

**ASSESSMENT OF ASSOCIATION AMONG THE
SEED QUALITY PARAMETERS AND YIELD IN
KHARIF SORGHUM (*Sorghum bicolor* (L.)
Moench)**

THESIS

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IN
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**By
PATIL RUPESH CHUDAMAN**

**DEPARTMENT OF AGRICULTURAL BOTANY
POST GRADUATE INSTITUTE, AKOLA**

**DR. PANJABRAO DESHMUKH KRISHI VIDYAPEETH,
KRISHINAGAR PO, AKOLA (MS) 444104**

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DECLARATION OF STUDENT

I hereby declare that the experimental work and its interpretation of the Thesis entitled “**ASSESSMENT OF ASSOCIATION AMONG THE SEED QUALITY 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.

Place: Akola

(Patil Rupesh Chudaman)

Date: / /2021

Enrolment No. - NN/115

CERTIFICATE

This is to certify that the thesis entitled “**ASSESSMENT OF ASSOCIATION AMONG THE SEED QUALITY 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 **Patil Rupesh Chudaman** under my guidance and supervision.

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

Place: Akola

(Dr. V. V. Kalpande)

Chairman

Date: / /2021

Advisory Committee

Countersigned

Associate Dean,

Post Graduate Institute,

Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola.

THESIS APPROVED BY THE STUDENT'S ADVISORY COMMITTEE
INCLUDING EXTERNAL EXAMINER (AFTER VIVA-VOCE)

1. Chairman Dr. V. V. Kalpande _____

2. Member Dr. R. B. Ghorade _____

3. Member Mrs. P. A. Sonkamble _____

4. Member Shri. R. D. Walke _____

5. External Member () _____

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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 hector
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
Viz.,	-	Videlicet (namely)
Σ	-	Summation
σ^2	-	Variance

(C)

THESIS ABSTRACT

- a. Title of the thesis : **“ASSESSMENT OF ASSOCIATION AMONG THE SEED QUALITY PARAMETERS AND YIELD IN KHARIF SORGHUM (*Sorghum bicolor* (L.) Moench)”**
- b. Name of student : **Patil Rupesh Chudaman**
- c. Name and Address of Major Advisor : **Dr. V. V. Kalpande**
Associate Professor,
Sorghum Research Unit,
Dr. Panjabrao Deshmukh Krishi
Vidyapeeth, Akola (M.S.) – 444104
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Head

Department of Agricultural Botany,
Dr. Panjabrao Deshmukh Krishi Vidyapeeth,
Akola

ABSTRACT

A present investigation entitled “Assessment of association among the seed quality 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 parameters and yield. The experiment was conducted during *kharif* season

of 2020 using Randomized Block Design with three replications. 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 GCV, PCV, heritability and EGA were estimated for all the characters.

The characters electrical conductivity and thresh grain mold rating showed high GCV and PCV values.

Highest heritability estimate in broad sense was observed for the character electrical conductivity. The highest value of expected genetic advance over mean was recorded for the character electrical conductivity.

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.

For grain yield per plant, the fourteen hybrids viz., AKMS-90-A x STR- 293 x 426-2, AKMS-733-A x IVT-4121, AKMS-30-A X ICSR-91016, AKMS-30-A x Indore-26, AKMS-751-A x IVT-4121, AKMS-751 x IVT-17-4013, AKMS-751-A X SPV 1616 x 89028-3, AKMS-733-A x IVT-17-4013, AKMS-90-A X IVT-4121, AKMS-733-A X ICSR-1048-Sel.-2, AKMS-751-A x IVT-3004-1, AKMS-30-A X STR-293 x 426-2, AKMS-733-A x ICSR-8086-7-49 and AKMS-90-A x ICSR-1048-Sel.2 were significantly superior over the national check hybrid CSH-35 along with substantial

percentage increase over the check. These fourteen hybrids hold promise in developing high grain yielding hybrids. For development of dual purpose hybrids, five hybrids *i.e.* AKMS-751-A x IVT-4121, AKMS-30-A x Indore-26, AKMS-30-A x ICSR-9106, AKMS-751-A x IVT-17-4013 and AKMS-90-A x STR-293 x 426-2 appeared best because of their good grain yield along with good fodder yield as compared to the national check hybrid CSH-35.

CHAPTER I

INTRODUCTION

1.1 Background Information

Sorghum (*Sorghum bicolor* (L.) Moench) is a genus of flowering plants in the grass family Poaceae. It has 10 pair of chromosome number ($2n = 20$). The word sorghum is derived from the word ' sorgo' means "rising above". Sorghum is normally a self pollinated crop but cross pollination takes place about 6 to 30% as stigma opens before dehiscence of anthers therefore it is referred as often cross pollinated crop. It is one of the cheapest sources of energy and micronutrients (after pearl millet). It is a C₄ 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".

Sorghum is the fifth most important cereal crop globally and is the dietary staple food of more than 500 million people over 30 countries. It is most widely grown throughout the arid and semi-arid tropics where water availability is limited and frequently subjected to drought. Sorghum is believed to be originated in Africa and spread all over the world. It had wide range of flexibility to grow in various climatic conditions of the world hence it is known by different names viz. Jowar, Jaur, Cholan or Jola in India , Guinea corn, Kafir corn and Dhuma in Africa, Kaoling in China and Milo Maize in America.

Recent USDA statistics (United State Department of Agriculture) indicates a world production of 61.62 million tones in year of 2020-21 of grain sorghum and it represent an increase of sorghum production by 3.66 million tones as compare to the last year. Major sorghum producing countries are United states, Nigeria, Ethiopia, Sudan, Mexico, India and China.

Sorghum is the common millet of India. It is the 3rd most important food crop in India after rice and wheat and cheapest source of

energy and micronutrients. 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 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 (410 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.

Sorghum improvement work in India resulted in the development of number of hybrids possessing high yield potential than the other local varieties. The first two commercial hybrids viz. CSH-1 and CSH-2 were released in the year 1964 & 1965 respectively by All India Coordinated Sorghum Improvement Project.

In Maharashtra, the area of sorghum under cultivation is 4.10 lakh hectare with total production 4.17 lakh tones and average productivity of 1018 kg/ha during the period of 2017-2018 (Agresco report). Sorghum is mainly grown in the states of 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) and 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		404.8	583	1440
India		46.56	46.33	995

	Season	Area ('00"ha)	Production ('00"tones)	Yield (kg/ha)
Maharashtra	<i>Kharif</i>	3898.81	2730.79	700.42
	<i>Rabi</i>	19815.91	15916.16	803.20
Vidharbha	<i>Kharif</i>	588.97	231.91	453.34
	<i>Rabi</i>	250.35	198.12	726.13

(Anonymous: 2019-20)

Source: - USDA (United state department of agriculture) and mahaagri.gov.in

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 other 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 of 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 program 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 principally 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 losses 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 kernel 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 programs.

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 assess the extent of variability for grain yield & seed quality parameters.
2. To assess the nature and extent of association among seed quality parameters and yield.

1.4 Hypothesis or assumptions

The genetic variability study is helpful to estimate the suitable parameter 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 programs.

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 crops 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 variation 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) observed 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) recorded 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) observed 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.* (2005) reported 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 variation higher for plant height, head weight, grain yield per plant and 100 kernel weight.

Rathod (2005) observed 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) reported 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 were 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) observed 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) recorded the genetic variability and nature of character association in 20 B lines and 16 R lines of *kharif* sorghum. The genotypic variance was lower than the phenotypic variance for all the characters. High genotypic and phenotypic variance 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) reported the thirty two diverse accessions of forage sorghum and estimates of phenotypic coefficient of variation (PCV) were comparable with genotypic coefficient of variation (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) studied significant variation 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 observed 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 recorded that 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 and 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) Significant variations were observed 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 germplasm of sorghum and studied that 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 that 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) studied 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 for 7 quantitative traits. The phenotypic co-efficient of variation (PCV) was greater than genotypic co-efficient 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 on 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 value.

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

Dhutmal *et al.* (2015) recorded 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) studied thirty eight lines consisting of thirty derived sorghum lines (named as AKENT numbers), four susceptible line and four resistant source lines of kharif sorghum were evaluated 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) studied sixty three genotypes consisting of sixty germplasm lines and three improved released varieties of kharif sorghum were evaluated for five seedling parameters. The study revealed that the characters vigour index length showed moderate GCV and PCV values indicating thereby good amount of variation.

Khandelwal *et al.* (2015) studied 224 genotypes to assess genetic parameters and character association among yield components. Significant variation 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 was 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%).

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 were recorded. 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) studied wide range of values were observed 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) carried out work to assess 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 characters 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) recorded 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) carried out investigation to assess 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 that 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 were categorized as low.

Dhutmal *et al.* (2018) conducted study to find out the traits conferring grain mould tolerance in kharif sorghum (*Sorghum bicolor* (L.) Moench) and to study the genetic variability and character association related to grain mold tolerance. Genotypic coefficient of variation estimates were lower than phenotypic coefficient of variation for all the characters and differences between them were of lower magnitude. High estimates of genotypic and phenotypic coefficient of variation were recorded for panicle type, threshed grain mold rating, germination percentage, grain hardness, however, grain density was categorized as low.

Massaoudou *et al.* (2018) reported that high GCV and PCV values for character like grain yield, midge damage and panicle weight, moderate GCV and PCV values for plant height and 1000 seed weight and lowest value of GCV and PCV were observed for the trait days to 50 % flowering.

More *et al.* (2018) assessed the variability in sorghum germplasm lines for shoot fly resistant traits, observations were recorded on 16 characters. 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%), where as lowest GCV and PCV were observed for the trait days to 50% flowering (8.77% and 9.15%).

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%). 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%). On the other hand, low GCV and PCV values were recorded for days to physiological maturity (3.71% and 4.10%).

Awate (2019) reported that high GCV and PCV values for characters like TGMR and electrical conductivity, moderate values of GCV and PCV were observed for fodder yield per plant, grain yield per plant, number of leaves and seed hardness. Whereas, for 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 and specific gravity of seed having low values of GCV and PCV.

Shivaprasad *et al.* (2019) reported wide range of variation for morphological and yield contributing trait among the genetic parameter studied. High genotypic and phenotypic coefficient was observed for grain yield, no. of leaves, plant height and panicle length the role indicating of these trait in high yielding variety.

Dhutmal *et al.* (2020) reported that high GCV and PCV were recorded for plant height, no. of primaries per panicle, FGMR, TGMR, grain yield per plant and fodder yield per plant, medium values for GCV and PCV were observed for panicle length and 100 seed weight and lowest value of GCV and PCV were observed for the trait days to 50 % flowering and days to maturity.

Goswami *et al.* (2020) observed that high values of GCV and PCV was recorded for leaf stem ratio, fodder yield per plant, grain yield per plant, panicle length and panicle width. Whereas medium for leaf area, 1000 seed weight, protein content, no. of leaves and stem girth and low values for plant height, leaf length and days to 50 % flowering.

Khade *et al.* (2020) studied 99 land races of kharif sorghum and reported that high GCV and PCV values for TGMR and seed hardness and low value of GCV and PCV observed for electrical conductivity, vigour index of seed, germination percentage of seed and specific gravity of seed.

Santosh *et al.* (2020) observed moderate GCV values for plant height, leaf area, stem girth, total soluble solids, HCN content, fodder yield, whereas low for no. of leaves per plant, leaf length, leaf width and protein content. High PCV values observed for total soluble solid, leaf stem ratio and HCN content.

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) recorded 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) reported heritability for yield, days to 50 % flowering 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) recorded 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) observed 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) recorded 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) recorded 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) observed 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) recorded 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) observed 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) observed 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 that high heritability accompanied with high GA as percent over mean was observed 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) observed 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) studied 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 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) observed 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 recorded high heritability 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.

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) observed 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) reported 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 recorded 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) studied that 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) reported that 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) studied highest heritability percent 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 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) observed 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) observed 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) reported high broad sense heritability values and broad genetic diversity in the character of the plant height, leaf number, panicle length, circumference panicle, panicle weight and grain weight per panicle.

Kareema *et al.* (2017) recorded 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 that genotypes under study showed heritability ranged from 41.18% to 96.27%. The heritability in broad sense ranged from 41.18 to 96.27 % for various characters under study. Highest heritability estimate in broad sense was observed 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%). All these eight characters exhibited high heritability (more than 61%). 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) reported 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) observed 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) 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.

More *et al.* (2018) reported variability in 116 sorghum germplasm lines and observed that heritability estimates was 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).

Massaoudou *et al.* (2018) observed high heritability for plant height, panicle weight, grain yield, midge damage and fodder yield and medium for 1000 seed weight.

Awate (2019) studied 66 genotypes of sorghum and recorded that high heritability for characters like fodder yield per plant, grain yield per plant, plant height, TGMR, no. of leaves, seed hardness and electrical conductivity. moderate heritability for vigour index length, germination percentage, shoot length, specific gravity and vigour index mass and low for root shoot ratio, 1000 seed weight, days to 50 % flowering, root length and panicle length.

Shivaprasad *et al.* (2019) reported high heritability for panicle length, panicle width, seed weight and grain yield.

Dhutmal *et al.* (2020) recorded high heritability in broad sense for characters like plant height, no of primaries per panicle, grain colour, FGMR, grain yield, TGMR, fodder yield and grain hardness.

Goswami *et al.* (2020) reported high heritability for days to 50 % flowering, no. of leaf per plant, panicle length, grain yield per plant, 1000 grain weight, dry fodder yield per plant and grain yield per plant and medium for plant height.

Khade *et al.* (2020) observed high heritability for TGMR, seed hardness, electrical conductivity, germination percentage of seed, vigour index of seed, specific gravity of seed.

