EVALUATION OF NEWLY COLLECTED KHARIF SORGHUM GERMPLASM FROM VIDARBHA REGION

THESIS

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BY

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DECLARATION OF STUDENT

I hereby declare that the experimental work and its interpretation of thesis entitled **"EVALUATION OF NEWLY COLLECTED KHARIF SORGHUM GERMPLASM FROM VIDARBHA REGION"** or part there of has neither been submitted for any other degree or diploma at any university nor the data have been derived from any thesis or publication of any university or scientific organization. The sources of materials used and all assistance received during the course of investigation have been duly acknowledged. This thesis is prepared as or the format prescribed by Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola as given in its manual.

Place: Akola

Date: 16 / 06 /2007

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CERTIFICATE

This is to certify that the thesis entitled **"EVALUATION OF NEWLY COLLECTED KHARIF SORGHUM GERMPLASM FROM VIDARBHA REGION"** submitted in partial fulfillment of the requirements for the degree of **"MASTER OF SCIENCE IN AGRICULTURE"** of the Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, is a record of bonafide research work carried out by **Mr. YOGHES NILKANTH WARKAD** under my guidance and supervision. The subject of the thesis has been approved by the students advisory committee.

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LIST OF ABBREVIATIONS

%	-	per cent
/	-	per
cm	-	Centimeter
EGA	-	Expected Genetic Advance
et al.	-	et alia
etc.	-	etcetera
g	-	Gram
GCV	-	Genetic Coefficient of Variation
h^2	-	heritability
ha	-	hectare
i.e.	-	that is
m	-	meter
MT	-	Million tonnes
No.	-	Number
PCV	-	Phenotypic Coefficient of Variation
SE(m)$\pm$	-	Standard error of mean
sig.	-	Significant
PKS	-	Panjabrao Kharif Sorghum

CHAPTER I

INTRODUCTION

Sorghum (*Sorghum bicolor* (L.) Moench) a dryland millet crop mainly grown in Semiarid Tropics of Africa, South Asia and Central America. In India it is mainly grown in Deccan plateau, Central and Western India apart from few patches in Northern India. India is the largest sorghum grower in the world comprises of area 9.19 M ha (2005-06) followed by Nigeria and Sudan. In case of production India ranked seventh and topped by China. In productivity India had its productivity about 20 per cent of that China. But there is an increase of about 15 per cent than in 1981. In India, sorghum is grown in 9.19 million hectare producing 7.47 million tones with an average productivity of 816 kg ha^{-1} in 2005-06. *Kharif* sorghum occupied 4.11 million hectare area, while *rabi* sorghum in relatively more acreage of 5.07 million hectares. *Rabi* sorghum area is slightly higher (56% of total sorghum) than *kharif* sorghum area (44% of the total sorghum) while the *kharif* production is 10 per cent higher than *rabi* production. In India, Maharashtra is the largest sorghum producer with 1.51 million hectare area under *kharif* and 3.10 million hectare under *rabi* followed by Karnataka, whose total sorghum area is 1.61 million hectare (1.31 million hectare under *rabi* and 0.30 million hectare under *kharif*), following is tabular distribution of sorghum area, production and productivity in respected regions.

Area, Production and Productivity of Sorghum during 2005-06.

Regions	Area (Mha)	Production (MT)	Productivity (kg ha^{-1})
World	44.37	58.99	1330
India	9.19	7.47	816
Maharashtra	4.61	3.79	764

(Source: FAO, Database).

In India sorghum was one of the major cereal staple food during 1960's occupied an area about 18 million ha but reduction in area continued from 1990 resulted in current area of 8.78 ha; therefore, during the last 15 years, total area of 7.22 million hectare has been diverted to other crops. This decline is more pronounced in *kharif* compared to *rabi* due to availability of more crop alternatives in the former than in later. However, in the recent past the negative growth in both *kharfi* and *rabi* area has reduced. Maharashtra is the only state where the production changes are positive and significant during last 15-20 years, it means area changes influenced more on the production than yield changes. The decline in over all time period has serious concern on the cropping systems and the food security of these dryland regions of the country. Following are the factors responsible for the decline in area of sorghum.

1. Lack of competitiveness/ low remuneration of grown cultivation of millets.
2. Consumption demand for the millets has been shifted to other fine cereals such as rice and wheat.

3. Policies such as discriminative government policies (ex. Input subsidies and output price incentives).
4. Price competition from oilseed, pulse and commercial crops such as cotton, soybean, groundnut, sunflower etc. and
5. Introduction of irrigation facilities led to shift in commercial crops.

However, sorghum is a risk aversion crop and cannot be completely eliminated from cropping system as it is a sustainable fodder source for meeting huge livestock demand under water scarce/ drought conditions, which is a common feature of sorghum growing regions. Further, it offers a good choice of rotation crop to maintain soil fertility and pest management.

Importance of sorghum as staple grain source is steadily declining. Static consumption of sorghum, in the rural India steeply declined from 1.59 kg/month in 1973 to 0.45 kg/month in 2003. However, regional differences exist. This decline is also significant in the Maharashtra where the grain is traditionally being used as the main staple food. This decline is mainly due to governmental policies which excluded sorghum from public procurement at minimum support price (MSP) and supply through public distribution system (PDS). The policies have encouraged increased consumption of wheat or rice in the regions where sorghum was traditionally valued as the preferred cereals.

Rabi sorghum (post-rainy sorghum) is a highly valued food grain and too expensive to be used as industrial raw material. The utilization of *kharif* sorghum grain as a raw material in various industries like poultry feed, animal feed, alcohol distilleries is increasing given the limited prospects of the rainy season (*kharif*) sorghum for human consumption. Sorghum in Southern India is consumed in the form of Sankati, annum and kanji. The consumption of sorghum roti is traditional practice in states like Maharashtra, Karnataka and Andhra Pradesh. However, due to the difficulties in processing for different foods its usage are very limited in urban areas. It used for production of rawa, noodles etc. The other possible promising alternative food products that can be produced from sorghum grain are bakery product, malto-dextrin as fat replacers in cookies, liquid / powder glucose, high fructose syrup and sorbitol. The technologies like production of glucose, malto dextrins, high fructose syrup are yet to be scaled up. Natural syrup, jaggery, alcohol, brewery etc. produced from sweet stalks of sweet sorghum.

Germplasm of any crop supply plentiful gene pool in breeding programme for the development of present day cultivar, it also fulfil the requirement of various adverse biotic and abiotic resistance characters and valuable genes for quality improvement. The amount of genetic variability available in sorghum (*Sorghum bicolor* (L.) Moench) is immense. The genetic variability is available in both cultivated species and wild progenitors of the crop.

In India, the varietal improvement programme in sorghum crop was initiated in 1930s. The locals were tall, late maturing, flowering after the rainfall seized, generally photosensitive and characterized by localized adoption and low harvest index. Their response to improved management in terms of increased yield was very poor. During that time, most of the improved varieties were the result of pure line selection practiced in principal local varieties. Local x local hybridization followed by selection resulted in varieties with marginal increase in grain yield. With the discovery of workable cytoplasmic-nuclear male sterility and initiation of accelerated sorghum project (AICSIP) in 1962 hybrid breeding was given due emphasis. Which resulted in the release of number of hybrids CSH-1 to CSH-20, based on different females. Whenever, there was a change in ms-line the yield benefit was obvious. Hence, there is a need for developing new male sterile lines having better combining ability in comparison to that of available ms-lines. So far, several germplasm lines of different botanical races have been utilized in development of parental lines. The grain yield levels of *kharif* (rainy season) hybrids have reached the plateau and there is a need to exploit unused germplasm and land races to diversify the genetic base.

The challenge to sorghum improvement will be to concentrate on utilization of desirable traits that may aid in evolution of superior improved lines aiming to surpass the present productivity plateau combined with better drought, disease and pest resistance and improved grain quality.

Genetic variability in yield contributing characters is essential for developing high yielding genotypes in sorghum. The observed variability is a combined measure of genetic and environmental causes.

Similarly, correlation analysis measures the intensity and direction of associations among characters that are important in a breeding programme, when selection is based on several plant characters. Hence computation of phenotypic and genotypic correlation between grain yield and its attributes along with their relative direct and indirect effects on yield are of immense value in selection of superior genotypes. Path coefficient analysis provided an aid for sorting out the total correlation into direct and indirect effect of different characters on yield. The objective of the study was to determine the extent of variability, association among grain yield and other yield related traits along with their direct and indirect effects in 64 sorghum local germplasms/ landraces collected from three districts of Vidarbha region.

OBJECTIVES

1) Collection of *kharif* Sorghum local germplasm by *in situ* selection from Vidarbha region.
2) To estimate the genetic variability parameters.
3) To estimate the correlation and path coefficients.

CHAPTER II

REVIEW OF LITERATURE

Sorghum is one of the most important food crop of Semiarid Tropics of world. Sorghum mainly cultivated for their grain, fodder and other industrial purposes, good quality of food grain for consumption, high protein and mineral content in fodder and ample quantity of energy i.e. carbohydrates for alcohol production are some major requirement of society and industry. High yielding varieties and resistance to diseases and pests for the sake of growing population in India is necessary, but genetic erosion, lack of genetic variability and thereby lack of gene pool in present cultivable crop varieties directly affect the effectiveness in breeding programme.

Hence selecting well combining parent, high heterotic combinations and to supply all kinds of genes through gene pool make breeding programmes successful. For this reason sorghum germplasm has no other option, hence its collection, classification, conservation and its utilization in breeding programmes is necessary. Present investigation is wholely dedicated for such findings to secure production and sustainability in sorghum based farming.

2.1 Genotypic coefficient of variation (GCV)

It is an index of genetic variability present in the population as regards to particular character and gives the idea of range of genetic variability present in the population.

Fisher(1930) first presented the method to separate iterraction of genotypic and environmental factor. The extent of genotypic variability was presented by him with appropriate statistical methods and the value was expressed a genotypic coefficient of variation.

Eckebil *et al.* (1977) studied genetic variability in 200 subscript families from each of three random mating populations of grain sorghum and found that mean of three populations differed significantly for all the characters except grain weight. Also recorded lowest variability for height and number of days required for flowering.

Bittinger and Contrell (1979) studied genetic variability in diverse, random mating grain sorghum population and found that additive effect had a greater influence than dominance effects on days to 50% flowering, plant height, panicle weight, panicle length, grain weight etc.

Lukhele and Obilona (1984) studied genetic variability in 250 subscript lines on selfing in grain sorghum and found that coefficient of variation were lowest for days to 50% flowering and highest for peduncle length.

Kumar and Singh (1986) studied genetic variability in 40 diverse gentypes of grain sorghum and found that genotypic and phenotypic coefficient of variation were high for grain yield per plant.

Bakheit (1990) studied the genotypic variance for traits of 22 genotypes of sorghum under drought conditions and reported significant variation for all the traits.

Maciel *et al.* (1994) studied genetic variability in 160 accessions of new grain sorghum germplasm and found high genotypic variability for plant height and grain yield.

Sankarapandain *et al.* (1996) studied 15 genotypes of grain sorghum, which exhibited significant genotypic variation for 10 characters selected in and around the earhead of the crop. The magnitude of phenotypic coefficients of variation (PCV) and genotypic coefficients of variance (GCV) were found more or less equal for number of whorls per ear head, rachis per ear head, number of grains per ear head, 1000 grain weight grain yield etc.

Can *et al.* (1998) while studied seven traits of thirteen genotyeps, they exhibited a wide range of genetic variability for all the seven traits under consideration. The phenotypic coefficient of variation (PCV) was found to be higher than genotypic coefficient of variation (GCV) for above traits. The highest PCV and GCV was obtained for total fodder weight followed by dry weight of leaves.

Dadheech *et al.* (1999) studied variability in thirty four genotypes and found significant differences among the genotypes for the characters like peduncle length, panicle weight, biological yield per plant harvest index etc. They also observed high estimates of GCV for those traits.

Narkhede *et al.* (2000) studied genetic variability on 168 *rabi* sorghum local types and found that phenotypic coefficient of variation (PCV) was found higher than genotypic coefficient of variation (GCV) for the characters like node length, panicle length, panicle breadth, number of whorls per panicle, number of primaries per panicle, ear head weight etc. They also recorded high values of GCV and PCV for aforesaid characters.

Soltani *et al.* (2001) studied genetic variability in grain sorghum and found significant differences for the characters days to maturity, grain filling rate per unit area etc. expect grain yield.

Sultan *et al.* (2002) studied variability among six different varieties of grain sorghum and found significant differences among the varieties for plant height, only and the non significant differences were noticed for number of leaves per plant, number of tillers per meter row, stem thickness, leaf area and green fodder yield.

Elangovan *et al.* (2005) studied variability in 745 accessions of sorghum landraces and found greater variability for the characters like days to 50% flowering, grain yield, 100 seed weight, earhead length, earhead width, stem thickness and days to maturity.

Geleta *et al.* (2005) assessed the genotypic and phenotypic variability in sixty four sorghum (*Sorghum bicolor* (L.) Moench) germplasm lines and found that genotypic and phenotypic coefficients of variation were greater than 12% for plant height, panicle length, head weight, grain yield per plant, 100 kernel weight and number of kernel per panicle.

Kishore and Singh (2005) studied genetic variability in 30 genetically diverse strains of fodder sorghum and 11 hybrids of sorghum and Sudan grass and found high estimates of phenotypic and genotypic coefficients of variation for green fodder yield and dry matter yield. They observed high genetic advance for plant height, days to 50% flowering, fodder yield, flag leaf area, grain yield and dry fodder yield.

Elangovan (2006) studied variability in 179 accesions of exotic sorghum germplasm collections and found wide range of variation for the characters like days to 50% flowering, plant height, earhead length, stem fresh weight, stem dry weight and grain yield.

Hemlata *et al.* (2006) studied variability in 178 sorghum germplasm lines including two checks and reported high estimates of PCV and GCV for grain yield per plant, panicle length and 100 seed weight.

2.2 Heritability in broad sense

Heritability in broad sense is important selection parameter and requires an estimates of genotypic variance in population. It is good index of the transmission of characters from parent to their offspring. The estimates of heritability helps the plant breeder in selection of elite genotype from diverse genetic populations.

Johnson *et al* (1950) suggested that heritability estimates accompanied by high expected genetic advance are usually more helpful than heritability values alone in predicting the effect of selecting best individuals.

Eckebil *et al.* (1977) conducted variability studies on random mating population of grain sorghum and found that the broad sense heritability estimates were high for the characters flowering date, plant height, grain yield per plant and grain weight.

Panchal *et al.* (1979) studied heritability in F_3 offspring population of sorghum genotypes and revealed that earhead length, earhead weight and 1000 seed weight exhibited high heritability estimates, whereas moderate heritability estimates shown by days to maturity and plant height.

Shinde *et al.* (1979) studied heritability in 20 sorghum varieties and found that days to 50% flowering exhibited very high value of heritability followed by weight of panicle, plant height, panicle length, grain yield per plant and 1000 seed weight. Whereas number of leaves per plant exhibited moderate values of heritability.

