EVALUATION OF SORGHUM GERMPLASM FOR VARIABILITY, CORRELATION AND PATH ANALYSIS

By

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DISSERTATION

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[Maharashtra], INDIA

2015

Affectionately

Dedicated

To My

Beloved

Parents

&

Research Guide

CANDIDATE'S DECLARATION

I hereby declare that the dissertation

or part thereof, has not been

previously submitted by

me for a degree of

any university or

Institution

Smita

Place: Parbhani

Date: 30 / 05/2015

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CERTIFICATE-I

This is to certify that **Doijad Smita Balaji** has satisfactorily prosecuted her course and research for a period of not less than four semesters and that the dissertation entitled **"EVALUATION OF SORGHUM GERMPLASM FOR VARIABILITY, CORRELATION AND PATH ANALYSIS"** submitted by her is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination.

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

Place : PARBHANI
Date : 30 / 05 /2015

Dr. A. B. Bagade
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CERTIFICATE-II

This is to certify that the dissertation entitled **"EVALUATION OF SORGHUM GERMPLASM FOR VARIABILITY, CORRELATION AND PATH ANALYSIS"** submitted by **Doijad Smita Balaji** to the Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani in partial fulfillment of the requirement for the degree of **MASTER OF SCIENCE (Agriculture)** in the subject of **GENETICS AND PLANT BREEDING** has been approved by the student's advisory committee after oral examination in collaboration with the external examiner.

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Smita

(Doijad Smita Balaji)

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ABBREVIATIONS

%	:	per cent
/	:	per
@	:	At the rate of
CD at 5 %	:	Critical difference at 5 per cent
cm	:	Centimeter
d. f.	:	Degrees of freedom
DH (%)	:	Dead heart percentage
EGA	:	Expected genetic advance
et al.	:	*et alia* (and others)
Fig	:	Figure
g	:	Gram (s)
GCV	:	Genotypic coefficient of variation
GA	:	Genetic advance
h^2	:	heritability
i.e.	:	il est (that is)
Kg	:	Kilogram (s)
m	:	Meter
M.S.	:	Maharashtra State
MSS	:	Mean sum of square
No.	:	Number
PCV	:	Phenotypic coefficient of variation
pp	:	pages
r	:	Correlation coefficient
R	:	Residual effect
RWC	:	Relative water content
S.E.	:	Standard error
viz.	:	Videlicet (Namely)

Introduction

CHAPTER I

INTRODUCTION

1.1 Background Information

Sorghum (*Sorghum bicolor* (L.) Moench) commonly known as great millet due to larger size of grain among millets and vast area under it. It is one of the most important grain and fodder crop grown in tropical and subtropical regions in India. The word sorghum is derived from the Latin word 'Sorgo' which mean 'rising above'. The cultivated sorghum originated in Ethiopia (Vavilov, 1935). It is believed to have spread from Africa to India.

It is predominantly a self-pollinated crop. Sorghum belongs to family Poaceae, subfamily Panicoidae, tribe Andropogonae and the sub tribe Sorghastrae (Price *et al.*, 2005). It has chromosome number 2n=20.

Sorghum is one of the most important cereal crop grown in Africa, Asia, USA, Australia, and Latin America. The sorghum crop has wide range of flexibility to grow in various climatic conditions of the world hence it is known by diverse names *viz., Jowar, Jaur, Cholam or Jola in India, Guinea corn, Kofir corn* and *Dhuma* in Africa, *kaoling* in China and *Milo* maize in America. Sorghum species are native to tropical and subtropical regions of all continents in addition to the South West Pacific and Australia. Its importance after wheat, maize, rice and barley is because of its good adaptation to a wide range of ecological conditions, low input cultivation and diverse uses (Aruna *et al.*, 2011). In India, it is third major cereal after rice and wheat and it is most important food crop grown under rainfed conditions. With the present scarcity situation, sorghum cultivation is the heart of dryland agriculture, being C_4 plant it can utilize sunlight and water efficiently (Godbharle *et al.*, 2010). As drought tolerant crop, it allows farmers to use one third less water than similar crops such as corn (Deepalakshmi and Ganeshmurthy 2007). Sorghum crop exhibits considerable differences in plant traits, panicle and grain characteristics including physiological responses to selection and is highly influenced by environmental factors (Ezeaku *et al.*, 1997).

Sorghum is the main staple diet of the people of Maharashtra, Karnataka and Andhra Pradesh. Maharashtra ranks first in terms of area and production. Due to its versatile use, drought hardiness, stability of yield and adaptability over wide range of climates, sorghum has maintained its importance and dependability. Hence, it proved its popularity with growers, especially in marginal areas with least fertile and low water holding capacity soils where, only few other crops can be grown.

The grains are used for making bread, pop beer and fodder is used as animal feed in the form of chops, hays, silage and pasture etc. Sorghum grain contain about 56-63% starch, 10-12% protein, 72.6% carbohydrate, 1.6% mineral matter, 1.9%fat, 7.6-9.2% dietary fiber. It plays predominant role in the food and fodder security for millions of rural families in arid and semi-arid regions of the world.

In the world, Sorghum is cultivated over 44 million hectares, production 60 metric tonnes of grains with an average yield 1238 kg/ hectare. Nearly 80 percent of the cultivated area in the world lies in Asia and Africa. Sorghum is the staple food in dry parts of tropical Africa, India and China because of its drought resistance nature. The productivity of this crop remained low in countries like India and parts of Africa, where sorghum culture has been ancient and constitutes major food crops and can withstand an adverse climatic conditions. (Anonymous 2009).

In India, sorghum is mainly grown in the states of Maharashtra, Karnataka, Andhra Pradesh, Tamil Nadu, Madhya Pradesh, Gujarat and Rajasthan. In Maharashtra, it is grown as major cereal crop in both *kharif* and *rabi* season for food and fodder purpose. Area under sorghum in India is 5.8 million hectare with 5.4 million tonnes of production and 1898 kg/ha productivity per hectare. (http:// e-stat.org.in.).

In Maharashtra, sorghum is cultivated on 28.58 lakh hectares area with production of 25.07 lakh tonnes and productivity of 1971 kg/ha. Out of which the area under *kharif* season is 6.18 lakh hectares with production 7.27 lakh tonnes and productivity of 1176 kg/ha while in *rabi* season the area is 22.40 lakh hectares with the production of 17.80 lakh tonnes and productivity of 795 kg/ha. (Anonymous 2015).

Sorghum area is fast declining for the past 10 decades yet it will continue to be an important food grain in India since its relative importance for alternate uses such as poultry and cattle feed, livestock forage, starch sugar, alcohol and other uses will increase. It is therefore of paramount importance that technological developments are extended to increase the productivity and sustainability of sorghum production (Deepalakshmi and Ganeshmurthy, 2007).

First step in any plant breeding programme is the study of genetic variability, which cannot easily be measured. The phenotypic variability in a given environment can be measured easily, but it reflects non genetic as well as genetic influence on the phenotypic expression. Hence, it is necessary to estimate the relative amounts of genetic and non-genetic variability exhibited by individual character. This is achieved by estimation of genetic variability using suitable parameters like genotypic coefficient of variations, heritability estimates and expected genetic advance for the individual character. Progress in plant breeding depends on the nature and extent of these parameters. Although genetic coefficient of variation is indicative of presence of degree of genetic variation, the amount of heritable portion of variation can only be determined with the help of heritability estimate and genetic gain. Therefore, for the development of high yielding varieties, it is necessary to study the genetic variability for yield and the yield contributing characters for their further exploitation in breeding programme.

Correlation simply measure mutual association without regards of causation while the path coefficient analysis studies specify causes and measure their relative importance also. As there are number of factors involved in a correlation study, their indirect association become more complex and confusing but path coefficient analysis help to avoid this complication by measuring the direct influence of one variable upon other as well as permits the partitioning of given correlation coefficients in to its components of direct and indirect effect. Wright (1921) outlined the technique of path coefficient analysis by which the extent and nature of direct and indirect effect of the component character can be understood.

OBJECTIVES

1. To study genetic variability for various traits in sorghum
2. To study correlation between various component traits in sorghum
3. To study path analysis for various traits in sorghum

Review of Literature

CHAPTER II

REVIEW OF LITERATURE

Sorghum (*Sorghum bicolor* (L.) Moench) is the fifth most important cereal crop followed by rice, maize and barley. It is staple food in the semi arid parts of the world and is most suitable for dry regions broad genetic variability in sorghum can be well exploited for crop improvement. An insight into the magnitude of variability present in crop species is of at most importance as it provides the basis for effective selection. Progress in any breeding programme depends upon magnitude of useful variability present in the population and the extent to which the desirable characters are heritable.

2.1 Genetic variability

Nguyen Duy Can and Tomohiko Yoshida (1999) on the basis of their study on 12 early maturing genotypes of grain sorghum for 5 characters reported that large proportion of phenotypic variance coupled with genotypic variance was obtained for plant height, 100 grain weight and grain yield.

Ambekar *et al.* (2000) studied the genetic variability for yield and yield contributing characters of *rabi* sorghum and revealed that most of the yield contributing characters like panicle length, panicle girth and test weight exhibited high heritability coupled with expected genetic advance.

Date (2002) studied genetic variability in 72 F_2 families of *rabi* sorghum and reported high genotypic coefficient of variability for fodder yield, grain yield per plant and panicle weight. High heritability coupled with high expected genetic advance was observed for fodder yield, grain yield per plant and leaf area.

Prabhakar (2003) studied the genetic variability and correlation in F_2 populations of sorghum and showed that phenotypic coefficient of variation and genotypic coefficient of variation were high for 1000 grain weight and grain yield per plant. High heritability associated with high genetic advance were recorded for 1000 grain weight and grain yield per plant.

Arunkumar *et al.* (2004) studied genetic variability, heritability and genetic advance for 8 quantitative traits in 138 genotypes of *rabi* sorghum (*Sorghum bicolor* (L) Moench). High phenotypic coefficient of variation and genotypic coefficient of variation were observed for grain yield per plant (g/plant), plant height(cm), earhead length(cm), number of primaries per earhead and leaves per plant. High heritability coupled with genetic advance over mean was observed for, earhead length, earhead diameter and number of leaves per plant indicating that additive gene effects were operating for these traits and selection for superior genotype was possible. The trait grain yield had positive and significant association with all traits except with earhead length.

Mallinath *et al.* (2004) estimated genetic variability and correlation for 13 characters. The character viz., fodder yield per plant, grain yield per plant, expansion ratio and popping yield exhibited high phenotypic coefficient of variability, genotypic coefficient of variability, heritability and genetic advance.

Lata Chaudhary *et al.* (2005) revealed high estimates of phenotypic coefficient of variation, genotypic coefficient of variation, heritability and genetic gain for number of leaves per plant while high estimates of phenotypic coefficient of variation and genotypic coefficient of variation and moderate values of heritability and genetic gain were observed for panicle length.

Anjana (2006) studied 87 genotypes of sorghum. High estimates of PCV and GCV were observed for grain per plant, panicle width, grains per primary branches, harvest index and number of primary branches per panicle. Maximum heritability was exhibited by days to 50% flowering, test weight, fodder yield, panicle length, panicle width, protein content, total carbohydrate content of grain, number of primaries reported high heritability.

Hemlata Sharma *et al.*, (2006) recorded all the characters under study exhibited more than 80% heritability. Also the study revealed that the high heritability estimates coupled with high genetic advance and genetic gain were found for grain yield per plant.

Bello *et al.* (2007) observed high heritability estimates in some characters such as panicle length, number of leaves per plant, plant height, number of nodes per plant, days to 95% maturity and days to 50% flowering.

Deepalakshmi and Ganeshmurthy (2007) reported high heritability accompanied with high GA as percent of mean for characters viz., days to 50% flowering, plant height, leaves per plant , leaf length, ear head weight, number of primaries per panicle , 100 grain weight , grain mould score and single plant yield suggesting that these characters are under additive gene action and thus gives better scope for selection.

Khapre *et al.* (2007) observed high heritability and genetic advance estimates for leaf area, number of grains per earhead, number of secondaries and grain yield indicated that these characters are controlled by additive gene action and phenotypic selection for these characters will be effective.

Khairnar (2007) studied thirty genotypes and two checks, high estimates of PCV and GCV were observed for grain yield and threshed grade score. Maximum heritability was estimated by test weight, plant height, days to 50% flowering, relative water content and fodder yield were reported high heritability.

Bidve (2008) studied genetic variability in 90 genotypes and 2 checks of *kharif* sorghum. The larger differences in PCV and GCV were exhibited for panicle length, test weight, grains per primary branches, number of primary branches and harvest index. The heritability with high genetic advance were exhibited for the characters viz., plant height, leaf area index, panicle width, fodder yield, primary branches per panicle, harvest index and grain yield.

Madne (2008) studied genetic variability in 78 genotypes and 2 checks of *kharif* sorghum. The large differences in PCV and GCV were exhibited for harvest index and panicle width. High heritability accompanied with high genetic advance for fodder yield, harvest index, grain yield, plant height, leaf area index.

Warkad *et al.* (2008) evaluated in 64 sorghum germplasm accessions ; the highest PCV and GCV values were for dry fodder yield per plant followed by earhead breadth and length, grain yield per plant, stem girth and 1000 seed weight. High heritability accompanied with high genetic advance over mean was observed for the characters- grain and dry fodder yield, stem girth, earhead length and breadth, suggesting the influence of additive genes and provides scope for selection. Also, high value of heritability along with low genetic advance over mean were observed for the characters days to maturity and number of leaves per plant indicating that variability is mainly due to the non-additive gene effects.

Jhansi Rani *et al.* (2009) estimated that the phenotypic coefficient of variance and genotypic coefficient of variance were high for fodder yield per plant and moderate for green leaves at maturity and dry weight of stem. Low variability noticed for days to 50% flowering, number of leaves per plant and relative water content.

Chavan *et al.* (2010) recorded high heritability coupled with high genotypic advance was for plant height and grain yield per panicle. Whereas, high heritability combined with low genetic advance was recorded for panicle width, panicle length and test weight.

Godbharle *et al.* (2010) reported genotypic variance was lower than the phenotypic variance for all the characters. High genotypic and phenotypic variance, heritability and genetic advance were observed for the characters panicle length, fodder yield, grain yield and plant height indicating that additive gene effects were operating for these traits.

Shinde *et al.* (2010) reported high estimates of broad sense heritability for the characters *viz.*, 50% days to flowering, plant height, number of leaves, number of internodes, panicle length, panicle breadth, number of primaries per panicle, test weight and number of grains per plant. Also reported high heritability coupled with high genetic advance over mean for the characters viz., plant height, number of leaves, panicle length, panicle breadth, number of primaries, test weight, number of grains per plant, fodder yield per plant and grain yield per plant. However, days to 50% flowering showed high heritability coupled with low genetic advance.

Mahajan *et al.* (2011) observed high heritability coupled with high genetic advance for number of grains per panicle, plant height and grain yield per panicle which indicated that these characters are controlled by additive gene action and phenotypic selection for these characters will be effective. This study also revealed that all the characters under investigation showed wide range of variation for individual character. The differences between GCV and PCV for the characters like panicle length, plant height, days to 50% flowering and test weight were found to be less.

Kamtar *et al.* (2011) reported that high genotypic coefficient of variation, phenotypic coefficient of variation and high heritability with high genetic advance for dead heart percentage and grain yield.

Ahmed *et al.*, (2012) reported that most of the characters under study had higher phenotypic and genotypic variance estimates than the environmental variance estimates. The study also revealed that the characters viz., grain weight per panicle, number of grains per panicle, 100-seed weight and grain yield showed low heritability estimates.

Jain and Patel (2012) reported that high heritability accompanied with high GA as per cent of mean was observed for days to 50% flowering, plant height, number of leaves per plant, leaf length and fodder yield per plant suggested that these characters are under additive gene action and gives better scope for selection.

Puspitasari *et al.* (2012) reported the genetic variabilities of grain quality characters among genotypes such as plant height, number of leaves, stalk diameter, biomass weight , panicle length, grain yield per plant, 100 seed weight and tannin content in the grain. Grain yield showed significantly positive correlation with agronomic characters but was negatively correlated with protein content.

Arun kumar (2013) reported that high estimates of genotypic and phenotypic coefficient of variation were observed for grain yield per plant, ear head length and plant height. High genetic advance for grain yield and fodder yield coupled with high heritability, indicating the preponderance of non-additive gene action.

Phuke *et al.* (2013) observed sufficient variability with high heritability for most of the yield component characters like plant height, number of primary branches per panicle, number of grains, grain yield and test weight are found to be more important for selection as they showed higher value for PCV , GCV, heritability and genetic advance.

Seetharam and Ganeshmurthy (2013) reported that high heritability coupled with high genetic advance was observed for days to 50 % flowering, leaf width, plant height, stem width, panicle length, panicle weight and single plant yield.

Sudhanshu and Indapurkar (2013) recorded high phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) values for grain yield per plant and fodder yield per plant. High heritability coupled with high genetic advance was observed for plant height at maturity and fodder yield per plant and grain yield per plant.

Kalpande *et al.* (2014) showed that phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) were more or less equal for the characters plant height, days to 50% flowering, relative water content, panicle length, fodder yield, test weight and grain yield. High heritability accompanied with high genetic advance was observed for the characters viz., test weight, plant height, fodder yield and grain yield.

Patil *et al.* (2014) reported high heritability coupled with high genetic advance was recorded for grain yield per plant, fodder yield per plant, panicle length, panicle weight and stem girth. It was moderate for days to maturity, days to 50 % flowering; leaf length and leaf width revealing that characters are governed by additive gene action and phenotypic selection for these characters will be effective.

Sushil Kumar (2014) reported that high heritability accompanied with high genetic advance as per cent of mean was observed for days to 50% flowering, plant height, number of leaves per plant, leaf length and fodder yield per plant and suggested that these characters are under additive gene action.

2.2 Correlation and path analysis

Correlation coefficient analysis measure the mutual relationship between various plant characters on which selection can be based for improvement in yield. Path analysis is simply standardized partial regression coefficient which splits the correlation coefficient into the measures of direct and indirect effects of independent variables on dependent variable.

