such cases direct selection for such traits should be practiced to reduce the undesirable in direct effect.

In present studies days to 50 % flowering had positive, high direct effect on millable cane yield while it is positively and significantly correlated with millable cane yield.

Days to physiological maturity had negative and non significant direct effect on millable cane yield while it has positively and significantly correlated with millable cane yield. The trait plant height at physiological maturity, total fresh biomass and grain yield had positive but non significant direct effect on millable cane yield while they had significant positive correlation with millable cane yield. Based on present investigation the more desirable character in sweet sorghum should have less days to 50 % flowering, and days to physiological maturity, and more plant height at physiological maturity and total biomass for more stalk yield.

5.2 QUALITY CHARACTERS

5.2.1 Variability

5.2.1.1 Range of variability

Wide range of variability was observed for brix, juice extraction, juice yield, non-reducing and ethanol yield indicating that there is wide scope for exploitation of these characters. Similar results were observed by Unche *et al.* (2008) and Bapat *et al.* (1986), for non-reducing sugar, Vidyanathan *et al.* (1987) for total soluble soluid. Choudhary *et al.* (1987) for total soluble solid and Ferraria *et al.*(1982) observed for total sucrose, brix reading and reducing sugar.

5.2.1.2 Genotypic and phenotypic coefficient of variation

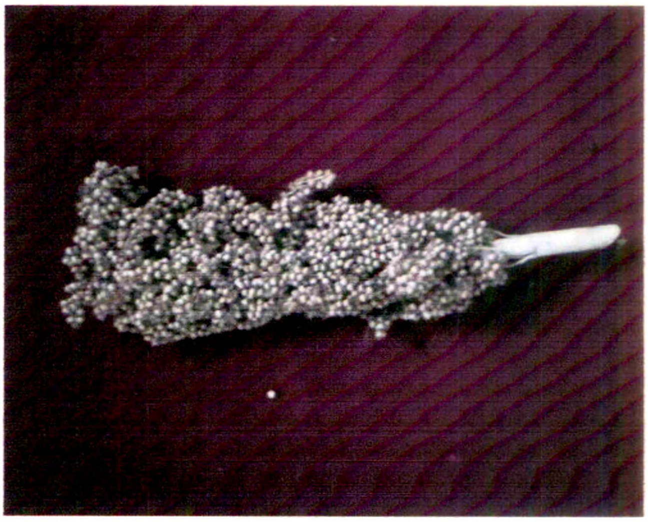
In present study high estimates of genotypic and phenotypic coefficient of variation were observed for juice extraction per cent and juice