Salilkumar and Singhania (1984) conducted heritability studies in grain sorghum and revealed that the characters plant height (83.38%), 250 grain weight (71.69%), grain yield per plant (70.66%) days to 50% flowering (65.59%), leaf length (65.43%) and panicle length (59.39%) exhibited high value of heritability. Whereas number of leaves per plant (46.24%) and number of whorls per panicle (43.99%) showed moderate values of heritability.

Lothrop *et al.* (1985) conducted variability studies in 3 cycles of gridded mass selection of 120 half sibs and 120 subscript families in grain sorghum and reported high heritability for 100 grain weight.

Kumar and Singh (1986) conducted variability studies in 40 diverse genotypes of grain sorghum and found high heritability (90.62%) for the character 1000 seed weight (93.99%), grain yield per plant (90.62%) and plant height (85.30%).

Amirthadevarathinam *et al.* (1990) conducted variability studies in 30 genotypes of fodder sorghum and revealed that the characters plant height exhibited very high heritability estimates (98.07%) followed by leaf length (97.40%), grain yield per plant (93.60%), number of leaves per plant (85.94%), days to 50% flowering (80.00%), earhead girth (78.83%), earhead length (77.40%), leaf width (61.00%), dry fodder weight per plant (57.50%).

Sankarapandian et al (1996) conducted variability studies in 15 varieties of sorghum and found very high heritability estimates for the character grain yield per plant (99.57%) followed by 1000 seed weight (98.90%), number of rachies per earhead (96.88%), peduncle length (96.21%), number of whorls per earhead (94.65%), panicle length (93.32%) and panicle breadth (88.83%).

Can *et al.* (1998) evaluated thirteen genotypes of sorghum, which exhibited the high heritability estimates coupled with high genetic advance for the characters plant height and 1000 seed weight.

Crasta *et al.* (1999) conducted variability studies in grain sorghum genotypes for drought resistance through molecular mapping technique and found that days to maturity exhibited high heritability (72.00%) among all the characters studied.

Dadheech *et al.* (1999) conducted variability studies in 34 genotypes of sorghum and found very high values of heritability for the characters days to maturity, peduncle length, biological yield per plant and panicle weight.

Narkhede *et al.* (2000) studied variability parameters in rabi sorghum local genotypes and found that the characters panicle length and number of primaries per panicle exhibited high heritability estimates of more than 80 per cent.

Chand and Govardhan (2001) conducted heritability studies in fodder sorghum genotypes and obtained moderate heritability estimates for the characters days to 50% flowering (44.7%) and plant height (36.8%).

Soltani *et al.* (2001) conducted variability studies in grain sorghum genotypes to determine the broad sense heritability and found high heritability of 99.40% for the character day to maturity.

Geleta *et al.* (2005) conducted variability studies in 64 sorghum germplasm lines using 12 quantitative traits and found higher estimates of heritability values (greater than 80 per cent) coupled with higher genetic advance for the characters plant height, panicle length and 1000 seed weight.

Kishore and Singh (2005) conducted variability studies on genetically diverse strains of fodder sorghum and observed high heritability estimates for days to flowering and moderate for all other traits.

2.3 Expected genetic advance per cent over mean

Expected genetic advance per cent over mean is important selection parameter. It is an improvement in the mean genotypic value of selected plant over the parental population. The estimates of genetic advance helps in understanding the gene actions involved in the expression of various polygenic characters and also in deciding a breeding procedure for the genetic improvement of various polygenic traits.

Salilkumar and Singhania (1984) studied genetic advance in grain sorghum and revealed that the characters grain yield per plant, plant height and 250 grain weight exhibited high value of expected genetic advance along with high heritability.

Kumar and Singh (1986) studied variability parameters in 40 diverse genotypes of grain sorghum and found high genetic advance (73.14%) for the character grain yield per plant.

Amirthadevarathinam *et al.* (1990) conducted variability studies in 30 genotypes of fodder sorghum and revealed that total fodder yield per plant exhibited high value (77.5%) of expected genetic advance along with high estimates of heritability followed by grain yield per plant. Further they revealed the characters days to 50% flowering, leaf length, earhead length exhibited low value of expected genetic advance.

Sankarapandian (1996) conducted variability studies in 15 genotypes of sorghum and found that the genetic advance per cent over mean was highest along with high value of heritability for grain yield per plant, 1000 grain weight, number of rachies per earhead and peduncle length.

Can *et al.* (1998) evaluated thirteen genotypes of sorghum and reported high genetic advance coupled with high heritability estimates for the characters plant height and 1000 seed weight.

Dadheech *et al.* (1999) studied variability parameters 34 genotypes of sorghum and found high order values of genetic advance along with high order values of heritability for the characters like peduncle length, panicle weight and biological yield per plant. While panicle breadth and number of primaries per earhead exhibited moderate value of EGA.

Narkhede *et al.* (2000) conducted variability studies in 168 rabi sorghum local types and found that the components of grain yield like plant height, number of leaves per plant and panicle length exhibited high genetic advance over mean coupled with high estimates of broad sense heritability. They also reported low values of heritability for the characters leaf width, leaf length and number of whorls per earhead.

Soltani *et al.* (2001) conducted variability studies in grain sorghum to determine expected genetic advance and found low value of expected genetic advance (9.2%) for the characters days to maturity and number of leaves per plant.

Geleta *et al.* (2005) assessed the genetic parameters in 64 sorghum germplasm lines and found higher values of genetic advance per cent over mean (greater than 20%) coupled with higher estimates of heritability (grater than 80%) were obtained for plant height, panicle length and 100 kernel weight, suggesting that additive gene actions are involved. Therefore significant improvement can be realised through selection for plant height, panicle length, grain yield per plant and 100 kernal weight.

2.4 Correlation between yield and yield component traits

Correlation analysis measures the intensity and direction of association among the characters that are important in a breeding programme when selection is based on several plant characters. Hence computation of phenotypic and genotypic correlation between grain yield and its attributes is essential. An attempt has been made therefore to review the literature concerning to these aspects in sorghum.

Robinson *et al* (1949) and Johnson *et al* (1955) advocated the role of correlation studies as it provides better understanding of yield components which helps the plant breeder during selection.

Eckebil *et al.* (1977) studied genetic correlations in 200 subscript families from each of three random mating populations of grain sorghum and found that grain yield per unit area was generally best correlated with grain yield per ear head, plant height and threshing percentage.

Shahane *et al.* (1984) studied character association in 8 male sterile and 10 fertility restorer lines of *kharif* and *rabi* grain sorghum and found that grain yield was positively correlated with most of the characters in both the seasons.

Berenji (1988) studied correlation in F_1 hybrids and their parents (8 restorer lines and 4 cms lines in diallel programme) of grain sorghum and reported that height exhibited a significant phenotypic and genotypic correlation with grain yield owing to indirect effect through number of grains per panicle.

Amirthadevarathinam *et al.* (1990) studied correlation in 30 genotypes of fodder sorghum and revealed that plant height and leaf width exhibited highly significant positive association with grain yield per plant. Further plant height exhibited highly significant positive correlation with leaf length and fodder yield. While number of leaves per plant exhibited highly significant positive correlation with leaf length.

Bakheit (1990) studied correlation of yield components and yield in 22 grain sorghum genotypes and reported that plant height and 1000 grain weight were highly correlated with grain yield, while leaf area index showed a poor correlation with plant height.

Shanmughasundaram and Subramanian (1990) studied correlation in 40 genotypes of sorghum and revealed that the characters plant height, leaf number and 100 grain weight showed high positive association with grain yield both at phenotypic and genotypic level.

Zongo *et al.* (1993) studied correlation in 74 accessions of grain sorghum and observed strong positive correlation between days to flowering, number of internodes, panicle length, panicle width, panicle weight etc. Further they observed that 100 kernel weight exhibited an antagonism with days 5o flowering and tillering.

Potdukhe *et al.* (1994) studied correlation of yield and yield components of 42 *kharif* sorghum genotypes and reported that the grain yield was positively and significantly correlated at the genotypic and phenotypic level with panicle length, panicle weight and 100 grain weight.

Sankarapandian *et al.* (1996) conducted correlation studies in 15 grain sorghum varieties and revealed that grain yield showed no correlation with most of the component characters except with 100 seed weight and number of grains per rachis, it may be due to elimination effect of one or other characters contributing for grain yield.

Jayprakash *et al.* (1997) studied correlation in 65 genotypes grain sorghum and observed that grain yield was significantly and positively correlated with panicle weight, panicle length and dry fodder yield. Plant height also had a positive, significant association with grain yield at genotypic level.

Can *et al.* (1998) worked out correlation between characters of 13 local germplasm lines of sorghum and found that harvest index and its yield components like total fodder yield, plant height, 100 seed weight, leaves per plant, number of internodes had a high positive correlation with grain yield.

Muppidathi *et al.* (2000) studied correlation among yield and yield components in sixty F_1 hybrids of sorghum produced by crossing 5 CGMS lines with 12 medium tall sorghum genotypes and reported that plant height, grains per panicle and 100 grain weight were highly correlated with grain yield.

Nawale *et al.* (2000) conducted correlation studies with fourty one sorghum inbreed lines and reported highly significantly positive correlation between grain yield and earhead weight. They also observed positive but non significant correlation between plant height, harvest index and grain yield.

Sankarapandian (2000) studied the correlation in fodder sorghum genotypes and found that crude protein content was positively correlated with grain and fodder yield, while it was negatively correlated with crude fibre. Further crude fibre content was negatively and significantly correlated with grain and fodder yield.

Bhongle *et al.* (2001) studied correlation in *kharif* sorghum and found that the grain yield per plant showed positive and significant correlation with germination percentage, plant height, head breadth, grain hardness at genotypic level. While, they also observed high significant positive association of days to 50 per cent flowering with plant height and also high positive association of plant height with earhead length.

Iyanger *et al.* (2001) conducted correlation studies in 54 sorghum genotypes including 10 restorer lines, 4 cms lines, 40 hybrids and reported that seed yield was significantly and positively correlated with panicle weight and panicle length.

Soltani *et al.* (2001) reported that grain yield had significant negative correlation with physiological traits related to development and vegetative growth. However, there was significant positive correlation between growth rate, grain filling rate and harvest index.

Vance (2001) studied correlation in grain sorghum and reported that only grain number per panicle were closely correlated with panicle length but grain yield was not correlated with panicle length.

Veerabandhiram and Kennedy (2001) studied selected lines of sorghum germplasm and found that genotypic correlation coefficient was generally higher than phenotypic correlation coefficient. Grain yield per plant exhibited significant positive correlation with 100 grain weight, while characters like days to 50 per cent flowering and days to maturity exhibited significant negative correlation with grain per plant.

Sunku *et al.* (2002) studied correlation in grain sorghum and found that correlation coefficients were significant and high among dry matter yield, green fodder yield, leaf length, plant height, number of leaves, dry matter content and leaf width.

node number per plant, panicle weight and kernel number per panicle correlated positively and significantly with seed yield per plant.

Kishore and Singh (2005) studied correlation in 30 genetically diverse sorghum strains and 11 hybrids of sorghum and sudan grass and found that days to 50% flowering, flag leaf area, plant height, green fodder yield, dry fodder yield are positively correlated with each other.

Elangovan (2006) studied correlation in 179 accessions of exotic sorghum collections and found that grain yield showed highly positive correlation with number of leaves per plant, leaf width and stem thickness. Also 100 seed weight showed highly positive correlation with number of leaves, leaf width, stem thickness and grain yield.

Ezeaku and Mohammed (2006) studied correlation among yield and yield attributing characters of 30 sorghum varieties and reported highly significant positive strong correlation between grain yield-head weight; grain yield -1000 grain mass; and 1000 grain mass-head weight etc.

Hemalata *et al.* (2006) studied correlation in 176 germplasm lines and two checks of sorghum and found that grain yield per plant showed significant positive correlation with 100 seed weight.

Premalatha *et al.* (2006) reported that grain yield was significantly and positively correlated with number of grains per panicle and 100 grain weight in grain sorghum.

2.5 Path Analysis

The method of path analysis is used in evaluating the relative direct and indirect influence of various traits towards the dependent variable. The path coefficient measures the importance of given path of influence from cause to effect. The path coefficient analysis technique was first published by Wright (1921). He also mentioned that path coefficient does give a method of working out of logical consequences of a hypothesis as to the casual relation in system of correlated variables.Dewey and Lu (1959) use path analysis technique first time for plant selection in wheat grass and gave detailed procedure for path analysis of replicated traits, which was quit different technique in eliminating the environmental variances. Recent summaries of basic feature of method and its application were given by Li (1948). An attempt has therefore made to review the literature concerning to these aspects in sorghum.

Singh *et al.* (1976) studied path analysis for yield components in 25 cultivars of grain sorghum and found that the panicle weight had the greatest direct effect on yield but this was counterbalanced by the negative indirect effect of panicle weight through the other characters measured viz. days to 50% flowering, leaf length and breadth, 1000 grain weight etc.

Patel *et al.* (1979) studied path analysis in 19 hybrids of sorghum during kharif season and found that 100 seed weight had high direct positive effect on grain yield per plant.

Shahane *et al.* (1984) studied path analysis in 8 sterile and 10 fertility restorer lines of *kharif* and *rabi* grain sorghum and found that panicle weight and number of secondary branches per panicle had the highest positive direct effects on yield.

Berenji (1988) studied path analysis in F_1 hybrids and their 12 parents (8 restorer lines and 4 cms lines) of grain sorghum and found that number of grains per panicle had the greatest direct effect on yield followed by 100 grain weight.

Shanmughasundaram and Subramanian (1990) studied path analysis in 40 genotypes of sorghum and revealed that grain weight had high direct effect on grain yield followed by days to 50% flowering. They also observed positive indirect effect of the characters, plant height and leaf number via. 1000 grain weight. Further grain weight via. days to 50% flowering, number of whorls via. grain number per plant followed by days to 50% flowering and number of leaves per plant via grain weight followed by days to 50% flowering exhibited maximum positive indirect effect on grain yield.

Potdukhe *et al.* (1994) studied path analysis in 42 *kharif* sorghum genotypes and found that plant height, stem girth and 100 grain weight had high positive direct effects on grain yield.

Saadalla *et al.* (1994) studied path analysis in 100 grain sorghum genotypes including locally adopted landraces, 5 introductions from the USA and 6 local commercial cultivars and found that seed index had the highest direct effect on grain yield per plant.

Sankarapandian *et al.* (1996) studied path analysis in genotypes of grain sorghum varieties and found that 1000 seed weight and number of grains per rachis are the prime key characters for the improvement of grain yield.

El-Nagar (1997) studied path analysis in 55 landraces of sorghum and revealed that 1000 grain weight, head length, head weight contributed high direct effect on grain yield.

Jayprakash *et al.* (1997) studied path analysis in 65 genotypes of grain sorghum and observed that panicle weight had the maximum influence on grain yield, followed by dry fodder yield, plant height and panicle length.

Can *et al.* (1998) reported that harvest index and its component like total biological yield, had strong direct or indirect effects on grain yield.