The method of partioning the direct and indirect effects on the dependent characters was detailed by Wright (1921), further Dewey and Lu (1959) gave the detailed procedure for path analysis of replicated traits which was quite a different technique incriminating the environmental variance.

Senthil and Palanysamy (1995) reported that grain yield exhibited a strong positive association with seedling vigour and 100 grain weight but a weak positive association with panicle length at genotypic level. The path analysis revealed that maximum direct effect on grain yield was exerted by panicle length followed by seedling vigour, 100 grain weight and number of leaves per plant.

Ambekar *et al.* (2000) examined 110 genotypes and found panicle length, panicle weight, panicle girth and test weight are positively correlated with grain yield per plant. High heritability coupled with expected genetic advance for number of primaries, secondaries, grain number of panicle and grain yield. Path coefficient revealed that the important yield contributing character influencing the grain yield. These characters also showed positive and significant correlation with grain yield through the direct and indirect effects and also showed high heritability with high expected genetic advance.

Sadia Alam *et al.* (2001) reported that plant height, panicle length, 100 seed weight, days to 50% flowering were positively highly significantly correlated with one another and grain yield.

Mallinath *et al.* (2004) revealed that correlation studies indicated grain yield per plant was found to be significantly and positively associated with panicle weight, fodder yield per plant. The positive correlation observed among days to 50% flowering, plant height, number of leaves, panicle weight, number of primaries and fodder yield per plant indicated that grain yield is largely a function of these five attributes.

Thorat *et al.* (2004) reported that the grain yield per plant was significantly and positively correlated with 100 seed weight, seed hardness, panicle length, panicle breadth and plant height.

Lata Chaudhary *et al.* (2005) reported that stover yield exhibited positive and significant correlation with days to flowering, plant height, stem girth and green fodder yield per plot. Characters like plant height and stem girth, revealed high and positive direct effects on stover yield in path coefficient analysis.

Ezeaku and Mohammed (2006) reported that there is significant high positive correlation between grain yield and head weight, grain yield and 1000 grain mass and 1000 grain mass and head weight. Similarly, significant but negative correlation exists between panicle count and panicle length. The plant height has high positive phenotypic and genotypic correlation coefficients with head weight and grain yield. Partitioning of yield and yield components into direct and indirect effects revealed that head weight had the highest direct effect on grain yield while 1000 grain mass contributed indirectly to grain yield *via* head weight.

Hemlata Sharma *et al.* (2006) estimated that PCV and GCV were observed high for grain yield per plant, panicle length and 100 seed weight. Maximum heritability was exhibited by the trait panicle length and grain yield per plant showed positive correlation with 100 seed weight. The path analysis for grain yield indicated highest direct effect of days to 50 % flowering followed by 100 seed weight.

Patil *et al.* (2006) revealed that the percent deadhearts was positively correlated with non-glossiness, percent plant having eggs and number of eggs per plant but negatively correlated with trichome density and seedling height at 14 days after emergence.

Kharinar (2007) studied 30 genotypes with 2 checks and concluded that the characters plant height, panicle length, test weight and harvest index are positively correlated with grain yield per plant and have positive direct effect.

Khapre *et al.* (2007) revealed that Earhead weight, earhead girth, number of grains per earhead, number of primaries and secondaries per earhead. These characters showed highly significant positive correlation with grain yield. The path coefficient analysis revealed the maximum contribution of earhead weight, earhead girth, number of secondaries and number of leaves to the grain yield.

Bidve (2008) studied 90 genotypes and 2 checks, the characters panicle length, panicle width, number of primary branches and test weight had significant correlation with grain yield per plant.

Madne (2008) studied 78 genotypes and 2 checks, the characters fodder yield, test weight, panicle length and panicle width had positive significant correlation and direct effect on grain yield per plant.

Godbharle *et al.* (2010) reported positive and significant correlation between grain yield and harvest index, total biomass, fodder yield and leaf area index was observed both at phenotypic and genotypic level.

Gomashe *et al.*(2010) reported that leaf glossiness showed high positive correlation with shootfly oviposition and deadhearts. The ovipoition percentage on 14th and 21st days after seedling emergence exhibited significant positive correlation with dead hearts and the leaf trichome density on adaxial and abaxial leaf surfaces showed significant negative correlation with shootfly dead hearts.

Iyanar *et al.* (2010) studied genotypic correlation coefficient analysis in 109 genotypes of multicut fodder sorghum showed that all the traits were positively correlated with green fodder yield per plant. Among these traits dry fodder yield exhibited high correlation coefficient with green fodder yield per plant followed by leaf length, plant height and number of leaves. Plant height exerted the highest direct effect on green fodder yield followed by leaf length and breadth and leaf stem ratio.

Jain *et al.* (2010) reported that plant height, stem girth and leaf length were positively and significantly associated with plant height, number of leaves per plant and leaf length. There is positive and significant correlation as well as high direct effect of dry fodder yield per plant, plant height and number of leaves per plant on green fodder yield per plant.

Prakash *et al.* (2010) reported that green fodder yield per plant was found to be significantly and positively correlated with plant height, number of tillers, leaf length and leaf breadth. Path analysis showed that plant height contributed high direct effect to green fodder yield per plant followed by leaf breadth and leaf length.

Thorat *et al.* (2011) conducted an experiment to evaluate yield and yield contributing characters related to shoot fly resistance. The correlation studies showed that deadhearts was positively associated with number of eggs per plant and chlorophyll content. The character percent infested plant and trichome density per mm^2 were negatively correlated with deadhearts for shoot fly resistance.

Ahmed *et al.*, (2012) reported that head weight (g) had highly significant and positive correlation with hay weight, plant height, number of head per plot, while it had highly significant and negative correlation with days to 50% flowering and 100 grain weight.

Jain and Patel (2012) reported that fodder yield was positively and significantly correlated with number of leaves per plant, leaf length, leaf width and panicle length. The characters leaf width, number of leaves per plant, days to 50% flowering and panicle length showed positive direct effect on fodder yield.

Mohammad Yazdani (2012) showed that biological yield was positively correlated with grain yield and obtained high amount of correlation coefficient. Lowest significiant and positive correlation was observed between plant height and grain yield. Results indicate breeders should select varieties with high grain number per panicle and biological yield.

Navneet Kumar and Singh (2012) reported that green fodder yield was found positive and significant association with leaf breadth and leaves per plant at genotypic and phenotypic level. Path coefficient analysis showed that leaf length, leaf breadth and leaves per plant were most important characters controlling directly green fodder yield.

Prasuna *et al.* (2012) reported that grain yield per plant was found to be significantly positive association with plant height, panicle length, panicle weight, 100 seed weight and number of grain per panicle at both levels. Panicle weight recorded significant positive correlation coefficient and contributed to maximum direct effect on grain yield.

Sameer Kumar *et al.* (2012) revealed that among various traits, plant height, 1000 seed weight and fodder yield had significant and positive genotypic correlation with the seed yield per plant.

Tag El-Din *et al.* (2012) showed that results of correlation analysis indicated that number of kernels per head has positive and highly significant correlation with grain yield. This study also revealed that there are negative and non-significant correlation between panicle width and grain yield per panicle. Path analysis showed that panicle length had low but positive direct effect on grain yield and positive indirect effect was through days to flowering, plant height, panicle length, panicle width and panicle internodes whereas indirect effect was negative through leaf area and 1000 kernel weight.

Arun Kumar (2013) reported that ear head length and fodder yield were positively and significantly associated with grain yield per hectare and grain yield per plant respectively at genotypic level. Negative and significant association at genotypic level was noticed between days to 50% flowering and ear head breadth. Days to 50% flowering, ear head length and test weight at both genotypic and phenotypic level have positive direct effect on yield.

Jain and Patel (2013) reported that the green fodder yield showed positive and significant correlation with dry fodder yield, number of leaves per plant, plant height, leaf length and stem girth. It was also observed that characters that exhibited positive associations with fodder yield also showed positive associations among themselves. The characters like green and dry fodder yield per day and number of leaves per plant exerted positive direct effects on green fodder yield. Whereas the plant height, leaf length and stem girth showed negative direct effect with green fodder yield.

Seetharam and Ganeshmurthy (2013) reported that the yield had significant and meaningful correlation with days to 50% flowering, leaf length, leaf width and panicle weight. Among the useful correlations, yield had significant correlation with days to 50% flowering, leaf length, leaf width and panicle weight. Panicle weight had positive direct effect on single plant yield.

Sudhanshu and Indapurkar (2013) reported that fodder yield per plant and 1000 grain weight were found to be significant and positively correlated with grain yield per plant. The path coefficient analysis showed that days to 50% flowering, plant height, length of panicle, width of panicle, fodder yield per plant and 1000 grain weight had positive direct effect on grain yield per plant.

Kalpande *et al.* (2014) reported that characters like number of primary branches, panicle length, grains per primary branches, plant height, fodder yield and panicle width had positive significant correlation with grain yield per plant . Path coefficient analysis revealed maximum contribution of plant height, fodder yield, panicle width, harvest index, days to 50% flowering, leaf area index and test weight to the grain yield.

Sushil Kumar (2014) reported that fodder yield was positively and significantly correlated with number of leaves per plant, leaf length, leaf width and panicle length. The characters leaf width, number of leaves per plant, days to 50% flowering and panicle length showed positive direct effect on fodder yield. Whereas, leaf length showed positive significant association with fodder yield but the direct effect of leaf length was negative with fodder yield, which may be a result of the indirect effect of this trait *via* other traits.

Materials and Methods

CHAPTER III

MATERIAL AND METHODS

The present investigation was undertaken in sorghum (*Sorghum bicolor* (L.) Moench) at Sorghum Research Station, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani (M.S.) during *rabi* 2013-14.

3.1 Experimental material

The experimental material composed of 60 entries and 1standard check. The list of 60 genotypes is given below in table 1.

Table 1: List of genotypes included in the study.

Sr.No.	Genotypes	Sr.No.	Genotypes
1	IS 27	16	IS 20713
2	IS 25596	17	IS 3971
3	IS 8348	18	GCP_Sb_0659
4	SSM 1370	19	SSM 547
5	IS 20665	20	IS 19053
6	IS 2398	21	IS 303
7	IS 9713	22	IS 6154
8	IS 30619	23	IS 25442
9	IS 29409	24	IS 19026
10	GCP_Sb_0510	25	E 36-1
11	IS 20700	26	SSM 379
12	IS 2807	27	IS 15526
13	GCP_Sb_0662	28	IS 18922
14	IS 20724	29	IS 13
15	IS 4027	30	SSM 501

Sr.No.	Genotypes	Sr.No.	Genotypes
31	E 36-1	46	IS 25910
32	IS 30441	47	IS 19455
33	IS 14446	48	IS 6973
34	IS 2179	49	IS 1127
35	IS 21425	50	IS 20763
36	IS 5867	51	IS 4821
37	IS 22040	52	IS 29472
38	IS 6193	53	IS 29375
39	IS 2367	54	IS 9586
40	IS 22325	55	IS 22291
41	IS 10876	56	IS 10234
42	IS 3121	57	IS 2430
43	IS 32050	58	IS 9911
44	IS 29569	59	IS 31693
45	IS 10978	60	IS 29496

Check included in the study: - Parbhani Moti

3.2 Experimental method

Single row of each of 60 entries along with 1standard check Parbhani Moti were sown in *rabi* season during 2013-14 in randomized block design with three replications at experimental farm of sorghum research station, V.N.M.K.V., Parbhani.

Experimental Details:-

1.	Design	:	Randomized block design
2.	Spacing	:	A) row to row -45cm
			B) Plant to plant-15cm
3.	Replications	:	Three
4.	(1) Plot size	:	1 row of 2 m length
	(2) Block	:	Four
5.	Fertilizer dose	:	40:20:0 N, P_2O_5, K_2O

3.2.1 Cultural practices

Seed treatment with 70% thiamethoxam @ 3 g per kg of seed was given to protect the crop from shoot fly infestation. Sowing was done by dibbling on 23rd October, 2013. Fertilizers were applied @ 40:20:0 NPK

Kg/ha at the time of sowing. The agronomic and plant protection measures were followed as and when required during the period of crop growth.

3.2.2 Recording of observations

Observations were recorded on five randomly selected plants in each entry from each replication for all the characters except days to 50% flowering, plant stand and shootfly deadheart % for which observations are recorded on plot basis. Observations were recorded for the following 16 characters.

1. Plant stand

Number of plants in the plot was counted after few days of emergence.

2. Days to 50% flowering

Days required from the date of sowing to the day when 50% of the plants in each entry commenced flowering.

3. Shoot fly deadheart (%)

Number of dead hearts first counted. The percentage of dead heart was calculated on the basis of total plants in plot.

DH% = No. of dead hearts/ total no. of plants in the entry x 100.

4. Seedling vigour (1 to 5)

The observation was recorded on 14^{th} days after emergence for each entry and measured on 1 to 5 scales.

Vigour scale	Plant vigour
1	> 90% of seedling vigour.
2	75 - 90% of seedling vigour.
3	51 - 75% of seedling vigour.
4	25 – 50% of seedling vigour.
5	< 25% of seedling vigour.

5. Number of leaves / plant

Number of leaves was counted from the base of plant to ear head at anthesis.

6. Leaf length (cm)

Length of the third leaf from top was measured in centimeter from base to the tip after panicle emergence.

7. Leaf breadth (cm)

Breadth of the third leaf was measured in centimeter at the broadest region of leaf after the panicle emergence.

8. Plant height (cm)

Height was measured in centimeters from the base of the plant to the top of the panicle at the time of maturity.

9. Panicle length (cm)

Length of panicle was measured in centimeters from lowest node of rachis to tip of head.

10. Panicle girth (cm)

Width of panicle in centimeters was measured at the broadest point of panicle.

11. Chlorophyll content (%)

Chlorophyll content of 3rd leaf from top was estimated by chlorophyll SPAD meter reading.

12. Relative water content

Relative water content (RWC) of leaves was estimated at flowering stage by using formula

$$RWC = \frac{\text{Fresh Weight} - \text{Dry weight}}{\text{Turgid weight} - \text{Dry weight}}$$

13. 100 seed weight (g)

Weight of 100 seed was measured in gram in respect of each selected plant in each replication.

14. Fodder yield / plant (g)

After harvesting of crop dry fodder weight per plant recorded in grams.

15. Grain yield / plant (g)

Observational plant panicles were threshed and grain weight per plant was recorded in grams.

16. Panicle weight (g)

Panicle from selected plants was weighed separately in grams.

3.3 Statistical Analysis

The data was subjected for statistical analysis as per Panse and Sukhatme, (1985).

3.3.1 General analysis of variance

$$\text{Correction Factor (C.F.)} = \frac{(\Sigma x....)^2}{N}$$

$$\text{Total sum of squares} = (\Sigma xij)^2 - \text{C.F.}$$

$$\text{Treatment sum of squares} = \frac{(\Sigma xi)^2}{r} - \text{C.F.}$$

$$\text{Replication sum of squares} = \frac{(\Sigma xj)^2}{t} - \text{C.F.}$$

The analysis of variance of simple randomized block design table is set out as under.

Source of variation	Degree of Freedom	S.S.	M.S.S.	F
Replications	(r-1)	$\frac{(\Sigma x.j)^2}{r}$ - C.F.	$\frac{\text{R.S.S.}}{r-1}$	$\frac{\text{RMSS}}{\text{EMSS}}$
Treatments	(t-1)	$\frac{(\Sigma x.i)^2}{r}$ - C.F.	$\frac{\text{T.S.S.}}{t-1}$	$\frac{\text{TMSS}}{\text{EMSS}}$
Error	(r-1) (t-1)	--	EMSS	--
Total	[(r x t) -1]	--	--	--

Estimation of mean and range

The mean value for each character will be worked out by dividing sum of all observations by number of observations

$$\bar{X} = \frac{\sum Xi}{n}$$

Where,

$\bar{X}$ = Mean of the character.

$\sum Xi$ = summation of all observations.

n = number of observations.

Range

The lowest and highest values from mean of each character will be recorded as range.

1. **Coefficient of variation (C.V.)**

$$\text{Coefficient of variation (C.V.)} = \frac{\sqrt{EMS}}{\bar{X}} \times 100$$

Where,

EMS = Error Mean Sum of Squares.

2. **Standard error and Critical difference**

The standard error (SE) and critical difference (CD) between two means will be calculated as below

a) Standard error of mean

$$SE(m) = \frac{\sqrt{\sigma^2 e}}{r}$$

Where,

$\sigma^2 e$ = EMS=Error Mean Sum of Squares.

b) Standard error of difference between two means will be calculated as S.E. of difference of mean [SE (d)],.

$$\text{S.E. of difference of means} = SE(m) \times \sqrt{2}$$

Critical difference (CD)

$$CD = S.E.(d) \times t \text{ table.}$$

Where,

t = value at 5 and 1 per cent level of probability for respective error degrees of freedom.

3. Estimation of components of variation

The phenotypic, genotypic and environmental variances will be calculated by utilizing the respective mean squares values from the variance table.

b) Genotypic variance

$$\sigma^2 g = \frac{GMS - EMS}{r}$$

c) Phenotypic variance

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

Where,

GMS = Genotypic mean sum of squares

EMS = Error mean sum of squares

r = Number of replications

4. Genetic Variability

The genetic variability will be estimated by calculation of following parameters.

a) Geniotypic coefficient of variation (GCV)

Genotypic and phenotypic coefficient of variation will be calculated by the formulae as suggested by Burton and Devane (1952).

$$GCV = \frac{\sqrt{\sigma^2 g}}{\overline{X}} \times 100$$

Where,

$\sigma^2 g$ = Genotypic variance

$\overline{X}$ = Mean of the character

b) Phenotypic coefficient of variation (PCV)

$$PCV = \frac{\sqrt{\sigma^2 p}}{\overline{X}} \times 100$$

Where,

$\sigma^2 p$ = Phenotypic variance

$\overline{X}$ = Mean of the character

5. Estimation of heritability (h^2b)

Heritability of characters is an index of its transmissibility. It may be defined as the proportion of genotypic variance to phenotypic variance in percentage. Broad sense Heritability will be estimated for various characters by the formulae suggested by Lush (1949).

