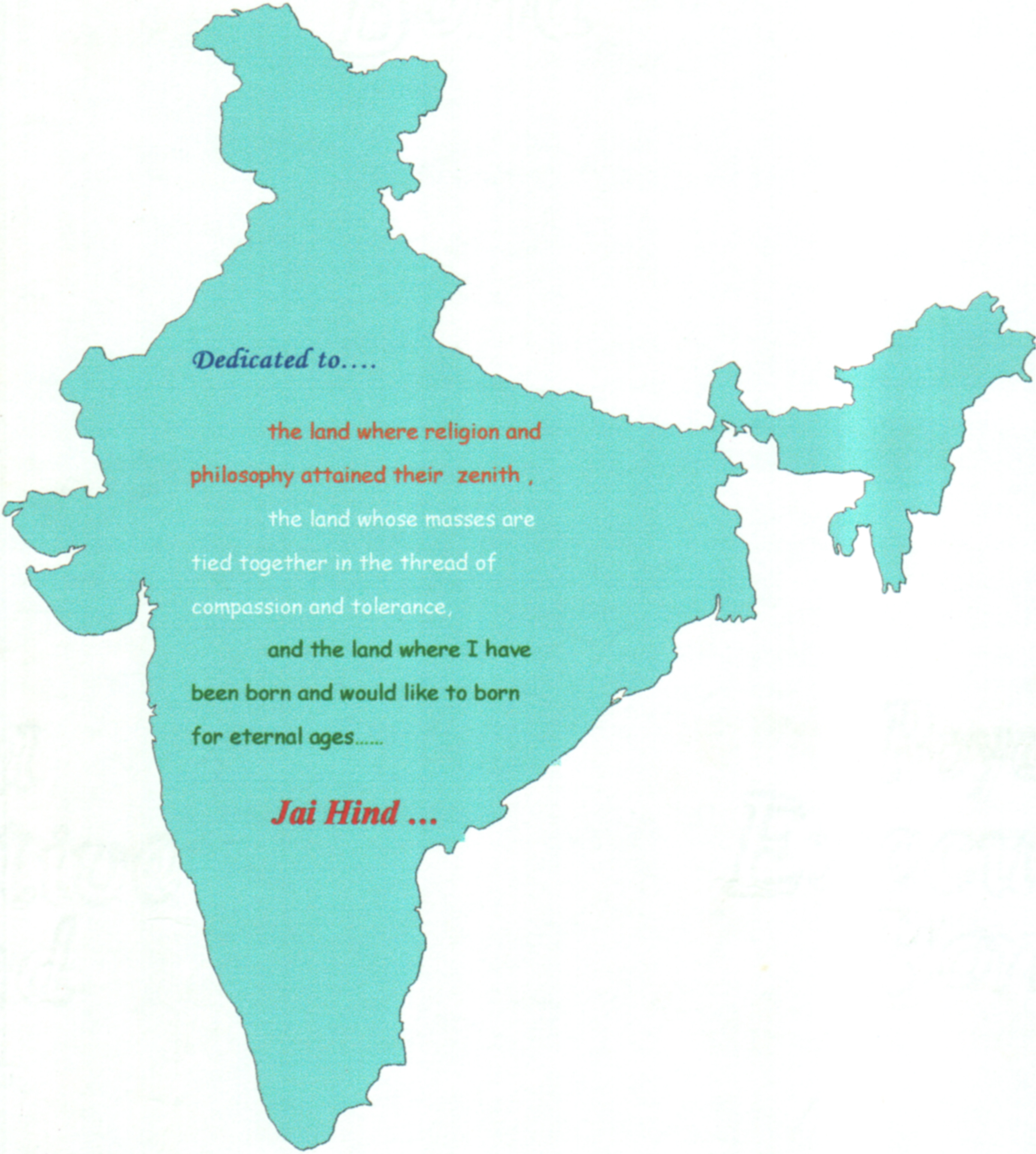

Dedicated to....

the land where religion and philosophy attained their zenith ,

the land whose masses are tied together in the thread of compassion and tolerance,

and the land where I have been born and would like to born for eternal ages......

Jai Hind ...

ABSTRACT DIGITIZED

PATH ANALYSIS AND GENETIC DIVERSITY IN SWEET SORGHUM [*Sorghum bicolor* (L.) Moench]

By

AMOL BABURAO PATANKAR
Reg. No. 0115

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A Thesis submitted to

MAHATMA PHULE KRISHI VIDYAPEETH,
RAHURI-413 722, DIST. AHMEDNAGAR
MAHARASHTRA STATE (INDIA)

In partial fulfilment of the requirements for the degree

of

MASTER OF SCIENCE (AGRICULTURE)

in

AGRICULTURAL BOTANY
(CYTOGENETICS AND PLANT BREEDING)

DEPARTMENT OF AGRIL. BOTANY
POST GRADUATE INSTITUTE
MAHATMA PHULE KRISHI VIDYAPEETH
RAHURI-413 722

2003

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Approved by

Prof. A. H. Sonone
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MAHATMA PHULE KRISHI VIDYAPEETH
RAHURI-413 722

2003

CANDIDATE'S DECLARATION

I hereby declare that, the dissertation entitled, "Path analysis and genetic diversity in sweet sorghum [Sorghum bicolor (L.) Moench]*" or part thereof has not been submitted by me or other person to any other University or Institute for a Degree or Diploma.*

Place : MPKV, Rahuri

Date : 1 / 9 /2003

(A. B. Patankar)

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M.Sc. (Agri.)
Assistant Professor,
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Maharashtra State (India)

CERTIFICATE

This is to certify that the thesis entitled, "**PATH ANALYSIS AND GENETIC DIVERSITY IN SWEET SORGHUM [*Sorghum bicolor* (L.) Moench]**", submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar, Maharashtra State in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **CYTOGENETICS AND PLANT BREEDING,** embodies the results of a *bona fide* research work carried out by **Shri. AMOL BABURAO PATANKAR,** under my guidance and supervision and that no part of the dissertation has been submitted for any other degree, diploma or publication.

Place : MPKV, Rahuri,

Date : 1 / 3 /2003

(**A. H. Sonone**)
Research Guide

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Associate Dean,
Post Graduate Institute,
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Rahuri-413 722, Dist. Ahmednagar,
Maharashtra State (India)

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Place : MPKV, Rahuri,

Date : 2 /9 /2003

(**D. M. Sawant**)
Associate Dean (PGI)

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Place : Rahuri,
Date : 1, 9, , 2003

(A. B. Patankar)

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ABBREVIATIONS

BJ	:	Beijing
BS	:	Broad sense
C.C.S.	:	Commercial cane sugar
C.D.	:	Critical difference
cm	:	Centimeter(s)
Cov	:	Covariance
C.V.	:	Coefficient of variation
°C	:	Degree celcious
D. F.	:	Degrees of freedom
EMP	:	Error mean sum of products
et al.	:	Et alli (and others)
Fig.	:	Figure
g	:	Gramme (s)
G.A.	:	Genetic advance
GCV	:	Genotypic coefficient of variation
GMP	:	Genotypic mean sum of products
GSSV	:	Gujrat Sweet Sorghum Variety
h^2	:	Heritability
MSS	:	Mean sum of squares
M.P.K.V.	:	Mahatma Phule Krishi Vidyapeeth
No.	:	Number (s)
NSS	:	National Sweet Sorghum
PCV	:	Phenotypic coefficient of variation
q/ha	:	Quintal(s) per hectare
RBD	:	Randomized Block Design
RSSV	:	Rahuri Sweet Sorghum Variety
S.E.	:	Standard error
SSV	:	Sweet Sorghum Variety
SS	:	Sum of squares
TSQ	:	Total sugar in quintals
TSS	:	Total soluble solids
t/ha	:	Tonne (s) per hectare
viz.	:	Namely
σ^2	:	Variance
Σ	:	Summation
/	:	Per
%	:	Per cent

ABSTRACT

PATH ANALYSIS AND GENETIC DIVERSITY IN SWEET SORGHUM (*Sorghum bicolor* (L.) Moench)

By

PATANKAR AMOL BABURAO

A candidate for the degree

of

MASTER OF SCIENCE (AGRICULTURE)

Mahatma Phule Krishi Vidyapeeth,

Rahuri-413 722

Research Guide	:	**Prof. A. H. Sonone**
Department	:	**Agricultural Botany**
Major field	:	**Cytogenetics and Plant Breeding**

The present investigation entitled, "Path analysis and genetic diversity in sweet sorghum [*Sorghum bicolor* (L.) Moench]" was carried out to study the correlation coefficients among the different cane yield and juice yield attributes; to find out the direct and indirect effects of components on cane yield and juice yield and to estimate the genetic divergence between different genotypes of sweet sorghum also to group them in to suitable gene clusters. Forty-one genotypes of sweet sorghum were grown in randomized block design with two replications at MPKV, Rahuri during *kharif*, 2002.

The observations were recorded on ten growth traits *viz.*, days to 50 per cent flowering, days to physiological maturity, plant height (cm), millable cane stalk height (cm), grain yield (q/ha), green cane yield (t/ha), stem girth (cm), number of green leaves at maturity, number of internode and length of internode and on ten quality traits like juice yield (q/ha), juice extraction per cent, reducing sugars per cent, non-reducing sugars per cent, total sugars per cent, commercial cane sugar per cent, total soluble solids, pH of juice, total sugars in quintals and starch per cent.

Contd...

A. B. PATANKAR **ABST. CONTD....**

The heritability in broad sense for growth characters was highest for all the characters studied except days to physiological maturity. In quality characters all the characters except pH of juice showed high estimates of heritability. High estimates of heritability accompanied with high genetic advance was observed for growth traits viz., grain yield, green cane yield, millable cane stalk height, number of internodes and length of internode, while same was observed for all the quality characters studied. Green cane yield was significantly positively correlated with millable cane stalk height, plant height, number of green leaves, number of internodes, stem girth and length of internode, whereas it was negatively correlated with days to 50 per cent flowering, days to physiological maturity and grain yield.

For quality traits, juice yield was significant positively correlated with total sugars in quintals, juice extraction per cent and starch per cent, whereas it was negatively correlated with commercial cane sugar and pH of juice.

Path analysis revealed that days to 50 per cent flowering had highest positive direct effect on green cane yield followed by plant height. Only millable cane stalk height had high positive direct effect and significant positive correlation with green cane yield indicating importance of these traits while selecting for improvement in green cane yield.

Path analysis for quality traits revealed that commercial cane sugar per cent had highest positive direct effect followed by total soluble sugars per cent on juice yield suggesting the importance of these traits while selecting for improvement in juice yield.

D^2 statistics showed that, there was considerable divergence among the genotypes with D^2 values ranging from 35.37 to 7956.40 for growth traits. Forty-one genotypes were grouped in to ten clusters. Clustering pattern of these genotypes did not follow the geographical distribution. Tentative crossing programme is suggested on the basis of the genetic divergence, cluster means and *per se* performance of the genotypes from distantly related cluster to secure improvement in sweet sorghum.

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INTRODUCTION

1. INTRODUCTION

Sorghum (*Sorghum bicolor* (L.) Moench) is the fifth most important cereal crop in the world after wheat (*Triticum aestivum*), rice (*Oryza sativa*), maize (*Zea mays*) and barley (*Hordeum vulgare*). Sorghum is one of the most important cereal crop of semi-arid tropics. It belongs to family graminae, subfamily poaceae, tribe andropogagonae, group sorghastre, genus sorghum, subsection arundinacea.

Cultivated sorghums are grouped into four main types based primarily on use of sorghum *viz.*, grain sorghum, sweet sorghum, sorgho sorghums and sudan grass, broomcom, etc. Cultivated sorghum is a diploid (2n = 2x = 20) species.

The area under sorghum in the world was 42.071 million hectares with production of 58.500 MT and productivity of 1391 kg/ha (Anonymous, 2000). The area under sorghum in Asia continent was 12.474 million hectares with production of 13.385 MT and productivity of 1073 kg/ha. Out of this, the area under sorghum in India was 10.500 million hectares with production of 9.500 MT and productivity of 905 kg/ha (Anonymous, 2000).

The states like Andhra Pradesh, Maharashtra, Karnataka and Gujarat had maximum area and production in sorghum. The Maharashtra state had 44.70 lakh ha. total area under sorghum of which 14.93 lakh ha. and 29.77 lakh ha area under *kharif* and *rabi* sorghum, respectively. The productivity of 11.65 and 547 kg/ha in *kharif* and *rabi* season, respectively (Anonymous, 2003).

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The higher *kharif* production is mainly due to large coverage under hybrids or high yielding varieties. *Rabi* sorghum is also major source of food, fodder giving excellent grain quality in rain free cool climate. High market price makes it economically sustainable despite its low yield. The productivity of *rabi* sorghum could boost up through genetic enhancement and improved production technology ensuring security of food and feed.

It has a strong root system to prevent lodging. In addition, the epidermis of the stalk is covered with a layer of wax powder; the leaf blade shrink itself in order to reduce the evaporation during the drought period.

Sweet sorghum has many good characteristics such as a wide adaptability, drought resistance, water logging tolerance, saline-alkali resistance, faster growth, higher sugar content and high yield of biomass. Research project from many countries are presently engaged in evaluating the potential of sweet sorghum and popularizing with great efforts. Sweet sorghum as a crop with so many characteristics of quality is more suitable to India, which has a very large population and deficient arable land. Development of sweet sorghum will play an important role on promoting use of non-conventional energy industry, sugar industry, live stock husbandry and paper industry.

Sweet sorghum is an energy crop. It has a low content of sulphur, the quantity of CO_2 absorbed by sweet sorghum during growth is equal to that excreted by it. Thus growing sweet sorghum and using ethanol extracted from it in automobiles holds a great promise for reducing air pollution from CO_2 and SO_2. The development, utilization of biomass and production of alcohol from sweet sorghum are future prospects. Besides, it can be used for the development and utilization of cellulose, gasohol and papermaking industry.

Sweet sorghum can be used as source of table syrup as well as for forage and silage. Sweet sorghum holds a great potential as a field crop for ethanol production throughout the world because it is adaptable for wide range of growing conditions. It is cheaper than sugarcane requiring less field labour, water and fertilizers. It is also short duration crop than sugarcane.

Average cane yield and juice quality needs to be increased using the existing germplasm resources of the sweet sorghum.

Selection of diverse parents is of paramount importance in any breeding programme so as to get maximum heterosis and wide spectrum of variability in the segregating generations. Consideration of geographical diversity as a reasonable index of genetic diversity may lead to erroneous conclusions. The D^2 statistics (Mahalabobis, 1936) determines the degree of genetic divergence.

Further, direct selection for yield may be unfruitful because yield is a complex trait with low heritability and is determined by number of yield components. Thus, the knowledge of genetic association that exists between various component characters with yield is very helpful to any breeder during selection. However, simple correlation does not take into consideration, the complex relationship among various independent characters that are related to dependent variable. In such situation path analysis (Dewey and Lu, 1959) provides an effective means of finding out the direct and indirect effects of such association.

The use of advanced, novel techniques of plant improvement will be certainly helpful in twenty first century, however the conventional plant breeding tools such as character associations, path analysis and genetic diversity will also play an important role in crop improvement.

The present investigation entitled, "Path analysis and genetic diversity in sweet sorghum (*Sorghum bicolor* (L.) Moench)", was therefore undertaken with following objectives.

1. To study the nature and amount of variability and associations among cane yield and it's components.
2. To study the direct and indirect contribution of components towards cane yield.
3. To study the nature and magnitude of genetic divergence among different germplasm accessions of sweet sorghum.
4. To provide basis for selection of parents for future sweet sorghum hybridization programme.

Chapter Opener Page

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

An attempt is made on the collection of literature published on related aspects on sweet sorghum, however, as there is little information available, literature on forage sorghum is also collected and reviewed in the present chapter.

2.1 Variability, Correlations and path analysis

Rohewal *et al.* (1964) studied four characters of thirty sorghum varieties and found that stalk diameter and plant height were positively and significantly correlated with fodder yield, the former being highly significant.

Badwal (1971) studied twenty four sorghum varieties which showed significant and positive correlation of grain yield, number of grains per ear per plant with yield of stalk; the leaf number with yield of semi green stalks per plant and plant height; plant height with stalk diameter, days to flowering and harvest stage; number of days to flowering with number of days at harvest stage.

