

**GENETIC STUDIES ON CHARCOAL ROT RESISTANCE AND
FODDER QUALITY PARAMETERS IN MINICORE COLLECTION
OF SORGHUM (*Sorghum bicolor* (L.) Moench) DURING
RABI SEASON**

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JULY, 2017

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in
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By
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CERTIFICATE

This is to certify that the thesis entitled “**GENETIC STUDIES ON CHARCOAL ROT RESISTANCE AND FODDER QUALITY PARAMETERS IN MINICORE COLLECTION OF SORGHUM (*Sorghum bicolor* (L.) Moench) DURING RABI SEASON**” submitted by **Miss. NAGAMANI V.**, for the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **GENETICS AND PLANT BREEDING** to the University of Agricultural Sciences, Dharwad is a record of research work done by her during the period of her study in this University under my guidance and the thesis has not been previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

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Gratitude takes three forms, “A feeling from the heart, an expression in words and a giving in return.....”

At last, the moment has come to look into the deeper layers of my heart which is filled with the feeling of togetherness and loveliness; consolation, gratitude and satisfaction. Some are permanent and some are momentary but both involve a number of persons to whom I acknowledge my warm regards.

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(NAGAMANI V.)

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LIST OF ABBREVIATIONS

%	Per cent
⁰ C	Degree Celcius
CD	Critical difference
cm	Centimeters
DAS	Days after sowing
DFP	Days to 50 % flowering
DM	Days to maturity
FN	Fort night
g	Gram/s
ha	Hectare/s
kg	Kilogram/s
ml	Milliliter
mm	Millimeter
SPAD	Soil Plant Analytical Development

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1. INTRODUCTION

Sorghum [*Sorghum bicolor* (L.) Moench] ($2n = 2x = 20$, family Poaceae) is an important grain and fodder crop. It is the fifth most important cereal crop world-wide after wheat, maize, rice and barley. It is grown in about 90 countries over an area of about 41.0 million hectares with a production of 64.16 million tonnes of grain and having a productivity of 1600 kg per hectare. In India, sorghum ranks fourth as food and first as forage. It is grown over an area 5.5 million hectares with a production of 5.0 million tonnes and productivity of 910 kg per hectare. In Karnataka, the crop has a total acreage of 1.18 million hectares with a total production of 1.30 million tonnes having productivity 1105 kg per hectare (Anon., 2015).

The genus Sorghum has five subgenus or sections: Eu-Sorghum, Chaetosorghum, Heterosorghum, Para-Sorghum and Stiposorghum (Garber, 1950), of which, Eu-Sorghum contains all sorghum races and varieties as *S. bicolor* sub sp. *bicolor* ($2n = 2x = 20$ chromosomes) and wild and weedy relatives (Harlan and de Wet, 1971; Doggett, 1988). Further, Harlan and De wet (1972) recognized five basic races (*bicolor*, *guinea*, *caudatum*, *kafir* and *durra*) and ten intermediate races (*guinea-bicolor*, *guinea-caudatum*, *guinea-kafir*, *guinea-durra*, *caudatum-bicolor*, *kafir-bicolor*, *durra-bicolor*, *kafir-caudatum*, *kafir-durra* and *durra-caudatum*) that originated as a result of natural intercrossing among basic races. All can be recognized on the basis of spikelet or panicle morphology alone, which can be linked back to their specific environments and the nomadic peoples that first cultivated them (Smith and Frederiksen, 2000). The race *bicolor* is widely distributed in Africa and Asia; *guinea*, predominant in West Africa; *caudatum*, throughout Central Africa; *kafir*, south of the equator in Africa; *durra*, in Ethiopia and India (Harlan and De wet, 1972).

For better and efficient utilization of germplasm in any crop, concept of core and minicore have been postulated which are logically similar to that of the entire germplasm and make possible to study individually all accessions (Upadhayaya and Ortiz 2001). Minicore serves as an efficient and convenient option for assessment of genetic diversity, population structure, association mapping and targeted allele mining for agronomically important traits and acts as a way for successful utilization of germplasm.

