

**EVALUATION OF SEED QUALITY, GROWTH
PARAMETERS AND YIELD IN *KHARIF* SORGHUM
(*Sorghum bicolor* (L.) Moench)**

THESIS

**Submitted to
Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola
in partial fulfilment of the requirements
for the Degree of**

**MASTER OF SCIENCE
IN
AGRICULTURE
(AGRICULTURAL BOTANY)
(SEED TECHNOLOGY)**

By

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DECLARATION OF STUDENT

I hereby declare that the experimental work and its interpretation of the Thesis entitled “**EVALUATION OF SEED QUALITY, GROWTH PARAMETERS AND YIELD IN KHARIF SORGHUM (*Sorghum bicolor* (L.) Moench)**” or part thereof has neither been submitted for any other degree or diploma of any University, nor the data have been derived from any thesis / publication of any University or scientific organization. The source of materials used and all assistance received during the course of investigation have been duly acknowledged.

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CERTIFICATE

This is to certify that the thesis entitled “**EVALUATION OF SEED QUALITY, GROWTH PARAMETERS AND YIELD IN KHARIF SORGHUM (*Sorghum bicolor* (L.) Moench)**” submitted in partial fulfilment of the requirement for the degree of “**MASTER OF SCIENCE IN AGRICULTURE (Agricultural Botany)**” of Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola is a record of bonafide research work carried out by **Awate Madhuri Dnyandeo** under my guidance and supervision.

The subject of the thesis has been approved by the student's Advisory Committee.

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ACKNOWLEDGMENT

I feel great at this moment to recapitulate all my beneficiaries in profound sense of gratitude and sentiments to all those who helped me during the course. It gives me immense pleasure to place on records my profound gratitude and sincere appreciation to each and every one of those who have helped me in this endeavour.

No word would sustain the appreciation for the eager involvement and encouragement of Dr. V. V. Kalpande, Associate professor, Sorghum Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth (Dr. P.D.K.V.), Akola, Maharashtra and Chairman of my Advisory Committee at every stage of investigation and preparation of my thesis. His efforts for providing me facilities that I needed for completing my research successfully are better appreciated than can be expressed here.

I am highly grateful to my advisory committee members Dr. R. S. Nandanwar, Ex-Head, Department of Agriculture Botany, Dr.PDKV, Akola, Dr. R.B. Ghorade, Senior Research Scientist, Sorghum Research Unit, Dr.PDKV, Akola, Shri. R.D. Walke, Associate Professor, Department of Agril.Economics and Statistics, Dr. PDKV, Akola for their timely and valuable suggestions.

I would like to express my immense gratitude to the Hon. Head of the department of Agricultural Botany, Dr. D. V. Durge for his persistent encouragement and timely suggestions during the period of investigations.

I am heartily thankful to Dr.V. M. Bhale, Hon. Vice-Chancellor, Dr. V. K. Kharche, Dean (Agri) and Dr. Y. B. Tayde, Associate Dean, PGI, Dr. PDKV, Akola for their kind cooperation and providing facilities and resources during my post graduate programme.

I am also sincerely thankful to Dr. A.A. Akhare (Seed Research Officer) Seed Technology Research Unit, Dr. R.D. Ratnaparkhi, Education incharge Department of Agricultural Botany, Dr.PDKV, Akola, Dr. N. R. Potdukhe Associate professor, Sau. P.A. Sonkamble, Associate Professor, Shri. M.R. Wandhare, Assistant Professor, Dr. N.V. Kayande, Assistant Professor, Dr. S. K. Burghate, Associate Professor, Shri. S. B. Thawari, Senior research Assistant, Department of Agricultural Botany, Dr.PDKV, Akola. for

their inspiration and whole hearted support during whole post graduation study.

I am cheered to place my gratitude to University Librarian Shri. A. B. Bhosale and staff members of Computer Centre (ARIS) for their valuable help during whole post graduation.

I am very much thankful to Dr. A.R. Gulhane (Assistant Professor), Dr. G.V. Thakre (Assistant Professor), Shri K.S. Pagire (SRA), Shri. A.T. Ambhore (Agril. Assistant), Shri. U.Z. Rathod (Agril. Assistant) and all staff members of Sorghum Research Unit, Dr. PDKV, Akola.

I am also thankful to Shri. Umale kaka, Shri. Damodar kaka, Ravi dada, and all the staff members, PGI, Akola for their valuable help during my research work.

I express my heartfelt thanks to my dearest friends Madhavi, Priyanka, Shital, pradnya, Akshay, Dhananjay, Karishma and senior cum friend Ankita di, Shubh di, Prabha di, Tursa di, Vrushali di and Anjali di for their friendly help and likely company throughout my study period.

I would like to record my cardiac sense of gratitude to my seniors Prajwal sir, Pravin Sir, Sanjay Sir and Amol Sir for their kind co-operation, throughout this academic programme.

Words seem inadequate to express my profound sense of loving thanks and gratitude to my beloved parents Shri. Dnyandeo Pandhari Awate and Sau. Kalpana Dnyandeo Awate. I also wish to record my deep love to my sweet brother Rahul and Shubham and cousins Amol dada, Yogesh, Vandana Akka and Ranjana Akka and their family for their encouragement and affection during my studies.

I am very much thankful to all the authors and researchers, whose articles helped me in organizing my research work in proper line and utilize proper tools for interpretation of the results.

The episode of acknowledge would not be complete without the mention of Mr. Rushikesh Shirkhate (Samarth Square, Akola) for their co-ordination in bringing out the printed script within the stipulated time frame.

Lastly, I would like to bow before the ever gracious and omni present, God for being there and supporting me through this Endeavour.

Place: Akola
Date: / / 2019

(Awate Madhuri Dnyandeo)
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(B) Abbreviations

%	- Per cent
/	- Per
C.D.	- Critical differences
cm	- Centimeter
CSV	- Co-ordinated Sorghum Variety
EGA	- Expected Genetic Advance
d. f.	- Degrees of freedom
<i>et al.</i>	- Et alia (and others)
Fig.	- Figure
g	- gram
GAM	- Genetic Advance over Mean
GA	- Genetic Advance
GCV	- Genotypic Coefficient of Variation
GV	- Genotypic variance
h^2	- Heritability
<i>i.e.</i>	- That is
ISTA	- International Seed Testing Association
J.	- Journal
Kg	- Kilogram
Mha	- million hectors
ml	- mili liter
mm	- mili meter
MSS	- Mean sum of square
MSe	- Error mean squares
MT	- Metric Tonnes
PCV	- Phenotypic Coefficient of Variation
PV	- Phenotypic variance
SE	- Standard Error
SE(d)	- Standard error of difference
SE(m) $\pm$	- Standard error of mean
SS	- Sum of square
Sr. No.	- Serial number
TGMR	Threshed grain mold rating
Unpub.	- Unpublished
<i>Viz.,</i>	- Videlicet (namely)
Σ	- Summation
σ^2	- Variance

(C)

THESIS ABSTRACT

- a. Title of the thesis : **“EVALUATION OF SEED QUALITY, GROWTH PARAMETERS AND YIELD IN KHARIF SORGHUM (*Sorghum bicolor* (L.) Moench)”**
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- d. Degree to be awarded : M. Sc. (Agriculture)
- e. Year of award of degree : 2019
- f. Major subject : Agricultural Botany
(Seed Technology)
- g. Total number of pages in the thesis : 110
- h. Total number of words in thesis abstract : 405
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ABSTRACT

A present investigation entitled “Evaluation of seed quality, growth parameters and yield in *kharif* sorghum (*Sorghum bicolor* (L.) Moench)” was conducted to estimate the genetic variability, heritability, genetic advance and correlation between seed quality, growth parameters and yield. The experiment was conducted during *kharif* season of 2018 using Randomized Block Design with three replications. Observations were recorded for each genotype on seventeen different characters namely days to

50% flowering, plant height (cm), number of leaves, panicle length (cm), seed hardness (kg/cm^2), threshed grain mold rating (%), specific gravity of seed (g/ml), germination percentage of seed, electrical conductivity (dsm^{-1}), 1000 seed weight (g), shoot length (cm), root length (cm), root shoot ratio, vigour index length, vigour index mass, fodder yield per plant (g) and grain yield per plant (g).

The ANOVA revealed highly significant difference among the all genotypes for all the characters studied indicating the presence of substantial amount of genetic variability.

The GCV, PCV, heritability and EGA were estimated for all the characters. The characters threshed grain mold rating and electrical conductivity showed high GCV and PCV values.

Highest heritability estimate in broad sense was observed for the character fodder yield per plant. The highest value of expected genetic advance over mean was recorded for the character threshed grain mold rating.

For the development of high yielding hybrids in sorghum, panicle length should be considered during selection. Due weightage should be given to plant height and number of leaves in developing high fodder yielding hybrids in sorghum. Similarly seed hardness should be taken into consideration for improvement in the germination percentage of seed.

For grain yield per plant, the nine hybrids viz., ICS 89022 A x AKR 519, AKMS 85 A x AKR 325-1, ICS 89022 A x AKR 567, AKMS 30 A x AKR 571, AKMS 85 A x AKR 567, AKMS 85 A x AKR 572, AKMS 85 A x AKR 519, ICS 89022 A x AKR 573 and ICS 89022 A x AKR 522 were significantly superior over the national check hybrid CSH-35 and recorded substantial percentage increase over the check hybrid. These nine hybrids hold promise in developing high grain yielding hybrids. For development of dual purpose hybrids, three hybrids *i.e* ICS 89022 A x AKR 519, AKMS 30 A x AKR 571 and ICS 89022 A x AKR 567 appeared best because of their high grain yield along with high fodder yield as compared to the national check CSH-35.

CHAPTER I

INTRODUCTION

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1.1 Background Information

Sorghum (*Sorghum bicolor* (L.) Moench), an annual diploid ($2n=2x=20$), belongs to the family Poaceae (grass), with a genome of 25% the size of Maize or Sugarcane. *Sorghum bicolor* Spp. *Verticilliflorum* is believed to be the progenitor of cultivated sorghum. The origin of sorghum is generally believed to be around the present day Ethiopia or East Central Africa. Sorghum was taken from East Africa to India during the first millennium. It is the fifth most important cereal crop globally after rice, maize, wheat and barley (FAO 2004). It is predominantly cultivated in semi-arid tropics (SAT) and is the dietary staple of more than 500 million people in 30 countries. Its grain is main food source in many developing countries. Besides food, it is also used for animal feed, fuel, syrup, alcoholic beverages and ethanol. It is one of the cheapest sources of energy and micronutrients (after pearl millet). It is a C_4 plant with higher abiotic stress tolerance which makes sorghum especially important in dry region. It thrives on very small quantity of rainfall and goes in dormant situation when there is short of soil moisture, and resumes to its growth as soon as moisture become available with very less reduction in the yields. So it is also known as "Camel of Desert".

Recent FAO statistics (<http://www.fao.org>) indicates a world production of 57.53 million tonnes of grain sorghum from 39.8 hectares of land with productivity of 1.45 tones/ ha. The major sorghum producing countries are Nigeria, Mali, Sudan, India, China, Pakistan, USA, Australia, Argentina and Mexico.

In India sorghum is cultivated in both rainy and post rainy season. Recent Trend of area and production indicates that there has been drastic reduction in sorghum area especially in rainy season from 11.53 million ha (1970-71) to 2.42 million ha (2012-13), but area under *rabi* sorghum has remained stable from 7.06 million ha (1970-71) to 3.78 million ha (2012-13). However the productivity of *kharif* sorghum in last 25 to 30 years is increased 2 by 3 to 4 times as compared to post rainy sorghum due to release

of high yielding hybrids and varieties. Though the productivity of post rainy sorghum (784 kg/ha.) is much lower than the rainy season sorghum (10.23 kg/ha), the produce is predominantly consumed as food, while sorghum grown in rainy season is mainly utilized as feed, as the grain is often caught in the rains and quality is affected due to grain mould.

In Maharashtra the area of sorghum under cultivation is 4.10 lakh hectare with total production of 4.17 lakh tones and average productivity of 1018 kg/ha during the period of 2017-2018 (Agresco report). Sorghum is mainly grown in Maharashtra, Karnataka, Telangana, Andhra Pradesh, Tamilnadu and Gujrat.

Sorghum is gaining importance as 'health food' now a days, because of its higher dietary fiber (7.6% to 9.2%). It contains 72.6 per cent carbohydrate, 10 to 12 per cent protein, 1.6 per cent mineral matter and 1.9 per cent fat. It is rich source of amino acids mainly lysine, thiamine, riboflavin and folic acid along with vitamin-B complex specially niacin (vitamin B₆). It contains nitrogen (212 mg), starch (5.6 % to 7.3 %) in high quantity along with copper, zinc and molybdenum. Its protein in bran, germ fractions contains four times the lysine and two times arginine and glycine than endosperm protein.

Area, production and productivity of Sorghum

	Season	Area (Lakh ha)	Production (Lakh ton)	Yield (kg/ha)
World		398.0	575.3	1450
India		46.3	47.3	980

	Season	Area (Lakh ha)	Production (Lakh ton)	Yield (kg/ha)
Maharashtra	<i>Kharif</i>	4.10	4.17	1018
	<i>Rabi</i>	17.05	15.10	886
Vidharbha	<i>Kharif</i>	1.488	1.361	648
	<i>Rabi</i>	0.250	0.184	477

(Anonymous: 2017-18)

Source: - Director Economics and Statistics Department of Agriculture and Co-operation (Anonymous 2017)

In India, total sorghum area has shrunk by 52% from 18.6 m ha in 1970 to 7.53 m ha in 2009. *Kharif* area reduced at a faster rate (70%) than the *rabi* area (32%). This decline in area is because the crop is gradually

disappearing in traditional areas due to access to irrigation and market which have enabled farmers to shift their area under cultivation to high value crops. Besides this, there is steady decline in consumption of sorghum. The annual per capita consumption of sorghum at national level has declined sharply by 68% (8.5 to 2.7 kg/year) in urban areas and by 70% (19.1 to 5.2 kg/year) in rural areas between 1972-1973 to 2004-2005 (Parthasarathy Rao, 2010).

The information on the nature and magnitude of variability and the knowledge of correlation between complex character like yield and its component is useful in improving the efficiency of selection for desirable characters. In present investigation variability parameters phenotypic and genotypic coefficients of variation (PCV and GCV), heritability, genetic advance (GA) and correlation were studied in *kharif* sorghum hybrids.

One hundred and seventy six germplasm lines and two checks of sorghum were evaluated to estimate the PCV, GCV, heritability, genetic advance (GA) and correlation. Higher PCV and GCV were recorded for grain yield per plant. Similarly high heritability estimates coupled with high genetic advance were observed for grain yield per plant. Grain yield per plant showed significant positive correlation with 100 seed weight (Hemlata *et al.* 2006).

1.2 Importance and need of the study

In India, varietal improvement programme in sorghum was initiated in 1930. The local were tall, late maturing and characterized by localize adaptation and low harvest index. Their response to improved management in terms of increase yield was very poor. During that time, most of the improved varieties were resulted from pure line selection practiced in principle local varieties. Local x local hybridization followed by selection resulted in varieties with marginal increase in grain yield. In order to meet the food requirement of increasing population, development of high yielding hybrids is essential.

In Maharashtra, sorghum is grown in "Monsoon" season and crop is usually caught in rains between flowering to maturity of the grains. Rain damaged grains fetches less value than the normal grains and seed loses its viability due to grain mold infestation. Since, grain mold is an

apprehensive problem in this area, it is necessary to work out the plant and grain characteristics contributing towards resistance. Due to grain mold problem, seed production of most of the hybrids cultivated in Maharashtra state, is being taken up in Southern states and hence state government is also emphasizing to concentrate the research on grain mold resistance. Because of this, resistance breeding for grain mold has become a major activity in many sorghum improvement programmes.

The intensity of association of characters is determined by correlation studies. Such correlation studies help us to know which character should be chosen for selection to bring about the maximum increase in the ultimate product. So, investigation was carried out to identify some of the potential hybrids of *kharif* sorghum which could be exploited further. Hence, present investigation was carried out with following objectives.

1.3 Objectives of study

1. To evaluate the extent of genetic variability for seed quality, growth parameters and yield.
2. To evaluate the nature and extent of correlation between seed quality parameters, seedling growth and yield.

1.4 Hypothesis or assumptions

The genetic variability study is helpful to estimate the suitable parameters of variation such as heritability estimates and expected genetic advance for the individual characters. Variability is therefore the key factors, which determine the amount of progress expected from selection.

The correlation studies between yield and its component characters are of immense help in selecting suitable plant type. The need for studying the magnitude of interrelationship between different characters is important in many cases. The phenotypic correlations do not give an accurate idea about inherent association between different variables because they are susceptible to environmental fluctuations. Hence it is very necessary to estimate genotypic correlation coefficients for designing a reliable and efficient breeding programme.

1.5 Scope and limitations of the study

For the study of genetic variability and correlations, sorghum hybrids offer a good scope because of presence of maximum variability and wider adaptability. Genetic variability is the basic requirement for any selection. Unless and until there is large amount of variability present in the population, the breeder has little scope for selection. Genetic association play significant role to study inter-relationship among the characters.

Hence one has to access genotypic association existing between yield and its components, while selecting such complex character directly. Correlation shows nature and extent of such association between any two characters.

The yield is very complex character and depends upon a numerous genetical factors interacting with environment. The environment has a bearing on the most of the characters which are quantitatively inherited and hence, selection made in field is not reliable.

CHAPTER II

REVIEW OF LITERATURE

Sorghum is one of the important cereal crop in India. Extensive research efforts are going on at various national and international research institutes to evolve and to release promising lines. A brief account of literature in respect of genetic variability in sorghum, heritability, genetic advance and correlation studies has been reviewed in this chapter.

2.1 Genotypic and phenotypic coefficient of variation

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 interaction of genotypic and environmental factor. The extent of genotypic variability was presented by him with appropriate statistical methods and the value was expressed as genotypic coefficient of variation.

Eckebil *et al.* (1977) studied the genetic variability in 200 subscript families from each 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 for flowering.

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

Wankhade *et al.* (1985) studied the variability in 40 genotypes of sorghum and observed that grain yield per panicle, plant height and panicle weight showed comparatively high genetic co-efficient of variation.

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

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

Satpute and Tiwari (1990) studied 20 forage sorghum genotypes and revealed high genetic variability for green fodder yield and dry matter yield per plant. Whereas, low phenotypic coefficient of variation (PVC) and genotypic coefficient of variation (GCV) for traits like plant height and number of leaves per plant.

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

Raut *et al.* (1994) evaluated twenty genotypes and found that of all the characters, fodder yield per plant, grain yield per plant and plant height exhibited comparatively high estimates of genotypic and phenotypic coefficient of variation.

Sankarapandian *et al.* (1996) studied 15 genotypes of grain sorghum and reported that the magnitude of phenotypic coefficient of variation (PVC) and genotypic coefficient of variation (GCV) were found more or less equal for number of grains per earhead and 1000 grain weight.

Can *et al.* (1998) studied seven traits of thirteen genotypes 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 these traits. The highest phenotypic coefficient of variation and genotypic coefficient of variation was obtained for total fodder weight followed by dry weight of leaves.

Dadheech *et al.* (1999) studied variability in 34 genotypes and found significant difference among the characters like peduncle length, panicle weight, biological yield per plant and harvest index etc. They also observed high estimate of genotypic coefficient of variation for those traits.

Bhongle (2000) studied the genetic variability and reported that genotypic coefficient of variation and phenotypic coefficient of variation was higher for the characters plant height followed by grain yield per plant,

electrical conductivity and 100 seed weight. While the characters grain hardness, followed by germination, TGMR, days to 50% flowering and specific gravity exhibited low GCV and PCV values.

Narkhede *et al.* (2000) studied genetic variability for 22 yield related traits in 168 genotypes of sorghum and reported that the phenotypic coefficient of variation was higher than the genotypic coefficient of variation for all traits studied. However, variations of both estimates were within a mean range, indicating the phenotypic variability is a reliable measure of genotypic variability.

Chaudhary and Arora (2001) studied genetic variability and interrelationship of characters in 23 genotypes of sorghum in four environments. The estimates of GCV and PCV were higher for stover yield and biological yield.

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

Arunkumar *et al.* (2004) studied the genetic variability for eight quantitative traits in 138 genotypes of *rabi* sorghum. High phenotypic coefficient of variation and genotypic coefficient of variation were observed for grain yield per plant and plant height.

Elangovan *et al.* (2006) studied variability in 745 accessions of sorghum landraces and found greater variability for characters like days to 50% flowering, grain yield and 100 seed weight.

Geleta and Daba (2005) assessed the genotypic and phenotypic variability in sixty four sorghum germplasm lines and found that genotypic and phenotypic coefficient of variations were higher for plant height, head weight, grain yield per plant and 100 kernel weight.

Rathod (2005) studied the genetic variability and reported that grain yield per plant exhibited high GCV and PCV values followed by TGMR, plant height, 1000 seed weight, seed hardness. While specific gravity, days to

50% flowering, germination of seed and electrical conductivity exhibited low GCV and PCV values.

Thorat *et al.* (2005) studied the variability in 20 derived sorghum lines and reported that the characters *viz.*, plant height, TGMR and panicle length exhibited high estimates of GCV and PCV. While days to 50% flowering, specific gravity, electrical conductivity and germination percentage of seed showed low GCV and PCV.

Hemlata *et al.* (2006) studied one hundred and seventy six germplasm lines and two checks and reported high estimates of PCV and GCV for grain yield per plant, panicle length and 100 seed weight. While low estimates of GCV and PCV was reported for days to 50% flowering.

Deepalakshmi and Ganeshmurthy (2007) studied sixteen genotypes of white grain sorghum and observed that high estimates of PCV and GCV were observed for single plant yield and grain mold score.

Muhammad *et al.* (2007) conducted experiment on seven sorghum genotypes and found that genotypic and phenotypic coefficients of variance were highest for economic yield and moderate for biological yield.

Warkad *et al.* (2008) studied the genetic variability in sixty-four sorghum germplasm accessions collected from various districts of Vidarbha region. Significant genetic variability was observed among these genotypes studied. Highest PCV and GCV values were observed for dry fodder yield per plant followed by ear head breadth and length, grain yield per plant and 1000 seed weight.

Jain *et al.* (2009) studied the genetic variability in 48 genotypes of dual sorghum for yield and their contributing traits. Significant variation among all the genotypes was recorded for all the characters. Most of the characters including grain yield per plant and fodder yield per plant had higher genotypic and phenotypic variation. Low values of GCV and PCV were observed for days to 50% flowering.