Santosh *et al.* (2020) reported that high heritability values were observed in plant height, leaf width, leaf area, stem girth, total soluble solid, leaf stem ratio and fodder yield. Whereas moderate for no. of leaves, HCN content and protein content, low for leaf length.

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) observed 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) recorded 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 observed 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) recorded 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) reported 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) studied 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) observed 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 observed 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) studied 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) studied 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) observed 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 recorded high heritability combined with high genetic advance for character plant height.

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

Kedar (2013) evaluated 63 germplasm 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) evaluated 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) recorded the highest value of expected genetic advance expressed as per cent of mean was obtained 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) observed highest genetic advance for grain yield per plant followed by panicle length.

Kumar (2014) reported 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) observed 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) recorded the highest values of expected genetic advance over mean were recorded 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%).

Ranjith *et al.* (2017) recorded the 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.

Kathalkar (2017) reported that expected genetic advance percent over mean ranged from 4.52 to 146.40 percent for different characters. The highest genetic advance percent over mean was observed 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.

Bhakad (2018) evaluated 84 germplasm lines of sorghum and recorded 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) observed that the characters TGMR and grain hardness expressed high estimate of heritability accompanied with moderate to high genetic advance.

Massaoudou *et al.* (2018) reported high value of expected genetic advance percent over mean for grain yield, midge damage, panicle weight, plant height and fodder yield

More *et al.* (2018) observed 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) observed that high heritability accompanied with high genetic advance over mean was observed 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%). However, days to physiological maturity (81.71% and 6.91%) showed high heritability coupled with low genetic advance.

Awate (2019) observed high expected genetic advance percent over mean for character TGMR, electrical conductivity, fodder yield per plant and no. of leaves. Whereas, medium for genetic advance recorded for seed hardness, plant height and vigour index length and low for shoot length, specific gravity of seed, panicle length, root length, vigour index mass, germination percentage of seed, 1000 seed weight, root shoot ratio and days to 50 % flowering.

Shivaprasad *et al.* (2019) reported high value of expected genetic advance percent over mean for panicle length, panicle width, seed weight and grain yield.

Dhutmal *et al.* (2020) reported high values of expected genetic advance over mean for TGMR, FGMR, grain yield per plant, fodder yield per plant, plant height, 100 seed weight and moderate for days to 50 % flowering.

Goswami *et al.* (2020) recorded high value of expected genetic advance percent over mean for leaf to stem ratio, fodder yield per plant, grain yield per plant, panicle length, panicle width, 1000 grain weight, protein in grain, leaf area and leaf width. Whereas moderate for no. of leaf, stem girth, days to 50 percent flowering, leaf length and days to maturity and low for plant height.

Khade *et al.* (2020) observed high value of expected genetic advance over mean for TGMR, seed hardness and electrical conductivity, medium for vigour index of seed and low for germination percentage and specific gravity of seed

Santosh *et al.* (2020) observed high genetic advance as percent of mean for leaf area, total soluble solids, leaf stem ratio, HCN content and green fodder yield.

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 program 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) studied that simple correlation between grain yield and plant height and recorded positive association.

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

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

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

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

Wankhade *et al.* (1985) evaluated 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) recorded correlation in F1 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) observed 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) evaluated 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 (1900) studied correlation of yield components and yield in 22 grain sorghum genotypes and recorded that plant height and 1000 grain weight were highly correlated with grain yield, while leaf area index showed a poor correlation with plant height.

Shanmughasundaram and Subramanian (1990) recorded 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) evaluated 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) studied that hard grain sorghum had shown more resistance to grain mould rather than soft grains.

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

Potdukhe *et al.* (1994) observed correlation of yield and yield components of 42 *kharif* sorghum genotypes and recorded 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) recorded significant positive correlation of grain hardness with grain density, 100-seed weight, grain yield and percentage germination.

Jayprakash *et al.* (1997) worked out 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) studied 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) observed 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. 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) worked out 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) evaluated correlation with 41 sorghum inbred lines and reported positive but non significant correlation between plant height and grain yield.

Patil and Padule (2000) observed 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) observed 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.* (2005) recorded 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) observed 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) studied 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) observed correlation among yield and yield contributing characters of 32 derived lines and 8 checks of sorghum and recorded 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.

Thorat *et al.* (2005) observed 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) recorded 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) observed 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) observed 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) studied that grain yield was significantly and positively correlated with 100 grain weight in grain sorghum.

Deepalakshmi and Ganeshmurthy (2007) recorded 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) evaluated sixty four germplasm accessions of sorghum and recorded that only character 1000 seed weight exhibited positive and highly significant association with grain yield per plant.

Jain *et al.* (2009) observed correlation in sorghum and recorded 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) studied 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) studied 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 observed 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) observed that 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) evaluated 99 land races and recorded 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) studied 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 root shoot ratio. 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. 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.

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) observed that 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) studied that 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) observed 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) 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) the field experiment was carried out 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) studied 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. Whereas, the character root length showed positive and significant association with grain yield per plant. On the other hand specific gravity, root shoot ratio and days to 50 % flowering showed negative but highly significant correlation with grain yield per plant. While, electrical conductivity and threshed grain mold rating showed negative significant association with grain yield per plant.

Bhakad (2018) observed 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) studied correlation among eleven characters of 122 rabi sorghum genotypes and showed 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 $r = 0.848$.

Awate (2019) reported that 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, TGMR, days to 50 % flowering and root shoot ratio showed negative and significant association with grain yield per plant.

Shivaprasad *et al.* (2019) observed significant and positive correlation among grain yield with no. leaves per plant, plant height, panicle length, panicle width and panicle area indicating role and importance of these traits in the development of high yielding varieties.

Dhutmal *et al.* (2020) reported that grain yield per plant showed positive and significant correlation with panicle length, no. of primaries per plant, fodder yield per plant, 100 seed weight and days to 50 percent flowering at both genotypic and phenotypic level.

Goswami *et al.* (2020) observed that grain yield per plant showed positive and significant association with leaf width, leaf area, fodder yield per plant and 1000 grain weight per plant at genotypic level.

CHAPTER III

MATERIAL AND METHODS

3.1 Materials

For the present study entitled as “Assessment of association among the seed quality parameters and yield in *kharif* sorghum (*Sorghum bicolor* (L.) Moench)”. The material consisted of 55 *kharif* sorghum genotypes comprising of 40 hybrids of *kharif* sorghum developed by crossing 4 lines and 10 testers in line x tester fashion along with one checks CSH-35.

The crossing program was carried out at the Research Field of Sorghum Research Unit, Dr. PDKV, Akola during *rabi* 2019-2020. The seed of parental lines was provided by Sorghum Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola.

Table 3.1 LIST OF MALE STERILE LINES AND RESTORERS

Sr.No	Parents	Source
	Lines	
1	AKMS-30-A	From Sorghum Research Unit Dr. PDKV Akola
2	AKMS-90-A	From Sorghum Research Unit Dr. PDKV Akola
3	AKMS-751-A	From Sorghum Research Unit Dr. PDKV Akola
4	AKMS-733-A	From Sorghum Research Unit Dr. PDKV Akola
	Testers	
1	ICSR-8086-7-49	From Sorghum Research Unit Dr. PDKV Akola
2	IVT-3004-1	From Sorghum Research Unit Dr. PDKV Akola
3	IVT-4121	From Sorghum Research Unit Dr. PDKV Akola
4	Indore-26	From Sorghum Research Unit Dr. PDKV Akola
5	ICSR-1048-sel ⁿ -2	From Sorghum Research Unit Dr. PDKV Akola
6	SPV1616x89028-3	From Sorghum Research Unit Dr. PDKV Akola
7	STR-293 x 426-2	From Sorghum Research Unit Dr. PDKV Akola
8	IVT-17-4013	From Sorghum Research Unit Dr. PDKV Akola
9	ICSR-91016	From Sorghum Research Unit Dr. PDKV Akola
10	AKR-426 x89058	From Sorghum Research Unit Dr. PDKV Akola
	Check	
1	CSH-35	From Sorghum Research Unit Dr. PDKV Akola

3.2 Methods

3.2.1 Location

The experiment was conducted on the field of Sorghum Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (MH.) during kharif 2020-2021. 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 vertisol, 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* 2020-2021. The experimental material comprised of 55 sorghum genotypes. The details of the experimental layout were as under.

- 1) Experimental design : Randomized Block Design
- 2) Number of genotypes : 55(40 Hybrids + 14 Parents + 1 check)
- 3) Replications : 3 (Three)
- 4) Plot size : 3.00 x 0.45m (One 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 : 07 July 2020
- 8) Fertilizer dose : 80 kg N: 40 kg P: 40 kg K (kg/ha) Out of these half dose of nitrogen, full 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 weeding)
Hoeing : 28 July, 26 Aug. 2020
Weeding : 05 Aug., 10 Sept. 2020

3.2.3 Recording of Observations

Observations were recorded on five randomly selected plants from each line for all the traits expect 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.

A) Field observation

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 centimeters, which included the length of main stem from soil level to the top of the panicle 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 genotypes 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 centimeters.

3.2.3.5 Grain yield/ plant (g)

Five randomly selected plants were threshed, weighted in grams 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.

B) Laboratory observation

3.2.3.7 Seed hardness (kg/cm²)

Since hard grained 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 kernel using Kiya hardness tester. Grains of same moisture content were used for observations. Five kernels 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 Fatonah *et al.* (2017).

75 seeds of each samples of each genotype under study was washed twice with the glass distilled water and placed in 250 ml of beakers and 150 ml of glass distilled water was added to each beaker. After 24 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 kernel weight (g) of each genotypes 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 centimeters.

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 centimeters.

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

a) Length vigour index

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

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

b) Mass Vigour index

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	$M. Sr = \delta^2 e + g \delta^2 r (M_1)$
2	Genotypes	(n-1)	S. Sg	$M. Sg = \delta^2 e + r \delta^2 g (M_2)$
3	Error	(r-1)(n-1)	S. Se	$M. Se = \delta^2 e (M_3)$
4	Total	(rn-1)		

Where, r = Number of replications

n = Number of genotypes

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

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

$$\text{Environmental variance} = M_3$$

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
 $x \text{ \& } y$ = 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 “Assessment of association among the seed quality 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 66.67 to 72.00 days and 62.33 to 72.33 days among the parents and hybrids, respectively (Table 4.2).

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

Source	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
Replications	2	16.339	27.087	2.755	3.465	0.320	2.630	0.000505	72.521
Treatments	54	639.115**	33496.470**	442.028**	657.519**	99.224**	3784**	0.202**	5032.581**
Error	108	854.993	15531.253	103.484	402.250	15.310	104.036	0.014	1310.145

Source	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
Replications	2	0.00712	0.551	0.199	1.623	0.0238	15720.25	0.0759	146.949	58.388
Treatments	54	38.037**	997.868**	352.028**	328.985**	0.758**	16811993.7**	417.175**	50342.652**	16681.354**
Error	108	0.636	174.927	19.175	43.606	0.784	954922.961	12.048	14075.905	1450.266

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

Among the lines, line AKMS-30-A (67 days). exhibited minimum days to 50% flowering followed by line AKMS-751-A (68.33 days). Among the testers, tester Indore-26 (66.67 days) exhibited minimum days to 50% flowering.

Among the 40 hybrids, three hybrids were found to be earlier and significantly superior over the check CSH-35 (69 days) and following hybrid recorded minimum days to 50 % flowering AKMS-751-A x ICSR-91016 (62.33 days) followed by hybrids AKMS-90-A x ICSR-8086-7-49 (63.66 days), AKMS-30-A x ICSR-8086-7-49 (64 days), AKMS- 30-A x IVT-17-4013 (66 days) and AKMS-751-A x ICSR-8086-7-49(66.33 days) and found promising for earliness.

b. Plant height (cm)

Plant height in the study ranged from 139.33 cm to 175.13 cm and 149.73 cm to 198.76 cm among the parents and hybrids, respectively (Table 4.2).

Out of the 14 parents, highest plant height was recorded by SPV-1616 x 89028-3 (175.13 cm). However, AKMS-30-A (139.33 cm) recorded lowest plant height and registered as a dwarf parent among the available parents.

Among the hybrids, seven hybrids exhibited significantly superior for plant height over the check CSH-35 (165.13 cm). Tallest hybrid AKMS-751-A x IVT-4121 (198.77 cm) was followed by AKMS-751-A x IVT-17-4013 (197.20 cm), AKMS-30-A x ICSR-91016 (194.2 days) AKMS-733-A x IVT-4121 (188.53 cm) and AKMS-30-A x STR-293 x 426-2 (187.13 cm). Whereas, the hybrid AKMS-751-A x Indore-26 (149.73 cm) recorded minimum plant height.

c. Number of leaves

The mean value for number of leaves ranged from 7.27 to 11.40 and 7.26 to 13 among the parents and hybrids, respectively (Table 4.2).

Among the parents, STR-293 x 426-2 (11.40) recorded superiority for number of leaves per plant, while IVT-3004-1(7.26) recorded minimum number of leaves per plant.

Among the 40 hybrids, four hybrids were found to be significantly superior over the check CSH-35 (10.87). The hybrids AKMS-30-A x ICSR-91016 (13), AKMS-751-A x IVT-4121(12.93), AKMS-733-A x ICSR-1048-Sel.-2 (12.87) and AKMS-751-A x IVT-17-4013 recorded maximum number of leaves per plant. Whereas, the hybrid AKMS-90- A x ICSR-91016 (7.27) recorded minimum number of leaves per plant.

d. Panicle length (cm)

The average panicle length ranged from 18.40 to 25.19 cm and 19.08 to 26.63 cm among the parents and hybrids, respectively (Table 4.2).

Among the testers, tester ICSR-1048-Sel.-2 (25.19 cm) recorded superiority for panicle length. Among the lines, line AKMS-751-A (23.11 cm) recorded maximum panicle length.