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

Where

$\sigma^2 g$ = Genotypic variance

$\sigma^2 p$ = Phenotypic variance

Estimation of genetic advance (GA)

The genetic advance will be calculated in percent by the formula suggested by Johnson *et al.* (1955a).

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

b) GA as percentage of mean

$$GA\,(m) = \frac{GA}{\overline{X}} \times 100$$

Where,

$\sigma^2 g$ = Genotypic variance

$\sigma^2 p$ = Phenotypic variance

σp = Phenotypic standard deviation

K = Selection differential at 5 per cent selection intensity (2.06)

$\overline{X}$ = Mean of the characters.

CORRELATION STUDIES

The relationship between two or more quantitative characters is of great interest and carries much practical significance. Correlation is a measure of the degree to which characters are associated with yield or among themselves (Burton, 1952)

1. Estimation of genotypic and phenotypic correlation coefficients

These will be estimated as a suggested by Hayes *et al.* (1995)

$$Genotypic\ r1{,}2 = \frac{\text{Genotypic covariance 1,2}}{\sqrt{\text{Genotypic variance of 1 X Genotypic variance of 2}}}$$

$$Phenotypic\ r1{,}2 = \frac{\text{phenotypic covariance 1,2}}{\sqrt{\text{Phenotypic variance of 1 X Phenotypic variance of 2}}}$$

Where, r = Correlation coefficient,

1and 2 = Two variable under study.

Significance test

Significance of simple correlation coefficient will be determined from table of correlation coefficient at 5% and 1% levels of significance and their values will be compared against n-2 degrees of freedom.

PATH COEFFICIENT ANALYSIS

The technique of path coefficient analysis was developed by Wright (1921) as a means of separating direct and indirect contributions of various factors. Path coefficient analysis is a standard partial regression coefficient analysis and such measures, the direct influence of one variable upon other and permits the separation of correlation coefficient into components of direct and indirect effects. To establish a cause and effect relationship, the genotypic and phenotypic correlation coefficients will be partitioned into direct and indirect effects by path analysis as suggested by Dewey and Lu (1959). The first step in path analysis is to prepare a path diagram based on cause and effect relationship. The concept is that yield is the function of various components like X_1, X_2, X_3. Then these components show following type of association with one another.

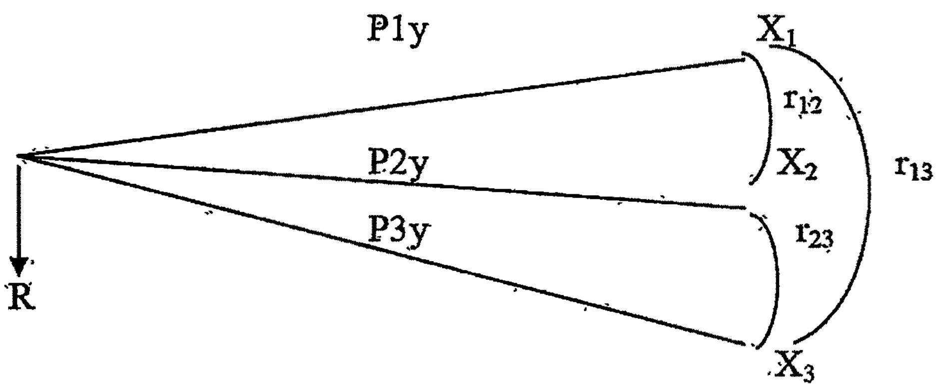


Fig. 1 Path Diagram

From this figure, it is obvious that yield is the result of X_1, X_2 and X_3 and some other undefined factor denoted by 'R'. The double arrowed lines indicate mutual association as measured by correlation coefficients and the single arrowed line represent direct influence as measured by path coefficients P_{ij}.

Direct and indirect contribution of 8 variables to seed cotton yield were calculated by solving a set of simultaneous equations of the form as per Dewey and Lu (1959).

rny = pny + rn2p2y + rn3p3y+…..

Where,

Rny = represents correction coefficient between one component and yield

rn2 = represents correlation coefficient between that character and each of other components

pny = represents path coefficient between that characters and yield.

Matrix-A **Matrix-B**

$$\begin{pmatrix} r1,y \\ r2,y \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ rn.y \end{pmatrix} = \begin{pmatrix} P1 \\ P2 \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ Pn \end{pmatrix} \begin{pmatrix} r1,1 & r1,2 \ldots\ldots r1,n \\ r2,1 & r2,2 \ldots\ldots r2,n \\ \cdot & \cdot \quad\quad \cdot \\ \cdot & \cdot \quad\quad \cdot \\ \cdot & \cdot \quad\quad \cdot \\ \cdot & \cdot \quad\quad \cdot \\ \cdot & \cdot \quad\quad \cdot \\ rn,1 & rn,2 \ldots\ldots 1 \end{pmatrix}$$

Where,

r1,y = Correlation between one component character and yield

The B matrix was inverted (B^{-1}) and path coefficients (P_{ij}) will be obtained as

$$(P_{ij}) = A \times (B^{-1})$$

The indirect effect of a particular character through other characters will be obtained by multiplication of direct path and particular correlation coefficients between the characters, separately.

$$\text{Indirect effects} = r_{ij} \times P_{ij}$$

Where,

i = 1 to 6

j = 1 to 6

$P_{ij} = P_{iY1}, P_1y_2, \ldots, P_{ny}$

Path coefficients (P_{ij}), correlation coefficients (r_{ij}) and residual factors will be diagrammatically presented.

Residual effect will be calculated by using the following formula-

The residual factors i.e. variation in yield unaccounted for by these association will be calculated from the following formula,

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

Where,

R^2 = (P1y, r1y + P2y, r2y +.........+ Pny, rny)

Where,

P1y, P2y ....Pny = path values

r1y, r2y ....rny = correlation coefficients

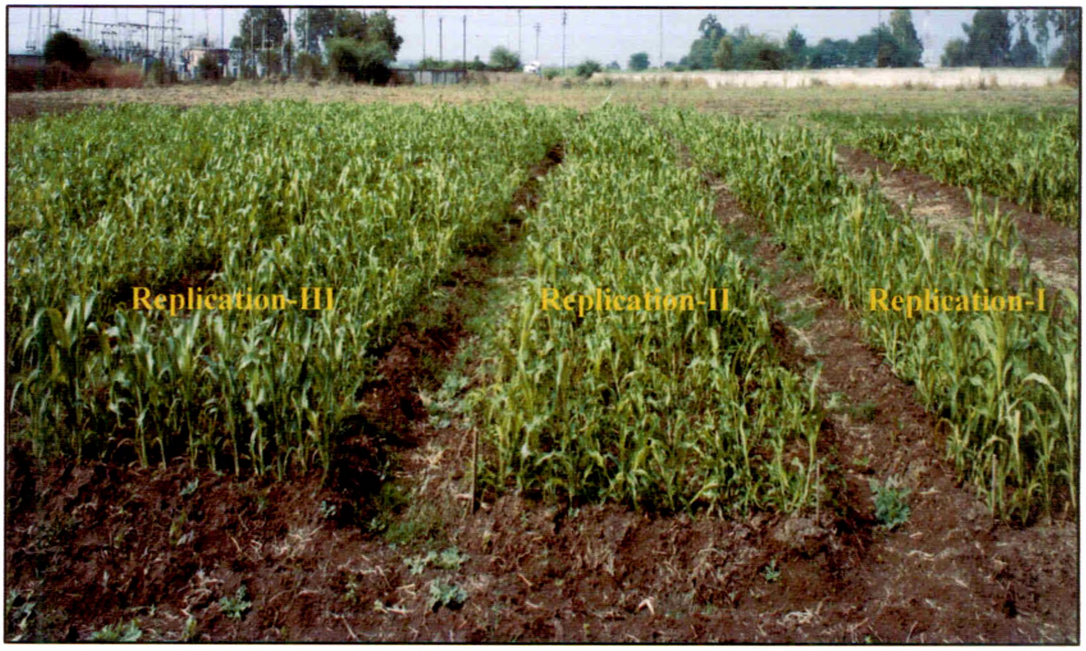


Plate 1. General view of experimental field.

Results

CHAPTER IV

RESULTS

The results of present investigation are presented under the following major headings:

4.1 Analysis of variance

4.2 Mean performance

4.3 Genetic parameter

4.4 Correlation

4.5 Path analysis

4.1 Analysis of variance

Analysis of variance for various characters are presented in Table-4.1. It revealed that the differences among the treatments in respect of all the characters studied were significant at 5 and 1 per cent level of significance indicating the presence of sufficient amount of variability among these characters.

4.2 Mean performance

The mean performance of lines for 16 characters are presented in (Table 4.2).

4.2.1 Plant stand

Plant stand ranged from 17.66 to 28.33 with mean of 23.30.Maximum plant stand was observed in genotypes IS 20713 (28.33) followed by IS 9586 and IS 2430 (28.00), IS 4821 (27.33). However, genotypes IS 2807 (17.66) followed by IS 30619 (19.00) recorded minimum plant stand.

Table 4.1. Analysis of variance for different yield and yield contributing characters in *rabi* sorghum.

Source of variation	d.f.	Plant stand	Days to 50 % flowering	Seedling vigour	Number of leaves	Leaf length (cm)	Leaf breadth (cm)	Plant height (cm)	Panicle length (cm)
Replications	2	11.62	36.30	0.62	0.07	24.12	0.14	336.50	2.84
Treatments	60	23.05**	117.58**	0.85**	1.15**	63.31**	0.69**	2430.54**	17.56**
Error	120	12.06	20.06	0.36	0.48	23.76	0.32	474.55	5.77

Source of variation	d.f.	Panicle girth (cm)	Chlorophyll content %	Relative water content %	100 seed weight (g)	Panicle weight (g)	Shootfly deadheart%	Fodder yield	Grain yield
Replications	2	1.29	4.24	35.56	0.23	3.48	101.09	7065.71	118.62
Treatments	60	3.59**	62.71**	179.84**	0.61**	62.70**	322.99**	12697.07 **	801.12**
Error	120	1.16	24.73	29.52	0.24	12.08	145.70	3537.44	141.91

**Significant at 1 per cent

*Significant at 5 per cent

4.2. Mean performance for yield and yield contributing characters in *rabi* sorghum.

Sr No.	Genotypes	Plant stand	Days to 50% flowering	Seedling vigour	Number of leaves	Leaf length (cm)	Leaf breadth (cm)	Plant height (cm)	Panicle length (cm)	Panicle girth (cm)	Chlorophyll content%	Relative water content%	100 seed weight (g)	Panicle weight (g)	Shootfly deadheart%	Fodder yield (g)	Grain yield (g)
1	IS 27	21.33	69.33	2.66	7.66	61.23	5.56	232.00	16.20	13.00	54.78	69.64	2.04	38.33	68.82	221.33	51.33
2	IS 25596	24.00	70.66	3.66	6.33	51.02	3.76	169.66	13.96	15.06	44.62	68.17	3.11	46.66	83.07	150.66	63.66
3	IS 8348	20.66	69.66	3.66	7.66	58.68	5.03	184.66	12.96	14.84	50.45	88.44	1.74	52.33	56.06	330.33	59.00
4	SSM 1370	22.00	64.33	3.66	6.66	51.19	5.03	138.33	18.30	13.73	49.90	83.72	2.14	53.00	57.57	219.33	60.00
5	IS 20665	20.00	70.33	3.00	6.66	50.68	5.16	194.33	15.96	13.93	51.86	65.84	2.63	44.00	53.50	195.00	46.66
6	IS 2398	22.33	73.33	3.00	8.00	51.18	4.61	109.33	16.16	16.20	50.09	75.53	3.04	52.00	67.82	258.00	38.33
7	IS 9713	20.00	76.00	3.33	7.33	54.90	4.74	169.33	15.63	15.13	51.28	65.93	2.31	59.33	76.37	223.33	39.33
8	IS 30619	19.00	57.33	3.33	6.33	52.84	5.14	96.00	18.50	15.53	51.12	76.76	3.00	44.00	48.05	171.66	39.66
9	IS 29409	20.33	74.33	2.66	6.66	50.62	4.54	215.00	14.96	13.56	38.98	81.87	2.28	48.66	52.29	156.66	67.66
10	GCP_Sb_0510	22.00	67.66	3.33	8.33	56.36	4.97	211.33	18.86	15.20	54.12	82.39	2.92	45.00	56.01	307.00	63.66
11	IS 20700	20.66	76.33	3.66	7.00	53.20	5.26	159.66	18.53	13.40	50.19	77.74	3.09	47.33	54.91	276.33	67.66
12	IS 2807	17.66	70.66	2.66	6.66	56.63	5.50	208.66	19.30	13.33	54.69	82.40	2.91	52.00	70.06	222.00	55.66
13	GCP_Sb_0662	20.66	70.00	3.00	6.66	53.69	4.66	175.33	19.06	13.50	54.55	69.67	2.52	42.33	63.80	273.00	70.66
14	IS 20724	20.00	68.66	3.33	6.00	59.73	5.56	160.33	17.43	15.10	61.64	69.03	2.15	56.33	50.84	252.33	67.66
15	IS 4027	21.00	66.00	2.66	6.33	49.94	4.44	167.00	19.10	14.00	50.76	78.03	2.21	47.00	41.11	229.33	64.33

Table 4.2 Contd…

Sr No.	Genotypes	Plant stand	Days to 50% flowering	Seedling vigour	Number of leaves	Leaf length (cm)	Leaf breadth (cm)	Plant height (cm)	Panicle length (cm)	Panicle girth (cm)	Chlorophyll content %	Relative water content %	100 seed weight (g)	Panicle weight (g)	Shootfly deadheart%	Fodder yield (g)	Grain yield (g)
16	IS 20713	28 33	71.33	3 66	7.00	53.37	5 42	176 00	20.73	12 86	49 66	67 17	3 30	50.00	61.32	311.00	69.00
17	IS 3971	26 00	76.00	3 66	7 00	59.39	4.82	218.33	14.73	12 93	55 36	63 79	2 81	48.33	55 14	304.33	55 33
18	GCP_Sb_0659	26 33	73 33	2 66	6.33	62 48	5 17	159 33	17 50	13.20	58 69	61.14	1 99	49 33	75 46	294 33	67 33
19	SSM 547	24 66	68.00	2.33	7 00	56 91	4 82	127 66	19.40	14 53	58.92	62.36	2 95	44 66	71.64	344.33	48 66
20	IS 19053	23 00	78.33	3 00	7 00	66 14	4 58	214 00	16 86	14.63	53.72	61 17	2.76	48 66	57.80	282.33	76 00
21	IS 303	22.66	72 00	3 00	7 66	55.68	4.22	168 66	19.73	15 93	50.75	64 29	1.97	54 66	68 69	287.66	56 66
22	IS 6154	22 00	76 33	3 33	7 00	58 44	5 04	162 33	12 86	16 00	48 72	61 29	2 48	48 00	64 34	232.33	61 33
23	IS 25442	25 33	80 33	3 00	8 33	54 46	5 42	198 66	14 53	14 50	53 82	61 03	2.89	50 33	82 22	232 66	81 66
24	IS 19026	26 33	89 00	3 00	7 33	51 30	4 97	128 00	18 63	15 03	47 06	60.56	2 54	53.33	58.30	289 33	49 66
25	E 36-1	26 66	82.66	3.33	8 00	56 51	4 84	180.33	16 76	15 20	50.89	62 14	2 67	52 00	55 52	408 33	41 00
26	SSM 379	26 66	80 66	2.66	7 33	56 85	5 00	175 33	18 40	13 13	53 77	62.11	2 31	51.33	70 36	273 66	44 00
27	IS 15526	25.00	69 66	3 66	7 00	62 17	4.26	163.66	18 53	13 03	55 87	58 35	2 82	59 00	56 51	144 00	81 00
28	IS 18922	25.00	70 66	4.33	6.33	43 22	3 94	189 33	16 06	16 66	45 80	57.89	2 26	54 33	53.10	194 66	33 00
29	IS 13	26 00	69.66	3 00	6 00	60 65	5.12	185 66	14 96	15.83	57.32	59.64	1 61	48 33	58 90	240 33	83 66
30	SSM 501	24.66	78 66	2.66	7 33	64.06	4.89	186.66	14 33	14 83	57 18	66.65	3 01	38.66	74.42	127 00	88 00

Table 4.2 Contd...