The importance of sorghum as a forage crop is growing in many regions of the world due to its high productivity and high water use efficiency even under drought conditions. It produces a tonnage of dry matter having digestible nutrients (50 %), crude protein (8 %), fat (2.5 %) and nitrogen free extracts (45 %) (Azam *et al.*, 2010). It can be used fresh as well as can be stored in form of silage and hay for future use.

It is an important *kharif* crop that is highly palatable and digestible than maize and pearl millet as far as the nutritional quality is concerned. It remains green and palatable as fodder over longer periods than maize and pearl millet. The farmers have a preference for this crop because it can be utilized for different purposes like fresh fodder, hay and silage and grows well in hot and dry climate (Dara and Sukhchain, 2010).

Charcoal rot has been reported to cause severe loss in post-rainy season and the indirect loss computed amounts to 23–64 %. Even disease infected fodder is unfit for livestock consumption due to poor fodder quality (Mayek *et al.*, 2001). But, performance of dairy animals depends on the consistent availability of quality fodder in adequate amount. Therefore, there is a pressing need to develop and transfer to growers high-yielding grain and dual purpose sorghum cultivars with superior grain and fodder quality.

Nearly 65 % of the total area in the state is covered during *rabi* (post rainy) season on stored moisture which accounts for 44 % of total sorghum production. *Rabi* sorghum area is mainly covered by states of Maharashtra, Karnataka, Andhra Pradesh, Tamil Nadu and Gujarat. The hunt for new varieties and hybrids with better productivity and resistance is a continuous process in crop improvement. Charcoal rot disease has become a major production constraint in *rabi* sorghum. The indirect loss computed due to this disease alone amounts to 40 % (Hiremath and Palakshappa, 1994). Patil (1980) reported that the loss in grain yield was more in *rabi* (40.83 %) than in *kharif* (17.69 %).

Charcoal rot of sorghum caused by the fungus *Macrophomina phaseolina* is a root and stalk rot disease of great destructive potential in most sorghum growing regions. *M. phaseolina* is a common soil borne, non-aggressive and plurivorous pathogen that attacks plants whose vigor has been reduced by unfavorable growing

conditions (Das *et al.* 2008). Improved, high-yielding cultivars under good management tend to be very susceptible to the disease (Mughogho and Pande, 1984). Drought stress is the primary factor that predisposes sorghum to charcoal rot. In diseased roots and stalks, *M. phaseolina* is often associated with other fungi, suggesting that the disease is of complex etiology.

Lodging at crop senescence stage is a major problem attributed to various anatomical weakness of the plant, environmental stress (terminal moisture stress) and a complex of stalk rotting organisms. The disease is favoured by moisture stress (<25 % available soil moisture) and high soil temperatures (35 °C) at the time of grain filling in susceptible cultivars. It is characterized by degradation of the pith tissue at or near the base of the stalk causing death of cells (Edmunds, 1964). This premature death of stalk cells may result in reduced transportation of nutrients and water, thus disrupting normal activity and may also cause breakage of the stalk at the zone of infection leading to lodging (Mughogho and Pande, 1984, Hundekar and Anahosur, 1994, Maranville and Clegg, 1984). These phenomena may slow down or inhibit the grain-filling process and thus result in shriveled seeds (Zummo, 1980).

Since sorghum being a poor man crop, identification of durable resistance becomes a viable alternative in the management of the charcoal rot disease. Thus the present study was undertaken with an aim to identify sorghum genotypes which are high yielding, charcoal rot resistant coupled with good fodder quality traits.

Keeping in view the above points, the present investigation was carried out with the following objectives:

1. To assess the minicore collection of sorghum for charcoal rot resistance, fodder quality parameters and grain yield components.
2. To estimate the association of the grain yield components and fodder quality parameters with charcoal rot.