Godbharle *et al.* (2010) studied the genetic variability and nature of character association in 20 B lines and 16 R lines of *kharif* sorghum. The genotypic variances were lower than the phenotypic variances for all the

characters. High genotypic and phenotypic variances were observed for the characters fodder yield, grain yield per plant and plant height indicating that additive gene effect operating for these traits.

Singh *et al.* (2010) studied the thirty two diverse accessions of forage sorghum and estimates of phenotypic coefficient of variations (PCV) were comparable with genotypic coefficient of variations (GCV) for all traits.

Sumathi *et al.* (2010) evaluated 47 genotypes of pearl millet and observed medium values of GCV and PCV for character root shoot ratio and low values of GCV and PCV for characters root length and shoot length.

Vedansh *et al.* (2010) evaluated thirty two diverse accessions of forage sorghum for green fodder yield and its components and reported that the estimate of GCV and PCV was highest for green fodder yield.

Mahajan *et al.* (2011) observed significant variations among the genotypes for various morphological and yield traits. High values for phenotypic coefficient of variation (PVC) and genotypic coefficient of variation (GCV) was recorded for grain yield per panicle, panicle width and number of grains per panicle and plant height.

Jain and Patel (2012) studied the 102 land races of forage sorghum and reported that genotypic coefficient of variation (GCV) was maximum for fodder yield per plant followed by panicle length and low estimates of GCV were observed for days to flowering and plant height.

Khade (2012) studied 99 land races of sorghum and reported high GCV and PCV values for characters like fodder yield per plant, grain yield per plant and threshed grain mold rating. Medium values for GCV and PCV were observed in characters days to 50% flowering, plant height, vigour index of seed and electrical conductivity of seed. Whereas, for specific gravity of seed and germination percentage of seed having low values for GCV and PCV.

Tomar *et al.* (2012) conducted experiment on 52 sweet sorghum genotypes and reported significant differences among the accessions for all the characters studied. PCV was greater than GCV for most of the character

but GCV was near to PCV for characters like days to 50% flowering and plant height.

Elangovan *et al.* (2013) studied 80 accessions from Madhya Pradesh and Rajasthan and reported significant differences among the genotypes for all the traits studied. PCV and GCV were higher for days to 50% flowering, number of leaves, plant height, earhead length, 100-seed weight and vigour.

Jain and Indapurkar (2013) reported significant variations among the genotypes for various morphological and yield attributing characters in sorghum. High values for phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) was recorded for grain yield/ plant (g) and fodder yield/ plant. High heritability coupled with high genetic advance was observed for plant height at maturity and fodder yield / plant and grain yield/ plant. Fodder yield /plant and 1000 grain weight were found to be significant and positively correlated with grain yield/ plant. The result of path coefficient analysis showed that days to 50% flowering, plant height, length of panicle, width of panicle, fodder yield / plant and 1000 grain weight had positive direct effect on grain yield/ plant.

Kedar (2013) studied 63 germplasms of sorghum and reported high GCV and PCV values for characters like fodder yield per plant, grain yield per plant, electrical conductivity and threshed grain mold rating. Medium values for GCV and PCV were observed in characters days to 50% flowering, plant height, number of leaves, panicle length, seed hardness, vigour index length and 1000 seed weight. Whereas, for specific gravity of seed and germination percentage of seed having low values for GCV and PCV.

Seetharam and Ganeshmurthy (2013) studied 39 genotypes and reported high GCV and PCV values for characters like plant height, panicle length and single plant yield. Medium values were observed for characters like days to 50% flowering and number of leaves per plant.

Dhutmal *et al.* (2014) observed that for grain yield per plant, seed vigor and panicle dry weight per plant showed high GCV and PCV. The characters, total biomass per plant and plant height exhibited moderate GCV

and PCV. Whereas, low values of GCV and PCV observed in day to 50% flowering, 1000 seed weight and total number of leaves per plant.

Kalpande *et al.* (2014) assess the extent of genetic variability and heritability of 12 genotypes and 4 standard checks of sweet sorghum (*Sorghum bicolor* (L.) Moench). The observations were recorded on 7 quantitative traits. The phenotypic co-efficient of variation (PCV) was greater than genotypic coefficient of variation (GCV) for most of the characters studied indicating influence of the environmental effect on the characters. But the GCV values were close to PCV values for the characters like days to fifty per cent flowering, days to physiological maturity and grain yield, indicating very little effect of environment in the genotype, on the phenotypic expression for these traits. The character grain yield showed high GCV and PCV value. Whereas, the characters green cane weight and total biomass showed moderate GCV and PCV values. The character day to fifty per cent flowering showed low GCV and PCV values.

Amare *et al.* (2015) reported high genotypic coefficient of variation (GCV) values (>20%) for plant height and grain yield.

Dhutmal *et al.* (2015) studied genetic variability, heritability and genetic advance for grain yield and its component characters in 16 drought tolerant germplasm of rabi sorghum and found the moderate GCV and PCV for the characters total biomass and grain yield. Whereas, low GCV and PCV for the characters 1000 seed weight, plant height and total number of leaves per plant.

Ghorade *et al.* (2015) evaluated thirty eight lines consisting of thirty derived sorghum lines (named as AKENT numbers), four susceptible lines and four resistant source lines of *kharif* sorghum for yield and yield components. The study revealed that the characters yield per plant and 100 seed weight showed high GCV and PCV values indicating thereby large amount of variation in these characters. All the characters showed close GCV and PCV values indicating less influence of environment of these characters. The high heritability estimate along with high value of expected genetic advance over mean was observed for yield per plant indicating that these characters would respond positively to selection. High values of heritability

along with low value of expected genetic advance were observed for the characters like 50% flowering, panicle length, panicle breadth and 100 seed weight indicating that these characters are mainly governed by non additive component of variation.

Kalpande *et al.* (2015^a) observed highest GCV for threshed grain mold rating (38.97%) while lowest for the specific gravity of seed (1.66%). While for PCV, the highest value was recorded by one thousand seed weight (44.99%) while specific gravity of seed (2.00%) recorded the lowest value.

Kalpande *et al.* (2015^b) evaluated sixty three genotypes consisting of sixty germplasm lines and three improved released varieties of kharif sorghum for five seedling parameters. The study revealed that the character vigour index length showed moderate GCV and PCV values indicating thereby good amount of variation.

Khandelwal *et al.* (2015) studied 224 genotypes for genetic parameters and character association among yield components. Significant variations were recorded among 224 sorghum genotypes for various morphological and yield traits. The phenotypic coefficients of variation (PCV) were higher than the genotypic coefficients of variation (GCV) for all the traits under investigation. High magnitude of genotypic and phenotypic coefficient of variations were observed for harvest index, grain yield per plant, dry and fresh weight per plant and panicle length. The association of high heritability with high genetic advance and GCV was reported in case of fresh weight per plant and leaf area. Grain yield per plant was significantly and positively correlated with harvest index, 1000 seed weight, panicle length, fresh weight per plant and leaf area.

Dhedhi *et al.* (2016) studied the genetic variability and character association among 17 genotypes of forage pearl millet for seven quantitative traits and found that PCV and GCV were high to moderate for harvest index (48.65%, 45.48%), grain yield per plant (43.92%, 36.59%), dry fodder yield per plant (21.77%, 15.32%) and green fodder yield per plant (18.09%, 11.35%) respectively.

Kour and Pradhan (2016) studied the magnitude of genetic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability and genetic advance as percentage of mean. It was observed that the characters like dry matter yield per plant, green fodder yield per plant and number of leaves per plant showed high GCV and PCV values. Whereas, the characters days to 50 per cent flowering and plant height at 50 per cent flowering showed moderate value for GCV and PCV.

Badigannavar *et al.* (2017) observed wide range of values for grain yield (6.6-124.4 g/plant), seed index (1.5-7.1 g/100 seeds) and panicle length (8-44 cm). Among them high genotypic and phenotypic coefficient of variation was observed for grain yield per plant.

Kathalkar (2017) assessed genetic variability and the nature of extent of correlation between seed quality, growth parameters and yield in 81 genotypes of kharif sorghum. High GCV along with high PCV values were observed for the character threshed grain mold rating and electrical conductivity. The characters fodder yield per plant, grain yield per plant, plant height, panicle length and seed hardness showed moderate GCV and PCV values. Low GCV and PCV values were found for the characters days to 50% flowering, number of leaves, root length, shoot length, 1000 seed weight, vigour index mass, root shoot ratio, vigour index length, germination parentage of seed and specific gravity of seed indicating small amount of variation and impediment in improvement through selection.

Ranjith *et al.* (2017) observed high genotypic coefficient of variation for the character fodder yield per plant (27.31%) followed by 1000-seed weight (25.33%) whereas moderate for panicle breadth (15.17%), plant height (14.36%) and grain yield per plant (13.94%) and low for the character 50 per cent flowering (7.96%). High phenotypic coefficient of variation was observed for the character fodder yield per plant (27.86%) followed by 1000-seed weight (26.78%) and panicle breadth (21.25%) whereas moderate for plant height (16.27 %) and grain yield per plant (15.24 %) and low for the character days to 50 per cent flowering (10.94 %).

Shaikh *et al.* (2017) assessed genetic variability, heritability and genetic advance for grain yield and its component characters in 52 genotypes

of *rabi* sorghum. It was observed that the values for PCV and GCV were more or less equal in magnitude for the characters. Panicle length and fodder weight per plant showed high GCV and PCV values. Plant height and grain weight per plant showed moderate GCV and PCV values and the character number of leaves showed low GCV and PCV values.

Bhakad (2018) studied 84 germplasm of sorghum and reported high GCV and PCV values for characters like plant height, TGMR, grain yield per plant, fodder yield, germination percentage, and grain hardness. Medium values for GCV and PCV were observed in characters 50% days to flowering, panicle length and 100-seed weight. Whereas, for days to maturity and grain density it was categorized as low.

Dhutmal *et al.* (2018) reported that high estimates of genotypic and phenotypic coefficient of variations were recorded for panicle type, threshed grain mold rating, germination percentage, grain hardness. However, grain density was categorized as low.

More *et al.* (2018) reported that the GCV was lower than PCV for all the characters. High estimates of GCV and PCV were observed for the traits grain yield per plant (42.56% and 46.16%), medium values for GCV and PCV were observed in characters seedling vigour (21.89% and 21.89%), plant height (17.83% and 18.01%) and 100 seed weight (17.94% and 19.46%) and lowest GCV and PCV were observed for the trait days to 50% flowering (8.77% and 9.15%) respectively.

Swamy *et al.* (2018) studied the genetic variability and nature of character association in 122 *rabi* sorghum genotype and found that GCV and PCV were high for the characters like stover weight (32.32% and 36.07%), panicle weight (28.92% and 32.53%), grain yield (27.59% and 31.30%), panicle length (26.07% and 27.80%) respectively. Moderate GCV and PCV values were recorded for the characters like, 1000- grain weight (15.97% and 19.14%), plant height (14.61% and 18.09%), panicle girth (13.29% and 16.42%), and days to 50% flowering (10.13% and 10.44%) respectively. On the other hand, low GCV and PCV values were recorded for days to physiological maturity (3.71% and 4.10%) respectively.

2.2 Heritability in broad sense

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

Johnson *et al.* (1955) suggested that high heritability estimates accompanied by high expected genetic advance are usually more helpful than heritability value alone in predicting the effect of selecting best individuals.

Naphade (1973) studied heritability for yield, days to flower and plant height. Heritability estimate was high for height indicating that required improvement can be made in this character. For grain yield both heritability estimate and possible genetic advance were moderate showing there by that required improvement can be made in this character also. Heritability estimate was high for days to flowering.

Eckebil *et al.* (1977) conducted the 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 F₃ offspring population of sorghum genotypes and revealed that earhead length, earhead weight and 1000 seed weight exhibited high heritability estimates, whereas moderate heritability estimates were shown by plant height and days 50% flowering.

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 plant height, 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 characters plant height (83.38%), 250 grain weight (71.69%), grain yield per plant (70.66%) and days to 50% flowering (65.59%) exhibited high values 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 three cycles of gridded mass selection of 120 half sibs and 120 subscript families in grain sorghum and reported high heritability for 1000 grain weight.

Kumar and Singh (1986) studied the variability in 40 diverse genotypes of grain sorghum and found high heritability for the characters 1000 seed weight, grain yield per plant and plant height.

Kulkarni and Shinde (1987) studied heritability for the characters days to 50% bloom, plant height, panicle length, 1000 grain weight, grain yield and dry fodder yield per plant and observed high heritability estimates for all characters except days to 50% bloom.

Satpute and Tiwari (1990) studied 20 forage sorghum genotypes and observed that heritability estimates were high for days to 50% flowering and green fodder yield. High genetic advance coupled with high heritability was observed for fodder yield.

Sankarapandian *et al.* (1996) studied variability in 15 varieties of sorghum and found high heritability estimates for the characters grain yield per plant (99.57%) followed by 1000 seed weight (98.90%), number of rachis 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 13 genotypes of sorghum which exhibited the high heritability estimates coupled with high genetic advance for the characters plant height and 1000 seed weight.

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

Bhongle (2000) conducted variability studies in grain sorghum and high heritability estimates were observed in genotypes for plant height, grain yield per plant, 100 seed weight and seed hardness. The medium heritability estimates were noticed in the genotypes for electrical conductivity,

days to 50% flowering and TGMR, whereas low heritability estimate was exhibited by specific gravity.

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

Chand and Govardhan (2001) conducted heritability studies in fodder sorghum genotypes and obtained moderate heritability estimates for the characters days to 50 percent 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 percent for the character days to maturity.

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

Kishor 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.

Rathod (2005) studied heritability in thirty two derived lines with 8 checks and reported that the character 1000 seed weight showed high heritability followed by electrical conductivity, grain yield per plant, TGMR, plant height, specific gravity and seed hardness. Medium heritability was observed for days to 50% flowering. Germination percentage exhibited comparatively low heritability.

Thorat *et al.* (2005) studied the variability in 20 derived sorghum lines and reported that the characters plant height, grain yield per plant, specific gravity of seed, germination percentage of seed and electrical conductivity recorded high heritability. Whereas, the character 1000 seed weight showed low heritability.

Hemlata *et al.* (2006) studied one hundred and seventy six germplasm lines and two checks of sorghum, and reported that the traits days

to 50% flowering, 100 seed weight, grain yield per plant and panicle length exhibited maximum heritability.

Deepalakshmi and Ganeshmurthy (2007) studied sixteen genotypes of white grain sorghum and observed high heritability accompanied with high GA as percent over mean for the characters days to 50% flowering, plant height, leaves per plant, 100 grain weight, grain mold score and single plant yield suggesting that these characters were under additive gene action and thus gives better scope for selection.

Warkad *et al.* (2008) studied sixty-four sorghum germplasm accessions collected from various districts of Vidarbha region and reported high heritability accompanied with high genetic advance over mean for the characters grain yield and dry fodder yield.

Jain *et al.* (2009) observed that characters such as grain yield per plant, dry fodder yield per plant and plant height responded positively to selection because of high broad sense heritability and high genetic advance.

Chavan *et al.* (2010) conducted experiment comprising of 20 F₅ with four checks and reported that high heritability coupled with high genotypic advance was observed for plant height and grain yield per panicle. Whereas high heritability combined with low genetic advance was recorded for test weight.

Godbharle *et al.* (2010) studied 20 B lines and 16 R lines of *kharif* sorghum and observed high heritability estimates for the characters grain yield per plant, fodder yield per plant, plant height and threshed grade score and days to 50% flowering.

Sumathi *et al.* (2010) evaluated 47 genotypes of pearl millet and observed high heritability for characters root length, shoot length and root shoot ratio.

Vedansh *et al.* (2010) evaluated 32 diverse accessions of forage sorghum and reported that character green fodder yield exhibited moderate heritability.

Mahajan *et al.* (2011) studied 20 F₅ families of sorghum along with four checks and reported high heritability coupled with high genetic

advance for plant height and grain yield per panicle indicating that these characters were controlled by additive gene action and phenotypic selection for these characters will be effective.

Ahmed *et al.* (2012) studied the eight grain sorghum genotypes and reported high heritability for the characters days to maturity followed by days to 50% flowering and plant height. While for grain yield and 100 seed weight heritability estimates were low.

Jain and Patel (2012) studied the 102 land races of forage sorghum and reported that high heritability accompanied with high genetic advance as per cent over mean was observed for days to 50% flowering, plant height, number of leaves per plant and fodder yield per plant.

Khade (2012) studied 99 land races and observed high heritability for characters like days to 50% flowering, plant height, seed hardness, TGM, electrical conductivity, vigour index of seed, fodder yield per plant and grain yield per plant.

Tomar *et al.* (2012) conducted experiment on 52 sweet sorghum genotypes and reported high heritability combined with high genetic advance for character plant height and moderate heritability for number of leaves.

Elangovan *et al.* (2013) studied 80 accessions from Madhya Pradesh and Rajasthan and reported that heritability estimates were higher for the characters vigour, earhead length and plant height.

Jain and Indapurkar (2013) observed high heritability coupled with high genetic advance for plant height at maturity, fodder yield / plant and grain yield/ plant.

Kedar (2013) studied 63 germplasm of sorghum and observed high heritability coupled with high genetic advance for characters like fodder yield per plant, electrical conductivity, seed hardness, plant height and threshed grain mold rating. High heritability was observed for days to 50% flowering, panicle length, 1000 seed weight, grain yield per plant, number of leaves and vigour index length. Whereas, medium heritability observed for characters root length, shoot length, vigour index mass and specific gravity of seed.

Seetharam and Ganeshmurthy (2013) studied 39 genotypes and reported that high estimates of heritability for characters like days to 50% flowering, plant height, panicle length and single plant yield.

Dhutmal *et al.* (2014) reported the high heritability coupled with high genetic advance for grain yield per plant and plant height. Whereas, high heritability with low genetic advance for days to 50% flowering. High heritability observed for character total biomass per plant.

Kalpande *et al.* (2014) genotypes under study showed high heritability for days to 50% flowering. High heritability combined with high genetic advance (as per cent of mean) was observed for grain yield, total biomass, days to 50% flowering.

Khadakabhavi *et al.* (2014) recorded highest heritability per cent in broad sense for grain yield per plant followed by panicle length and moderate heritability percent in broad sense for day to 50% flowering.

Ghorade *et al.* (2015) reported the high heritability estimate along with high value of expected genetic advance over mean was observed for grain yield per plant indicating that these characters would respond positively to selection. High values of heritability along with low value of expected genetic advance were observed for the characters like 50% flowering, panicle length, panicle breadth and 100 seed weight.

Kalpande *et al.* (2015^a) reported the high heritability in broad sense along with high genetic advance for threshed grain mold rating and seed hardness. High heritability was observed for electrical conductivity, germination percentage of seed, vigour index of seed and specific gravity of seed while the character 1000 seed weight recorded low heritability.

Tadesse *et al.* (2015) studied characters such as plant height, days to 50 % flowering and grain yield responded positively to selection because of high broad sense heritability estimates. High heritability and genetic advance was noted for plant height and days to 50% flowering.

Insan *et al.* (2016) recorded high broad sense heritability values and broad genetic diversity in the characters plant height, leaf number,

panicle length, circumference panicle, panicle weight and grain weight per panicle.

Kareema *et al.* (2017) studied broad sense heritability for traits days to 50% anthesis (DTA), plant height (PH), panicle length (PL), panicle weight (PW), and grain yield per plant (GY). These traits and variances were recorded on three genotypes of sorghum. Results of statistical analysis showed that most traits had higher genotypic and phenotypic variances.

Kathalkar (2017) reported highest heritability estimate in broad sense for fodder yield per plant (96.27%) followed by threshed grain mold rating (91.66%), grain yield per plant (90.93%), electrical conductivity (84.43%), plant height (82.30%), seed hardness (81.55%), germination percentage of seed (67.55%) and 1000 seed weight (63.53%). Medium heritability was observed for the characters vigour index length (59.11%), number of leaves (57.08%), root length (55.88%), specific gravity of seed (52.75%), vigour index mass (49.56%), days to 50% flowering (48.06%), shoot length (47.63%), root shoot ratio (43.77%) and panicle length (41.18).

Ranjith *et al.* (2017) recorded high heritability in broad sense for fodder yield per plant (96%), 1000-seed weight (89.4), grain yield per plant (83.6) and plant height (77.9), while moderate heritability was recorded for days to 50 per cent flowering (52.9%) and panicle breadth (50.9%).

Shaikh *et al.* (2017) reported heritability in broad sense was high for characters, grain weight per plant (98.10%), fodder weight per plant (96.30%), panicle length (91.80%) and plant height (89.40%).

Bhakad (2018) studied 84 germplasm lines of sorghum and observed the heritability ranged from 92.3% to 39.6%. High estimates of heritability in broad sense were obtained for plant height, grain yield per plant, fodder yield, TGMR and grain hardness.

Dhutmal *et al.* (2018) reported that genotypes under study showed heritability ranged from 92.3% to 39.6%. High estimates of heritability in broad sense were obtained for TGMR and grain hardness. While medium heritability was observed for characters germination percentage of seed and 1000 seed weight.

More *et al.* (2018) studied variability in 116 sorghum germplasm lines and observed that heritability estimates were high for plant height (98.02), days to 50% flowering (91.80), grain yield per plant (84.89), 100 seed weight (84.97), seedling vigour (74.68).

2.3 Expected genetic advance per cent over mean

Expected genetic advance percent over mean is important selection parameter. It is an improvement in mean genotypic value of selected plants over parental population. The estimate of genetic advance helps in understanding the gene action involved in the expression of various polygenic characters and also in deciding the 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 values 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.

Satpute and Tiwari (1990) studied 20 forage sorghum genotypes and reported high genetic advance coupled with high heritability for fodder yield.

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

Can *et al.* (1998) evaluated 13 genotypes of sorghum and reported high genetic advance coupled with high heritability estimates for the character plant height and 1000 seed weight.

Dadheech *et al.* (1999) studied variability parameters 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 values of EGA.

Bhongle (2000) reported that highest expected genetic advance was shown by the character plant height followed by grain yield per plant, 100 seed weight, electrical conductivity, grain hardness, germination, TGMR, days to 50% flowering and specific gravity.

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

Rathod (2005) studied the variability in thirty two derived lines with eight checks of sorghum and reported that the highest expected genetic advance was for plant height followed by grain yield per plant, electrical conductivity, 1000 seed weight, days to 50% flowering, germination, seed hardness, Threshed grain mold rating (TGMR) and lowest expected genetic advance over mean was noted for specific gravity.