Muppidathi *et al.* (2000) studied path analysis in sixty F_1 hybrids of sorghum produced by crossing 5 CGMS (cytoplasmic genetic male sterile) lines with 12 medium tall sorghum genotypes and found that number of rachis per panicle, stem thickness and 100 grain weight showed positive and direct effect on grain yield in sorghum.

Sankarapandian (2000) studied the path analysis in fodder sorghum and revealed that the component traits viz., plant height, stem girth and number of leaves per plant showed positive direct effects. Whereas juice yield and crude protein in fodder shows negligible direct effect on dry fodder yield.

Iyanger *et al.* (2001) worked out path analysis in 54 sorghum genotypes including 10 restorer lines, 4 cms lines and 40 hybrids and reported that panicle weight had high direct effect on seed yield followed by panicle length, days to 50% flowering and 100 seed weight.

Veerabandhiram and Kennedy (2001) conducted studies on selected lines of sorghum germplasm and found that 100 seed weight, contributed high direct effect toward grain yield and this was followed by days to 50% flowering.

Sunku *et al.* (2002) studied path analysis in grain sorghum and found that leaf length, plant height, number of leaves per plant, leaf width, green fodder had high direct effect on dry matter yield.

Maman *et al.* (2004) carried out path analysis of grain yield and yield components and found that 100 kernel weight contributed high direct effect on grain yield of grain sorghum.

Geleta and Daba (2005) evaluated 64 sorghum land races for yield and yield related traits and found that high panicle weight 100 kernel weight and kernel number per panicle had indirect effect on grain yield and hence could be used in indirect selection strategy to improve seed yield in landraces.

Kishore and Singh (2005) worked out path analysis in 30 genetically diverse strains, 11 hybrids of sorghum and sudan grass and found that days to 50% flowering, flag leaf area, plant height, green fodder yield and dry fodder yield has maximum direct effect on grain yield.

Ezeaku and Mohammed (2006) studied path analysis in 30 sorghum varieties and found that head weight had highest direct effect on grain yield, while 1000 grain mass contributed indirectly to grain yield via head weight.

Hemlata *et al.* (2006) studied path analysis in 176 germplasm lines and two checks of sorghum and found that days to 50% flowering followed by 100 seed weight had highest direct effect on grain yield.

Premalatha *et al.* (2006) studied path analysis in 49 genotypes of grain sorghum and found that direct contribution of 100 grain weight was high on grain yield followed by number of grains per panicle, leaf area index, plant height and days to 50% flowering.

14. Glume colour : The glume colour was observed visually and recorded by referring descriptors.

15. Glume covering (%): The amount of grain covered by glumes was observed visually and recorded by taking the reference of descriptors.

16. Seed colour : The seed colour was observed visually and recorded just before harvesting.

17. Seed shape : The seed shape was observed and decided as per provided in descriptors before harvesting.

18. Threshability: The observations of threshability were recorded by simply rubbing primaries between hands and grades gives as freely, partially and difficult (Hard), number of grains separated from glumes and number of grains with glumes.

3.2.2 Post harvest observation

19. Earhead length (cm) : Length of earhead was measured in centimeters and mean earhead length was calculated.

20. Earhead breadth (cm) : As above length, the breadth of earhead was measured in centimeters and mean was calculated.

21. Number of whorls per earhead: The total number of whorls were counted by removing the each and every primaries from base to top of earhead and mean was calculated.

22. Number of primaries per whorl : From the lower, middle and upper whorls of the earhead primaries were counted and mean was worked out for calculating number of primaries per whorl.

23. **Number of primaries per ear head**: Total number of primaries were counted by separating out from the earhead and mean number was calculated.

24. **1000 seed weight (g)**: From composite grain sample of observational plant 1000 grains were measured and weighed in grams. Mean weight was calculated treatmentwise.

25. **Dry fodder yield per plant (g)**: After harvesting of earhead, plants were cutted at base and allowed to dry for 25 to 30 days, thereafter weight of dry fodder per plant was measured in gram and mean was worked out.

26. **Grain yield per plant (g)**: Each and every observations plant was threshed separately, weighted in grams and per plant grain yield was calculated.

3.2 Statistical Analysis

The data obtained in respect of all the characters has been subjected to following statistical analysis

3.3.1 Analysis of variance

Analysis of variance was carried out in order to partition the total variation exhibited by different characters under study into its components viz., blocks, treatments and error. This is carried out as per the standard method suggested by Panse and Sukhatme (1957). The details are given in the following table.

Analysis of variance

Sources of variation	df	M.S.S.	Expectations
Replication	(r-1)	M_1	$\sigma^2 e + g\,\sigma^2 r$
Treatment	(t-1)	M_2	$\sigma^2 e + r\,\sigma^2 g$
Error	(r-n)(t-1)	M_3	$\sigma^2 e$

Where,

r = number of replications

t = number of genotypes / treatments

$$\text{Genotypic variance } (V_G) = \frac{M_2 - M_3}{r}$$

$$\text{Phenotypic variance } (V_P) = \frac{M_2 - M_3}{r} + M_3$$

Environmental variance (V_E) = M_3

3.3.2 Genetic parameters

The genetic parameters, such as genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability and genetic advance for different characters were worked out for all the genotypes under study as per the standard procedures.

Genotypic and phenotypic coefficients of variation

Genotypic and phenotypic coefficients of variation were estimated by the formulae as suggested by Burton (1951).

$$GCV = \frac{\sqrt{\text{Genotypic variance}}}{\bar{X}} \times 100$$

Where, $\bar{X}$ = mean of the character

$$PCV = \frac{\sqrt{\text{Phenotypic variance}}}{\bar{X}} \times 100$$

Where, $\bar{X}$ = mean of the character

Heritability (h^2)

Heritability of character is an index of its transmissibility. It is the ratio of genotypic variance to phenotypic variance and heritability in broad sense is calculated by the formula as suggested by Johnson *et al.* (1955).

$$h^2 = \frac{V_G}{V_p} \times 100$$

Where,

h^2 = heritability (broad sense)

V_G = Genotypic variance

V_p = Phenotypic variance

Genetic Advance (GA)

$$GA = \frac{V_G}{\sqrt{V_P}} \times k$$

Where,

V_G = Genotypic variance

V_P = Phenotypic variance

k = Selection differential at 5% selection intensity

Value of K = 2.06 at 5% level (Lush, 1949).

Expected genetic advance is expressed in percentage over mean.

$$\text{EGA in \% over mean} = \frac{GA}{\bar{X}} \times 100$$

Where,

$\bar{X}$ = mean of the character

3.3.3 Correlation studies

The relationship between two or more quantitative characters is of great interest and carried much practical significance. Correlation is a measure of the degree to which characters are associated with yield or among themselves (Burton, 1951).

Partitioning of variance

Variance is partitioned into genotypic, phenotypic and environmental components. In order to form a reliable basis for selection, it is necessary to breakup the observed variances and covariances into its heritable (Genetic) and non heritable (non genetic) components. This was as per the method suggested by Fisher (1954).

$$\text{Genotype variance } (V_G) = \frac{\text{Treatment variance} - \text{Error variance}}{\text{Number of replications}}$$

Phenotypic variance (V_P) = Genotypic variance + Error variance

Environmental variance (V_E) = Error variance

Calculation of genotypic and phenotypic correlation coefficients

To study the extent of association between different traits under study, the simple genotypic, phenotypic and environmental correlation coefficients were worked out from the respective variances and covariances as per the formulae suggested by Hayes, Immer and Smith (1955).

$$\text{Genotypic } r_{x.y} = \frac{\text{Genotypic covariance}_{xy}}{\sqrt{\text{Genotypic variance of x X Genotypic variance of y}}}$$

$$\text{Phenotypic } r_{x.y} = \frac{\text{Phenotypic covariance}_{xy}}{\sqrt{\text{Phenotypic variance of x X Phenotypic variance of y}}}$$

$$\text{Environmental } r_{x.y} = \frac{\text{Environmental covariance}_{xy}}{\sqrt{\text{Environmental variance of x X Environmental variance of y}}}$$

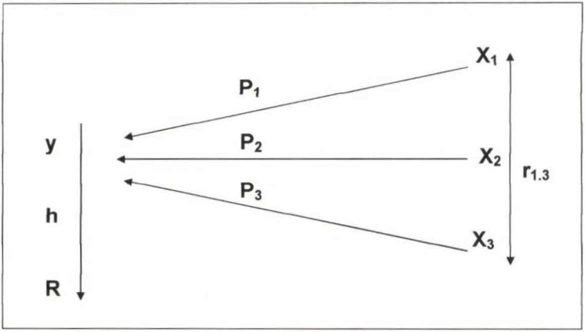
Significance test of simple correlation coefficient

Significance of simple correlation coefficient is determined from Table of correlation coefficient at 5 per cent and 1 per cent levels of significance. The calculated `r' values were compared against table `r' values at (n-2) degree of freedom.

3.3.4 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 standardized partial regression coefficient analysis and as such measures, the direct influence of one variable upon other and permits the separation of correlation coefficients into components of direct and indirect effects. The use of this technique requires a cause and effect situation among the variables.

Path coefficient were calculated by the method used by Dewey and Lu (1959) by solving simultaneous equations which express the basic relationship between path coefficient and correlation coefficient.



The estimates of direct and indirect effects are obtained by solving the following set of simultaneous equations.

$$\begin{pmatrix} 1 & r_{12} & r_{13} \cdots\cdots & r_{1n} \\ r_{21} & 1 & r_{23} \cdots\cdots & r_{2n} \\ . & . & . & . \\ . & . & . & . \\ . & . & . & . \\ r_{n1} & r_{n2} & r_{n3} \cdots\cdots & 1 \end{pmatrix} \begin{pmatrix} P_1 \\ P_2 \\ . \\ . \\ . \\ P_n \end{pmatrix} = \begin{pmatrix} r_{1y} \\ r_{2y} \\ . \\ . \\ . \\ r_{ny} \end{pmatrix}$$

Where,

i=r=1,2,3..............n

r_{ij} is correlation coefficient between xi and xj

riy is correlation coefficient between xi and y

pi is direct effect of xi on y

rij Pi is the indirect effect of xi on y through xj

The residual effect i.e. variation in yield unaccounted for these association was calculated from the following formula.

Residual effect (x) = 1 = R^2

Where,

$$R^2 = P_1y\, r_1y + P_2y\, r_2y + P_3y\, r_3y + \ldots\ldots\ldots\ldots\ldots + P_ny\, r_ny$$

Where,

P_1y, P_2y, P_3y .... P_ny = Path values

r_1y, r_2y, r_3y .... r_ny = Correlation coefficients

CHAPTER IV

EXPERIMENTAL FINDINGS

The present investigation entitled as "Evaluation of newly collected *kharif* Sorghum germplasm from Vidarbha region" was undertaken with the following objectives.

1. Collection of *Kharif* Sorghum local germplasm by *in situ* selection from Vidarbha region.
2. To estimate the genetic variability parameters
3. To estimate the correlation and path coefficients

The results obtained in the present investigation have been given under the following sub-heads.

4.1 Analysis of variance

4.2 Genetic variability studies

4.3 Correlation studies

4.4 Path analysis studies

4.1 Analysis of variance

The analysis of variance was carried out for all the characters under study to know, whether the genotypes included differed significantly among themselves. Analysis of variance for all the characters under study is presented in Table 1.

The ANOVA revealed highly significant differences among the genotypes for all the characters studied viz. Days to 50 per cent flowering, days to maturity, plant height (cm), number of internodes per plant, number

Table 1. Analysis of variance for various characters in sorghum

Source	d.f.	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of internodes per plant	No. of leaves per plant	Leaf length (cm)	Leaf width (cm)
		1	2	3	4	5	6	7
Replication	2	32.75*	22.77	667.02	1.46	1.86	49.4	0.613
Treatments	63	257.25**	259.74**	897.48**	2.92**	3.10**	125.187**	1.00**
Error	126	8.29	8.32	344.89	0.78	0.73	66.42	0.25

Source	d.f.	Stem girth (cm)	Earhead length (cm)	Earhead breadth (cm)	No. of whorls per earhead	No. of primaries per whorls	No. of primaries per earhead	1000 seed wt. (g)	Dry fodder wt. per plant (g)	Grain yield per plant (g)
		8	9	10	11	12	13	14	15	16
Replication	2	0.14	14.68	0.89	0.07	0.21	95.30	6.35	60.15	0.35
Treatments	63	2.78**	67.08**	7.58**	3.80**	2.59**	339.29**	43.76**	107.41**	47.92**
Error	126	0.05	5.72	0.70	1.49	0.88	71.09	11.42	59.74	2.46

* Significant at 5%
** Significant at 1%

of leaves per plant, leaf length (cm), leaf width (cm), stem girth (cm), earhead length (cm), earhead breadth (cm), number of whorls per earhead, number of primaries per whorl, number of primary per earhead, 1000 seed weight (g), dry fodder yield per plant (g) and grain yield per plant (g). This indicates the presence of substantial amount of genetic variability in the genotypes for all the characters under study.

4.2 Genetic variability studies

The mean performance of all genotypes for different traits is presented in Appendix-I The values of Mean, Range, Standard Error of difference, Coefficient of variation, Genotypic variance, Phenotypic variance, Genotypic coefficient of variation, Phenotypic coefficient of variation, Heritability in broad sense and Expected Genetic Advance per cent over mean for various characters are presented in Table 2.

4.2.1 Genotypic coefficient of variation (%)

It is revealed from Table 2 that genotypic coefficient of variation (GCV) ranged from 5.49 to 41.17 per cent for different characters under study. The high order value of genotypic coefficient of variation were observed for dry fodder weight per plant (41.17%) followed by earhead breadth (28.62%), grain yield per plant (28.37%), earhead length (27.73%), stem girth (21.42%), 1000 seed weight (15.76%) and plant height (14.54). While low order values of genotypic coefficient of variation noted for number of primaries per earhead (13.65%), days to 50% flowering (11.45%), number of primaries per whorl (10.24%), number of whorls per earhead (9.31%), leaf width (8.77%), days to maturity (7.53%), number of internodes

Table 2. Estimation of genetic parameters - range, mean, CV, GV, GCV, PCV, h^2 and EGA for characters under study

Sr. no.	Characters	Range	Mean	SE(d)	Coefficient of variation	Genotypic variance	Phenotypic variance	Genotypic coefficient of variation	Phenotypic coefficient of variation	H^2 (%)	Expected genetic advance per cent over mean
1	Days to 50% flowering	62.7-99.3	79.83	2.352	3.621	82.98	91.28	11.45	12.01	90.91	22.49
2	Days to maturity	104.7-141.3	121.51	2.355	2.374	83.80	92.12	7.53	7.89	90.96	14.80
3	Plant height (cm)	126.2-345.6	167.87	15.163	6.933	1517.52	1862.42	14.54	16.11	81.48	27.04
4	No. of internodes/plant	9.0-13.4	11.76	0.723	7.525	0.714	1.497	7.18	10.40	47.68	10.21
5	No. of leaves/plant	9.8-14.3	12.63	0.696	6.761	0.793	1.523	7.04	9.76	52.07	10.47
6	Leaf length (cm)	63.3-90.7	80.48	6.665	10.127	19.586	86.014	5.49	11.52	22.77	5.40
7	Leaf width (cm)	4.4-7.5	5.67	0.415	8.960	0.247	0.505	8.77	12.54	48.95	12.65
8	Stem girth (cm)	2.3-7.1	4.44	0.196	5.396	0.908	0.966	21.42	22.09	94.03	42.80
9	Earhead length (cm)	9.8-29.6	16.3	1.954	14.673	20.45	27.176	27.73	31.37	78.12	50.49
10	Earhead breadth (cm)	3.7-13.2	5.29	0.686	15.884	2.294	3.00	28.62	32.73	76.45	51.56
11	No. of whorls/earhead	8.0-15.5	9.43	0.997	12.952	0.771	2.263	9.31	15.95	34.08	11.19
12	No. of primaries / whorls	4.7-10.1	7.38	0.766	12.704	0.572	1.453	10.24	16.32	39.42	13.25
13	No. of primaries/ earhead	41.5-92.9	69.23	6.884	12.179	89.40	160.492	13.65	18.29	55.70	20.99
14	1000 seed weight (g)	11.8-28.5	20.82	2.76	16.230	10.77	22.205	15.76	22.62	48.54	22.62
15	Dry fodder weight /plant (g)	25.0-155.8	63.44	6.311	12.182	682.55	742.29	41.17	42.94	91.95	51.60
16	Grain yield/plant (g)	7.4-26.4	13.71	1.282	11.445	15.15	17.619	28.37	30.59	86.00	54.21

per plant (7.18%), number of leaves per plant (7.04%) and leaf length (5.49%).