2. REVIEW OF LITERATURE

The pathogen *Macrophomina phaseolina* (Tassi) Goid. occurs over varied climatic conditions ranging from arid to tropical areas with a broad host range and charcoal rot incited by this pathogen is an important disease (Iqbal *et al.*, 2010). *M. phaseolina* is a soil and seed-borne pathogenic fungus (Kaur *et al.*, 2012) with more than 500 plant hosts including legume and cereal crops (Mihail and Taylor, 1995). Sorghum is fifth major cereal crop in the world, is subject to a number of constraints with charcoal rot being a serious concern. The pathogen causes the formation of red to brown lesions on the stems and roots, which produces dark mycelia and black pycnidia and eventually the plants defoliate and wilt (Mihail and Taylor, 1995). The disease may cause up to 100 per cent yield losses (Patil and Kamble, 2011).

The host resistance is an important component of integrated disease management because it is easily adopted, requires few inputs and is economically advantageous. The selection of resistant cultivars in different species against *M. phaseolina* has proven to play a crucial role in breeding programmes (Iqbal and Mukhtar, 2014).

All the reviews carried out by earlier workers pertaining to the objectives set up for the present research work has been compailed in this section.

2.1 Variability, heritability and other genetic parameters for

2.1.1 Charcoal rot disease resistance.

2.1.2 Fodder quality parameters.

2.1.3 Grain yield and its component traits.

2.2 Correlation studies.

2.1 Variability, heritability and other genetic parameters

Phenotypic variability expressed by a genotype or a group of genotypes in any species can be partitioned into genotypic and phenotypic components. The genotypic

component being the heritable part of the total variability, its magnitude on yield and its component characters influences the selection strategies to be adopted by the breeder.

In the later part of 19th century, Lush (1940) defined heritability in broad sense as the ratio between the genotypic variance and phenotype variance. Lush (1949) further defined heritability in narrow sense as the ratio of additive genetic variance to the phenotypic variance.

The genetic gain that can be expected for a particular character through selection is the product of its heritability, phenotypic standard deviation and selection differential as proposed by Burton and Devane (1953). Heritability estimates along with genetic gain are considered to be more useful in predicting the outcome of selecting the best individuals (Johanson *et al.*, 1955).

According to Panse (1957), if heritability is mainly due to non additive effects (dominance and epistasis), the genetic advance will be low, where as if the heritability is due to additive effects it would be associated with high genetic advance. Swarup and Chagule (1962) observed that high heritability need not be associated with high genetic advance.

2.1.1 Charcoal rot disease resistance

In arid and semiarid regions, charcoal rot disease caused by *Macrophomina phaseolina* is a major problem due to depleting residual moisture. The types of crop losses may be in terms of reduced grain yield and quality due to thin and stunted plants, ultimately leading to lodging. Sorghum plants are predisposed to charcoal rot disease as the root cells senesce due to the reduced carbohydrate, which is required to maintain regular metabolic functions. If the combination of photosynthetic stress and translocation balance reduces carbohydrate supply to root tissue, root cells and also those of the lower part of the stalk senesce and lose resistance to the charcoal rot pathogen. The charcoal rot pathogen invades and destroys root tissue and subsequently rots the stalk, reducing its strength, finally leading to lodging. Even improved high yielding cultivars are susceptible to the disease even under good management practices.

Availability genetic variability is the prerequisite factor for the crop improvement programme in order to identify genetic stock with desirable genes. The

genetic facts for most of quantitative traits such as charcoal rot resistance can be inferred from phenotypic observations, which are the results of interactions of genotype and the environment. Analysis of genetic parameters viz., genotypic variance, phenotypic variance, heritability and genetic advance allows deciphering the quantitative traits.