Sr No.	Genotypes	Plant stand	Days to 50% flowering	Seedling vigour	Number of leaves	Leaf length (cm)	Leaf breadth (cm)	Plant height (cm)	Panicle length (cm)	Panicle girth (cm)	Chlorophyll content%	Relative water content%	100 seed weight (g)	Panicle weight (g)	Shootfly deadheart%	Fodder yield (g)	Grain yield (g)
31	E 36-1	22.66	76.33	2.33	5.66	48.68	5 95	143 33	14 53	15.46	54 59	61.29	3.10	51.00	60 91	297.00	63.33
32	IS 30441	21 66	69 33	3.00	6 33	49.97	5.36	121 33	16 43	12.23	41.72	60.69	3.20	48.00	73.13	185.66	87.00
33	IS 14446	21.66	69 00	2 66	7 00	50.82	5.15	186 00	13.10	15 16	49 96	72 32	3 06	52.00	62 98	248.00	51.00
34	IS 2179	19 33	71 00	3.66	7.33	55.31	4 36	166 33	18.20	14.86	51 92	69 48	2.28	54 00	55.75	199.33	58 00
35	IS 21425	24.00	80 00	3 33	7 66	52 37	5 30	167 66	16 73	14 16	49.20	58.19	1.46	47.66	63 47	250 66	78.33
36	IS 5867	20.00	81.00	3 66	8 00	58 2	4.48	170 00	18 30	14 56	54.76	73 28	3.23	45 33	64 81	322.66	54.66
37	IS 22040	22 33	78.00	3.66	7 33	57.76	5 37	160.66	16.50	14.60	51 79	61 43	3.05	46.00	61 87	255 00	88 33
38	IS 6193	19.33	68.00	2 66	6.66	52 70	4.41	152.66	13 30	14 90	46 12	64.03	2 28	41 00	83 56	167.33	39.00
39	IS 2367	21 33	75 66	3.00	7 00	58 03	4 05	189 66	16 96	14.90	50 66	59 23	2.24	45.66	75.30	260 33	49.66
40	IS 22325	19 66	77 00	3 00	7 33	57 75	5.11	171 66	20 86	14 90	53 90	59.49	3 49	53.33	67 38	191 33	93 33
41	IS 10876	22 00	78 33	3 33	7.66	53 64	5 34	147 66	15 76	15.23	51 41	58.88	2.81	47 33	50 64	226.66	66 33
42	IS 3121	25.00	65.00	2 66	6 33	52.36	4.76	193 66	13 23	13 80	44 49	58 38	1 86	52.66	71 00	306 00	55.00
43	IS 32050	23 66	78 33	2 33	6 33	53 60	5 38	161 66	13.83	14.73	48.26	59.09	2.84	37.33	48.10	311.66	75 66
44	IS 29569	21 66	80.33	3.33	6.66	55 82	5 04	157.33	11 66	14.60	54 67	62 51	2 94	51.33	61 48	388.00	81 66
45	IS 10978	23 00	72.66	3 33	7 66	58.68	5.08	178 33	20.26	14.20	55 88	63.17	2.57	49 33	70.95	252 33	76 00

Table 4.2 Contd...

Sr No.	Genotypes	Plant stand	Days to 50% flowering	Seedling vigour	Number of leaves	Leaf length (cm)	Leaf breadth (cm)	Plant height (cm)	Panicle length (cm)	Panicle girth (cm)	Chlorophyll content%	Relative water content%	100 seed weight (g)	Panicle weight (g)	Shootfly deadheart%	Fodder yield (g)	Grain yield (g)
46	IS 25910	22 66	71.33	3.33	7 33	51 94	4 85	169.66	18.86	16 10	52 69	65.22	2 45	50.00	63.77	315.00	47.00
47	IS 19455	23.33	98.00	5 00	7 00	54.97	4 66	197.66	15.20	14 13	52.20	63.98	2 08	49 33	70 30	280 33	56 00
48	IS 6973	23.33	77.66	2.33	7 33	50 51	4 95	188.33	16.86	15.86	46 92	64.37	2.97	49.66	87.15	237.33	49 33
49	IS 1127	26.00	71.33	2 66	7 33	57 95	4 68	141.66	12.26	12 76	48.44	60.04	2.91	52 33	68.42	246.66	83 33
50	IS 20763	22.00	77.00	3 33	7.66	58 28	4 22	126 33	17 53	16 16	54 64	61.11	3.22	50 33	68 60	359 66	75 00
51	IS 4821	27.33	76.33	2 66	7.00	61.48	5 92	140.33	12 20	17 43	50.52	66 41	2 96	51 33	61 94	356 00	41 00
52	IS 29472	26.00	70 66	3.66	8 00	54 49	5.24	185.00	19.96	14.20	50 42	64 40	2.51	54 33	63.10	407.33	37.66
53	IS 29375	23.33	70.66	3.33	6.66	48 74	4.11	195 00	20 40	14 63	47.60	67 53	2.55	43.66	60 41	285.66	47 66
54	IS 9586	28.00	69.33	2 33	7 33	56 44	4.42	124 66	15.01	13.26	48.54	61.73	2.93	44.66	57 37	203 03	78 66
55	IS 22291	23 00	76 33	3 66	7.00	49.80	4.32	144.33	15.43	13.63	46 51	65 30	2 34	45.33	41 49	212 33	82 00
56	IS 10234	21.33	76 66	4.00	6 66	42.90	4.74	145 33	16.63	15.76	44.21	61 44	2 61	47 33	69 90	282.66	76 00
57	IS 2430	28 00	74 66	3.33	7 66	54.88	5 09	153 33	12.10	15 10	43.87	63 12	2 38	43.00	59.52	280 66	36.33
58	IS 9911	26 33	76.33	3.00	6 33	55 91	5.04	177.00	15.93	14 53	50.22	77.96	2 53	50.00	68.29	385.66	87 66
59	IS 31693	25.00	76 33	4 00	6.00	49.41	3.85	137.66	14.63	12 83	40.38	64.77	2.98	45.00	87 63	211.33	48 00
60	IS 29496	27.33	68.00	3.33	7.00	50.86	5.13	134.66	14 20	15 76	44.96	59 53	3.09	48.00	68.42	290 66	89 33
61	Parbhani moti (Check)	30 66	62.66	2.33	6 00	59 33	5 20	125 00	13 83	14 23	45 78	83.96	2 04	52 00	48 32	166 70	64 00
	Mean	23.30	73.68	3.16	7.02	54.87	4.88	166.86	16 37	14 56	50 72	66.51	2.61	48.81	63 60	259.60	62.42
	SE+/-	2 00	2 58	0 35	0 40	2 81	0 32	12.57	1 38	0.62	2.87	3.13	0 28	2.00	6.96	34 33	6.87
	CD at 5%	5 61	7 24	0.98	1 12	7 88	0.92	35.21	3 88	1.74	8.04	8.78	0 80	5 62	19.51	96.15	19.25

4.2.2 Days to 50 % flowering

For the character days to 50 % flowering the range was observed from 57.33 to 98.00 with a mean of 73.68. Among all genotypes earliest flowering was observed in IS 30619 (57.33 days).

Among all genotypes late flowering was observed in IS 19455(98 days) followed by IS 19026 (89 days), E 36-1 (82.66 days).

Among all genotypes IS 30619 (57.33 days) shown earliness over check Parbhani Moti (62.66 days).

4.2.3 Seedling vigour (scale 1 to 5)

Seedling vigour ranged from 2.33 to 5.00 with mean of 3.16. Among all genotypes high seedling vigour was observed for genotypes SSM 547 (2.33) followed by E 36-1 (2.33), IS 32050 (2.33), IS 6973(2.33), IS 9586 (2.33).

Among all genotypes low seedling vigour was observed for genotypes IS 19455 (5.00) followed by IS 18922 (4.33), IS 10234 (4.00).

4.2.4 Number of leaves / plant

Number of leaves ranged from 5.66 to 8.33 with mean of 7.02. Among all genotypes maximum number of leaves were observed in genotypes GCP_Sb_0510 (8.33) followed by IS 25442 (8.33), IS 2398 (8.00), E 36-1 (8.00), IS 5867 (8.00).

Minimum number of leaves were observed in genotypes E 36-1 (5.66) followed by IS 13 (6.00), IS 31693 (6.00).

4.2.5 Leaf length (cm)

Leaf length ranging from 42.90 cm to 66.14 cm with mean of 54.87 cm. Among all genotypes highest leaf length was observed in genotypes

IS 19053 (66.14 cm) followed by SSM 501 (64.06 cm), GCP_Sb_0659 (62.48 cm), IS15526 (62.17cm).

The lowest leaf length was observed in genotypes IS 10234 (42.90 cm) followed by IS 18922 (43.22 cm), E 36-1 (48.68 cm).

4.2.6 Leaf breadth (cm)

Leaf breadth ranging from 3.76 cm to 5.95 cm with mean of 4.88 cm. Among all genotypes the highest leaf breadth was observed in genotypes E 36-1 (5.95 cm) followed by IS 4821 (5.92 cm), IS 27 (5.56 cm), IS 20724 (5.56 cm).

The lowest leaf breadth was observed in genotypes IS 25596 (3.76 cm) followed by IS 31693 (3.85 cm), IS 18922 (3.94 cm).

4.2.7 Plant height (cm)

Wide variation was observed for plant height ranging from 96.00 cm to 232.00 cm with mean of 166.86 cm. Among all genotypes the highest plant height was observed in IS 27 (232.00 cm) followed by IS 3971 (218.33 cm), IS 29409 (215.00 cm), IS 19053 (214 cm), GCP_Sb_0510 (211.33 cm). These genotypes had shown highest value over check Parbhani Moti (125.00 cm).

The lowest plant height was observed in genotypes IS 30619 (96.00 cm) followed by IS 2398 (109.33 cm), IS 30441 (121.33 cm).

4.2.8 Panicle length (cm)

Panicle length ranging from 11.66 cm to 20.86 cm with mean of 16.37 cm. The highest panicle length was observed in genotypes IS 22325 (20.86 cm) followed by IS 20713 (20.73 cm), IS 29375 (20.40 cm), IS 10978 (20.26 cm).

The lowest panicle length was observed in IS 29569 (11.66 cm) followed by IS 2430 (12.10 cm), IS 4821 (12.20 cm).

4.2.9 Panicle girth (cm)

Panicle girth ranged from 12.23 cm to 17.43 cm with mean of 14.56 cm. The panicle girth was highest in genotypes IS 4821 (17.43 cm) followed by IS 20763 (16.16 cm), IS 25910 (16.10 cm), IS 303 (15.93 cm).

The lowest panicle girth was observed in genotypes IS 30441 (12.23 cm) followed by IS 1127 (12.76 cm), IS 31693 (12.83 cm).

4.2.10 Chlorophyll content %

Chlorophyll content % in the plant ranging from 38.98% to 61.64 % with mean of 50.72 %. The chlorophyll content was highest in IS 20724 (61.64 %) followed by SSM 547 (58.92 %), GCP_Sb_0659 (58.69 %), IS 13 (57.32 %), SSM 501 (57.18 %). These genotypes had shown highest value over check Parbhani Moti (45.78 %).

The lowest chlorophyll content % was observed in genotypes IS 29409 (38.98 %) followed by IS 31693(40.38 %), IS 30441 (41.72 %).

4.2.11 Relative water content

Relative water content ranging from 57.89 % to 88.44 % with mean of 66.51 %. Among all genotypes relative water content was observed highest in IS 8348 (88.44 %) followed by SSM 1370 (83.72 %), IS 2807 (82.40 %), GCP_Sb_0510 (82.39 %), IS 29409 (81.87 %).

The lowest relative water content was observed in genotypes IS 18922 (57.89 %) followed by IS 15526 (58.35 %), IS 3121 (58.38 %).

4.2.12 100 seed weight (g)

The character 100 seed weight ranging from 1.46 g to 3.30 g with mean of 2.61. Among all genotypes 100 seed weight was observed highest in IS 20713 (3.30 g) followed by IS 5867 (3.23 g), IS 20763 (3.22 g) IS 30441

(3.20). These genotypes had shown highest value over check Parbhani Moti (2.04 g).

The lowest 100 seed weight was observed in genotypes IS 21425 (1.46 g) followed by IS 13 (1.61 g), IS 8348 (1.74 g).

4.2.13 Panicle weight (g)

Wide range of variation was observed for panicle weight ranging from 33.33 g to 59.33 g with mean of 48.81. The highest panicle weight was observed in genotypes IS 9713 (59.33 g) followed by IS 15526 (59.00 g), IS 20724 (56.33 g), IS 303 (54.66 g). These genotypes had shown highest value over check Parbhani Moti (52.00 g).

The lowest panicle weight was observed in IS 32050 (37.33 g) followed by IS 27 (38.33 g), SSM 501 (38.66 g).

4.2.14 Shootfly deadheart %

Shootfly deadheart % ranging from 41.11 % to 87.63 % with mean of 63.60 %. The highest per cent of shootfly deadheart was observed in genotypes IS 31693 (87.63 %) followed by IS 6973 (87.15 %), IS 6193 (83.56 %).

The lowest per cent of shootfly deadheart was observed in IS 4027 (41.11 %) followed by IS 22291 (41.49 %), IS 30619 (48.05 %). These genotypes had shown lowest % of shootfly deadheart over check Parbhani Moti (48.32).

4.2.15 Fodder yield / plant (g)

Wide range of variation was observed for fodder weight ranging from 127.00 g to 408.33 g with mean of 259.60 g. The highest fodder weight was observed in genotypes E 36-1 (408.33 g) followed by IS 29472 (407.33 g), IS 29569 (388.00 g), IS 9911 (385.66 g), IS 20763 (359.66 g). These genotypes had shown highest value over check Parbhani Moti (166.70 g).

The lowest fodder weight was observed among genotypes SSM 501 (127.00 g) followed by IS 15526 (144.00 g), IS 25596 (150.66 g).

4.2.16 Grain yield / plant (g)

Wide range of variation was observed for grain yield ranging from 33.00 g to 93.33 g with mean of 62.42 g. The highest grain weight was observed in genotypes IS 22325 (93.33 g) followed by IS 29496 (89.33 g), IS 22040 (88.33 g), SSM 501 (88.00 g), IS 9911 (87.66 g), IS 13 (83.66 g). These genotypes had shown highest grain weight over check Parbhani Moti (64.00 g).

The lowest grain weight was observed in genotypes IS 18922 (33.00 g) followed by IS 2430 (36.33 g), IS 29472 (37.66 g).

4.3 Genetic parameters

The characters under investigation were analyzed for various parameters viz. genotypic variance (σ^2 g), phenotypic variance (σ^2 p), genotypic coefficient of variation (GCV), phenotypic coefficient of variance (PCV), heritability (broad sense), genetic advance (GA) and expected genetic advance as % mean (EGA). The results are presented in Table-4.3.

4.3.1 Variability parameters for various characters

Heritability estimates are grouped as 60 % and above high, 30-60 % moderate and low below 30 %. Genetic advance as per cent of mean grouped as 20 % and above high, 11-20% moderate and below 10 % low.

4.3.1.1 Plant stand

The genotypic coefficient of variation (8.21 %) was lower than phenotypic coefficient of variation (17.02 %). Low heritability estimates (23.30 %) coupled with moderate expected genetic advance (10.46 %) was observed for this character.

Table 4.3. Range, mean, genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability and genetic advance for various characters in *rabi* sorghum.

Sr. No.	Characters	Range	Mean	GCV%	PCV%	Heritability %	GA (%)	EGA (%)
1	Plant stand	17.66-28.33	23.30	8.21	17.02	23.30	2.43	10.46
2	Days to 50% flowering	57.33-98.00	73.68	7.73	9.84	61.80	11.83	16.06
3	Seedling vigour	2.33-5.00	3.16	12.64	22.96	30.30	0.58	18.38
4	Number of leaves	5.66-8.33	7.02	6.71	11.99	31.30	0.69	9.91
5	Leaf length (cm)	42.90-66.14	54.87	6.61	11.07	35.70	5.72	10.43
6	Leaf breadth (cm)	3.76-5.95	4.88	7.17	13.71	27.40	0.48	9.91
7	Plant height (cm)	96.00-232.00	166.86	15.30	20.11	57.90	51.28	30.73
8	Panicle length (cm)	11.66-20.86	16.37	12.10	19.02	40.50	3.32	20.32
9	Panicle girth (cm)	12.23-17.43	14.56	6.17	9.65	40.90	1.51	10.42
10	Chlorophyll content%	38.98-61.64	50.72	7.01	12.05	33.80	5.46	10.77
11	Relative water content%	57.89-88.44	66.51	10.64	13.41	62.90	14.82	22.28
12	100 seed weight (g)	1.46-3.30	2.61	13.48	23.25	33.60	0.54	20.64
13	Panicle weight (g)	37.33-59.33	48.81	8.41	11.02	58.30	8.27	16.95
14	Shootfly deadheart%	41.11-87.63	63.60	12.08	22.49	28.90	10.90	17.13
15	Fodder yield (g)	127.00-408.33	259.60	21.28	31.27	46.30	99.28	38.24
16	Grain yield (g)	33.00-93.33	62.42	23.74	30.46	60.80	30.50	48.86

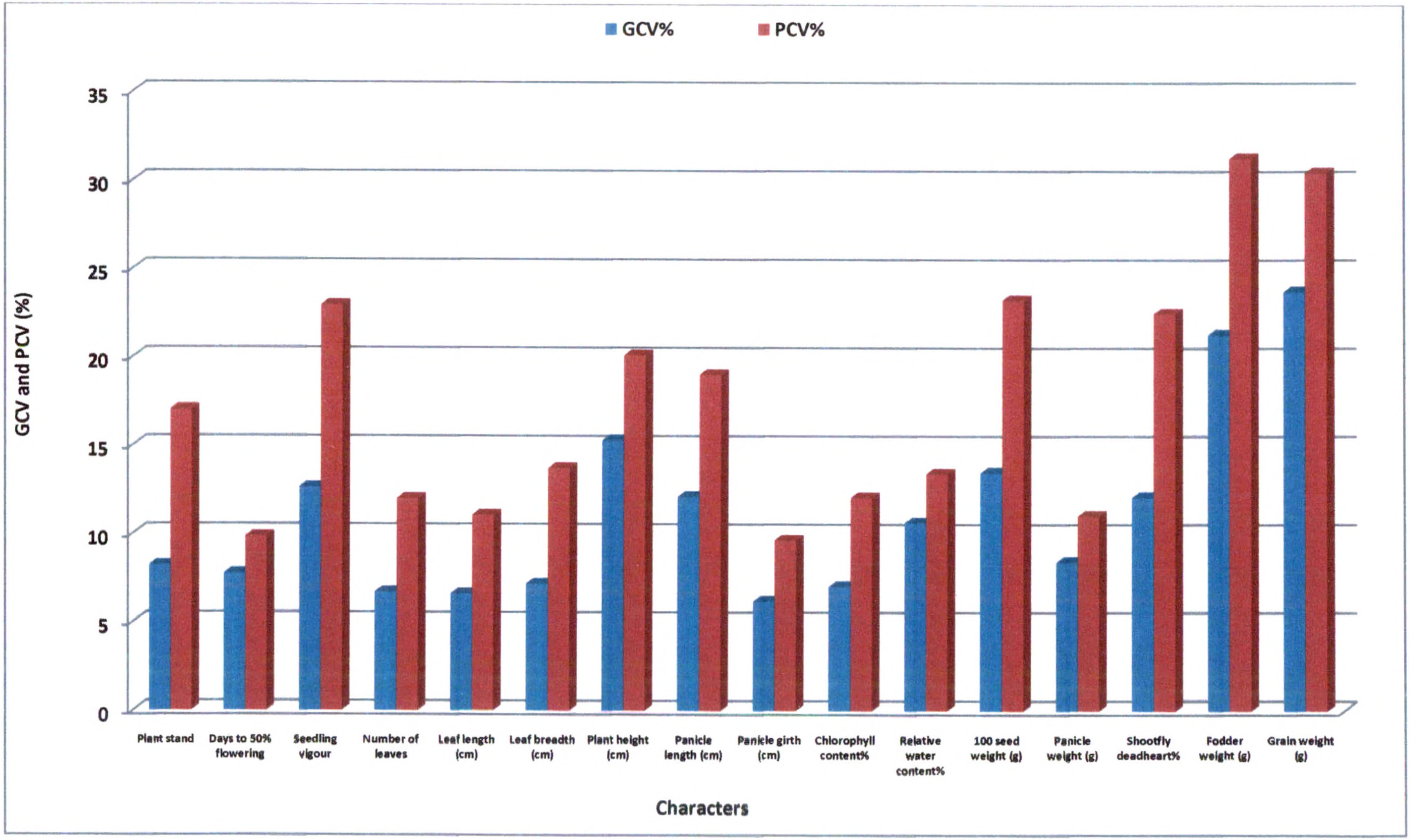


Fig 2. Genotypic and phenotypic coefficient of variations for yield and yield contributing characters in *rabi* sorghum.