Among the hybrids, none of cross found significantly superior for panicle length over the check CSH-35 (23.63cm) but within hybrids AKMS-733-A x IVT-4121 (26.63 cm) recorded the maximum panicle length followed by AKMS-30-A x ICSR-91016 (25.55 cm), AKMS-30-A x Indore-26 (25.52 cm) and AKMS-751-A x SPV-1616 x 89028-3 (24.82 cm). whereas, the hybrid AKMS-751-A x ICSR-91016 (19.08 cm) recorded minimum panicle length.

e. Seed hardness (kg/cm²)

The average seed hardness ranged between 5.83 to 7.91 kg/cm² for parents and 5.83 to 9.07 kg/cm² for hybrids (Table 4.2).

Among the parents, highest seed hardness was recorded by tester ICSR-1048-sel.-2 (7.91 kg/cm²) followed by STR-293 x 426-2 (7.65 kg/cm²) and female line AKMS-30-A (5.823 kg/cm²) recorded minimum seed hardness.

Among 40 hybrids, three hybrids recorded significantly superiority over the check CSH-35 (7.59 kg/cm²). Hybrid AKMS-733-A x IVT4121 (9.07 kg/cm²) recorded maximum seed hardness followed by AKMS-90-A x STR-293 x 426-2 (8.83kg/cm²), AKMS-751-A x IVT-17-4013 (8.51 kg/cm²) and AKMS-90-A x IVT-4121 (8.20 kg/cm²). Whereas, AKMS-90-A x Indore-26 (5.83 kg/cm²) recorded minimum seed hardness.

f. Threshed grain mold rating (%)

The average threshed grain mold rating ranged between 15.33 to 32.00% for parents and 11.66 to 30.00 % for hybrids (Table 4.2).

Among the parents, lowest threshed grain mold rating was recorded by tester ICSR-1048-Sel.-2 (15.33%) followed by AKR-426 x 89058 (16.33%), while IVT-3004-1 (32.00%) recorded maximum threshed grain mold rating.

Among 40 hybrids, nineteen hybrids were significantly superior over the check CSH-35 (22.33%). There were four hybrids which recorded minimum threshed grain mold rating that is AKMS-733-A x IVT-4121(11.66%). followed by AKMS-90-A x STR-293 x 426-2 (12.67%), AKMS-30-A x ICSR-91016 (13.67%) and AKMS-751-A x IVT-4121 (14.00%). Whereas, AKMS-90-A x Indore-26 (30%) recorded maximum threshed grain mold rating.

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
0		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Lines(females)																		
1	AKMS-30-A	67.00	139.33	7.60	20.96	5.83	28.00	1.06	69.33 (56.38)	2.58	26.43	8.75	10.95	1.25	1365.91	10.52	130.35	38.27
2	AKMS-90-A	71.00	144.67	8.53	22.50	6.39	24.33	1.05	71.00 (57.42)	2.36	26.81	8.91	11.37	1.28	1439.91	10.96	141.22	42.49
3	AKMS-751-A	68.33	145.00	10.20	23.11	6.70	25.67	1.04	71.33 (57.63)	2.11	28.64	9.09	12.21	1.34	1519.07	11.49	156.19	43.62
4	AKMS-733-A	69.67	150.67	10.00	21.60	7.03	19.00	1.06	76.67 (61.12)	1.60	29.08	11.72	13.53	1.15	1935.49	12.34	158.94	45.47
Testers (males)																		
5	ICSR-8086-7-49	67.67	167.20	10.27	18.59	6.16	25.33	1.02	70.33 (57.00)	2.51	26.76	9.05	11.40	1.26	1438.25	12.23	135.39	41.66
6	IVT-3004-1	67.00	142.47	7.27	21.47	5.85	32.00	0.98	68.33 (55.76)	2.72	24.57	8.52	9.97	1.17	1263.77	9.87	131.28	34.90
7	IVT-4121	72.00	164.60	9.00	22.29	6.44	27.67	1.03	73.33 (58.92)	2.62	28.31	9.61	12.71	1.32	1637.26	10.58	145.63	43.01
8	Indore-26	66.67	170.07	9.07	23.47	6.84	28.00	1.03	74.67 (59.80)	2.70	28.01	10.82	13.06	1.21	1782.71	11.55	151.15	46.78
9	ICSR-1048-Sel.-2	69.33	164.73	11.33	25.19	7.91	15.33	1.07	78.00 (62.06)	1.60	30.07	11.63	13.51	1.16	1960.19	12.65	164.77	55.16

Sr.No.	Genotype	DT50%F	PH	NOL	PL	SH	TGMR	SG	GP	EC	1000SW	SL	RL	RSR	VIL	VIM	FY	GY
0		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
10	SPV-1616 x 89028-3	67.00	175.13	9.67	18.40	7.10	21.67	1.06	73.67 (59.16)	2.20	28.71	9.46	11.73	1.24	1559.53	11.32	135.95	42.68
11	STR-293 x 426-2	70.67	159.87	11.40	24.11	7.65	18.00	0.98	76.67 (61.16)	1.81	29.84	11.07	13.60	1.23	1893.04	12.22	161.83	43.49
12	IVT-17-4013	68.67	149.27	8.13	19.18	7.17	23.67	1.02	70.33 (57.04)	2.66	25.03	10.16	13.43	1.32	1656.90	10.36	142.13	32.59
13	ICSR-91016	69.00	151.60	7.80	18.53	6.85	24.67	0.98	68.00 (55.55)	2.63	26.80	8.97	11.08	1.24	1362.94	11.45	135.33	43.02
14	AKR-426 x 89058	68.33	142.67	9.13	24.07	7.54	16.33	1.03	74.33 (59.56)	1.62	27.85	9.09	12.57	1.38	1610.41	12.04	150.35	47.10
Hybrids																		
15	AKMS-30-A x ICSR-8086-7-49	64.00	152.13	7.53	22.72	6.03	27.33	1.02	72.67 (58.54)	2.41	25.05	8.78	11.69	1.33	1482.35	11.74	141.34	41.39
16	AKMS-30-A x IVT- 3004-1	68.67	157.80	9.53	24.07	6.12	25.67	1.06	74.67 (59.83)	1.82	26.59	9.03	12.16	1.35	1580.48	12.14	149.72	47.65
17	AKMS-30-A x IVT- 4121	68.00	163.87	7.67	22.16	6.36	26.33	1.02	77.67 (61.90)	2.50	25.38	9.20	12.37	1.35	1671.74	10.10	153.49	40.23
18	AKMS-30-A x Indore-26	67.33	186.20	11.67	25.52	7.69	20.00	1.09	82.67 (65.57)	1.45	32.84	12.18	13.97	1.15	2161.40	15.04	195.74	68.24
19	AKMS-30-A x ICSR-1048-Sel.-2	71.33	179.93	10.73	23.29	7.37	17.67	1.06	79.67 (63.45)	1.41	30.80	10.48	13.07	1.25	1871.71	13.38	166.22	58.23
20	AKMS-30-A x SPV-1616 x 89028-3	68.67	166.00	8.07	20.18	6.47	25.00	1.00	74.67 (59.86)	2.45	25.40	9.50	11.22	1.19	1549.80	12.05	155.15	55.21
21	AKMS-30-A x STR-293 x 426-2	69.67	187.13	11.73	23.95	7.17	20.33	1.08	76.67 (61.17)	2.06	29.93	11.08	14.07	1.27	1927.54	14.09	171.88	64.53
22	AKMS-30-A x IVT- 17-4013	66.00	171.87	9.73	22.31	7.19	22.33	1.00	76.33 (60.96)	2.15	27.77	9.05	12.27	1.36	1630.52	13.71	154.65	56.37

Sr.No.	Genotype	DT50%F	PH	NOL	PL	SH	TGMR	SG	GP	EC	1000SW	SL	RL	RSR	VIL	VIM	FY	GY
0		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
23	AKMS-30-A x ICSR-91016	68.33	194.20	13.00	25.55	7.67	13.67	1.09	83.33 (65.92)	1.29	31.62	13.11	15.45	1.18	2379.60	15.09	194.56	68.83
24	AKMS-30-A x AKR-426 x 89058	67.67	167.13	7.40	21.00	6.89	20.67	1.03	78.67 (62.60)	2.17	26.12	10.08	12.34	1.23	1760.77	11.59	146.51	45.36
25	AKMS-90-A x ICSR-8086-7-49	63.67	167.07	9.20	23.35	6.96	22.33	1.06	69.67 (56.62)	2.29	24.64	9.97	13.08	1.31	1607.38	10.83	151.50	43.36
26	AKMS-90-A x IVT-3004-1	70.33	169.60	7.60	22.23	6.40	26.33	1.00	70.33 (57.03)	2.55	24.54	10.14	13.19	1.30	1637.89	10.51	140.65	41.87
27	AKMS-90-A x IVT-4121	72.33	179.20	10.00	24.58	8.20	15.67	1.08	82.67 (65.50)	1.48	30.79	12.05	14.23	1.18	2171.06	14.98	169.11	65.55
28	AKMS-90-A x Indore-26	67.33	162.73	8.13	20.10	5.83	30.00	0.98	70.33 (57.04)	2.64	24.46	11.54	14.62	1.27	1841.61	10.31	140.11	40.80
29	AKMS-90-A x ICSR-1048-Sel.-2	71.00	185.87	11.00	22.03	7.73	14.67	1.06	76.67 (61.23)	1.64	29.85	12.06	14.35	1.19	2025.74	13.22	172.59	60.05
30	AKMS-90-A x SPV-1616 x 89028	69.67	158.87	9.13	20.65	7.03	25.00	1.03	78.67 (62.57)	1.45	27.56	10.08	13.01	1.29	1817.48	11.06	145.22	53.54
31	AKMS-90-A x STR-293 x 426-2	69.67	180.60	12.13	23.72	8.83	12.67	1.12	86.00 (68.06)	1.27	31.18	12.80	15.40	1.20	2424.05	15.02	185.73	71.01
32	AKMS-90-A x IVT-17-4013	69.33	165.40	9.07	22.82	6.01	25.33	1.04	74.67 (59.84)	2.47	26.62	8.72	11.53	1.33	1512.20	10.96	160.50	51.39
33	AKMS-90-A x ICSR-91016	67.00	172.80	7.27	19.42	7.19	20.33	1.06	76.33 (60.96)	2.18	25.77	9.01	11.09	1.24	1534.06	11.18	141.87	43.59
34	AKMS-90-A x AKR-426 x 89058	67.67	175.93	9.93	20.66	6.35	24.33	1.05	72.00 (58.09)	2.25	25.65	9.05	12.14	1.34	1524.97	11.58	145.42	47.17
35	AKMS-751-A x ICSR-8086-7-49	66.33	157.87	8.67	20.21	6.19	25.67	1.01	69.33 (56.39)	2.67	26.48	8.45	11.63	1.38	1392.60	12.58	150.97	50.85
36	AKMS-751-A x IVT-3004-1	71.67	180.67	11.40	22.19	8.03	15.67	1.08	81.33 (64.45)	1.45	27.60	12.53	15.09	1.21	2248.61	14.52	179.47	64.67

Sr.No.	Genotype	DT50%F	PH	NOL	PL	SH	TGMR	SG	GP	EC	1000SW	SL	RL	RSR	VIL	VIM	FY	GY
0		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
37	AKMS-751-A x IVT-4121	68.00	198.77	12.93	24.74	7.23	14.00	1.08	83.67 (66.24)	1.36	31.94	12.62	15.32	1.21	2336.82	13.66	196.39	67.76
38	AKMS-751-A x Indore-26	67.67	149.73	9.80	21.36	7.19	24.00	1.04	70.33 (57.04)	1.50	26.18	8.57	10.97	1.28	1376.73	11.67	144.20	52.60
39	AKMS-751-A x ICSR-1048-Sel.-2	70.67	157.60	10.00	20.73	7.03	22.33	1.02	69.67 (56.59)	2.22	24.51	9.84	12.60	1.28	1563.51	11.16	140.59	44.83
40	AKMS-751-A x SPV-1616 x 89028-3	69.33	182.93	12.13	24.82	7.65	18.33	1.06	80.67 (63.93)	1.43	30.87	12.50	14.42	1.15	2171.08	14.94	173.87	65.90
41	AKMS-751-A x STR-293 x 426-2	68.67	165.73	8.27	24.41	6.51	25.67	1.02	70.33 (57.00)	2.61	24.18	9.53	12.96	1.36	1581.94	10.52	145.35	46.24
42	AKMS-751-A x IVT-17-4013	69.67	197.20	12.80	24.31	8.51	14.67	1.10	83.33 (65.96)	1.52	30.35	12.37	15.13	1.23	2292.44	14.79	189.84	65.94
43	AKMS-751-A x ICSR-91016	62.33	164.00	7.33	19.08	6.08	25.00	0.97	69.00 (56.17)	2.64	25.04	9.16	12.64	1.39	1504.29	10.33	162.63	43.70
44	AKMS-751-A x AKR-426 x 89058	68.00	176.07	9.93	20.79	7.68	19.67	1.02	72.67 (58.52)	2.15	25.68	9.69	12.97	1.34	1645.22	11.45	168.49	50.58
45	AKMS-733-A x ICSR-8086-7-49	71.33	182.40	12.13	24.30	8.11	17.67	1.06	76.00 (60.71)	1.71	28.53	11.73	14.24	1.21	1974.46	13.15	176.66	61.41
46	AKMS-733-A x IVT-3004-1	68.33	158.20	9.40	21.02	6.10	22.00	1.01	73.33 (58.96)	2.30	26.74	8.58	11.24	1.31	1452.98	10.43	146.51	47.91
47	AKMS-733-A x IVT-4121	70.00	188.53	11.40	26.63	9.07	11.67	1.12	85.67 (67.92)	1.25	33.56	13.30	16.05	1.21	2512.92	15.02	174.78	70.13
48	AKMS-733-A x Indore-26	69.67	175.33	9.60	21.98	6.73	23.67	1.04	71.33 (57.64)	2.28	25.57	9.49	12.74	1.34	1585.54	10.58	168.51	45.03
49	AKMS-733-A x ICSR-1048-Sel.-2	70.00	182.93	12.87	23.50	8.01	15.00	1.08	82.67 (62.47)	1.40	30.75	12.55	15.06	1.20	2281.83	13.58	179.57	65.16
50	AKMS-733-A x SPV-1616 x 89028-3	67.67	172.07	8.93	21.07	7.45	22.00	1.02	70.67 (57.23)	2.18	26.18	8.79	11.15	1.27	1408.33	10.77	144.78	49.60