Arora *et al.* (1972) observed that stem girth, the number of leaves per plant, the length and breadth of leaves were highly correlated with fodder yield, phenotypically and genotypically in sorghum. Path coefficient analysis showed that length and breadth of leaf and girth of stem contributed maximum to fodder yield, directly as well as indirectly through other inter-related variables. The number of leaves exerted a negative direct effect on the fodder yield. Though it contributed significantly through the length and breadth of the leaf.

Naphade (1972) studied twenty sorghum varieties and reported fodder yield to be correlated with leaf number and plant height positively and significantly at one per cent, whereas leaf number is correlated with single leaf area and plant height at five per cent level of significance. The path analysis showed leaf number having direct effect on fodder yield followed by plant height and leaf area.

Paroda *et al.* (1975) studied correlation and path analysis in forage sorghum and revealed that days to flower and stem girth were positively correlated with both green and dry matter yield. Path coefficient analysis further revealed that direct effect of stem girth was positive for the green fodder yield, whereas it's effect on dry matter yield was negative. The leaf breadth showed high positive direct effect on both green and dry matter yield and thus appeared to be more reliable component character. The direct effect of leaf length was also high on dry matter yield and days to flowering while, plant height showed negative direct effect on both the yield characters studied. This revealed importance of more leaf area per plant in forage sorghum.

Gopalan and Balsubramanian (1978) studied correlation and path coefficient analysis for yield and yield components in twenty-three lines of fodder sorghum. They observed that number of leaves; length and breadth of leaves and thickness of stem were positively correlated with green fodder yield. The path coefficient analysis revealed high positive direct effect of leaf length and breadth on green fodder yield. Eventhough, the direct effect of number of leaves and stem thickness on yield were low and negative, their contribution through leaf length and breadth were considerable.

Henry *et al.* (1983) studied genetic advance and correlation in sorghum and revealed that dry matter yield was significantly correlated with total green weight, leaf weight, stem weight, plant height, leaf length and leaf number. The path coefficient analysis of dry matter yield indicated that green weight and leaf length were two major characters that directly contributed to total dry matter production.

Grewal *et al.* (1983) studied correlation and path analysis between yield and it's components in 46 lines of forage sorghum. They observed positive and highly significant correlation of days to flower, leaf length, leaf breadth, leaves per plant and stem girth with both green fodder and dry matter yield. The path analysis revealed positive direct effect of stem girth on green and dry matter.

Bangarwa *et al.* (1989) reported that green and dry fodder yields were positively correlated with stem girth and weight, leaves per plant and leaf weight in sorghum. Dry fodder yield was also correlated with plant height. It was suggested that selection for dry matter should be based on plant height and number of broad leaves.

Potdukhe *et al.* (1992) analyzed forty four diverse sorghum genotypes and found plant height, days to 50 per cent flowering, leaf area index, stem girth, panicle weight and 1000 grain weight all had positive direct or indirect effect on yield. However, panicle weight had greatest direct effect on yield and influenced most of the other traits indirectly.

Potdukhe *et al.* (1993) studied variability and genetic correlation in sorghum grain yield/plant recorded high GCV indicating that these characters might offer better scope for selection. Wide range of variability was observed for all the characters studied. The highest heritability estimates and genetic advance were recorded by characters *viz.,* days to 50 per cent flowering and leaf area index. The correlation studies revealed that panicle weight showed high correlation with yield/plant.

Jayamani and Dorairaj (1993) studied genetic association between five sweet and one forage 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.

Pandian *et al.* (1993) studied main and ratoon crops of 15 cultivars and a local cultivar were studied for correlation between grain, extractable juice, jaggary yields, total soluble solids, and six other quantitative characters. None of the traits were significantly correlated with grain yield. However, significant positive correlation was observed between stem girth, number of internodes and between jaggary and extractable juice yields. The soluble solid content decreased significantly with crop age, as number of nodes increased so did the plant height and stem girth. In the ratoon crop, extractable juice, jaggary and grain yield were considerably reduced by increasing number of side shoots. The results suggested that simultaneous selection for high grain and sugar yield is not possible.

Choudhari and Tattapure (1993) conducted an experiment with seven genotypes of high-energy sorghums (HES-2, HES-3, HES-4, HES-6, HES-13, CSH-1 and CSH-5) 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 weight, juice yield percent, whereas it increased juice brix and pH. Minimum juice yield reduction was observed in HES-3, HES-4 and HES-13 and maximum in HES-2, CSH-5, CSH-1. An interaction between genotype x time of crushing was significant in stem weight, juice yield brix and pH. Hence, there is a scope for selection of genotype for required characters.

Khare (1994) studied correlation and path analysis in forage sorghum. It was revealed that dry matter yield had significant positive association with leaf area and green forage yield. However, green forage yield had strong positive association with number of leaves, stem girth and leaf area, which had positive significant association *inter se*. Selection for above characters may be helpful in improving green and dry matter yield. The leaf area, leaf to shoot ratio and crude protein had positive direct effect on dry matter yield. The selection for number of leaves, stem girth and leaf area can improve green and dry forage yield.

Patel *et al.* (1994) studied six parents and their 15 F_1s resulting from diallel 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 for 50 per cent flowering and brix at 50 per cent flowering were negatively correlated with grain yield. In general, the interrelationship of characters under study except days for 50 per cent flowering was significant and positive. The path analysis showed that, the leaf area at harvest, juice yield per cent, panicle length and number of secondaries both at genotypic and phenotypic levels were having maximum direct effect on grain yield through leaf area at harvest. Therefore, the components like juice yield percent, number of primaries and secondaries, test weight and leaf area at harvest were the major components influencing grain yield in sorghum.

Yang Wei Guang (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.

Patil *et al.* (1995) reported juice yield, panicle length, and no. of secondaries and test weight were significantly and positively correlated with grain yield at both genotypic and phenotypic levels. A significant positive correlation between days to 50 per cent flowering, physiological maturity, leaf area at 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 percent, panicle length, no. of primaries and secondaries had high direct and indirect contribution to grain yield.

Rao and Patil (1996) reported variation, heritability and yield correlation in sorghum. They observed high genotypic and phenotypic coefficient of variation for grains/panicle followed by grain yield/plant and panicle weight. High heritability values were reported for plant height whereas high heritability and genetic advance was reported for grains/panicle, yield/plant and panicle weight.

Patil *et al.* (1996) studied genetic variability in one hundred genotypes of sorghum from different regions of world for five forage yield components. Among all the characters studied, the widest range of variability was recorded for green forage yield, followed by plant height. The estimates of coefficients of variation, heritability and genetic advance revealed that large portion of phenotypic variability was due to genetic cause as these characters were highly heritable particularly for days to 50 per cent flowering, green forage yield and leaf length. The selection based on these characters may bring desired improved in this crop.

Jeyprakash *et al.* (1997) studied correlation and path analysis in sorghum which showed that grain yield was significantly and positively correlated with panicle weight, panicle length and dry fodder yield. Plant height also had positive and significant association with grain yield at genotypic level. Path analysis indicated that panicle weight had maximum influence on grain yield followed by dry fodder yield, plant height and panicle weight.

Mallikarjun *et al.* (1997) conducted field trials of sweet sorghum genotypes *viz.*, SSV-53, 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. Rio recorded the highest calculated sugar yield (2.36 t/ha) followed by SSV-84 (1.98 t/ha), which also gave highest grain yield (2.46 t/ha). Rio gave the highest juice yield (12303 liters/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 plants/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 considered suitable for sugar production (both at a crop density 2.2 and 3.3 lakh plants/ha).

Choudhary *et al.* (2001-a) evaluated hundred germplasm lines and five checks of sorghum in augmented block designs. High estimates of PCV, GCV, heritability and GA were observed for days to maturity, earhead width, grain yield per plant and plant height.

Iyanar *et al.* (2001) studied genotypic correlation and path coefficient analysis in sorghum. Results revealed that seed yield was significantly and positively correlated with panicle weight and panicle length. Path analysis showed that direct contribution of panicle weight was maximum (0.987) on seed yield, followed by panicle length, days to fifty per cent flowering and test weight.

Choudhary *et al.* (2001-b) studied genetic variability and inter-relationship of eighteen characters in 23 genotypes of sorghum in four environments. The sorghum was grown on two dates of sowing i.e. before and after onset of monsoon at two locations. Estimates of GCV and PCV were higher on stover yield and biological yield, which reflected the importance of additive gene effects in controlling these characters. Grain yield was positively correlated with biological yield, stover yield and number of leaves per plant. Eighteen characters accounted for 72.42 per cent of variation in grain yield. Path analysis revealed the importance of stover yield, harvest index, number of leaves per plant and flag leaf area.

Veerbhadhiran and Kennedy (2001-a) studied genetic variability in 75 genotypes of sorghum. The characters 100-grain weight and grain yield showed high estimates of GCV and PCV. The heritability estimates were high for all the characters studied. The highest heritability was recorded for grain yield per plant (99.9 per cent) followed by days to 50 per cent flowering

(98.9 per cent), among the characters studied. 100-grain weight and grain yield exhibited highest heritability coupled with high genetic advance.

Prabhakar (2001) studied 46 *Rabi* sorghum genotypes. The phenotypic coefficient of variation was higher than genotypic coefficient of variation for all the character studied. The characters days to 50 per cent flowering and days to maturity showed significant genetic association with grain yield per plant. Association between yield themselves, days to 50 per cent flowering was significantly associated with 1000-grain weight and days to maturity. The significant positive association between days to 50 per cent flowering and grain yield was observed.

Veerbhadhiran and Kennedy (2001-b) studied correlation and path analysis in 75 sorghum genotypes. The correlation at both genotypic and phenotypic level exhibited the same trend. Grain yield/plant showed significant positive correlation with 100-grain weight contributed high direct effect towards grain yields and this was followed by days to 50 per cent flowering.

2.2 Genetic divergence

Murty and Arunachalam (1967) classified world sorghum collection into 15 major classes, according to genetic diversity. The relationship between genetic and geographic diversity was found in some maturity groups but in some no relation was found. The distance between the whorls and within the whorls, length of panicle and length of primary branches contributed substantially to D^2 besides days to flowering, spikelet density, growth rate, number of secondaries and angle of primaries with rachis.

Mehndiratta *et al.* (1971) grouped thirty varieties into seven clusters and found that length of leaves and fodder yield contributed more to genetic divergence. In general, genetic diversity was not related with geographical diversity. However, some varieties having common origin were grouped together in some clusters. They concluded that highly divergence stalks isolated on the basis of D^2 analysis could be exploited successfully in evolving high yielding fodder strains.

Govil and Murty (1973) confirmed the contribution of grain quality characters specially protein content, lysine, endosperm texture and leucine very high towards genetic divergence and considered them as important than those related to fitness in evolution of cultivated sorghum.

Sisodia *et al.* (1983) reported that days to maturity, plant height, ear girth, and ear length were mainly responsible for genetic divergence. They suggested that only genetically diverse lines with specific characters of interest and having high yield potentials be crossed.

Nath *et al.* (1985) studied genetic diversity for grain yield and five related traits in 171 non-restorer lines by using Mahalanobis D^2 statistic by canonical variate analysis and observed that considerable variation in grain yield was added to collection by addition of lines derived from panmictic populations. The efficiency of D^2 and canonical variate techniques in distinguishing extremely diverse genotypes was confirmed. However, techniques showed weak correspondence in their clusters. The F_1 hybrids of fifteen diverse lines exhibited no relationship between heterosis or performance of crosses and diversity in their parents.

Sarawate (1985) studies genetic diversity using D^2 analysis in twenty-two geographically diverse genotypes of sorghum and classified them in fourteen clusters showing substantial divergence. Cluster 'A' was largest comprising of thirteen genotypes followed by cluster 'B' and 'E' each having three genotypes, rest having single genotype. Fodder yield, plant height, panicle weight and grain weight were very potent in contributing towards divergence.

Bangarwa *et al.* (1985) studied genetics of sweetness in sorghum by crossing sweet and non-sweet varieties. Irrespective of direction of crossing, it was observed that non sweet characters was dominant over sweet character and that there was no cytoplasmic effect on expression of this character.

Prasad and Singh (1989) studied twelve characters in diallel cross of ten varieties of sorghum on basis of D^2 analysis and found the magnitude of heterosis for grain yield and six components was greater when parents were moderately diverse than highly diverse. So concluded that genetic diversity is not the sole criteria in choosing parents for hybridization and that *per se* performance should also be taken in account.

Patil *et al.* (1993) studied genetic diversity in sorghum by D^2 statistic. Twenty-nine genotypes comprising of nine parents and their twenty F_1s were grouped into nine clusters. All the hybrids except two were grouped into one cluster (A), cluster (B) had five, while cluster (C) had three genotypes cluster (D) had two and remaining clusters were solitary. Substantial diversity was reported within cluster. Results also revealed no relationship between parents and hybrids in clustering parents.

Barhate (1996) studied genetic diversity in sweet sorghum, fifty genotypes under light and medium soil types and found substantial genetic diversity among them. The fifty genotypes were grouped into thirteen and sixteen clusters under light and medium soil conditions, respectively. The plant height, panicle length, flag leaf area, panicle breadth, 1000 grain weight and fodder yield per plant appeared to be very potent in contributing towards divergence. Genotypes from extreme divergence groups with better values for yield and its components were recommended in breeding programme.

Hendre (1998) studied genetic divergence and path analysis in 75 genotypes of sorghum. Considerable divergence was found among genotypes. The genotypes were grouped into nine clusters. The plant height, panicle width, 1000-grain weight and grain yield were the main characters contributing to the genetic divergence. Path analysis revealed that panicle length had highest positive direct effect (0.691) followed by days to 50 per cent flowering (0.622), but out of these only panicle length had a positive and significant correlation revealing that it had a true and perfect association. Fodder yield had negative correlation as well as very high direct effect. Other characters like plant height exhibited both positive and negative indirect effect through panicle length and days to 50 per cent flowering, respectively. The fodder yield also had a high and positive indirect effect via 1000-grain weight.

Silli *et al.* (2000) studied fodder yield and quality of sweet sorghum genotypes. The field experiment was carried out to screen out the high yielding and nutritious fodder sorghum varieties and their N and P requirement under rainfed conditions. The study indicated superiority of SSV-series of sweet sorghum genotypes over DFJ-1 for fodder purpose. In addition to high yielding quality, these sweet sorghum genotypes were found to contain high brix, more protein and low crude fibre making them more palatable to animals.

Narkhede *et al.* (2000-a) studied sixty-four Rahuri sorghum local germplasm (RSLG) collected from different geographical origin of Maharashtra and classified into 19 clusters. There were six solitary clusters and in remaining clusters, the genotypes varied from 2-14. No parallelism was observed between geographic diversity. Amongst the thirteen quantitative characters studied, days to 50 per cent flowering contributed most to divergence, followed by plant height, 1000-grain weight, internode length and panicle length. Based on D^2 values and *per se* performance divergent pairs for hybridization programme and other genotypes in possible combinations are suggested to obtain superior types to secure yield improvement in *Rabi* sorghum.

Kadam *et al.* (2001) studied genetic diversity of sixty-four genotypes in sweet sorghum and found considerable amount of genetic diversity amongst genotypes studied. The D^2 statistic showed that there was adequate diversity among the genotypes ranging from 0.856 to 70.13. The clustering pattern of these genotypes did not necessarily follow the geographic distribution on the basis of inter cluster distance, cluster means and *per se* performance, the female lines *viz.*, MMS-35A, MMS-53A, MMS-104A and the restorers RFSS-57, RFSS-1966, RFSS-23, RFSS-76, RFSS-35, RFSS-20, RFSS-112, RFSS-1502, RFSS-10, RFSS-58, RFSS-128 and RFSS-2 had been identified for hybridization.

Umakant *et al.* (2002) studied eighteen exotic and thirty established genotypes having different geographical origins, plant height contributed enormously (60 per cent) to total variation followed by panicle length (12 per cent) and time of 50 per cent flowering (11 per cent) clustering pattern showed that genetic diversity was not necessarily parallel to geographic diversity.

2.3 Quality aspect in sweet sorghum

1. Brix

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 (Gill *et al.* 1977). Bapat and Choudhari (1976) observed that the brix percentage increased from flowering to the harvest stage and highest brix was recorded in genotype IS-4465 (23.95%).

2. Non-reducing sugars (sucrose)

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.

Ferrais (1981) examined the maturity factors in sweet sorghum the juice characteristics, sucrose yield in stem were highest at grain maturity.

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 and subsequently increased to maximum at 126 days of age.