4.3.1.2 Days to 50 % flowering

The genotypic coefficient of variation (7.73 %) was lower than phenotypic coefficient of variation (9.84 %). High heritability estimates (61.80 %) coupled with moderate expected genetic advance (16.06 %) was observed.

4.3.1.3 Seedling vigour (1 to 5)

The genotypic coefficient of variation (12.64 %) was lower than phenotypic coefficient of variation (22.96 %). High heritability estimates (30.30 %) coupled with moderate expected genetic advance (18.38 %) was observed.

4.3.1.4 Number of leaves / plant

The genotypic coefficient of variation (6.71 %) was lower than phenotypic coefficient of variation (11.91 %). Moderate heritability estimates (31.30 %) coupled with low expected genetic advance (9.91 %) was observed.

4.3.1.5 Leaf length (cm)

The genotypic coefficient of variation (6.61 %) was lower than phenotypic coefficient of variation (11.07 %). Moderate heritability estimates (35.70 %) coupled with moderate expected genetic advance (10.43 %) was observed.

4.3.1.6 Leaf breadth (cm)

The genotypic coefficient of variation (7.17 %) was lower than phenotypic coefficient of variation (13.71 %). Low heritability estimates (27.40 %) coupled with low expected genetic advance (9.91 %) was observed.

4.3.1.7 Plant height (cm)

The genotypic coefficient of variation (15.30%) was lower than phenotypic coefficient of variation (20.11 %). Moderate heritability estimates (57.90 %) coupled with high expected genetic advance (30.73 %) was observed.

4.3.1.8 Panicle length (cm)

The genotypic coefficient of variation (12.10 %) was lower than phenotypic coefficient of variation (19.02 %). Moderate heritability estimates (40.50 %) coupled with high expected genetic advance (20.32 %) was observed.

4.3.1.9 Panicle girth (cm)

The genotypic coefficient of variation (6.17 %) was lower than phenotypic coefficient of variation (9.65 %). Moderate heritability estimates (40.90 %) coupled with moderate expected genetic advance (10.42 %) was observed.

4.3.1.10 Chlorophyll content %

The genotypic coefficient of variation (7.01 %) was lower than phenotypic coefficient of variation (12.05 %). Moderate heritability estimates (33.80 %) coupled with moderate expected genetic advance (10.77 %) was observed.

4.3.1.11 Relative water content

The genotypic coefficient of variation (10.64 %) was lower than phenotypic coefficient of variation (13.41 %). High heritability estimates (62.90 %) coupled with high expected genetic advance (22.28 %) was observed.

4.3.1.12 100 seed weight (g)

The genotypic coefficient of variation (13.48 %) was lower than phenotypic coefficient of variation (23.25 %). Moderate heritability estimates (33.60 %) coupled with high expected genetic advance (20.64 %) was observed.

4.3.1.13 Panicle weight (g)

The genotypic coefficient of variation (8.41 %) was lower than phenotypic coefficient of variation (11.02 %). Moderate heritability estimates (58.30 %) coupled with moderate expected genetic advance (16.95 %) was observed.

4.3.1.14 Shootfly deadheart %

The genotypic coefficient of variation (12.08 %) was lower than phenotypic coefficient of variation (22.49 %). Low heritability estimates (28.90 %) coupled with moderate expected genetic advance (17.13 %) was observed.

4.3.1.15 Fodder yield / plant (g)

The genotypic coefficient of variation (21.28 %) was lower than phenotypic coefficient of variation (31.27 %). Moderate heritability estimates (46.30 %) coupled with high expected genetic advance (38.24 %) was observed.

4.3.1.16 Grain yield / plant (g)

The genotypic coefficient of variation (23.74 %) was lower than phenotypic coefficient of variation (30.46 %). High heritability estimates (60.80 %) coupled with high expected genetic advance (48.86 %) was observed.

4.4 Correlation

The correlation was studied in 61 genotypes for 16 characters in order to find out inter relationship of different yield components at genotypic and phenotypic levels. The genotypic (g) and phenotypic (p) correlation coefficient for 16 characters given in Table-4.4 and Table-4.5.

The character plant stand showed the positive and significant correlation with days to 50 % flowering (0.149 and 0.059) and leaf length (0.230 and 0.103) at both genotypic and phenotypic level. It showed positive and significant correlation with fodder yield (0.325 and 0.178) at both genotypic and phenotypic level. It showed negative and significant correlation with seedling vigour (-0.431), plant height (-0.157), panicle length (-0.406), panicle girth (-0.148), chlorophyll content (-0.336) and relative water content (-0.556) at genotypic level only.

The character days to 50 % flowering showed positive and significant correlation with seedling vigour (0.415 and 0.176), number of leaves (0.413 and 0.121), plant height (0.194 and 0.149) and fodder yield (0.369 and 0.195) both at

Table 4.4. Genotypic correlation coefficient between yield and yield contributing characters in *rabi* sorghum.

	Plant stand	Days to 50% flowering	Seedling vigour	Number of leaves	Leaf length (cm)	Leaf breadth (cm)	Plant height (cm)	Panicle length (cm)	Panicle girth (cm)	Chlorophyll content%	Relative water content%	100 seed weight (g)	Panicle weight (g)	Shootfly deadheart%	Fodder yield (g)	Grain yield (g)
Plant stand		0.149*	-0.431**	-0.102	0.230**	0.060	-0.157*	-0.406**	-0.148*	-0.336**	-0.556**	-0.128	0.100	-0.130	0.325**	0.057
Days to 50% flowering			0.415**	0.413**	0.080	0.005	0.194**	-0.129	0.083	0.096	-0.410**	0.095	-0.014	0.343**	0.369**	0.127
Seedling vigour				0.066	-0.337**	-0.504**	0.139	0.087	0.031	-0.228**	-0.081	-0.203**	0.241**	-0.163*	0.078	-0.129
Number of leaves					0.447**	-0.332**	0.296**	0.194**	0.189*	0.270**	-0.048	0.236**	0.065	0.095	0.417**	-0.095
Leaf length (cm)						0.266**	0.241**	0.007	-0.159*	1.002**	-0.029	-0.049	0.062	0.089	0.076	0.273**
Leaf breadth (cm)							0.005	-0.140	-0.093	0.338**	0.156*	0.120	0.019	-0.353**	0.240**	0.237**
Plant height (cm)								0.082	-0.212**	0.287**	0.097	-0.316**	-0.085	0.190**	0.063	-0.057
Panicle length (cm)									-0.198**	0.441**	0.137	0.109	0.182*	-0.132	0.038	-0.024
Panicle girth (cm)										0.039	-0.121	-0.029	0.089	-0.070	0.311**	-0.358**
Chlorophyll content%											-0.080	-0.047	0.175*	-0.061	0.361**	0.236**
Relative water content%												-0.164*	0.020	-0.436**	-0.123	-0.183*
100 seed weight (g)													-0.210**	0.158*	0.0120	0.229**
Panicle weight (g)														-0.053	0.196**	-0.089
Shooyfly deadheart%															-0.046	-0.087
Fodder yield (g)																-0.201**

*Significant at 5 per cent

**Significant at 1 per cent

Table 4.5. Phenotypic correlation coefficients between yield and yield contributing characters in *rabi* sorghum.

	Plant stand	Days to 50% flowering	Seedling vigour	Number of leaves	Leaf length (cm)	Leaf breadth (cm)	Plant height (cm)	Panicle length (cm)	Panicle girth (cm)	Chlorophyll content%	Relative water content%	100 seed weight (g)	Panicle weight (g)	Shootfly deadheart%	Fodder yield (g)	Grain yield (g)
Plant stand		0.059	0.065	0.062	0.103	0.062	-0.137	-0.137	-0.015	-0.054	-0.106	-0.00	0.045	0.102	0.178*	0.058
Days to 50% flowering			0.176*	0.212**	0.073	0.020	0.149*	-0.061	0.053	0.027	-0.315**	0.077	0.068	0.073	0.195**	0.033
Seedling vigour				0.157*	-0.140	-0.195**	0.021	0.150*	0.042	-0.007	0.028	0.038	0.147*	-0.016	0.063	-0.008
Number of leaves					0.087	0.032	0.074	0.167*	0.081	0.099	-0.019	0.046	0.034	0.123	0.130	-0.095
Leaf length (cm)						0.167*	0.181*	-0.054	-0.075	0.364**	0.005	-0.057	-0.010	-0.025	0.118	0.190
Leaf breadth (cm)							-0.027	-0.054	0.071	0.270**	0.006	0.051	0.014	-0.036	0.217**	0.077
Plant height (cm)								0.065	-0.121	0.122	0.054	-0.204**	0.016	-0.027	0.037	-0.039
Panicle length (cm)									-0.098	0.259**	0.080	0.068	0.079	-0.049	0.074	-0.047
Panicle girth (cm)										0.030	-0.067	0.060	0.173*	0.026	0.104	-0.157
Chlorophyll content%											-0.000	0.047	0.035	-0.070	0.145*	0.040
Relative water content%												-0.016	0.006	-0.143	-0.034	-0.122
100 seed weight (g)													-0.039	0.156*	0.047	0.158
Panicle weight (g)														-0.006	0.056	-0.062
Shootfly deadheart%															-0.025	-0.022
Fodder yield (g)																-0.048

*Significant at 5 per cent

**Significant at 1 per cent

genotypic and phenotypic level. It showed positive and significant correlation with shootfly deadheart % (0.343) at genotypic level only while negative and significant correlation with relative water content (-0.315) at phenotypic level only.

The character seedling vigour showed positive and significant correlation with panicle weight (0.241 and 0.147) both at genotypic and phenotypic level. It showed significant and positive correlation with number of leaves (0.157) and panicle length (0.150) at phenotypic level only. It showed negative and significant correlation with leaf length (-0.337), chlorophyll content (-0.228), 100 seed weight (-0.203) and shootfly deadheart % (-0.163) at genotypic level only. It also showed negative and significant correlation with leaf breadth (-0.504 and -0.195) at both genotypic and phenotypic level.

The character number of leaves showed positive and significant correlation with leaf length (0.447), plant height (0.296), panicle girth (0.189), chlorophyll content % (0.270), 100 seed weight (0.236) and fodder yield (0.417) at genotypic level only. It showed positive and significant correlation with panicle length (0.194 and 0.167) at both genotypic and phenotypic level. It showed negative and significant correlation with leaf breadth (-0.332) at genotypic level only.

The character leaf length showed positive and significant correlation with leaf breadth (0.266 and 0.167), plant height (0.241 and 0.181) and chlorophyll content (1.002 and 0.364) both at genotypic and phenotypic level. It showed positive and significant correlation with grain yield (0.273) at genotypic level only. It showed negative and significant correlation with panicle girth (-0.159) at genotypic level only. It showed positive and non significant correlation with grain yield at both genotypic and phenotypic level.

The character leaf breadth showed positive and significant correlation with chlorophyll content (0.338 and 0.270) and fodder yield (0.240 and 0.217) at both genotypic and phenotypic level. It showed positive and significant correlation with grain yield (0.237) while negative and significant correlation with shootfly deadheart % (-0.353) at genotypic level only.

The character plant height showed positive and significant correlation with chlorophyll content (0.287) and shootfly deadheart % (0.190) at genotypic level only. It had shown negative and significant correlation with 100 seed weight (-0.316 and -0.204) at both genotypic and phenotypic level. It also showed negative and significant correlation with panicle girth (-0.212) at genotypic level only. It had positive and non significant correlation with panicle length, relative water content and fodder yield.

The character panicle length showed positive and significant correlation with chlorophyll content (0.441 and 0.259) at both genotypic and phenotypic level. It showed positive and significant correlation with panicle weight (0.182) while-negative and significant correlation with panicle girth (-0.198) at genotypic level only. It had positive and non significant correlation with fodder yield at both genotypic and phenotypic level.

The character panicle girth showed positive and significant correlation with fodder yield (0.311) while negative and significant correlation with grain yield (-0.358) at genotypic level only. It showed positive and significant correlation with panicle weight (0.175) at phenotypic level only.

The character chlorophyll content % showed positive and significant correlation with panicle weight (0.175) and grain yield (0.236) at genotypic level only. It also showed positive and significant correlation with fodder yield (0.361 and 0.145) both at genotypic and phenotypic level.

The character relative water content showed negative and significant correlation with 100 seed weight (-0.164), shootfly deadheart % (-0.436) and grain yield (-0.183) at genotypic level only.

The character 100 seed weight showed positive and significant correlation with grain yield (0.229) while negative and significant correlation with panicle weight at genotypic level only. It also showed positive and significant correlation with shootfly deadheart (0.158 and 0.156) at both genotypic and phenotypic level.

The character panicle weight showed positive and significant correlation with fodder yield (0.196) at genotypic level only. It showed positive and non significant association with fodder yield (0.056) at phenotypic level only.

The character shootfly deadheart % showed negative and non significant correlation with fodder yield (-0.046 and -0.025) and grain yield (-0.087 and -0.022) both at genotypic and phenotypic level.

The character fodder yield showed negative and significant correlation with grain yield (-0.201) at genotypic level only.

4.5 Path analysis

The correlation studies do not show the exact picture of direct and indirect effects of yield contributing characters. Path analysis was carried out to find out the direct and indirect contribution of each of the characters towards grain yield per plant. Path coefficient analysis with genotypic and phenotypic correlation was calculated and presented in Table- 4.6 and Table- 4.7 respectively.

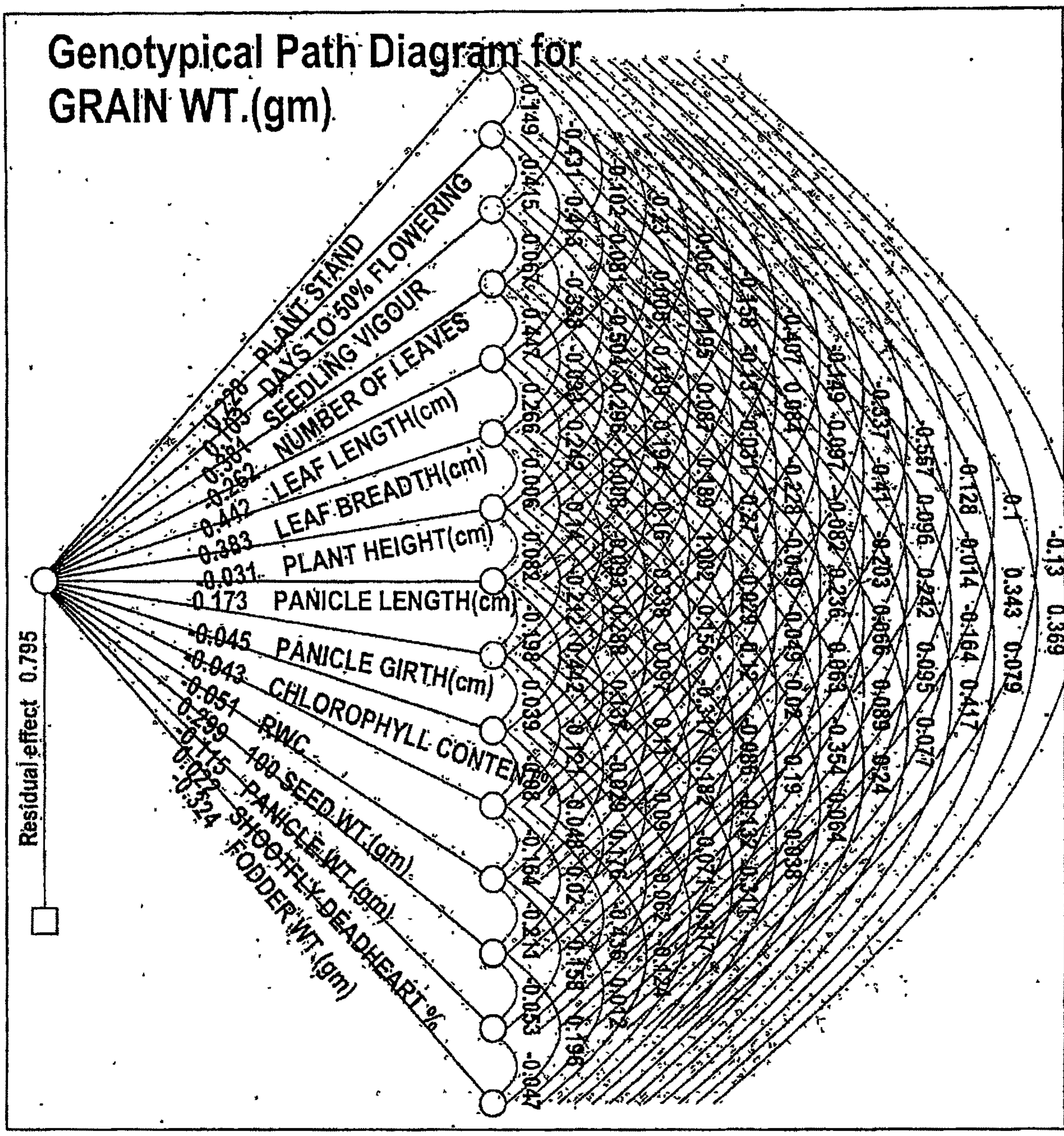
The character plant stand showed positive direct effect (0.2284 and 0.0265) on grain yield both at genotypic and phenotypic level. It had positive indirect effect on grain yield through days to 50 % flowering, leaf length, leaf breadth, panicle weight and fodder yield .