4.2.2 Phenotypic coefficient of variation (%)

The phenotypic coefficient of variation (Table 2) ranged from 7.89 to 42.94 per cent for various characters under study. Highest phenotypic coefficient of variation was observed for the character dry fodder weight per plant (42.94%) followed by earhead breadth (32.75%), earhead length (31.37%), grain yield per plant (30.59%), 1000 seed weight (22.62%), stem girth (22.09), number of primaries per earhead (18.29%), number of primaries per whorl (16.32%), plant height (16.11%) and number of whorls per earhead (15.95%). While low order values were observed for characters like leaf width (12.54%), days to 50% flowering (12.01%), leaf length (11.52%), number of internodes per plant (10.40%), number of leaves per plant (9.76%) and days to maturity (7.89%).

4.2.3 Heritability estimates in broad sense (%)

Data presented in Table 2 revealed that the heritability estimates ranged from 22.77% (leaf length) to 94.03% (stem girth) for different characters under study. The maximum broad sense heritability

was recorded for the character stem girth (94.03%) followed by dry fodder weight per plant (91.95%), days to maturity (90.96%), days to 50% flowering (90.91%), grain yield per plant (86.00%), plant height (81.48%), earhead length (78.12%), earhead breadth (76.45%), number of primaries per earhead (55.70%) and number of leaves per plant (52.07%). The moderate heritability was recorded for leaf width (48.95%), 1000 seed weight (48.54%), number of internodes per plant (47.68%), number of primaries per whorl (39.42%), number of whorls per earhead (34.08) and leaf length (22.77%).

4.2.4 Expected genetic advance (%)

Expected genetic advance per cent over mean was estimated for different characters and data presented in Table 2. Data revealed that expected genetic advance per cent over mean was in the range of 5.40 to 54.21 per cent for different characters. The higher expected genetic advance per cent over mean observed for the characters grain yield per plant (54.21%) dry fodder weight per plant (51.60%), earhead breadth (51.56%), earhead length (50.49%), stem girth (42.80%), plant height (27.04%), 1000 seed weight (22.62%), days to 50% flowering (22.49%) and number of primaries per earhead (20.99%). While lower values were observed for the characters days to maturity (14.80%), number of primaries per whorl (13.25%), leaf width (12.65%), number of whorls per earhead (11.19%), number of leaves per plant (10.47%), number of internodes per plant (10.21%) and leaf length (5.40%).

4.3 Correlation studies

In order to find out the degree of association of yield with yield contributing characters genotypic and phenotypic correlation coefficients were worked out and are presented in Table 3.

4.3.1 Genotypic correlation

4.3.1.1 Association between yield and yield contributing characters

Data revealed that the genotypic correlation coefficients of yield were higher in magnitude as compared to phenotypic correlation coefficients (Table 3).

The character 1000 seed weight (r=0.481) showed highly significant positive association with grain yield per plant at genotypic level, whereas earhead length (r=0.206), dry fodder weight per plant (r=0.183), leaf length (r=0.182), number of whorls per earhead (r=0.103), plant height (r=0.075), stem girth (r=0.045), number of primaries per earhead (r=0.022), earhead breadth (r=0.022) and leaf width (r=0.013) showed positive but non significant association with the grain yield per plant. While negative association with grain yield was exhibited by the characters, number of internodes per plant (r=-0.090), number of leaves per plant (r=-0.087), number of primaries per whorl (r=-0.079), days to maturity (r=-0.010) and days to 50% flowering (r=-0.007) at genotypic level.

4.3.1.2 Association between yield contributing characters among themselves

a. Days to 50% flowering

Days to 50% flowering showed highly significant positive association with days to maturity (r=1.00), plant height (r=0.548), dry fodder weight per plant (r=0.395), number leaves per plant (r=0.327) and moderately significant positive association with number of internodes per plant (r=0.319) and leaf length (r=0.316).Where as days to 50% flowering had negatively significant association with number of whorls per earhead (r=-0.524).

The characters stem girth (r=0.227), 1000 seed weight (r=0.203), number of primaries per whorl (r=0.153) and leaf width (r=0.077) showed positive association and number of primaries per earhead (r=-0.242), earhead length (r=-0.130) and earhead breadth (r=-0.002) showed negative association with days to 50% flowering, however the values are non-significant.

b. Days to maturity

Days to maturity exhibited highly significant positive genotypic correlation with plant height (r=0.548), dry fodder weight per plant (r=0.392), number of leaves per plant (r=0.337), number of internodes per plant (r=0.328) , moderately significant positive correlation with leaf length (r=0.316) and only positive association with stem girth (r=0.228), 1000 seed weight (r=0.194), number of primaries per earhead (r=0.148) and leaf width (r=0.083).

Similarly days to maturity exhibited highly significant but negative genotypic correlation with number of whorls per earhead (r=-0.519). While negative and non significant genotypic correlation with number of primaries per earhead (r=-0.224), earhead length (r=-0.137) and earhead breadth (r=-0.003).

c. Plant height (cm)

Plant height exhibited highly significant and positive correlation with dry fodder weight per plant (r=0.529), number of internodes per plant (r=0.421) and number of leaves per plant (r=0.418) and moderately significant correlation with earhead (r=0.311) and leaf length (r=0.253).

Similarly, plant height exhibited positive correlation with the 1000 seed weight (r=0.227), earhead breadth (r=0.175), leaf width (r=0.144), stem girth (r=0.109) and number of primaries per whorl (r=0.016),while exhibited negative correlation with number of whorls per earhead (r=-0.221) and number of primaries per earhead (r=-0.134) however, the genotypic coefficient value are non significant.

d. Number of internodes per plant

At genotypic level number of internodes per plant expressed very strong correlation only with number of leaves per plant (r=1.000), it exhibited positive but non-significant correlation with stem girth (r=0.249), earhead breadth (r=0.235), leaf length (r=0.134), number of primaries per whorl (r=0.036), number of whorls per earhead (r= 0.032), dry fodder weight per plant (r= 0.031) and number of primaries per earhead (r= 0.027).

The characters 1000 seed weight (r=-0.129), leaf width (r=-0.097) and earhead length (r=-0.066) exhibited non-significant association in negative direction.

e. Number of leaves per plant

Number of leaves per plant had moderately significant positive association with stem girth only (r=0.251) and it had positive association with leaf length (r=0.200), earhead breadth (r=0.197), number of primaries per whorl (r=0.090) as well as dry fodder weight per plant (r=0.078) and number of primaries per earhead (r=0.003), however the correlation coefficient values are non significant. Similarly the number of leaves per plant had exhibited negative and non-significant correlation with the traits 1000 seed weight (r=-0.103), earhead length (r=-0.081), number of whorls per earhead (r=-0.078) as well as leaf width (r=-0.053).

f. Leaf length (cm)

Leaf length showed highly significant and positive association with number of primaries per whorl (r=0.486) and moderately significant association with 1000 seed weight (r=0.282). Whereas it showed positive but non-significant association with number of primaries per earhead (r=0.220), stem girth (r=0.134), earhead breadth (r=0.107) and earhead length (r=0.027), Similarly this character showed negative and non-significant association with leaf width (r=-0.235), number of whorls per earhead (r=-0.112) and dry fodder weight per plant (r=-0.005) at genotypic level.

g. Leaf width (cm)

Leaf width expressed highly significant positive association with stem girth (r=0.339) and moderately significant but negative association with earhead breadth (r=-0.252). It showed positive association with dry fodder weight per plant (r=0.131), number of primaries per earhead (r=0.099), number of whorls per earhead (r=0.071), number of primaries per whorl (r=0.047) and earhead length (r=0.005) however, the coefficients are non-significant. It also showed negative and non-significant association with 1000 seed weight (r=-0.020).

h. Stem girth (cm)

Stem girth expressed positive association with dry fodder weight per plant (r=0.191), earhead length (r=0.075), 1000 seed weight (r=0.023) and negative association with earhead breadth (r=-0.144), number of whorls per earhead (r=-0.100), number of primaries per earhead (r=-0.070) and number of primaries per whorl (r=-0.015) at genotypic level, however, the magnitudes of correlation coefficients are very low.

i. Earhead length (cm)

One of the important yield contributing character earhead length, exhibited strong correlation with earhead breadth (r=0.555) in positive direction and with number of primaries per whorl (r=-0.596) in negative direction. This character also expressed moderately significant but negative correlation with 1000 seed weight (r=-0.316) and number of primaries per earhead (r=-0.309). It showed positive association with number of whorls per earhead (r=0.136) and negative with dry fodder weight per plant (r=-0.075) at genotypic level.

j. Earhead breadth (cm)

Earhead breadth exhibited moderately significant but negative correlation with number of primaries per whorl (r=-0.265) and 1000 seed weight (r=-0.257). While it exhibited negative association with number of primaries per earhead (r=-0.240), number of whorls per earhead (r=-0.205) and dry fodder weight per plant (r=-0.162) at genotypic level, however, association is non-significant.

k. Number of whorls per earhead

The character number of whorls per earhead showed highly significant positive association only with number of primaries per earhead (r=0.623). It also showed positive association with 1000 seed weight (r=0.158) but the association is non-significant. The character number of whorls per earhead showed moderately significant negative association with dry fodder weight per plant (r=-0.276) and negative association with number of primaries per whorl (r=-0.236) at genotypic level.

l. Number of primaries per whorl

Number of primaries per whorl showed highly significant positive association with number of primaries per ear head (r=0.818) and non-significant positive association with 1000 seed weight (r=0.177) and dry fodder weight per plant (r=0.003).

m. Number of primaries per earhead

Number of primaries per earhead showed positive non-significant association with 1000 seed weight (r=0.240) and negative non-significant association with dry fodder weight per plant (r=-0.189) at genotypic level.

n. 1000 seed weight (g)

1000 seed weight expressed positive and significant association with dry fodder weight per plant (r=0.525) at genotypic level.

Table 3. Genotypic, phenotypic correlation coefficient (r) between yield and yield contributing characters

Source		Days to 50% flowering	Days to maturity	Plant height (cm)	No. of internodes per plant	No. of leaves per plant	Leaf length (cm)	Leaf width (cm)	Stem girth (cm)	Earhead length (cm)	Earhead breadth (cm)	No. of whorls per earhead	No. of primaries per whorls	No. of primaries per earhead	1000 seed wt. (g)	Dry fodder wt. per plant (g)	Grain yield per plant (g)
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Days to 50% flowering	G	1.000	1.000**	0.548**	0.319*	0.327**	0.316*	0.077	0.227	-0.130	-0.002	-0.524**	0.153	-0.242	0.203	0.395**	-0.007
	P	1.000	0.997**	0.483**	0.206	0.248	0.094	0.042	0.198	-0.140	-0.020	-0.264*	0.070	-0.174	0.133	0.363**	-0.196
Days to maturity	G		1.000	0.548**	0.328**	0.337**	0.316*	0.083	0.228	-0.137	-0.003	-0.519**	0.148	-0.224	0.194	0.392**	-0.010
	P		1.000	0.482**	0.210	0.251*	0.096	0.040	0.195	-0.130	-0.200	-0.270*	0.077	-0.180	0.133	0.352**	-0.018
Plant height	G			1.000	0.421**	0.418**	0.253*	0.144	0.109	0.311*	0.175	-0.221	0.016	-0.134	0.227	0.529**	0.075
	P			1.000	0.228	0.306*	0.143	0.072	0.111	0.232	0.202	-0.080	0.021	-0.069	0.119	0.458**	0.043
No. of plant internode	G				1.000	1.00**	0.134	-0.097	0.249	-0.066	0.235	0.032	0.036	0.027	-0.129	0.031	-0.090
	P				1.000	0.736**	0.104	-0.074	0.162	-0.020	0.085	-0.008	0.050	-0.017	-0.048	0.008	-0.024
No. of leaves per plant	G					1.000	0.200	-0.053	0.251*	-0.081	0.197	-0.078	0.090	0.003	-0.103	0.078	-0.087
	P						0.103	-0.052	0.166	-0.076	0.098	-0.020	0.136	0.021	-0.018	0.032	-0.040
Leaf length	G						1.000	-0.235	0.134	0.027	0.107	-0.112	0.486**	0.220	0.282*	-0.005	0.182
	P						1.000	-0.035	0.080	-0.013	0.031	0.065	0.070	0.017	-0.012	-0.045	0.069
Leaf width	G							1.000	0.339**	0.005	-0.252*	0.071	0.047	0.099	-0.020	0.131	0.013
	P							1.000	0.240	0.011	-0.117	0.085	0.013	0.048	0.011	0.071	-0.038
Stem girth	G								1.000	0.075	-0.144	-0.100	-0.015	-0.070	0.023	0.191	0.045
	P								1.000	0.056	-0.096	-0.060	-0.007	-0.042	0.006	0.194	0.038
Earhead length	G									1.000	0.555**	0.136	-0.596**	-0.309*	-0.316*	-0.075	0.206
	P									1.000	0.441**	0.048	-0.286*	-0.155	-0.179	-0.043	0.188
Earhead breadth	G										1.000	-0.205	-0.265*	-0.240	-0.257*	-0.162	0.022
	P										1.000	-0.077	-0.105	-0.182	-0.166	-0.132	0.020
No. of whorls per earhead	G											1.000	-0.236	0.623**	0.158	-0.276*	0.103
	P											1.000	-0.117	0.451**	0.046	-0.152	0.021
No. of primaries per whorls	G												1.000	0.818**	0.177	0.003	-0.079
	P												1.000	0.571**	0.116	-0.017	-0.012
No. of primaries per earhead	G													1.000	0.240	-0.189	0.022
	P													1.000	0.104	-0121	0.022
1000 seed wt.	G														1.000	0.525**	0.481**
	P														1.000	0.342*	0.360**
Dry fodder wt. per plant	G															1.000	0.183
	P															1.000	0.160
Grain yield per plant	G																1.000
	P																1.000

G – Genotypic correlation coefficient, P – Phenotypic correlation coefficient * Significant at 5% ** Significant at 1%

4.3.2 Phenotypic correlation

4.3.2.1 Association between yield and yield contributing characters

The data presented in Table 3 revealed that, only character 1000 seed weight (r=0.360) exhibited highly significant positive phenotypic correlation with grain yield. While other characters viz., earhead length (r=0.188), dry fodder weight per plant (r=0.160), leaf length (r=0.069), plant height (r=0.043), stem girth (r=0.038), number of primaries per earhead (r=0.022), number of whorls per earhead (r=0.021) and earhead breadth (r=0.020) were exhibited positive correlation with grain yield, however, the correlation coefficients are non significant. Further, the characters days to 50% flowering (r=-0.196), number of leaves per plant (r=-0.040), leaf width (r=-0.038), number of internodes per plant (r=-0.024), days to maturity (r=-0.018) and number of primaries per whorl (r=-0.012) exhibited non significant correlation in negative direction.