Bapat *et al.* (1986) tested twelve cultivars in sweet sorghum for juice quality and reported that reducing 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 17.8 and 16.4 per cent, respectively.

In the study of 70 cultivar 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.

4. pH

Bapat *et al.* (1986) reported the pH of the juice of all sweet sorghum varied from 4.9 to 5.3. The low pH (4.9) was observed in cv. SSV-119 and SSV-685. A high pH (5.3) was reported in cv. SSV-20894.

Thorat *et al.* (1987) reported the highest pH in cultivar NSS-1 (6.0) followed by HES-4 (5.8) and HES-6 (5.6).

5. Starch

Smith and Lime (1975) reported that the juice of sweet sorghum contains high starch content about 2 per cent.

Blum *et al.* (1977) studied quality of extracted juice from 3 cultivars, *viz.*, MN-9, MN-29 and Rio. It was satisfactory with per centstarch content ranged from 0.10 to 0.37 per cent.

Sharma *et al.* (1983) found that with increase in sucrose content, the proportion of starch decreased. Starch showed irregular association with other organic non-sugars. In early varieties containing higher proportion of sucrose generally accumulated higher amount of starch. The high percentage of starch interferes with clarification.

Singh and Singh (1986) studied presence of starch in juice of sweet sorghum, which poses problem for crystallization of sugar. The removal of maximum amount of starch (93.7 per cent) can be obtained by using true flock 53 @ 500 ppm.

Bapat *et al.* (1986) screened sweet sorghum cultivars for production of quality syrup and jaggary. Among 284 lines tested for developmental, ear and grain characters, 87 were selected for maturity, height and total soluble solids. After further studies, 12 of them were analyzed for stalk juice quality and five for syrup and jaggary quality. SSV-108 was good for both green stalk and grain yield (41.15 t/ha and 41.05 q/ha, respectively) and gave good yield of commercial cane sugar (CCS) (3.78 t/ha). SSV-1333 gave good quality juice with high sucrose percentage in cane (10.41 per cent) and low content of reducing sugar (0.73 per cent). SSV-108 was best for syrup production (TSS 90.5 per cent) and jaggary production (Non-reducing sugar 63.725 and reducing sugar 9.32 per cent) eight seven lines showed considerable variation in millable heights (150-187 cm), days to flowering (59-140 days) and total soluble solids (17-25.5 per cent).

Narkhede *et al.* (2000b) studied twelve cultivars of sweet sorghum for juice quality and recorded the reducing sugar content varies from 0.59 to 1.48 per cent and the total sugar content varies from 10.76 per cent to 14.00 per cent.

Kamble (2001) studied juice quality of sweet sorghum of ten cultivars and found varietal differences were significant in respect of brix, sugars and starch. The mean value of brix, non-reducing sugar, and pH were 19.26, 12.72

and 5.1, respectively. The per cent purity of juice ranged from 51.70 to 76.49 per cent. Highest pH was noticed in IS-20962. However, there were no significant differences among the varieties in respect of pH. Varieties IS-8007, BJ-248 and RSSV-9 showed lowest starch content. Cultivars showed significant differences in respect of CCS (commercial cane sugar, t/ha), green stalk yield and CCS per cent in stalk were different in each cultivar. The highest value of total sugar index was noticed in NSS-104, Wray and RSSV-9. The correlation studies indicated that, juice yield was positively correlated with grain yield, green cane yield and juice extraction percent. The relationship between non-reducing sugar to purity, brix, were found to be positively correlated while it was negatively correlated with starch and reducing sugars. Considering all the quality parameters of juice, it was concluded that the cultivars Wray, BJ-248, NSS-104, Kellar and RSSV-9 had superior juice quality.

Chapter Opener Page

MATERIALS AND METHODS

3. MATERIAL AND METHODS

The present investigation on path analysis and genetic diversity in sweet sorghum was undertaken at the All India Coordinated Sorghum Improvement Project farm, Mahatma Phule Krishi Vidyapeeth, Rahuri, during *kharif*, 2002. The details of material used, methods adopted and statistical analysis conducted during the course of investigation are described below.

3.1 Experimental material

The material used for the present study included fourty-one genotypes of diverse phenotypic characters and different geographical origins (Table 1).

3.2 Experimental design

For present study, the experiment was laid out in randomized block design with two replications. Each genotype was represented by two rows of six meter length. A distance of 45 cm was kept between rows and 20 cm between plants in a row. The crop was fertilized with 100 kg N with 50 kg P_2O_5 and 50 kg K_2O kg/ha and need based plant protection measures were followed.

3.3 Cultural practices

The land selected was light medium black which was brought to fine titlth. Fourty-one genotypes were sown on 2nd July, 2002. 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. Remaining

Table 1. Sweet sorghum genotypes used

Sr. No.	Genotype	Source
1	RSSV-9	MPKV, Rahuri
2	RSSV-24	MPKV, Rahuri
3	RSSV-34	MPKV, Rahuri
4	RSSV-38	MPKV, Rahuri
5	RSSV-39	MPKV, Rahuri
6	RSSV-40	MPKV, Rahuri
7	RSSV-43	MPKV, Rahuri
8	RSSV-44	MPKV, Rahuri
9	RSSV-45	MPKV, Rahuri
10	RSSV-46	MPKV, Rahuri
11	RSSV-47	MPKV, Rahuri
12	RSSV-48	MPKV, Rahuri
13	RSSV-49	MPKV, Rahuri
14	RSSV-50	MPKV, Rahuri
15	RSSV-54	MPKV, Rahuri
16	RSSV-55	MPKV, Rahuri
17	RSSV-57	MPKV, Rahuri
18	RSSV-59	MPKV, Rahuri
19	RSSV-60	MPKV, Rahuri
20	RSSV-61	MPKV, Rahuri
21	RSSV-62	MPKV, Rahuri
22	RSSV-63	MPKV, Rahuri
23	RSSV-64	MPKV, Rahuri
24	RSSV-65	MPKV, Rahuri
25	RSSV-67	MPKV, Rahuri
26	RSSV-68	MPKV, Rahuri
27	GSSV-314	Surat, Gujrat
28	GSSV-317	Surat, Gujrat
29	GSSV-318	Surat, Gujrat
30	NSS-5	NRC, Hyderabad
31	NSS-9	NRC, Hyderabad
32	NSS-204	NRC, Hyderabad
33	NSS-208	NRC, Hyderabad
34	NSS-209	NRC, Hyderabad
35	NSS-216	NRC, Hyderabad
36	NSS-218	NRC, Hyderabad
37	NSS-219	NRC, Hyderabad
38	Wray	Australia
39	Kellar	Australia
40	BJ-248	Beijing, China
41	SSV-84	MPKV, Rahuri

quality of nitrogen was given 30 days after sowing. The crop was protected from insect pest like jowar shoot fly (*Atherigona soccata*).

3.4 Observations recorded

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

3.4.1 Growth characters

1. Days to fifty per cent flowering

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

2. Days to physiological maturity

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

3. Plant height (cm)

The plant height was recorded from ground level to tip of main earhead at the time of maturity on observational plants and averages were calculated.

4. Millable cane stalk height (cm)

It was measured by subtracting the peduncle length of earhead from total plant height.

ABSTRACT DIGITIZED

5. Stem girth (cm)

Stem girth was measured by using centimeter scale on five observational plants and averages were calculated.

6. Number of green leaves at maturity

Total number of green leaves at maturity were counted on five observational plants and averages were calculated.

7. Number of internodes

It was measured by counting the number of internodes of observational plants and averages were worked out.

8. Length of internode (cm)

Length of internode was measured by using centimeter scale on five observational plants and averages were calculated.

9. Green cane yield (t/ha)

The plants in the net plot were harvested at physiological maturity stage. The leaves and panicles were cut and were weighed on balance. Cane yield per plot was further multiplied by hectare factor to obtain green cane yield (t/ha).

10. Grain yield (q/ha)

Grain yield per hectare was calculated by multiplying the grain yield per plot by hectare factor.

MPKV

T-5115

3.4.2 Quality characters

1. Juice extraction percentage

It was calculated by using following formula.

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

2. Juice yield (q/ha)

It was calculated by multiplying juice yield per plot by the hectare factor.

3. pH of juice

The pH of sweet sorghum juice was measured with pH meter (Elico make).

4. Reducing sugars

The determination of reducing sugars was carried out by using DNS method (3,5-dinitrosalicyclic acid) (Somogyi, 1952).

Principle

Several reagents have been employed which assay sugars by using their reducing properties. One such compound is 3,5-dinitrosalicyclic acid (DNS) which in alkaline solution is reduced to 3-amino-5-nitrosalicyclic acid.

The chemistry of reaction is complicated since standard curves do not always go through the origin and different sugars gives different colour yields. The method is, therefore, not suitable for the determination of a complex mixture of reducing sugars.

Materials :

1. Sodium potassium tartarate : It was prepared by dissolving 300 gm of it in about 500 ml of water.
2. 3,5-Dinitrosalicyclic acid : It was prepared by dissolving 10 gm of this reagent in 200 ml of water of 1 mol/litre sodium hydroxide.
3. Dinitrosalicyclic acid reagent : The reagent was prepared by mixing solutions (1) and (2) and volume made upto 1 litre.
4. Sodium hydroxide (1 mol/litre).
5. Stock sugar standards : It was prepared by dissolving glucose 1 gm/litre solution in saturated benzoic acid.
6. Working solutions : The glucose stock solution was diluted 1 in 4 before use to give solutions containing 250 μg/ml.
7. Some sugar solutions of 'unknown' concentration.
8. Boiling water bath.
9. Marbles.

Methods

The DNS reagent was prepared just before use by mixing the stock solutions as indicated. One ml of DNS reagent to the 3 ml sugar solution was added in a test tube. Blank was prepared by adding 1 ml of reagent to 3 ml of distilled water. Each tube was covered with marble and was placed in boiling water bath for five minutes. The test tubes were cooled at room temperature. Absorbance was measured on Spectronic-20 at 540 nm against the blank. Care was taken that all the tubes were cooled to room temperature before reading as absorbance is sensitive to temperature. Then per cent reducing sugar was calculated by following formula.

Reducing sugars (per cent) = Absorbance x 1.852

5. Total soluble sugars

Principle

The total soluble sugars were extracted with hot aqueous ethyl alcohol and the sugars on treatment with phenol sulphuric acid, produces a stable and sensitive golden yellow colour. This method can be applied to simple sugars, oligosaccharides, polysaccharides and their derivatives (Dubois *et al.*, 1956).

Reagents :

1. 80 per cent (v/v) ethyl alcohol : It was prepared by mixing 800 ml ethyl alcohol in water and volume made up to 1 litre with distilled water.
2. 5 per cent (w/v) phenol : It was prepared by mixing 5 gm phenol in distilled water and volume made up to 100 ml.
3. 96 per cent sulphuric acid : 96 per cent sulphuric acid at specific gravity 1.84 was used.
4. Glucose (w/v) standard : It was prepared by dissolving 1000 mg of glucose in one litre of distilled water.
5. Working standard : It was prepared by pipetting out ten ml of standard stock in to a 100 ml volumetric flask and volume was made up to 100 ml so that final concentration made was 100 μg/ml.

Procedure :

1. 100 mg juice of sweet sorghum was weighed and taken in boiling tube.
2. 25 to 30 ml of hot 80 per cent ethyl alcohol was added in boiling test tube and it was shaked on the vertex mixture.
3. The material was allowed to settle for 20-30 minutes.
4. The above solution was filtered in to a beaker through a Whatman No. 41 filter paper.
5. This steps (2-4) was repeated for 3 to 4 times.
6. The extract was evaporated on hot sand bath until the ethyl alcohol was evaporated.
7. The content in extract was dissolved by adding 10 ml of distilled water and it was transferred to 100 ml volumetric flask. The contents were washed in a beaker 2 to 3 times. Then content was added in 100 ml volumetric flask and volume made up to the 100 ml with distilled water.
8. One ml of aliquot from above solution was taken and 1 ml of water as blank in a test tube.
9. One ml phenol (5 per cent) was added and shaked.
10. Five ml 96 per cent sulphuric acid was added and mixture was shaked vigorously on the vertex mixture. Later on the test tubes were cooled in running tap water.
11. Absorbance of golden yellow colour on Spectronic-20 at 490 nm was taken against the blank.

12. The standard was run with different concentrations (i.e. 10, 20, 30, 40 and 50 μg of standard glucose) from the working standard. The volume was kept 1 ml with water, and reagent as in step 9 and 10 were added.

Calculation

Total sugars was calculated by using following formula.

Total sugars = Absorbance x 45.66

5. Non-reducing sugars

It was determined from difference between the total and reducing sugars.

Non-reducing sugars = [Total sugars – Reducing sugars]

7. Total soluble solids (TSS)

The TSS content of the juice in degrees brix was recorded with Erma make hand refractometer and hydrometer at physiological maturity.

8. Commercial cane sugar (CCS %)

Commercial cane sugar per cent in cane was calculated by Winters formula as given below :

CCS per cent in cane [{S -0.4(B - S) x 0.74}]

Where, S = sucrose per cent in juice

B = Corrected Brix

9. Total sugar in quintals (TSQ)

Total sugar in quintals was calculated by using following formula :

$$TSQ = \frac{\text{Juice yield (lit/ha) x Total sugar per cent}}{10,000}$$

10. Starch (%)

The starch content was determined by the method of Mc Cready *et al.* (1950).

Reagents :

1. Perchloric acid (52 per cent) : 74.29 ml of 70 per cent perchloric acid was diluted to 100 ml with distilled water.
2. Anthrone reagent : It was prepared by dissolving 2 gm of anthrone in 1 litre of 95 per cent sulphuric acid. Freshly prepared reagent was used for analysis.
3. Ethyl alcohol (80 per cent) : 80 ml of ethyl alcohol was diluted with distilled water and final volume was made to 100 ml.

Extraction :

Ten gram juice was taken in centrifuge tube, 20 ml of 80 per cent ethanol was added to it and tubes were kept in beaker. The beaker was kept in boiling water bath for 20 minutes. Then the centrifugation was done for 10 minutes at 5000 rpm. The supernatant was removed and residue was used for same procedure as mentioned above for making residue sugar free. This procedure was repeated for 3-4 times.

The sugar free residue obtained was suspended in 5 ml of distilled water, heated for 5 minutes to gelatinize the starch, and while stirring 6.5 ml of diluted perchloric acid (52 per cent) was added. Stirring was continued for 20 minutes and the content were centrifuged after adding 20 ml of distilled water (5,000 rpm for 20 minutes). The supernatant was collected in 100 ml volumetric flask, 5 ml of distilled water again added to the residue, stirred and 6.5 ml of perchloric acid (52 per cent) was added, the residue was solubilized as above for 20 minutes with occasional stirring and the content were washed into previous supernatant. The combined solutions were diluted to 100 ml, filtered and filtrate was used for starch determination.

Colour development

Five ml of diluted starch solution was pipetted into 25 x 250 mm borosilicate glass tubes, kept in ice water bath. The ten ml of fresh anthrone reagent was added. After boiling, the content in each tube was mixed thoroughly. All the tubes were then heated together for exactly 7.5 minutes, in boiling water bath. The tubes were cooled rapidly to room temperature under running water and the colour intensities were determined at 630 nm against blank on Spectronic-20. A standard curve was prepared by using D-glucose. The starch content was calculated by multiplying glucose content from standard curve by a factor 0.9.

Standard curve for glucose (Anthrone reagent)

Reagents

1. **Stock glucose solution :** 100 mg of glucose weighed accurately, dissolved in distilled water and volume was made to 100 ml.
2. **Working glucose solution** : Ten ml of glucose solution was diluted to 100 ml with distilled water. This solution contain 100 μg of glucose per ml.
3. Other reagents were prepared as described above.

Procedure :

Different concentrations of glucose solutions i.e. 0, 10, 20, 40, 80, 100 ug/ml were pipetted in a test tube and volume was made to 1 ml with distilled water. The rest of the procedure was same as described above.

3.5 Statistical analysis

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

A. Growth characters

3.5.1 Analysis of variance

The data collected on individual characters were subjected to the method of analysis of variance commonly applicable to the Randomized Block Design (Panse and Sukhatme, 1967).

Genotypic mean squares (GMS) were tested for their significance against error mean squares (EMS) by 'F' test for n1 =(g - 1) and n2 = (r –1) (g – 1) degrees of freedom.

g = Number of genotypes and

r = Number of replications

The characters showing significant differences were only subjected to further analysis.