The character days to 50 % flowering showed positive direct effect (0.1030) on grain yield. It had positive indirect effect on grain yield through plant stand, seedling vigour, number of leaves, plant height, 100 seed

Table 4.6. Direct and indirect effects (genotypic level) of yield components on grain yield in *rabi* sorghum.

	Plant stand	Days to 50% flowering	Seedling vigour	Number of leaves	Leaf length (cm)	Leaf breadth (cm)	Plant height (cm)	Panicle length (cm)	Panicle girth (cm)	Chlorophyll content%	Relative water content%	100seed weight (g)	Panicle weight (g)	Shootfly deadheart	Fodder yield (g)	Correlation with grain yield (g)
Plant stand	0.2284	0.0342	-0.0985	-0.0234	0.0526	0.0137	-0.0360	-0.0929	-0.03400	-0.0770	-0.1272	-0.0293	0.0229	-0.0298	0.0744	0.0572
Days to 50% flowering	0.0154	0.1030	0.0428	0.0425	0.0083	0.0005	0.0200	-0.0134	0.0086	0.0099	-0.0422	0.0099	-0.0015	0.0353	0.0380	0.1274
Seedling vigour	-0.1643	0.1582	0.3810	0.0254	-0.1286	-0.1922	0.0529	0.0333	0.0118	-0.0870	-0.0312	-0.0774	0.0920	-0.0623	0.0300	-0.1291
Number of leaves	0.0268	-0.1081	-0.0175	-0.2617	-0.1171	0.0087	-0.0775	-0.0508	-0.0495	-0.0707	0.0128	-0.0618	-0.0172	-0.0250	-0.1092	-0.0953
Leaf length (cm)	0.1019	0.0357	-0.1493	0.1979	0.4424	0.1177	0.1069	0.0034	-0.0706	0.4434	-0.0129	-0.0219	0.0277	0.0396	0.0340	0.2735
Leaf breadth (cm)	0.0231	0.0019	-0.1933	-0.0127	0.1020	0.3833	0.0023	-0.0537	-0.0358	0.1297	0.0599	0.0461	0.0075	-0.1356	0.0920	0.2372
Plant height (cm)	0.0049	-0.0061	-0.0044	-0.0093	-0.0076	-0.0002	-0.0313	-0.0026	0.0066	-0.0090	-0.0030	0.0099	0.0027	-0.0059	-0.0020	-0.0578
Panicle length (cm)	-0.0703	-0.0224	0.0151	0.0335	0.0013	-0.0242	0.0143	0.1728	-0.0343	0.0764	0.0237	0.0190	0.0315	-0.0228	0.0066	-0.0245
Panicle girth (cm)	0.0066	-0.0037	-0.0014	-0.0085	0.0071	0.0042	0.0095	0.0089	-0.0447	-0.0018	0.0054	0.0013	-0.0040	0.0032	-0.0139	-0.3588
Chlorophyll content%	0.0147	-0.0042	0.0099	-0.0118	-0.0436	-0.0147	-0.0125	-0.0192	-0.0017	-0.0435	0.0035	0.0021	-0.0076	0.0027	-0.0138	0.2361
Relative water content%	0.0283	0.0208	0.0042	0.0025	0.0015	-0.0079	-0.0049	-0.0070	0.0061	0.0041	-0.0508	0.0083	-0.0010	0.0221	0.0063	-0.1830
100 seed weight (g)	-0.0384	0.0287	-0.0608	0.0708	-0.0148	0.0360	-0.0948	0.0329	-0.0088	-0.0142	-0.0492	0.2995	-0.0630	0.0474	0.0036	0.2293
Panicle weight (g)	-0.0115	0.0016	-0.0277	-0.0076	-0.0072	-0.0023	0.0099	-0.0209	-0.0103	-0.0202	-0.0023	0.0242	-0.1148	0.0061	-0.0226	-0.0897
Shootfly deadheart	0.0029	0.0075	-0.0036	0.0021	0.0020	-0.0077	0.0042	-0.0029	-0.0015	-0.0013	-0.0095	0.0035	-0.0012	0.0219	-0.0010	-0.0879
Fodder yield (g)	-0.1055	-0.1195	-0.0255	-0.1351	-0.0249	-0.0777	-0.0206	-0.0124	-0.1008	-0.1026	0.0401	-0.0039	-0.0636	0.0152	-0.3238	-0.2013

Residual effect = 0.794

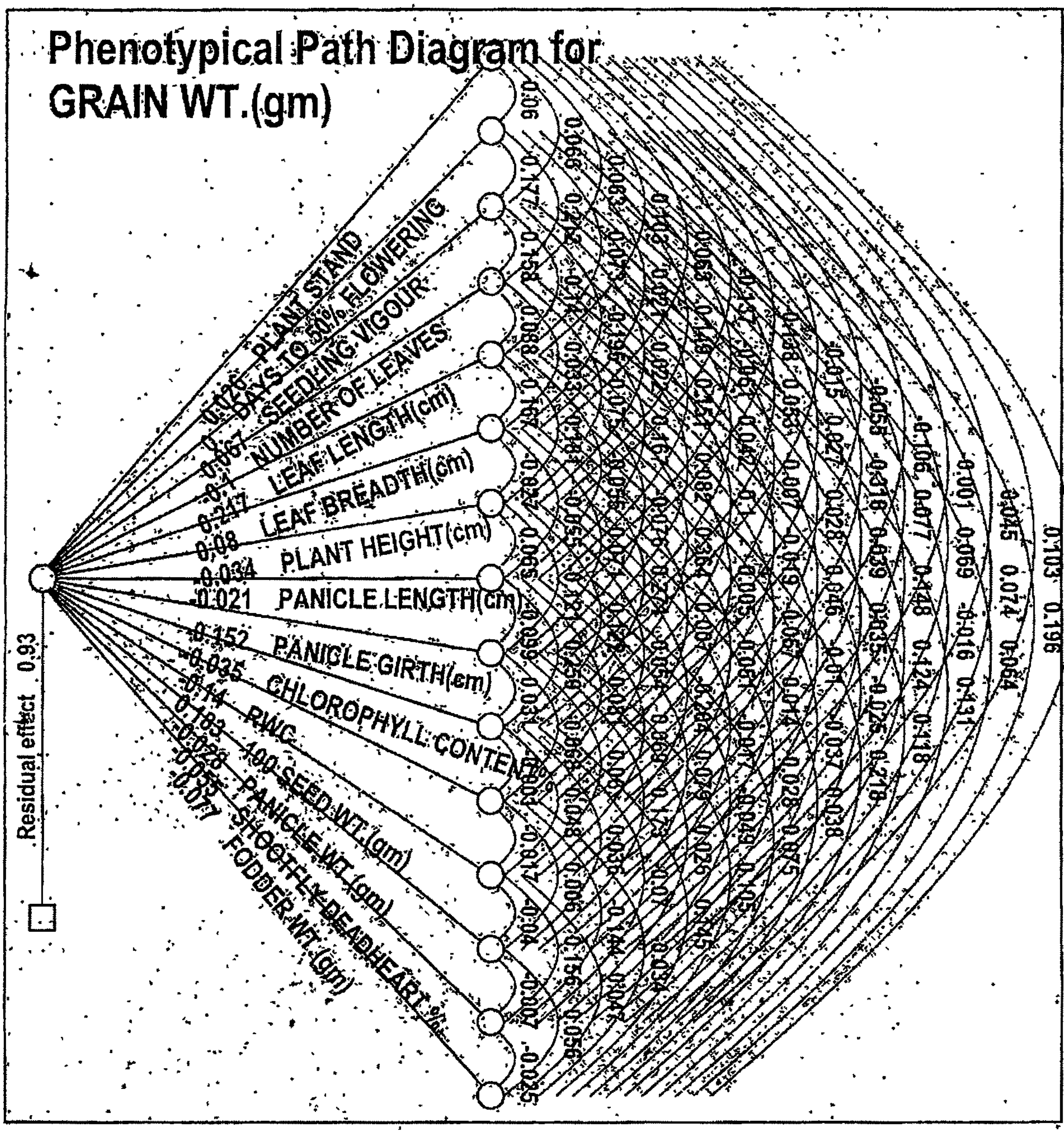


Genotypical Path Diagram for
GRAIN WT.(gm)
0.228 PLANT STAND
-0.165 DAYS TO 50% FLOWERING
-0.384 SEEDLING VIGOUR
-0.262 NUMBER OF LEAVES
-0.442 LEAF LENGTH(cm)
0.383 LEAF BREADTH(cm)
-0.031 PLANT HEIGHT(cm)
0.173 PANICLE LENGTH(cm)
-0.045 PANICLE GIRTH(cm)
-0.043 CHLOROPHYLL CONTENT
-0.051 RWC
0.299 100 SEED WT.(gm)
-0.115 PANICLE WT.(gm)
0.022 SHOOTFLY DEADHEART %
-0.324 FODDER WT.(gm)
Residual effect 0.795

Table 4.6. Direct and indirect effects (phenotypic level) of yield components on grain yield in *rabi* sorghum.

	Plant stand	Days to 50% flowering	Seedling vigour	Number of leaves	Leaf length (cm)	Leaf breadth (cm)	Plant height (cm)	Panicle length (cm)	Panicle girth (cm)	Chlorophyll content%	Relative water content%	100seed weight (g)	Panicle weight (g)	Shootfly deadheart	Fodder yield (g)	Correlation with grain yield (g)
Plant stand	0.0265	0.0016	0.0017	0.0017	0.0027	0.0017	-0.0036	-0.0036	-0.0004	-0.0014	-0.0028	0.0000	0.0012	0.0027	0.0047	0.0581
Days to 50% flowering	0.0000	-0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0339
Seedling vigour	0.0044	0.0118	0.0667	0.0105	-0.0094	-0.0130	0.0015	0.0101	0.0028	-0.0005	0.0019	0.0026	0.0098	-0.0011	0.0043	-0.0086
Number of leaves	-0.0063	-0.0213	-0.0159	-0.1004	-0.0088	-0.0033	-0.0075	-0.0168	-0.0082	-0.0100	0.0019	-0.0047	-0.0035	-0.0124	-0.0131	-0.0952
Leaf length (cm)	0.0225	0.0159	-0.0305	0.0191	0.2174	0.0363	0.0394	-0.0119	-0.0165	0.0792	0.0011	-0.0125	-0.0022	-0.0055	0.0257	0.1905
Leaf breadth (cm)	0.0050	0.0017	-0.0157	0.0026	0.0134	0.0803	-0.0022	-0.0044	0.0057	0.0217	0.0005	0.0041	0.0011	-0.0029	0.0175	0.0770
Plant height (cm)	0.0047	-0.0051	-0.0007	-0.0026	-0.0062	0.0009	-0.0342	-0.0022	0.0041	-0.0042	-0.0019	0.0070	0.0006	0.0010	-0.0013	-0.0397
Panicle length (cm)	0.0029	0.0013	-0.0032	-0.0035	0.0012	0.0012	-0.0014	-0.0212	0.0021	-0.0055	-0.0017	-0.0015	-0.0017	0.0010	-0.0016	-0.0479
Panicle girth (cm)	0.0023	-0.0081	-0.0065	-0.0125	0.0115	-0.0109	0.0185	0.0150	-0.1524	-0.0047	0.0103	-0.0092	-0.0264	-0.0040	-0.0160	-0.1575
Chlorophyll content%	0.0019	-0.0009	0.0002	-0.0035	-0.0127	-0.0095	-0.0043	-0.0091	-0.0011	-0.0350	0.0000	-0.0017	-0.0012	0.0025	-0.0051	0.0402
Relative water content%	0.0149	0.0441	-0.0039	0.0027	-0.0007	-0.0010	-0.0076	-0.0112	0.0095	0.0001	-0.1397	0.0023	-0.0009	0.0201	0.0048	-0.1229
100 seed weight (g)	-0.0001	0.0142	0.0071	0.0085	-0.0105	0.0094	-0.0374	0.0126	0.0110	0.0087	-0.0030	0.1832	-0.0073	0.0287	0.0087	0.1587
Panicle weight (g)	-0.0013	-0.0019	-0.0041	-0.0010	0.0003	-0.0004	0.0005	-0.0022	-0.0048	-0.0010	-0.0002	0.0011	-0.0277	0.0002	-0.0016	-0.0620
Shootfly deadheart	0.0056	-0.0040	0.0009	-0.0068	0.0014	0.0020	0.0015	0.0027	-0.0014	0.0038	0.0079	-0.0086	0.0004	-0.0548	0.0014	-0.0228
Fodder yield(g)	-0.0137	-0.0150	-0.0049	-0.0100	-0.0091	-0.0167	-0.0029	-0.0057	-0.0080	-0.0111	0.0026	-0.0036	-0.0043	0.0019	-0.0767	-0.0484

Residual effect = 0.929



Phenotypical Path Diagram for
GRAIN WT.(gm)
PLANT STAND
DAYS TO 50% FLOWERING
SEEDLING VIGOUR
NUMBER OF LEAVES
LEAF LENGTH(cm)
LEAF BREADTH(cm)
PLANT HEIGHT(cm)
PANICLE LENGTH(cm)
PANICLE GIRTH(cm)
CHLOROPHYLL CONTENT
RWC
100 SEED WT.(gm)
PANICLE WT.(gm)
SHOOTFLY DEADHEART %
FODDER WT.(gm)
Residual effect 0.93

weight, shootfly deadheart % and fodder yield. It had negative indirect effect on grain yield through panicle length, relative water content and panicle weight.

The character seedling vigour showed positive direct effect (0.3810) on grain yield. It had positive indirect effect on grain yield through days to 50 % flowering, number of leaves, plant height, panicle length, panicle girth, panicle weight and fodder yield.

The character number of leaves showed negative direct effect (-0.2617) on grain yield. It had positive indirect effect on grain yield through plant stand, leaf breadth and relative water content.

The character leaf length showed the highest positive direct effect (0.4424) on grain yield. It had positive indirect effect on grain yield through plant stand, days to 50 % flowering, number of leaves, leaf breadth, plant height, panicle length, chlorophyll content, panicle weight, shootfly deadheart % and fodder yield.

The character leaf breadth showed positive direct effect (0.3833) on grain yield. It had positive indirect effect on grain yield through plant stand, leaf length, plant height, chlorophyll content %, relative water content, 100 seed weight, panicle weight and fodder yield.

The character plant height showed negative direct effect (-0.0313) on grain yield. It had positive indirect effect on grain yield through plant stand, panicle girth, 100 seed weight and panicle weight.

The character panicle length showed positive direct effect (0.1728) on grain yield. It had positive indirect effect on grain yield through seedling vigour, number of leaves, plant height, chlorophyll content %, relative water content, 100 seed weight and panicle weight.

The character panicle girth showed negative direct effect (-0.0447) on grain yield. It had positive indirect effect on grain yield through plant stand, plant height, panicle length, relative water content, 100 seed weight and shootfly deadheart %.

The character chlorophyll content % showed negative direct effect (-0.0435) on grain yield. It had positive indirect effect on grain yield through plant stand, seedling vigour, relative water content and 100 seed weight.

The character relative water content showed negative direct effect (-0.0508) on grain yield. It had positive indirect effect on grain yield through plant stand, days to 50 % flowering, seedling vigour, number of leaves, leaf length, chlorophyll content, 100 seed weight and fodder yield.

The character 100 seed weight showed positive direct effect (0.2995) on grain yield. It had positive indirect effect on grain yield through days to 50 % flowering, number of leaves, panicle length, shootfly deadheart % and fodder yield.

The character panicle weight showed negative direct effect (-0.1148) on grain yield. It had positive indirect effect on grain yield through days to 50 % flowering, plant height and 100 seed weight.

The character shootfly deadheart % showed positive direct effect (0.0219) on grain yield. It had positive indirect effect on grain yield through plant stand, days to 50 % flowering, number of leaves, leaf length, plant height and 100 seed weight.

The character fodder yield showed the highest negative direct effect (-0.3238) on grain yield. It had positive indirect effect on grain yield through relative water content and shootfly deadheart %.

The residual effect was **0.794** and **0.929** at genotypic and phenotypic level of path analysis respectively.

Discussion

CHAPTER V

DISCUSSION

Sorghum (*Sorghum bicolor* L. Moench) is an important food and feed crop cultivated in both rainy (*kharif*) and winter (*rabi*) season in Maharashtra. *Rabi* sorghum depends on residual moisture and its yield is a function of monsoon rains.

The success of any breeding programme depends upon the genetic variability in the materials in hand. The greater the genetic variability the higher would be heritability, hence the better chances of success could be achieved through selection. (Bello *et al.* 2007). Plant breeding deals with the management of genetic variability present in a plant population. Its assessment in available germplasm is of immense importance for further crop improvement and to identify the superior genotypes. It is therefore necessary to study the nature and magnitude of genetic diversity systematically. Selection on the basis of *per se* performance for plant yield does not give fruitful results because yield is a complex characters. Simple correlation coefficient are of limited value in selecting superior plants and hence, it is important to study the cause and effect relationship between yield and its components. Effectiveness of selection depends on amount of heritability and genetic advance.