4.3.2.2 Association between yield contributing characters among themselves

a. Days to 50% flowering

Days to 50% flowering exhibited highly significant phenotypic correlation with days to maturity (r=0.997), plant height (r=0.483) and dry fodder weight per plant (r=0.363) in positive direction and moderately significant correlation with number of whorls per earhead (r=-0.264) in negative direction.

Similarly, days to 50 per cent flowering had positive correlation with number of leaves per plant (r=0.248), number of internodes per plant (r=0.206), stem girth (r=0.198), 1000 seed weight (r=0.133), leaf length (r=0.094), number of primaries per whorl (r=0.070) and leaf width (r=0.042), however it had negative correlation with number of primaries per earhead (r=-0.174), earhead length (r=-0.140) and earhead breadth (r=-0.020) at phenotypic level, however, the correlation coefficient values are non-significant.

b. Days to maturity

Days to maturity exhibited highly significant positive phenotypic correlation with plant height (r=0.482), dry fodder weight per plant (r=0.352); moderately significant positive correlation with number of leaves per plant (r=0.251) and only positive association with number of internodes per plant (r=0.210), stem girth (r=0.195), 1000 seed weight (r=0.133), leaf length (r=0.096), number of primaries per whorl (r=0.077) and leaf width (r=0.040).

Similarly days to maturity exhibited moderately significant negative correlation with number of whorls per earhead (r=-0.270) and negatively non-significant association with number of primaries per earhead (r=-0.180), earhead length (r=-0.130) and earhead breadth (r=-0.020).

c. Plant height (cm)

Plant height exhibited highly significant positive phenotypic correlation with dry fodder weight per plant (r=0.458); moderately significant positive correlation with number of leaves per plant (r=0.306) and only positive correlation with earhead length (r=0.232),number of internodes per plant (r=0.228), earhead breadth (r=0.202), leaf length (r=0.143), 1000 seed weight (r=0.119), stem girth (r=0.111), leaf width (r=0.072) and number of primaries per whorl (r=0.021).

Similarly plant height exhibited negative and non-significant phenotypic correlation with number of whorls per earhead (r=-0.080) and number of primaries per earhead (r=-0.069) at phenotypic level.

d. Number of internodes per plant

Number of internodes per plant exhibited highly significant positive phenotypic correlation with number of leaves per plant (r=0.736). Whereas, the character exhibited positive but non-significant correlation with stem girth (r=0.162), leaf length (r=0.104), earhead breadth (r=0.085), number of primaries per whorl (r=0.050) and dry fodder weight per plant (r=0.008).

As regards the other characters number of internodes per plant showed negative correlation with leaf width (r=-0.074), 1000 seed weight (r=-0.048), earhead length (r=-0.020), number of primaries per earhead (r=-0.017) and number of whorls per earhead (r=-0.008) at phenotypic level.

e. Number of leaves per plant

Number of leaves per plant exhibited positive phenotypic association with stem girth (r=0.166), number of primaries per whorl (r=0.136), leaf length (r=0.103), earhead breadth (r=0.098), dry fodder weight per plant (r=-0.032) and number of primaries per earhead (r=0.021), while negative phenotypic association with the traits viz., earhead length (r=-0.076), leaf width (r=-0.052), number of whorls per earhead (r=-0.020) and 1000 seed weight (r=-0.018).

f. Leaf length (cm)

Leaf length expressed positive association with stem girth (r=0.080), number of primaries per whorl (r=0.070), number of whorls per earhead (r=0.065), earhead breadth (r=0.031) and number of primaries per earhead (r=0.017) and negative association with dry fodder weight per plant (r=-0.045), leaf width (r=-0.035), earhead length (r=-0.013) and 1000 seed weight (r=-0.012) at phenotypic level.

g. Leaf width (cm)

Leaf width expressed positive but non-significant association with stem girth (r=0.240), number of whorls per earhead (r=0.085), dry fodder weight per plant (r=0.071), number of primaries per earhead (r=0.048), number of primaries per whorl (r=0.013), 1000 seed weight (r=0.011), earhead length (r=0.011) and negative non-significant association with earhead breadth (r=-0.117) at phenotypic level.

h. Stem girth (cm)

Stem girth expressed positive association with dry fodder weight per plant (r=0.194), earhead length (r=0.056) and 1000 seed weight (r=0.006) and negative association with earhead breadth (r=-0.096), number of whorl per earhead (r=-0.060), number of primaries per earhead (r=-0.042) and number of primaries per whorl (r=-0.007) at phenotypic level.

i. Earhead length (cm)

Earhead length exhibited highly significant positive association with earhead breadth (r=0.441) and moderately significant association with number of primaries per whorl (r=-0.286) but in negative direction.

This character also expressed positive association with number of whorls per earhead (r=0.048) and negative association with 1000 seed weight (r=-0.179), number of primaries earhead (r=-0.155) and dry fodder weight per plant (r=-0.043) at phenotypic level, however, correlation coefficient values are non-significant.

j. Earhead breadth (cm)

Earhead breadth showed negative association with number of primaries per earhead (r=-0.182), 1000 seed weight (r=-0.166), dry fodder weight per plant (r=-0.132), number of primaries per whorl (r=-0.105) and number of whorls per earhead (r=-0.077) at phenotypic level, however, magnitude of correlation coefficients are very low.

k. Number of whorls per earhead

Number of whorls per earhead expressed highly significant positive association only with number of primaries per earhead (r=0.451). It also showed positive association with 1000 seed weight (r=0.046) and negative association with dry fodder weight per plant (r=-0.152) and number of primaries per whorl (r=-0.117) but association is non-significant at phenotypic level.

l. Number of primaries per whorl

Number of primaries per whorl exhibited highly significant positive association with number of primaries per earhead (r=0.571). This character also expressed non-significant positive association with 1000 seed weight (r=0.116) and negative association with dry fodder weight per plant (r=-0.017) at phenotypic level.

m. Number of primaries per earhead

Number of primaries per earhead expressed positive association with 1000 seed weight (r=0.104) and negative association with dry fodder weight per plant (r=-0.121) at phenotypic level.

n. 1000 seed weight (g)

1000 seed weight showed highly significant positive association with dry fodder weight per plant (r=0.342) at phenotypic level.

4.4 Path coefficient analysis

For path analysis, grain yield per plant considered as dependent variable and other yield contributing characters are independent variables. The direct and indirect effect of yield and yield contributing characters on grain yield per plant are presented in Table 4 and 5.

a. Days to 50% flowering

Path coefficient analysis revealed that the character 50% flowering exhibited highest positive direct effect (2.270) on grain yield per plant. Similarly maximum positive indirect effect through number of whorls per earhead (0.364) followed by 1000 seed weight (0.273) and minimum negative indirect effect (-2.211) through the character days to maturity.

b. Days to maturity

Days to maturity expressed lowest direct effect (-2.208) on grain yield per plant which is in negative direction. This character expressed maximum indirect effect on grain yield through days 50% flowering (2.273) and minimum through plant height (-0.515).

c. Plant height

Plant height had negative and lowest direct effect (-0.938) on grain yield per plant.

Maximum positive indirect effect (1.245) of this character on grain yield was observed through days to 50% flowering and minimum through days to maturity (-1.212).

d. Number of internodes per plant

Number of internodes per plant exhibited positive direct effect (0.130) of lower magnitude on grain yield per plant. Where as it had maximum positive indirect effect (0.745) through number of leaves per plant and minimum indirect effect (-0.725) through days to maturity on grain yield per plant.

e. Number of leaves per plant

Number of leaves per plant exhibited 4th ranking direct effect (0.613) on grain yield per plant.

The number of leaves per plant had maximum positive indirect effect (0.744) through days to 50% flowering and minimum (-0.744) through days to maturity.

f. Leaf length (cm)

It had minimum direct effect (-0.271) on grain yield per plant. While, leaf length exhibited maximum positive indirect effect on grain yield through days to 50% flowering (0.718) followed by 1000 seed weight (0.380) and number of leaves per plant (0.122), and minimum indirect effect (-0.699) through days to maturity.

Table 4. Path coefficient analysis showing direct (underlined) and indirect effect of various traits on grain yield

Source	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of internodes per plant	No. of leaves per plant	Leaf length (cm)	Leaf width (cm)	Stem girth (cm)	Earhead length (cm)	Earhead breadth (cm)	No. of whorls per earhead	No. of primaries per whorls	No. of primaries per earhead	1000 seed wt. (g)	Dry fodder wt. per plant (g)	Grain yield per plant (g)
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Days to 50% flowering	**2.270**	-2.211	-0.514	0·041	0.201	-0.085	0.013	-0.074	-0.227	0.001	0.364	0.048	-0.023	0.273	-0.085	-0.007
Days to maturity	2.273	**-2.208**	-0.515	0.042	0.206	-0.086	0.014	-0.075	-0.226	0.002	0.360	0.047	-0.023	0.161	-0.084	-0.010
Plant height (cm)	1.245	-1.212	**-0.938**	0.055	0.256	-0.068	0.025	-0.036	0.511	-0.101	0.153	0.005	-0.013	0.306	-0.113	0.075
No. of internodes per plant	0.724	-0.725	-0.396	**0.130**	0.745	-0.036	-0.017	-0.082	-0.109	-0.135	-0.022	0.011	0.002	-0.174	-0.006	-0.090
No. of leaves per plant	0.744	-0.744	-0.393	0.158	**0.613**	-0.054	-0.009	-0.082	-0.133	-0.113	0.054	0.028	0.0004	-0.139	-0.016	-0.087
Leaf length (cm)	0.718	-0.699	-0.237	0.017	0.122	**-0.271**	-0.041	-0.044	0.044	-0.061	0.078	0.154	0.021	0.380	0.001	0.182
Leaf width (cm)	0.176	-0.183	-0.135	-0.012	-0.032	0.063	**0.175**	-0.111	0.009	0.145	-0.050	0.015	0.009	-0.027	-0.028	0.013
Stem girth (cm)	0.515	-0.504	-0.102	0.032	0.154	-0.036	0.059	**-0.329**	0.124	0.082	0.069	-0.004	-0.006	0.032	-0.041	0.045
Earhead length (cm)	-0.314	0.304	-0.292	-0.008	-0.049	-0.007	0.001	-0.024	**1.642**	-0.319	-0.094	-0.189	-0.030	-0.426	0.016	0.206
Earhead breadth (cm)	-0.005	0.008	-0.164	0.030	0.121	-0.029	-0.044	0.047	0.911	**-0.575**	0.143	-0.084	0.023	-0.346	0.034	0.022
No. of whorls per earhead	-1.189	1.146	0.207	0.004	-0.048	-0.030	0.012	0.033	0.224	0.118	**-0.694**	-0.075	0.060	0.213	0.059	0.103
No. of primaries per whorls	0.348	-0.327	-0.015	0.004	0.055	-0.132	0.008	0.004	-0.979	0.152	0.164	**0.317**	0.079	0.239	-0.0008	-0.079
No. of primaries per earhead	-0.550	0.539	0.126	0.003	0.002	-0.059	0.017	0.023	-0.508	0.138	-0.433	0.260	**0.097**	0.323	0.040	0.022
1000 seed wt. (g)	0.461	-0.429	-0.213	-0.016	-0.063	-0.076	-0.003	-0.007	-0.520	0.148	-0.110	0.056	0.023	**1.346**	-0.112	0.481
Dry fodder wt. per plant (g)	0.897	-0.867	-0.196	0.004	0.048	0.001	0.023	-0.062	-0.124	0.093	0.192	0.001	-0.018	0.706	**-0.215**	0.183

Residual effect - 59.407

Table 5: Total direct and indirect effect of different characters on yield

Sr. No.	Name of character	Correlation coefficient	Direct effect	Indirect effect	Maximum indirect contribution through the characters
1	Days to 50% flowering	-0.007	2.270	-2.278	no. of whorls per earhead and 100 seed weight
2	Days to maturity	-0.010	-2.208	2.198	Days to 50% flowering
3	Plant height (cm)	0.075	-0.938	1.014	Days to 50% flowering
4	No. of internodes per plant	-0.090	0.130	-0.221	No. of leaves per plant
5	No. of leaves per plant	-0.087	0.613	-0.700	Days to 50% flowering
6	Leaf length (cm)	0.182	-0.271	0.454	Days to 50% flowering , 1000 seed weight and no. of leaves per plant
7	Leaf width(cm)	0.013	0.175	-0.162	Days to 50% flowering
8	Stem girth (cm)	0.045	-0.329	0.374	Days to 50% flowering
9	Earhead length (cm)	0.206	1.642	-0.436	Days to maturity and dry fodder weight per plant
10	Earhead breadth (cm)	0.022	-0.575	0.598	Earhead length
11	No. of whorls per earhead	0.103	-0.694	0.798	Days to maturity
12	No. of primaries per whorls	-0.079	0.317	-0.397	Days to 50% flowering, 1000 seed weight
13	No. of primaries per earhead	0.022	0.097	-0.075	Days to maturity
14	1000 seed wt. (g)	0.481	1.346	-0.865	Days to 50% flowering
15	Dry fodder wt. per plant (g)	0.183	-0.215	0.398	Days to 50% flowering

g. Leaf width (cm)

The direct effect of this trait on grain yield per plant (0.175) was of low magnitude.

Maximum indirect effect of this trait on grain yield was through days to 50% flowering (0.176) and minimum through days to maturity (-0.183)

h. Stem girth (cm)

Stem girth character exhibited -0.329 direct effect on grain yield per plant, which is very low magnitude. This character exhibited maximum positive indirect effect through the days to 50% flowering (0.515) and minimum through days to maturity (-0.504).

i. Earhead length (cm)

Earhead length had second highest positive direct effect (1.642) on grain yield per plant. However, it had maximum indirect effect through days to maturity (0.304) followed by dry fodder yield per plant (0.016) and minimum indirect effect through the character earhead breadth (-0.319).

j. Earhead breadth (cm)

Earhead breadth expressed minimum direct effect (-0.575) on grain yield per plant.