PANICLES OF SOME SWEET SORGHUM GENOTYPES

SSPV - 2

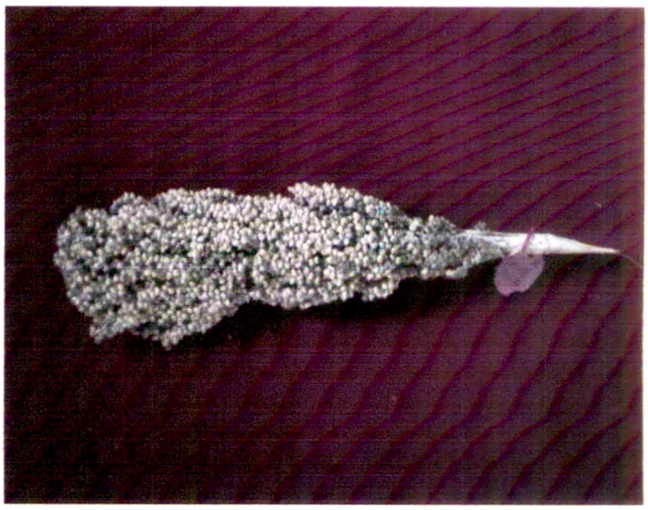
PMS - 42 B

PMS - 74 B



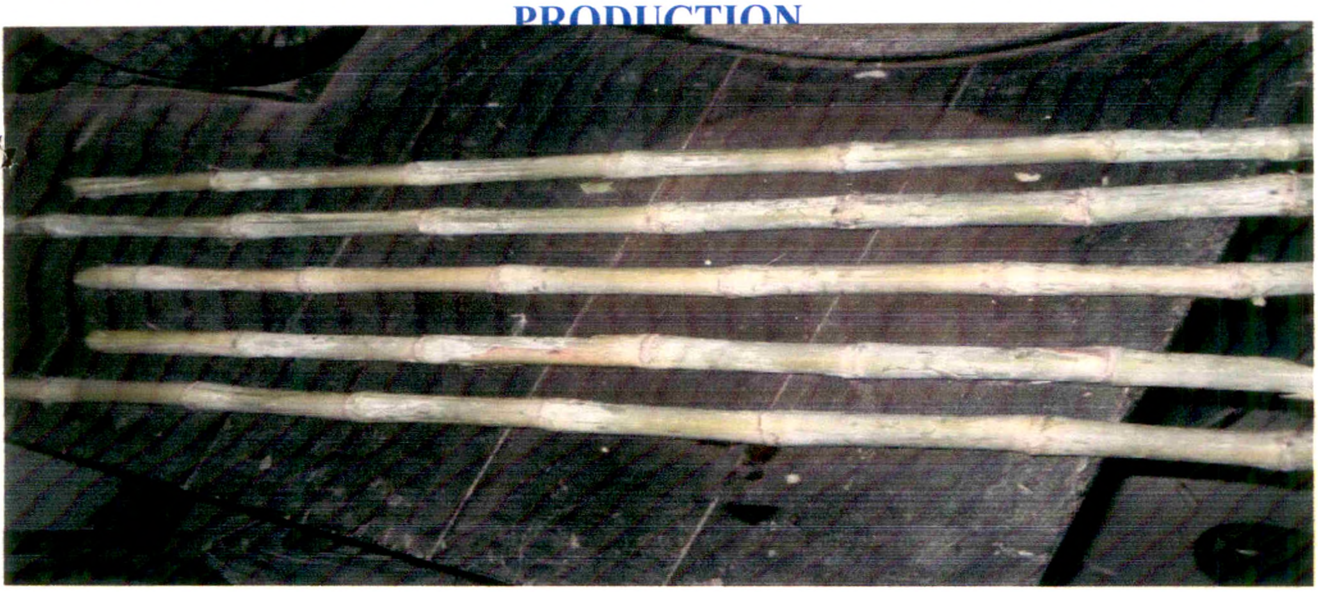
PMS - 90 B

PMS - 71 B

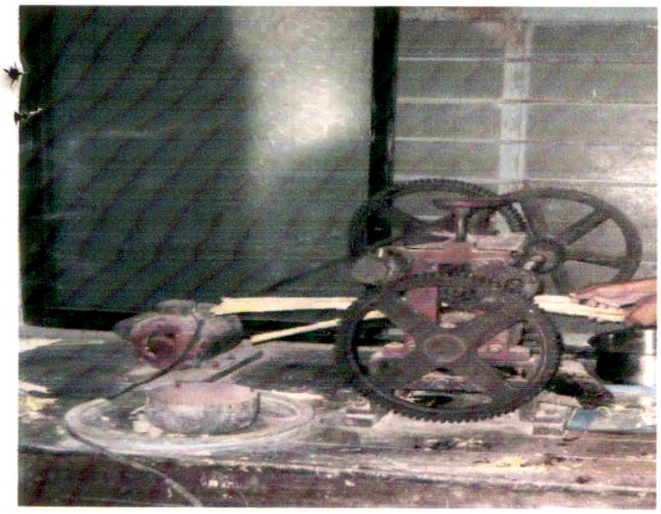


SSPV - 1

PROCESSING OF SWEET SORGHUM FOR JUICE & ETHANOL PRODUCTION

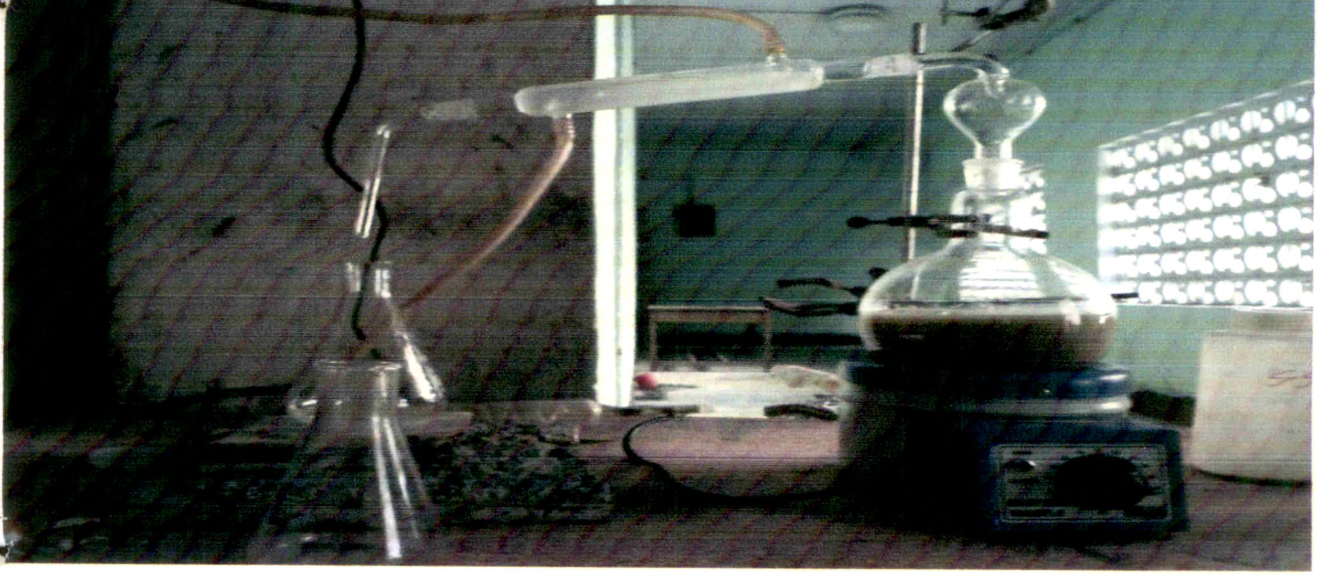


MILLABLE CANE



CRUSHING OF MILLABLE CANE

JUICE OF SWEET SORGHUM



ETHANOL UNIT

yield indicating more variability and scope for selection of improving these characters. Sankarapandian et al. (1996) and Umakant et al. (2004). Where as medium estimates of GCV and PCV were observed for juice brix, TSS, reducing sugar, and ethanol yield showing some scope for improving these traits.The estimates of genotypic and phenotypic coefficient of variation were nearly equal for all quality characters studied in sweet sorghum. This indicated that the variability for these characters was due to genetic factor and there was less influence of environmental factor is expressing of these characters.

5.2.1.3 Heritability and Genetic Advance (GA)

In present investigation, high estimate of heritability was observed for juice extraction and juice yield. Sankarpandian et al. (1996) was observed same result for plant height, green stalk yield and juice yield. While it was moderate in juice brix, TSS, reducing and non reducing sugar. This suggested that non-additive gene action was playing an important role in the inheritance of these traits. Hence simple selection would be ineffective for them. On contrary, Sandkrapandian *et al.* (1996) ascertained high heritability coupled with high genetic advance for these traits. Ethanol yield and total sugar content indicates, these character are least effected by environments.

The character juice extraction per cent and juice yield with high heritability accompanied by high genetic advance indicates predominance of additive gene effects, in such cases selection may be effective. In respect of ethanol yield, TSS, juice brix, reducing and non-reducing sugar exhibits high to moderate heritability with low genetic advance reveals performance of non additive gene action.

5.2.2 Correlation studies

In present investigation a significantly positive correlation was observed for juice brix, juice yield, TSS, reducing and non reducing sugar and ethanol yield except juice extraction. Sandeep et al. (2010 and 2011) confirmed positive association of juice yield with plant height, cane weight, and ethanol yield which was in conformity with the current finding. Juice brix had significant positive correlation with TSS, reducing sugar and non reducing sugar, ethanol yield and total sugar content, indicates that there was inherent relationship between these characters. A similar report of significant positive association of brix per cent with total soluble solids (TSS) was reported by Kachapur (2007) and Sandeep *et al.* (2010). Juice yield had positive and significant correlation with total sugar content while it was negatively and significant correlation with reducing and non reducing sugar, and ethanol yield.