Thorat *et al.* (2005) studied the variability in 20 derived lines of sorghum and reported that the characters TGMR, 100 seed weight, seed hardness, specific gravity and electrical conductivity showed high heritability accompanied with low values of expected genetic advance.

Deepalakshmi and Ganeshmurthy (2007) reported that high heritability accompanied with high GA as per cent over mean was observed for the characters like days to 50% flowering, plant height, leaves per plant, 100 grain weight, grain mold score and single plant yield. Whereas, the character 1000 seed weight showed low expected genetic advance.

Jain *et al.* (2009) reported that high heritability accompanied with high genetic advance percent over mean was observed for characters grain yield per plant and plant height.

Chavan *et al.* (2010) conducted experiment comprising of 20 F₅ with four checks of sorghum and high heritability coupled with high genetic advance was observed for plant height and grain yield per panicle. Whereas

high heritability combined with low genetic advance was recorded for test weight.

Godbharle *et al.* (2010) studied 20 B lines and 16 R lines of *kharif* sorghum and reported that high heritability coupled with high genetic advance was observed for the characters plant height, threshed grade score, fodder yield and grain yield per plant. This indicated the predominance of additive gene effect, which are less affected by environment. The phenotypic selection for these traits will be effective. The character days to 50% flowering had medium heritability with low genetic advance which indicated non additive gene effects and limited score for selection.

Sumathi *et al.* (2010) evaluated 47 genotypes of pearl millet and observed medium values for estimates of genetic advance for characters root shoot ratio, root length and shoot length.

Vedansh *et al.* (2010) evaluated thirty two diverse accessions of forage sorghum and reported that genetic advance was highest for leaves per plant, plant height and green fodder yield.

Mahajan *et al.* (2011) studied 20 F₅ families of sorghum along with four checks and reported that high heritability coupled with high genetic advance was observed for number of grains per panicle and plant height.

Jain and Patel (2012) evaluated one hundred and two land races of forage sorghum and reported that character plant height has high estimates of heritability coupled with high genetic advance, while for the character fodder yield per plant high heritability was accompanied with low genetic advance.

Khade (2012) studied 99 land races and observed high estimates of heritability coupled with high genetic advance for characters like days to 50% flowering, plant height, seed hardness, TGMR, electrical conductivity, vigour index of seed, fodder yield per plant and grain yield per plant. Low genetic advance was observed for the characters germination percentage of seed and specific gravity of seed.

Tomar *et al.* (2012) conducted experiment on 52 sweet sorghum genotypes and reported high heritability combined with high genetic advance for character plant height.

Elangovan *et al.* (2013) studied 80 accessions from Madhya Pradesh and Rajasthan reported that high genetic advance for character like earhead length and vigour.

Kedar (2013) studied 63 germplasms of sorghum and observed high genetic advance per cent over mean for the character fodder yield per plant, electrical conductivity, threshed grain mold rating, grain yield per plant, plant height, panicle length, seed hardness, 1000 seed weight, days to 50% flowering and number of leaves. Whereas, medium genetic advance observed for the character vigour index length and root length and low for shoot length, vigour index mass, germination percentage of seed, root shoot ratio and specific gravity of seed.

Seetharam and Ganeshmurthy (2013) studied 39 genotypes and reported that high estimates of heritability coupled with high genetic advance was observed for characters like days to 50% flowering, plant height, panicle length and single plant yield.

Dhutmal *et al.* (2014) reported highest value of expected genetic advance expressed as per cent of mean for grain yield per plant, seed vigor and total biomass per plant. Character days to 50% flowering showed lowest value of expected genetic advance.

Khadakabhavi *et al.* (2014) reported highest genetic advance for grain yield per plant followed by panicle length.

Kumar (2014) recorded high heritability accompanied with high GA as per cent of mean for days to 50% flowering, plant height, number of leaves per plant and fodder yield per plant.

Ghorade *et al.* (2015) reported high values of heritability along with low value of expected genetic advance for the characters like 50% flowering, panicle length, panicle breadth and 100 seed weight.

Kalpande *et al.* (2015^a) recorded highest values of expected genetic advance over mean for the characters threshed grain mold rating

(79.90%) followed by seed hardness (54.19%) and electrical conductivity (31.97%) and lowest for specific gravity of seed (2.85%).

Kathalkar (2017) observed highest genetic advance percent over mean for the character threshed grain mold rating (146.40%) followed by electrical conductivity (84.54%), fodder yield per plant (39.12%), grain yield per plant (34.29%), seed hardness (22.48%) and plant height (21.03%). These six characters exhibited high expected genetic advance (more than 21%). Medium expected genetic advance over mean was found for the characters like vigour index length (14.08%), 1000 seed weight (14.03%), number of leaves (13.55%), panicle length (12.98%), vigour index mass (12.60%), root length (11.42%) and shoot length (11.37%). While root shoot ratio (10.18%), days to 50% flowering (7.50%), germination percentage of seed (6.46%) and specific gravity of seed (4.52%) showed low expected genetic advance over mean. The characters fodder yield per plant, threshed grain mold rating, grain yield per plant, electrical conductivity, panicle length and seed hardness exhibited high heritability values along with high values of expected genetic advance. Whereas the characters specific gravity and germination percentage of seed showed medium or high heritability values along with low values of expected genetic advance.

Ranjith *et al.* (2017) observed highest genetic advance percentage over mean for the character fodder yield per plant (55.14%) followed by 1000-seed weight (49.35%), grain yield per plant (26.25%), plant height (26.10%) and panicle breadth (22.32%), while for days to 50 per cent flowering the expected genetic advance was moderate (11.93%). The characters fodder yield per plant, 1000-seed weight, grain yield per plant and plant height exhibited high heritability values along with high values of expected genetic advance.

Bhakad (2018) studied 84 germplasm lines of sorghum and observed moderate to low genetic advance as per cent over mean for the characters days to 50% flowering, panicle length, Days to maturity, and grain density.

Dhutmal *et al.* (2018) reported that the characters TGMR and grain hardness expressed high estimate of heritability accompanied with

moderate to high genetic advance. Whereas grain density showed low estimate of heritability accompanied with low genetic advance.

More *et al.* (2018) reported that the characters plant height and grain yield per plant showed high heritability coupled with high genetic advance as % mean. Days to 50% flowering and 100 seed weight showed high heritability but low genetic advance as percent of mean.

Swamy *et al.* (2018) reported high heritability accompanied with high genetic advance over mean for characters days to 50% flowering (94.20% and 20.95%), plant height (65.21% and 24.30%), panicle length (87.89% and 50.34%), grain yield (77.66% and 50.08%) and 1000 grain weight (69.64% and 27.46%) respectively. However, days to physiological maturity (81.71% and 6.91%) showed high heritability coupled with low genetic advance respectively.

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. Similarly the knowledge of correlation between grain yield and its associated traits is also useful. An attempt has been made therefore to review the literature concerning to these aspect in sorghum.

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

Rohewal *et al.* (1964) worked out simple correlation between grain yield and plant height and recorded positive association.

Eckebil *et al.* (1977) studied genetic correlation in 200 subspecies 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.

Patel *et al.* (1980) reported that grain yield exhibited positive significant association with days to 50 per cent flowering and 100 seed weight.

Singh (1982) observed negative association between electrical conductivity and seedling vigour in sorghum.

Nandanwankar *et al.* (1983) found negative ($r = -0.11$) non-significant association between grain yield and days to 50 percent flowering in sorghum.

Wankhade *et al.* (1985) studied 40 genotypes of sorghum and reported that grain yield was positively and significantly correlated with stem girth and panicle girth. Whereas days to 50% flowering showed highest positive correlation with number of leaves and plant height.

Berenji (1988) studied correlation in F_1 hybrids and their parents (8 restorer lines and 4 CSM lines in diallel programme) of grain sorghum and reported that height exhibited a significant phenotypic and genotypic correlation with grain yield.

Raut *et al.* (1988) reported that seed density exhibited significant positive correlation with germination. However, 100 seed weight revealed significantly negative association with seedling vigour index.

Amirthadevarathinam *et al.* (1990) studied correlation in 30 genotypes of fodder sorghum and reported 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.

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.

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

Satpute and Tiwari (1990) studied 20 forage sorghum genotypes and revealed that days to 50% flowering was positively and significantly associated with plant height. Similarly number of leaves per plant had exhibited positive and highly significant correlation with green fodder yield per plant.

Stenhonse *et al.* (1990) observed that hard grain sorghum had shown more resistance to grain mould rather than soft grains.

Somani (1992) observed that electrical conductivity of seed leachates was more in susceptible cultivars.

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 levels 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 character except with 100 seed weight.

Ghorade and Shekar (1997) observed significant positive correlation of grain hardness with grain density, 100-seed weight, grain yield and percentage germination.

Jayprakash *et al.* (1997) studied correlation in 65 genotypes of grain sorghum and observed that grain yield was significantly and positively correlated with 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 had a positive correlation with grain yield.

Bhongle (2000) reported that grain yield per plant was positively and significantly associated with germination percentage, plant height and grain hardness. On the other hand specific gravity was negatively but significantly associated with grain yield. Whereas, the character specific

gravity showed positive and significant association with 100 seed weight, grain hardness and germination. The character germination showed positive and non significant association with plant height, days to 50% flowering and grain hardness. Days to 50% flowering exhibited positive non significant association with 100 seed weight and germination percentage. Plant height showed positive and significant correlation with threshed grain mold rating. While the characters electrical conductivity, threshed grain mold rating and specific gravity of seed showed negative and significant association with plant height. TGMR showed negative association with germination percentage of seed. While, seed hardness showed positive significant association with germination percentage and negative non significant association with TGMR. Similarly days to 50% flowering, plant height and 100 seed weight showed negative but significant association with electrical conductivity.

Muppidathi *et al.* (2000) studied the correlation among yield and yield components in sixty F₁ hybrids of sorghum produced by crossing 5 GCMS 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) studied correlation with 41 sorghum inbred lines and reported positive but non significant correlation between plant height and grain yield.

Patil and Padule (2000) reported that dark black sorghum seeds caused by *Curvularia penniseti* and *Drechslera rostrata* showed significantly reduced seed germination and seedling vigour index as compared to healthy seeds.

Iyanar *et al.* (2001) studied genotypic correlation in 54 genotypes of sorghum and observed that seed yield was significantly and positively correlated with panicle weight and panicle length. Sunku *et al.* (2002) studied correlation in grain sorghum and observed that correlation coefficients were significant and high among grain yield, fodder yield and plant height.

Maman *et al.* (2004) studied correlation between grain yield and yield components and found that the number of kernels per panicle and 100 kernel weight were positively associated with grain yield.

Elangovan *et al.* (2006) studied correlation among morphological characters in 745 accessions of sorghum landraces and found that days to flowering and number of leaves, stem thickness and days to maturity, number of leaves and leaf length, plant height and stem thickness were highly and positively correlated with each other.

Geleta and Daba (2005) studied correlation among yield and yield components of 64 sorghum germplasm lines and found positive and significant correlation among days to 50% flowering and plant height.

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

Rathod (2005) studied correlation among yield and yield contributing characters of 32 derived lines and 8 checks of sorghum and reported that plant height was positively and significantly associated with specific gravity. On the other hand, days to 50% flowering, electrical conductivity, plant height, seed hardness and germination showed positive but non significant association with yield per plant. Seed hardness showed positive significant association with germination. Whereas, TGMR showed positive but non significant association with 1000 seed weight and specific gravity. TGMR showed negative and non significant association with germination percentage. TGMR showed negative and significant association with seed hardness, grain yield per plant, plant height and days to 50% flowering. Specific gravity showed negative and non significant association with germination percentage and electrical conductivity. Days to 50% flowering showed negative and significant correlation with electrical conductivity and threshed grain mold rating.

Thorat *et al.* (2005) studied correlation in 20 derived lines of grain sorghum and found that grain yield per plant was significantly and

positively correlated with 100 seed weight, seed hardness, germination percentage and plant height.

Elangovan (2006) studied correlation in 179 accessions of exotic sorghum collection and found that 100 seed weight showed highly positive correlation with grain yield.

Ezeaku and Mohammed (2006) studied correlation among yield and yield attributing characters of 30 sorghum varieties and reported highly significant positive 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 100 grain weight in grain sorghum.

Deepalakshmi and Ganeshmurthy (2007) studied correlation among yield and yield contributing characters in sixteen genotypes of white sorghum and reported that seed yield was positively and significantly correlated with days to maturity. While 100 seed weight showed negative correlation with grain mold score.

Warkad (2007) studied sixty four germplasm accessions of sorghum and reported that only character 1000 seed weight exhibited positive and highly significant association with grain yield per plant.

Jain *et al.* (2009) studied correlation in sorghum and reported that plant height was significantly associated with dry fodder yield per plant. Whereas number of leaves per plant showed positive and highly significant association with plant height and fodder yield.

Bhakare (2010) reported negative and highly significant association between electrical conductivity and 100 seed weight. Seed hardness showed negative and highly significant correlation with grain mold and electrical conductivity. Electrical conductivity showed positive and highly significant association with grain mold attack. Germination percentage and

electrical conductivity exhibited negative and highly significant correlation with each other.

Godbharle *et al.* (2010) studied the nature of character association in 20 B lines and 16 R lines of *kharif* sorghum. Positive and significant correlation between grain yield and harvest index, total biomass, fodder yield and leaf area index was observed both at phenotypic and genotypic levels. Days to 50% flowering exhibited positive and highly significant association with fodder yield and 100 seed weight. Whereas, character 100 seed weight had positive and highly significant association with fodder yield per plant. While the characters field grade score, threshed grade score and days to 50% flowering exhibited negative correlation with grain yield.

Mahajan *et al.* (2011) reported that grain yield per panicle showed positive and significant correlation with plant height, panicle length and test weight at both the levels. Similarly plant height showed positive and significant association with 1000 weight. While, grain yield per panicle showed negative non significant association days to 50% flowering.

Ahmed *et al.* (2012) studied the eight grain sorghum genotypes and reported that plant height exhibited positive and highly significant correlation with grain yield per ha. Similarly, days to 50% flowering showed significantly positive correlation with 100 grain weight.

Jain and Patel (2012) studied 102 land races of forage sorghum and reported that fodder yield per plant exhibited positive and highly significant association with number of leaves. Whereas plant height showed negatively non significant association with days to 50% flowering.

Jain and Indapurkar (2013) studied days to 50% flowering, plant height, panicle length, fodder yield /plant and 1000 grain weight were found to be significant and positively correlated with Grain yield/ plant.

Kalpande *et al.* (2013) studied 99 land races and reported that days to 50% flowering exhibited positive and highly significant association with plant height and fodder yield per plant. Seed hardness showed positive and highly significant association with germination percentage of seed and

vigour index of seed. TGMR showed negative but highly significant association with germination percentage. Whereas germination percentage showed positive and highly significant association with vigour index of seed. Specific gravity of seed showed negative and non significant association with germination percentage of seed and vigour index of seed.

Kedar (2013) reported that the character grain yield per plant showed positive and highly significant association with vigour index mass, vigour index length, germination percentage of seed, panicle length, root length, shoot length and 1000 seed weight. whereas the traits specific gravity, number of leaves, electrical conductivity and threshed grain mold rating showed negative and significant association with grain yield per plant. Whereas, the character days to 50% flowering showed positive and significant association with root shoot ratio and number of leaves. While days to 50% flowering exhibited negative and highly significant association with electrical conductivity, threshed grain mold rating, specific gravity and panicle length. The character plant height showed positive and significant association with number of leaves, 1000 seed weight and specific gravity of seed. Panicle length showed positive and significant association with germination percentage of seed, seed hardness and vigour index mass. Seed hardness showed positive and highly significant association with germination percentage of seed, vigour index length and specific gravity of seed. Whereas character threshed grain mold rating and electrical conductivity showed negative and significant correlation with seed hardness. Specific gravity of seed showed negative and significant association with vigour index mass, germination percentage and vigour index length. Electrical conductivity showed negative and significant association with vigour index mass and vigour index length. Whereas, the character shoot length showed positive and significant correlation with vigour index length, vigour index mass and root length. The character fodder yield per plant showed positive and significant association with the number of leaves, plant height, day to 50% flowering and thousand seed weight. Threshed grain mold rating showed positive and significant association with specific gravity and electrical conductivity, while significant negative association was observed for

characters germination percentage, vigour index mass and vigour index length. Whereas germination percentage showed positive and highly significant association with vigour index of seed, 1000 seed weight, fodder yield per plant and shoot length. Germination percentage and electrical conductivity exhibited negative and highly significant correlation with each other. Root length exhibited positive and significant association with vigour index length, vigour index mass and root shoot ratio. Vigour index length showed positive and significant association with vigour index mass.

Seetharam and Ganeshmurthy (2013) studied 39 sorghum genotypes and observed that days to 50% flowering exhibited positive and highly significant association with plant height and number of leaves per plant.

Kalpande *et al.* (2014) studied correlation analysis indicating the days to 50% flowering and days to physiological maturity showed significant positive association with plant height at 50% flowering and plant height at physiological maturity, while significant negative association was observed for grain yield.

Kumar (2014) studied fodder yield was positively and significantly correlated with number of leaves per plant, leaf length and panicle length. The characters number of leaves per plant, days to 50% flowering and panicle length showed positive direct effect on fodder yield.

Amare *et al.* (2015) reported grain yield showed significant ($P=0.01$) positive phenotypic correlations with plant height, panicle weight, panicle yield and harvest index and genotypic correlations with panicle yield. Similarly, significant ($P=0.01$) positive phenotypic and genotypic correlations between the independent traits was observed. From the path analysis, plant height, panicle weight and harvest index showed high positive phenotypic direct effect on grain yield whereas panicle yield showed negligible positive phenotypic direct effect with considerable indirect effect via panicle weight. At genotypic level, panicle yield showed the highest positive direct effect followed by harvest index and plant height whereas panicle weight showed negative direct effect with high positive indirect effect via panicle yield.

Chittapur and Biradar (2015) showed that grain yield had positive and highly significant association with plant height, panicle weight and test weight.

Khandelwal *et al.* (2015) studied that grain yield per plant was significantly and positively correlated with harvest index, 1000 seed weight, panicle length, fresh weight per plant and leaf area.

Salih *et al.* (2015) reported that grain yield was significantly and positively correlated with straw yield, number of heads plant, plant height and 1000-grain weight. However, it was significantly and negatively correlated with days to 50% flowering.

Girish *et al.* (2016) carried out field experiment using advanced breeding lines of *rabi* sorghum to study association among the yield and its component traits, direct and indirect effects of traits on the yield. Association studies indicated that seed yield per plot showed significant positive correlation with traits viz., plant height, ear head length, 100 seed weight, fodder yield and lodging percentage at both phenotypic and genotypic level. 100 seed weight showed positive and significant association with plant height.

Badigannavar *et al.* (2017) showed that seed weight, days to flowering, panicle width and leaf area were significantly correlated with grain yield ($P \leq 0.01$). Seed weight was positively correlated with panicle width (correlation coefficient 0.31), while negatively correlated with panicle length (correlation coefficient -0.15).

Kathalkar (2017) reported that the character grain yield per plant showed positive and highly significant association with 1000 seed weight, vigour index mass, panicle length, shoot length, vigour index length, germination percentage of seed, plant height, seed hardness, fodder yield per plant and number of leaves. On the other hand, specific gravity, electrical conductivity, threshed grain mold rating, root shoot ratio and days to 50 % flowering showed negative but highly significant correlation with grain yield per plant. Days to 50% flowering showed positive and significant association with root shoot ratio, while significant negative association was observed for grain yield per plant. The character threshed grain mold rating showed

positive and significant association with electrical conductivity and root shoot length. Plant height showed positive and significant association with shoot length, fodder yield, 1000 seed weight, panicle length, seed hardness and vigour index length. Panicle length showed positive and significant association with 1000 seed weight, fodder yield per plant, shoot length, vigour index of seed, germination percentage and seed hardness. Fodder yield per plant showed positive and significant association with number of leaves, plant height, 1000 seed weight and shoot length. Seed hardness exhibited positive and significant association with vigour index length, shoot length, germination percentage, 1000 seed weight, vigour index mass, root length and fodder yield per plant, while significant negative association was observed for characters like threshed grain mold rating, electrical conductivity, root shoot ratio and specific gravity of seed. While the characters germination percentage, vigour index length and shoot length showed negative and significant association with threshed grain mold rating. Specific gravity of seed exhibited positive and highly significant association with electrical conductivity and root shoot ratio. Whereas the characters vigour index mass, shoot length, germination percentage, vigour index length, 1000 seed weight and fodder yield per plant showed negative and highly significant association with specific gravity of seed. Electrical conductivity showed negative and significant association with vigour index of seed, shoot length, 1000 seed weight and fodder yield per plant. The character 1000 seed weight showed positive and highly significant association with shoot length, vigour index of seed, fodder yield per plant and root length. Shoot length showed positive and significant association with vigour index of seed, root length and fodder yield per plant. Germination percentage showed significant positive association with vigour index of seed, shoot length, 1000 seed weight and fodder yield per plant. Root length showed positive and significant association with vigour index length and root shoot ratio. The character root shoot ratio showed negative and significant association with vigour index mass and fodder yield. Vigour index length showed positive and significant association with vigour index mass and fodder yield. The character vigour index mass showed positive and highly significant association with fodder yield.

Bhakad (2018) reported that the characters grain yield per plant showed positive and highly significant association with panicle length, fodder yield per plant, 100-seed weight.

Dhutmal *et al.* (2018) studied correlation in grain sorghum and observed that TGMR showed negative and significant association with grain density, seed hardness and germination percentage.

Swamy *et al.* (2018) assessed correlation among eleven characters of 122 *rabi* sorghum genotypes and found that days to 50% flowering, days to physiological maturity, plant height and 1000 seed weight had a positive correlation with grain yield. Among these, grain yield and panicle weight had highest positive significant value of $r = 0.848$.

CHAPTER III

MATERIAL AND METHODS

3.1 Materials

For the present study entitled “Evaluation of seed quality, growth parameters and yield in *kharif* sorghum (*Sorghum bicolor* (L.) Moench)” the material consisted of 66 *kharif* sorghum genotypes comprising of 48 hybrids of *kharif* sorghum developed by crossing 4 lines and 12 testers in line x tester fasion along with two checks CSH-14 and CSH-35.

The crossing programme was carried out at the Research Field of Sorghum Research Unit, Dr. PDKV, Akola during *rabi* 2017-2018. The seed of parental lines was provided by Sorghum Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola.