Sr.No.	Genotype	DT50%F	PH	NOL	PL	SH	TGMR	SG	GP	EC	1000SW	SL	RL	RSR	VIL	VIM	FY	GY
0		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
51	AKMS-733-A x STR-293 x 426-2	68.33	155.73	8.40	22.69	6.86	20.33	1.05	73.00 (58.70)	2.05	25.50	8.64	11.56	1.34	1475.31	10.97	150.08	52.13
52	AKMS-733-A x IVT-17-4013	70.67	180.00	10.60	24.13	7.60	15.67	1.09	82.33 (65.15)	1.29	31.15	12.11	13.91	1.15	2143.25	14.83	181.08	65.71
53	AKMS-733-A x ICSR-91016	70.00	167.33	8.07	19.80	6.05	26.33	1.06	74.00 (59.35)	2.59	25.57	10.56	13.46	1.28	1777.59	10.29	184.83	50.64
54	AKMS-733-A x AKR-426 x 89058	67.33	174.93	9.40	20.07	7.07	24.67	1.00	69.67 (56.58)	2.43	25.22	8.94	11.16	1.25	1400.13	10.69	146.99	40.16
Check																		
55	CSH-35	69.00	165.13	10.87	23.63	7.59	22.33	1.05	78.33 (62.26)	1.86	29.19	9.87	12.48	1.27	1751.24	12.54	165.44	53.10
	Mean	68.63	168.09	9.73	22.28	7.05	21.67	1.04	75.23	2.05	27.64	10.27	12.89	1.27	1752.99	12.12	158.06	51.25
	SE(m)	1.63	6.92	0.57	1.11	0.22	0.57	0.01	1.38	0.04	0.74	0.24	0.37	0.05	54.29	0.19	6.59	2.12
	CD at 5 %	4.55	19.41	1.58	3.12	0.61	1.59	0.02	3.87	0.12	2.06	0.68	1.03	0.14	152.18	0.54	18.48	5.93

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 (figures in parenthesis are Arc sine value), 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.

g. Specific gravity of seed (g/ml)

The average specific gravity of seed ranged between 0.98 to 1.07 g/ml for parents and 0.97 to 1.12 g/ml for hybrids (Table 4.2).

Among the parents, highest specific gravity of seed was recorded by tester ICSR-1048-Sel.-2 (1.07 g/ml) followed by tester SPV-1616 x 89028-3 (1.06 g/ml) and female lines AKMS-733-A (1.06 g/ml) while IVT-3004-1, STR-293 x 426-2 and ICSR-91016 (0.97 g/ml) recorded minimum specific gravity of seed.

Among the hybrids, eleven hybrids were significantly superior over the check CSH-35 (1.05 g/ml). Two hybrids found maximum specific gravity AKMA-90-A x STR-293 x 426-2 and AKMS-733-A x IVT-4121 (1.12 g/ml) recorded maximum specific gravity of seed followed by AKMS-751-A x IVT-17-4013 (1.10 g/ml), AKMS-30-A x Indore-26, AKMS-733-A x IVT-17-4013 and AKMS-30-A x ICSR-91016 (1.09 g/ml). Whereas, AKMS-751-A x ICSR-91016 (0.97 g/ml) recorded minimum specific gravity of seed.

h. Germination percentage of seed (%)

The average germination percentage of seed ranged between 68.00 to 78.00 % for parents and 69.00 to 86.00 % for hybrids (Table 4.2).

Among the parents, highest germination percentage of seed was recorded by tester ICSR-1048-Sel.-2 (78.00%) followed by STR-293 x 426-2 (76.67%) and female line AKMS-733-A (76.67%), while ICSR-91016 (68.00%) recorded lowest germination percentage of seed.

Among the hybrids, nine hybrids recorded significant superiority over the check CSH-35 (78.33%) for germination percentage of seed. Hybrid AKMS-90-A x STR-293 x 426-2 (86.00%) was recorded maximum germination percentage of seed followed by AKMS-733-A x IVT-4121 (85.67%), AKMS-751-A x IVT-4121 (83.67%) and AKMS-30-A x ICSR-91016, AKMS-751-A x IVT-17-4013(83.33%). Whereas, AKMS-751-A x ICSR-91016 (69.00%) recorded lowest germination percentage of seed.

i. Electrical conductivity (dSm⁻¹)

The average electrical conductivity of seed ranged between 1.60 to 2.72 dSm⁻¹ for parents and 1.25 to 2.67 dSm⁻¹ for hybrids (Table 4.2).

Among the parents, lowest electrical conductivity was recorded by tester ICSR-1048 Sel.-2 (1.60 dSm⁻¹) and line AKMS-733-A (1.60 dSm⁻¹), while the tester IVT-3004-1 (2.72 dSm⁻¹) and line AKMS-30-A (2.58 dSm⁻¹) recorded maximum electrical conductivity.

Among the hybrids, sixteen hybrids were significantly superior over the check CSH-35 (1.86 dSm⁻¹). Hybrid AKMS-733-A x IVT-4121 (1.25 dSm⁻¹) recorded minimum electrical conductivity followed by AKMS-90-A x STR-293 x 426-2 (1.27dSm⁻¹), AKMS-30-A x ICSR-91016 (1.29 dSm⁻¹), AKMS-733-A x IVT-17-4013 (1.29 dSm⁻¹) and AKMS-751-A x IVT-4121 (1.36 dSm⁻¹). Whereas, AKMS-751- A x ICSR-8086-7-49 (2.67 dSm⁻¹) recorded maximum electrical conductivity.

j. 1000 seed weight (g)

1000 seed weight per plant ranged between 24.57 to 30.07 g for parents and 24.18 to 33.56 g for hybrids (Table 4.2).

Among the parents, highest 1000 seed weight was recorded by ICSR 1048-Sel.-2 (30.07 g) followed by STR-293 x 426-2 (29.83g), while IVT-3004-1 (24.57 g) recorded minimum 1000 seed weight.

Among 40 hybrids, four hybrids recorded significant superiority over the check CSH-35 (29.19 g) for 1000 seed weight. The hybrid AKMS-733-A x IVT-4121 (33.56 g) recorded maximum 1000 seed weight followed by AKMS-30-A x Indore-26 (32.83 g) and AKMS-751-A x IVT-4121 (31.94 g). Whereas, AKMS-751-A x STR-293 x 426-2 (24.18 g) recorded lowest 1000 seed weight.

k. Shoot length (cm)

The average shoot length ranged from 8.52 to 11.72 cm and 8.45 to 13.30 cm among the parents and hybrids, respectively (Table 4.2).

Among 14 parents, maximum shoot length was recorded by line AKMS-733-A (11.71 cm). However, tester IVT-3004 (8.52 cm) recorded minimum shoot length.

Among the hybrids, sixteen hybrids were significantly superior for shoot length over the check CSH-35 (9.87 cm). Hybrid AKMS-733-A x IVT-4121 (13.30 cm) was significantly superior for shoot length followed by AKMS-30-A x ICSR-91016 (13.11 cm), AKMS-90-A x STR-293 x 426-2 (12.80 cm) and AKMS-751-A x IVT-4121 (12.62 cm). Whereas, the hybrid AKMS-751-A x ICSR-8086-7-49 (8.45 cm) recorded minimum shoot length.

l. Root length (cm)

The average root length ranged from 9.97 to 13.60 cm and 10.97 to 16.05 cm among the parents and hybrids, respectively (Table 4.2).

Among 14 parents, maximum root length was recorded by tester STR-293 x 426-2 (13.60 cm). However, tester IVT-3004-1 (9.97 cm) recorded minimum root length.

Among the hybrids, fifteen hybrids were significantly superior over the check CSH-35 (12.48 cm) for root length. Hybrid AKMS-733 x IVT-4121 (16.05 cm) significantly superior followed by AKMS-30-A x ICSR-91016 (15.45 cm), AKMS-90-A x STR-293 x 426-2 (15.40 cm) and AKMS-751-A x IVT-4121 (15.32 cm). Whereas, AKMS-751-A x Indore-26 (10.97 cm) recorded minimum root length.

m. Root shoot ratio

The average root shoot ratio ranged from 1.15 to 1.38 and 1.15 to 1.39 among the parents and hybrids, respectively (Table 4.2).

Among 14 parents, maximum root shoot ratio was recorded by tester AKR-426 x 89058 (1.39). However, line AKMS-733-A (1.15) recorded minimum root shoot ratio.

Among the hybrids, none of hybrid was significantly superior for root shoot ratio over the check CSH-35 (1.27). Hybrid AKMS-751-A x ICSR-8086-7-49 and AKMS-751-A x ICSR-91016 (1.39) recorded maximum root shoot ratio followed by AKMS-30-A x IVT-17-4013 and

AKMS-751-A x STR-293 x 426-2 (1.36). Whereas, the hybrid AKMS-30-A x Indore-26, AKMS-751-A x SPV-1616 x 89028-3 and AKMS-733-A x IVT-4013 (1.15) recorded minimum root shoot ratio.

n. Length vigour index

The average vigour index length ranged from 1263.77 to 1960.19 and 1376.72 to 2512.92 among the parents and hybrids, respectively (Table 4.2).

Among 14 parents, maximum vigour index length was recorded by tester ICSR-1048-Sel.-2 (1960.19). However, tester IVT-3004 (1263.77) recorded minimum vigour index length.

Among the hybrids, fourteen hybrids were significantly superior for vigour index length over the check CSH-35 (1751.24). Hybrid AKMS-733-A x IVT-4121 (2512.92) was significantly superior for vigour index length followed by AKMS-90-A x STR-293 x 426-2 (2424.05), AKMS-30-A x ICSR-91016 (2379.60) and AKMS-751-A x IVT-4121 (2336.82). Whereas, the hybrid AKMS-751-A x Indore-26 (1376.72) recorded minimum vigour index length.

o. Mass vigour index

The average vigour index mass ranged from 9.87 to 12.65 and 10.09 to 15.09 among the parents and hybrids, respectively (Table 4.2).

Among 14 parents, maximum vigour index mass was recorded by tester ICSR-1048-Sel.-2 (12.65). However, tester IVT-3004-1 (9.87) and line AKMS-30-A (10.52) recorded minimum vigour index mass.

Among the hybrids, sixteen hybrids were significantly superior for vigour index mass over the best check CSH-35 (12.54). Hybrid AKMS-30-A x ICSR-91016 (15.09) was significantly superior for vigour index mass followed by AKMS-30-A x Indore-26 (15.04), AKMS-90-A x STR-293 x 426-2 (15.02), AKMS-733-A x IVT4121 (15.02) and AKMS-90-A x IVT-4121 (14.98). Whereas, the hybrid AKMS-30-A x IVT-4121 (10.10) recorded minimum vigour index mass.

p. Fodder yield per plant (g)

The average fodder yield per plant ranged from 130.35 to 164.77 g and 140.11 to 196.39 g among the parents and hybrids, respectively (Table 4.2).

Among the parents, tester ICSR-1048-Sel.-2 (164.77 g) recorded the highest fodder yield followed by tester STR-293 x 426-2 (161.83 g). Whereas, line AKMS-30-A (130.35 g) recorded minimum fodder yield per plant.

Among the hybrids, six hybrids recorded significant superiority over the check CSH-35 (165.44 g) for fodder yield per plant. The hybrid AKMS-751-A x IVT-4121 (196.39 g) recorded maximum fodder yield per plant followed by AKMS-30-A x Indore-26 (195.74 g), AKMS-30-A x ICSR-91016 (194.56 g) and AKMS-751-A x IVT-17-4013 (189.84g). Whereas, AKMS-90-A x Indore-26 (140.11g) recorded lowest fodder yield per plant.

q. Grain yield per plant (g)

The average grain yield per plant ranged from 32.59 g to 55.16 g and 40.16 g to 71.01 g among the parents and hybrids, respectively (Table 4.2).

Among the parents, ICSR-1048-Sel.-2 (55.16 g) recorded the highest grain yield followed by tester AKR-426 x 89058 (47.10 g) whereas, tester IVT-17-4013 (32.59 g) recorded minimum grain yield per plant.

Among the 40 hybrids, fourteen hybrids recorded significant superiority over the check CSH-35 (53.10 g) for grain yield per plant. The hybrid AKMS-90-A x STR-293 x 426-2 (71.01 g) recorded maximum grain yield per plant followed by AKMS-733-A x IVT-4121 (70.13 g), AKMS-30-A x ICSR-91016 (68.83 g), and AKMS-30-A x Indore-26 (68.24 g). Whereas, AKMS-733-A x AKR-426 x 89058 (40.16 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 1.67 to 23.58 % for different characters under study. The highest order value of genotypic coefficient of variation was observed for electrical conductivity (23.58%) followed by threshed grain mold rating (22.15%), grain yield per plant (19.37%), vigour index length (18.11%), no. of leaves (15.96%), shoot length (14.16%), vigour index mass (13.15%), root length (10.68%), seed hardness (10.67%), fodder yield per plant (10.34%), 1000 seed weight (8.58%), panicle length (7.54%), plant height (7.50%), germination percentage of seed (6.07%) , root shoot ratio (3.76%), specific gravity of seed (3.32%) and days to 50% flowering (1.67%).