Total soluble soluid had positively significant correlation with reducing and non reducing sugar, ethanol yield and total sugar content. Reducing sugar had significant and positive correlation with non reducing sugar, ethanol yield and total sugar content shows inherent relationship between these characters. Non reducing sugar had positive significant correlation with ethanol yield and total sugar content while ethanol yield had positive and significant correlation with total sugar content.

The above findings reveals that the desirable plant type of sweet sorghum shuld have the quality character viz., high total soluble soluid content, reducing and non reducing sugar content, juice yield and juice brix, for high ethanol yield. If total sugar content that is reducing sugar and non reducing sugar content is high in juice of sweet sorghum plant more ethanol will be produced.

5.2.3 Path coefficient analysis

In present investigation juice brix, had negative and high direct effect on total sugar content while it has high positive correlation with total sugar content. In respect of juice extraction per cent it had negative and non significant direct effects while it was high and positive correlation with sugar content. Juice yield had positive and non significant direct effect while it had negative and non significant correlation with total sugar content.

Total soluble soluid had negative and non significant direct effect while high and positive correlation value for total sugar content. Reducing sugar had negative direct effect on total sugar while it was significant and positively correlated with total sugar content. Non reducing sugar had positive direct effect on sugar content while significantly positive correlated with sugar content, ethanol yield had very high positive direct effect on total sugar content and it was significant and positively correlated with total sugar content. Finding revealed that there is the relationship between these character and direct selection would be rewarding.

FUTURE LINE OF WORK

It was noticed that improving the sweet sorghum plant for specific traits like biofuel traits such as juice brix percent, total biomass, total sugar content, juice yield and ethanol yield can be achieved reasonable effort. For improvement of all these characters parents with high gca value indicates that well planned selection procedure can result in to significant progress.

The genes governing the traits like total biomass, millable cane yield and ethanol yield appears to have additive mode of inheritance, hence selection would be effective for these traits. In respect of days to 50 % flowering, days to physiological maturity non additive gene action plays an important role suggests simple selection would be effective for these traits as there was limited scope for improvement through phenotypic selection.

The genotypes PVR-652, , SPV-422, SSPV-1, ICSV-93046, SSART-1002, SSAVRT-1003, SSPV-1005, SSART-1013, SSART-1015, SSART-1026,SSART-1024, SSV-84, can be recommended for use as one of the parent with high brix per cent, total soluble soluid, total biomass, juice yield, and ethanol yield to generate hybrid as well as varietal improvement programme in sweet sorghum.

Summary & Conclusions

Chapter-VI

SUMMARY AND CONCLUSION

The present investigation on " Genetic variability and correlation studies in sweet sorghum(*sorghum bicolar*(L.)Moench)" was undertaken to know the association between different characters and direct and indirect contribution of components on millable cane yield and total sugar content, among twenty three genotypes in sweet sorghum. The experiment was laid out in randomized block design with two replication during *kahrif* 2011.

The observation were recorded on days to 50 per cent flowering, days to physiological maturity, plant height at physiological maturity(cm), total fresh biomass(kg/plant), millable cane yield(kg/plant) and grain yield(g/plant) as growth characters. And juice brix, juice extraction per cent(%), juice yield(ml/plant), total soluble solids(TSS%), reducing sugar (%), non-reducing sugar(%), total sugar content(%), and ethanol yield(ml/1 lit of juice) as quality traits. Results obtained were summarized as below.

1 There was substantial genetic variability between the genotypes studied.

2 High estimates of GCV were observed for growth characters viz., millable cane yield, grain yield, total fresh biomass and plant height at physiological maturity.

3 High heritability with high genetic advance indicated additive gene control in inheritance of four growth characters viz., millable cane yield, grain yield, total fresh biomass and plant height at physiological maturity.

4 For growth characters total fresh biomass, plant height at physiological maturity, days to physiological maturity and days to 50 per cent flowering had positive genotypic correlation with millable cane yield.

5 For growth characters total fresh biomass, plant height at physiological maturity and days to 50 per cent flowering had direct effect on millable cane yield.