Table 3.1 List of genotypes / parents along with pedigree record

Sr. No	Parents	Source	Pedigree
	Lines		
1	AKMS 30 A	Dr. PDKV Akola	Selection from (2077BXB-57319)X(296B)-10-1
2	AKMS 85 A	Dr. PDKV Akola	Selection from ICS 1006 A
3	AKMS 90 A	Dr.PDKV Akola	Selection from 1008 A
4	ICS 89022 A	ICRISAT,Hydrabad	Female from ICRISAT, Hydrabad
	Testers		
1	AKR 325-1	Dr. PDKV Akola	Selection from SPV-1230
2	AKR 456	Dr. PDKV Akola	Selection from (RS-29 X R-150)- 4
3	AKR 517	Dr. PDKV Akola	Selection from (STR-293 X436-1)
4	AKR 519	Dr. PDKV Akola	Selection from GJ-40
5	AKR 522	Dr. PDKV Akola	Selection from Indore- 26
6	AKR 545	Dr. PDKV Akola	Selection from KR-192-2
7	AKR 551	Dr. PDKV Akola	Selection from AKSV-182-3
8	AKR 566	Dr. PDKV Akola	Selection from AKSV-267
9	AKR 567	Dr. PDKV Akola	Selection from (ICSR-76436 X 1447)-9-3
10	AKR 571	Dr. PDKV Akola	Selection from (MBR-45-1)
11	AKR 572	Dr. PDKV Akola	Selection from IVT-17-4022
12	AKR 573	Dr. PDKV Akola	Selection from IAVHT-23-3
	Checks		
1	CSH-14	Dr. PDKV Akola	(AKMS-14 A x AKR-150)
2	CSH-35	Dr. PDKV Akola	(AKMS-30 A x AKR-504)

3.2 Methods

3.2.1 Location

The experiment was conducted on the field of Sorghum Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (M.S.) during *kharif* 2018-2019. Akola is situated at latitude 23° 43' North and longitude 77° 64' East with an altitude of 281 m above mean sea level. The soil is vertisols, medium to deep black, derived mostly from basalt rocks.

3.2.2 Experimental Layout

Field experiment was laid out on the field of Sorghum Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (M.S.) during *kharif* 2018-2019. The experimental material comprised of 66 sorghum genotypes. The details of the experimental layout were as under.

- 1) Experimental design : Randomized Block Design
- 2) Number of genotype : 66
- 3) Replication : 3 (Three)
- 4) Plot size : 3.00 x 0.45m (two rows of 3 m each)
- 5) Spacing : Row to Row – 45 cm
Plant to Plant – 15 cm
- 6) Method of sowing : Hand dibbling
- 7) Date of sowing : 2nd July, 2018
- 8) Fertilizer dose : 80 kg N: 40 kg P: 40 kg K (kg/ha) Out of these half dose of nitrogen, full dose of P₂O₅ and K₂O was applied at time of sowing and remaining half nitrogen was given as top dressing after 25 days from sowing.
- 9) Plant protection : 1. Soil application of Thimet granules @ 10 Kg per hectare was applied at the time of sowing.

2. Two sprayings of Quinolphos 25 EC at 7 and 14 days after sowing at the dose of 14 ml Quinolphos in 10 liters of water were done.

10) Intercultural operations : Intercultural operations were done as per recommendations (two hoeing and two weedings)

Hoeing : 25 July, 26 Aug 2018

Weeding : 10 Aug., 10 Sept 2018

3.2.3 Recording of Observations

Observations were recorded on five randomly selected plants from each line for all the traits except days to 50% flowering. For days to 50% flowering observations were recorded on plot basis. Observations like root length, shoot length and root shoot ratio were recorded on ten normal seedlings at final count in laboratory.

3.2.3.1 Days to 50 percent flowering

The number of days required for 50 percent flowering of 50 percent of the plants in a plot from the date of sowing were recorded.

3.2.3.2 Plant height (cm)

Plant height was recorded at harvest in centimeter, which included the length of main stem from soil level to the top of the earhead and mean height per plant was calculated.

3.2.3.3 Number of leaves

The number of leaves per plant at the time of maturity in each genotype were recorded in five randomly selected plants. The average was computed and expressed in number.

3.2.3.4 Panicle length (cm)

The length of ear was measured with the scale from the point of peduncle to the tip of the ear from the five randomly tagged plants. The average was computed and expressed in centimeter.

3.2.3.5 Grain yield/ plant (g)

Five randomly selected plants were threshed, weighted in gram and per plant grain yield was calculated.

3.2.3.6 Fodder yield/ plant (g)

After harvesting of earheads, five randomly selected plants were cut at base and allowed to dry for 25-30 days, thereafter weight of fodder per plant was measured in gram and mean worked out.

3.2.3.7 Seed hardness (kg/cm²)

Since hard grains sorghum have been shown to be more resistant to grain molds rather than soft grains, a study was undertaken to see the physical strength required in kg/cm² to break the grains using Kiya hardness tester. Grains of same moisture content were used for observations. Five grains of each genotype were tested for their strength to break and mean was calculated and hardness was expressed in kg/cm².

3.2.3.8 Threshed grain mold rating (TMGR)

Seeds were tested for infection caused due to grain mold. With the visual observation infection percentage was measured on the basis of mold rating *i.e.* disease score scale of 1-9 given as below.

Grade	Description	Reaction
1	No spikelet affected by mold	Immune
2	1-5% of the panicle affected by mold	Highly resistant
3	6-10% of the panicle affected by mold	Resistant
4	11-20% of the panicle affected by mold	Moderately resistant
5	21-30% of the panicle affected by mold	Moderately resistant
6	31-40% of the panicle affected by mold	Moderately susceptible
7	41-50% of the panicle affected by mold	Moderately susceptible
8	51-75% of the panicle affected by mold	Susceptible
9	>75% of the panicle affected by mold	Highly susceptible

Source:- AICRPS, IIMR, Hyderabad, Annual Sorghum Group Meeting 21 to 23 April 2018.

3.2.3.9 Specific gravity of seed (g/ml)

Specific gravity of sorghum grains was determined by liquid displacement method. Five grams of sample of each genotype (dried and stored under similar conditions) were drawn and added in 50 ml fractionally graduated measuring cylinder containing 25 ml of water and grain density was calculated.

$$\text{Grain density (g/ml)} = \frac{\text{Weight of sorghum grain (g)}}{\text{Increase in volume of liquid (ml)}}$$

3.2.3.10 Germination percentage of seed

The Ragdoll's (rolled paper towel) method (ISTA, 1976) was used for germination studies. Towel paper (48x25 cm; 55-58 sheet/ kg) was spread on the table on which germination paper was placed. The germination paper was made wet with water before keeping seeds. 50 seeds were placed in rows on the germination paper with a definite and uniform spacing. The seeds were then covered with another germination paper. It was then folded once in lengthwise, rolled breadth wise and secured with rubber strap. The strapped material was then placed in the germinator for germination test at room temperature (*i.e.* 27°C ± 2°C). On tenth day of germination test final count for normal seedlings was made and expressed as germination percentage.

3.2.3.11 Electrical conductivity (dSm⁻¹)

Electrical conductivity of the grain leachates was measured using the method of Hendricks and Tylorson (1976).

Three grams of seed sample of each genotype under study was washed twice with the glass distilled water and placed in clean corning glass test tube and 12 ml of glass distilled water was added to each tube. After four hours of soaking at 25°C, the supernatant liquid was used for measuring the electrical conductivity. 'YSI model 32' conductance meter of scientific division, Yellow Spring Instrument Co. INC., was used. The electrical conductivity was expressed in dSm⁻¹.

3.2.3.12 1000 Seed weight (g)

Thousand grain weight (g) of each line was recorded after compositing the threshed and sun-dried grains to 12% moisture and a representative random sample of 1000 seeds per genotype was weighed in grams.

3.2.3.13 Shoot length (cm)

Ten normal seedlings which were used for measuring root length were also used for measuring shoot length. The shoot length was measured from the collar region to the insertion of primary leaf. The average shoot length was worked out and expressed in centimeter.

3.2.3.14 Root length (cm)

Ten normal seedlings from the germination test were randomly selected for measurement of root length on final day. The root length was measured from the collar region to the tip of the primary root. The mean root length was expressed in centimeter.

3.2.3.15 Root shoot ratio

Seedlings which were used for measuring root length and shoot length were used for measuring root shoot ratio. It was calculated by root length (cm) divided by shoot length and mean was worked out.

3.2.3.16 Vigour index length

Vigour index length was calculated by using the formula as suggested by Abdul-Baki and Anderson (1973) and expressed in whole number.

Vigour Index = Germination (%) x (Root length + Shoot length in cm)

3.2.3.17 Vigour index mass

Vigour index in terms of mass is determined by the multiplication of germination percentage with seedling dry weight on the day of final count (Khare and Bhale, 2000).

3.3 Statistical Analysis

The data obtained in respect of all the characters was subjected to following statistical analysis.

3.3.1 Analysis of Variance

Analysis of variance was estimated for the different characters as per the method, suggested by Panse and Sukhatme (1967) for Randomized Block Design.

ANOVA Table

Sr. No.	Sources of variation	Degrees of freedom	SS	MSS
1	Replications	(r-1)	S. Sr	M. Sr= $\delta^2e+g\delta^2r(M_1)$
2	Genotypes	(n-1)	S. Sg	M. Sg= $\delta^2e+r\delta^2g(M_2)$
3	Error	(r-1)(n-1)	S. Se	M. Se= $\delta^2e(M_3)$
4	Total	(rn-1)		

Where, r = Number of replications

n = Number of genotypes

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

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

Environmental variance = M_3

Standard error and critical difference.

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

$$SE(d) = (2Mse/r)^{1/2}$$

$$CD = SE(d) \times t \text{ value}$$

Where,

t = value at 5 and 1% level of probability for error degrees of freedom.

3.3.2 Genetic parameters

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

3.3.2.1 Genotypic and phenotypic coefficient of variation

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

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

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

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

GCV and PCV values were categorized as low, moderate and high values as indicated by Subramanian and Menon (1973). It is as follow:

1-10%	: Low
11-20%	: Moderate
21% and above	: High

3.3.2.2 Heritability estimates (h^2)

Heritability of characters is an index of its transmissibility. It may be defined as the proportion of genotypic variance to phenotypic variance and heritability percentage 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

The heritability percentage was categorized as low, moderate and high as given by Robinson *et al.* (1949).

0-30% : Low

31-60% : Moderate

61% and above : High

3.3.2.3 Genetic Advance (GA)

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

Where,

GA = Genetic advance

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

Genetic advance as per cent of mean was categorized as low, moderate and high by following Johnson *et al.* (1955).

It is as follows.

0-10%	: Low
11-20%	: Moderate
21% and above	: High

3.3.3 Correlation studies

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

Partitioning of variance

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

$$\text{Genotypic variance (V}_G\text{)} = \frac{\text{Treatment variance} - \text{Error variance}}{\text{Number of replications}}$$

$$\text{Phenotypic variance (V}_P\text{)} = \text{Genotypic variance} + \text{Error variance}$$

$$\text{Environmental variance (V}_E\text{)} = \text{Error variance}$$

Genotypic and phenotypic correlation coefficients

To study the extent of association between different traits the simple genotypic, phenotypic and environmental correlation coefficients were worked out from the respective variances and covariance as per the formulae suggested by Dewey and Lu (1959).

$$\text{Genotypic } r_{x,y} = \frac{\text{Genotypic co-variance}_{xy}}{\sqrt{\text{Genotypic variance of } x \times \text{Genotypic variance of } y}}$$

$$\text{Phenotypic } r_{x,y} = \frac{\text{Phenotypic co-variance}_{xy}}{\sqrt{\text{Phenotypic variance of } x \times \text{Phenotypic variance of } y}}$$

$$\text{Environmental } r_{x,y} = \frac{\text{Environmental co-variance}_{xy}}{\sqrt{\text{Environmental variance of } x \times \text{Environmental variance of } y}}$$

Where,

r = Correlation coefficient

x & y = Two variables under study

Significance test

Significance of simple correlation coefficient was determined from table of correlation coefficient at 5 per cent and 1 per cent levels of significance and their values were compared against $n - 2$ degrees of freedom.

CHAPTER IV

RESULTS AND DISCUSSION

The experimental results obtained from the present investigation entitled as “Evaluation of seed quality, growth parameters and yield in *kharif* sorghum (*Sorghum bicolor* (L.) Moench)” have been presented under the following subheads.

4.1 Analysis of variance

4.2 Mean performance of genotypes

4.3 Genetic variability studies

4.4 Correlation 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 4.1.

The ANOVA revealed highly significant differences among the all genotypes for all the characters studied viz. days to 50% flowering, plant height (cm), number of leaves, panicle length (cm), seed hardness (kg/cm²), threshed grain mold rating (%), specific gravity of seed (g/ml), germination percentage of seed, electrical conductivity (dSm⁻¹), 1000 seed weight (g), shoot length (cm), root length (cm), root shoot ratio, vigour index length, vigour index mass, fodder yield per plant (g) and grain yield per plant (g). This indicated the presence of substantial amount of genetic variability in the genotypes for all the characters under study.

4.2. Mean performance of genotypes

The mean performance of all the genotypes for different traits is presented in Table 4.2.

a. Days to 50% flowering

The average number of days to 50 percent flowering ranged from 62.33 to 71.33 days and 53.66 to 68 days among the parents and hybrids, respectively (Table 4.2). Among the lines, line AKMS 30 A (64 days)

Table 4.1. Analysis of variance for various characters in sorghum.

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Sources of variation	d. f.	Days to 50 % flowering	Plant height (cm)	Number of leaves	Panicle length (cm)	Seed hardness (kg/cm ²)	Threshed grain mold rating (%)	Specific gravity of seed (g/ml)	Germination percentage of seed
		1	2	3	4	5	6	7	8
Replication	2	8.234	151.496	0.071	11.564	0.315	9.399	0.001	44.752
Treatment	65	40.037**	770.625**	4.396**	13.132**	1.991**	31.728**	0.026**	54.163**
Error	130	21.183	68.908	0.577	5.909	0.264	3.332	0.010	17.429

Sources of variation	d f.	Electrical conductivity (dSm ⁻¹)	1000 seed weight (g)	Shoot length (cm)	Root length (cm)	Root shoot ratio	Vigour index length	Vigour index mass	Fodder yield (g)	Grain yield (g)
		9	10	11	12	13	14	15	16	17
Replication	2	0.059	12.066	0.046	0.393	0.006	32663.960	2.980	235.481	4.777
Treatment	65	0.181**	20.556**	3.379 **	4.115**	0.045**	133355.710**	2.886**	1937.643**	141.707**
Error	130	0.025	12.566	1.252	1.910	0.027	27384.582	1.245	146.236	12.589

*Significant at 5%, **Significant at 1%

exhibited minimum days to 50% flowering followed by line AKMS85A (65.33 days). Among the testers, tester AKR 456 (62.33 days) exhibited minimum days to 50% flowering.

Among the 48 hybrids, none of cross found significantly superior for days to 50% flowering over the early check CSH-14 (58.33 days) however the hybrids, ICS89022A x AKR 456 (53.66 days) recorded minimum days to 50% flowering followed by hybrids AKMS 85 A x AKR 456 (56 days) and AKMS 30 A x AKR 456 (57.33 days) found promising for earliness.

b. Plant height (cm)

Plant height in the study ranged from 127.13 cm to 181.83 cm and 155.03 cm to 200.67 cm among the parents and hybrids, respectively (Table 4.2).

Out of the 16 parents, highest plant height was recorded by AKR 519 (181.83 cm). However, AKMS 30 A (127.13 cm) recorded lowest plant height and registered as a dwarf parent among the available parents.

Among the hybrids, eleven hybrids exhibited significantly superior plant height over the check CSH-35 (173.4 cm). The hybrid ICS89022A x AKR 519 (200.67 cm) followed by AKMS 30 A x AKR 567 (198.53 cm), AKMS 85 A x AKR 522 (198.46 cm), AKMS 90 A x AKR 517 (198.06 cm) and AKMS 90 A x AKR 572 (197.78 cm) recorded maximum plant height. Whereas, the hybrid AKMS 90 A x AKR 551 (155.03 cm) recorded minimum plant height.

c. Number of leaves

The mean value for number of leaves ranged from 7.06 to 10.60 and 6.7 to 12 among the parents and hybrids, respectively (Table 4.2).

Among the parents, AKMS 90A (10.6) recorded maximum number of leaves per plant, while AKR 325-1 (7.06) recorded minimum number of leaves per plant.

Among the 48 hybrids, eight hybrids were found to be superior over the check CSH-35 (7.8). The hybrids AKMS 90A x AKR 517 (12), AKMS 90 A x AKR 572 (11), AKMS 85 A x AKR 567 (11) and AKMS 85 A x AKR 519

(11) recorded maximum number of leaves per plant. Whereas, the hybrid ICS 89022 A x AKR 456 (6.7) recorded minimum number of leaves per plant.

d. Panicle length (cm)

The average panicle length ranged from 19.28 to 24.45 cm and 16.13 to 26.21 cm among the parents and hybrids, respectively (Table 4.2).

Among the lines, line AKMS 85 A (24.45 cm) recorded superiority for panicle length. Among the testers, tester AKR 571 (24.15 cm) recorded maximum panicle length.

Among the hybrids, none of cross found superior for panicle length over the check CSH-35 (27.24 cm) but within hybrids AKMS 85 A x AKR 325-1 (26.21 cm) recorded the maximum panicle length followed by AKMS 85 A x AKR 519 (26.03 cm), ICS89022 A x AKR 571 (25.36 cm) and AKMS 85 A x AKR 456 (25.34 cm). whereas, the hybrid AKMS 30 A x AKR 456 (16.13 cm) recorded minimum panicle length.

e. Seed hardness (Kg/cm²)

The average seed hardness ranged between 5.38 to 8.82 kg/cm² for parents and 5.3 to 9.50 kg/cm² for hybrids (Table 4.2).

Among the parents, highest seed hardness was recorded by tester AKR 567 (8.82 kg/cm²) followed by AKR 551 (8.17 kg/cm²), while AKR 545 (5.38 kg/cm²) recorded minimum seed hardness.

Among 48 hybrids, five hybrids recorded significantly superior performance for seed hardness over the check CSH-14 (7.48 kg/cm²). Hybrid ICS89022 A x AKR 571 (9.50 kg/cm²) recorded maximum seed hardness followed by ICS89022 A x AKR 567 (9.26 kg/cm²), AKMS 85 A x AKR 573 (8.82 kg/cm²) and ICS89022 A x AKR 519 (8.38 kg/cm²). Whereas, AKMS 85 A x AKR 551 (5.3 kg/cm²) recorded minimum seed hardness.

f. Threshed grain mold rating (%)

The average threshed grain mold rating ranged between 6 to 20% for parents and 6 to 15 % for hybrids (Table 4.2).

Table 4.2. Mean performance of the genotypes for different characters.

Sr.No.	Genotype	DT50%F	PH	NOL	PL	SH	TGMR	SG	GP	EC	1000SW	SL	RL	RSR	VIL	VIM	FY	GY
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Lines (females)																		
1	AKMS 30 A	64.00	127.13	7.33	22.08	7.91	8.67	1.10	78.00	1.16	26.25	10.48	13.61	1.31	1878.10	11.34	102.74	33.70
2	AKMS 85 A	65.33	176.33	7.6	24.45	7.92	7.00	1.05	78.33	0.97	28.95	10.96	14.52	1.35	1998.63	12.38	127.04	46.00
3	AKMS 90A	71.33	158.33	10.6	23.79	5.77	14.00	1.06	78.00	1.21	23.30	10.54	13.82	1.32	1900.17	11.48	121.08	35.54
4	ICS 89022 A	69.67	168.13	8.13	23.06	6.37	15.33	1.07	79.33	1.46	24.06	10.94	13.77	1.26	1959.25	11.61	116.60	33.23
Testers (males)																		
5	AKR 325-1	69.66	142.79	7.06	20.44	6.17	12.00	1.07	78.33	1.26	23.95	9.69	12.75	1.33	1751.81	11.34	107.04	31.40
6	AKR 456	62.33	147.46	8.06	23.72	7.51	6.67	1.03	81.33	0.98	20.21	11.01	12.35	1.12	1900.94	12.24	118.74	32.23
7	AKR 517	64.67	153.53	7.80	20.42	6.67	10.67	1.09	72.67	1.21	24.29	10.12	13.84	1.37	1741.72	11.77	118.49	30.29
8	AKR 519	69.67	181.83	7.73	19.28	7.18	9.33	1.20	79.33	1.20	26.00	10.45	13.58	1.3	1907.05	11.90	114.03	28.21
9	AKR 522	71.33	149.13	8.13	19.44	6.67	12.00	1.11	78.00	1.26	23.55	9.72	13.03	1.36	1775.47	11.71	103.41	29.68
10	AKR 545	66.33	143.33	7.19	23.50	5.38	20.00	1.23	73.67	1.46	24.75	10.34	13.97	1.35	1785.82	11.34	99.14	28.33
11	AKR 551	67.33	152.20	9.20	24.00	8.17	7.00	1.02	79.00	0.87	31.38	11.44	14.06	1.24	2006.29	12.66	142.43	38.40
12	AKR 566	66.33	153.20	8.00	21.67	7.12	10.33	1.11	76.00	1.43	29.83	9.81	12.34	1.27	1684.00	11.47	110.26	28.66
13	AKR 567	69.00	171.33	9.54	23.24	8.82	8.67	1.03	76.00	1.24	32.40	9.95	13.03	1.30	1740.33	12.00	132.67	32.93
14	AKR 571	68.00	154.00	9.20	24.15	7.51	10.00	1.06	75.33	1.36	25.43	9.97	12.79	1.28	1712.95	11.55	126.08	30.10
15	AKR 572	68.33	149.66	7.20	22.70	7.38	6.00	1.04	78.33	1.01	25.71	10.90	14.21	1.31	1965.60	12.24	137.21	32.00
16	AKR 573	64.33	137.73	8.53	22.32	7.20	7.66	1.05	81.33	0.99	27.08	10.19	14.06	1.38	1970.25	12.79	135.28	37.33

DT50%F - Days to 50% flowering, PH - Plant height, NOL - Number of leaves, PL - Panicle length, SH - Seed hardness, TGMR - Threshed grain mold rating, SG - Specific gravity of seed, GP - Germination percentage of seed, EC - Electrical conductivity, 1000SW - 1000 Seed weight, SL - Shoot length, RL - Root length, RSR - Root shoot ratio, VIL - Vigour index length, VIM - Vigour index mass, FY - Fodder yield per plant, GY - Grain yield per plant.