4.3.2 Phenotypic Coefficient of Variation (%)

The phenotypic coefficient of variation (Table 4.3) ranged from 23.88 to 3.51 % for various characters under study. The highest order value of phenotypic coefficient of variation was observed for electrical conductivity (23.88%) followed by threshed grain mold rating (22.61%), grain yield per plant (20.64%), vigour index length (18.89%), number of leaves (18.87%), shoot length (14.75%), vigour index mass (13.43%), fodder yield per plant (12.62%), seed hardness (11.93%), root length (11.76%), panicle length (11.48%), plant height (10.35%), 1000 seed weight (9.73) root shoot ratio (7.72%), germination percentage (7.63%) days to 50% flowering (4.43%) and specific gravity (3.51).

4.3.3 Heritability estimates in broad sense (%)

Data presented in Table 4.3 revealed that heritability estimates ranged from 14.20 to 97.50 % for various characters under study. Highest heritability estimate in broad sense was observed for electrical conductivity (97.50%) followed by threshed grain mold rating (96.00%), vigour index mass (95.80%), shoot length (92.30%), vigour index length (91.90%), specific gravity (89.90%), grain yield per plant (88.00%), root length (82.40%), seed hardness (79.90%), 1000 seed weight (77.60%), no. of leaf (71.50%), fodder yield per plant (67.20%), germination percentage (63.20%), plant height (52.50%), panicle length (43.10%), root length (23.70%), days to 50 % flowering (14.20%).

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 1.29 to 47.98 percent for different characters. The highest genetic advance percent over mean was observed for the character electrical conductivity (47.98%) followed by threshed grain mold rating (44.71%), grain yield per plant (37.42%), vigour index length (35.78%), shoot length (28.02%), no. of leaf (27.81%), vigour index mass (26.50%), root length (19.98%), seed hardness (19.65%), fodder yield per plant (17.47%), 1000 seed weight (15.37%), plant height (11.19%), panicle length (10.19%), germination percentage (9.94%), specific gravity of seed (6.49%), root shoot ratio (3.77%), days to 50% flowering (1.29%).

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

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	62.33 – 72.33	68.630	2.297	1.31	9.22	1.67	4.43	14.20	1.29
2	Plant height (cm)	139.33 -198.76	168.087	9.791	158.83	302.64	7.50	10.35	52.50	11.19
3	number of leaves	7.26 – 13.00	9.725	0.799	2.41	3.37	15.96	18.87	71.50	27.81
4	Panicle length (cm)	16.40 -26.63	22.277	1.575	2.82	6.54	7.54	11.48	43.10	10.19
5	Seed hardness (kg/cm ²)	5.82 - 9.07	7.049	0.307	0.57	0.71	10.67	11.93	79.90	19.65
6	Threshed grain mold rating (%)	11.66 – 32.00	21.667	0.801	23.04	24.00	22.15	22.61	96.00	44.71
7	Specific gravity of seed (g/ml)	0.97 - 1.12	1.044	0.0095	0.00	0.00	3.32	3.51	89.90	6.49
8	Germination % of seed	68.00 -86.00	75.230	1.952	20.85	32.98	6.07	7.63	63.20	9.94
9	Electrical conductivity (dSm ⁻¹)	1.25 -2.72	2.046	0.0627	0.23	0.24	23.58	23.88	97.50	47.98
10	1000 seed weight (g)	24.18 -33.56	27.641	1.0391	5.62	7.24	8.58	9.73	77.60	15.37
11	Shoot length (cm)	8.45 -13.29	10.265	0.344	2.11	2.29	14.16	14.75	92.30	28.02
12	Root length (cm)	10.97 -16.05	12.894	0.5188	1.90	2.30	10.68	11.76	82.40	19.98
13	Root shoot ratio	1.15 -1.38	1.265	0.0696	0.00	0.01	3.76	7.72	23.70	3.77
14	Vigour index length	1263.77 -2512.92	1752.991	76.776	100830.40	109672.30	18.11	18.89	91.90	35.78
15	Vigour index mass	9.87 -15.08	12.120	0.2727	2.54	2.65	13.15	13.43	95.80	26.50
16	Fodder yield per plant (g)	130.35 -196.39	158.064	9.3214	267.31	397.65	10.34	12.62	67.20	17.47
17	Grain yield per plant (g)	32.58 – 71.01	51.248	2.992	98.50	111.92	19.37	20.64	88.00	37.42

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 fodder yield per plant ($r = 0.938^{**}$), germination percentage of seed ($r = 0.928^{**}$), vigour index mass ($r = 0.926^{**}$), plant height ($r = 0.867^{**}$), no of leaf ($r = 0.866^{**}$), 1000 seed weight ($r = 0.862^{**}$), vigour index length ($r = 0.857^{**}$), shoot length ($r = 0.788^{**}$), seed hardness ($r = 0.778^{**}$), specific gravity ($r = 0.776^{**}$), panicle length ($r = 0.768^{**}$), root length ($r = 0.754^{**}$) and days to 50 % flowering ($r = 0.663^{**}$). On the other hand electrical conductivity ($r = -0.836^{**}$), threshed grain mold rating ($r = -0.805^{**}$), and root shoot ratio ($r = -0.739^{**}$) 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 1000 seed weight ($r = 0.795^{**}$), germination percentage ($r = 0.782^{**}$), vigour index length ($r = 0.769^{**}$), number of leaves ($r = 0.752^{**}$), shoot length ($r = 0.750^{**}$), root length ($r = 0.733^{**}$), specific gravity ($r = 0.688^{**}$), fodder yield per plant ($r = 0.683^{**}$), grain yield per plant ($r = 0.663^{**}$), seed hardness ($r = 0.618^{**}$), vigour index mass ($r = 0.593^{**}$), plant height ($r = 0.548^{**}$) and panicle length ($r = 0.511^{**}$). On the other hand, it showed negative and highly significant association with root shoot ratio ($r = -0.758^{**}$), electrical conductivity electrical ($r = -0.728^{**}$), and thresh grain mold rating ($r = -0.701^{**}$) at genotypic level.

b. Plant height

Plant height exhibited positive and highly significant correlation with fodder yield per plant ($r = 0.939^{**}$), germination percentage ($r = 0.876^{**}$), grain yield per plant ($r = 0.867^{**}$), vigour index length ($r = 0.860^{**}$), number of leaves ($r = 0.849^{**}$), shoot length ($r = 0.815^{**}$), root length ($r = 0.809^{**}$) vigour index mass ($r = 0.781^{**}$), seed hardness ($r = 0.733^{**}$) 1000 seed weight ($r = 0.707^{**}$), specific gravity ($r = 0.654^{**}$) and panicle length ($r = 0.579^{**}$). On the other hand, plant height showed negative and highly significant association with root shoot ratio ($r = -0.728^{**}$), threshed grain mold rating ($r = -0.724^{**}$), electrical conductivity ($r = -0.592^{**}$) at genotypic level.

c. Number of leaves

Number of leaves showed positive and highly significant correlation with 1000 seed weight ($r = 0.903^{**}$), fodder yield per plant ($r = 0.895^{**}$), grain yield per plant ($r = 0.866^{**}$), vigour index mass ($r = 0.851^{**}$), and vigour index length ($r = 0.834^{**}$), germination of seed ($r = 0.816^{**}$), seed hardness ($r = 0.800^{**}$), shoot length ($r = 0.799^{**}$), root length ($r = 0.798$), panicle length ($r = 0.789^{**}$) and specific gravity ($r = 0.723^{**}$). While characters like electrical conductivity ($r = -0.842^{**}$), thresh grain mold rating ($r = -0.823^{**}$) and root shoot ratio ($r = -0.682^{**}$) expressed negative and highly significant association with number of leaves at genotypic level.

d. Panicle length

Panicle length expressed positive and highly significant association with germination percentage ($r = 0.889^{**}$), 1000 seed weight ($r = 0.856^{**}$), fodder yield per plant ($r = 0.834^{**}$), vigour index length ($r = 0.806^{**}$), vigour index mass ($r = 0.777^{**}$), grain yield per plant ($r = 0.768^{**}$), root length ($r = 0.743^{**}$), shoot length ($r = 0.714^{**}$), specific gravity ($r = 0.713^{**}$) and seed hardness ($r = 0.665^{**}$). While Electrical conductivity ($r = -0.769^{**}$), threshed grain mold rating ($r = -0.678^{**}$) and root shoot ratio ($r = -0.492^{**}$) exhibited negative and highly significant association with panicle length 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	0.548**	0.752**	0.511**	618**	-0.701**	0.688**	0.782**	-0.728**	0.795**	0.750**	0.733**	-0.758**	0.769**	0.593**	0.683**	0.663**
PH		0.849**	0.579**	0.733**	-0.724**	0.654**	0.876**	-0.592**	0.707**	0.815**	0.809**	-0.728**	0.860**	0.781**	0.939**	0.867**
NOL			0.789**	0.800**	-0.823**	0.723**	0.816**	-0.842**	0.903**	0.799**	0.798**	-0.682**	0.834**	0.851**	0.895**	0.866**
PL				655**	-0.678**	0.713**	0.889**	-0.769**	0.856**	0.714**	0.743**	-0.492**	0.806**	0.777**	0.834**	0.768**
SH					-0.917**	0.689**	0.825**	-0.831**	0.784**	0.759**	0.734**	-0.722**	0.801**	0.788**	0.715**	0.778**
TGMR						-0.735**	-0.863**	0.864**	-0.801**	-0.756**	-0.725**	0.709**	-0.810**	-0.796**	-0.783**	-0.805**
SG							0.855**	-0.751**	0.767**	0.685**	0.658**	-0.653**	0.762**	0.730**	0.734**	0.776**
GP								-0.909**	0.962**	0.906**	0.845**	-0.948**	0.947**	0.911**	0.915**	0.928**
EC									-0.838**	-0.724**	-0.670**	0.757**	-0.796**	-0.814**	-0.743**	-0.836**
1000SW										0.800**	0.724**	-0.877**	0.860**	0.895**	0.813**	0.862**
SL											0.987**	-0.901**	0.993**	0.784**	0.861**	0.788**
RL												-0.819**	0.969**	0.721**	0.866**	0.754**
RSR													-0.923**	-0.819**	-0.689**	-0.739**
VIL														0.839**	0.908**	0.857**
VIM															0.811**	0.926**
FY																0.938**

*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.

e. Seed hardness

Seed hardness exhibited positive and highly significant association with germination percentage ($r = 0.825^{**}$), vigour index length ($r = 0.801^{**}$), vigour index mass ($r = 0.788^{**}$), 1000 seed weight ($r = 0.784^{**}$), grain yield per plant ($r = 0.778^{**}$), shoot length ($r = 0.759^{**}$), root length ($r = 0.734^{**}$), fodder yield per plant ($r = 0.715^{**}$) and specific gravity ($r = 0.689^{**}$). Whereas, the characters threshed grain mold rating ($r = -0.917^{**}$), electrical conductivity ($r = -0.831^{**}$) and root shoot ratio ($r = -0.722^{**}$) 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 electrical conductivity ($r = 0.864^{**}$) and root shoot ratio ($r = 0.709^{**}$). On the other hand, the characters germination percentage of seed ($r = -0.863^{**}$), vigour index length ($r = -0.810^{**}$), grain yield per plant ($r = -0.805^{**}$), 1000 seed weight ($r = 0.801^{**}$), vigour index mass ($r = -0.796^{**}$), fodder yield per plant ($r = -0.783^{**}$), shoot length ($r = -0.756^{**}$), specific gravity ($r = -0.735^{**}$) and root length ($r = -0.725^{**}$) 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 germination percentage ($r = 0.855^{**}$), grain yield per plant ($r = 0.776^{**}$), 1000 seed weight ($r = 0.767^{**}$), vigour index length ($r = 0.762^{**}$), fodder yield per plant ($r = 0.734^{**}$), vigour index mass ($r = 0.730^{**}$), shoot length ($r = 0.685^{**}$) and root length ($r = 0.658^{**}$). Whereas the characters electrical conductivity ($r = -0.751^{**}$) and root shoot ratio ($r = -0.653^{**}$) 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 1000 seed weight ($r = 0.962^{**}$) vigour index

length ($r = 0.947^{**}$), grain yield per plant ($r = 0.928^{**}$), fodder yield per plant ($r = 0.915^{**}$), vigour index mass ($r = 0.911^{**}$), shoot length ($r = 0.906^{**}$), and root length ($r = 0.845^{**}$). On the other hand, character root shoot ratio ($r = -0.948^{**}$) and electrical conductivity ($r = -0.909^{**}$) 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 1000 seed weight ($r = -0.838^{**}$), grain yield per plant ($r = -0.836^{**}$), vigour index mass ($r = -0.814^{**}$), vigour index length ($r = -0.796^{**}$), fodder yield per plant ($r = -0.743^{**}$), shoot length ($r = -0.724^{**}$), and root length ($r = -0.670^{**}$). Whereas, character root shoot ratio ($r = 0.757^{**}$) 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 ($r = 0.895^{**}$), vigour index length ($r = 0.860^{**}$), grain yield per plant ($r = 0.862^{**}$), fodder yield per plant ($r = 0.813^{**}$), shoot length ($r = 0.800^{**}$), root length ($r = 0.724^{**}$), and character like root shoot ratio ($r = -0.877^{**}$) showed the highly significant negative correlation with 1000 seed weight at genotypic level.