As against, earhead breadth had maximum indirect effect (0.911) through earhead length on grain yield and minimum through 1000 seed weight (-0.346).

k. Number of whorls per earhead

The direct effect of very low magnitude (-0.694) was exerted by this trait, number of whorls per earhead on grain yield per plant.

It had maximum indirect effect (1.146) through days to maturity and minimum indirect effect (-1.189) through days to 50% flowering.

l. Number of primaries per whorls

Number of primaries per whorl had positive direct effect (0.317) on grain yield per plant, maximum indirect effect (0.348) through days to 50% flowering followed by 1000 seed weight (0.239) and minimum indirect effect through earhead length (-0.979) followed by days to maturity (-0.327).

m. Number of primaries per earhead

Number of primaries per earhead had minimum direct effect (0.097) on grain yield per plant. While it had maximum indirect effect through days to maturity (0.539) and minimum indirect effect through days to 50% flowering (-0.550).

n. 1000 seed weight (g)

The character 1000 seed weight showed very high positive direct effect (1.346) on grain yield per plant and maximum positive indirect effect (0.461) through days to 50% flowering and minimum through earhead length (-0.520) followed by days to maturity (-0.429).

o. Dry fodder weight per plant (g)

This character exhibited negligible direct effect (-0.215) on grain yield per plant, whereas it had maximum positive indirect effect (0.897) through days to 50% flowering and minimum indirect effect (-0.897) through days to maturity.

CHAPTER V

DISCUSSION

The present investigation entitled as "Evaluation of newly collected *kharif* Sorghum germplasm from Vidarbha region" was carried out on sixty four genotypes of *kharif* sorghum during 2006-2007 with following objectives.

1. Collection of *kharif* sorghum local germplasm by *in situ* selection from Vidarbha region.
2. To estimate the genetic variability parameters.
3. To estimate the correlation and path coefficients.

The existence of sufficient amount of genetic variability is a pre-requisite for success of any breeding programme. Therefore, it is necessary to assess the extent of variability existing in the population. The assessment of variability may be carried out by estimating genetic parameters like Phenotypic coefficient of variation, Genotypic coefficient of variation, Heritability as well as Expected genetic advance per cent over mean. The genetic variability estimated in terms of genotypic coefficient of variation and phenotypic coefficient of variation is not sufficient for the estimation of heritable variation. The heritable variation can be estimated with greater degree of accuracy, when heritability is studied along with genetic advance. The heritability values in broad sense are also helpful in selection on the basis of phenotypic performance of the quantitative characters. However, heritability estimates alone are not of any use in predicting the results of selection unless it is accompanied by genetic advance.

The correlation studies indicate the degree and direction of relationship between yield and its components and among the components themselves, which helps, the plant breeder to know whether two attributes are related with each other either by cause of linkage or pleiotropy. Path coefficient analysis at this juncture helps in understanding the direct and indirect contribution of each character on yield. Hence, correlation studies aided by path coefficient analysis will be a powerful tool in selecting the plants for desired characters. Considering these and the ultimate aim of exploiting all the possibilities for the improvement of the characters studied, the results obtained in the present investigation are discussed here below.

a. Analysis of variance

Perusal of the Table 1, indicated highly significant differences among the genotypes for all the traits studied. This indicates the presence of substantial amount of genetic variability in the genotypes for all the characters under study. Results are in agreement with Narkhede *et al.* (2000), Soltani *et al.* (2001), Elangovan *et al.* (2005), Geleta *et al.* (2005), Elangovan (2006) and Hemlata *et al.* (2006).

b. Genetic variability

The characters dry fodder weight per plant, ear head breadth, grain yield per plant, earhead length, stem girth, 1000 seed weight and plant height showed high GCV and PCV values indicating thereby large amount of variation in aforesaid characters. Low GCV and PCV values were found for the characters number of primaries per earhead, days to 50% flowering, number of primaries per whorl, number of whorls per earhead, leaf width, days to maturity, number of internodes per plant, number of leaves per plant and leaf length indicating small amount of variation.

These results are in conformity with the result of Kumar and Singh (1986), Bakheit (1990), Maicel *et al.* (1994), Dadheech *et al.* (1999), and Geleta *et al.* (2005) for grain yield per plant. While for plant height, similar results were obtained by Bakheit (1990), Maicel *et al.* (1994), Sultan *et al.* (2002) and Geleta *et al.* (2005).

Similar results obtained by Can *et al.* (1998), Dadheech *et al.* (1999) and Kishore and Singh (2005) for fodder yield per plant. While, Narkhede *et al.* (2000) and Geleta *et al.* (2005) recorded similar results for earhead length and earhead breadth.

Geleta *et al.* (2005) and Bakheit (1990) recorded similar results for 1000 seed weight, while Lukhele and Obilona (1984) and Eckebil *et al* (1977) reported the similar kind of results for days 50% flowering as found in the present investigation.

The higher magnitude of PCV as compared to GCV in respect of characters, 1000 seed weight, number of whorls per earhead, number of primaries per whorl, leaf length and number of primaries per earhead, indicated the greater effect of environment on these character. While the characters like number of internodes per plant, number of leaves per plant, leaf width, leaf length, earhead length and earhead breadth showed closer

GCV and PCV values indicating less influence of environment on these characters.

With the genotypic coefficient of variation, it is difficult to determine the relative amounts of heritable and non-heritable components of variation present in the population. Estimates of heritability and genetic advance would supplement this parameter. The heritability in broad sense ranged from 22.77 to 94.03 per cent. The high heritability estimates were observed for the characters stem girth (94.03%), dry fodder weight per plant (91.95%), days to maturity (90.96%), days to 50% flowering (90.91%), grain yield per plant (86.00%), plant height (81.48%), earhead length (78.12%), earhead breadth (76.45%), number of primaries per earhead (55.70%) and number of leaves per plant (52.07%).

Shinde *et al.* (1979), Kumar and Singh (1986), Amirthadevarathinam *et al.* (1990) and Shankarapandian *et al* (1996) reported similar results i.e. broad sense heritability upto 90 per cent for the character grain yield per plant.

Similarly, high heritability estimates were reported by Panchal *et al.* (1979), Shinde *et al.* (1979), Salilkumar and Singhania (1984), Sankarapandian *et al* (1996) and Geleta *et al.* (2005) for 1000 grain weight, Sankarapandian *et al* (1996) for number of whorls per earhead breadth, Panchal *et al.* (1979), Shinde *et al.* (1979), Salilkumar and Singhania (1984), Sankarapandian *et al* (1996) and Narkhede *et al.* (2000) for earhead length, Shinde *et al.* (1979), Salilkumar and Singhania (1984), Can *et al.* (1998), Geleta *et al.* (2005) for plant height and 1000 seed weight, Crasta *et* *al.* (1999) and Solatni *et al.* (2001) for days to maturity, Dadheech *et al.* (1999) for days to maturity and biological yield per plant, Narkhede *et al.* (2000) for number of primaries per earhead as well as Salilkumar and Singhani (1984), Amirthadevarathinam *et al.* (1990) and Kishor and Singh (2005) for days to 50% flowering.

Similarly, moderate heritability estimates exhibited by the traits leaf width (48.95%), 1000 seed weight (48.54%), number of internodes per plant (47.68%), number of primaries per whorl (39.42%), number of whorls per earhead (34.08%) and moderate to low heritability by leaf length (22.71%).

The results are in conformity with findings of Salilkumar and Singhania (1984) for the character number of whorls per earhead. Kishor and Singh (2005) also reported moderate heritability estimates for most of the traits in the forage sorghum.

The expected genetic advance over mean ranged from 10.21 to 54.21 per cent. High value of EGA over mean were recorded for the characters grain yield per plant (54.21%), dry fodder weight per plant (51.60%), earhead breadth (51.56%), earhead length (50.40%) and stem girth (42.80%).

Salilkumar and Singhania (1984), Kumar and Singh (1986), Amirthadevarathinam *et al.* (1990), Shakarapandian *et al* (1996), Dadheech *et al.* (1999) and Geleta *et al.* (2005) also reported higher values of genetic advance in particular for grain yield per plant. As regards with yield component traits Shankarapandian *et al* (1996) and Dadheech *et al.* (1999)

and Narkhede *et al.* (2000) also reported high genetic advance for earhead length. Dadheech *et al.* (1999) reported high genetic advance for fodder yield per plant.

In general high heritability accompanied with high expected genetic advance for characters suggest that the genes governing these characters may have additive effect. It can be mentioned here that characters dry fodder weight per plant, grain yield per plant, stem girth, earhead length and earhead breadth exhibited high heritability values along with high values of expected genetic advance. The phenotypic expression of these characters may be governed by the genes acting additively and thereby indicating the importance of these characters for selection.

The results are in conformity with the results of Sankarapandian *et al* (1996), Salilkumar and Singhania (1984) and Amirthadevarathinam *et al.* (1990) for grain yield per plant, Narkhede *et al.* (2000) and Geleta *et al.* (2005) for earhead length.

Moderate value of expected genetic advance per cent over mean were observed for the character plant height (27.04%), 1000 seed weight (22.62%), days to 50% flowering (22.49%) and number of primaries per earhead (20.99%). Similarly lower values were observed for days to maturity (14.80%), number of primaries per whorl (13.25%), leaf width (12.65%), number of whorls per earhead (11.19%), number of leaves per plant (10.47%), number of internodes per plant (10.21%) and leaf length (5.40%).

The results obtained are in agreement with Amirthadevarathinam *et al.* (1990) and Narkhede etal (2000) for the character leaf length, Narkhede et al (2000) for leaf width, number of whorls per earhead, earhead breadth and number of primaries per earhead.

High value of heritability along with low value of expected genetic advance were observed for the characters like days to maturity and number of leaves per plant, because regarding these characters the heritability is mainly due to non additive gene effect (dominance and epistasis) hence the expected genetic advance would be low. Since the characters are mainly governed by non-additive component of variation which is non fixable, heterosis breeding can be fruitfully exploited in improving these characters.

5.3 Correlation

The association between two characters which can be directly observed is called phenotypic correlation. It include both genotype and environmental effects. That's why it differs under different environmental conditions.

The heritable association between two characters is known as genotypic or genetic correlation. This type of correlation may be either due to pleiotropic action of gene or due to linkage or due to both (Falconer, 1960). The main genetic cause of such correlation is pleiotropy, which refers manifold effect of gene.

The study of relationship among quantitative traits is important for assessing the feasibility of joint selection of two or more characters and hence for evaluating the effect of selection for secondary characters on genetic gain for the primary character under consideration. A positive genotypic or genetic correlation between two desirable characters makes the job of the plant breeder easy for improvement in both the characters simultaneously. Even the lack of correlation is useful for the joint improvement of both the characters. On the other hand, a negative correlation between two desirable characters impedes or makes it impossible to achieve a significant improvement in both characters.

The table 3 revealed that the only character 1000 seed weight showed highly significant association with grain yield per plant at both genotypic and phenotypic level. This indicates that strong association of this trait with grain yield per plant could be fruitfully exploited for enhancing the yield potential in sorghum.

Similar findings were reported by Bakheit (1990), Shanmughasundaram and Subramanian (1990), Potdukhe *et al.* (1994), Sankarapandian *et al.* (1996), Can *et al.* (1998), Muppidathi *et al.* (2000), Maman *et al.* (2004), Thorat *et al.* (2004), Elangovan (2006) and Hemlata *et al.* (2006) for 1000 seed weight.

The characters earhead length, dry fodder weight per plant, leaf length, number of whorls per earhead, plant height, stem girth, number of primaries per earhead, earhead breadth and leaf width showed positive but non-significant association with grain yield.

The results are in conformity with the findings of Jayaprakash *et al.*(1997), Can *et al.* (1998), Narkhede *et al.* (2000), Patil *et al.* (2003) for plant height, Can *et al.* (1998) for dry fodder weight per plant, number of leaves per plant, number of internodes per plant, Patil *et al.* (2003) for number of leaves per plant and total dry matter.

The characters days to 50% flowering, days to maturity, number of primaries per whorls, number of leaves per plant and number of internodes per plant showed negative but non-significant association with grain yield per plant.

Sanakarapandian *et al.* (1996) conducted correlation studies and revealed that grain yield showed no correlation with most of the component characters except 1000 seed weight and number of grains per rachis, they concluded that, it might be due to elimination effect of one or other characters contributing for grain yield. In present investigation also only the character 1000 seed weight exhibited highly significant positive correlation with grain yield per plant and not any other character.

Among the yield components themselves, days to 50% flowering showed highly significant positive association with days to maturity, plant height, dry fodder weight per plant and number of leaves per plant. Similar results obtained by Bhongle *et al.* (2001), Geleta and Daba (2005) and Kishore and Singh (2005) for days to 50% flowering with plant height. Similar kinds of results for days to 50% flowering with number of internodes per plant obtained by Geleta and Daba (2005). Thus selection for days to 50% flowering might be helpful for simultaneous improvement of plant height, number of internodes per plant as well as earhead breadth.

Similarly, days to maturity exhibited highly significant positive association with plant height, dry fodder weight per plant, number of leaves per plant and number of internodes per plant while moderately significant with leaf length.

The plant height exhibited highly significant positive association with dry fodder weight per plant, number of internodes per plant and number of leaves per plant while moderately significant for earhead length and leaf length. Similar results obtained by Bhongle *et al.* (2001) for plant height with earhead length, Amirthadevarathinam *et al.* (1990) only for plant height, Patil *et al.* (2003) and Sunku *et al.* (2002) for plant height with number of leaves per plant, Kishor and Singh (2005), Patil *et al.*(2003) and Sunku *et al.* (2003) for plant height with dry fodder yield per plant and Amirthadevarathinam *et al.* (1990) only for dry fodder yield per plant. Thus selection of plant height might be helpful in simultaneous improvement of earhead length, number of leaves per plant and total fodder weight per plant.

The character number of internodes per plant exhibited very strong positive correlation with number of leaves per plant and stem girth. While number of leaves showed moderately significant positive association with stem girth. Thus selection for number of leaves per plant might be helpful in simultaneous improvement of number of internodes per plant and stem girth.

Leaf length showed highly significant positive association with number of primaries per whorl and moderately significant association with 1000 seed weight, so selection of leaf length might be helpful in improvement of 1000 seed weight and number of primaries per whorl.

Similarly leaf width showed significant positive association with stem girth hence selection of leaf width might be helpful for improvement in stem girth.

The phenotypic correlation coefficient value (r=0.194) of the character stem girth is greater than value of genotypic correlation coefficient (r=0.191) of the character dry fodder weight per plant it shows that the apparent association of these two characters is not due to genes but due to favourable influence of environment (Dhindsa, 2006).

The character earhead length showed very strong positive association with earhead breadth. The similar results obtained by Patil *et al.* (2003) and Zongo *et al.*(1993). According to them selection for earhead length might be helpful for improvement in earhead breadth simultaneously.