Seetharama *et al.* (1987) reported that grain yields were reduced in proportion to the deficit in water supply along the gradient, whereas the incidence of charcoal rot increased. Inoculation with the fungus increased the incidence of disease when natural incidence was low. The rows of plants farthest from the line source, which received the least irrigation, showed disease incidence earlier than those nearest, which were better watered. This was apparent for each of the three different, but highly correlated, parameters of disease spread, % of soft stalks, number of nodes crossed and the length of fungal spread (cm). It is concluded that the line source is an effective method to study the quantitative relationship between severity of water stress and the degree of charcoal rot incidence during rain free dry seasons.

In another study Pande *et al.* (1989) documented that lodging increased linearly along the gradient of water supply suggesting a positive relationship between moisture stress and disease development. Lodging was also highly correlated with other charcoal rot disease parameters such as soft stalk, number of nodes crossed, root infection and plant senescence. There were no significant differences ($P < 0.05$) in charcoal rot incidence among inoculation treatments. Lodging increased in both high nitrogen and high plant population treatments under moisture stress conditions.

Gururaja *et al.* (1993) demonstrated that general and specific combining ability variances were highly correlated with the additive and non-additive gene action. The components of variance analysis indicated predominance of additive gene action and moderate heritability. Low per cent of lodging indicated greater resistance due to high proportion of recessive genes in the parents.

Tenkouano *et al.* (1993) determined that both charcoal rot resistance and non-senescence were controlled by dominant and recessive epistatic interactions between two gene loci and a third locus with modifying effects. They proposed that non-senescence should not be used as sole criteria for resistance to charcoal rot in sorghum.

Khanure *et al.* (1997) evaluated 31 sorghum genotypes and observed sufficient genetic variability for resistance to the charcoal rot. Similarly, Desai (1998) evaluated twenty different sorghum genotypes and recorded wide variation with respect to charcoal rot incidence (5.95 to 48.20 %), per cent lodging (7.25 to 33.45 %), mean number of nodes crossed (0.42 to 2.19) and mean length of spread (6.75 to 25.22 cm).

In another study, Patil *et al.* (1998) reported a new *rabi* variety GRS1 resistant to charcoal rot as an alternative to M-35-1 (susceptible variety) with 13.4 % higher grain yield levels than M-35-1. Similarly, Narkhede *et al.* (1999) reported that a new variety SPV 1359 was more tolerant to charcoal rot than M-35-1.

Kamatar *et al.* (2000) studied that DSV-4 (9-13), a charcoal rot resistance *rabi* sorghum variety has been developed following pedigree method using highly stable charcoal rot resistance source E-36-1. This variety matures in 120 days, stays green till maturity and yields 28 q ha⁻¹ and 75 q ha⁻¹ fodder which is about 27 and 20 % higher grain fodder yield, respectively than popular widely adopted variety M-35-1.

As a C₄ species, sorghum has very high yield potential comparable with maize and rice. However, numerous biotic and abiotic stresses pose formidable challenges to the realization of this potential. In addition to various cropping systems and management practices, host plant resistance and tolerance to these stresses have been widely recognized as the most viable approach to enhancing productivity under these conditions (Waniska *et al.*, 2001). However, Garud *et al.* (2002) proposed that an increase in stay green level is an important factor in charcoal rot resistance.

Jahagirdar *et al.* (2002) tested local genotypes against charcoal rot of sorghum caused by *M. phaseolina* in *rabi* season for two years. Their study revealed that the local genotypes like Honnutagilocal and Muddehallijola along with 9-13 (DSV-4), BRJ 356, CRP 3, CRP 48 and E-36-1 recorded reduced levels of charcoal rot incidence. Screening trials against charcoal rot disease of sorghum caused by *M. phaseolina* to develop resistant sources by crossing locally adapted genotypes in sick soil and found that susceptible check, CSV-8R showed more lodging. Palakshappa and Padaganur (2002) reported that cross between E-36-1 x M-35-1 revealed that the genotypes DCCR-15, DCCR- 17, DCCR-20 and DCCR-25 were found highly promising in both the years for lodging and other parameters.