Table 4.2. Mean performance of the genotypes for different characters

Sr. No.	Genotype	DT50%F	PH	NOL	PL	SH	TGMR	SG	GP	EC	1000SW	SL	RL	RSR	VIL	VIM	FY	GY
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
	Hybrid																	
17	AKMS 30A × AKR 325-1	61.33	175.60	7.86	24.15	7.36	6.66	1.03	86.23	0.78	28.56	11.64	14.29	1.23	2236.28	12.84	127.58	50.80
18	AKMS 30A × AKR -456	57.33	179.08	7.13	16.13	6.45	12	1.07	76.00	1.57	24.62	10.64	11.96	1.13	1710.45	11.67	113.54	35.56
19	AKMS 30A × AKR -517	64.33	184.33	7.13	24.43	7.15	8.66	1.07	77.66	1.20	27.49	11.15	14.56	1.32	1996.53	12.33	127.27	44.40
20	AKMS 30A × AKR -519	63.00	182.45	9.60	17.32	7.36	7.33	1.06	79.00	1.04	25.86	12.94	13.59	1.06	2093.38	12.75	152.33	32.16
21	AKMS 30A × AKR -522	59.33	180.05	7.00	22.25	8.01	7.66	1.05	86.00	0.99	25.00	12.53	12.49	1.03	2151.00	14.91	174.14	45.05
22	AKMS 30A × AKR -545	64.33	190.49	7.86	21.68	7.21	7	1.06	77.00	1.03	24.32	11.38	12.95	1.14	1871.88	12.87	129.33	41.73
23	AKMS 30A × AKR- 551	64.00	171.19	7.03	19.73	7.33	9.66	1.07	80.33	1.50	24.26	10.32	11.97	1.16	1792.01	11.81	107.27	39.60
24	AKMS 30A × AKR -566	63.00	186.45	8.26	21.70	7.62	6.33	1.02	81.66	0.98	26.02	11.92	14.79	1.25	2181.84	12.41	134.33	47.74
25	AKMS 30A × AKR -567	62.00	198.53	7.00	20.42	6.47	14.66	1.24	77.33	1.26	24.00	10.88	12.00	1.10	1770.16	11.83	135.21	33.80
26	AKMS 30A × AKR- 571	62.33	196.06	11.00	24.11	7.22	7.2	0.99	85.10	0.78	30.3	10.43	15.02	1.44	2166.91	15.09	184.66	50.37
27	AKMS 30A × AKR- 572	61.00	178.33	8.26	19.80	6.08	12.66	1.24	73.14	1.33	23.73	10.61	12.38	1.17	1677.56	11.59	147.14	31.40
28	AKMS 30A × AKR-573	61.33	179.66	8.86	20.36	6.78	10.33	1.11	79.33	1.26	23.82	10.58	12.02	1.14	1792.28	11.87	140.77	37.13
29	AKMS 85A × AKR-325-1	64.33	172.10	10.00	26.21	7.06	6.01	0.99	88.00	0.72	31.02	11.66	11.31	0.98	2020.57	13.28	165.06	51.63
30	AKMS 85A × AKR-456	56.00	168.80	7.80	25.34	7.66	8.00	1.06	78.66	1.03	26.85	10.35	12.73	1.26	1816.50	12.17	124.24	45.37
31	AKMS 85A × AKR-517	61.66	182.93	7.90	22.16	7.09	11.00	1.18	74.00	1.16	22.61	10.29	12.31	1.18	1670.73	10.74	126.87	39.23
32	AKMS 85A × AKR-519	62.00	174.54	11.00	26.03	7.00	6.21	0.98	85.33	0.73	28.78	12.34	15.45	1.26	2371.22	13.3	154.55	47.09
33	AKMS 85A × AKR-522	63.00	198.46	7.33	23.72	7.56	7.00	1.06	76.66	1.06	24.75	11.86	13.55	1.14	1948.68	11.17	130.71	40.16
34	AKMS 85A × AKR-545	61.00	158.34	7.60	25.02	7.26	7.00	0.99	81.63	0.91	30.73	12.18	13.97	1.15	2134.27	12.09	136.32	46.14
35	AKMS 85A × AKR-551	60.36	175.83	8.93	21.83	5.30	13.66	1.21	71.00	1.55	23.30	10.38	13.88	1.35	1724.33	11.43	135.64	33.66
36	AKMS 85A × AKR-566	63.33	167.16	7.86	22.80	6.40	10.00	1.11	74.00	1.76	25.43	12.03	13.62	1.15	1902.49	11.47	156.94	37.73
37	AKMS 85A × AKR-567	63.66	161.86	11.00	24.01	7.47	7.00	1.02	78.00	0.94	29.83	13.79	13.71	1.02	2147.17	12.05	150.71	49.83
38	AKMS 85A × AKR-571	61.33	169.53	7.40	22.87	7.40	12.00	1.26	74.00	1.70	27.08	10.89	12.94	1.19	1760.96	11	113.01	31.50

DT50%F - Days to 50% flowering, PH - Plant height, NOL - Number of leaves, PL – Panicle length, SH - Seed hardness, TGMR – Threshed grain mold rating, SG - Specific gravity of seed, GP – Germination percentage of seed, EC – Electrical conductivity, 1000SW – 1000 Seed weight, SL – Shoot length, RL – Root length, RSR – Root shoot ratio, VIL – Vigour index length, VIM – Vigour index mass, FY – Fodder yield per plant, GY – Grain yield per plant.

Table 4.2. Mean performance of the genotypes for different characters

Sr.No.	Genotype	DT50%F	PH	NOL	PL	SH	TGMR	SG	GP	EC	1000SW	SL	RL	RSR	VIL	VIM	FY	GY
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
39	AKMS 85A × AKR-572	63.00	183.6	10.00	23.44	8.36	6.00	1.04	78.33	1.02	25.11	11.733	13.14	1.11	1949.09	12.35	165.51	47.33
40	AKMS 85A × AKR-573	68.00	194.93	7.00	23.28	8.82	6.00	1.02	81.33	0.98	25.56	12.73	16.9	1.36	2412.18	13.14	193.88	41.64
41	AKMS 90A × AKR-325-1	58.66	176.66	7.66	20.64	6.78	15.00	1.17	74.00	1.8	23.53	10.26	13.87	1.35	1787.14	11.33	113.91	34.14
42	AKMS 90A × AKR-456	64.00	175.33	7.46	20.97	8.00	7.00	1.03	74.00	1.23	24.00	10.85	14.08	1.299	1845.52	11.45	127.78	37.57
43	AKMS 90A × AKR-517	66.00	198.06	12.00	20.63	6.40	7.66	1.05	80.66	1.01	22.51	11.43	14.00	1.22	2054.64	12.37	198.53	32.70
44	AKMS 90A × AKR-519	67.66	186.73	8.60	23.22	7.06	7.33	1.03	80.33	1.01	26.85	10.71	14.04	1.31	1987.75	12.76	180.44	43.27
45	AKMS 90A × AKR-522	61.33	158.00	7.33	24.07	7.46	6.33	0.98	84.66	0.86	28.65	10.55	13.96	1.32	2075.13	11.75	115.75	47.33
46	AKMS 90A × AKR-545	63.33	165.93	7.86	21.78	6.98	7.00	1.04	77.66	1.12	25.40	8.22	12.60	1.54	1619.26	11.94	134.83	41.50
47	AKMS 90A × AKR-551	59.66	155.03	6.80	24.12	7.60	7.33	0.98	87.33	0.76	27.37	10.77	14.44	1.34	2202.07	13.95	156.8	49.80
48	AKMS 90A × AKR-566	62.33	186.80	7.30	18.94	7.92	9.00	1.12	73.00	1.16	23.46	11.01	12.64	1.15	1724.46	11.94	103.67	38.66
49	AKMS 90A × AKR-567	58.33	169.40	7.73	21.31	6.55	12.66	1.45	73.00	1.28	21.06	10.61	12.34	1.16	1675.11	11.09	113.53	34.34
50	AKMS 90A × AKR-571	68.00	177.73	8.46	22.43	6.75	7.00	1.06	82.33	1.00	25.71	12.62	13.35	1.07	2137.12	13.05	136.8	43.16
51	AKMS 90A × AKR-572	65.66	197.78	11.00	19.15	8.24	8.33	1.04	81.66	1.01	23.68	12.25	12.26	1.01	1997.80	12.75	194.24	42.04
52	AKMS 90A × AKR-573	63.66	174.48	10.00	23.3	7.88	7.66	1.05	80.00	1.02	26.04	12.26	13.32	1.09	2046.70	12.34	162.47	43.04
53	ICS 89022A× AKR-321-1	61.33	176.00	7.40	21.43	6.47	11.33	1.16	77.33	1.22	22.28	11.68	12.88	1.14	1897.12	11.55	124.04	31.37
54	ICS 89022A× AKR-456	53.66	165.42	6.70	22.24	6.60	15.00	1.29	72.00	1.30	21.71	10.33	10.26	1.00	1476.44	11.53	100.23	29.01
55	ICS 89022A× AKR-517	60.33	182.02	8.00	21.26	6.95	8.00	1.16	78.66	1.10	26.27	8.64	13.00	1.51	1702.86	12.25	151.46	40.16
56	ICS 89022A× AKR-519	64.00	200.67	8.66	22.13	8.38	6.00	1.02	84.33	0.71	26.93	12.73	14.39	1.14	2285.71	15.03	196.28	53.60
57	ICS 89022A× AKR-522	64.66	185.46	8.40	22.87	7.08	7.00	1.04	79.00	0.99	24.13	10.83	12.40	1.15	1833.25	13.35	163.23	44.80
58	ICS 89022A× AKR-545	65.33	171.46	7.33	19.95	6.68	6.00	1.02	79.00	1.01	23.91	10.27	13.87	1.35	1915.74	12.513	145.68	41.50
59	ICS 89022A× AKR-551	61.33	189.33	8.00	24.74	8.27	6.00	1.03	78.00	1.01	25.52	12.03	14.66	1.21	2092.34	12.64	156.54	46.83
60	ICS 89022A× AKR-566	60.33	162.10	8.06	21.16	6.87	12.00	1.26	70.66	1.13	23.00	8.46	11.29	1.33	1394.34	10.41	130.8	35.67
61	ICS 89022A× AKR-567	63.66	178.70	8.33	24.62	9.26	6.00	1.02	82.33	0.82	26.77	12.31	15.04	1.23	2252.86	13.64	181.16	50.66
62	ICS 89022A× AKR-571	61.33	171.60	7.33	25.36	9.50	10.00	1.22	70.87	1.20	22.49	10.08	11.29	1.12	1514.78	10.63	128.51	37.86
63	ICS 89022A× AKR-572	58.33	157.86	7.13	22.72	6.77	13.66	1.29	72.33	1.31	22.17	10.47	13.94	1.33	1766.54	11.2	138.31	38.63
64	ICS 89022A× AKR-573	58.33	166.82	7.80	23.45	7.95	8.00	1.09	71.66	1.08	26.7	11.69	13.86	1.19	1831.74	10.98	168.96	46.13
checks																		
65	CSH 14	58.33	160.73	7.60	19.47	7.48	19.00	1.02	72.33	1.47	28.78	11.60	15.96	1.39	1985.97	13.53	131.27	37.46
66	CSH35	65.33	173.4	7.80	27.24	6.97	10.66	1.01	80.66	1.12	27.26	11.77	15.06	1.28	2164.56	12.91	149.11	39.83
	mean	63.46	171.81	8.20	22.35	7.26	9.34	1.08	78.19	1.13	25.64	11.00	13.43	1.23	1912.78	12.19	138.53	39.25
	SE(m)±	2.55	4.79	0.44	1.40	0.29	1.05	0.05	2.41	0.09	2.04	0.64	0.79	0.09	95.54	0.64	6.98	2.04
	CD at 5%	7.13	13.4	1.23	3.93	0.83	2.94	0.16	6.74	0.25	5.72	1.81	2.23	0.27	267.31	1.8	19.53	5.73

DT50%F - Days to 50% flowering, PH - Plant height, NOL - Number of leaves, PL – Panicle length, SH - Seed hardness, TGMR – Threshed grain mold rating, SG - Specific gravity of seed, GP – Germination percentage of seed, EC – Electrical conductivity, 1000SW – 1000 Seed weight, SL – Shoot length, RL – Root length, RSR – Root shoot ratio, VIL – Vigour index length, VIM – Vigour index mass, FY – Fodder yield per plant, GY – Grain yield per plant.

Among the parents, lowest threshed grain mold rating was recorded by tester AKR 572 (6%) followed by AKR 456 (6.67%), while AKR 545 (20%) recorded maximum threshed grain mold rating.

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Among 48 hybrids, sixteen hybrids were significantly superior for TGMR over the check CSH-35(10.66%). These were six hybrids which recorded minimum threshed grain mold rating viz., AKMS 85 A x AKR 572 (6%), AKMS 85 A x AKR 573 (6%), ICS89022 A x AKR 519 (6%), ICS89022 A x AKR 545 (6%), ICS89022 A x AKR 551 (6%) and ICS89022 A x AKR 567 (6%) followed by AKMS 85 A x AKR 325-1 (6.01%), AKMS 85 A x AKR 519 (6.21%) and AKMS 90 A x AKR 522 (6.33) and AKMS 30 A x AKR 566 (6.33%). Whereas, AKMS 90 A x AKR 335-1 (15%) and ICS 89022 A x AKR 456 (15%) recorded maximum threshed grain mold rating.

g. Specific gravity of seed (g/ml)

The average specific gravity of seed ranged between 1.02 to 1.23 g/ml for parents and 0.98 to 1.45 g/ml for hybrids (Table 4.2).

Among the parents, highest specific gravity of seed was recorded by tester AKR 545 (1.23 g/ml) followed by tester AKR 519 (1.20 g/ml) while AKR 551 (1.02 g/ml) recorded minimum specific gravity of seed.

Among the hybrids, ten hybrids recorded superior specific gravity of seed over the check CSH-14 (1.02 g/ml). Hybrids AKMS 90 A x AKR 567 (1.45 g/ml) recorded maximum specific gravity of seed followed by ICS 89022 A x AKR 456 (1.29 g/ml), ICS89022 A x AKR 572 (1.29), ICS 89022 A x AKR 566 (1.26 g/ml), AKMS 85 A x AKR 571 (1.26 g/ml), AKMS 30 A x AKR 572 (1.24 g/ml) and AKMS 30 A x AKR 567 (1.24 g/ml). Whereas, AKMS 85 A x AKR 519 (0.98 g/ml) recorded minimum specific gravity of seed.

h. Germination percentage of seed (%)

The average germination percentage of seed ranged between 72.67 to 81.33 % for parents and 70.66 to 88 % for hybrids (Table 4.2).

Among the parents, highest germination percentage of seed was recorded by tester AKR 456 (81.33%) and AKR 573 (81.33%) followed by ICS 89022 A (79.33%) and AKR 519 (79.33%), while AKR 517 (72.67%) recorded lowest germination percentage of seed.

Among the hybrids, only one hybrid recorded highly superior germination percentage of seed over the check CSH-35 (80.66%). Hybrid AKMS 85 A x AKR 325-1 (88.00%) was significantly superior for germination percentage of seed over the check CSH-35 (80.66%). Whereas, ICS 89022 A x AKR 566 (70.66%) recorded lowest germination percentage of seed.

i. Electrical conductivity (dSm^{-1})

The average electrical conductivity of seed ranged between 0.87 to 1.46 dSm^{-1} for parents and 0.71 to 1.76 dSm^{-1} for hybrids (Table 4.2).

Among the parents, lowest electrical conductivity was recorded by tester AKR 551 (0.87 dSm^{-1}) followed by line AKMS 85 A (0.97 dSm^{-1}), while the line ICS 89022 A (1.46 dSm^{-1}) and tester AKR 545 (1.46 dSm^{-1}) recorded maximum electrical conductivity.

Among the hybrids, seven hybrids exhibited superior electrical conductivity over the check CSH-35 (1.12 dSm^{-1}). Hybrids ICS89022 A x AKR 519 (0.71 dSm^{-1}) recorded minimum electrical conductivity followed by AKMS 85 A x AKR 325-1 (0.72 dSm^{-1}), AKMS 85 A x AKR 519 (0.73 dSm^{-1}), AKMS 90 A x AKR 551 (0.76 dSm^{-1}), AKMS 30 A x AKR 325-1 (0.78 dSm^{-1}) and AKMS 30 A x AKR 571 (0.78 dSm^{-1}). Whereas, AKMS 85 A x AKR 566 (1.76 dSm^{-1}) recorded maximum electrical conductivity.

j. 1000 seed weight (g)

1000 seed weight per plant ranged between 20.21 to 32.4 g for parents and 21.06 to 31.02 g for hybrids (Table 4.2).

Among the parents, highest 1000 seed weight was recorded by AKR 567 (32.4 g) followed by AKR 551 (31.38 g), while AKR 456 (20.21 g) recorded minimum 1000 seed weight.

Among 48 hybrids, none of cross found superior for 1000 seed weight over the check CSH-14 (28.78 g) but within the hybrids, AKMS 85 A x AKR 325-1 (31.02 g) recorded maximum 1000 seed weight followed by AKMS 85 A x AKR 545 (30.73 g) and AKMS 85 A x AKR 567 (29.83 g). Whereas, AKMS 90A x AKR 567 (21.06 g) recorded lowest 1000 seed weight.

k. Shoot length (cm)

The average shoot length ranged from 9.69 to 11.44 cm and 8.22 to 13.79 cm among the parents and hybrids, respectively (Table 4.2).

Among 16 parents, maximum shoot length was recorded by tester AKR 551 (11.44 cm). However, tester AKR 335-1 (9.69 cm) recorded minimum shoot length.

Among the hybrids, only one hybrid AKMS 85 A x AKR 567 (13.79 cm) was significantly superior for shoot length over the check CSH-35 (11.77 cm). Whereas, the hybrid AKMS 90 A x AKR 545 (8.22 cm) recorded minimum shoot length.

l. Root length (cm)

The average root length ranged from 12.34 to 14.52 cm and 10.26 to 16.9 cm among the parents and hybrids, respectively (Table 4.2).

Among 16 parents, maximum root length was recorded by line AKMS 85 A (14.52 cm). However, tester AKR 566 (12.34 cm) recorded minimum root length.

Among the hybrids, none of cross could found significantly superior for root length over the check CSH-14 (15.96 cm) but within the hybrids, AKMS 85 A x AKR 573 (16.9) recorded the maximum root length. Whereas, ICS 89022 A x AKR 456 (10.26 cm) recorded minimum root length.

m. Root shoot ratio

The average root shoot ratio ranged from 1.12 to 1.38 and 0.98 to 1.54 among the parents and hybrids, respectively (Table 4.2).

Among 16 parents, maximum root shoot ratio was recorded by tester AKR 573 (1.38). However, tester AKR 456 (1.12) recorded minimum root shoot ratio.

Among the hybrids, none of cross found superior for root shoot ratio over the check CSH-14 (1.39) but within the hybrids, AKMS 90 A x AKR 545 (1.54) recorded maximum root shoot ratio followed by ICS 89022 A x AKR 517 (1.51), and AKMS 30 A x AKR 571 (1.44). Whereas, the hybrid AKMS 85 A x AKR 325-1 (0.98) recorded minimum root shoot ratio.

n. vigour index length

The average vigour index length ranged from 1684.00 to 2006.29 and 1394.34 to 2412.18 among the parents and hybrids, respectively (Table 4.2).

Among 16 parents, maximum vigour index length was recorded by tester AKR 551 (2006.29). However, tester AKR 566 (1684.00) recorded minimum vigour index length.

Among the hybrids, none of cross could found significantly superior for vigour index length over the check CSH-35 (2164.56) but the hybrids AKMS 85 A x AKR 573 (2412.18) recorded maximum vigour index length followed by AKMS 85 A x AKR 519 (2371.22), ICS 89022 A x AKR 519 (2285.71), ICS 89022 A x AKR 567 (2252.86) and AKMS 90 A x AKR 551 (2202.07). Whereas, the hybrid ICS 89022 A x AKR 566 (1394.34) recorded minimum vigour index length.

o. Vigour index mass

The average vigour index mass ranged from 11.34 to 12.79 and 10.41 to 15.09 among the parents and hybrids, respectively (Table 4.2).

Among 16 parents, maximum vigour index mass was recorded by tester AKR 573 (12.79). However, tester AKR 545 (11.34), AKR 325-1(11.34), and line AKMS 30 A (11.34) recorded minimum vigour index mass.

Among the hybrids, none of cross found superior for vigour index mass over the best check CSH-14 (13.53) but within the hybrids AKMS 30 A x AKR 571 (15.09) recorded maximum vigour index mass followed by ICS 89022 A x AKR 519 (15.03), AKMS 30 A x AKR 522 (14.91), AKMS 90 A x AKR 551 (13.95) and ICS 89022 A x AKR 567 (13.64). Whereas, the hybrid ICS 89022 A x AKR 566 (10.41) recorded minimum vigour index mass.

p. Fodder yield per plant (g)

The average fodder yield per plant ranged from 99.14 to 142.43 g and 100.23 to 198.53 g among the parents and hybrids, respectively (Table 4.2).

Among the parents, tester AKR 551 (142.43 g) recorded the highest fodder yield followed by tester AKR 572 (137.21 g). whereas, tester AKR 545 (99.14 g) recorded minimum fodder yield per plant.

Among the hybrids, seven hybrids recorded significant superiority over the check CSH-35 (149.11 g) for fodder yield per plant. The hybrid AKMS 90 A x AKR 517 (198.53 g) recorded maximum fodder yield per plant followed by ICS 89022 A x AKR 519 (196.28 g), AKMS 90 A x AKR 572 (194.24 g) and AKMS 85 A x AKR 573 (193.88 g). Whereas, ICS 89022 A x AKR 456 (100.23 g) recorded lowest fodder yield per plant.

q. Grain yield per plant (g)

The average grain yield per plant ranged from 28.21 g to 46 g and 29.01 g to 53.6 g among the parents and hybrids, respectively (Table 4.2).

Among the parents, AKMS 85A (46.00 g) recorded the highest grain yield followed by tester AKR 573 (37.33 g) whereas, tester AKR 519 (28.21 g) recorded minimum grain yield per plant.

Among the 48 hybrids, fourteen hybrids with grain yield more than 45.56 g/plant recorded significant superiority over the check CSH-35 (39.83 gm) for grain yield per plant. The hybrid AKMS 85 A x AKR 325-1 (51.63 g) recorded maximum grain yield per plant followed by AKMS 30 A x AKR 325-1 (50.8 g), ICS 89022 A x AKR 567 (50.66 g), and AKMS 30 A x AKR 571 (50.37 g). Whereas, ICS 89022 A x AKR 456 (29.01 g) recorded lowest grain yield per plant.