k. Shoot length

Shoot length expressed positive and highly significant association with vigour index length ($r = 0.993^{**}$), root length ($r = 0.987^{**}$), fodder yield per plant ($r = 0.861^{**}$), grain yield per plant ($r = 0.788^{**}$) and vigour index mass ($r = 0.784^{**}$). Whereas root shoot ratio ($r = -0.901^{**}$) 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 ($r = 0.969^{**}$), fodder yield per plant ($r = 0.866^{**}$), grain yield per plant ($r = 0.754^{**}$), and vigour index mass ($r =$

0.721**), Whereas root shoot ratio ($r = -0.819^{**}$) exhibited negative and highly significant association with root length at genotypic level.

m. Root shoot ratio

Root shoot ratio exhibited negative and highly significant association with vigour index length ($r = -0.923^{**}$), vigour index mass ($r = -0.819$), grain yield per plant ($r = -0.739^{**}$) and fodder yield per plant ($r = -0.689^{**}$) at genotypic level.

n. Vigour index length

Vigour index length showed positive and highly significant association with fodder yield per plant ($r = 0.908^{**}$), grain yield per plant ($r = 0.857^{**}$) and vigour index mass ($r = 0.839^{**}$) at genotypic level.

o. Vigour index mass

Character grain yield per plant ($r = 0.926^{**}$) and fodder yield per plant yield ($r = 0.811^{**}$) 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 vigour index mass ($r = 0.845^{**}$), vigour index length ($r = 0.784^{**}$), seed germination percentage ($r = 0.726^{**}$), shoot length ($r = 0.710^{**}$), fodder yield ($r = 0.710^{**}$), 1000 seed weight ($r = 0.685^{**}$), specific gravity ($r = 0.681^{**}$), no. of leaves ($r = 0.674^{**}$), seed hardness ($r = 0.642^{**}$) root length ($r = 0.642^{**}$), plant height ($r = 0.625^{**}$), panicle length ($r = 0.517^{**}$) and days to 50 % flowering ($r = 0.248^{**}$). On the other hand, traits like electrical conductivity ($r = -0.762^{**}$), threshed grain mold rating ($r = -0.740^{**}$) and root shoot ratio ($r = -0.338$) 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 seed hardness ($r = 0.3495^{**}$), shoot length ($r = 0.2983^{**}$), vigour index length ($r = 0.2740^{**}$), no. of leaves ($r = 0.2740^{**}$), panicle length ($r = 0.2356^{**}$), germination percentage ($r = 0.2261^{**}$), root length ($r = 0.2238^{**}$), 1000 seed weight ($r = 0.2126^{**}$), vigour index mass ($r = 0.2183^{**}$) and specific gravity ($r = 0.2123^{**}$) showed positive and highly significant association with day to 50% flowering. On the other hand, negative and highly significant association with day to 50% flowering was shown by character electrical conductivity ($r = -0.2769^{**}$), thresh grain mold rating ($r = -0.2650^{**}$) and root shoot ratio ($r = -0.2288^{**}$). While positive and non significant association exhibited by characters fodder yield per plant ($r = 0.1244$) and plant height ($r = 0.0792$) at phenotypic level.

b. Plant height

Plant ($r = 0.6245^{**}$), vigour index length ($r = 0.5793^{**}$), shoot length ($r = 0.5573^{**}$), root length ($r = 0.5402^{**}$), vigour index mass ($r = 0.5350^{**}$), fodder yield per plant ($r = 0.5268^{**}$), number of leaves ($r = 0.4882^{**}$), specific gravity ($r = 0.4870^{**}$), germination percentage ($r = 0.4670^{**}$), seed hardness ($r = 0.4270^{**}$) and panicle length ($r = 0.2518^{**}$). On the other hand threshed grain mold rating ($r = -0.5254^{**}$), electrical conductivity ($r = -0.4299^{**}$) and root shoot ratio ($r = -0.2133^{**}$) exhibited negative but highly significant correlation at phenotypic level.

c. Number of leaves

Number of leaves showed positive and highly significant correlation with vigour index mass ($r = 0.7259^{**}$), vigour index length ($r = 0.6790^{**}$), grain yield per plant ($r = 0.6741^{**}$), 1000 seed weight ($r = 0.6713^{**}$), shoot length ($r = 0.6657^{**}$), seed hardness ($r = 0.6242^{**}$), root length ($r = 0.5870^{**}$) fodder yield per plant ($r = 0.5862^{**}$) specific gravity ($r = 0.5743^{**}$), germination percentage ($r = 0.5598^{**}$) and panicle length ($r = 0.4588^{**}$) While, the character electrical conductivity ($r = -0.7057^{**}$), thresh grain mold rating ($r = -0.6731^{**}$) and root shoot ratio ($r = -0.3502^{**}$) exhibited negative and highly significant association with number of leaves at phenotypic level.

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	0.0792	0.2463**	0.2356**	0.3495**	-0.2650**	0.2123**	0.2261**	-0.2769**	0.2126**	0.2983**	0.2238**	-0.2288**	0.2740**	0.2183**	0.1244	0.2483**
PH		0.4882**	0.2518**	0.4270**	-0.5254**	0.4870**	0.4670**	-0.4299**	0.4420**	0.5573**	0.5402**	-0.2133**	0.5793**	0.5350**	0.5268**	0.6245**
NOL			0.4588**	0.6242**	-0.6731**	0.5743**	0.5598**	-0.7057**	0.6713**	0.6657**	0.5870**	-0.3502**	0.6790**	0.7259**	0.5862**	0.6741**
PL				0.4259**	-0.4225**	0.4602**	0.4118**	-0.5001**	0.4659**	0.4663**	0.4406**	-0.1937**	0.4928**	0.4824**	0.3903**	0.5166**
SH					-0.8094**	0.6006**	0.6054**	-0.7312**	0.6148**	0.6515**	0.5694**	-0.3547**	0.6871**	0.6947**	0.5081**	0.6422**
TGMR						-0.6903**	-0.6805**	0.8325**	-0.6900**	-0.7076**	-0.6540**	0.3192**	-0.7656**	-0.7653**	-0.6236**	-0.7395**
SG							0.6345**	-0.7130**	0.6226**	0.6261**	0.5525**	-0.3219**	0.6832**	0.6706**	0.5564**	0.6806**
GP								-0.7071	0.6670**	0.6644**	0.6010**	-0.3138**	0.8584**	0.7111**	0.6135**	0.7258**
EC									-0.7374**	-0.6822**	-0.5951**	0.3611**	-0.7466**	-0.7893**	-0.6006**	-0.7615**
1000SW										0.6884**	0.5670**	-0.4266**	0.7256**	0.7803**	0.5843**	0.6846**
SL											0.8591**	-0.5780**	0.9304**	0.7368**	0.6734**	0.7100**
RL												-0.0841	0.8989**	0.6323**	0.6638**	0.6424**
RSR													-0.3715**	-0.4026**	-0.2427**	0.3377**
VIL														0.7850**	0.7269**	0.7841**
VIM															0.6487**	0.8446**
FY																0.7103**

*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 grain yield per plant ($r = 0.5166^{**}$), vigour index length ($r = 0.4928^{**}$), vigour index mass ($r = 0.4824^{**}$), shoot length ($r = 0.4663^{**}$), 1000 seed weight ($r = 0.4659^{**}$), specific gravity ($r = 0.4602^{**}$), root length ($r = 0.4406^{**}$) seed hardness ($r = 0.4259^{**}$), germination percentage ($r = 0.4118^{**}$) and fodder yield per plant ($r = 0.3903^{**}$). On the other hand, panicle length showed negative and highly significant association with electrical conductivity ($r = -0.5001^{**}$), threshed grain mold rating ($r = -0.4225^{**}$) and root shoot ratio ($r = -0.1937^{*}$) at phenotypic level.

e. Seed hardness

Seed hardness exhibited positive and highly significant association with vigour index mass ($r = 0.6947^{**}$), vigour index length ($r = 0.6871^{**}$), shoot length ($r = 0.6515^{**}$), grain yield per plant ($r = 0.6422^{**}$), 1000 seed weight ($r = 0.6148^{**}$), germination percentage ($r = 0.6054^{**}$), specific gravity ($r = 0.6006^{**}$), root length ($r = 0.5694^{**}$) and fodder yield plant ($r = 0.5081^{**}$). On other hand, the characters threshed grain mold rating ($r = -0.8094^{**}$), electrical conductivity ($r = -0.7312^{**}$) and root shoot ratio ($r = -0.3547^{**}$) showed negative and highly significant correlation with seed hardness at phenotypic level.

f. Threshed grain mold rating

Threshed grain mold rating expressed positive and highly significant association with electrical conductivity ($r = 0.8325^{**}$) and root shoot ratio ($r = 0.3192^{**}$) Whereas, the characters vigour index length ($r = -0.7653^{**}$), vigour index mass ($r = -0.7653^{**}$), grain yield per plant ($r = -0.7395^{**}$), shoot length ($r = -0.7076^{**}$), specific gravity ($r = 0.6903^{**}$), 1000 seed weight ($r = -0.6900^{**}$), germination percentage ($r = -0.6805^{**}$), root length ($r = 0.6540^{**}$) and fodder yield per plant ($r = 0.6236^{**}$) 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 vigour index mass ($r = 0.6832^{**}$), grain yield per plant ($r = 0.6806^{**}$), vigour index length ($r = 0.6706^{**}$), germination percentage of seed ($r = 0.6345^{**}$), shoot length ($r = 0.6261^{**}$), 1000 seed weight ($r = 0.6226^{**}$), fodder yield per plant ($r = 0.5564^{**}$), and root length ($r = 0.5525^{**}$). Whereas character electrical conductivity ($r = -0.7130^{**}$) and root shoot ratio ($r = -0.3219$) 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 ($r = 0.8584^{**}$), grain yield per plant ($r = 0.7258^{**}$), vigour index mass ($r = 0.7111^{**}$), 1000 seed weight ($r = 0.6670^{**}$), shoot length ($r = 0.6644^{**}$), fodder yield per plant ($r = 0.6135^{**}$) and root length ($r = 0.6010^{**}$). On the other hand electrical conductivity ($r = -0.7071^{**}$) and root shoot ratio ($r = -0.3138^{**}$) 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 vigour index mass ($r = -0.7893^{**}$), grain yield per plant ($r = -0.7615^{**}$), vigour index length ($r = -0.7466^{**}$), and 1000 seed weight ($r = -0.7374^{**}$) shoot length ($r = -0.6822^{**}$), fodder yield per plant, ($r = -0.6006^{**}$) and root length ($r = -0.5951^{*}$). whereas root shoot ratio ($r = 0.3611^{**}$) exhibited positive and significant correlation with electrical conductivity at phenotypic level.

j. 1000 seed weight

Thousand seed weight expressed positive and highly significant association with vigour index length ($r = 0.7803^{**}$), vigour index mass ($r = 0.7256^{**}$), shoot length ($r = 0.6884^{**}$) grain yield per plant ($r = 0.6846^{**}$), fodder yield per plant ($r = 0.5843^{**}$), and root length ($r =$

0.5670**). Whereas root shoot ratio ($r = -0.4266^{**}$) expressed negative and highly significant association with 1000 seed weight at phenotypic level.

k. Shoot length

Shoot length expressed positive and highly significant association with vigour index length ($r = 0.9304^{**}$), root length ($r = 0.8591^{**}$), vigour index mass ($r = 0.7368^{**}$), grain yield per plant ($r = 0.7100^{**}$) and fodder yield per plant ($r = 0.6734^{**}$) Whereas root shoot ratio ($r = -0.5780^{**}$) expressed negative and highly significant association with shoot length at phenotypic level.

l. Root length

Root length exhibited positive and highly significant association with vigour index length ($r = 0.8989^{**}$), fodder yield per plant ($r = 0.6638^{**}$), grain yield per plant ($r = 0.6424^{**}$) and vigour index mass ($r = 0.6323^{**}$), whereas root shoot ratio ($r = -0.0841$) show negative correlation but non significant with root length at phenotypic level.

m. Root shoot ratio

Root shoot ratio exhibited negative and highly significant association with vigour index mass ($r = -0.4026^{**}$), vigour index length ($r = -0.3715^{**}$), grain yield per plant ($r = -0.3377^{**}$) and fodder yield per plant ($r = -0.2427^{**}$) with root shoot ratio at phenotypic level.

n. Vigour index length

Character vigour index mass ($r = 0.7850^{**}$) grain yield per plant ($r = 0.7841^{**}$) and fodder yield per plant ($r = 0.7269^{**}$) exhibited positive and highly significant association with vigour index length at phenotypic level.

o. Vigour index mass

Vigour index mass show positive and highly significant association with grain yield per plant ($r = 0.8446^{**}$) and fodder yield per plant ($r = 0.6487^{**}$) at genotypic level.

4.5 Discussion

In any crop improvement program existence of sufficient amount of genetic variability is a prerequisite for success of any breeding program. 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 fifty five genotypes of *kharif* sorghum with the following objectives.

1. To assess the extent of variability for grain yield & seed quality parameters. .
2. To assess the nature and extent of association among seed quality parameters 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), Sheikh *et al.* (2017) and Santosh *et al.* (2020).

4.5.2 Genetic variability

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

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 and 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), Dhutmal *et al.* (2018), Dhutmal *et al.* (2020) and Khade *et al.* (2020).

The characters, grain yield per plant, vigour index length, number of leaves, shoot length, vigour index mass, root length, seed hardness and fodder yield per plant 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 grain yield per plant moderate GCV and PCV values were obtained by Dhutmal *et al.* (2015), Ranjith *et al.* (2017) and Shaikh *et al.* (2017).

For vigour index length moderate GCV and PCV values were found by kalpande *et al.* (2015^b).

Moderate value of GCV and PCV were recorded for number of leaves by Kedar (2013), Seethharam and Ganeshmurthy (2013) and Goswami *et al.* (2020).