Similarly, Das and Prabhakar (2003) reported that under the condition of moisture, temperature and photosynthesis stresses that often coincide with the onset of flowering. The host-defense-system is weakened and activity of *M. phaseolina* increases many folds leading to rapid and extensive rotting of roots and stalks that result in lodging of the crop. The pathogen produces phytotoxins which injure cell protoplast and often prime the infected plants towards more severe disease in later stages. High degree of variations in pathogenic properties in *M. phaseolina* and very strong relation of the disease with yield and environmental stresses, particularly moisture and temperature, makes the task of evaluating host resistance more challenging.

Palamreddy *et al.* (2006) concluded that high estimates of broad sense heritability were noticed for four character viz., stem thickness, grain yield per plant and two disease parameter, length of infection and per cent lodging. Studies performed by Rajkumar *et al.* (2007) revealed that highly significant and positive association between plant height and lodging percentage with infection both at phenotypic and genotypic level was expected as the shorter plants are always resistant to lodging, irrespective of the disease. A combination of medium height, thick stem, large ear head and resistance to charcoal rot disease are desirable in productive genotypes.

Srinivasa *et al.* (2008) revealed that population of F9 generation recombinant inbred lines (RILs), derived from IS22380 (susceptible) × E36-1 (resistant), along with parents were phenotyped in sick plots at two locations (Dharwad and Vijayapura, Karnataka, India). A total of 85 polymorphic marker loci (62 nuclear and 4 genic SSRs, 19 RAPDs) were available for the construction of genetic map, spanning 650.3 cm in all the ten linkage groups. Analysis with QTL Cartographer (2.5b), adopting composite interval mapping method (LOD > 2.0) at both locations, revealed 5 QTLs at Dharwad and 4 QTLs at Bijapur locations for the component traits of charcoal rot disease resistance. QTLs for number of internodes crossed, length of infection and per cent lodging accounted for 31.83, 10.76 and 18.90 % at Dharwad location and 14.87, 10.47 and 26.44 % phenotypic variability at vijayapura location, respectively. The QTLs for number of internodes crossed by the rot, length of infection and % lodging were common across two locations. These QTLs, consistent over environments for the component traits, are likely to assist in marker-assisted selection (MAS) for charcoal rot resistance in sorghum.

Hernandez *et al.* (2009) demonstrated that charcoal rot resistance in BAT 477 is controlled by two dominant genes with double-recessive epistasis. AFLP analysis detected one QTL (ATA/AGT19) that appeared to be associated with resistance to charcoal rot in BAT 477, with a significant P value (0.0029) based on conventional regression analysis, not however supported by permutation tests. The association between the locus and genetic resistance will need a larger sample size to be statistically reliable.

Upadhyaya *et al.* (2010) revealed that utilizing germplasm is the best option for crop improvement, which provides basic genetic stock to the international scientific community for further improvement of sorghum cultivars. Finding crop germplasm diversity is the major target to develop improved crop cultivars with increased productivity. The mini core provides a means for easy exploration of comparatively a large germplasm and helps in proper assessment of genetic diversity and population structure and for association mapping and targeted gene mining as well as greater utilization of diverse germplasm for developing broad-based cultivars, more importantly in the context of global weather change

Desphande *et al.* (2011) reported that presence of non-allelic interaction effects was observed based on significance of genetic parameters. Preponderance of dominance effects followed by dominance $\times$ dominance effects was observed for inheritance of resistance to charcoal rot. Epistasis governing inheritance of resistance was of duplicate type. This depicted possibility of obtaining transgressive variants for resistance to charcoal rot. Partial dominance of resistance to charcoal rot was observed in the cross SPV-86 $\times$ GRS-1.