The present study was conducted on 61 genotypes of sorghum including check at experimental farm of Sorghum Research Station, V.N.M.K.V., Parbhani. The genotypes were evaluated in randomized block design. The present investigation was undertaken to estimate the extent of genetic variability, heritability, expected genetic advance, correlation and path analysis for yield and yield contributing characters in sorghum. The results of present study were discussed below.

5.1 Analysis of variance

The analysis of variance for different characters is presented in Table-4.1. The treatments i.e. mean sum of squares due to genotypes showed significant differences for all characters under study, suggesting that the genotypes were genetically divergent. This indicates that there is ample scope for selection of promising genotypes. The analysis of variance for the characters viz. plant stand, days to 50 % flowering, seedling vigour, number of leaves, leaf length, leaf breadth, plant height, panicle length, panicle girth, chlorophyll content %, relative water content, 100 seed weight, panicle weight, shootfly deadheart %, fodder yield and grain yield showed significant genotypic difference indicating presence of variability among the lines selected for study. (Can and Yoshida 1999, Prabhakar *et al.* 2003, Chavan *et al.*2010, Warkad *et al.* 2008 and Patil *et al.* 2014).

5.2 Mean performance

Mean performance of the different characters studied is presented in Table- 4.2.

Maximum plant stand among all genotypes was recorded in IS 20713 (28.33) followed by IS 9586 and IS 2430 (28.00), IS 4821 (27.33). However, minimum plant stand was exhibited in genotypes IS 2807 (17.66) followed by IS 30619 (19.00). Among all genotypes, IS 30619 (57.33 days) was the earliest in flowering and genotypes IS 19455 (98 days) followed by IS 19026 (89 days), E 36-1 (82.66 days) were late in flowering. Seedling vigour was the highest in genotype SSM 547 (2.33) and was the lowest in genotype IS 19455 (5.00).

Among all genotypes, GCP_Sb_0510 (8.33) and IS 25442 (8.33) recorded maximum number of leaves, while genotypes IS 13 (6.00) and IS 31693 (6.00) recorded minimum number of leaves. Among all genotypes IS 19053 (66.14 cm) recorded maximum leaf length while genotype IS 10234 (42.90 cm) recorded minimum leaf length. Among all genotypes E 36-1 (5.95 cm) recorded maximum leaf breadth while IS 25596 (3.76 cm) recorded minimum leaf breadth. Maximum plant height was recorded in IS 27 (232.00 cm) and minimum in IS 30619 (96.00 cm).

The highest panicle length was observed in IS 22325 (20.86 cm) and the lowest in IS 29569 (11.66 cm). The highest panicle girth was observed in IS 4821 (17.43 cm) and the lowest in IS 30441 (12.23 cm). Among all genotypes the highest chlorophyll content % was observed in IS 20724 (61.64 %) and lowest in IS 29409 (38.98 %). The relative water content was highest in IS 8348 (88.44 %) and was lowest in IS 18922 (57.89 %). The 100 seed weight was highest in IS 20713 (3.30 g) and was lowest in 21425 (1.46 g).

Among all genotypes the highest panicle weight was observed in IS 9713 (59.33 g) and the lowest in IS 32050 (37.33 g). The highest shootfly deadheart % was observed in IS 31693 (87.63 %) and the lowest in IS 4027 (41.11 %). The highest fodder yield was observed in E 36-1 (408.33 g) and the lowest in SSM 501 (127.00 g). Among all genotypes the highest grain yield was recorded in IS 22325 (93.33 g) and the lowest in IS 18922 (33.00 g).

5.3 Genetic variability

The magnitude of genetic variability present in base population of any crop species is pivotal to crop improvement which must be exploited by plant breeders for yield improvement. Breeder has to quantify the fixable and non fixable components of variation for further effective selection and this can be only effective when the character is controlled by additive action.

Hence, for the successful selection programme, the knowledge of genetic variability, heritability and genetic advance is a prime requisite and hence the present study were undertaken to acquire the knowledge of these genetic parameters in selected genotypes of *rabi* sorghum.

5.3.1 Range of variability

Wide range of variability was observed for majority of yield contributing characters. Range of variation on the basis of mean was more for the characters days to 50 % flowering, plant height, panicle length, panicle girth, relative water content, fodder yield and grain yield. Similar results were reported by several workers including, Prabhakar (2003), Arunkumar *et al.* (2004), Mallinath *et al.* (2004), Hemlata Sharma *et al.* (2006), Bello *et al.* (2007), Warkad *et al* (2008), Chavan *et al* (2010), Ali *et al* (2012), Puspitasari *et al* (2012) and Jain and Patel (2012).

The phenotypic variance was higher than genotypic variance for all the characters. High genotypic and phenotypic variance were observed for the characters plant height, panicle length, 100 seed weight, fodder yield and grain yield. Similar findings have been reported by several workers, Wankhede *et al.* (1985) for plant height and number of leaves, Prabhakar (2003) for grain yield per plant and 1000 grain weight, Mallinath *et al* (2004) for fodder yield and grain yield, Bello *et al.* (2007) for plant height, days to 50 % flowering and panicle length, Warkad *et al.* (2008) for earhead length and breadth, grain yield per plant and 1000 seed weight and Jhansi Rani *et al.* (2009) for fodder yield per plant.

5.3.2 Genotypic and Phenotypic coefficient of variability

The selection under field condition may be strongly influenced by environmental factors affecting progress in the improvement programme.

In the present study, genotypic coefficient of variation estimates was lower than phenotypic coefficient of variation for all the characters suggest that influence of environment on them. Although the phenotypic coefficient of variations were greater than genotypic coefficient of variations, the differences between them were of lower magnitude.

In the present study high estimates of genotypic and phenotypic coefficient of variation were observed for seedling vigour, plant height, panicle length, 100 seed weight, shootfly deadheart %, fodder yield and grain yield. This indicates the presence of substantial amount of genetic variability in the genotypes for all these characters. The results are in agreement with those of Wankhede *et al.* (1985), Can and Yoshida (1999), Lata Choudhary *et al.*

(2005), Prabhakar (2003), Arunkumar *et al.* (2004), Mallinath *et al.* (2004), Hemlata Sharma *et al.* (2006), Chavan *et al.* (2010), Kamtar *et al.* (2011).

The low genotypic and phenotypic coefficient of variation were observed for days to 50 % flowering, number of leaves, leaf length, leaf breadth, panicle weight and relative water content. This indicates small amount of variation and impediment in improvement through selection. Similar results were reported by Mallinath *et al.* (2004), Warkad *et al.* (2008), Jhansi Rani *et al.* (2009), Godbharle *et al.* (2010), Kamtar *et al.* (2011), Arunkumar (2013), Kalpande *et al.* (2014) and Patil *et al.* (2014).

5.3.3 Heritability and Genetic advance

The genotypic coefficient of variation alone does not 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. The heritability estimates along with expected genetic advance are more useful predicting yield under phenotypic selection than heritability estimates alone.

The success of genetic advance under selection depends on the magnitude of genetic variability in the base population, heritability of the character under consideration and selection intensity of plants selected (Allard 1960). High heritability accompanied with high genetic advance indicates preponderance of additive gene effect, in such case selection may be effective. High heritability with low genetic advance reveals preponderance of non additive gene action. Low genetic advance is due to low variability, so simple selection would not be effective for their improvement. Heritability in conjunction with genetic gains is more effective and dependable in predicting the improvement through selection (Johnson *et al.* 1955).

The heritability estimates along with expected genetic advance are more useful in predicating yield under phenotypic selection than heritability estimates alone. According to Johnson *et al.* (1955) heritability is categorized less than 30 % as low, 30-60 % as moderate and more than 60 % as high. In the present investigation heritability ranged from 23.30 % to 62.90 %. The characters days to 50 % flowering (61.80 %), relative water content (62.90 %) and grain yield (60.80 %) reported high heritability. These characters would respond positively to selection because of their high broad sense heritability.

Ambekar *et al.* (2000) reported high heritability for panicle length, panicle girth and test weight. Prabhakar (2003) reported high heritability coupled with high genetic advance for 1000 grain weight and grain yield per plant. Bello *et al.* (2007) reported high heritability for panicle length, number of leaves per plant and days to 50 % flowering.

Mallinath (2004) reported high heritability for fodder yield per plant and grain yield per plant. Hemlata Sharma *et al.* (2006), Khapare *et al.* (2007), Bidve (2008), Madne (2008), Warkad *et al.* (2008), Godbharle *et al.* (2010), Shinde *et al.* (2010) and Mahajan *et al.* (2011) reported similar results.

Johnson *et al.* (1955) has given the scale of genetic advance according to which genetic advance of less than 10 % is low, 10-20 % is moderate and more than 20 % is categorized as high. Higher values of genetic advance was reported for the characters plant height, panicle length, relative water content, 100 seed weight, fodder weight and grain weight.

Deepalakshmi and Ganeshmurthy (2007) reported genetic advance was more for days to 50% flowering plant height, leaves per plant , leaf length, ear head weight and 100 grain weight, Date (2002) for fodder yield and grain yield per plant, Prabhakar (2003) for grain yield per plant, Lata chaudhary *et al.* (2005) for number of leaves per plant, Bidve (2008) for plant height, leaf area index, fodder yield and grain yield, Shinde *et al.* (2010) for plant height, number of leaves, test weight, fodder yield and grain yield, Arunkumar (2013) for grain yield and fodder yield.

High heritability and genetic advance estimates for grain yield and relative water content indicated that straight selection will be rewarding for these character, similar findings were reported by Prabhakar (2003), Mallinath *et al.* (2004), Warkad *et al.* (2008)and Patil *et al.* (2014). Wankhede *et al.* (1985) reported moderate heritability coupled with moderate genetic advance for panicle girth.

High heritability coupled with moderate genetic advance was exhibited for days to 50 % flowering. Similar results were reported by Chavan *et al.* (2010), Godbharle *et al.* (2010) and Patil *et al.* (2014) for days to 50 % flowering and Kalpande *et al.* (2014).

Thus from the foregoing discussion, it is clear that the character grain weight recorded high heritability and high expected genetic advance indicating involvement of additive gene action. Such high estimates were indicative of the fact that these traits were less attracted by the environment and thus, while expecting genetic variability due emphasis should be given to these characters (Patil *et al.* 2014).

5.4 Correlation

For the improvement of any crop, yield is the most important character which must has to be taken into account. Yield is multiplicative product function of yield contributing components. The knowledge of interaction among the component characters is therefore, useful to plant breeder for improving the yield directly. At genetic level, a positive correlation occurs due to coupling phase of linkage and negative correlation arises due to repulsion phase of linkage of genes controlling two different traits. Genotypic correlation coefficient provides an estimate of inherent association between any two characters. The estimate of correlation coefficient may be helpful to identify the characters that prove to be of little or no importance in selection programme. Hence, it is essential to find out the relative contribution of each of the component character in yield so as to give weightage during selection.

The genotypic correlation of grain yield with leaf length, leaf breadth, chlorophyll content % and 100 seed weight were positive and significant indicating that increase in grain weight is because of one or more above characters.

Similar results were reported by Senthil and Palanysamy (1995) for 100 grain weight and seedling vigour, Sadia Alam *et al.* (2001) for plant height, 100 seed weight and panicle length, Thorat *et al.* (2004) for 100 seed weight, panicle length and panicle breadth, Hemlata Sharma *et al.* (2006) for 100 seed weight, Prasuna *et al.* (2012) for 100 seed weight and plant height. Seetharam and Ganeshmurthy (2013) for leaf length, leaf width and panicle weight.

The characters panicle girth, relative water content and fodder yield showed negative and significant correlation with grain weight.

The character days to 50 % flowering showed positive and significant correlation with seedling vigour , number of leaves , plant height and fodder yield both at genotypic and phenotypic level. Similar results were reported by Arunkumar *et al.* (2004). The character seedling vigour showed negative and significant correlation with shootfly deadheart %. Similar results were reported by Phuke *et al.* (2013). Contrast results were reported by Gomashe *et al.* (2010).

The character number of leaves per plant showed positive and significant correlation with panicle length at both genotypic and phenotypic level. Similar findings were reported by Gururaja Rao (1995) and Jain and Indapurkar (2013). The character leaf length showed positive and significant correlation with leaf breadth and it had positive and non significant correlation with fodder weight. Similar results were reported by Jain and Patel (2013).

The character leaf breadth showed positive and significant correlation with fodder yield and chlorophyll content. Similar results were reported by Sushil kumar (2014) for fodder yield. The character plant height showed positive and non significant correlation with panicle length, relative water content and fodder weight. Similar results were reported by Lata Choudhary *et al.* (2005) for panicle length, Arunkumar (2013) for panicle length and fodder yield.

The character panicle length showed positive and non significant correlation with fodder yield. Similar results were reported by Jhansi Rani *et al.* (2008). The character 100 seed weight showed positive and significant correlated with grain weight. Similar results were reported by Thorat *et al.* (2004) and Prasuna *et al.* (2012).

It is important to note that the characters viz. leaf length, leaf breadth, chlorophyll content % and 100 seed weight were positively correlated with grain yield. These traits could be considered as an important traits for improving grain weight i.e., grain yield.

5.5 Path analysis

Path coefficient analysis was outlined by Dewey and Lu (1959) was to find out the direct and indirect effect of various components on grain yield.

Direct effect of any component character on grain yield gives an idea about reliability of indirect selections to be made through that character to bring about improvement in grain yield. If both correlation and the direct effect are high and positive then correlation explains its true relationship and selection for the character will be effective. If correlation coefficient is positive, but the direct effect is negative or negligible, in such situations 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 (Singh and Narayanam 2006).

The residual effect determines how best the causal factors account for variability of the dependent factor (grain yield). If the value of residual factors is moderate or high, it indicates that besides the character studies there are some other attributes which contributes for yield.

In the present study, days to 50 % flowering, seedling vigour, leaf length, leaf breadth, panicle length, 100 seed weight and shootfly deadheart % had positive direct effect on grain yield. Similar findings were reported by Senthil and Palanysamy (1995), Hemlata Sharma *et al.* (2006), Tag El-Din *et al.* (2012), Arun Kumar (2013) and Sudhanshu and Indapurkar (2013).

Number of leaves showed negative direct effect on grain yield followed by plant height, panicle girth, plant height, relative water content, panicle weight and fodder yield. Sudhanshu and Indapurkar (2013) for grain yield, Kalpande *et.al* (2014) for relative water content.

Days to 50% flowering and panicle length showed low but positive direct effect on grain yield. Similar results were reported by Tag El-Din *et al.* (2012) for panicle length, Mohammad Yazdani (2012) for panicle length and Arun Kumar (2013) for days to 50 % flowering.

Plant height and fodder yield showed negative direct effect through negative correlation with grain yield. Similar results were reported by Arun Kumar (2013) for plant height and fodder yield , Senthil and Palanysamy (1995) for plant height. Panicle girth showed negative and direct effect through negative correlation on grain weight. Contrast results were reported by Wankhede *et al.* (1985).

The character 100 seed weight showed positive direct effect along with positive correlation with grain yield. It had positive indirect effect on grain yield through days to 50 % flowering, number of leaves, panicle length, shootfly deadheart % and fodder yield. Similar results were reported by Hemlata Sharma *et al.* (2006).

The character panicle weight showed negative and direct effect on grain yield. It had positive indirect effect on grain weight through days to 50

% flowering and plant height. Similar results were reported by Gururaja Rao (1995).

Summary and Conclusion

CHAPTER VI

SUMMARY AND CONCLUSION

The present investigation entitled "Evaluation of sorghum germplasm for variability, correlation and path analysis" was undertaken during *rabi*-2013-14.

1. To study genetic variability for various traits in sorghum.
2. To study correlation between various component traits in sorghum.
3. To study path analysis for various traits in sorghum.

The experimental material comprised of 61 genotypes including 1standard check. The experiment was conducted in randomized block design with three replications at farm of Sorghum Research Station, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani.

Genotypes were evaluated and observations were recorded for plant stand, days to 50 % flowering, seedling vigour, number of leaves, leaf length (cm), leaf breadth (cm), plant height (cm), panicle length (cm), panicle girth (cm), chlorophyll content %, relative water content (RWC), 100 seed weight (g), panicle weight (g), shootfly deadheart %, fodder yield (g) and grain yield (g).

The results obtained are summarized below

1. Analysis of variance showed significant difference for all characters among genotypes indicating the presence of wide genetic variability in an experimental material.
2. Maximum plant stand among all genotypes was recorded in IS 20713 (28.33) and minimum in IS 2807 (17.66).
3. Among all genotypes, the lowest days to 50 % flowering was recorded for IS 30619 (57.33 days) and highest in IS 19455 (98 days).
4. Seedling vigour was the highest in genotype SSM 547 (2.33) and was the lowest in genotype IS 19455 (5.00).

5. Among all genotypes, GCP_Sb_0510 (8.33) and IS 25442 (8.33) recorded maximum number of leaves, while genotypes IS 13 (6.00) and IS 31693 (6.00) recorded minimum number of leaves.
6. Among all genotypes IS 19053 (66.14 cm) recorded maximum leaf length while genotype IS 10234 (42.90 cm) recorded minimum leaf length.
7. Among all genotypes E 36-1 (5.95 cm) recorded maximum leaf breadth while IS 25596 (3.76 cm) recorded minimum leaf breadth.
8. Maximum plant height was recorded in IS 27 (232.00 cm) and minimum in IS 30619 (96.00 cm).
9. The highest panicle length was observed in IS 22325 (20.86 cm) and the lowest in IS 29569 (11.66 cm).
10. The highest panicle girth was observed in IS 4821 (17.43 cm) and the lowest in IS 30441 (12.23 cm).
11. Among all genotypes the highest chlorophyll content % was observed in IS 20724 (61.64 %) and lowest in IS 29409 (38.98 %).
12. The relative water content was highest in IS 8348 (88.44 %) and was lowest in IS 18922 (57.89 %).
13. The 100 seed weight was highest in IS 20713 (3.30 g) and was lowest in 21425 (1.46 g).
14. Among all genotypes the highest panicle weight was observed in IS 9713 (59.33 g) and the lowest in IS 32050 (37.33 g).
15. The lowest shootfly deadheart % was observed in SSM 501 (127.00 g) and the highest in IS 31693 (87.63 %).
16. Among all genotypes the highest fodder yield was recorded in E 36-1 (93.33 g) and the lowest in IS 18922 (33.00 g).
17. Among all genotypes the highest grain yield was recorded in IS 22325 (408.33 g) and the lowest in SSM 501 (127.00 g).
18. Genotypic coefficient of variation estimates was lower than phenotypic coefficient of variation for all the characters. High genotypic and

phenotypic variance were observed for the characters plant height, panicle length, 100 seed weight, fodder weight and grain weight.