3.5.2 Variability

a. Estimation of mean and range

The mean values for each characters were worked out by dividing the total by corresponding number of observations.

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

Where,

$\bar{x}$ = Mean of characters

ΣXi = Total of all observations for characters and

n = Number of observations

The lowest and highest value of mean 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 from variance table (Johnson *et al.*, 1955) as below.

Environmental variance $\sigma^2 e$ = EMS

Genotypic variance $\sigma^2 g = \dfrac{GMS - EMS}{r}$

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

Where,

GMS	=	Genotypic mean sum of squares
EMS	=	Error mean sum of square
r	=	Number of replications

c. Estimation of coefficient of variation

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

i. Genotypic coefficient of variation (GCV)

$$GCV = \frac{\sqrt{\sigma^2 g}}{\bar{x}} \times 100$$

Where,

$\sigma^2 g$	=	Genotypic variance
$\bar{x}$	=	Mean of character

ii. Phenotypic coefficient of variation (PCV)

$$PCV = \frac{\sqrt{\sigma^2 p}}{\bar{x}} \times 100$$

Where,

$\sigma^2 p$ = Phenotypic variance

$\bar{x}$ = Mean of character

d. Estimation of heritability

Heritability in broad sense was estimated for various characters as 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 (1966) 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. $$GA = K \frac{\sigma^2 g}{\sigma^2 p} . \sqrt{\sigma^2 p}$$

Where,

$\sigma^2 g$	=	Genotypic variance
$\sigma^2 p$	=	Phenotypic 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)

ii. GA as percentage of mean.

$$\text{GA as percentage of mean} = \frac{GA}{\bar{x}} \times 100$$

Where,

GA	=	Genetic advance
$\bar{x}$	=	Character mean

3.5.3 Correlation

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

$$\text{Environmental covariance} = [e^{cov}_{1.2}) = EMP$$

$$\text{Genotypic covariance} = [g^{cov}_{1.2}] = \left[\frac{GMP - EMP}{r}\right]$$

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

The appropriate variances and co-variances were used for calculating phenotypic and genotypic correlation coefficients (Johnson *et al.*, 1955). The phenotypic correlation coefficient (rp) was calculated as,

$$rp_{1.2} = \frac{[p^{cov}_{1.2}]}{\sqrt{(\delta^2 p_1) . (\delta^2 p_2)}}$$

Where,

$rp_{1.2}$ = Phenotypic correlation coefficient between character 1and 2.

$p^{cov}_{1.2}$ = Phenotypic covariance between character 1 and 2.

$\delta^2 p_1$ and $\delta^2 p_2$ = Phenotypic variance of character 1 and 2, respectively.

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

The genotypic correlation coefficient (rg) was calculated as,

$$rg_{1.2} = \frac{[g^{cov}_{1.2}]}{\sqrt{(\delta^2 g_1) . (\delta^2 g_2)}}$$

Where,

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

$g^{cov}_{1.2}$ = Genotypic covariance between character 1 and 2.

$\delta^2 g_1$ and $\delta^2 g_2$ = Genotypic variance of character 1 and 2, respectively.

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

3.5.4 Path coefficient analysis

To establish the cause and relationship, the genotypic and phenotypic correlation coefficients were partitioned in to 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 relationships. 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 equations in the form,

$$r_{ny} = P_{ny} + r_{n2} \cdot P_2y + r_{n3} \cdot P_3y$$

Where,

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

P_{ny} = represent path coefficient between that 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**

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

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 coefficients (Pij) were obtained as,

$$(Pij) = A \times [B]^{-1}$$

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

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

Where,

i = 1....20

j = 1....20

Pij = $P_{1y}, P_{2y}.....P_{ny}$

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

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

Where,

$$R^2 = P_{1y} r_{1y} + p_{2y} . r_{2y} + \text{------} + P_{ny} . r_{ny}$$

Where,

P_{1y}, P_{2y}, ----- P_{ny} = Path values.

r_{1y}, r_{2y},----- r_{ny} = Correlation coefficients.

3.5.5 Genetic divergence

D^2 analysis

The analysis of divergence was carried out by D^2 statistic proposed by Mahalanobis (1928, 1936) as described by Rao (1952). Analysis of variance for the individual character studied was worked out as per RBD analysis, to test the significance of differences among genotypes. The characters exhibiting significant differences were only used for further analysis of D^2 statistic. The analysis of covariance for character pairs based on plot average was carried out (Cochran and Cox, 1957).

a) Wilk's criteria

After testing differences among populations for ten characters, a simultaneous test of significance of difference between the mean value of number of correlated variables with regard to pooled effect of ten characters considered together was carried out using Wilk's criteria 'Λ' (Wilks, 1932) which was estimated using the relationship.

$$\Lambda = \frac{|E|}{|E+V|}$$

Where,

$|E|$ = is determinant of experimental error sum of squares and sum of products matrix and

$|E+V|$ = The determinant of experimental error sum of squares and sum of products plus population sum of squares and product matrix

The significance of Wilk's criteria (Λ) was tested by X^2 as :

$$X^2pq = V = -m.\log_e(\Lambda)$$

Where,

$$m = n - \frac{(p+q+1)}{2}$$

n = $N_1 + \text{-----} + N_k - 1$ (Total no. of obs^n – 1)

p = No. of significant characters

q = K-1 (no. of genotypes –1)

k = No. of genotypes

b) Mahalanobis's generalized distance (D^2)

The generalized distance between any two populations is defined as :

$$D^2 = \Sigma\Sigma\lambda_{ij} . \delta_i . \delta_j$$

Where

λ_{ij} = Reciprocal matrix to the common dispersion matrix

δ_i = Difference between mean value of the two populations for the ith character

δ_j = Difference between mean value of the two populations for the jth character

This quantity is estimated by D^2 statistic (Majumdar and Rao, 1958) as:

$$D^2 = \Sigma\Sigma S_{ij} . d_i . d_j$$

Where, Sij, di, dj are the sample estimates of $\lambda_{ij,}$ d_i and d_j respectively, since this formula for computation requires inversion of tenth order determinant and then evaluation of 10 (10+1) terms, whose sum is D^2.

c) Computation of D^2 values

For each combination, D^2 was calculated. Thus, total 41(40)/2 number of D^2 values were worked out

d) Determination of population constellations

No rules can be laid down for finding the clusters, because cluster is not well defined term. The only criteria appears to be that, any two groups belonging to same cluster should be at least, on an average show a smaller D^2 value than those belonging to two different clusters.

The simple method suggested by Tocher (Rao, 1952) for cluster formation is to start with two closely related groups and find third group which has a smaller average D^2 value from the first two. Similarly, the fourth group is chosen to have smaller average D^2 values from the first three and so on. While proceeding further from cluster formation, it at any stage, the average D^2 value of the group appears to be high than those already listed, then this group doesnot fit in that format group and taken outside of that cluster.

The genotypes included in first cluster are then omitted and the rest are treated similarly to form next cluster.

e) Average intra-cluster distances

The intracluster distances were calculated as,

$$\frac{\Sigma Di^2}{n}$$

Where

ΣDi^2 = Sum of distances between all possible combinations.

n = Number of genotypes included in a cluster.

f) Average inter-cluster distances

The procedure followed for calculating inter-cluster distances was first to measure the distance between cluster-I and cluster-II, between cluster-I and cluster-III, and between cluster-I and cluster-IV and so on. Likewise the clusters were taken one by one and the distances between other clusters were calculated. The average inter-cluster distances were they calculated as,

$$\frac{\Sigma Di^2}{ni \cdot nj}$$

Where,

ni = Number of genotypes in cluster 'i'

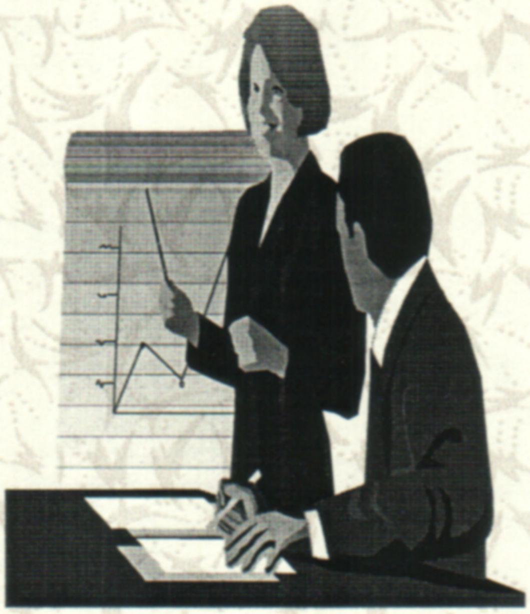
nj = Number of genotypes in cluster 'j'

g) Cluster diagram

The intra and inter-cluster distances (D values) were obtained by taking square root of average D^2 values of respective groups.

With the help of D^2 values between the clusters, a diagram showing the relationship between different populations was drawn.

Chapter Opener Page



EXPERIMENTAL RESULTS

4. EXPERIMENTAL RESULTS

The results obtained in present investigation entitled, "Path analysis and genetic diversity in sweet sorghum (*Sorghum bicolor* (L.) Moench.)" are presented below under various subheadings.

(A) Growth characters

4.1 Analysis of variance

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

4.1.1 Mean performance and variability parameters

The mean performance and variability are presented in Table 3 and 4, respectively.

In general, the estimates of PCV were higher than those for GCV, high estimates of GCV were observed for grain yield (61.51) and green cane yield (37.19), whereas for plant height (13.59), millable cane stalk height (18.41), number of internodes (11.88) and length of internode (13.19), medium estimates of GCV were observed. Low estimates of GCV were observed for four characters namely days to 50 per cent flowering (7.58), days to physiological maturity (8.06), stem girth (8.03) and number of green leaves at maturity (9.39).

Similar trend was observed for phenotypic coefficient of variation.

Table 2. Analysis of variance of ten growth characters in sweet sorghum

Sr. No.	Characters	M.S.S.	
		Genotype	Error
		40	40
1	Days to 50 per cent flowering	86.799**	3.203
2	Days to physiological maturity	322.229**	132.018
3	Plant height (cm)	2141.510**	4.353
4	Millable cane stalk height (cm)	2408.419**	3.734
5	Stem girth (cm)	0.597**	0.119
6	Number of green leaves at maturity	2.031**	0.111
7	Number of internodes	3.057**	0.181
8	Length of internode (cm)	11.592**	0.084
9	Green cane yield at physiological maturity (t/ha)	206.352**	24.499
10	Grain yield (q/ha)	151.122**	0.592

** Significant at 1 per cent level.

Table 3. Mean performance of ten growth characters studied in sweet sorghum.

Sr. No.	Genotype	Days to 50 per cent flowering	Days to physiological maturity	Plant height (cm)	Millable cane stalk height (cm)	Stem girth (cm)	No. of green leaves at maturity	No. of internodes	Length of internode (cm)	Green cane yield (t/ha)	Grain yield (q/ha)
1	RSSV-9	88.0	119.0	286.40	250.6	5.93	11.70	13.50	18.90	30.98	18.34
2	RSSV-24	79.5	114.5	281.60	243.5	6.12	11.20	10.90	18.75	26.89	10.95
3	RSSV-34	85.5	123.5	262.50	248.0	6.67	10.20	11.20	19.39	32.98	03.16
4	RSSV-38	82.5	121.5	220.7	173.9	5.90	09.70	10.80	18.05	24.68	38.04
5	RSSV-39	85.0	124.0	248.3	193.5	6.24	10.70	12.90	15.00	22.81	23.30
6	RSSV-40	79.5	113.0	191.4	136.5	5.44	10.10	07.90	14.55	14.25	29.57
7	RSSV-43	84.5	124.0	233.8	180.9	6.24	10.70	10.50	13.30	31.17	17.34
8	RSSV-44	90.5	128.0	211.0	179.8	6.09	10.20	10.30	15.80	25.58	20.59
9	RSSV-45	78.0	117.5	294.5	240.3	5.90	10.40	10.70	14.25	46.74	16.79
10	RSSV-46	94.5	131.0	272.0	220.7	6.48	09.80	11.50	18.15	31.47	13.92
11	RSSV-47	85.0	112.0	265.0	212.5	6.63	10.80	10.60	20.65	25.58	19.07
12	RSSV-48	88.5	114.0	261.3	222.6	6.50	11.80	12.10	20.50	63.93	14.87
13	RSSV-49	78.5	116.0	210.3	143.0	5.58	09.50	11.10	18.00	17.65	36.89
14	RSSV-50	91.5	126.0	273.6	219.5	6.10	10.00	12.00	17.95	29.03	09.18
15	RSSV-54	93.5	135.0	246.7	196.6	6.77	11.70	11.70	17.15	24.79	15.11
16	RSSV-55	96.50	140.50	229.90	148.50	6.72	10.70	10.50	17.45	22.97	03.98
17	RSSV-57	96.00	140.00	224.10	162.60	6.59	10.70	09.70	20.30	18.33	04.59
18	RSSV-59	98.00	147.00	208.10	156.00	4.90	09.90	0.9.50	17.30	20.04	27.36
19	RSSV-60	90.00	124.50	290.80	225.90	6.55	09.90	10.80	20.45	21.71	05.10
20	RSSV-61	82.00	120.50	289.70	232.60	6.18	10.20	10.10	23.00	29.82	05.55
21	RSSV-62	85.00	125.50	282.30	233.30	6.34	11.30	10.30	22.75	24.67	07.36
22	RSSV-63	86.00	124.50	296.30	209.45	6.69	11.10	11.30	19.80	30.75	05.90
23	RSSV-64	93.50	127.50	204.00	160.80	6.63	11.10	09.35	18.10	14.84	03.94

Table 3 (Contd..)

Sr. No.	Genotype	Days to 50 per cent flowering	Days to physiological maturity	Plant height (cm)	Millable cane stalk height (cm)	Stem girth (cm)	No. of green leaves at maturity	No. of internodes	Length of internode (cm)	Green cane yield (t/ha)	Grain yield (q/ha)
24	RSSV-65	86.50	124.50	171.90	117.40	6.08	08.70	08.30	14.20	05.78	08.15
25	RSSV-67	96.00	127.00	201.90	201.00	6.40	10.70	10.30	19.40	16.18	05.52
26	RSSV-68	79.50	113.50	245.80	199.60	6.60	10.10	10.30	19.65	19.80	09.48
27	GSSV-314	76.50	117.50	248.20	218.00	5.14	08.50	09.65	20.10	15.10	05.10
28	GSSV-317	81.50	118.00	200.10	143.80	6.04	08.10	09.70	14.70	19.05	11.24
29	GSSV-318	76.00	115.00	204.30	142.70	5.47	08.10	07.20	19.50	13.45	16.79
30	NSS-5	76.50	162.00	231.90	171.70	5.59	10.80	09.90	17.00	28.83	30.48
31	NSS-9	87.00	121.00	228.00	258.80	5.40	10.90	10.10	15.70	26.09	15.85
32	NSS-204	91.50	130.50	199.40	250.50	6.70	12.10	10.70	14.10	25.93	08.88
33	NSS-208	86.00	124.50	196.30	153.10	5.34	10.80	10.10	15.20	23.41	15.85
34	NSS-209	79.00	118.50	240.50	200.90	6.35	10.20	09.50	20.50	46.77	14.63
35	NSS-216	85.50	123.50	235.00	173.40	5.86	09.60	09.00	19.20	14.41	14.49
36	NSS-218	85.00	124.00	245.85	163.30	6.03	10.80	09.30	17.80	26.51	16.08
37	NSS-219	91.00	131.00	221.00	180.80	6.66	09.90	08.90	20.20	29.90	10.14
38	Wray	76.00	114.00	272.20	207.50	5.69	12.60	10.20	20.30	24.46	12.46
39	Kellar	76.00	111.00	265.50	190.50	5.94	11.90	09.50	20.00	25.73	11.64
40	BJ-248	74.50	111.50	229.90	171.30	4.47	09.70	08.70	19.20	21.07	13.73
41	SSV-84	81.50	117.50	225.70	196.00	6.49	11.10	10.10	19.40	37.18	06.77
	Mean	85.29	121.06	240.43	188.32	6.08	10.43	10.26	18.18	25.64	14.10
	CD at 5%	3.61	23.22	4.21	3.90	0.69	0.67	0.57	0.58	10.03	1.55
	CD at 1%	4.84	31.07	5.64	5.22	0.93	0.90	0.77	0.78	13.38	2.08

Table 4. Variability parameters for ten growth characters in sweet sorghum.