Mutations had no effect on stalk rot disease severity in either sorghum or maize though stalks strength was markedly affected by the mutations in both species. While maize bm entries broke easily in response to mild mechanical stress, bmr sorghums did not exhibit sign of stalk collapse in all backgrounds. The result suggests that the bmr genes in both maize and sorghum can be deployed without incurring losses to stalk rot disease. (Srinivasa *et al.* 2011).

Virupaksha *et al.* (2012) studied the Sixty four germplasm lines including local genotypes were screened for charcoal rot resistance in the sickplot. The results of the

study indicated that the genotypes Dagadi Solapur (12.35 %), followed by GRS-1 (13.15 %), BCR-9 (14.25 %) showed less disease incidence compared to other genotypes. Highest per cent charcoal rot incidence was recorded in CSV-8R (56.10 %). The study also revealed that the local genotypes recorded reduced levels of other charcoal rot parameters such as per cent lodging due to charcoal rot (soft stalk), mean length of spread (MLS) and mean number of nodes crossed (MNC). The local genotypes also possessed desired breeding traits such as delayed senescence and stay green type which could be employed in resistance breeding programme of *rabi* sorghum.

Mohankumar *et al.* (2013) reported that genotypes IS30562 and 1790E R had tolerance to both stalk rot and charcoal rot respectively and IS12706 was the most susceptible to both diseases. PI510898 showed combined tolerance to drought and Fusarium stalk rot under dry land conditions. The genotypes identified are potential sources of drought and disease tolerance and will be used to develop better adaptable parental lines followed by high yielding hybrids.

Bandara *et al.* (2015) mentioned that new resistance-tolerance index (Index RT) was used to rank 36 advanced sorghum male sterility maintainers (B-lines). Index RT was formulated in such a way that a lower index value indicates increased disease resistance and reduced yield loss (*i.e.* greater tolerance) and vice-versa after infection.

The estimate of genetic variability parameters indicated that a wide range of variation was evident for root length, root spread, primary root, fresh and dry root weight, yield traits and disease reaction. Moderate to high heritability (ranging from 26 to 87 %) along with genetic advance as per cent (15.98–74.73) was observed for seed yield, root volume, fresh root weight, per cent lodging, mean node crossed and mean length spread (Girish *et al.*, 2016).

2.1.2 Fodder quality parameters

The improvement of sorghum began just after the domestication of the species (Doggett, 1965). The first study on sorghum genetics was reported by Graham and Lessman (1966) and since that time numerous such studies has been conducted and as a result that considerable amount of genetic information is now available with respect to

grain yield and its components. On the contrary, relatively little efforts have been made in the past to determine the genetic basis of forage yield and quality characters thereby limited improvement has been made in sorghum for fodder quality.

Warkad *et al.* (2008) investigated that high heritability accompanied with high genetic advance over mean was observed for the characters- grain and dry fodder yield, stem girth, ear head length and breadth, suggesting the influence of additive genes and provides scope for selection. Also, high value of heritability along with low genetic advance over mean were observed for the characters days to maturity and number of leaves per plant indicating that variability is mainly due to the non-additive gene effects and hence heterosis breeding can be fruitfully exploited in improving such characters.

Parkhe *et al.* (2010) demonstrated that introgressed stay green genotype S35SG 06026 recorded more plant height, number of leaves per plant and leaf area per plant. The introgressed genotypes were found earlier in maturity, more in leaf dry weight, maximum total dry matter, higher brix and higher total sugar content. Genotype S35SG06026 recorded significantly higher green and dry fodder yield over all the checks. Several desirable yield determining factors and yield limiting factors in 24 genotypes have been identified. Such parameters may be helpful in further crop improvement programme. The genotype may be considered for future breeding programme for developing varieties suitable for rainfed condition.