6 High estimates of GCV were observed for two quality characters viz., juice yield and juice extraction percentage.

7 Two quality characters shows high estimates of heritability accompanied with high genetic advance viz., juice yield and juice extraction percentage, indicating additive gene control. While it was moderate in juice brix, TSS, reducing sugar, non-reducing sugar so this suggest that non-additive gene action playing an important role in the inheritance of these traits. Hence simple selection would be ineffective for them.

8 For quality traits all traits viz., ethanol yield, non-reducing sugar, reducing sugar, total soluble solids(TSS), juice brix, juice yield had strong positive genotypic correlation with total sugar content.

9 For quality traits, ethanol yield, non-reducing sugar, juice yield had direct effect on total sugar content.

CONCLUCSION

In present investigation twenty three genotypes of sweet sorghum were analysed and out of which eleven genotypes viz., SSPV-1, ICSV-93046, SSPV-1005, SSART-1026, SSART-1024, SSATR-1003, SSART-1002, SPV-422, PVR-652, SSART-1015, SSART-1-1013 were found better over check viz., SSV-84. These selected genotypes were having more plant height(cm), millable cane yield(kg/plant), juice yield(ml/plant), juice extraction percentage, total fresh biomass(kg/plant), juice brix, ethanol yield(ml/1 lit of juice) hence, these genotypes can be used in breeding programme for improvement of sweet sorghum genotypes.

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* original not seen.

Abstract

THESIS ABSTRACT

a) Title of the thesis	:	**GENETIC VARIBILITY AND CORRELATION STUDIES IN SWEET SORGHUM (*Sorghum bicolar (L.) Moench*)**
b) Name of the student	:	**Zade Sandeep Bhagwanrao**
c) Degree to be awarded	:	M.Sc. (Agriculture)
d) Year of award of degree	:	2012
e) Major subject	:	Genetics and Plant Breeding
f) Total number of pages in the thesis	:	71
g) Number of words in thesis abstract	:	241
h) Signature of the student	:	(Zade S. B.)
i) Signature, name and address of major advisor	:	**Dr. S. S. Ambekar** Ex Sorghum Breeder Sorghum Research Station MKV. Parbhani
j) Signature, name and address of forwarding authority	:	**Dr. D.B. Deosarkar** Head, Department of Agril. Botany, MKV, Parbhani.

The present investigation on "Genetic Variability and correlation studies in sweet sorghum (*Sorghum bicolar* (L.) Moench)" was aimed to know i) To study the variability for cane yield, sugar content and grain yield in sweet sorghum. ii) To study the association and direct and indirect effect of mill able cane yield, sugar content and its attributing traits. In this study four 'B' lines and Nineteen 'R/V' lines of sweet sorghum were evaluated along with standard check SSV – 84 in randomized block design with two replication at experimental farm, Sorghum Research Station, MKV Parbhani, in *kharif* 2011. Observations recorded on fourteen characters were subjected to pooled analysis.

Variability studies reveals that simple directional selection may be helpful for millable cane yield and grain yield. The estimates of genotypic and phenotypic coefficient of variation were nearly equal to almost all traits like days to 50% flowering, days to physiological maturity, Plant height at physiological maturity, total biomass, millable cane yield a indicates that the variability existing in these characters was due to influence of environmental factors in the expression of these characters.

Critical analysis of character association and path analysis suggested that importance of selection programmes should be given for growth traits viz., more total biomass maximum plant height at physiological maturity, less days to 50 per cent flowering and quality characters total soluble solids (TSS), reducine sugar and non reducing sugar, brix of juice, juice yield for high ethanol production. If total sugar content that is reducing sugar and non reducing sugar content is high in juice of sweet sorghum plant then more ethanol will be produced. So that are the important traits to be considered while selection of genotypes for identification of varieties or utilization in breeding programmes. Inrespect of 'B' lines PMS 71B, PMS 74 B and PMS 42B (Bold grain) can be utilize in production of sweet sorghum hybrids while the genotypes SSPV-1, ICSV-93046, SSPV-1005, SSART-1026, SSART-1024, SSART-1003, SSART-1002, SPV-422, PVR-652, SSART-1013 were found suitable as a sweet sorghum genotypes for production of ethanol.