Sr. No.	Parameters	Days to 50 per cent flowering	Days to physiological maturity	Plant height (cm)	Millable cane stalk height (cm)	Stem girth (cm)	No. of green leaves at maturity	No. of internodes	Length of internode (cm)	Green cane yield (t/ha)	Grain yield (q/ha)
1	Range	74.50-98.0	108.50-147.00	119.40-296.30	136.50-250.60	4.47-6.77	8.10-12.10	7.20-13.50	13.30-23.00	5.78-63.93	3.16-38.04
2	GCV	7.58	8.06	13.59	18.41	8.03	9.39	11.88	13.19	37.19	61.51
3	PCV	7.86	12.45	13.62	18.44	9.84	9.12	12.21	13.29	41.89	61.76
4	h^2 (bs) (%)	92.9	41.9	99.6	99.7	66.7	89.6	94.8	98.5	78.8	99.2
5	GA as % of mean	15.05	10.74	27.95	37.87	13.52	18.30	23.84	26.97	67.99	126.23

High estimates of heritability were observed for all the characters studied except days to physiological maturity (41.9).

High estimates of genetic advances per cent of mean were observed for six characters viz., grain yield (126.23), green cane yield at physiological maturity (67.99), millable cane stalk height (37.87), plant height (27.95), length of internode (26.97) and number of internodes (23.85), while for the remaining four traits medium estimates of GA were observed.

4.1.2 Correlation studies

a. Association of green cane yield with its components

Green cane yield was significantly and positively correlated with millable cane stalk height (0.574) followed by plant height (0.531), number of green leaves at maturity (0.471), number of internodes (0.460) and stem girth (0.338) (Table 5).

b. Associations among the components

Days to 50 per cent flowering had positive and significant association with days to physiological maturity (0.915) and stem girth (0.534), days to physiological maturity had significant and negative association with grain yield while it had positive and significant association with stem girth. Plant height had significant and positive association with millable cane stalk height (0.881), number of green leaves at maturity (0.368), number of internodes (0.549) and length of internodes (0.511). Millable cane stalk height showed significant and positive association with stem girth (0.327), number of green leaves at maturity (0.339), number of internodes (0.606) and length of internodes (0.521).

Table 5. Genotypic correlation coefficients for ten growth characters in sweet sorghum.

Characters	Days to 50 per cent flowering	Days to physiological maturity	Plant height (cm)	Millable cane stalk height (cm)	Stem girth (cm)	No. of green leaves at maturity	No. of internodes	Length of internode (cm)	Grain yield (q/ha)	Green cane yield (t/a)
Days to 50 per cent flowering	1.00	0.915**	-0.136	-0.070	0.534**	0.163	0.290	-0.09	-0.260	-0.034
Days to physiological maturity		1.00	-0.126	-0.114	0.362**	-0.049	0.126	-0.073	-0.410**	-0.230
Plant height (cm)			1.00	0.881**	0.284	0.368**	0.549**	0.511**	-0.250	0.531**
Millable cane stalk height (cm)				1.00	0.327*	0.339*	0.606**	0.521**	-0.306	0.574**
Stem girth (cm)					1.00	0.396*	0.413**	0.214	-0.513**	0.338*
No. of green leaves at maturity						1.00	0.467**	0.111	-0.112	0.471**
No. of internodes							1.00	0.007	0.039	0.460**
Length of internode (cm)								1.00	-0.350*	0.162
Grain yield (q/ha)									1.00	-0.008

* , ** Significant at 1 and 5 per cent level, respectively.

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Grain yield showed negative association with stem girth (-0.513) and length of internodes (-0.350). Stem girth was significantly and positively correlated with number of green leaves at maturity (0.396) and number of internodes (0.413).

Number of green leaves at maturity exhibited significant positive association with number of internodes (0.467).

4.1.3 Genotypic path coefficient analysis

The genotypic correlation coefficients were further partitioned into direct and indirect path coefficient which are presented in Table 6 and Fig. No.1(a).

1. Days to 50 per cent flowering

Days to 50 per cent flowering had high and positive (1.474) direct effect on green cane yield. It's indirect effect via remaining characters were negative except grain yield, number of green leaves at maturity and length of internode which had negligible positive indirect effects.

2. Days to physiological maturity

Days to physiological maturity had high negative (-1.507) direct effect on green cane yield. It's indirect effects via most of the components were negligible and negative while that via days to 50 per cent flowering were high and positive.

3. Plant height (cm)

Plant height had high positive direct effect (0.497) on green cane yield. It's indirect effects via days to physiological maturity and millable cane stalk height was high and positive.

Table 6. Genotypic path matrix of nine components on green cane yield in sweet sorghum.

Characters	Days to 50 per cent flowering	Days to physiological maturity	Plant height (cm)	Millable cane stalk height (cm)	Stem girth (cm)	No. of green leaves at maturity	No. of internodes	Length of internode (cm)	Grain yield (q/ha)	Genotypic correlation coefficient
Days to 50 per cent flowering	1.474	-1.380	-0.067	-0.020	-0.049	0.001	-0.057	0.024	0.040	-0.034
Days to physiological maturity	1.350	-1.507	-0.063	-0.034	-0.033	-0.000	-0.024	0.018	0.064	-0.230
Plant height (cm)	-0.200	0.191	0.497	0.263	-0.026	0.004	-0.107	-0.130	0.039	0.531**
Millable cane stalk height (cm)	-0.103	0.172	0.438	0.298	-0.030	0.003	-0.118	-0.133	0.047	0.574**
Stem girth (cm)	0.788	-0.546	0.141	0.097	-0.092	0.004	-0.080	-0.054	0.080	0.338*
No. of green leaves at maturity	0.240	0.074	0.183	0.101	-0.036	0.011	-0.091	-0.028	0.017	0.471**
No. of internodes	0.432	-0.191	0.273	0.181	-0.038	0.005	-0.195	-0.001	-0.006	0.460**
Length of internodes (cm)	-0.138	0.111	0.254	0.155	-0.019	0.001	-0.001	-0.255	0.054	0.162
Grain yield (q/ha)	-0:84	0.618	-0.124	-0.091	0.047	-0.001	-0.007	0.089	-0.155	-0.008

Underlined figures indicate direct effects. Residual effect = 0.651

* , ** Significant at 1 and 5 per cent level, respectively.

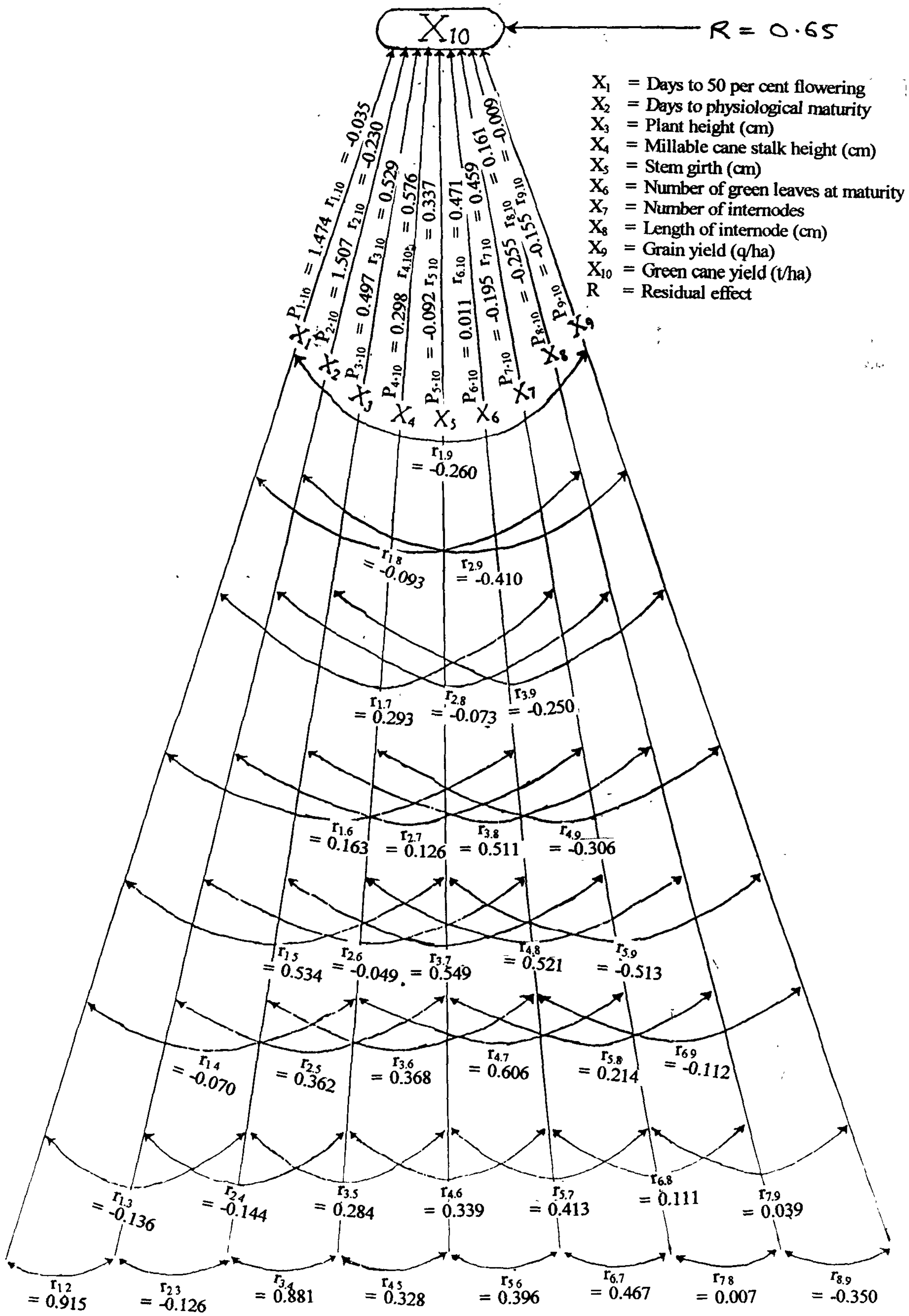

Fig. 1 (a) Genotypic path diagram for ten growth characters

4. Millable cane stalk height (cm)

Millable cane stalk height had high and positive (0.298) direct effect on green cane yield. It's indirect effects via plant height and days to physiological maturity were high and positive.

5. Grain yield (q/ha)

Grain yield had negative and medium direct effect (-0.155) on green cane yield. It's indirect effects via remaining characters were negative except days to physiological maturity, stem girth and length of internode.

6. Stem girth (cm)

Stem girth had low and negative (-0.093) direct effect on green cane yield. It's indirect effects via days to 50 per cent flowering were high and positive while that via days to physiological maturity were high and negative (-0.546).

7. Number of green leaves at maturity

The number of green leaves at maturity had very low positive (0.011) direct effect on green cane yield. However, it's indirect effects via days to 50 per cent flowering, plant height and millable cane stalk height were medium and positive.

8. Number of internodes

The number of internodes had negative direct effect (-0.195) on green cane yield. It's indirect effects via days to 50 per cent flowering and plant height were high and positive.

9. Length of internode (cm)

The length of internodes had high negative (-0.255) direct effect on green cane yield. It's indirect effects via plant height and days to physiological maturity were medium and positive.

The residual effect observed for the path analysis of growth characters in sweet sorghum was 0.65.

4.1.4 Genetic divergence

The data obtained for ten growth characters on forty-one genotypes of sweet sorghum was subjected to Mahalanobis (1936) D^2 analysis to calculate genetic distance between them.

Mahalanobis's generalized distance (D)

Wilk's criteria showed significant differences between the genotypes for pooled effect on ten charactes (Wilk's criteria, X^2 = 1950.97 at 400 d.f.). Hence, D^2 values were calculated. The D^2 values ranged from 35.37 to 7956.40.

The lowest value between the genotypes RSSV-61 and RSSV-62 and the highest value between the genotypes RSSV-9 and RSSV-65 was observed.

4.1.4.1 Clustering of the genotypes

The 41 genotypes of sweet sorghum were grouped in to ten clusters (Table 7). Cluster-III was largest cluster containing eleven genotypes followed by cluster-II with eight genotypes, cluster-V with seven genotypes, cluster-I had six genotypes and cluster-VI with four genotypes. The remaining clusters

Table 7. Distribution of forty-one genotypes sweet sorghum in different clusters

Cluster	Number of genotypes included	Name of genotypes includes
I	6	RSSV-61, RSSV-62,RSSV-60, RSSV-63, RSSV-24, Wray
II	8	RSSV-46, RSSV-50, RSSV-48, RSSV-47, RSSV-68, RSSV-54, NSS-209, GSSV-314
III	11	NSS-216, BJ-248, NSS-218, NSS-219, RSSV-57, RSSV-55, NSS-9, RSSV-64, SSV-84, GSSV-318, RSSV-44
IV	1	Kellar
V	7	GSSV-317, NSS-208, NSS-204, RSSV-65, RSSV-59, RSSV-40, RSSV-43
VI	4	RSSV-38, RSSV-49, NSS-5, RSSV-39
VII	1	RSSV-9,
VIII	1	RSSV-34
IX	1	RSSV-67
X	1	RSSV-45

viz., IV, VII, VIII, IX and X were solitary clusters having only one genotype each.

4.1.4.2 Inter and intra-cluster distance (D)

The average inter and intra-cluster D values are presented in Table 8 and depicted in Fig. 2. It is seen from the table that a maximum inter-cluster distance was between cluster V and cluster-VII (70.81) followed by cluster-V and cluster-VIII (68.73), cluster-I and cluster-V (67.75) and cluster-V and cluster-X (65.36).

The maximum intra-cluster distance was observed for cluster-V (27.32) followed by cluster VI (25.70), cluster III (24.25), cluster-II (20.52) and cluster-I (19.10). The remaining clusters being solitary clusters had no intra-cluster distance.

4.1.4.3 Cluster means

The cluster means for ten characters studied are presented in Table 10. Considerable variation in respect of cluster means was observed for all the characters studied except for stem girth, number of green leaves at maturity and number of internodes. Cluster means for days to 50 per cent flowering ranged from 76.00 (cluster-IV) to 96.00 (cluster-IX). The cluster means for days to physiological maturity ranged from 105.87 (cluster-VI) to 127.0 (cluster-IX). For plant height, cluster mean ranged from 200.14 (cluster- V) to 294.50 (cluster-X) also for millable cane stalk height cluster mean ranged from 148.31 (cluster-V) to 250.60 (cluster-VII). For stem girth cluster mean ranged from 5.82 (cluster-V) to 6.67 (cluster-VIII) also for number internodes ranged from 9.38 (cluster-III) to 13.50 (cluster-VII) also for length of internode, the

Table 8. Average inter and intra-cluster distance (D) value for ten growth characters in sweet sorghum.

	I	II	III	IV	V	VI	VII	VIII	IX	X
I	19.10	27.13	47.56	26.85	67.75	60.49	32.42	28.08	49.79	32.92
II		20.52	35.19	26.36	51.83	45.72	31.57	28.57	35.74	33.13
III			24.25	31.60	34.19	40.85	57.23	51.41	36.02	53.00
IV				0.00	51.57	47.67	45.28	41.74	46.69	37.89
V					27.32	38.62	70.81	68.73	45.98	65.36
VI						25.70	56.23	65.25	54.11	53.70
VII							0.00	28.34	52.00	26.97
VIII								0.00	37.00	37.78
IX									0.00	58.27
X										0.00

Table 10. Cluster means for ten growth characters in sweet sorghum.