4.3 Genetic variability studies

The values of Range, Mean, Standard error of difference, 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 4.3.

4.3.1 Genotypic Coefficient of Variation (%).

It is revealed from Table 4.3 that genotypic coefficient of variation (GCV) ranged from 3.88 to 32.94 % for different characters under study. The highest order values of genotypic coefficient of variations were observed for threshed grain mold rating (32.94%) followed by electrical conductivity (21.03%), fodder yield per plant (17.63), grain yield per plant (16.71%), no. of leaves (13.76%), seed hardness (10.45%), vigour index length (9.82%), plant height (8.90%), shoot length (7.65%), panicle length (6.94), specific gravity of seed (6.65%), root length (6.38%), 1000 seed weight (6.36), root shoot ratio (6.17%), vigour index mass (6.06), germination percentage of seed (4.47%) and days to 50% flowering (3.88%).

4.3.2 Phenotypic Coefficient of Variation (%)

The phenotypic coefficient of variation (Table 4.3) ranged from 6.96 to 38.30 % for various characters under study. The highest order value of phenotypic coefficient of variation was observed for threshed grain mold rating (38.30%) followed by electrical conductivity (24.43%), fodder yield (19.68%), grain yield per plant (19.00%), number of leaves (16.59%), 1000 seed weight (15.21%), root shoot ratio (14.83%), vigour index length (13.09%), panicle length (12.90%), shoot length (12.72%), seed hardness (12.62%), root length (12.11%), specific gravity of seed (11.47%), vigour index mass (10.97%), plant height (10.12%), days to 50% flowering (7.96%) and germination percentage (6.96%).

Table 4.3 Estimation of genetic parameters – range, mean, SE (d), GV, PV, GCV, PCV, h² and EGA for characters under study.

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Sr. No.	Character	Range	Mean	SE(d)	Genotypic variance	Phenotypic variance	Genotypic coefficient of variation	Phenotypic coefficient of variation	h ² %	EGA as % over mean
1	Days to 50 % flowering	53.66 - 71.33	63.46	3.60	6.09	25.58	3.88	7.96	23.80	3.90
2	Plant height (cm)	127.13 -200.67	171.80	6.77	233.90	302.81	8.90	10.12	77.20	16.11
3	number of leaves	6.8 – 12	8.19	0.62	1.27	1.85	13.76	16.59	68.80	23.51
4	Panicle length (cm)	16.13 -26.24	22.35	1.98	2.40	8.31	6.94	12.90	28.90	7.69
5	Seed hardness (kg/cm ²)	5.3 - 9.5	7.25	0.41	0.57	0.84	10.45	12.62	68.60	17.83
6	Threshed grain mold rating (%)	6.0 -20	9.33	1.49	9.46	12.79	32.94	38.30	74.0	58.36
7	Specific gravity of seed (g/ml)	0.98 - 1.45	1.08	0.08	0.01	0.02	6.65	11.47	33.70	7.95
8	Germination % of seed	70.66 -88	78.19	3.40	12.24	29.67	4.47	6.96	41.30	5.92
9	Electrical conductivity (dSm ⁻¹)	0.71 -1.8	1.13	0.13	0.05	0.07	21.03	24.43	67.20	33.83
10	1000 seed weight (g)	20.21 -32.4	25.64	2.89	2.66	15.23	6.36	15.21	17.50	5.48
11	Shoot length (cm)	8.22 -13.79	11.00	0.91	0.70	1.96	7.65	12.72	36.10	9.47
12	Root length (cm)	10.26 -16.89	13.42	1.12	0.73	2.64	6.38	12.11	27.80	6.93
13	Root shoot ratio	0.98 -1.54	1.23	0.13	0.01	0.03	6.17	14.83	17.30	5.29
14	Vigour index length	1394.34 -2412.18	1912.78	135.11	35323.71	62708.29	9.82	13.09	56.30	15.19
15	Vigour index mass	10.4133 -15.09	12.19	0.91	0.54	1.79	6.06	10.97	31.50	6.90
16	Fodder yield per plant (g)	99.1433 -181.16	135.82	9.87	507.13	743.37	17.63	19.68	83.30	32.56
17	Grain yield per plant (g)	28.2033 - 53.60	39.24	2.89	43.03	55.62	16.71	19.00	77.40	30.28

4.3.3 Heritability estimates in broad sense (%)

Data presented in Table 4.3 revealed that heritability estimates ranged from 17.3 to 83.3 % for various characters under study. Highest heritability estimate in broad sense was observed for fodder yield per plant (83.30%) followed by grain yield (77.40%), plant height (77.20%), threshed grain mold rating (74%), number of leaves (68.8%), seed hardness (68.60%), electrical conductivity (67.20%), vigour index length (56.30%), germination percentage (41.30%), shoot length (36.10%), specific gravity of seed (33.70%), vigour index mass (31.50%), panicle length (28.90%), root length (27.80%), days to 50% flowering (23.80%), 1000 seed weight (17.50%), root shoot ratio (17.30%).

4.3.4 Expected genetic advance (%)

Expected genetic advance percent over mean was estimated for different characters and data is presented in Table 4.3. Data revealed that expected genetic advance percent over mean was in the range of 3.90 to 58.36 percent for different characters. The highest genetic advance percent over mean was observed for the character threshed grain mold rating (58.36%) followed by electrical conductivity (33.83%), fodder yield per plant (32.56%), grain yield per plant (30.28%), number of leaves (23.51%), seed hardness (17.83%), plant height (16.11%), vigour index length (15.19%), shoot length (9.47%), specific gravity of seed (7.95%), panicle length (7.69%), root length (6.93%), vigour index mass (6.90%), germination percentage (5.92%), 1000 seed weight (5.48%), root shoot ratio (5.29%), days to 50% flowering (3.90%).

4.4 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 4.4 and Table 4.5 respectively.

4.4.1 Genotypic correlation

4.4.1.1 Association between yield and yield contributing characters

The character grain yield per plant showed positive and highly significant association with vigour index mass ($r = 0.8559^{**}$), 1000 seed weight ($r = 0.8199^{**}$), germination percentage of seed ($r = 0.7518^{**}$), vigour index length ($r = 0.7491^{**}$), panicle length ($r = 0.6977^{**}$), fodder yield per plant ($r = 0.6597^{**}$), shoot length ($r = 0.6179^{**}$), root length ($r = 0.5129^{**}$), seed hardness ($r = 0.4966^{**}$), and plant height ($r = 0.4640^{**}$). On the other hand electrical conductivity ($r = -0.7725^{**}$), specific gravity of seed ($r = -0.7507^{**}$), threshed grain mold rating ($r = -0.6940^{**}$), days to 50 % flowering ($r = -0.2983^{**}$) and root shoot ratio ($r = -0.1832^{**}$) showed negative but highly significant correlation.

4.4.1.2 Association between yield contributing characters among themselves

a. Days to 50% flowering

Days to 50% flowering showed highly significant and positive association with root length ($r = 0.4364^{**}$), root shoot ratio ($r = 0.4259^{**}$), 1000 seed weight ($r = 0.3872^{**}$), germination percentage ($r = 0.3771^{**}$), vigour index length ($r = 0.3230^{**}$), number of leaves ($r = 0.2149^{**}$), vigour index mass ($r = 0.1880^{**}$). On the other hand, it showed negative and highly significant association with specific gravity of seed ($r = -0.6851^{**}$), grain yield ($r = -0.2983^{**}$), plant height ($r = -0.2923^{**}$), threshed grain mold rating ($r = -0.2815^{**}$), and electrical conductivity ($r = -0.2639^{**}$) at genotypic level.

b. Plant height

Plant height exhibited positive and highly significant correlation with fodder yield per plant ($r = 0.5782^{**}$), vigour index mass ($r = 0.5134^{**}$), grain yield ($r = 0.4640^{**}$), shoot length ($r = 0.4040^{**}$), number of leaves ($r = 0.3476^{**}$), vigour index length ($r = 0.3154^{**}$), germination percentage ($r = 0.2478^{**}$), and seed hardness ($r = 0.2038^{**}$). While positive and significant correlation with root length ($r = 0.1473^{*}$). On the other hand, plant height showed negative and highly significant association with root shoot ratio ($r = -0.3528^{**}$),

threshed grain mold rating ($r = -0.3105^{**}$), electrical conductivity ($r = -0.2430^{**}$) and specific gravity of seed ($r = -0.2040^{**}$) at genotypic level.

c. Number of leaves

Number of leaves showed positive and highly significant correlation with fodder yield ($r = 0.4962^{**}$), shoot length ($r = 0.3997^{**}$), germination percentage of seed ($r = 0.2939^{**}$), 1000 seed weight ($r = 0.2806^{**}$), and vigour index length ($r = 0.2416^{**}$). While, vigour index mass ($r = 0.1639^{*}$) exhibited positive and significant association with number of leaves.

While characters like root shoot ratio ($r = -0.5421^{**}$) and electrical conductivity ($r = -0.2860^{**}$) expressed negative and highly significant association with number of leaves. Negative and significant association with number of leaves shown by traits threshed grain mold rating ($r = -0.1769^{*}$) and specific gravity of seed ($r = -0.1656^{*}$) at genotypic level.

Table 4.4 Genotypic correlation coefficients between yield and yield contributing characters

CHARACTER	PH	NOL	PL	SH	TGMR	SG	GP	EC	1000SW	SL	RL	RSR	VIL	VIM	FY	GY
DT50%F	-0.2923**	0.2149**	0.1269	0.0919	-0.2815**	-0.6851**	0.3771**	-0.2639**	0.3872**	0.0132	0.4364**	0.4259**	0.3230**	0.1880**	-0.0065	-0.2983**
PH		0.3476**	-0.0514	0.2038**	-0.3105**	-0.2040**	0.2478**	-0.2430**	-0.0348	0.4040**	0.1473*	-0.3528**	0.3154**	0.5134**	0.5782**	0.4640**
NOL			0.0215	0.0057	-0.1769*	-0.1656*	0.2939**	-0.2860**	0.2806**	0.3997**	-0.0839	-0.5421**	0.2416**	0.1639*	0.4962**	0.1085
PL				0.4152**	-0.4235**	-0.6125**	0.5968**	-0.6192**	0.8827**	0.3553**	0.5761**	0.1215	0.6141**	0.4003**	0.3744**	0.6977**
SH					-0.6770**	-0.4612**	0.2815**	-0.5132**	0.5962**	0.4488**	0.2871**	-0.2636**	0.3943**	0.4296**	0.3824**	0.4966**
TGMR						0.8692**	-0.7627**	0.8533**	-0.6226**	-0.4740**	-0.3319**	0.1863**	-0.6411**	-0.6280**	-0.5871**	-0.6940**
SG							-0.8302**	0.7710**	-0.8796**	-0.6583**	-0.7718**	-0.0335	-0.9801**	-0.9862**	-0.5836**	-0.7507**
GP								-0.8783**	0.8396**	0.6862**	0.5005**	-0.2583**	0.8751**	0.9431**	0.5205**	0.7518**
EC									-0.5919**	-0.5286**	-0.3773**	0.2255**	-0.7321**	-0.9417**	-0.6103**	-0.7725**
1000SW										0.5411**	0.7817**	0.2671**	0.8383**	0.8831**	0.4719**	0.8199**
SL											0.6451**	-0.6022**	0.8887**	0.7495**	0.6495**	0.6179**
RL												0.2120**	0.8122**	0.7714**	0.4648**	0.5129**
RSR													-0.2491**	-0.0702	-0.2660**	-0.1832**
VIL														0.8973**	0.6361**	0.7491**
VIM															0.8660**	0.8559**
FY																0.6597**

*Significant at 5%, ** Significant at 1%

DT50%F - Days to 50% flowering, PH - Plant height, NOL - Number of leaves, PL – Panicle length, SH - Seed hardness, TGMR – Threshed grain mold rating, SG - Specific gravity of seed, EC – Electrical conductivity, GP – Germination percentage of seed, 1000SW – 1000 Seed weight, SL – Shoot length, RL – Root length, RSR – Root shoot ratio, VIL – Vigour index length, VIM – Vigour index mass, FY – Fodder yield per plant, GY – Grain yield per plant.

d. Panicle length

Panicle length expressed positive and highly significant association with 1000 seed weight ($r = 0.8827^{**}$), grain yield per plant ($r = 0.6977^{**}$), vigour index length ($r = 0.6141^{**}$), germination percentage ($r = 0.5968^{**}$), root length ($r = 0.5761^{**}$), seed hardness ($r = 0.4152^{**}$), vigour index mass ($r = 0.4003^{**}$), fodder yield per plant ($r = 0.3744^{**}$) and shoot length ($r = 0.3553^{**}$). While Electrical conductivity ($r = -0.6192^{**}$), specific gravity ($r = -0.6125^{**}$) and threshed grain mold rating ($r = -0.4235^{**}$) exhibited negative and highly significant association with panicle length at genotypic level.

e. Seed hardness

Seed hardness exhibited positive and highly significant association with 1000 seed weight ($r = 0.5962^{**}$), grain yield per plant ($r = 0.4966^{**}$), shoot length ($r = 0.4488^{**}$), vigour index mass ($r = 0.4296^{**}$), vigour index length ($r = 0.3943^{**}$), fodder yield per plant ($r = 0.3824^{**}$), root length ($r = 0.2871^{**}$) and germination percentage ($r = 0.2815^{**}$). Whereas, the characters threshed grain mold rating ($r = -0.6770^{**}$), electrical conductivity ($r = -0.5132^{**}$), specific gravity of seed ($r = -0.4612^{**}$) and root shoot ratio ($r = -0.2636^{**}$) showed negative and highly significant correlation with seed hardness at genotypic level.

f. Threshed grain mold rating

Threshed grain mold rating expressed positive and highly significant association with specific gravity ($r = 0.8692^{**}$), electrical conductivity ($r = 0.8533^{**}$) and root shoot ratio ($r = 0.1863^{**}$). On the other hand, the characters germination percentage of seed ($r = -0.7627^{**}$), grain yield per plant ($r = -0.6940^{**}$), vigour index length ($r = -0.6411^{**}$), vigour index mass ($r = -0.6280^{**}$), 1000 seed weight ($r = -0.6226^{**}$), fodder yield ($r = -0.5871^{**}$), shoot length ($r = -0.4740^{**}$) and root length ($r = -0.3319^{**}$) showed the negative and highly significant association with threshed grain mold rating at genotypic level.

g. Specific gravity of seed

Specific gravity of seed exhibited positive and highly significant association with electrical conductivity ($r = 0.7710^{**}$). Whereas the characters vigour index mass ($r = -0.9862^{**}$), vigour index length ($r = -0.9801^{**}$), 1000 seed weight ($r = -0.8796^{**}$), germination percentage ($r = -0.8302^{**}$), root length ($r = -0.7718^{**}$), grain yield per plant ($r = -0.7507^{**}$), shoot length ($r = -0.6583^{**}$), and fodder yield ($r = -0.5836^{**}$) exhibited negative and highly significant association with specific gravity of seed at genotypic level.

h. Germination percentage of seed

Germination percentage of seed showed positive and highly significant association with vigour index mass ($r = 0.9431^{**}$), vigour index length ($r = 0.8751^{**}$), 1000 seed weight ($r = 0.8396^{**}$), grain yield per plant ($r = 0.7518^{**}$), shoot length ($r = 0.6862^{**}$), fodder yield per plant ($r = 0.5205^{**}$), and root length ($r = 0.5005^{**}$). On the other hand, character electrical conductivity ($r = -0.8783^{**}$) and root shoot ratio ($r = -0.2583^{**}$) showed negative and highly significant association with germination percentage of seed at genotypic level.

i. Electrical conductivity

Electrical conductivity expressed negative and highly significant association with vigour index mass ($r = -0.9417^{**}$), grain yield per plant ($r = -0.7725^{**}$), vigour index length ($r = -0.7321^{**}$), fodder yield per plant ($r = -0.6103^{**}$), 1000 seed weight ($r = -0.5919^{**}$), shoot length ($r = -0.5286^{**}$), and root length ($r = -0.3773^{**}$). Whereas, character root shoot ratio ($r = 0.2255^{**}$) showed positive and highly significant association with electrical conductivity at genotypic level.

j. 1000 seed weight

1000 seed weight exhibited positive and highly significant association with vigour index mass ($r = 0.8831^{**}$), vigour index length ($r = 0.8383^{**}$), grain yield per plant ($r = 0.8199^{**}$), root length ($r = 0.7817^{**}$), shoot length ($r = 0.5411^{**}$), fodder yield per plant ($r = 0.4719^{**}$), root shoot ratio ($r = 0.2671^{**}$) at genotypic level.

k. Shoot length

Shoot length expressed positive and highly significant association with vigour index length ($r = 0.8887^{**}$), vigour index mass ($r = 0.7495^{**}$), fodder yield per plant ($r = 0.6495^{**}$), root length ($r = 0.6451^{**}$) and grain yield per plant ($r = 0.6179^{**}$). Whereas root shoot ratio ($r = -0.6022^{**}$) exhibited negative and highly significant association with shoot length at genotypic level.

l. Root length

Root length exhibited positive and highly significant association with vigour index length ($r = 0.8122^{**}$), vigour index mass ($r = 0.7714^{**}$), grain yield per plant ($r = 0.5129^{**}$), fodder yield per plant ($r = 0.4648^{**}$), and root shoot ratio ($r = 0.2120^{**}$) at genotypic level.

m. Root shoot ratio

Root shoot ratio exhibited negative and highly significant association with fodder yield per plant ($r = -0.2660^{**}$), vigour index mass ($r = -0.2491^{**}$) and grain yield per plant ($r = -0.1832^{**}$) at genotypic level.

n. Vigour index length

Vigour index length showed positive and highly significant association with vigour index mass ($r = 0.8973^{**}$), grain yield per plant ($r = 0.7491^{**}$) and fodder yield per plant ($r = 0.6361^{**}$) at genotypic level.

o. Vigour index mass

Character fodder yield per plant ($r = 0.8660^{**}$) and grain yield ($r = 0.8559^{**}$) exhibited positive and highly significant association with vigour index mass at genotypic level.

4.4.2. Phenotypic correlation

4.4.2.1 Association between yield and yield contributing characters

The character grain yield per plant showed positive and highly significant association with fodder yield ($r = 0.5666^{**}$), vigour index length ($r = 0.4731^{**}$), vigour index mass ($r = 0.3943^{**}$), seed hardness ($r = 0.3850^{**}$), plant height ($r = 0.3645^{**}$), panicle length ($r = 0.3187^{**}$), shoot length ($r = 0.3165^{**}$), 1000 seed weight ($r = 0.2433^{**}$), germination percentage ($r =$

0.441**), and root length ($r = 0.189^{**}$). On the other hand, traits like, electrical conductivity ($r = -0.5692^{**}$), threshed grain mold rating ($r = -0.5184^{**}$), and specific gravity of seed ($r = -0.3749^{**}$) showed negative and highly significant association with grain yield per plant at phenotypic level.

4.4.2.2. Association between yield contributing characters among themselves

a. Days to 50% flowering

The character germination percentage ($r = 0.1847^{**}$) showed positive and highly significant association with day to 50% flowering, while, the characters like vigour index length ($r = 0.1556^{*}$) and panicle length ($r = 0.1501^{*}$) showed positive and significant association with days to 50% flowering. On the other hand, negative and highly significant association with day to 50% flowering was shown by character specific gravity of seed ($r = -0.2113^{**}$). Negative and significant association exhibited by threshed grain mold rating ($r = -0.1809^{*}$) at phenotypic level.

b. Plant height

Plant height exhibited positive and highly significant correlation with fodder yield per plant ($r = 0.4316^{**}$), grain yield per plant ($r = 0.3645^{**}$), shoot length ($r = 0.3035^{**}$), vigour index mass ($r = 0.2562^{**}$), number of leaves ($r = 0.2523^{**}$), and vigour index length ($r = 0.2140^{**}$). Whereas, the character seed hardness ($r = 0.1800^{*}$) showed positive but significant association with plant height. On the other hand, threshed grain mold rating ($r = -0.2383^{**}$), and root shoot ratio ($r = -0.2339^{**}$) exhibited negative but highly significant correlation, while negative and significant association with plant height exhibited by electrical conductivity ($r = -0.1815^{*}$) at phenotypic level.

c. Number of leaves

Number of leaves showed positive and highly significant correlation with fodder yield ($r = 0.3556^{**}$) and shoot length ($r = 0.2430^{**}$). While, the character root shoot ratio ($r = -0.2520^{**}$) exhibited negative and highly significant association with number of leaves. On other hand,

Table 4.5 Phenotypic correlation coefficients between yield and yield contributing characters

CHARACTER	PH	NOL	PL	SH	TGMR	SG	GP	EC	1000SW	SL	RL	RSR	VIL	VIM	FY	GY
DT50%F	-0.1200	0.1317	0.1501*	-0.0093	-0.1809*	-0.2113**	0.1847**	-0.0596	0.0070	0.0485	0.0796	0.0263	0.1556*	0.0154	-0.0168	-0.0744
PH		0.2523***	-0.0631	0.1800*	-0.2383**	-0.0589	0.1128	-0.1815*	-0.0849	0.3035**	0.0292	-0.2339**	0.2140**	0.2562**	0.4316**	0.3645**
NOL			-0.0080	0.0486	-0.1348	-0.1162	0.0778	-0.1507*	0.0536	0.2430***	-0.0684	-0.2520**	0.1142	0.0832	0.3556**	0.0559
PL				0.1835**	-0.2151**	-0.0793	0.1218	-0.2753**	0.2219**	0.1109	0.0968	-0.0179	0.1682*	0.0553	0.2152**	0.3187**
SH					-0.4290**	-0.2925**	0.1506*	-0.3289**	0.1767*	0.2051**	0.0857	-0.1097	0.2206**	0.2061**	0.2588**	0.3850**
TGMR						0.4032**	-0.4266**	0.5930**	-0.2090**	-0.2303**	-0.0963	0.0977	-0.3820**	-0.3091**	-0.4344**	-0.5184**
SG							-0.3756**	0.3697**	-0.397**	-0.1950**	-0.2888**	-0.0794	-0.4294**	-0.3294**	-0.2750**	-0.3749**
GP								-0.5325**	0.2292**	0.1638*	0.1423*	-0.0224	0.6772**	0.3518**	0.3201**	0.441**
EC									-0.257**	-0.2073**	-0.1676*	0.0289	-0.4652**	-0.3444**	-0.4414**	-0.5692**
1000SW										0.0928	0.2314**	0.0997	0.2748**	0.2106**	0.1674*	0.2433**
SL											0.2516**	-0.6142**	0.6526**	0.2753**	0.3156**	0.3165**
RL												0.5932**	0.6924**	0.2231**	0.2029**	0.189**
RSR													0.1718*	-0.1634*	-0.0870	-0.1002
VIL														0.4195**	0.4131**	0.4731**
VIM															0.3708**	0.3943**
FY																0.5666**

*Significant at 5%, ** Significant at 1%

DT50%F - Days to 50% flowering, PH - Plant height, NOL - Number of leaves, PL – Panicle length, SH - Seed hardness, TGMR – Threshed grain mold rating, SG - Specific gravity of seed, EC – Electrical conductivity, GP – Germination percentage of seed, 1000SW – 1000 Seed weight, SL – Shoot length, RL – Root length, RSR – Root shoot ratio, VIL – Vigour index length, VIM – Vigour index mass, FY – Fodder yield per plant, GY – Grain yield per plant.