19. High heritability coupled with high genetic advance was exhibited for grain weight and relative water content. High heritability coupled with moderate genetic advance was exhibited for days to 50 % flowering.
20. Characters leaf length, leaf breadth, chlorophyll content % and 100 seed weight had positive and significant correlation with grain weight.
21. The path coefficient analysis revealed that the characters viz. days to 50 % flowering, seedling vigour, leaf length, leaf breadth, panicle length, 100 seed weight and shootfly deadheart % had positive and direct effect on grain weight.

CONCLUSION

The present study revealed that, the genotypes IS 27, SSM 1370, GCP_Sb_0510, IS 22040, IS 22325 and IS 9911 showed better performance for days to 50 % flowering, panicle length, chlorophyll content %, relative water content and 100 seed weight. Days to 50 % flowering, chlorophyll content % and 100 seed weight showed positive correlation with grain yield through their direct and indirect effects and also relative water content exhibited high heritability coupled with high genetic advance and chlorophyll content % exhibited moderate heritability coupled with moderate genetic advance. Hence, it can be utilized for development and identification of both variety as well as breeding stock.

Literature Cited

LITERATURE CITED

Ahmed M. E.l. Naim, M. Ibrahim, Ibrahim, Mohammed E. Abdel Rahman, Elshiekh A. Ibrahim. (2012). Evaluation of some local sorghum (*Sorghum Bicolor* (L.) Moench) genotypes in rain-fed. *International Journal of Plant Research.* **2(1)** : 15-20.

Allard, R.W. (1960). Principles of Plant Breeding. John Wiley and Sons Inc., New York.

Ambekar, S.S., Gayakwad, D.S., Khapre, P.R. and Borikar, S.T. (2000). Genetic variability, character association and path coefficient studies in selected germplasm lines of *rabi* sorghum. Paper presented in VIII Vasantrao Naik Memorial National Agriculture Seminar on Sorghum under different agro-ecological systems and its industrial utilization, March 1-2, 2000 at College of Agriculture, Nagpur.

Aml A. Tag El-Din, Eatmad M.Hessein and E.A. Ali (2012). Path coefficient and correlation assessment of yield and yield associated traits in sorghum. (*Sorghum bicolor* L.) genotypes. *American-Eurasin J. Agric. and Environ. Sci.* **12(6)**: 815-819.

Anjana, S. (2006). Genetic variability and divergence studies in B and R lines of *Kharif* sorghum. M.Sc. (Agri.) Thesis, Marathwada Agricultural University, Parbhani (M.S.).

Anonymous 2009. Sorghum area, yield and production, world and selected countries. Foreign agri. Services, official USDA estimates, PS and Official statistics.

Annonymous 2015. Area, production and productivity of Maharashtra. Economics and statistics, Dep. Of. Agri. Co. op. 2014-15.

Aruna, C., V. R. Bhagwat, R. Madhusudhana, Vittal Sharma, T. Hussain, R. B. Ghorade, H. G. Khandalkar, S. Audilakshmi and N. Seetharama. 2011. Identification and validation of genomic regions that affect shootfly resistance in sorghum [Sorghum bicolor (L.) Moench]. *Theor Appl Genet.* **122**:1617–1630.

Arun Kumar (2013) Studies of genetic parameters and inter relationship among yield and yield contributing traits in sorghum *(sorghum bicolor* L.moench).*The bioscan* **8(4)**:1311-1314.

Arunkumar, B., Biradar, B.D. and Salimath, P.M. (2004). Genetic variability and character association studies in *rabi* sorghum. *Karnataka J. Agri. Sci.,***17 (3)**:471-475.

Bello. D, Kadams, A.M., Simon, S.Y. and Mashi, D.S. (2007). Studies on genetic variability in cultivated sorghum (*Sorghum bicolor* L. Moench) cultivars of Adamawa state Nigeria. *American-Eurasian J. Agric. and Environ. Sci.*, **2(3)** : 297-302.

Bidve, M.S. (2008). Genetic variability studies in promising B lines of *Kharif* sorghum (*Sorghum bicolor* (L.) Moench). M.Sc. (Agri.) Thesis submitted to Marathwada Agricultural University, Parbhani.

*Burton, G. N. and Devane, E. M., 1952, Estimating heritability in tall fescue (*Festuca arundianacea* L.) from replicated clonal material. *Agronomy Journal.* **45** : 478-481.

*Burton, G.W.1952. Quantitative inheritance in grasses proceeding of the sixth International Grasslands Congress I. 277 -283.

Chavan, S.K., Mahajan, R.C., Sangita U. Fatak (2010). Genetic variability studies in sorghum. *Karnataka J. Agric. Sci.,* **23 (2)** : (322-323).

Date, D.M. (2002). Genetic variability and character association studies in selected segregating progenies of *rabi* Sorghum (*Sorghum bicolor* (L.) Moench). M.Sc. (Agri.) Thesis, Marathwada Agricultural University, Parbhani (M.S.).

Deepalakshmi ,A.J. and Ganeshmurthy, K. (2007). Studies on genetic variability and character association in *kharif* sorghum. *Indian J. Agril. Res.* **41(3)**:177-182.

*Deway, D.R. and Lu, K.H. (1959). A correlation and path analysis components of crested wheat grass seed production. *Agron. J.* **51(6)**: 515-518.

Ezeaku I.E., Gupta S.C., Prabhakar V.R. 1997. Classification of sorghum germplasm accessions using multivariate methods. *African Crop Science Journal* **7**: 97-108.

Ezeaku, I.E. and Mohammed, S.G. (2006). Character association and path analysis in grain sorghum. *Afr. J. Biotechnol.* **5(14)**: 1337-1340.

Godbharle, A.R., More, A.W. and Ambekar, S.S. (2010). Genetic variability and correlation studies in elite 'B' and 'R' lines in *kharif* sorghum. *Elec.J.plant breeding.* **1(4)**: 989-993.

Gomashe, S., M.B. Misal., K.N. Ganpathy and Sujay Rakshit (2010). Correlation studies for shootfly resistance in sorghum (*Sorghum bicolor* (L.) Moench). *Elec. J. Plant breeding.* **1(4)**: 899-902.

Gururaja Rao M.R. (1995). Correlation and path coefficient analysis in F2 population of two Exotic x Indian crosses of sorghum. *Karnataka J. Agric. Sci.* **9(1)**: 164-167.

Hayes, H.K., F.R. Immer and D.C. Smith, 1995. Method of Plant Breeding.

McGraw Hill Book Company, New York.

Hemlata Sharma, D.K. Jain and Vithal Sharma (2006). Genetic variability and path coefficient analysis in sorghum. *Indian J. Agric. Res.*,**40**:310-312.

Iyanar, K., Vijayakumar, G. and Fazllullah Khan, A.K. (2010). Correlation and path analysis in multicut fodder sorghum. *Elec. J. Plant breeding.* **1(4)**: 1006-1009.

Jain, SK., Elangovan, M and Patel, NV. (2010). Correlation and path coefficient analysis for agronomical traits in forage sorghum

(*Sorghum bicolor* (L.) Moench). *Indian J. Plant Genet. Resour.* **23(1)**: 15-18.

Jain, S.K. and Patel, P.R. (2012). Genetic variability in land races of forage sorghum {*Sorghum bicolor* (L.) Moench} collected from different geographical origin of India. *International Journal of Agri. Sciences.* **4(2)**:182-185.

Jain, S.K. and Patel, P.R. (2013). Variability, correlation and path analysis studies in sorghum (*Sorghum bicolor* (L.) Moench). *Forage Res.,* **39 (1):** 27-30.

Jhansi Rani, K., Rana, B.S., Swarnalata Kaul, Rao, S.S. and Ganesh, M. (2009). Parental lines improvement for morphophysiological characters in *rabi* sorghum. *J. Maharashtra agric. Univ.,* **34 (2)**: 138-140.

Johnson, H,W., Robinson, H.F. and Comstock, R.E. (1955). Genotypic and phenotypic correlation in soyabean and their implications in selection. *Agron. J.* **47**: 477-485.

Kalpande, H.V., Chavan, S.K., More, A.W., Havinale, V.C., Patil, V.S. and Misal, M.B. (2014). Genetic variability and correlation studies in selected F_4 population of sorghum (*Sorghum bicolor* (L.) Moench). *Bioinfolet* **11 (4 A)** : 1058 – 1064.

Kamatar, M.Y., Kotragouda, M., Deepakkumar, G. Shinde and Salimath, P.M. (2011). Studies on variability, heritability and genetic advance in F_3 progenies of *kharif* x *rabi* and *rabi* x *rabi* crosses of sorghum (*Sorghum bicolor* L. Moench). *Plant archives.* **11(2)**: 899-901.

Khairnar, P.D. (2007). Genetic variability and correlation studies in selected B and R lines of *Kharif* sorghum (*Sorghum bicolor* L. Moench.). M.Sc. (Agri.) Thesis submitted to Marathwada Agricultural University.

Khapre, P.R., Narayankar, S.K., Pole, S.P. and Borgaonkar, S.B. (2007). Genetic advance and path analysis in the F2 generation of an intraspecific crosses in *rabi* sorghum. *Internat. J. Plant Sci.* **2(2)**: 212-216.

Lata chaudhary, Sheeshram and Lakshyadeep (2005). Variability and association studies for stover yield in sorghum. *Indian J. Plant Genet. Resour.* **18(2)**: 209-211.

*Lush, 1949. Heritability of quantitative characters in animals. 8th Int. Cong. Genet. Heredilas (Supp.Vol.): 356-357.

Madne, R.D. (2008). Genetic variability studies in restorer line of *Kharif* sorghum (*Sorghum bicolor* (L.) Moench). M.Sc. (Agri.) Thesis submitted to Marathwada Agricultural University, Parbhani.

Mahajan. R.C., Wadikar, S. P. Pole and M.V. Dhuppe (2011). Variability, correlation and path analysis studies in sorghum. *Res.J.Agril.Sci,*2**(1)**:101-103.

Mallinath, V., Biradar, B.D., Chittapur, B.M. Salimath, P.M., Yenagi Nirmala and Patil, S.S. (2004).Variability and correlation studies in pop sorghum. *Karnataka J. Agril. Sci.,* **17(3)**: 463-467.

Mohammad Yazdani (2012). Correlation and path analysis studies on main agronomic characters with its yield of *sorghum bicolor. International journal of agronomy and plant production.* **3(12)**: 645-650.

Navneet Kumar and Singh, S.K. (2012). Character association and path analysis in forage sorghum. *Prog. Agric.* **12(1)**: 148-153.

Nguyen Duy Can and Tomohiko Yoshida (1999). Genotypic and phenotypic variances and covariances in early maturing grain sorghum in a double cropping. *Plant Prod. Sci.* **2(1)**: 67-70.

Panse, V.G. and Sukhatme, P.V. (1985). Statistical methods for agricultural workers ICAR, New Delhi, India.

Patil, C.N., Dapke,J.S., Shah, D.S. and Pawar, G.N. (2014). Genetic variability analysis for various yield and yield attributing traits in sorghum (*Sorghum bicolor* H.). *Trends in Biosciences* 7**(19)**: 2889-2891.

Patil, S.S., Narkhede, B.N., Barhate, K.K. and Chaudhari, G.B. (2006). Correlation analysis associated with shootfly resistance in sorghum. *Agril. Sci. Digest* 26(2): 114-116.

Phuke, R.M., Hariprassana K.,Kailashnath and Mahadevswamy H.K.(2013).Variability in grain yield and yield contributing characters of sorghum. *IJTA*.**31(3-4)**:163-165.

Prabhakar (2003). Genetic variability and correlation studies in F_2 population of *rabi* sorghum. *J. Maha. Agril. Univ.,* **28(2)**: 202-203.

Prakash, R., Ganesamurthy, K., Nirmalakumari, A. and Nagarajan, P. (2010). Correlation and path analysis in sorghum (*Sorghum bicolor* L. Moench)*.Elec. J. Plant breeding.* **1(3)**: 315-318.

Prasuna, CH., Farzana Jabeen and Aruna, C. (2012). Association of grain yield and component traits in sorghum. *J. Res. ANGRAU.* **40(4)**: 66-69.

Price, J. H., S. D. Dillon, G. Hodnett, W. L. Rooney, L. Ross and J. S. Johnston. 2005. Genome evolution in the Genus sorghum (Poaceae). *Ann. of Botany.* **95(1)**:219-227.

Puspitasari, W., Human, S., Wirnas, D. and Trikoesoemaningtyas (2012).Evaluating genetic variability of sorghum mutant lines tolerant to acid soil. *Atom Indonesia* **38 (2)**:83-88.

Sadia Alam, Asghar Ali, I.A. Qamar, M. Arshad and Salim Sheikh (2001). Correlation of economically important traits in *Sorghum bicolor* varieties. *Online journal of biological sciences.* **1(5)**: 330-331.

Sameer Kumar, C.V., Sreelakshmi, Ch. and Shivani. D. (2012). Selection indices for yield in *rabi* sorghum (*Sorghum bicolor* L. Moench) Genotypes. *Elec. J. Plant breeding.* **3(4)**: 1002-1004.

Seetharam, K. and Ganesamurthy, K. (2013). Characterization of sorghum genotypes for yield and other agronomic traits through genetic variability and diversity analysis. *Elec.J.plant breeding.* **4(1)**: 1073- 1079.

Senthil, N. and Palanisamy, S. (1995). Character association and path analysis in sorghum (*Sorghum bicolor*). *Madras Agric. J.* **82(3)**: 169-170.

Shinde D. G., Biradar, B.D., Salimath, P.M., Kamatar, M.Y., Hundekar, A.R. and Deshpande, S.K. (2010). Studies on genetic variability among the derived lines of B X B, B X R and R X R crosses for yield attributing traits in *rabi* sorghum (*Sorghum bicolor* (L.) Moench). *Elec.J.plant breeding.***1(4)**: 695-705.

Singh, P and Narayanam, S.S. (2006). Biometrical techniques in plant breeding. Kalyani publishers. pp. 61-62.

Sudhanshu Jain and Indapurkar, Y.M. (2013). Variability, correlation and path analysis studies in sorghum (*Sorghum bicolor* (L.) Moench). *Advances in Life Sciences* **2 (1)**: 58-59.

Sushil Kumar (2014). Genetic variability in land races of forage sorghum (*Sorghum* bicolor (L) Moench) collected from different geographical origin of India. *Prime journal* **3(2)**: 146-153.

Throat Archana, Hasnale Pushpa, Ghorade, R.B. Sweta P. Bharsakal (2011). Variability studies for shootfly resistance in sorghum. *Ann.Plant Physiol.***25(1)**:30-34.

Thorat, S.T., Datke, S.B., Sudhir A. Bhongle, Santosh A. Bhongle and Dudhe, M.Y. (2004). Correlation studies in some grain mould tolerant derivatives in sorghum genotypes. *PKV Res. J.* **28(2)**: 135-141.

*Vavilov, N.I. 1935. The origin of variation, immunity of cultivated plants translated in 1950, Walthan, Mass USA.

Wankhede, M.G., Shekar, V.B. and Khorgade, P.W. (1985). Variability, correlation and path analysis studies in sorghum (*Sorghum bicolor* (L.) Moench), *PKV Res. J.*, **9(2)**: 1-5.

Warkad, Y.N., Potdukhe, N.R., Dethe, A.M., Kahate, P.A. and Kotgire, R.R. (2008). Genetic variability, heritability and genetic advance for quantitative trait in sorghum Germplasm. *Agric. Sci. Digest,* **28 (3)**: 165-169.

Wright S. (1921). Correlation and causation. *J.Agric. Res.* **20**: 557-586.

* Original not seen.

Thesis Abstract

THESIS ABSTRACT

1.	Title of the thesis	:	**Evaluation of sorghum germplasm for variability, correlation and path analysis**
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ABSTRACT

An experiment was conducted in randomized block design with three replications at the experimental farm at Sorghum Research Station, VNMKV, Parbhani during *rabi* (2013-14) to study genetic variability, correlation and path analysis for various yield and yield contributing characters. Sixty one genotypes including one check named Parbhani Moti were included in the present investigation. Observations were recorded on the characters *viz.,* plant stand, days to 50% flowering, seedling vigour, number of leaves, leaf length, leaf breadth, plant height, panicle length, panicle girth, chlorophyll content %, relative water content, 100 seed weight, panicle weight, shootfly deadheart %, fodder yield and grain yield. The data was collected and analyzed for genotypic and phenotypic coefficient of variation, heritability, expected genetic advance, correlation and path analysis.

Analysis of variance showed the significant variability for all the studied characters. The present investigation revealed that the characters *viz.,* days to 50 % flowering, plant height, panicle length, chlorophyll content %; relative water content, panicle weight and fodder yield showed sufficient variability. The genotypic coefficient of variation was lower than the phenotypic coefficient of variation for all the characters, indicating the role of environment in predicting the performance of genotypes.

High heritability was observed for the characters relative water content (62.90) and grain yield (60.80) coupled with high expected genetic advance (22.28 and 48.86), indicating the preponderance of non-additive gene action; suggesting that hybridization will be effective. Leaf length, leaf breadth, chlorophyll content % and 100 seed weight were positively and significantly correlated with grain yield while, negative and significant association at genotypic level was noticed in panicle girth, relative water content and fodder yield. Seedling vigour (0.3810 and 0.0667) and 100 seed weight (0.2995 and 0.1832) at both genotypic and phenotypic level have positive direct effect on grain yield indicating importance of these characters and can be strategically used to improve yield of sorghum.