Characters / Clusters	Days to 50 per cent flowering	Days to physiological maturity	Plant height (cm)	Millable cane stalk height (cm)	Stem girth (cm)	No. of green leaves at maturity	No. of internodes	Length of internode (cm)	Green cane yield (t/a)	Grain yield (q/ha)
I	83.08	120.58	285.48	225.37	06.26	11.05	10.60	20.84	26.38	07.89
II	86.00	119.68	256.64	211.31	06.32	10.36	10.92	19.33	32.06	12.67
III	87.00	125.41	224.43	166.18	06.04	10.25	09.38	18.42	22.75	11.54
IV	76.00	111.00	265.50	190.50	05.94	11.90	09.50	20.00	25.73	11.64
V	86.78	125.93	200.14	148.31	05.82	10.06	09.53	14.76	19.95	16.91
VI	80.62	105.87	227.80	170.52	05.83	10.17	11.17	17.01	23.49	32.18
VII	88.00	119.00	286.40	250.60	05.93	11.70	13.50	18.90	30.98	18.34
VIII	85.50	123.50	262.50	248.00	06.67	10.20	11.20	19.35	32.98	03.16
IX	96.00	127.00	201.90	201.00	06.40	10.70	10.30	19.40	16.18	05.52
X	78.00	117.50	294.50	240.30	05.90	10.40	10.70	14.25	46.74	16.79

Table 9. Relative contribution of different characters towards genetic diversity

Characters	Number of times appearing in first rank	Per cent contribution
Days to 50 per cent flowering	4	0.49
Days to physiological maturity	0	0.00
Plant height (cm)	231	28.17
Millable cane stalk height (cm)	248	30.24
Stem girth (cm)	0	0.00
Number of green leaves at maturity	7	0.82
Number of internodes	29	3.54
Length of internode (cm)	141	17.20
Green cane yield (t/ha)	3	0.37
Grain yield (q/ha)	157	19.15

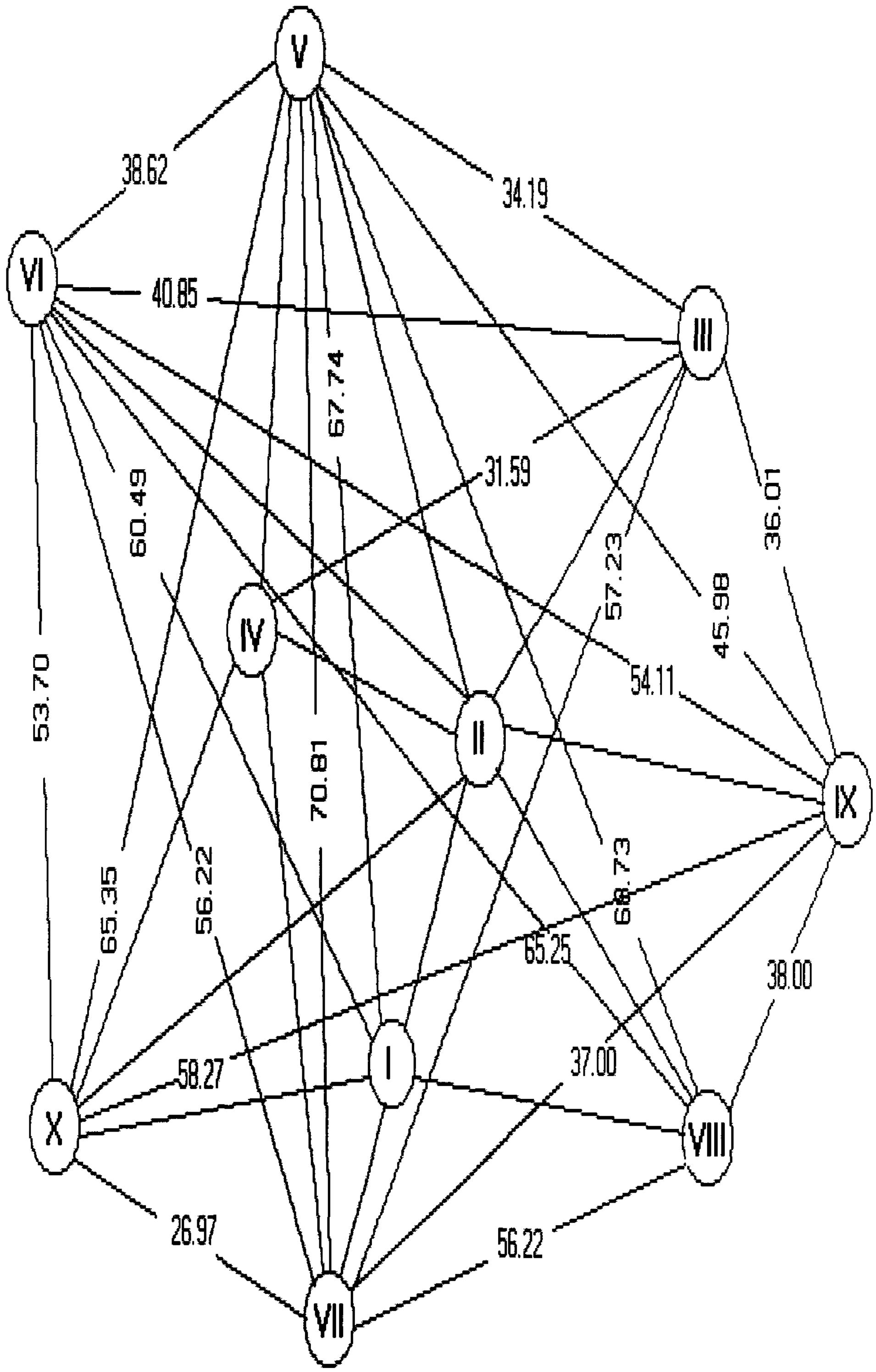

Fig 2 : Cluster diagram

(NB : For remaining inter cluster D values please refer to Table 8)

Millable cane stalk height (30.24%) had the highest contributior towards genetic divergence followed by plant height (28.17%) and grain yielc (19.15%) and length of internode (17.20%) (Table 9).

(B) Quality characters

4.2 Analysis of variance

For ten quality characters studied in sweet sorghum, the analysis oi variance is given in Table 12. The mean squares due to treatment werε significant for all characters indicating the genotypes studied differeć significantly for the concerned characters.

4.2.1 Mean performance and variability parameters

The mean performance and variability parameters of ten quality characters studied in forty-one genotypes of sweet sorghum are presented in Table 13 and Table 14, respectively.

In general, the estimates of PCV were higher than GCV. High estimates of GCV and PCV were observed for total sugar in quintals (56.59-56.91) followed by juice yield (56.07-56.30) and juice extraction per cent (38.41-40.49) whereas for reducing sugar (18.30-18.57), starch per cent (17.06-17.31), commercial cane sugar (16.13-16.42), total soluble solids (13.92-14.15) and non-reducing sugar (10.35-10.41) moderate estimates of GCV and PCV

Table 13. Mean performance of ten quality characters studies in sweet sorghum.

Sr. No.	Genotype	Juice extraction (%)	Juice yield (q/ha)	pH of juice	Reducing sugars (%)	Non-reducing sugars (%)	Total soluble sugars (%)	Total soluble solids (°B)	Commercial cane sugar (%)	Total sugar in quintals	Starch (%)
1	RSSV-9	47.05	14.59	5.18	1.67	13.45	15.12	21.00	11.21	22.16	2.14
2	RSSV-24	15.21	40.91	5.17	1.36	14.02	15.39	17.60	12.96	04.29	1.97
3	RSSV-34	25.50	133.90	5.16	1.81	12.13	13.95	13.50	11.46	18.48	1.91
4	RSSV-38	18.10.	44.71	5.15	1.11	15.09	16.20	15.60	14.07	07.23	2.26
5	RSSV-39	16.05	36.28	5.20	1.42	14.37	15.80	14.00	14.46	05.74	2.43
6	RSSV-40	13.23	19.22	5.20	1.71	08.75	10.46	14.00	07.19	02.00	2.14
7	RSSV-43	15.05	47.20	5.06	1.60	14.11	15.71	18.20	13.15	07.49	1.87
8	RSSV-44	25.00	49.91	5.18	1.55	14.15	15.70	15.35	13.65	07.33	1.85
9	RSSV-45	19.74	92.37	5.06	1.59	14.14	15.73	19.80	12.46	14.51	2.37
10	RSSV-46	22.10	69.68	5.18	1.58	13.70	15.28	22.20	10.98	10.65	2.12
11	RSSV-47	21.47	54.87	5.16	1.90	13.60	15.50	18.80	12.06	08.56	2.65
12	RSSV-48	11.00	48.27	5.16	1.79	13.67	15.46	20.20	11.74	07.43	2.56
13	RSSV-49	17.19	30.38	5.14	1.52	13.05	14.57	16.20	12.11	04.42	1.98
14	RSSV-50	13.21	38.37	5.15	1.46	12.79	14.25	18.50	10.95	05.46	1.87
15	RSSV-54	19.62	48.64	5.07	1.26	13.51	14.77	17.00	12.17	07.16	1.11
16	RSSV-55	19.29	44.91	5.01	1.42	12.23	13.65	15.00	11.40	06.11	2.12
17	RSSV-57	21.04	38.48	5.10	1.82	10.53	12.36	21.90	07.14	04.76	2.69
18	RSSV-59	34.93	70.08	5.08	1.72	14.66	16.38	16.80	14.02	11.47	1.44
19	RSSV-60	24.45	53.11	5.08	1.86	13.03	14.89	2170	10.31	07.92	2.70
20	RSSV-61	37.03	110.59	4.99	1.28	12.47	13.75	21.40	09.83	15.24	2.30
21	RSSV-62	36.21	89.18	5.11	1.56	11.19	12.75	19.40	08.75	12.48	2.63
22	RSSV-63	17.94	55.28	5.08	1.59	14.10	15.70	.21.21	11.76	08.68	2.60
23	RSSV-64	29.55	43.90	5.04	1.84	10.74	12.58	19.60	11.11	05.52	2.69

Table 13 (Contd.)

Sr. No.	Genotype	Juice extraction (%)	Juice yield (q/ha)	pH of juice	Reducing sugars (%)	Non-reducing sugars (%)	Total soluble sugars (%)	Total soluble solids (°B)	Commercial cane sugar (%)	Total sugar in quintals	Starch (%)
24	RSSV-65	50.00	28.92	5.20	2.00	14.24	16.24	13.20	14.54	04.33	2.45
25	RSSV-67	34.57	56.93	5.02	1.63	12.83	14.47	20.40	10.59	10.93	2.61
26	RSSV-68	35.23	68.50	5.08	1.75	14.18	15.94	20.20	12.16	08.25	2.41
27	GSSV-314	12.65	20.05	5.02	0.95	13.29	14.25	19.70	11.48	03.04	2.63
28	GSSV-317	21.92	70.15	5.02	1.25	14.01	15.26	23.20	11.28	10.97	2.75
29	GSSV-318	34.88	30.18	5.06	1.32	14.31	15.63	19.80	12.68	07.40	2.34
30	NSS-5	18.21	52.54	5.16	1.76	12.53	14.29	18.60	10.74	07.45	2.42
31	NSS-9	22.22	57.99	5.05	1.63	14.14	15.78	16.60	11.91	09.15	1.79
32	NSS-204	33.48	86.85	5.00	1.74	11.37	13.11	19.30	09.18	11.07	1.81
33	NSS-208	32.37	67.20	5.02	1.80	14.32	16.12	18.20	13.64	10.80	2.70
34	NSS-209	41.94	196.20	5.06	1.62	13.64	15.26	22.30	11.34	30.01	2.30
35	NSS-216	37.48	54.26	5.00	2.10	13.05	15.15	17.80	11.64	08.20	1.92
36	NSS-218	34.28	90.89	4.96	1.75	12.68	14.43	21.30	10.15	13.09	2.72
37	NSS-219	33.75	100.94	4.97	2.30	12.12	14.42	18.45	10.76	14.59	2.23
38	Wray	18.89	52.86	4.95	0.99	13.61	1460	22.90	10.88	07.83	1.80
39	Kellar	38.04	97.89	5.01	1.13	16.60	17.73	18.30	16.12	17.31	2.10
40	BJ-248	11.10	23.34	5.03	1.65	13.89	15.54	18.80	12.43	03.62	1.80
41	SSV-84	28.12	104.60	4.97	2.15	13.89	16.04	19.50	12.37	16.71	2.40
	Mean	25.83	61.83	5.08	1.61	13.27	14.88	18.71	11.60	09.75	2.23
	CD at 5%	06.69	06.31	0.13	0.10	00.28	00.31	00.96	00.72	01.19	0.13
	CD at 1%	8.95	08.44	0.17	0.13	00.38	00.42	01.29	00.96	01.60	0.17

Table 14. Variability parameters for ten quality characters in sweet sorghum.

Sr. No.	Parameters	Juice extraction (%)	Juice yield (q/ha)	pH of juice	Reducing sugars (%)	Non-reducing sugars (%)	Total soluble sugars (%)	Total soluble solids (°B)	Commercial cane sugar (%)	Total sugar in quintals	Starch (%)
1	Range	11.00-50.00	14.59-196.20	4.95-5.20	0.95-2.30	8.75-16.60	10.46-17.73	13.20-23.20	7.14-16.12	2.00-30.01	1.11-2.74
2	GCV	38.41	56.07	1.19	18.30	10.35	8.81	13.92	16.13	56.59	17.06
3	PCV	40.49	56.30	1.74	18.57	10.41	8.88	14.15	16.42	56.91	17.31
4	h^2 (bs) (%)	90.00	99.20	46.60	97.10	99.00	98.60	96.70	96.50	98.90	97.10
5	GA as % of mean	75.06	115.05	1.67	37.16	21.21	18.03	28.20	32.64	115.92	34.63

were observed. Low estimates of GCV and PCV were observed for total soluble sugar per cent (8.81-8.88) and pH of juice (1.19-1.74).

High estimates of heritability were observed for juice yield (99.20) followed by non-reducing sugar (99.00), total sugar in quintals (98.90), total soluble sugar (98.60), reducing sugar (97.10), starch content (97.10), total soluble solids (96.70), commercial cane sugar (96.50) and juice extraction per cent (90.00) whereas medium estimates of heritability was observed for pH of juice.

High estimates of genetic advance as per cent of mean were observed for eight characters viz., total sugar in quintals (115.92), juice yield (115.05), juice extraction per cent (75.06), reducing sugar (37.16), starch per cent (34.63), commercial cane sugar (32.64), total soluble solid (28.20) and non-reducing sugar (21.21). Medium estimates of genetic advance as per cent of mean were observed for total soluble sugar (18.03) and low for pH of juice (1.67).

4.2.2 Correlation studies

a. Association of juice yield with its components

Juice yield was significantly and positively correlated with total sugar in quintals (0.816) followed by juice extraction per cent (0.414) whereas it was negatively but significantly correlated with pH of juice (-0.438).

b. Association among the components

Juice extraction per cent had positive and significant association with total sugar in quintals (0.607) followed by reducing sugar (0.327), pH of juice had negative significant association with total soluble solids (-0.559).

Reducing sugar had negative significant association with non-reducing sugar (-0.313) at 5 per cent level.

Non-reducing sugar had positive and significant association with total soluble sugar (0.997) followed by commercial cane sugar (0.921).

Total soluble sugar had positive significant association with commercial cane sugar (0.917).

Total soluble solids had significant positive association with starch per cent (0.379) followed by total sugar in quintals (0.325) while it had significant and negative association with commercial cane sugar (-0.376) (Table 15).

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 16 and Fig. 1(b).

1. Juice extraction per cent

Juice extraction per cent had medium and negative direct effect on juice yield (-0.318), however its correlation with juice yield was positive and significant (0.414). This might be due to positive indirect effects of juice extraction per cent via total soluble sugar, total sugar in quintal and commercial cane sugar.

2. pH of juice

pH of juice had negligible and positive direct effect on juice yield (0.046), whereas it was significantly and negatively associated with juice yield. This might be due to negative indirect effects via total soluble solids and total sugar in quintals.

Table 15. Genotypic correlation coefficients for ten quality characters in sweet sorghum

Characters	Juice extraction (%)	pH of juice	Reducing sugar (%)	Non-reducing sugar (%)	Total soluble sugar (%)	Total soluble solids (°B)	Commercial cane sugar (%)	Total sugar in quintals	Starch (%)	Juice yield (q/ha)
Juice extraction (%)	1.00	-0.281	0.327*	0.080	0.157	0.119	0.066	0.607**	0.124	0.414**
pH of juice		1.00	0.066	-0.038	-0.025	-0.559**	0.140	-0.288	-0.032	-0.438**
Reducing sugar (%)			1.00	-0.313*	-0.103	-0.099	-0.214	0.147	0.183	0.177
Non-reducing sugar (%)				1.00	0.997**	0.007	0.921**	0.173	-0.146	0.053
Total soluble sugar (%)					1.00	-0.014	0.917**	0.214	-0.112	0.094
Total soluble solids (°B)						1.00	-0.376*	0.325*	0.379*	0.244
Commercial cane sugar (%)							1.00	0.060	-0.257	-0.021
Total sugar in quintals								1.00	0.031	0.816**
Starch (%)									1.00	0.043

*, ** Significant at 1 and 5 per cent level.