The character earhead breadth exhibited moderately significant correlation with number of primaries per whorl and 1000 seed weight but it is in negative direction.

Number of whorls per earhead showed highly significant positive association with number of primaries per earhead, while number of primaries per whorl showed highly significant positive association with number of primaries per earhead hence selection for number of primaries per earhead might be helpful in simultaneous improvement of number of primaries per whorl and number of whorls per earhead.

Number of primaries per earhead showed negative and non-significant association with dry fodder weight per plant, it means that increase in number of primaries per earhead may cause decrease in dry fodder weight per plant and vice versa. According to Dhindsa (2006) it arises from repulsion phase linkage of genes controlling these traits.

5.4 Path analysis

The overall correlations observed between two attributes is a function of a series of direct and indirect relationship between those attributes. In order to know the specific forces in building up the total correlation, it is essential to work out path coefficient developed by Wright (1921). It measures the direct influence of one component upon the other and permits the partitioning of the total correlation coefficients in to direct and indirect effects.

The Table 4 revealed that character days to 50% flowering (2.270) exhibited positive direct effect of very high magnitude on grain yield per plant followed by earhead length (1.642) and 1000 seed weight (1.346), number of leaves per plant (0.613) and number of primaries per whorl (0.317).

Similar kind of results obtained by Shanmugasudaram and Subramanian (1999) and Kishore and Singh (2005) for days to 50% flowering, Sankarapandian (2000) and Sunku *et al.* (2002) for number of leaves per plant. Patel *et al.* (1979), Shanmughasundaram and Subramaniam (1990), El-nagar (1997), Jayprakash *et al.* (1997)and Iyangar *et al.* (2001) for 1000 seed weight.

The days to 50% flowering had very high positive direct effect (2.270) on grain yield per plant, but the correlation of this character with grain yield per plant found negative and non-significant (-0.007).

Since correlation between days to 50% flowering and grain yield per plant is minimum and negative according to Veerabadhiram and Kennedy (2001) yield improvement can be obtained in early flowering genotypes.

The characters days to maturity via days to 50% flowering (2.273) followed by plant height via days to 50% flowering (1.245) and number of whorls per earhead via day to maturity (1.146) showed very high indirect effect on grain yield per plant.

Earhead breadth via. Earhead length (0.911), dry fodder weight per plant via days to 50% flowering (0.897), number of internodes per plant via. number of leaves per plant (0.745), number of leaves per plant via days to 50% flowering (0.744), leaf length via day to 50% flowering (0.718), number of primaries per earhead via days to maturity (0.539), stem girth via days to 50% flowering (0.515), 1000 seed weight via days to 50% flowering (0.461), days to 50% flowering via number of whorls per earhead (0.364), number of primaries per whorl via days to 50% flowering (0.348) and earhead length via days to maturity (0.304) showed high positive indirect effect.

The positive but low indirect effect on grain yield per plant showed by the characters leaf width via days to 50% flowering (0.176).

The value of residual effect is high (59.407) which indicates that besides the characters studied, there are some other important traits which contributes for dependent character i.e. grain yield per plant.

From above study, it can be concluded that the character days to 50% flowering had very high direct positive effect on grain yield per plant, while the character days to maturity had maximum positive indirect effect via days to 50% flowering. 1000 seed weight had highly significant positive association with grain yield per plant, while most of the characters had their positive and direct effect on grain yield per plant via days to 50% flowering. Hence the character days to maturity, days to 50% flowering and 1000 seed weight were found to be promising characters for selection.

CHAPTER VI

SUMMARY

The present investigation entitled as "Evaluation of newly collected *kharif* sorghum germplasm from Vidarbha region" was conducted to estimate the genetic variability to determine correlation between yield and yield components and to assess the direct and indirect effects of yield components on yield. The experiment was conducted during *kharif* season of the year 2006 using Randomized Block Design with three replications.

The experimental material comprised of sixty four genotypes of sorghum collected by *in situ* selection from three districts of Vidarbha region. Observations were recorded on five randomly selected competitive plants in each replication for each genotype on sixteen different characters namely days to 50 per cent flowering, days to maturity, plant height (cm), number of internodes per plant, number of leaves per plant, leaf length (cm), leaf width (cm), stem girth (cm), earhead length (cm), earhead breadth (cm), number of whorls per earhead, number of primaries per whorl, number of primaries per earhead, 1000 seed weight, dry fodder weight per plant and grain yield per plant.

The characters dry fodder weight per plant, ear head breadth, grain yield per plant, earhead length, stem girth, 1000 seed weight and plant height showed high GCV and PCV values indicating thereby large amount of variation in aforesaid characters.

The higher magnitude of PCV as compared to GCV in respect of characters, 1000 seed weight, number of whorls per earhead, number of primaries per whorl, leaf length and number of primaries per earhead, indicated the greater effect of environment on these character.

The high heritability estimates were observed for the characters stem girth, dry fodder weight per plant, days to maturity, days to 50% flowering, grain yield per plant, plant height, earhead length, earhead breadth, number of primaries per earhead and number of leaves per plant.

The high value of EGA per cent over mean were recorded for the characters grain yield per plant, dry fodder weight per plant, earhead breadth, earhead length and stem girth. Similarly lower values were observed for days to maturity, number of primaries per whorl, leaf width, number of whorls per earhead, number of leaves per plant, number of internodes per plant and leaf length.

In present study the character dry fodder per plant, grain yield per plant, stem girth, earhead length and earhead breadth exhibited high heritability value along with high value of expected genetic advance per cent over mean, indicates that the phenotypic expression of these characters may be governed by the gene acting additively and their by indicating the impotance of these traits.

High values of heritability along with low values of expected genetic advance were observed for the characters like days to maturity and number of leaves per plant. This indicates that, the characters are mainly governed by non-additive component of variation, which is not fixable, heterosis breeding can be fruitfully exploited in improving these characters.

The present investigation revealed that the only character 1000 seed weight showed highly significant association with grain yield per plant at both genotypic and phenotypic level. This indicates that strong association of this trait with grain yield per plant could be fruitfully exploited for enhancing the yield potential in sorghum.

Among the yield components themselves, days to 50% flowering showed highly significant positive association with days to maturity, plant height, dry fodder weight per plant and number of leaves per plant. Similarly, days to maturity exhibited significant positive association with plant height, dry fodder weight per plant, number of leaves per plant, leaf length and number of internodes per plant.

The plant height exhibited significant positive association with dry fodder weight per plant, number of internodes per plant, number of leaves per plant, earhead length and leaf length. Fether, the character number of internodes per plant exhibited very strong positive correlation with number of leaves per plant and stem girth while number of leaves showed moderately significant positive association with stem girth.

The character leaf length showed highly significant positive association with number of primaries per whorl and moderately significant association with 1000 seed weight. Similarly leaf width showed significant positive association with stem girth.

The character earhead length showed very strong positive association with earhead breadth. Similarly, number of whorls per earhead showed highly significant positive association with number of primaries per earhead while number of primaries per whorl showed highly significant positive association with number of primaries per earhead.

Present investigation revealed that character days to 50% flowering exhibited positive direct effect of very high magnitude on grain yield per plant followed by earhead length, 1000 seed weight, number of leaves per plant and number of primaries per whorl.

The characters days to maturity via days to 50% flowering followed by plant height via days to 50% flowering and number of whorls per earhead via day to maturity showed very high indirect effect on grain yield per plant.

The value of residual effect is high (59.407 %) which indicates that besides the characters studied, there are some other important traits which also contributes for dependent character i.e. grain yield per plant.

From above study, it can be concluded that, the character days to 50% flowering had very high direct positive effect on grain yield per plant, also the character days to maturity had maximum positive indirect effect via days to 50% flowering. While most of the characters had their positive and indirect effect on grain yield via. days to 50% flowering, hence days to 50% flowering and days to maturity were found to be promising characters for selection.

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APPENDIX - I

Sr. No.	Genotypes	Place of collection	Tahsil	District	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of plant internode	No. of leaves per plant	Leaf length (cm)	Leaf width (cm)	Stem girth (cm)	Plant pigmentation	Internode cover	Leaf colour	Midrib colour	Panicle Shape & Compactness	Glume Colour	Glume Cover	Seed Colour	Seed Shape	Threshability	Earhead length (cm)	Earhead breadth (cm)	No. of whorls per earhead	No. of primaries per whorls	No. of primaries per earhead	1000 seed wt. (g)	Total fodder wt. per plant (g)	Grain yield per plant (g)
1	PKS - 1	Ambikapur	Daryapur	Amravati	71.0	113.0	207.8	11.7	12.8	70.4	6.2	5.3	3	1	2	1	2	8	2	3	1	2	15.8	4.8	11.2	6.5	72.9	23.7	52.7	19.3
2	PKS - 2	Apatapa	Akola	Akola	99.3	141.3	310.9	12.6	13.6	82.0	6.2	5.5	3	1	2	1	1	2	3	3	3	3	10.7	5.5	8.1	7.8	63.2	23.5	101.8	10.4
3	PKS - 3	Yeoda	Daryapur	Amravati	95.0	137.0	285.2	10.9	12.0	87.7	5.9	5.1	3	1	1	1	2	2	2	3	3	2	15.9	5.1	8.6	7.2	61.9	16.7	66.4	8.3
4	(check)	SPV-669	Akola	Akola	71.3	113.3	197.7	10.0	10.6	68.3	5.5	3.6	1	1	2	2	2	2	2	2	3	2	15.3	4.2	8.7	4.7	41.5	19.6	40.7	17.6
5	PKS - 5	Karodi	Murtizapur	Akola	64.7	105.0	231.9	9.0	9.8	75.0	5.2	4.2	2	1	2	1	2	7	2	2	1	1	16.2	5.1	10.3	8.4	86.3	26.2	97.6	16.0
6	PKS - 6	Karodi	Murtizapur	Akola	64.7	106.7	218.6	12.6	13.3	77.3	4.9	5.0	2	1	2	1	2	9	3	2	2	3	15.0	4.1	8.3	7.8	65.1	14.8	65.0	8.0
7	PKS - 7	Karodi	Murtizapur	Akola	70.0	112.0	196.0	9.9	10.8	77.0	5.3	4.6	1	1	2	2	2	2	2	2	3	2	15.3	3.7	11.0	7.5	83.2	24.5	45.0	11.4
8	PKS - 8	Karodi	Murtizapur	Akola	63.3	105.3	191.0	10.3	11.0	68.0	5.8	3.2	1	1	2	2	4	4	2	3	1	2	17.4	4.3	10.2	7.6	76.9	18.3	36.5	13.5
9	PKS - 9	Karodi	Murtizapur	Akola	68.3	110.3	225.7	10.9	11.3	82.7	6.4	4.4	2	1	2	2	2	8	2	3	3	2	10.3	3.8	9.7	8.0	78.0	20.1	45.0	11.5
10	PKS - 10	Karodi	Murtizapur	Akola	79.7	121.7	286.0	9.7	10.2	85.7	5.4	3.6	3	2	2	1	7	2	3	1	1	3	29.6	7.3	10.0	5.5	54.9	16.4	42.7	17.1
11	PKS - 11	Karodi	Murtizapur	Akola	77.3	119.3	302.7	11.7	12.4	76.0	6.1	4.7	3	1	2	1	8	2	4	1	1	3	29.4	13.2	8.3	6.6	54.9	15.0	33.6	12.6
12	PKS - 12	Tandulwadi	Murtizapur	Akola	83.0	125.0	297.8	11.1	11.8	63.3	6.0	3.9	3	1	1	1	9	2	2	2	3	2	15.9	4.4	9.4	6.0	56.6	22.0	98.4	11.3
13	PKS - 13	Karla	Anjangaon	Amravati	82.7	124.7	236.7	12.8	13.4	79.3	5.5	4.3	2	2	2	2	1	2	2	3	3	2	17.8	4.7	9.1	8.3	76.6	23.0	71.5	23.6
14	PKS - 14	Karla	Anjangaon	Amravati	73.0	115.0	269.8	12.8	13.6	66.0	7.3	5.3	3	1	1	1	4	2	2	3	2	2	18.7	5.5	9.7	7.5	72.1	19.1	69.3	15.0
15	PKS - 15	Bhandaraj	Anjangaon	Amravati	76.7	118.7	281.7	11.9	12.7	81.3	5.4	4.2	3	2	1	1	7	2	3	1	3	3	27.7	8.2	8.2	7.2	58.9	14.1	31.2	12.1
16	PKS - 16	Bhandaraj	Anjangaon	Amravati	77.0	119.0	126.2	11.9	12.2	81.7	5.7	3.9	1	1	2	1	4	2	3	3	2	3	19.2	5.4	10.0	5.2	52.5	18.5	25.0	11.0
17	PKS - 17	Ugawa	Akola	Akola	63.7	105.7	224.6	11.1	12.0	81.0	5.7	4.2	2	1	2	1	4	2	4	2	1	3	13.2	4.4	9.3	7.2	66.5	22.3	34.9	12.2
18	PKS - 18	Ugawa	Akola	Akola	75.0	117.0	235.7	12.7	13.3	82.7	4.8	4.2	3	1	2	1	1	2	3	3	2	3	12.0	5.7	8.3	7.8	64.1	18.1	47.3	11.4
19	PKS - 19	Ugawa	Akola	Akola	77.7	119.7	260.6	12.0	12.9	81.7	5.2	3.8	2	2	2	1	4	2	4	3	3	3	10.9	5.1	9.4	7.3	68.3	17.3	31.9	10.5
20	PKS - 20	Ugawa	Akola	Akola	77.3	119.3	270.0	12.2	13.2	77.0	6.0	4.5	2	1	2	1	3	2	4	2	2	3	12.8	6.6	10.7	6.8	73.4	16.7	55.1	7.4
21	PKS - 21	Nimbi	Akola	Akola	67.3	109.3	242.9	11.1	11.8	84.7	5.9	3.9	2	1	2	1	4	2	4	2	3	3	15.8	5.1	10.5	8.5	90.7	17.6	33.0	14.6
22	PKS - 22	Nimbi	Akola	Akola	62.7	104.7	235.3	10.9	11.9	78.3	5.4	3.9	2	2	2	1	4	4	3	2	1	2	15.1	4.5	10.2	6.6	66.9	16.0	67.9	9.6
23	PKS - 23	Jawala	Shegaon	Buldana	75.7	117.7	230.1	12.4	13.3	76.3	6.1	4.2	2	1	2	1	2	2	3	3	2	2	13.4	3.8	10.1	7.4	74.8	15.6	26.8	9.6
24	PKS - 24	Jawala	Shegaon	Buldana	83.0	125.0	303.6	10.4	11.2	86.0	6.2	3.9	3	1	1	1	4	2	3	2	3	2	16.5	5.1	8.9	7.2	63.1	25.2	97.3	10.8
25	PKS - 25	Jawala	Shegaon	Buldana	96.7	138.7	287.8	12.0	12.7	66.3	5.6	5.8	2	2	2	2	4	2	3	2	2	3	16.9	3.7	9.0	7.0	62.5	13.3	60.6	10.1
26	PKS - 26	Srirampur	Srirampur	Ah'nagar	83.0	125.0	264.1	11.6	12.7	74.7	6.1	4.4	2	1	2	1	2	2	2	3	2	1	11.8	5.2	9.5	6.2	58.8	27.8	71.4	17.1
27	PKS - 27	Dasala	Chikhali	Buldana	83.7	125.7	284.4	10.7	11.7	90.0	5.1	3.8	3	2	2	1	9	2	3	2	1	3	19.0	4.2	10.3	7.2	71.8	21.8	95.6	10.3
28	PKS - 28	Dasala	Chikhali	Buldana	81.3	123.3	303.7	11.8	12.9	73.6	5.5	4.0	3	2	1	1	4	2	4	2	1	3	18.7	5.2	8.3	7.6	61.6	18.5	64.7	14.4
29	PKS - 29	Shegaon	Shegaon	Buldana	67.3	109.3	241.3	11.7	12.4	68.3	5.1	4.3	2	2	2	1	4	9	3	2	2	3	15.2	5.4	10.3	7.9	80.8	17.2	56.9	12.9
30	PKS - 30	Ramtirth	Daryapur	Amravati	79.7	121.7	287.8	11.4	12.3	88.3	6.0	4.3	3	2	1	2	4	2	2	2	2	2	16.3	6.5	8.8	6.4	56.5	25.2	155.8	26.4
31	PKS - 31	Ramtirth	Daryapur	Amravati	65.3	107.3	299.8	12.2	13.1	82.3	6.1	4.3	3	2	1	2	2	3	3	3	3	3	13.2	4.9	9.3	7.9	72.8	20.3	115.7	8.7
32	PKS - 32	Ramtirth	Daryapur	Amravati	73.7	115.7	236.9	11.0	12.4	79.0	5.3	4.3	3	1	2	1	2	2	3	3	2	3	11.3	5.7	8.1	9.1	73.5	25.4	41.6	11.5
33	PKS - 33	Buldana	Buldana	Buldana	82.0	124.0	243.7	11.4	12.1	85.7	4.6	3.8	2	1	2	1	2	2	3	3	3	3	11.0	5.1	8.5	7.2	61.4	23.3	45.3	14.6
34	PKS - 34	Lakhpuri	Murtizapur	Akola	80.3	122.3	267.9	12.4	13.3	85.0	5.9	4.0	2	2	2	1	3	2	3	3	1	2	10.2	5.9	10.1	7.7	77.6	22.6	46.8	12.3
35	PKS - 35	Lakhpuri	Murtizapur	Akola	79.7	121.7	250.2	11.9	12.6	78.3	5.9	4.3	2	2	2	1	3	2	3	3	1	3	13.3	5.5	9.3	8.6	79.3	21.3	33.4	10.6