For shoot length and root length moderate GCV and PCV values were found by Rajarajan *et al.* (2018).

For vigour index mass low GCV and PCV values were found by Kalpande *et al.* (2015^b).

Moderate values of PCV and GCV were recorded for seed hardness and fodder yield per plant indicating that these are amenable for improvement. Similar results were observed for seed hardness Kedar (2013) and Amare *et al.* (2015). for fodder yield similar result found by Muhammad *et al.* (2007), Dhutmal *et al.* (2014), Kalpande *et al.* (2014), Dhutmal *et al.* (2015), Dhedhi *et al.* (2016), kathalkar (2017) and santosh *et al.* (2020)

Low GCV and PCV values were found for the characters days to 50% flowering, plant height, panicle length, specific gravity, germination percentage of seed, 1000 seed weight and root shoot ratio of seed indicating small amount of variation and impediment in improvement through selection. Lukhule and Obilona (1984), Bhongle (2000), Hemlata *et al.* (2006), Jain *et al.* (2009), Dhutmal *et al.* (2014) Ranjith *et al.* (2017), More *et al.* (2018) and Goswmi *et al.* (2020) reported the similar result for days to 50% flowering. Ekebil *et al.* (1977), Satpute and Tiwari (1990), and Dhutmal *et al.* (2015), Goswmi *et al.* (2020) reported similar result for plant height. Dhutmal *et al.* (2014) reported similar results for 1000 seed weight. Bhongle (2000), Rathod (2005), Thorat *et al.* (2005), Khade (2012), Kedar (2013) and Kalpande *et al.* (2015^a), Kathalkar (2017) reported the similar findings for the characters germination percentage of seed, specific gravity of seed and root shoot ratio.

The higher magnitude of PCV as compared to GCV in respect of characters panicle length, number of leaves, plant height, days to 50 % flowering and fodder yield per plant indicated the greater effect of environment on these characters. Whereas rest of the characters showed close GCV and PCV values indicating less influence 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 14.20 to 97.50% for various characters under study. Highest heritability estimate in broad sense was observed for electrical conductivity (97.50%), threshed grain mold rating (96.00%), vigour index mass (95.80%), shoot length (92.30%), vigour index length (91.90%), specific gravity (89.90%), grain yield per plant (88.00%), root length (82.40) seed hardness (79.90%), 1000 seed weight (77.60%), number of leaves (71.50%), fodder yield per plant (67.20%) and germination percentage (63.20%). All these thirteen characters exhibited high heritability (more than 60%). These characters would respond positively to selection because of their high broad sense heritability.

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).

Rathod (2005), Deepalakshmi and Ganeshmurty (2007) and Khade (2012), Kedar (2013), Kalpande *et al.* (2015^a), Kathalkar (2017), Dhutmal *et al.* (2018) and Dhutmal *et al.* (2020) reported similar high heritability for character threshed grain mold rating.

For vigour index mass similar heritability results were obtained by Khade *et al.* (2020).

Kour and Pradhan (2016) high heritability observed for character stem girth.

High heritability for vigour index length was in conformity with the result of Khade (2012), Elangovan *et al.* (2013) and Kedar (2013).

For specific gravity similar heritability observed by P. A. Khade *et al.* (2020).

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), Kathalkar (2017), swamy *et al.* (2018) and Goswami *et al.* (2020).

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 *et al.* (2020).

High heritability for 1000 seed weight was conformity with the result of More *et al.* (2018), Salih *et al.* (2015) and Goswami *et al.* (2020).

For number of leaves similar result was obtained by Deeplakshmi and Ganeshmurthy (2007), Kedar (2013) and Goswami *et al.* (2020).

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) Kathalkar (2017) and Santosh *et al.* (2020).

For germination percentage of seed similar high heritability were observed by Thorat *et al.* (2005), Kalpande *et al.* (2015^a) and Khade *et al.* (2020).

Medium heritability was observed for the characters plant height (50.20%) and panicle length (43.10%). Similar results were found for plant height by Massaoudou *et al.* (2018) and Dhutmal *et al.* (2020) found similar medium heritability for panicle length.

Low heritability was observed for the character root shoot ratio (23.70%) and days to 50 % flowering (14.20%). for root shoot ratio similar result obtained by Kalpande *et al.* (2015^b). and low heritability observed in the character days to 50 % flowering by Massaoudou *et al.* (2018).

4.5.4 Expected genetic advance (%)

Expected genetic advance percent over mean ranged from 1.29 to 47.98 percent for different characters. The highest genetic advance percent over mean was observed for the character electrical conductivity (47.98%) followed by threshed grain mold rating (44.71%), grain yield per plant (37.42%), vigour index length (35.78%), shoot length (28.02%), number of leaves (27.81%) and vigour index mass (26.50%). These seven characters exhibited higher expected genetic advance.

For the character electrical conductivity similar high expected genetic advance was reported by Bhongle (2000), Rathod (2005), Kedar (2013), Kalpande *et al.* (2015^a), Kathalkar (2017) and Khade *et al.* (2020).

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) Dhutmal *et al.* (2020) and Khade *et al.* (2020).

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), Deepalaxmi 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), Swamy *et al.* (2018) and Goswami *et al.* (2020).

For the character vigour index length similar high expected genetic advance was obtained by Vandana *et al.* (2021) in foxtail millet.

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

For the character vigour index mass similar high expected genetic advance was recorded by More *et al.*(2018)

Medium expected genetic advance over mean was found for the characters like root length (19.98%), seed hardness (19.65%), fodder yield per plant (17.47%), 1000 seed weight (15.37%), plant height (11.19%) and panicle length (10.19%). Kedar (2013) and Kalpande *et al.* (2015^b) medium expected genetic advance over mean for root length is observed. For seed hardness similar medium expected genetic advance over mean recorded by Kathalkar (2017). for seed hardness, plant height and panicle length medium expected genetic advance over mean observed by Awate (2019).

Low expected genetic advance over mean was found for the characters germination percentage (9.94%), specific gravity (6.49%), root shoot ratio (3.77%) and days to 50 % flowering (1.29%).

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) and Khade *et al.* (2020) 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 electrical conductivity, threshed grain mold rating, vigour index mass, vigour index length, shoot length, grain yield per plant and Number of leaves 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 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), Jain and

Indapurkar (2013), Kedar (2013), Dhutmal *et al.* (2014), Kalpande *et al.* (2014), Ghorade *et al.* (2015), 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), Kedar (2013) 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), Kedar (2013), Kalpande *et al.* (2015^a), 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, specific gravity of seed, root shoot ratio and days to 50 % flowering. 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. Dhutmal *et al.* (2014) and Ghorade *et al.* (2015) reported similar result for day to 50 % flowering. 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 days to 50% flowering, 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 fodder yield per plant, germination percentage of seed, vigour index mass, plant height, number of leaf, 1000 seed weight, vigour index length, shoot length, seed hardness, specific gravity, panicle length, root length and days to 50 % flowering Whereas, the character electrical conductivity, threshed grain mold rating and root shoot ratio showed negative and highly significant association with grain yield per plant.

The character grain yield per plant positive and highly significant association with fodder yield similar result found by Kathalkar (2017) Awate (2019), Goswami *et al.* (2020) and Dhutmal *et al.* (2020). Bhongle *et al.* (2000), Thorat *et al.* (2005) and Kedar (2013) found positive

and significant association between germination percentage and grain yield per plant. 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) Goswami *et al.* (2020). 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, germination percentage of seed and root length. Potdukhe *et al.* (1994), Iyanar *et al.* (2001), Mahajan *et al.* (2011), Jain and Indapurkar (2013), Kedar (2013) and Khandelwal *et al.* (2015) reported that panicle length showed positive and significant association with grain yield per plant. Thus selection for fodder yield per plant, germination percentage of seed, 1000 seed weight, vigour index of seed, panicle length, seed hardness and number of leaves will be helpful for simultaneous improvement of grain yield per plant.

For electrical conductivity Rathod (2005), 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). Awate (2019) reported negative and significant correlation among the root shoot ratio with grain yield per plant. 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 1000 seed weight, germination percentage, vigour index length, number of leaves, shoot length, root length, specific gravity of seed, fodder yield per plant, grain yield per plant, seed hardness, vigour index

mass, plant height and panicle length. On the other hand, day to 50 % flowering showed negative and highly significant association with root shoot ratio, electrical conductivity and threshed grain mold rating. Wankhade et al. (1985) and Kedar (2013) reported positive and significant correlation between days to 50% flowering and number of leaves. Awate (2019) found similar result for highly significant and positive correlation among days to 50 % flowering and 1000 seed weight, germination percentage, vigour index length, vigour index mass and root length. highly positive correlation between days to 50 % flowering and specific gravity is recorded by Kathalkar (2017).

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 and threshed grain mold rating. Bhongle (2000), Rathod (2005), Kedar (2013) and Awate (2019) 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) and Awate (2019).

b. Plant height

Plant height exhibited positive and highly significant correlation with fodder yield per plant, germination percentage of seed, grain yield per plant, vigour index length, number of leaves, shoot length, root length, vigour index mass, seed hardness, 1000 seed weight, specific gravity and panicle length. Sunku *et al.* (2002), Kishor and Singh (2005), Jain *et al.* (2009), Kedar (2013), Kathalkar (2017), Awate (2019) and Goswami et al. (2020) observed similar correlation between plant height and fodder yield per plant. Jain *et al.* (2009), Kedar (2013) Kathalkar

(2017), Goswami *et al.* (2020) reported similar positive and significant correlation between plant height and number of leaves. Kathalkar (2017) reported similar correlation between plant height and root length. Awate (2019) reported highly significant correlation among plant height with shoot length and grain yield. For specific gravity similar result found by Rathod (2005). 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 1000 seed weight, fodder yield per plant, grain yield per plant, vigour index mass, vigour index length, germination percentage of seed, seed hardness, shoot length, root length, panicle length and specific gravity of seed. Similar positive and significant correlation was reported by Satpute and Tiwari (1990), Jain *et al.* (2009), Jain and Patel (2012), Kedar (2013) Kathalkar (2017), Awate (2019) and Goswami *et al.* (2020) 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 germination percentage of seed, 1000 seed weight, fodder yield per plant, vigour index length, vigour index mass, grain yield per plant, root length, shoot length, specific gravity and seed hardness. Similar positive and significant correlation of panicle length with germination percentage of seed, seed hardness and vigour index mass was reported by Kedar (2013), Kathalkar (2017) and Awate (2019). Badigannavar *et al.* (2017), Awate (2019) and Dhutmal *et al.* (2020) reported similar positive correlation between panicle length and 1000 seed weight.

e. Seed hardness

Seed hardness exhibited positive and highly significant association with germination percentage of seed, vigour index length, vigour index mass, 1000 seed weight, grain yield per plant, shoot length, root length, fodder yield per plant and specific gravity. Whereas, the characters threshed grain mold rating, electrical conductivity and root shoot ratio showed negative and highly significant correlation with seed hardness. Kathalkar (2017) and Awate (2019) reported similar positive and significant correlation between seed hardness and characters like 1000 seed weight, grain yield per plant, 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), Kedar (2013) and Awate (2019) 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. Bhongale (2000) reported similar results for specific gravity of seed. Similar negative and significant correlation between seed hardness and characters like threshed grain mold rating, electrical conductivity of seed and root shoot ratio was reported by Kathalkar (2017) and Awate (2019). 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 electrical conductivity. 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), Kathalkar (2017) and Awate (2019).

The characters germination percentage of seed, vigour index length, grain yield per plant, 1000 seed weight, vigour index mass, fodder yield, shoot length, specific gravity and root length showed the negative and highly significant association with threshed grain mold rating. Bhongle (2000), Kedar (2013), Kathalkar (2017) and Awate (2019) reported similar negative and significant association. While Dhutmal *et al.* (2018) and Awate (2019) reported negative and significant association between TGMR and 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), Kathalkar (2017) and Awate (2019) 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 improves 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 germination percentage of seed, grain yield per plant, 1000 seed weight, vigour index length, fodder yield per plant, vigour index mass, shoot length and root length. Whereas the characters electrical conductivity and root shoot ratio exhibited negative and highly significant association with specific gravity of seed. Similar result was reported by Susana *et al.* (1993) for germination of seed and vigour of

seed. For 1000 seed weight and germination of seed similar result is observed by Bhongale (2000).

h. Germination percentage of seed

Germination percentage of seed showed positive and highly significant association with 1000 seed weight, vigour index length, grain yield per plant, fodder yield per plant, vigour index mass, shoot length, and root length. Kathalkar (2017) and Awate (2019) reported similar 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) and Awate (2019) reported similar result positive and significant correlation between germination percentage of seed 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), Kedar (2013) and Awate (2019).

i. Electrical conductivity

Electrical conductivity expressed negative and highly significant association with 1000 seed weight, grain yield per plant, vigour index length, vigour index mass, fodder yield per plant, shoot length and root length. Kathalkar (2017) and Awate (2019) 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), Bhakare (2010) and Awate (2019) reported similar negative and significant correlation between electrical conductivity and 1000 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, fodder yield per plant, root length and shoot length. Kathalkar (2017) and Awate (2019) 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), Kedar (2013) and Awate (2019). 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 and lead to higher fodder yield per plant.

k. Shoot length

Shoot length expressed positive and highly significant association with vigour index length, root length, fodder yield per plant, grain yield per plant and vigour index mass Kedar (2013) reported similar positive and significant correlation of shoot length with vigour index length, vigour index mass and root length. Kathalkar (2017) and Awate (2019) 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 it might be useful in increasing the shoot length of seedling also 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.

l. Root length

Root length exhibited positive and highly significant association with vigour index length, fodder yield per plant, grain yield per plant and vigour index mass. 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 finding for character vigour index length. Awate (2019) recorded similar result for fodder yield per plant. 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 highly significant association with vigour index length, vigour index mass, grain yield per plant and fodder yield per plant. Kathalkar (2017) and Awate (2019) reported similar result for vigour index, fodder yield per plant 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 fodder yield per plant, grain yield per plant and vigour index mass. Kedar (2013) and Kathalkar (2017) reported similar finding for character vigour index mass and grain yield per. Kathalkar (2017) and Awate (2019) reported similar positive and significant association among 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 grain yield per plant and fodder yield per plant. Kathalkar (2017) and Awate (2019) reported similar finding for 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.