Table 16. Genotypic path matrix of nine components on quality characters on juice yield

Characters	Juice extraction (%)	pH of juice	Reducing sugars (%)	Non-reducing sugars (%)	Total soluble sugars (%)	Total soluble solids (°B)	Commercial cane sugar (%)	Total sugar in quintals	Starch (%)	Genotypic correlation coefficient
Juice extraction (%)	<u>-0.318</u>	-0.013	-0.389	-0.946	0.744	0.340	0.486	0.526	-0.016	0.414**
pH of juice	0.089	<u>0.046</u>	-0.079	0.449	-0.118	-1.595	1.023	-0.249	-0.004	-0.438**
Reducing sugars (%)	-0.104	0.003	<u>-1.192</u>	3.699	-0.487	-0.284	-1.561	0.127	-0.024	0.177
Non-reducing sugars (%)	-0.025	-0.001	0.373	<u>-11.815</u>	4.620	0.020	6.712	0.150	0.019	0.053
Total soluble sugars (%)	-0.050	-0.001	0.123	-11.543	<u>4.729</u>	-0.042	6.679	0.185	0.014	0.094
Total soluble solids (°B)	-0.038	-0.026	0.119	-0.085	-0.070	<u>2.852</u>	-2.741	0.282	-0.049	0.244
Commercial cane sugar (%)	-0.021	0.006	0.255	-10.891	4.337	-1.074	<u>7.282</u>	0.052	0.033	-0.021
Total sugar in quintals	-0.193	-0.013	-0.175	-2.047	1.014	0.929	0.440	<u>0.866</u>	-0.004	0.816**
Starch (%)	-0.039	-0.001	-0.218	1.727	-0.529	1.083	-1.877	0.027	<u>-0.130</u>	0.043

Underlined figures indicate direct effects. Residual effect = 0.651
*, ** Significant at 1 and 5 per cent level.

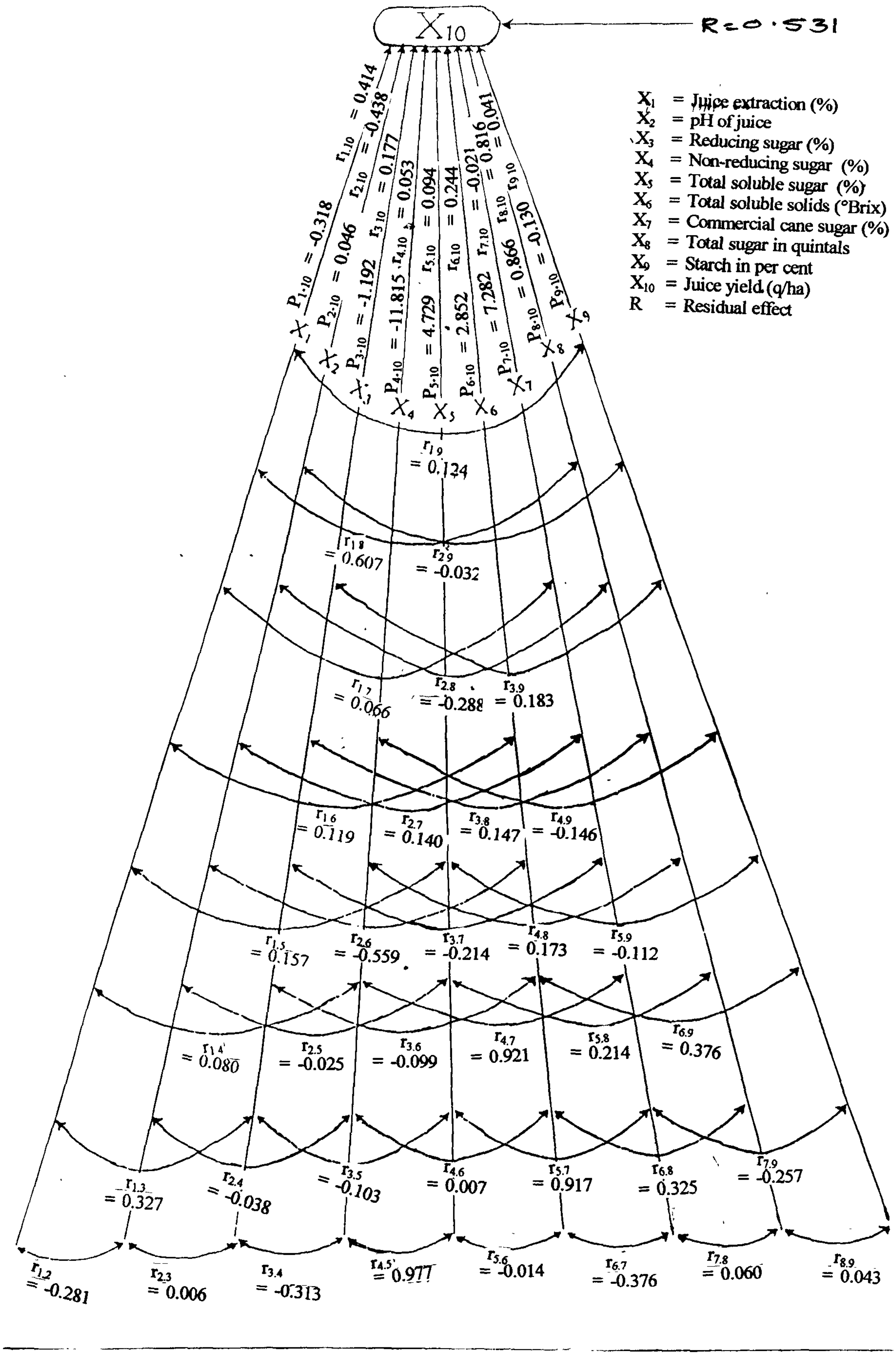

Fig. 1 (b) Geneotypic path diagram for ten quality characters

3. Reducing sugars

Reducing sugars had high negative direct effect on juice yield (-1.192), while it has positive correlation. This might be due to high positive indirect effect via non-reducing sugars and total sugars in quintals.

4. Non-reducing sugars

Non-reducing sugars had high negative direct effect on juice yield (-11.815), while it was positively correlated. This might be due to high positive indirect effect via commercial cane sugar and total sugars in quintals.

5. Total soluble sugars

Total soluble sugars had high and positive direct effect on juice yield (4.729), while its correlation was positive but negligible. This might be due to high negative indirect effect via non-reducing sugars.

6. Total soluble solids

Total soluble solids had high positive direct effect (2.852) on juice yield whereas its correlation with juice yield was positive. It might be due to high positive indirect effect via total sugar in quintals as well as high negative indirect effect via commercial cane sugar.

7. Commercial cane sugar

Commercial cane sugar had high positive direct effect (7.282) on juice yield. Its correlation was negligible and negative. This might be due to high negative indirect effect via non-reducing sugar and total soluble solids.

8. Total sugars in quintals

Total sugar in quintals had high and positive direct effect (0.866) on juice yield. While its correlation with juice yield was high and positive. This might be due to high positive indirect effect via total soluble sugar followed by total soluble solids.

9. Starch per cent

Starch per cent had medium and negative direct effect on juice yield (-0.130), while it was negligibly and positively correlated with juice yield. This might be due to high and positive indirect effect via non-reducing sugars.

Chapter Opener Page

DISCUSSION

5. DISCUSSION

Plant breeding deals with the management of genetic variability. Hence it's assessment in available germplasm is of immense value to design a suitable selection procedure to identify the superior genotypes. It is, therefore, necessary to study the nature and magnitude of the genetic diversity systematically for its exploitation in genetic upgradation of biological population. Selection on the basis of *per se* performance for plant yield doesn't give fruitful results because yield is very complex character. Simple correlation coefficients are of limited value in selecting superior plants. Hence, it is important to study the cause and effect relationship between yield and it's various components.

In present investigation forty-one genotypes of sweet sorghum were therefore assessed to understand the nature and magnitude of variability, correlation coefficients, path coefficients and genetic divergence based on nine components of green cane yield. Similarly, genetic variability, correlation coefficients were also worked out for juice yield and other nine independent quality components of juice yield. The results presented in chapter four are 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 in respect of days to 50 per cent flowering, days to physiological maturity, plant height, millable cane stalk height, length of internode, green cane yield and grain yield. This indicated ample scope for exploitation of the above characters.

Potdukhe *et al.* (1993) observed similar results for days to 50 per cent flowering, plant height, number of leaves, stem girth and grain yield/plant. Patil *et al.* (1996) reported wider range of variability for green forage yield and plant height.

Umakant *et al.* (2002) observed similar results for plant height and days to 50 per cent flowering.

5.1.1.2 Genotypic and phenotypic coefficient of variation

Genetic variability in material with which the breeder is working is the basis for any successful breeding programme. It is, therefore, essential to know the genetic component of variation before variability can be utilized for further genetic improvements in crop plants. Genotypic and phenotypic coefficients of variation are important in this respect.

In present study, higher estimates of genotypic and phenotypic coefficients of variation were observed for green cane yield and grain yield indicating more variability and scope for selection in improving these characters.

The similar results were reported by Patil *et al.* (1996) for green forage yield. Rao and Patil (1996) reported high GCV and PCV for grain yield per plant. Veerbhadhiran and Kennedy (2001-a) reported high GCV and PCV for grain yield. Choudhary *et al.* (2001-a) reported similar results for biological yield.

The characters *viz.*, plant height, millable cane stalk height, number of internodes and length of internode indicated medium genotypic and phenotypic coefficient of variation, respectively showing some scope for selection in these characters. Choudhary *et al.* (2001a) reported higher estimates of GCV and PCV for days to maturity and plant height.

The estimates of genotypic and phenotypic coefficients of variation were nearly equal in days to 50 per cent flowering, plant height, millable cane stalk height, stem girth, number of green leaves at maturity, number of internode and length of internode indicating that the variability existing in these characters was due to genetic factors and there was less influence of environmental factors in the expression of these characters.

5.1.1.3 Heritability (B.S.) and genetic advance

The genotypic coefficient of variation alone doesnot indicate the proportion of total heritable variation. The heritability estimates are better indicator in this respect. High heritability indicates the effectiveness of selection based on phenotypic performance but does not necessarily mean a high genetic gain for particular character. Consideration of both heritability and genetic advance, is more important for predicting effectiveness of selection than heritability alone. High heritability accompanied with high genetic advance indicates preponderance of additive gene effects, in such cases selection may be effective. High heritability with low genetic advance reveals preponderance of non-additive gene action. High heritability is due to favourable environmental effect rather than genotype. Selection for such traits may not be rewarding. Low heritability with high genetic advance indicates preponderance of additive gene effects. Low heritability is due to high environmental effects. Selection may be effective for such traits. Low heritability with low genetic advance reveals high influence of environment traits hence selection would not be effective for such traits.

In present study, the characters *viz.*, millable cane stalk height, plant height, grain yield, length of internode, number of internodes, days to 50 per cent flowering, number of green leaves at maturity, green cane yield and stem girth expressed high estimates of heritability while days to physiological maturity expressed medium estimates of heritability.

The characters *viz.*, grain yield, green cane yield, millable cane stalk height, plant height, length of internode and number of internode expressed high estimates of heritability accompanied with high genetic advance indicating additive gene action and thus selection for these characters in genetically diverse material would be more effective for desired genetic improvement. Potdukhe *et al.* (1993) reported similar results for days to 50 per cent flowering, Rao and Patil (1996) for grain yield and Choudhary *et al.* (2001-a) for biological yield.

The characters *viz.*, number of green leaves, days to 50 per cent flowering and stem girth had high heritability accompanied with low genetic advance suggesting that variability for these characters are governed by non-additive gene action indicating the limited scope for improving these characters through phenotypic selection.

Thus, considering the estimates of genetic parameters like genotypic coefficient of variation, heritability and genetic advance together, it is evident that green cane yield, grain yield, millable cane stalk height, plant height and length of internode are most important characters. Selection for these characters could be more effective for improving green cane yield in sweet sorghum.

5.1.2 Correlation studies

In the improvement of any crop, yield is most important characters that have to be taken into account. Yield is multiplicative product function of yield attributing plant components. The knowledge of interrelation among the component characters is therefore, useful to the plant breeder for improving the yield indirectly. Genotypic correlation coefficients provide an estimate of an inheritant association between any two characters. The estimates of correlation coefficients may also help to identify the characters that prove to be little or no importance in selection programme.

In present investigations, significant and positive correlation were observed between green cane yield and millable cane stalk height followed by plant height, number of green leaves at maturity, number of internodes and stem girth. The grain yield, days to 50 per cent flowering and days to physiological maturity had negative and non-significant association with green cane yield.

Bangarwa *et al.* (1989) reported similar results for stem girth, plant height. Jayamani and Dorairaj (1993) for green biomass yield with plant height, number of leaves and stem diameter for days to 50 per cent flowering. Yang Wei Guang (1995) for plant height and stalk diameter. Khare (1994) reported strong positive association with number of leaves and stem girth.

Days to 50 per cent flowering showed significant positive association with days to physiological maturity, stem girth indicating that there was certain inherent relationship between these characters. Jayamani and Dorairaj (1993), reported similar results for days to 50 per cent flowering. Prabhakar (2001) for days to 50 per cent flowering with days to maturity.

Days to physiological maturity showed significant positive association with stem girth while significant negative association was observed for grain yield. Patil *et al.* (1995) reported similar results for physiological maturity.

Plant height was significantly associated with millable cane stalk height, number of green leaves at maturity, number of internode and length of internode. Badwal (1971) reported significant and positive association between number of days to flowering and number of days to harvest.

Millable cane stalk height showed significant positive association with stem girth, number of green leaves at maturity, number of internodes and with length of internodes.

Stem girth showed significant and positive association number of internodes and number of green leaves at maturity. Pandian *et al.* (1993) reported similar results for stem girth.

Number of green leaves at maturity showed significant and positive correlation with number of internode. Pandian *et al.* (1993) observed same results for number of green leaves.

Thus to summarise, the characters *viz.*, millable cane stalk height, plant height, number of green leaves at maturity, number of internode and stem girth were positively and significantly correlated with green cane yield.

Therefore, desirable plant type in sweet sorghum should be high millable cane stalk height, plant height, more number of internode, high number of green leaves at maturity and stem girth for high green cane yield.

5.1.3 Path coefficient analysis

Genotypic path coefficient analysis as outlined by Dewey and Lu (1959) was carried out to find out the direct and indirect effect of various components on green cane yield.

Direct effect of any component characters on cane yield gives an idea about reliability of indirect selections to be made through that characters to bring about improvement in cane yield. If both correlation coefficient and the direct effect are high and positive then correlation explains its true relationship and a selection for that character will be effective. If the correlation coefficient is positive, but the direct effect is negative or negligible, in such relations the indirect causal factors 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 indirect effect.

The residual effect determines how best the causal factors account for variability of the dependent factor; the green cane yield in this case if the value of residual effect is moderate or high, it indicates that besides the character studied these are some other attributes which contributes for yield.

In the present studies plant height and millable cane stalk height had high positive direct effect on green cane yield at the same time these traits also had significant and positive association with cane yield. These two characters also had high positive indirect effects on cane yield via plant height, millable cane stalk height, number of internodes, length of internode, number of green leaves at maturity and stem girth, indicating importance of these two characters during selection programme.

It indicates that there is true association between plant height and millable cane stalk height. Selection for these traits could be rewarding. Similar results were found by Naphade (1972) for plant height. Yang Wei Guang (1995) for plant height and stalk diameter.

Days to 50 per cent flowering had high direct effect with negative negligible correlation indicating scope for direct selection to reduce undesirable indirect effect via days to physiological maturity. Similar results were reported by Potdukhe *et al.* (1992) for days to 50 per cent flowering and plant height.

Days to physiological maturity had high negative direct effect white it was negatively correlated with green cane yield which reveals that selection for these traits could not yield much breeding objectives.

Based on present investigation the most desirable characters in sweet sorghum should have more plant height and millable cane stalk height for more green cane yield.

5.1.4 Genetic divergence

The information about genetic divergence is crucial for selection of parents for hybridization aimed to produce heterotic F_1 hybrid or wide spectrum of transgressive segregants in segregating generations. D^2 statistic is measure that appraises the genetic diversity quantitatively among the set of genotypes.

A set of forty-one genotypes of sweet sorghum under study was therefore assessed for genetic diversity for ten different growth characters.