36	PKS - 36	Ramgadh	Daryapur	Amravati	95.0	137.0	313.7	12.3	13.3	88.0	6.1	4.1	3	2	1	1	2	2	2	2	1	2	10.6	5.1	9.1	8.5	76.3	20.0	63.8	11.5
37	PKS - 37	Ramgadh	Daryapur	Amravati	87.3	129.3	277.7	12.4	13.6	88.3	5.3	3.4	3	1	1	1	1	3	2	2	1	2	12.0	5.0	9.7	8.4	82.1	24.4	62.7	13.2
38	PKS - 38	Pimpalkhuta	Akot	Akola	96.7	138.7	269.7	13.1	14.0	83.0	5.1	4.2	3	1	1	1	1	3	2	3	1	2	10.1	6.3	8.5	8.6	72.7	17.8	65.0	16.3
39	PKS - 39	Pimpalkhuta	Akot	Akola	95.7	137.7	253.5	12.1	13.0	88.0	6.0	4.2	3	2	1	1	1	3	2	3	1	2	11.4	4.7	8.5	10.1	86.5	19.8	56.8	11.4
40	PKS - 40	Jainpur	Daryapur	Amravati	79.3	121.3	255.0	11.8	13.2	86.7	6.1	4.3	2	2	2	2	2	2	2	3	3	2	23.6	4.4	8.4	8.7	73.0	22.6	39.7	13.4
41	PKS - 41	Jainpur	Daryapur	Amravati	83.0	125.0	316.4	10.5	11.6	84.0	7.5	5.5	3	1	2	1	9	2	2	2	3	2	23.3	4.0	8.6	7.5	74.0	21.0	66.5	13.2
42	PKS - 42	Rustampur	Daryapur	Amravati	80.0	122.0	331.9	13.0	14.0	80.3	5.9	3.6	3	1	2	1	9	2	2	2	3	1	14.9	4.9	9.2	6.5	51.1	22.5	75.2	16.9
43	PKS - 43	Bhamod	Daryapur	Amravati	88.7	130.7	276.6	10.3	11.4	82.0	6.1	4.4	3	1	2	2	2	8	2	2	3	1	22.8	4.4	8.0	7.3	57.9	22.1	80.3	12.5
44	PKS - 44	Bhamod	Daryapur	Amravati	80.7	122.7	306.4	12.4	13.5	76.7	5.7	2.3	3	1	1	1	9	2	2	2	3	2	16.9	6.9	9.7	6.9	67.0	21.8	76.2	11.2
45	PKS - 45	Bhamod	Daryapur	Amravati	80.0	122.0	324.7	13.2	14.3	75.3	5.6	3.5	3	1	1	1	4	4	2	6	1	2	21.2	5.2	9.9	8.0	78.8	22.4	95.2	10.1
46	PKS - 46	Bhamod	Daryapur	Amravati	82.0	124.0	311.7	12.8	13.7	78.3	4.6	3.9	3	1	2	1	10	2	3	3	3	3	23.2	6.6	8.3	6.7	69.2	20.7	80.6	15.9
47	PKS - 47	Bhamod	Daryapur	Amravati	80.7	122.7	310.9	13.3	14.0	85.3	4.4	4.4	3	2	2	1	9	8	3	2	3	2	18.7	11.4	9.8	6.6	65.9	22.5	46.1	14.5
48	PKS - 48	Bhamod	Daryapur	Amravati	69.0	111.0	275.5	12.9	13.6	83.7	5.9	4.5	2	1	2	1	9	4	3	2	3	3	19.5	4.4	15.5	6.3	89.3	22.5	35.7	15.7
49	PKS - 49	Bhamod	Daryapur	Amravati	80.0	122.0	295.4	12.0	13.2	90.3	5.3	5.5	3	1	2	1	4	2	4	2	2	3	15.9	4.3	9.0	7.3	65.5	19.6	66.1	16.7
50	PKS - 50	Katyar	Akola	Akola	75.0	117.0	198.9	11.5	12.5	83.7	5.6	4.3	2	1	2	1	2	2	4	2	2	3	16.6	7.3	9.3	7.5	69.4	11.8	34.9	8.9
51	PKS - 51	Apoti	Akola	Akola	81.0	123.0	291.4	12.0	12.6	81.0	5.4	3.2	3	1	2	1	4	2	4	3	2	3	16.4	5.2	10.3	7.5	77.3	20.7	52.7	13.7
52	PKS - 52	Apoti	Akola	Akola	80.7	122.7	291.8	11.5	12.0	78.7	5.2	3.3	3	1	2	1	2	2	3	3	3	3	12.3	4.8	10.0	7.3	74.5	28.2	70.2	15.0
53	PKS - 53	Apoti	Akola	Akola	78.3	120.3	242.3	11.9	12.9	81.7	4.9	3.3	2	1	2	2	2	2	3	3	2	3	17.6	5.6	9.2	7.5	68.3	25.6	45.0	20.8
54	PKS - 54	Lotwada	Daryapur	Amravati	79.7	121.7	294.4	11.9	12.6	82.7	5.1	3.6	3	2	1	1	9	2	3	2	3	3	14.2	4.1	11.1	8.4	92.9	21.6	47.3	17.7
55	PKS - 55	Lotwada	Daryapur	Amravati	81.7	123.7	268.1	10.8	12.1	77.3	6.1	4.1	3	1	2	2	2	3	4	2	3	3	17.3	4.5	9.3	8.2	66.1	18.9	69.2	13.6
56	PKS - 56	Lotwada	Daryapur	Amravati	84.0	126.0	273.0	11.8	13.1	84.0	5.0	4.4	3	1	2	1	2	8	2	2	3	2	9.8	5.9	8.0	7.4	58.6	21.1	94.6	19.0
57	PKS - 57	Khandala	Akot	Akola	94.7	136.7	319.2	12.3	13.1	84.3	4.9	4.7	3	1	2	1	1	2	2	2	1	2	25.2	3.8	8.2	7.4	50.3	26.0	89.7	11.5
58	PKS - 58	Lotwada	Daryapur	Amravati	67.7	109.7	255.1	13.4	14.3	90.7	5.2	7.1	2	1	2	1	7	8	3	5	1	3	23.8	5.8	9.7	6.3	61.6	16.6	32.4	9.4
59	PKS - 59	Lotwada	Daryapur	Amravati	79.7	121.7	345.6	12.5	13.3	86.3	6.1	5.6	3	1	2	1	9	2	3	2	3	3	14.6	5.7	10.2	7.2	73.6	23.8	71.4	21.5
60	PKS - 60	Lotwada	Daryapur	Amravati	82.3	124.3	289.0	12.7	13.4	90.7	6.4	6.2	3	1	2	1	2	3	3	2	1	2	16.2	3.7	8.9	6.8	60.4	16.7	53.6	17.4
61	PKS - 61	Nandrun	Daryapur	Amravati	98.0	140.0	294.9	12.0	12.7	77.7	5.6	7.0	3	1	1	2	2	2	2	2	3	2	14.3	4.9	9.4	7.3	68.9	27.4	123.7	11.6
62	PKS - 62	Nandrun	Daryapur	Amravati	97.7	139.7	316.7	13.4	14.3	72.0	6.1	6.6	3	1	1	2	2	2	2	2	3	2	20.9	4.1	9.2	6.3	58.3	21.1	114.5	10.6
63	PKS - 63	Pimplod	Daryapur	Amravati	79.7	121.7	263.2	9.9	10.9	84.0	5.9	6.2	3	2	1	1	4	2	3	2	1	3	12.2	4.7	9.3	8.4	78.4	24.4	76.4	22.3
64	PKS - 64	Pimplod	Daryapur	Amravati	80.3	122.3	245.4	12.5	13.4	85.7	6.2	6.7	2	1	2	2	2	2	2	3	3	2	14.3	4.1	9.7	8.5	83.1	28.5	70.5	19.3
	General	Mean	-	-	79.8	121.5	167.9	11.8	12.6	80.5	5.7	4.4	-	-	-	-	-	-	-	-	-	-	16.3	5.3	9.4	7.4	69.2	20.8	63.4	13.7
	SE(m)+	-	-	-	1.7	1.7	10.8	0.5	0.5	4.7	0.3	0.1	-	-	-	-	-	-	-	-	-	-	1.4	0.5	0.7	0.5	4.9	2.0	4.5	0.9
	CD	-	-	-	4.7	4.7	30.0	1.4	1.4	13.2	0.8	0.4	-	-	-	-	-	-	-	-	-	-	3.9	1.4	2.0	1.5	13.6	5.5	12.5	2.5
	C.V. (%)	-	-	-	3.6	2.4	6.9	7.5	6.8	10.1	8.9	5.4	-	-	-	-	-	-	-	-	-	-	14.7	15.9	12.9	12.7	12.2	16.2	12.2	11.4

Scale or Grade used as per discriptors

1 Plant pigmentation	1- Tan	2- Non-tan	3- Semi tan					
2 Internode cover	1- Fully covered	2- 3/4 covered	3- 1/2 covered	4- 1/4 covered				
3 Leaf colour	1- Light green	2- Dark green						
4 Midrib colour	1- White	2- Dull green	3- Yellow	4- Brown				
5 Panicle Shape & Compactness	1- Compact oval	2- Com. elliptic	3- Semi com. ova	4- Semi com. Elliptic	5- Loose oval	6- Loose elliptic 7- Very lax panicle	8- loose drooping primaries	9- Loose errect primaries
6 Glume Colour	1- White	2- Straw	3- Light red	4- Brown	5- Reddish brown	6- Light brown 7- Red	8- Dark red	9- Black
7 Glume Cover	1- 1/4 covered	2- 1/2 covered	3- 3/4 covered	4- full grain covered				
8 Seed Colour	1- Chalky white	2- White	3- Straw	4- Yellow	5- Brown	6- Rddish brow7- Pearly white	8- Extra pearly white	9- Red
9 Seed Shape	1- Round	2- Flat	3- Turtle					
10 Threshability	1- Frely	2- Partially	3- Hard/ difficult					

VITA

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THESIS ABSTRACT

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b. Name of student	: Yogesh Nilkanth Warkad
c. Name and address of Major Advisor	: Dr. N.R. Potdukhe Junior Sorghum Breeder, Sorghum Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (M.S.) – 444 104.
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ABSTRACT

The present investigation entitled "Evaluation of newly collected *kharif* sorghum germplasm from Vidarbha region" was conducted with a view to determine genetic variability, correlation between yield and yield components and direct and indirect effect of

yield components on yield. The experiment was conducted during *kharif* season of year 2006, using Randomized Block Design with three replications. Observations were recorded on five randomly selected competitive in each replication for each genotype on sixteen different characters viz. days to 50% flowering, days to maturity, plant height (cm), number of internodes per plant, number of leaves per plant, leaf length (cm), leaf width (cm), stem girth (cm), earhead length (cm), earhead breadth (cm), number of whorls per earhead, number of primaries per whorl, number of primaries per earhead, 1000 seed weight, dry fodder weight per plant (g) and grain yield per plant (g).

The GCV, PCV, heritability and EGA were estimated for all the characters. The characters dry fodder weight per plant, earhead length, stem girth, 1000 seed weight and plant height exhibited high GCV and PCV values.

The characters stem girth, dry fodder weight per plant, days to 50% flowering, days to maturity, grain yield per plant, plant height, earhead length, earhead breadth, number of primaries per earhead and number of leaves per plant had high heritability values.

High values of EGA were recorded for the characters grain yield per plant, dry fodder weight per plant, earhead breadth, earhead length, stem girth, plant height, 1000 seed weight, days to 50% flowering and number of primaries per earhead.

The characters dry fodder weight per plant, days to 50% flowering, grain yield per plant, plant height, stem girth, earhead length, earhead breadth and number of primaries per earhead exhibited high heritability values along with high value of EGA.

High value of heritability along with low value of expected genetic advance were observed for the characters like days to maturity and number of leaves per plant. Hence, heterosis breading can be fruit fully exploited in improving these traits.

The genotypic correlation between yield and yield contributing traits revealed that the only character 1000 seed weight exhibited highly significant association with grain yield per plant, indicated the direct contribution of this character for improvement of yield.

Path coefficient analysis revealed that days to 50% flowering had very high direct positive effect on grain yield per plant, also the character days to maturity had highest indirect effect via days to 50% flowering. Whereas most of the characters had maximum indirect positive effect on grain yield per plant via days to 50% flowering.

Hence, the characters days to 50% flowering and days to maturity were found to be promising characters for enhancing the grain yield.