Singh *et al.* (2011) estimated genetic variability for green fodder yield and attributing traits in forage sorghum. High range of variation was observed for leaf area, green fodder yield, plant height, days to 50 per cent flowering, leaf length, internode length, leaves per plant, nodes per plant, leaf breadth, protein content, stem girth and leaf stem ratio. The estimates of PCV were generally higher than their corresponding GCV for all the characters studied indicating that all traits were influenced by the environment. High heritability coupled with high genetic advance was observed for leaf area, leaf stem ratio, green fodder yield and stem girth.

Durrishahwar *et al.* (2012) conducted a study to evaluate and characterize 24 sorghum accessions for various morphological and fodder yield parameters. The germplasm displayed considerable variability for leaf color, midrib color, panicle shape, days to 50 per cent flowering, leaf area, flag leaf area, plant height and green fodder

yield, while differences of smaller magnitude were observed for number of leaves and tillers per plant. Genotype Fsd -sorghum was mature early with minimum days to maturity (63) while maximum plant height (232 cm) was observed for Acc.1692. Moreover, Acc.1827 exhibited maximum leaf area (447 cm²) and the highest green fodder yield at 50 per cent maturity (58 t ha⁻¹) was recorded for Acc. 1763. Further, these genotypes are recommended for commercial cultivation to meet the fodder needs of the country.

Jain and Patel (2012) estimated genetic variability parameters for forage yield and yield components in 102 land races of forage sorghum. The results revealed that, days to 50 % flowering, plant height, number of leaves per plant, leaf length and fodder yield per plant had high heritability coupled with high genetic advance as per cent of mean.

Radhika and Bharathi (2012) reported that traits such as green fodder yield, green fodder yield per day, dry fodder yield, dry fodder yield per day and brix per cent had high difference between PCV and GCV, whereas small difference between GCV and PCV was recorded for other characters which indicated less influence of environment on these characters. The characters viz., early vigour, plant height, number of leaves per plant, leaf width, stem weight, stem girth, biomass per plant, green fodder yield, green fodder yield per day, dry fodder yield, dry fodder yield per day and crude protein per cent exhibited high heritability estimates coupled with high genetic advance as per cent of mean indicating that simple selection could be effective for improving these characters.

Gore *et al.* (2016) noticed that characters like number of tillers per plant, stem thickness, leaf to stem ratio and green fodder yield showed high GCV and PCV. The estimates of genotypic as well as phenotypic coefficients of variances were the higher for leaf to stem ratio, stem thickness (mm), green forage yield and number of tillers per plant. Maximum heritability was observed for leaf to stem ratio (97.10 %) and minimum for dry matter (61.90 %). High estimates of heritability accompanied by high estimates of genetic advance as per cent of mean were observed for characters like number of tillers per plant, stem thickness, leaf to stem ratio, number of leaves, leaf length, leaf breadth, crude protein (%) and green forage yield indicating that these traits

are predominately governed by additive gene action and selection for these characters will be effective.

2.1.3 Grain yield and its component traits

The crop is mainly cultivated by marginal farmers during post rainy (*rabi*) season. The ultimate goal of the breeding program is to increase the production per unit area with minimum input cost. Most of the yields contributing traits are quantitative in nature. The wide genetic variability present in the Indian sorghum germplasm lines has been the driving force for the development of high yielding hybrids and varieties suitable for the *kharif* (rainy) and *rabi* seasons, respectively. The genetic improvement of these traits depends on the nature and amount of genetic variability present in the genetic stock and the extent to which desirable traits are heritable.

Narkhede *et al.* (2001) studied genetic variability for 22 yield related traits in 168 genotypes of sorghum and noticed that phenotypic coefficient of variation was higher than the genotypic coefficient of variation. All the traits showed moderate to high estimates of broad sense heritability. Similarly, Prabhakar (2001) noticed that phenotypic coefficient of variation (PCV) was higher than the genotypic coefficient of variation (GCV) of all the characters studied in 48 *rabi* sorghum genotypes, higher PCV and GCV values were observed for 100-grain weight and grain yield per plant. Heritability for all the characters was higher, ranging from 65.76 to 82.81 %.