5.1.4.1 Diversity based on set of ten characters

Analysis of variance (Table 2) revealed highly significant differences among the genotypes for all the characters under study. Hence D^2 values were estimated as per Mahalanobis (1936) based on ten characters. The range of D^2 values was from 35.37(between genotypes RSSV-61 and RSSV-62) and 7956.40 (between the genotypes RSSV-9 and RSSV-65). Hendre (1998) reported that D^2 range as from 30.38 to 16220.83. Kadam *et al.* (2001) found D^2 range from 0.856 to 70.13.

5.1.4.2 Cluster formation

The aim of cluster formation and estimation of intra and inter-cluster divergence is to provide a basis for selecting parents for hybridization programme.

The theoretical concept behind such grouping is that the genotypes grouped in to the same cluster presumably are less diverse from each other than those belonging to different cluster (Rao, 1952). Therefore, crossing between genotypes belonging to different clusters may yield desired heterotic combination and transgressive segregants instead crossing of genotypes within cluster. Therefore, while selecting a parents on the basis of genetic diversity, their *per se* performance and cluster means for the characters for which those are to be included in breeding programme, also need the consideration.

In present investigation, forty-one genotypes were grouped in to ten clusters. Cluster-III was largest comprising of eleven genotypes followed by cluster-II (8), cluster-V (7), cluster-I (6), cluster-VI (4) and remaining clusters were solitary. Sarawate (1985) grouped twenty-two genotypes in fourteen clusters, while Patil *et al.* (1993) clubbed twenty-nine genotypes in to nine clusters. Barhate (1996) grouped fifty genotypes into thirteen and sixteen clusters under light and medium soil conditions, respectively. Hendre (1998) grouped seventy-five genotypes in to nine clusters. Narkhede (2000-a) grouped sixty-four genotypes in to 19 clusters.

It is apparent from Table 8 and Fig. 2 that the maximum intercluster distance was observed between cluster-V and cluster-VII followed by cluster-V and cluster-VIII and cluster-I and cluster-V. The maximum intracluster distance was observed for cluster-V followed by cluster-VI and cluster-III.

The characters millable cane stalk height, plant height, grain yield and length of internode contributed more to genetic divergence in forty-one genotypes of sweet sorghum (Table 9).

Similar results were reported by Sisodia *et al.* (1983) for plant height; Sarawate (1985) and Barhate (1996) for plant height and grain weight; Hendre (1998) for plant height and grain yield; Narkhede *et al.* (2000-a) for plant height, 1000 grain weight and length of internode; and Umakant *et al.* (2002) for plant height.

On the basis of inter-cluster distance, cluster means and *per se* performance observed in present study. The tentative crossing programme involving the genotypes *viz.*, Kellar, BJ-248, Wray, NSS-209, RSSV-68, RSSV-48 and RSSV-45 is suggested (Table 11).

Thus, D^2 analysis proved to be very useful technique in identifying diverse group from larger germplasm.

5.2 QUALITY CHARACTERS

5.2.1 Variability

5.2.1.1 Range of variability

Wide range of variability was observed for juice extraction (per cent), juice yield, non-reducing sugars, total soluble sugar, total soluble solids, commercial cane sugar and total sugars in quintals. This indicated wide scope for exploitation of above characters. Similar results were obtained by Choudhary *et al.* (1987) for total soluble solids, Bapat *et al.* (1986) for non-reducing sugars, Vaidyanathan *et al.* (1987) for total soluble sugar, Kamble (2001) for total soluble solids, non-reducing sugars, commercial cane sugar and for total sugars in quintals.

5.2.1.2 Genotypic and phenotypic coefficient of variation

In present study, higher estimates of genotypic and phenotypic coefficient of variation were observed for total sugars in quintals followed by juice yield and for juice extraction per cent indicating more variability and scope for selection in improving these characters whereas medium estimates of GCV and PCV were observed for reducing sugars followed by commercial cane sugar, total soluble solids and for non-reducing sugars. The low estimates of GCV and PCV were observed for total soluble sugar and pH of juice indicating limited scope for improving these characters (Table 14).

Table 11. Tentative crossing programme

Sr. No.	Characters to be improved	Cluster combinations	Possible crosses
1	Earliness	VI x IV	RSSV-38 x Kellar
		IV x X	Kellar x RSSV-45
		X x VII	RSSV-45 x RSSV-9
2	Height	I x VII	RSSV-61 x RSSV-9
		VIII x X	RSSV-34 x RSSV-45
		I x X	RSSV-61 x RSSV-45
3	Internode component	VII x VIII	RSSV-9 x RSSV-34
		I x IV	RSSV-61 x Kellar
		I x IX	RSSV-61 x RSSV-67
4	Green cane yield	X x VIII	RSSV-45 x RSSV-34
		VIII x II	RSSV-34 x RSSV-46
		X x II	RSSV-45 x RSSV-46

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 indicated in these characters was due to genetic factors and there was less influence of environmental factors in expression of these characters.

5.2.1.3 Heritability (B.S.) and genetic advance

In present investigation, high estimates of heritability was observed for all the characters except pH of juice which showed moderate heritability indicated that these characters are least affected by environments. The selection for improvement of such characters may not be useful as broad sense heritability is based on total genetic variance [Additive (fixable) and non-additive (non-fixable)] (Table 14).

High estimates of genetic advance observed for all the characters.

The characters which showed high heritability and high genetic advance as per cent of mean indicated that, these characters are governed by additive gene action and selection for these characters in genetically diverse material would be more effective for desired genetic improvement.

The character total soluble solids exhibited high heritability with low/medium genetic advance as per cent of mean indicated that variability for these characters are governed by non-additive gene action here high heritability is being exhibited due to favourable influence of environment rather than genotype, suggesting limited scope for improvement in these characters through phenotypic selection (Table 14).

Thus considering the estimates of GCV, heritability (bs) and genetic advance together, it is evident that juice yield, juice extraction, total sugars in quintals, starch per cent, reducing sugars, commercial cane sugar, total soluble solids, and non-reducing sugars are most important characters. Selection for these characters could be more effective for improving juice yield in sweet sorghum.

5.2.2 Correlation studies

In present investigation, genotypic correlation coefficients were higher than phenotypic one indicating strong inherent association between various characters studied and some was less influenced by environmental variations.

A significant positive correlation was observed for total sugars in quintals and juice extraction whereas pH of juice was negatively and significantly correlated with juice yield.

The juice extraction had significant positive correlation with juice yield, total sugars in quintals and reducing sugars indicating that there was inherent relationship between these characters. Similar results were reported by Kamble (2001) for juice extraction per cent.

pH of juice had negative significant correlation with juice yield followed by total soluble solids implies that increase in pH of juice will lad to decrease in juice yield. Hence, selection for low pH should be preferred.

Reducing sugars had positive non-significant correlation with juice yield while it was significantly and negatively correlated with non-reducing sugars. It indicated that reducing sugars had low association with juice yield while increase in reducing sugars will increase the juice yield. There was high association between reducing and non-reducing sugars but increase in one will lead to decrease in other. Similar results were reported by Kamble (2001) for reducing sugars.

Non-reducing sugars had non-significant positive correlation with juice yield while it was significantly and positively correlated with total soluble sugars and commercial cane sugar. It indicated that there was inherent association between these characters.

Total soluble sugars was positively and non-significantly correlated with juice yield while there was significant positive correlation with commercial cane sugar. It revealed that there was inherent association between them.

Total soluble solids had significant positive correlation with total sugars in quintals and starch per cent indicating inherent association between these characters, while it was negatively and significantly correlated with commercial cane sugar revealing that there was high association between total soluble solids and juice yield but increase in total soluble solids will lead to decrease in commercial cane sugar.

Commercial cane sugar was negatively and non-significantly correlated with juice yield suggesting inherent association between them.

Starch per cent had negligible positive correlation with juice yield but it was significantly and positively correlated with total soluble solids indicated that increase in total soluble solids will lead to increase in starch content.

Therefore, desirable plant type in sweet sorghum with quality characters *viz.*, high juice extraction per cent, high total soluble solids and high total sugars in quintals are needed for high juice yield.

5.2.3 Path coefficient analysis

In present investigation, juice extraction per cent had negative direct effect on juice yield while it was significantly and positively correlated with same. This might be due to high positive indirect via total soluble sugar, total sugars in quintals, commercial cane sugar and total soluble solids so indirect selection through these traits would be effective in juice yield improvement.

pH of juice had negligible positive direct effect on juice yield while it was negatively and significantly correlated with same. This might be due to high negative indirect effect via total soluble solids followed by total sugars in quintals indirect selection through these traits would be effective for juice yield improvement.

Reducing sugars had high negative direct effect but same had positive correlation with juice yield. This might be due to high positive indirect effect via non-reducing sugars indirect selection through non-reducing sugars will be rewarding for improvement in juice yield.

Non-reducing sugars had very high negative direct effect while its correlation with juice yield was negligibly positive. This might be due to high positive indirect effect via commercial cane sugar and total soluble sugar so indirect selection through these characters would be beneficial to plant breeder.

Total soluble sugars had high positive direct effect on juice yield while it was negligibly and positively correlated with juice yield. This might be due to high negative indirect effect via non-reducing sugars and positive indirect effect via commercial cane sugar in such cases, direct selection for total soluble sugars would be rewarding for yield improvement.

Total soluble solids had high positive direct effect on juice yield while it was positively correlated with juice yield. It reveals that there is true relationship between these characters. Direct selection would be rewarding.

Commercial cane sugar had high positive direct effect while its correlation with juice yield was negative. This might be due to high negative indirect effect via non-reducing sugars and via total soluble solids. Indirect selection would be rewarding through non-reducing sugars. There was also high positive indirect effect via total soluble sugar.

Total sugars in quintal had high positive direct effect along with significant and positive correlation with juice yield. The influence via other character was nullified among themselves. It reveals that there was true relationship between them. Direct selection would be effective for total sugars in quintals.

Starch had negative direct effect though it was negligibly and positively correlated with juice yield. This might be due to high positive indirect effect via non-reducing sugars and total soluble solids.

In such cases, indirect selection through non-reducing sugars and total soluble solids would be rewarding for juice yield improvement in sweet sorghum.

Considering both the correlation coefficients and path coefficients, it can be concluded that, juice extraction, total sugars in quintals and total soluble solids are important yield contributing characters and should be given due importance during selection as they were correlated significantly with juice yield and also among themselves.

In present study for quality characters, the estimate of residual effect was of 0.531 magnitude.

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SUMMARY AND CONCLUSIONS

6. SUMMARY AND CONCLUSIONS

The present investigation on "Path analysis and genetic diversity in sweet sorghum [*Sorghum bicolor* (L.) Moench]" was undertaken to know the association between different characters and direct and indirect contribution of component characters on green cane yield and juice yield and to assess genetic divergence among forty-one genotypes belonging to different geographical origins. The experiment was laid in a randomized block design with two replications during *kharif*, 2002.

The observations were recorded on days to 50 per cent flowering, days to physiological maturity, plant height, millable cane stalk height (cm), stem girth (cm), number of green leaves at maturity, number of internodes, length of internode, green cane yield (t/ha) and grain yield (q/ha) as growth traits and juice extraction per cent, juice yield (lit/ha), pH of juice, reducing sugars per cent, non-reducing sugars per cent, total soluble sugars per cent, total soluble solids, commercial cane sugar (per cent), total sugars in quintals (per cent) and starch per cent as quality traits.

6.1 Summary

6.1.1 Variability

Significant treatment differences, genotypic and phenotypic coefficients of variation revealed existence of substantial amount of variability for green cane yield and grain yield. Heritability estimates were high for all growth characters studied except for days to physiological maturity. Grain yield, green cane yield, millable cane stalk height, plant height, number of internodes and length of internode expressed high estimates of heritability accompanied with high genetic advance which showed high genetic progress under phenotypic selection.

For quality characters, high estimates of GCV and PCV were observed for total sugars in quintals, juice yield and juice extraction per cent. High estimates of heritability were observed for all the quality characters except pH of juice. High estimates of heritability accompanied with high genetic advance were observed for all the quality characters except total soluble solids.

6.1.2 Correlation studies

Green cane yield was positively and significantly correlated with millable cane stalk height (0.574), plant height (0.531), number of green leaves (0.471), number of internodes (0.460) and stem girth (0.338) whereas it was negatively and non-significantly correlated with days to 50 per cent flowering, days to physiological maturity and grain yield.

For quality traits, juice yield was positively and significantly correlated with total sugars in quintals and juice extraction per cent whereas it was negatively and significantly correlated with pH of juice but negatively and non-significantly correlated with commercial cane sugar.

6.1.3 Path coefficient analysis

Path analysis for growth traits revealed that days to 50 per cent flowering, plant height and millable cane stalk height had high positive direct effect (1.474, 0.497 and 0.298, respectively). Whereas, days to physiological maturity, grain yield, number of internodes and length of internode had negative direct effect on green cane yield.

For quality traits, commercial cane sugar, total soluble sugars and total soluble solids (7.282, 4.729 and 2.852, respectively) had high positive direct effect on juice yield whereas non-reducing sugars, reducing sugars, juice extraction per cent and starch per cent had negative direct effect on juice yield.

6.1.4 Genetic divergence

The D^2 values ranged from 35.37 to 7956.40 for growth traits indicating adequate diversity between the genotypes. On the basis of Tocher's method, the genotypes were grouped in to ten clusters with substantial genetic divergence between them. Cluster-III had maximum (11) number of genotypes followed by cluster-II (8), V (7), I (6), VI (4) while cluster IV, VII, VIII, IX and X were solitary one. Maximum inter-cluster distance was found between cluster-V and cluster-VII (70.81) whereas minimum between cluster-II and cluster-IV (26.36). Clustering pattern of these genotypes did not necessarily follow the geographical distribution.

6.2 Conclusions

1. High estimates of GCV were observed for two growth characters *viz.*, green cane yield and grain yield.

2. High estimates of GCV were observed for three quality characters *viz.*, total sugars in quintals, juice yield and juice extraction per cent indicating more variability for these characters.

3. High heritability accompanied with high genetic advance indicated additive gene control in inheritance for six growth characters *viz.*, grain yield, green cane yield, millable cane stalk height, plant height, length of internode and number of internodes.

4. For quality characters, all the characters showed high estimates of heritability accompanied with high genetic advance except for pH of juice. Therefore, phenotypic selection for these characters will bring about high genetic progress.

5. Millable cane stalk height, plant height, number of green leaves at maturity, number of internodes and stem girth had strong positive genotypic correlations with green cane yield.

6. For quality traits, total sugar in quintals, starch per cent and juice extraction per cent had strong positive genotypic correlations with juice yield.

7. Days to 50 per cent flowering, plant height and millable cane stalk height had high direct effect on green cane yield.

8. For quality traits commercial cane sugar, total sugars and total soluble solids had high direct effect on juice yield.

9. There was substantial genetic diversity between the genotypes studied.

10. Forty-one genotypes were grouped in to ten clusters.

11. The pair of genotypes viz., RSSV-9 and RSSV-65 was most divergent from one another (7956.40).

12. On the basis of inter-cluster distances, cluster means and *per se* performance, hybridization programme is suggested for improvement of sweet sorghum.

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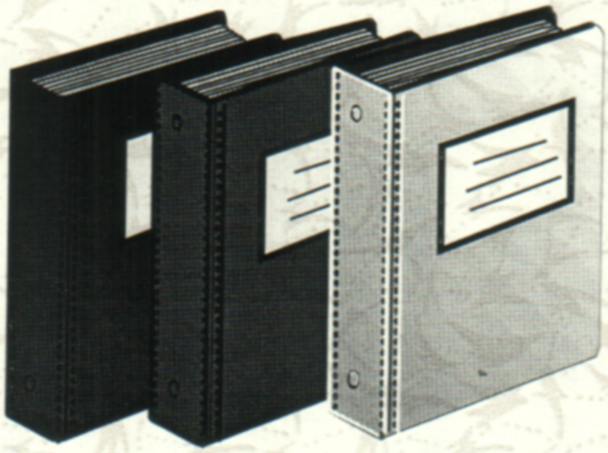

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VITA

8. VITA

AMOL BABURAO PATANKAR

A candidate for the degree

of

MASTER OF SCIENCE (AGRICULTURE)

in

AGRICULTURAL BOTANY

(Cytogenetics and Plant Breeding)

Title of thesis	:	"Path analysis and genetic diversity in sweet sorghum [*Sorghum bicolor* (L.) Moench]
Major field	:	Cytogenetics and Plant Breeding
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- NCC 'C' certificate in 'C' grade.
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