Number of leaves showed negative and significant correlation with electrical conductivity ($r = -0.1507^*$) at phenotypic level.

d. Panicle length

Panicle length expressed positive and highly significant association with grain yield per plant ($r = 0.3187^{**}$), fodder yield per plant ($r = 0.2152^{**}$), 1000 seed weight ($r = 0.2219^{**}$) and seed hardness ($r = 0.1835^{**}$). Similarly positive and significant correlation was found with vigour index length ($r = 0.1682^*$). On the other hand, panicle length showed negative and highly significant association with electrical conductivity ($r = -0.2753^{**}$) and threshed grain mold rating ($r = -0.2151^{**}$) at phenotypic level.

e. Seed hardness

Seed hardness exhibited positive and highly significant association with grain yield per plant ($r = 0.3850^{**}$), fodder yield per plant ($r = 0.2588^{**}$), vigour index length ($r = 0.2206^{**}$), vigour index mass ($r = 0.2061^{**}$) and shoot length ($r = 0.2051^{**}$). Similarly positive and significant correlation were found for 1000 seed weight ($r = 0.1767^*$) and germination percentage ($r = 0.1506^*$). On other hand, the characters threshed grain mold rating ($r = -0.4290^{**}$), electrical conductivity ($r = -0.3289^{**}$) and specific gravity of seed ($r = -0.2925^{**}$) showed negative and highly significant correlation with seed hardness at phenotypic level.

f. Threshed grain mold rating

Threshed grain mold rating expressed positive and significant association with electrical conductivity ($r = 0.5930^*$) and specific gravity of seed ($r = 0.4032^*$). Whereas, the characters grain yield per plant ($r = -0.5184^{**}$), fodder yield per plant ($r = -0.4344^{**}$), germination percentage of seed ($r = -0.4266^{**}$), vigour index length ($r = -0.3820^{**}$), vigour index mass ($r = -0.3091^{**}$), shoot length ($r = -0.2303^{**}$), and 1000 seed weight ($r = -0.2090^{**}$) showed the negative and highly significant association with threshed grain mold rating at phenotypic level.

g. Specific gravity of seed

Specific gravity of seed exhibited positive and highly significant association with electrical conductivity ($r = 0.3697^{**}$). Whereas characters vigour index length ($r = -0.4294^{**}$), germination percentage of seed ($r = -0.3756^{**}$), grain yield per plant ($r = -0.3749^{**}$), vigour index mass ($r = -$

0.3294**), root length ($r = -0.2888^{**}$), fodder yield per plant ($r = -0.2750^{**}$), shoot length ($r = -0.1950^{**}$) and 1000 seed weight ($r = -0.397^{**}$) showed negative and highly significant association with specific gravity of seed at phenotypic level.

h. Germination percentage of seed

Germination percentage of seed showed positive and highly significant association with vigour index length ($r = 0.6772^{**}$), vigour index mass ($r = 0.3518^{**}$), fodder yield per plant ($r = 0.3201^{**}$), 1000 seed weight ($r = 0.2292^{**}$) and grain yield per plant ($r = 0.441^{**}$). Whereas germination percentage of seed showed positive and significant association with shoot length ($r = 0.1638^{*}$) and root length ($r = 0.1423^{*}$). On the other hand electrical conductivity ($r = -0.5325^{**}$) expressed negative and highly significant correlation with germination percentage of seed at phenotypic level.

i. Electrical conductivity

Electrical conductivity expressed negative and highly significant association with grain yield ($r = -0.5692^{**}$), vigour index length ($r = -0.4652^{**}$), fodder yield per plant ($r = -0.4414^{**}$), vigour index mass ($r = -0.3444^{**}$), shoot length ($r = -0.2073^{**}$) and 1000 seed weight ($r = -0.257^{**}$). Similarly, character root length ($r = -0.1667^{*}$) exhibited negative and significant correlation with electrical conductivity at phenotypic level.

j. 1000 seed weight

Thousand seed weight exhibited positive and highly significant association with vigour index length ($r = 0.2748^{**}$), grain yield per plant ($r = 0.2433^{**}$), root length ($r = 0.2314^{**}$) and vigour index mass ($r = 0.2106^{**}$) at phenotypic level.

k. Shoot length

Shoot length expressed positive and highly significant association with vigour index length ($r = 0.6526^{**}$), grain yield per plant ($r = 0.3165^{**}$), fodder yield per plant ($r = 0.3156^{**}$), vigour index mass ($r = 0.2753^{**}$), and root length ($r = 0.2516^{**}$). Whereas root shoot ratio ($r = -0.6142^{**}$) expressed negative and highly significant association with shoot length at phenotypic level.

I. Root length

Root length exhibited positive and highly significant association with vigour index length ($r = 0.6924^{**}$), root shoot ratio ($r = 0.5932^{**}$), vigour index mass ($r = 0.2231^{**}$), fodder yield per plant ($r = 0.2029^{**}$) and grain yield per plant ($r = 0.189^{**}$) at phenotypic level.

m. Root shoot ratio

Root shoot ratio exhibited positive and significant association with vigour index length ($r = 0.1718^{*}$) and negative but significant association with character vigour index mass ($r = -0.1634^{*}$) with root shoot ratio at phenotypic level.

n. Vigour index length

Vigour index length showed positive and highly significant association with grain yield ($r = 0.4731^{**}$), fodder yield per plant ($r = 0.4131^{**}$) and vigour index mass ($r = 0.4195^{**}$) at phenotypic level.

o. Vigour index mass

Character grain yield per plant ($r = 0.3943^{**}$) and fodder yield per plant ($r = 0.3708^{**}$) exhibited positive and highly significant association with vigour index mass at phenotypic level.

4.5 Discussion

In any crop improvement programme existence of sufficient amount of genetic variability is a prerequisite for success of any breeding programme. It is therefore necessary to assess the extent of variability existing in the population. Hybridization is one of the methods to create variability. Variability can be assessed by estimating genetic parameters like phenotypic coefficient of variation, genotypic coefficient variation, heritability as well as expected genetic advance percent over the mean. The genetic variability estimated in terms of genotypic coefficient variation and phenotypic coefficient of variation is not sufficient for the estimation of heritable variation. The heritable variation can be estimated with the greater degree of accuracy, when heritability studied along with genetic advance. 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. Therefore, the present investigation was undertaken on sixty six genotypes of *kharif* sorghum with the following objectives.

1. To evaluate the extent of genetic variability for seed quality, growth parameters and yield.
2. To evaluate the nature and extent of correlation between seed quality parameters, seedling growth and yield.

The results obtained in the present investigation are discussed here under the following subheads.

4.5.1 A) Analysis of Variance

Perusal of the Table 4.1 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 Elangovan *et al.* (2005), Warkad *et al.* (2008), Jain *et al.* (2009), Tomar *et al.* (2012) , Elangovan *et al.* (2013) , Jain and Indapurkar (2013), Khandelwal *et al.* (2015) and Sheikh *et al.* (2017).

4.5.2 Genetic variability

High GCV along with high PCV values were observed for the characters threshed grain mold rating and electrical conductivity (Table 4.3). For such characters low values are desirable. So these traits can be improved by selecting the genotypes showing less values.

For threshed grain mold rating, high GCV along with high PCV values were obtained by Rathod (2005), Thorat *et al.* (2005), Deepalakshmi and Ganeshmurty (2007), Khade (2012), Kedar (2013), Kalpande *et al.* (2015^a) and Dhutmal *et al.* (2018). For electrical conductivity high GCV and PCV values were obtained by Bhongle (2000) and Kedar (2013). Kathalkar (2017) reported the similar findings for the characters threshed grain mold rating and electrical conductivity.

The characters fodder yield per plant, grain yield per plant, number of leaves and seed hardness showed moderate GCV and PCV values. It indicated that there is good scope for improvement in these traits by involving chosen parents in hybridization.

For fodder yield per plant moderate GCV and PCV results were obtained by Muhammad *et al.* (2007), Dhutmal *et al.* (2014), Kalpande *et al.* (2014), Dhutmal *et al.* (2015), Dhedhi *et al.* (2016) and Kathalkar (2017).

For grain yield per plant moderate GCV and PCV values were obtained by Dhutmal *et al.* (2015), Ranjith *et al.* (2017), Shaikh *et al.* (2017) and Kathalkar (2017).

Moderate values of PCV and GCV were recorded for seed hardness and number of leaves indicating that these are amenable for improvement. Kedar (2013) and Kathalkar (2017) reported similar results for character seed hardness. Kedar (2013) and Seetharam and Ganeshmurthy (2013) reported similar results for number of leaves per plant.

Low GCV and PCV values were found for the characters days to 50% flowering, plant height, panicle length, root length, shoot length, 1000 seed weight, vigour index mass, vigour index length, root shoot ratio, germination percentage of seed and specific gravity of seed indicating small amount of variation and impediment in improvement through selection. Ekebil *et al.* (1977), Satpute and Tiwari (1990) and Dhutmal *et al.* (2015) reported the similar result for plant height. Lukhele and Obilona (1984), Bhongle (2000), Hemlata *et al.* (2006), Jain *et al.* (2009), Dhutmal *et al.* (2014), Ranjith *et al.* (2017) and More *et al.* (2018) reported the similar result for days to 50% flowering. Sumathi *et al.* (2010) in pearl millet reported similar results for characters root length and shoot length. Dhutmal *et al.* (2014) reported similar results for 1000 seed weight. Bhongle (2000), Rathod (2005), Thorat *et al.* (2005), Khade (2012), Kedar (2013) and Kathalkar (2017) reported the similar findings for the characters germination percentage of seed and specific gravity of seed. Kalpande *et al.* (2015^a) reported similar result for specific gravity of seed.

The higher magnitude of PCV as compared to GCV in respect of all the characters indicated the greater effect of environment on these characters.

4.5.3 Heritability estimates in broad sense

The coefficient of variation indicates only the extent of variability present in different characters and do not indicate the heritable portion. This could be ascertained from the heritability estimates. The broad sense heritability includes both additive and non additive gene effects (Hanson *et al.* 1956) and narrow sense includes only those due to additive components (Lush, 1949). Further, Johnson *et al.* (1955) suggested that heritability in conjunction with genetic advance is more effective and reliable in predicting resultant effect of selection. Thus, for the prediction of response to selection it is apt to use broad sense heritability because the entire genotypic value is transmitted to the progeny when any selection is advanced through selfing.

The heritability in broad sense ranged from 17.3 to 83.3% for various characters under study. Highest heritability estimate in broad sense was observed for fodder yield per plant (83.3%) followed by grain yield (77.4%), plant height (77.27%), threshed grain mold rating (74.00%), number of leaves (68.8%), seed hardness (68.6%) and electrical conductivity (67.2%). All these seven characters exhibited high heritability (more than 61%). These characters would respond positively to selection because of their high broad sense heritability.

For fodder yield per plant high heritability estimates were reported by Kulkarni and Shinde (1987), Satpute and Tiwari (1990), Warkad *et al.* (2008), Jain *et al.* (2009), Godbharle *et al.* (2010), Jain and Patel (2012), Khade (2012), Jain and Indapurkar (2013), Kedar (2013), Dhutmal *et al.* (2014), Kalpande *et al.* (2014), Ranjith *et al.* (2017), Shaikh *et al.* (2017) and Kathalkar (2017).

For the character grain yield per plant high heritability was obtained by Jain *et al.* (2009), Mahajan *et al.* (2011), Khade (2012), Jain and Indapurkar (2013), Kedar (2013), Seetharam and Ganeshmurthy (2013), Dhutmal *et al.* (2014), Kalpande *et al.* (2014), Khadakabhavi *et al.* (2014),

Ghorade *et al.* (2015), Ranjith *et al.* (2017), Shaikh *et al.* (2017) and Kathalkar (2017)

For plant height high heritability estimates were reported by Ekebil *et al.* (1977), Shinde *et al.* (1979), Salilkumar and Singhania (1984), Kumar and Singh (1986), Kulkarni and Shinde (1987), Can *et al.* (1998), Bhongle (2000), Geleta and Daba (2005), Rathod (2005), Thorat *et al.* (2005), Deepalaxmi and Ganeshmurthy (2007), Jain *et al.* (2009), Chavan *et al.* (2010), Godbharle *et al.* (2010), Mahajan *et al.* (2011), Ahmad *et al.* (2012), Jain and Patel (2012), Khade (2012), Jain and Indapurkar (2013), Kedar (2013), Seetharam and Ganeshmurthy (2013), Dhutmal *et al.* (2014), Tadesse *et al.* (2015), Insan *et al.* (2016), Ranjith *et al.* (2017), Shaikh *et al.* (2017), Kathalkar (2017) and More *et al.* (2018).

Rathod (2005), Deepalakshmi and Ganeshmurthy (2007) and Khade (2012), Kedar (2013), Kalpande *et al.* (2015^a), Kathalkar (2017) and Dhutmal *et al.* (2018) reported similar high heritability for character threshed grain mold rating.

For number of leaves similar result was obtained by Deepalakshmi and Ganeshmurthy (2007) and Kedar (2013).

For seed hardness similar high heritability results were obtained by Bhongle (2000), Rathod (2005), Khade (2012), Kedar (2013) Kalpande *et al.* (2015^a), Kathalkar (2017) and Dhutmal (2018).

For character electrical conductivity high heritability estimates were reported by Rathod (2005), Thorat *et al.* (2005), Khade (2012), Kedar (2013), Kalpande *et al.* (2015^a) and Kathalkar (2017).

Medium heritability was observed for the characters vigour index length (56.30%), germination percentage (41.30%), shoot length (36.10%), specific gravity of seed (33.70%) and vigour index mass (31.50%). Kedar (2013) reported similar results for the characters shoot length, vigour index mass and specific gravity of seed. Kathalkar (2017) reported similar results for the characters shoot length, specific gravity, vigour index mass and vigour index length. Dhutmal *et al.* (2018) reported similar result for germination percentage of seed.

4.5.4 Expected genetic advance (%)

Expected genetic advance percent over mean ranged from 3.90 to 58.36 percent for different characters. The highest genetic advance percent over mean was observed for the character threshed grain mold rating (58.36%) followed by electrical conductivity (33.83%), fodder yield per plant (32.56%), grain yield per plant (30.28%) and number of leaves (23.51%). These five characters exhibited high expected genetic advance (more than 21%).

For the character threshed grain mold rating results were in conformity with results of Bhongle (2000), Rathod (2005), Deepalakshmi and Ganeshmurty (2007), Godbharle *et al.* (2010), Khade (2012), Kedar (2013), Kalpande *et al.* (2015^a), Kathalkar (2017) and Dhutmal *et al.* (2018).

For the character electrical conductivity similar high expected genetic advance was reported by Bhongle (2000), Rathod (2005), Kedar (2013), Kalpande *et al.* (2015^a) and Kathalkar (2017).

For the character fodder yield per plant similar high expected genetic advance was obtained by Satpute and Tiwari (1990), Godbharle *et al.* (2010), Khade (2012), Kedar (2013), Dhutmal *et al.* (2014), Kumar (2014), Ranjith *et al.* (2017) and Kathalkar (2017).

Higher values of genetic advance for grain yield per plant were reported by Salilkumar and Singhania (1984), Kumar and Singh (1986), Shankarpandian *et al.* (1996), Bhongle (2000), Rathod (2005), Deepalakshmi and Ganeshmurty (2007), Jain *et al.* (2009), Godbharle *et al.* (2010), Khade (2012), Seetharam and Ganeshmurthy (2013), Dhutmal *et al.* (2014), Khadakabhavi *et al.* (2014), Ranjith *et al.* (2017), Kathalkar (2017), More *et al.* (2018) and Swamy *et al.* (2018).

For the character number of leaves similar high expected genetic advance was reported by Kedar (2013).

Medium expected genetic advance over mean was found for the characters like seed hardness (17.83%), plant height (16.11%) and vigour index length (15.19%). While shoot length (9.47%), specific gravity of seed days (7.95%), panicle length (7.69%), root length (6.93), vigour index mass

(6.90), germination percentage (5.92), 1000 seed weight (5.48), root shoot ratio (5.29) and days to 50% flowering (3.90%) showed low expected genetic advance over mean. Kedar (2013), Kathalkar (2017) reported medium expected genetic advance for vigour index length. For day to 50% flowering low expected genetic advance reported by Dhutmal *et al.* (2014), Ghorade *et al.* (2015) and Kathalkar (2017). Khade (2012) reported low expected genetic advance over mean for the characters germination percentage of seed and specific gravity of seed. Dhutmal *et al.* (2018) reported low expected genetic advance over mean for specific gravity of seed.

In general high heritability accompanied with high expected genetic advance for the characters suggest that the genes governing these character may have additive effect. It can be mentioned here that characters fodder yield per plant, grain yield per plant, threshed grain mold rating, Number of leaves and electrical conductivity 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.

For fodder yield per plant similar high heritability accompanied with high expected genetic advance was reported by Satpute and Tiwari (1990), Godbharle *et al.* (2010), Khade (2012), Kumar (2014), Ranjith *et al.* (2017) and Kathalkar (2017).

For grain yield per plant high heritability accompanied with high expected genetic advance was reported by Deepalakshmi and Ganeshmurty (2007), Godbharle *et al.* (2010), Khade (2012), Ranjith *et al.* (2017), Kathalkar (2017) and More *et al.* (2018). For electrical conductivity high heritability accompanied with high expected genetic advance was reported by Khade (2012) and Kathalkar (2017).

For threshed grain mold rating high heritability accompanied with high expected genetic advance was reported by Godbharle *et al.* (2010), Khade (2012), Kathalkar (2017) and Dhutmal *et al.* (2018).

Medium or high values of heritability along with low value of expected genetic advance were observed for the characters like germination percentage, shoot length, specific gravity of seed and vigour index mass. 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 for improving these characters. Thorat *et al.* (2005) reported high values of heritability along with low value of expected genetic advance for the character specific gravity of seed. Kathalkar (2017) reported similar findings for specific gravity of seed and germination percentage.

4.5.4 Correlation

The phenotype of a plant is the result of interaction of a large number of factors. Hence, the final yield is sum total of effects of several component factors. Therefore, it is important to know the extent and nature of interrelationship between grain yield and its contributory characters and also among themselves. The correlation coefficient helps the breeder in determining the direction and number of characters to be considered in improving the grain yield. In the present study, phenotypic and genotypic correlations were computed for various characters.

The association between two characters which can be directly observed is called as phenotypic correlation. It includes 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. 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. On the other hand, a negative correlation between two desirable characters impedes or makes it impossible to achieve a significant improvement in both characters.

4.5.4.1 Genotypic association between grain yield and yield contributing characters

The results presented in Table 4.4 revealed that the character grain yield per plant showed positive and highly significant association with vigour index mass, 1000 seed weight, germination percentage, vigour index length, panicle length, fodder yield, shoot length, root length, seed hardness and plant height. Whereas, the character electrical conductivity, specific gravity, threshed grain mold rating, days to 50% flowering and root shoot ratio showed negative and significant association with grain yield per plant.

The character 1000 seed weight exhibited positive and significant correlation with grain yield per plant and this result was in conformity with the results of Potdukhe *et al.*(1994), Maman *et al.* (2004), Thorat *et al.*(2005), Elangovan *et al.* (2006), Hemlata *et al.* (2006), Premlatha *et al.* (2006), Jain and Indapurkar (2013), Kedar (2013), Khandelwal *et al.* (2015), Salih *et al.* (2015), Girish *et al.* (2016) and Kathalkar (2017). Kedar (2013) and Kathalkar (2017) reported that grain yield showed positive and significant association with the characters vigour index mass, panicle length, shoot length, vigour index length and germination percentage of seed. Potdukhe *et al.* (1994), Iyanar *et al.* (2001), Mahajan *et al.* (2011), Jain and Indapurkar (2013), Kedar (2013), Khandelwal *et al.* (2015) and Kathalkar (2017) reported that panicle length showed positive and significant association with grain yield per plant. Bhongle *et al.* (2000), Thorat *et al.* (2005), Kedar (2013) and Kathalkar (2017) found positive and significant association between germination percentage and grain yield per plant. Thus selection for 1000 seed weight, vigour index of seed, panicle length, germination percentage of seed, seed hardness and fodder yield per plant will be helpful for simultaneous improvement of grain yield per plant.

Bhongle (2000), Kedar (2013) and Kathalkar (2017) reported that specific gravity of seed was negatively and significantly associated with grain yield per plant. Kedar (2013) and Kathalkar (2017) reported negative and significant association between grain yield per plant and electrical conductivity. Threshed grain mold rating showed negative and significant association with grain yield per plant and similar results were obtained by Rathod (2005), Godbharle *et al.* (2010), Kedar (2013) and Kathalkar (2017). Selection for low values for such characters will be helpful for improvement of grain yield per plant.

4.5.4.2 Genotypic association between yield and yield contributing characters among themselves

a. Days to 50% flowering

Days to 50% flowering showed highly significant and positive association with root length, root shoot ratio, 1000 seed weight, germination percentage, vigour index length, number of leaves and vigour index mass. On the other hand, day to 50 % flowering showed negative and highly significant association with specific gravity, grain yield per plant, plant height, threshed grain mold rating and electrical conductivity. Kedar (2013) and Kathalkar (2017) reported positive correlation between days to 50% flowering and root shoot ratio. Wankhade *et al.* (1985) and Kedar (2013) reported positive and significant correlation between days to 50% flowering number of leaves. Godbharle *et al.* (2010), Kalpande *et al.* (2014), Salih *et al.* (2015) and Kathalkar (2017) reported negative and significant association between days to 50% flowering and grain yield per plant.