For grain yield per plant, the fourteen hybrids viz., AKMS-90-A x STR- 293 x 426-2, AKMS-733-A x IVT-4121, AKMS-30-A X ICSR-91016, AKMS-30-A x Indore-26, AKMS-751-A x IVT-4121, AKMS-751-A x IVT-17-4013, AKMS-751-A X SPV 1616 x 89028-3, AKMS-733-A x IVT-17-4013, AKMS-90-A X IVT-4121, AKMS-733-A x ICSR-1048-Sel.-2, AKMS-751-A x IVT-3004-1, AKMS-30-A X STR-293 x 426-2, AKMS-733-A x ICSR-8086-7-49 and AKMS-90-A x ICSR-1048-Sel.2 were significantly superior over the national check hybrid CSH-35 along with substantial and significant percentage increase over the check CSH-35. These fourteen hybrids hold promise in developing high grain yielding hybrids. For development of dual purpose hybrids, five hybrids *i.e.* AKMS-751-A x IVT-4121, AKMS-30-A x Indore-26, AKMS-30-A x ICSR-9106, AKMS-751-A x IVT-17-4013 and AKMS-90-A x STR-293 x 426-2 appeared best because of their good grain yield along with good fodder yield as compared to the national check hybrid CSH-35.

Top ten promising crosses with high grain yield along with low value of grain mold (TGMR) and significantly superior over check CSH-35 *i.e.*, AKMS-733-A x IVT-4121, AKMS-90-A x STR -293 x 426-2, AKMS-30-A x ICSR-9106, AKMS-751-A x IVT-4121, AKMS-751-A x IVT-17-4013, AKMS-90-A x ICSR-1048-Sel.-2, AKMS-733-A x ICSR-1048 Sel.-2, AKMS-733 x IVT-17-4013, AKMS-90-A x IVT-4121, AKMS-751-A x IVT-3004-1.

Future breeding strategies

From the findings of the present investigation following suggestions regarding the use of the experimental material for further breeding program 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 gain 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 fourteen hybrids recorded substantial and significant % increase for grain yield over the national check hybrid CSH-35. These fourteen 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, five hybrids *i.e.*, 1) AKMS-751-A x IVT-4121 2) AKMS-30-A x Indore-26 3) AKMS-30-A x ICSR-91016 4) AKMS-751-A x IVT-17-4013 5) AKMS-90-A x STR-293 x 426-2 appeared best because of their high grain yield along with high fodder yield as compared to the national check CSH-35.

In the present study important characters *i.e.* fodder yield per plant, grain yield per plant, plant height and seed hardness 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.

Table 4.6 Top ranking hybrids for grain yield per plant

Sr. No.	Hybrids	Grain yield per plant (g)	Percentage increase over check for grain yield/plant	Fodder yield per plant (g)	Percentage increase over check for fodder yield/ plant (g)	Seed hardness (kg/cm ²)	TGMR (%)	Specific gravity of seed (g/ml)	Germination percentage of seed (%)	Vigour index mass
1	AKMS-90-A x STR-293 x 426-2	71.01	33.72	185.73	12.26	8.83	12.67	1.12	86.00	15.02
2	AKMS-733-A x IVT-4121	70.13	32.05	174.78	5.63	9.07	11.67	1.12	85.67	15.02
3	AKMS-30-A x ICSR-9106	68.83	29.90	194.56	17.60	7.67	13.67	1.09	83.33	15.09
4	AKMS-30-A x Indore-26	68.24	28.51	195.74	18.31	7.69	20.00	1.09	82.67	15.04
5	AKMS-751-A x IVT-4121	67.76	27.60	196.39	18.70	7.23	14.00	1.08	83.67	13.66
6	AKMS-751-A x IVT-17-4013	65.94	24.18	189.84	14.80	8.51	14.66	1.10	83.33	14.79
7	AKMS-751-A x SPV-1616 x 98028-3	65.90	24.10	173.87	8.43	7.65	18.33	1.06	80.67	14.94
8	AKMS-733-A x IVT-17-4013	65.71	23.70	181.08	9.45	7.60	15.67	1.09	82.33	14.83
9	AKMS-90-A X IVT-4121	65.55	24.44	169.11	2.21	8.20	15.67	1.08	82.67	14.98
10	AKMS-733-A x ICSR-1048-Sel.-2	65.16	22.69	179.57	8.54	8.01	15.00	1.09	82.67	13.58
11	AKMS-751-A x IVT-3004-1	64.67	21.77	179.47	8.48	8.03	15.67	1.08	81.33	14.52
12	AKMS-30-A x STR-293 x 426-2	64.43	21.33	171.88	3.88	7.17	20.33	1.08	76.67	14.09
13	AKMS-733-A x ICSR-8086-7-49	61.41	15.60	176.66	6.70	8.11	17.67	1.06	76.00	13.15
14	AKMS-90-A x ICSR-1048-Sel.2	60.05	13.08	172.59	4.32	7.73	14.67	1.06	76.67	13.22
15	Check- CSH-35	53.10	-	165.44	-	7.59	22.33	1.05	78.33	12.54

Table 4.7 Top ranking hybrids for dual purpose

Sr. No.	Hybrids	Grain yield per plant (g)	Percentage increase over check for grain yield/plant	Fodder yield per plant (g)	Percentage increase over check for fodder yield/ plant (g)
1	AKMS-751-A x IVT-4121	67.76	27.60	196.39	18.70
2	AKMS-30-A x Indore-26	68.24	28.51	195.74	18.31
3	AKMS-30-A x ICSR-9106	68.83	29.90	194.56	17.60
4	AKMS-751-A x IVT-17-4013	65.94	24.18	189.84	14.80
5	AKMS-90-A x STR-293 x 426-2	71.01	33.72	185.73	12.26
6	Check- CSH-35	53.10	-	165.44	-

Table 4.8 Top ten hybrids for high grain yield along with low TGMR

Sr. No.	Hybrids	Grain yield per plant (g)	Percentage increase over check for grain yield/plant	TGMR (%)
1	AKMS-733-A x IVT-4121	70.13	32.05	11.67
2	AKMS-90-A x STR - 293 x 426-2	71.01	33.72	12.67
3	AKMS-30-A x ICSR-9106	68.83	29.90	13.67
4	AKMS-751-A x IVT-4121	67.76	27.60	14.00
5	AKMS-751-A x IVT-17-4013	65.94	24.18	14.66
6	AKMS-90-A x ICSR-1048-Sel.2	60.05	13.08	14.67
7	AKMS-733-A x ICSR-1048-Sel.-2	65.16	22.69	15.00
8	AKMS-733-A x IVT-17-4013	65.71	23.70	15.67
9	AKMS-90-A X IVT-4121	65.55	24.44	15.67
10	AKMS-751-A x IVT-3004-1	64.67	21.77	15.67
11	Check- CSH-35	53.10	-	22.33

CHAPTER V

SUMMARY AND CONCLUSION

The present study entitled “Assessment of association among the seed quality 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* 2020-21. In *rabi* 2019-20 four male sterile lines viz., AKMS-30-A, AKMS-90-A, AKMS-751-A and AKMS-733-A were crossed with Ten testers ICSR-8086-7-49, IVT-3004-1, IVT-4121, Indore-26, ICSR-1048-Sel.-2, SPV-1616 x 89028-3, STR-293 x 426-2, IVT-17-4013, ICSR-91016 and AKR-426 x 89058 in line x tester design and produced 40 hybrids. Enough quantity of seed of these resulting hybrids was produced during *rabi* 2019-20. Actual planting of experiment was done during *kharif* 2020-21 by using fourteen parents, their 40 possible hybrids along with one standard CSH-35 (national check).

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 electrical conductivity followed by threshed grain mold rating, vigour index mass, shoot length, vigour index length, specific gravity, grain yield per plant, root length, seed hardness, 1000 seed weight, number of leaves, fodder yield per plant and germination percentage these characters would respond positively to selection.

The highest genetic advance percent over mean was observed for the character electrical conductivity followed by threshed grain mold rating, grain yield per plant, vigour index length, shoot length, number of leaves and vigour index mass. grain yield per plant, vigour index length, shoot length and number of leaves In the present study, the characters electrical conductivity, threshed grain mold rating, vigour index mass, shoot length, vigour index length, grain yield per plant and number of leaves 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 seed hardness, germination percentage, specific gravity and fodder yield per plant. 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 fodder yield per plant, germination percentage, vigour index length, plant height, number of leaf, 1000 seed weight, vigour index mass, shoot length, seed hardness, specific gravity, panicle length, root length and days to 50 % flowering. Whereas, the character electrical conductivity, threshed grain

mold rating and root shoot ratio showed negative and highly significant association with gain yield per plant.

Among the yield components themselves, the character days to 50% flowering showed highly significant and positive association with 1000 seed weight, germination percentage, vigour index length, no. of leaf, shoot length, root length, specific gravity, fodder yield per plant, grain yield per plant, seed hardness, vigour index mass, plant height and panicle length.

Plant height exhibited positive and highly significant correlation with fodder yield per plant, germination percentage of seed, grain yield per plant, vigour index length, number of leaves, shoot length, root length, vigour index mass, seed hardness, 1000 seed weight, specific gravity and panicle length 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 1000 seed weight, fodder yield per plant, grain yield per plant, vigour index mass, vigour index length, germination percentage of seed, and seed hardness shoot length, root length, panicle length and specific gravity.

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

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

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

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

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

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

CONCLUSIONS

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

The characters electrical conductivity and threshed grain mold rating 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 , grain yield per plant, vigour index mass, vigour index length, shoot length, specific gravity and number of leaves suggesting the importance of selection in improving these traits.

For grain yield per plant, the fourteen hybrids viz., AKMS-90-A x STR- 293 x 426-2, AKMS-733-A x IVT-4121, AKMS-30-A X ICSR-91016, AKMS-30-A x Indore-26, AKMS-751-A x IVT-4121, AKMS-751 x IVT-17-4013, AKMS-751-A X SPV 1616 x 89028-3, AKMS-733-A x IVT-17-4013, AKMS-90-A X IVT-4121, AKMS-733-A x ICSR-1048-Sel.-2, AKMS-751-A x IVT-3004-1, AKMS-30-A X STR-293 x 426-2, AKMS-733-A x ICSR-8086-7-49 and AKMS-90-A x ICSR-1048-Sel.2 were significantly superior over the national check hybrid CSH-35 and recorded substantial percentage increase over the check hybrid. These fourteen hybrids hold promise in developing high grain yielding hybrids. For development of dual purpose hybrids, five hybrids *i.e.* AKMS-751-A x IVT-4121, AKMS-30-A x Indore-26, AKMS-30-A x ICSR-9106, AKMS-751-A x IVT-17-4013 and AKMS-90-A x STR-293 x 426-2 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 variation, phenotypic coefficient of variation, heritability estimates (%), expected genetic advance (%) and correlation, the following suggestions are offered for the further utilization of this breeding material.

For grain yield per plant, the fourteen hybrid viz., AKMS-90-A x STR x 293 x 426-2, AKMS-733-A x IVT-4121, AKMS-30-A X ICSR-91016, AKMS-30-A x Indore-26, AKMS-751-A x IVT-4121, AKMS-751 x IVT-17-4013, AKMS-751-A X SPV 1616 x 89028-3, AKMS-733-A x IVT-17-4013, AKMS-90-A X IVT-4121, AKMS-733-A X ICSR-1048-Sel.-2, AKMS-751-A x IVT-3004-1, AKMS-30-A X STR-293 x 426-2, AKMS-733-A x ICSR-8086-7-49 and AKMS-90-A x ICSR-1048-Sel.-2 were significantly superior over the national check hybrid CSH-35 and recorded substantial percentage increase over the check hybrid. These fourteen hybrids hold promise in developing high grain yielding hybrids. For development of dual purpose hybrids, five hybrids *i.e.*, AKMS-751-A x IVT-4121, AKMS-30-A x Indore-26, AKMS-30-A x ICSR-9106, AKMS-751-A x IVT-17-4013 and AKMS-90-A x STR-293 x 426-2 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 crosses combination with high grain yield along with low grain mold infestation (TGMR) need to be tested in multilocation trails to identify the best cross combination.

CHAPTER VII

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VITA

1. **Name of student** : **PATIL RUPESH CHUDAMAN**
2. **Date of Birth** : 10/05/1997
3. **Name of the College** : Post Graduate Institute,
Dr. Panjabrao Deshmukh
Krishi Vidyapeeth, Akola.
4. **Residential Address** : At. Post- Saundane
Tal- Dhule, Dist- Dhule.
Pin code- 424001
Mob. No.-7219316374
Email ID – patil721931637489@gmail.com
5. **Academic Qualification** :

Sr. No.	Name of Degrees awarded	Year in which obtained	Division/ Class (CGPA)	Name of awarding University	Subjects
1.	B.Sc. (Agri.)	2019	First Class	Dr. PDKV, Akola	Agriculture and allied subjects

6. **Research papers published (if any)** : - NIL-
7. **Field of Interest (in which you desire to work)** : Research and Development in the field of Agriculture

Place: Akola

Signature of Student

Date: / /2021

(PATIL RUPESH CHUDAMAN)