Negative correlation between days to 50% flowering and electrical conductivity and threshed grain mold rating indicated that early maturing lines (less days to 50% flowering) will show more threshed grain mold rating which in turn will increase the electrical conductivity due to damage of the seed by grain mold. It is well known that in early flowering lines, generally flowering to grain maturity stage is caught in the late rains and the condition becomes suitable for development of grain mold. Kedar (2013) reported similar negative and significant correlations between days to 50% flowering and characters like electrical conductivity, specific gravity of seed

and threshed grain mold rating. Bhongle (2000), Rathod (2005) and Kedar (2013) reported similar correlation between days to 50% flowering and electrical conductivity. Similar negative and significant correlation between days to 50% flowering and threshed grain mold rating was reported by Rathod (2005).

b. Plant height

Plant height exhibited positive and highly significant correlation with fodder yield per plant, vigour index mass, grain yield per plant, shoot length, number of leaves, vigour index length, germination percentage and seed hardness. While plant height exhibited positive and significant correlation with root length. Kishor and Singh (2005), Jain *et al.* (2009), Kedar (2013) and Kathalkar (2017) observed similar correlation between plant height and fodder yield per plant. Jain *et al.* (2009) and Kedar (2013) reported similar positive and significant correlation between plant height and number of leaves. Kathalkar (2017) reported similar correlation between plant height and shoot length. Thus selection of plant height will be helpful in simultaneous improvement of number of leaves and fodder yield per plant and it can be very well exploited for development of high fodder yielding varieties in sorghum.

c. Number of leaves

Number of leaves showed positive and highly significant correlation with fodder yield per plant, shoot length, germination percentage of seed, 1000 seed weight and vigour index length. While vigour index mass exhibited positive and significant association with number of leaves. Similar positive and significant correlation was reported by Satpute and Tiwari (1990), Jain *et al.* (2009), Jain and Patel (2012) and Kedar (2013) and Kathalkar 2017 between number of leaves and fodder yield per plant. Thus selection for number of leaves will be helpful in simultaneous improvement of fodder yield per plant and it can be very well exploited for development of high fodder yielding varieties in sorghum.

d. Panicle length

Panicle length expressed positive and highly significant association with 1000 seed weight, grain yield per plant, vigour index length,

germination percentage, root length, seed hardness, vigour index mass, fodder yield per plant and shoot length. Similar positive and significant correlation of panicle length with germination percentage of seed, seed hardness and vigour index mass was reported by Kedar (2013) and Kathalkar (2017). However Badigannavar *et al.* (2017) reported negative correlation between panicle length and seed weight.

e. Seed hardness

Seed hardness exhibited positive and highly significant association with 1000 seed weight, grain yield per plant, shoot length, vigour index mass, fodder yield per plant, root length and germination percentage of seed. Whereas, the characters threshed grain mold rating, electrical conductivity, specific gravity of seed and root shoot ratio showed negative and highly significant correlation with seed hardness. Kathalkar (2017) reported similar positive and significant correlation between seed hardness and characters like 1000 seed weight, shoot length, vigour index mass, vigour index length, fodder yield per plant, root length and germination percentage of seed. Kalpande *et al.* (2013) and Kedar (2013) reported similar positive and significant association between seed hardness and characters like germination percentage of seed and vigour index of seed. Ghorade and Shekhar (1997), Bhongle (2000), Rathod (2005) and Kedar (2013) observed positive and significant association between seed hardness and germination percentage of seed. Ghorade and Shekhar (1997) reported similar positive and significant association between seed hardness and 100 seed weight. Ghorade and Shekar (1997) and Kedar (2013) reported similar results for specific gravity (grain density). Similar negative and significant correlation between seed hardness and characters like threshed grain mold rating, electrical conductivity, specific gravity of seed and root shoot ratio was reported by Kathalkar (2017). Similar negative and significant correlation between seed hardness and grain mold attack as well as electrical conductivity was reported by Bhakare (2010) and Kedar (2013). Thus selection for seed hardness will be helpful in simultaneous improvement of germination percentage of seed, vigour index of seed, root length, shoot length, 1000 seed weight and fodder yield per plant. Similarly it will reduce

threshed grain mold rating and subsequently the electrical conductivity due to less damage to seed due to grain mold attack. Negative association between seed hardness and grain mold indicated the importance of seed hardness in reducing the grain mold infestation.

f. Threshed grain mold rating

Threshed grain mold rating expressed positive and highly significant association with specific gravity of seed, electrical conductivity and root shoot ratio. It is well known that due to the attack of the grain mold the seed coat gets damaged and it ultimately increases the electrical conductivity. Similar positive and highly significant correlation between grain mold attack and electrical conductivity was reported by Bhakare (2010), Kedar (2013) and Kathalkar (2017).

The characters germination percentage of seed, grain yield per plant, vigour index length, vigour index mass, 1000 seed weight, fodder yield, shoot length and root length showed the negative and highly significant association with threshed grain mold rating. Bhongle (2000), Kedar (2013) and Kathalkar (2017) reported similar negative and significant association of threshed grain mold rating with germination percentage of seed. Deepalakshmi and Ganeshmurthy (2007) reported similar negative and significant association between grain mold and 100 seed weight. Patil and Padule (2000), Kedar (2013) and Kathalkar (2017) reported similar results for threshed grain mold rating and vigour index of seed and germination percentage of seed. The characters germination percentage of seed, 1000 seed weight and vigour index of seed exhibited negative and highly significant association with threshed grain mold rating, which suggested that reduction in grain mold infestation improve the vigour index of seed, 1000 seed weight and the germination percentage of seed.

g. Specific gravity of seed

Specific gravity of seed exhibited positive and highly significant association with electrical conductivity. Whereas the characters vigour index mass, vigour index length, 1000 seed weight, germination percentage, root length, shoot length, grain yield per plant and fodder yield per plant exhibited

negative and highly significant association with specific gravity of seed. Similar result was reported by Kathalkar (2017). Kedar (2013) reported negative and significant association between specific gravity of seed and germination percentage of seed as well as vigour index of seed, while Rathod (2005) reported negative but non significant association between specific gravity of seed and germination percentage of seed.

h. Germination percentage of seed

Germination percentage of seed showed positive and highly significant association with vigour index mass, vigour index length, 1000 seed weight, grain yield per plant, shoot length, fodder yield per plant and root length. Kathalkar (2017) reported similar positive and significant correlation between germination percentage of seed and characters like vigour index mass, vigour index length, shoot length, 1000 seed weight and fodder yield per plant. Kalpande *et al.* (2013) and Kedar (2013) reported similar positive and significant correlation between germination percentage of seed and vigour index of seed. Kedar (2013) reported similar result positive and significant correlation between germination percentage of seed, 1000 seed weight, fodder yield per plant and shoot length. Thus improvement in germination percentage of seed will be helpful in simultaneous improvement of vigour index of seed and shoot length which give better plant stand in the field and ultimately increase the yield of crop. Germination percentage of seed exhibited negative and highly significant association with electrical conductivity indicating that higher the electrical conductivity lower will be germination percentage. It is well known that due to high grain mold attack the seed coat gets damaged which increases the electrical conductivity ultimately it results in lower germination percentage. Similar negative and highly significant correlation between germination percentage and electrical conductivity were reported by Bhakare (2010) and Kedar (2013).

i. Electrical conductivity

Electrical conductivity expressed negative and highly significant association with vigour index mass, grain yield per plant, vigour index length, fodder yield per plant, 1000 seed weight, shoot length and root length. Kathalkar (2017) reported similar negative and significant correlation of

electrical conductivity with vigour index mass, vigour index length, shoot length, 1000 seed weight and fodder yield per plant. Kedar (2013) reported similar negative and significant correlation of electrical conductivity with vigour index mass and vigour index length. Bhongle (2000) and Bhakare (2010) reported similar negative and significant correlation between electrical conductivity and 100 seed weight. Due to grain mold attack seed coat gets damaged and it increases the electrical conductivity and reduces the germination percentage of seed and 1000 seed weight. It ultimately reduces the vigour index of seed because vigour index is calculated using germination percentage of seed.

j. 1000 seed weight

Thousand seed weight exhibited positive and highly significant association with vigour index mass, vigour index length, grain yield per plant, root length, shoot length, fodder yield and root shoot ratio. Kathalkar (2017) reported similar positive and significant association with vigour index mass, vigour index length, shoot length, fodder yield per plant and root length. Godbharle *et al.* (2010) and Kedar (2013) reported similar positive and significant association between 1000 seed weight and fodder yield per plant. Seeds having more weight of 1000 seed (*i.e.* bold seeded entries) might give better seed vigour index and higher vigour index of seed may lead to higher fodder yield per plant.

k. Shoot length

Shoot length expressed positive and highly significant association with vigour index length, vigour index mass, fodder yield per plant, root length and grain yield per plant. Kedar (2013) reported similar positive and significant correlation of shoot length with vigour index length, vigour index mass and root length. Kathalkar (2017) reported similar result for vigour index length, vigour index mass, root length and fodder yield per plant. It means increase in root length of seedling might be useful in increasing the shoot length of seedling which ultimately increases the vigour index length and vigour index mass because of these indexes are calculated on the basis of seedling length and seedling dry weight respectively.

I. Root length

Root length exhibited positive and highly significant association with vigour index length, vigour index mass, grain yield, fodder yield per plant and root shoot ratio. Kedar (2013) reported similar positive and significant correlation of root length with vigour index mass and grain yield per plant. Kedar (2013) and Kathalkar (2017) reported similar findings for characters vigour index length and root shoot ratio. More root length is ultimately useful in increasing the vigour index length and root shoot ratio and this relationship is confirmed by the positive and highly significant association between them.

m. Root shoot ratio

Root shoot ratio exhibited negative and significant association with fodder yield, vigour index mass and grain yield per plant. Kathalkar (2017) reported similar result for vigour index mass, fodder yield and grain yield per plant. It means increase in root shoot ratio may reduce vigour index of mass and fodder yield per plant.

n. Vigour index length

Vigour index length showed positive and highly significant association with vigour index mass, grain yield per plant and fodder yield per plant. Kedar (2013) and Kathalkar (2017) reported similar findings for characters vigour index mass and grain yield per plant. Kathalkar (2017) reported similar positive and significant association of vigour index length with fodder yield per plant. It is well known that more the seedling length more will be the vigour index length. Also due to more seedling length the mass of the seedling will be more which in turn will increase the vigour index mass. This relationship is confirmed by the positive and highly significant correlation between them.

o. Vigour index mass

vigour index mass showed positive and highly significant association with fodder yield per plant and grain yield. Kathalkar (2017) reported similar positive and significant association of vigour index mass with fodder yield per plant. Vigour index mass is calculated by multiplication of seedling dry weight and germination percentage. Both seedling dry weight

and germination percentage positively associated with fodder yield per plant. This relationship is confirmed by the positive and highly significant correlation between them.

Future breeding strategies

From the findings of the present investigation following suggestions regarding the use of the experimental material for further breeding programme are given.

The need of sorghum crop is to develop genotypes with high grain yield, fodder yield and low grain mold infestation. The mean values of grain yield per plant of top ranking hybrids are presented in the table 4.6.

Perusal of table 4.6 indicated that for grain yield per plant, the top nine hybrids recorded substantial % increase for grain yield (more than 10%) over the national check hybrid CSH-35. These nine hybrids hold promise in developing high grain yielding hybrids. But, in sorghum grain yield alone is not sufficient. Along with grain yield, the fodder yield is also equally important. So as to develop such dual purpose hybrids, three hybrids *i.e* ICS 89022 A x AKR 519, AKMS 30 A x AKR 571 and ICS 89022 A x AKR 567 appeared best because of their high grain yield along with high fodder yield as compared to the national check CSH-35.

Table 4.6 Top ranking hybrids for grain yield per plant

Sr. No.	Hybrids	Grain yield per plant (g)	Percentage increase over check CSH-35 for grain yield/plant	Fodder yield per plant (g)	Percentage increase over check CSH-35 for fodder yield/plant	Seed hardness (kg/cm ²)	TGMR (%)	Specific gravity of seed (g/ml)	Germination percentage of seed	Vigour index mass
1	ICS 89022 A x AKR 519	53.60	34.57	196.28	31.63	8.38	6.00	1.02	84.33	15.03
2	AKMS 85 A x AKR 325-1	51.63	29.62	165.06	10.69	7.06	6.01	0.99	88.00	13.28
3	ICS 89022 A x AKR 567	50.66	27.19	181.16	21.49	9.26	6.00	1.02	82.33	13.64
4	AKMS 30 A x AKR 571	50.37	26.46	184.66	23.84	7.22	7.20	0.99	85.10	15.09
5	AKMS 85 A x AKR 567	49.83	25.10	150.71	1.07	7.47	7.00	1.02	78.00	12.05
6	AKMS 85 A x AKR 572	47.33	18.83	165.51	10.99	8.36	6.00	1.04	78.33	12.35
7	AKMS 85 A x AKR 519	47.09	18.22	154.55	3.64	7.00	6.21	0.98	85.33	13.30
8	ICS 89022 A x AKR 573	46.13	15.81	168.96	13.31	7.95	8.00	1.09	71.66	10.98
9	ICS 89022 A x AKR 522	44.80	12.47	163.23	9.46	7.08	7.00	1.04	79.00	13.35
10	CSH-35(National check)	39.83	00.00	149.11	00.00	6.97	10.66	1.01	80.66	12.91

In the present study important characters *i.e.* fodder yield per plant, grain yield per plant, threshed grain mold rating, number of leaves and electrical conductivity exhibited high heritability accompanied with high expected genetic advance suggesting use of selection method will be helpful for improving these traits.

From correlation studies it was found that panicle length exhibited positive and highly significant association with grain yield per plant. So for the development of high yielding genotypes in sorghum, panicle length should be considered during selection. Plant height and number of leaves had shown positive and highly significant correlation with fodder yield per plant. So, due weightage should be given to plant height and number of leaves in developing high fodder yielding genotypes in sorghum. Similarly seed hardness should be taken in to consideration for improvement in the germination percentage of seed due to positive and significant association. This is because seed hardness and TGMR (Threshed Grain Mold Rating) has shown the negative and highly significant association indicating that grain mold attack will be low on the seeds having more seed hardness. It is known that the grain mold is responsible for reduction in the germination percentage of the seed. So it is necessary that the proper control measures for grain mold should be undertaken during seed production to maintain the seed health and improve the germination percentage of the seed. Breeding efforts need to be intensified for developing grain mold resistant genotypes.

CHAPTER V

SUMMARY AND CONCLUSIONS

The present study entitled "Evaluation of seed quality, growth parameters and yield in *kharif* sorghum (*Sorghum bicolor* (L.) Moench)" was carried out at Sorghum Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during *kharif* 2018-19. In *rabi* 2017-18, four male sterile lines viz., AKMS 30 A, AKMS 85 A, AKMS 90 A and ICS 89022 A were crossed with twelve testers viz., AKR 325-1, AKR 456, AKR 517, AKR 519, AKR 522, AKR 545, AKR 551, AKR 566, AKR 567, AKR 571, AKR 572 and AKR 573 in line x tester design and produced 48 hybrids. Enough quantity of seed of these resulting hybrids was produced during *rabi* 2017-18. Actual planting of experiment was done during *kharif* 2018-19 by using sixteen parents, their 48 possible hybrids along with two standard checks CSH-14 (for earliness) and CSH-35 (for yield).

All these genotypes were grown in randomized block design with three replications. The study was undertaken to estimate the genetic variability, heritability, genetic advance and correlation between yield and yield components in *kharif* sorghum.

Observations were recorded for each genotype on seventeen different characters viz. days to 50% flowering, plant height (cm), number of leaves, panicle length (cm), seed hardness (kg/cm²), threshed grain mold rating (%), specific gravity of seed (g/ml), germination percentage of seed, electrical conductivity (dSm⁻¹), 1000 seed weight (g), shoot length (cm), root length (cm), root shoot ratio, vigour index length, vigour index mass, fodder yield per plant (g) and grain yield per plant (g).

The ANOVA revealed highly significant difference among the all genotypes for all the characters studied indicating the presence of substantial amount of genetic variability.

The characters electrical conductivity and threshed grain mold rating 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 all the characters indicated the greater effect of environment on these characters.

Highest heritability estimate in broad sense was observed for fodder yield per plant followed by grain yield, plant height, threshed grain mold rating, number of leaves, seed hardness and electrical conductivity and these characters would respond positively to selection.

The highest genetic advance percent over mean was observed for the character threshed grain mold rating followed by electrical conductivity, fodder yield per plant, grain yield per plant, and number of leaves.

In the present study, the characters fodder yield per plant, grain yield per plant, threshed grain mold rating, number of leaves and electrical conductivity exhibited high heritability along with high value of expected genetic advance per cent over mean, which indicated that phenotypic expression of these characters may be governed by the gene acting additively and thereby indicating the importance of these traits for selection.

High values of heritability along with low values of expected genetic advance were observed for the characters like germination percentage, shoot length, specific gravity of seed and vigour index mass. This indicated that these characters are mainly governed by non additive component of variation which is non fixable, heterosis breeding can be fruitfully exploited in improving these characters.

The present investigation revealed that the character grain yield per plant showed positive and highly significant association with vigour index mass, 1000 seed weight, germination percentage of seed, vigour index length, panicle length, fodder yield per plant, shoot length, root length, seed hardness and plant height. Whereas, the character electrical conductivity, specific gravity of seed, threshed grain mold rating, days to 50% flowering and root shoot ratio showed negative and highly significant association with grain yield per plant.

Among the yield components themselves, the character days to 50% flowering showed significant and positive association with root length,

root shoot ratio, 1000 seed weight, germination percentage, vigour index length, number of leaves and vigour index mass.

Plant height exhibited positive and highly significant correlation with fodder yield per plant, vigour index mass, grain yield per plant, shoot length, number of leaves, vigour index length, germination percentage and seed hardness at genotypic level. It confirmed the role of plant height in improving the fodder yield.

Number of leaves showed positive and highly significant correlation with fodder yield, shoot length, germination percentage of seed, 1000 seed weight and vigour index length.

Panicle length expressed positive and highly significant association with 1000 seed weight, grain yield per plant, vigour index length, germination percentage, root length, seed hardness, vigour index mass, fodder yield per plant and shoot length.

Seed hardness exhibited positive and highly significant association with 1000 seed weight, grain yield per plant, shoot length, vigour index mass, fodder yield per plant, root length and germination percentage. It underlines the significance of seed hardness in improving the germination percentage of seed, 1000 seed weight and increase seed vigour index of seed.

The characters germination percentage of seed, grain yield per plant, vigour index length, vigour index mass, 1000 seed weight, fodder yield per plant, shoot length and root length showed the negative and highly significant association with threshed grain mold rating which suggested that improvement in these characters will reduce the grain mold infestation.

Specific gravity of seed exhibited positive and significant association with electrical conductivity.

Germination percentage of seed showed positive and highly significant association with vigour index mass, vigour index length, 1000 seed weight, grain yield per plant, shoot length fodder yield per plant and root length. This indicated the importance of germination percent in improving the

vigour index mass, vigour index length, shoot length, 1000 seed weight and fodder yield per plant.

Electrical conductivity expressed negative and highly significant association with vigour index mass, grain yield per plant, vigour index length, fodder yield per plant, 1000 seed weight, shoot length and root length.

Shoot length expressed positive and highly significant association with vigour index length, vigour index mass, fodder yield per plant, root length and grain yield per plant.

Vigour index length showed positive and highly significant association with vigour index mass, grain yield per plant and fodder yield per plant. While vigour index mass showed positive and significant association with vigour index mass.

CONCLUSIONS

This experimental study revealed substantial amount of genetic variability among the genotypes under study.

The characters threshed grain mold rating and electrical conductivity showed high GCV and PCV values indicating thereby large amount of variation in aforesaid characters.

Due weightage should be given to plant height and number of leaves in developing high fodder yielding varieties. Similarly, seed hardness should be taken into consideration for improving germination percentage of seed. High heritability accompanied with high genetic advance was observed for the characters like fodder yield per plant, grain yield per plant, plant height and seed hardness suggesting the importance of selection in improving these traits.

For grain yield per plant, the nine hybrids viz., ICS 89022 A x AKR 519, AKMS 85 A x AKR 325-1, ICS 89022 A x AKR 567, AKMS 30 A x AKR 571, AKMS 85 A x AKR 567, AKMS 85 A x AKR 572, AKMS 85 A x AKR 519, ICS 89022 A x AKR 573 and ICS 89022 A x AKR 522 were significantly superior over the national check hybrid CSH-35 and recorded substantial percentage increase over the check hybrid. These nine hybrids hold promise in developing high grain yielding hybrids. For development of dual purpose

hybrids, three hybrids *i.e* ICS 89022 A x AKR 519, AKMS 30 A x AKR 571 and ICS 89022 A x AKR 567 appeared best because of their high grain yield along with high fodder yield as compared to the national check CSH-35.

CHAPTER VI

IMPLICATIONS

On the basis of information obtained from mean values, genotypic coefficient of variations, phenotypic coefficient of variations, heritability estimates (%), expected genetic advances (%) and correlations, the following suggestions are offered for the further utilization of this breeding material.

For grain yield per plant, the nine hybrids viz., ICS 89022 A x AKR 519, AKMS 85 A x AKR 325-1, ICS 89022 A x AKR 567, AKMS 30 A x AKR 571, AKMS 85 A x AKR 567, AKMS 85 A x AKR 572, AKMS 85 A x AKR 519, ICS 89022 A x AKR 573 and ICS 89022 A x AKR 522 were significantly superior over the national check hybrid CSH-35 and recorded substantial percentage increase over the check hybrid. These nine hybrids hold promise in developing high grain yielding hybrids. For development of dual purpose hybrids, three hybrids *i.e* ICS 89022 A x AKR 519, AKMS 30 A x AKR 571 and ICS 89022 A x AKR 567 appeared best because of their high grain yield along with high fodder yield as compared to the national check CSH-35.

For the development of high yielding hybrids in sorghum, panicle length should be considered during selection. Due weightage should be given to plant height and number of leaves in developing high fodder yielding hybrids in sorghum. Similarly seed hardness should be taken in to consideration for improvement in the germination percentage of seed. So it is necessary that the proper control measures for grain mold should be undertaken during seed production to maintain the seed health and improve the germination percentage of the seed. Promising cross combinations with high grain yield along with low grain mold infestation (TGMR) need to be tested in multilocation trails to identify the best cross combinations.

CHAPTER VII

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