Soltani *et al.* (2001) demonstrated that grain yield gave a significant negative correlation with physiological traits related to development and vegetative growth. But, this correlation was positive and significant for growth rate, grain filling rate and harvest index. It is, therefore, concluded that indirect selection for grain yield via growth rate, grain filling rate per unit area and harvest index is efficient. Results suggest that use of easily physiological traits in sorghum breeding is possible.

Arunkumar *et al.* (2004) noticed high phenotypic and genotypic coefficients of variation for grain yield per plant, plant height, ear head length among 138 genotypes of *rabi* sorghum (*Sorghum bicolor*). High heritability coupled with high genetic advance over mean was observed for ear head length and ear head thickness.

Umakanth *et al.* (2004) studied range, phenotypic and genotypic coefficients of variation, heritability, genetic advance and the relationship between yield and yield components in 40 landraces and three established lines. High heritability estimates coupled with high genetic advance were observed for panicle length and 100 seed weight.

Negash *et al.* (2005) reported more than 12 per cent of genotypic and phenotypic coefficients of variation for plant height, panicle length, panicle weight, grain yield per plant, 100-kernel weight and kernel number per panicle. Higher estimates of heritability coupled with higher predicted genetic advance was obtained for plant height, panicle length and 100-kernel weight among 64 sorghum germplasm accessions.

In line x tester analysis, Patel *et al.* (2006) revealed the importance of non-additive type of gene action for plant height, days to 50 per cent flowering, number of leaves per plant, stem girth, leaf to stem ratio, protein content, HCN content, green fodder yield and dry matter yield. Further they had suggested the breeding methodology population improvement for above character for getting better segregants.

Bheemashankar (2007) studied 154 sorghum F_3 progenies of each of resistant x susceptible crosses including parents and checks. He observed grain yield per plant, 1,000 grain weight, exhibited, high GCV and PCV. High heritability coupled with high genetic advance was observed for plant height. Similarly, Deepalakshmi and Ganesamurthy (2007) conducted experiment on sixteen sorghum genotypes noticed that high heritability accompanied with high GA as per cent of mean was observed for the characters like plant height, ear head weight, 100 grain weight and single plant yield suggesting that these characters are under additive gene action and thus gives better scope for selection.

Ashok *et al.* (2008) reported that the photosynthetic rate, stomatal resistance, RWC and epicuticular wax content on leaf surface was significantly higher in hybrids, 117A x DRR-1, 117A x DRR-2 and 117A x DRR-3 and also in the parents DRR-2, DRR-1 and DRR-3 at both the stages. Further, the hybrids (117A x DRR-2, 117A x DRR-1; 117A x DRR-3; 117A x DRR-5; 401A x DRR3 and 401A x DRR-5) also maintained lower transpiration rate as they have one of the parents, which had lower transpiration rate and these hybrids also recorded higher yields. Similarly, the relative

water content and epicuticular wax also showed a significant positive association with grain yield at 50 % flowering (0.963 and 0.867, respectively) and at dough stage (0.918 and 0.778, respectively).

Channappagoudar *et al.* (2008) reported that photosynthetic rate at flowering ranged from 23.6 to 44.5 $\mu\text{mol m}^{-2}\text{S}^{-1}$. Sorghum genotypes which accumulated more than 600 g total dry matter accumulation per m² at maturity with higher test weight (> 28.0 g) and harvest index above 42 % gave higher grain yield. In the present investigation genotype ICSV-95 is the only genotype which has out yielded the check M-35-1, which had higher grain yield with higher values of all growth parameters.

Warkad *et al.* (2008) studied sixty-four sorghum germplasm accessions found that highest PCV and GCV values along with high heritability accompanied with high genetic advance over mean were observed for dry fodder yield per plant followed by ear head breadth and length, grain yield per plant and 1,000 seed weight.

Sharanabasappa *et al.* (2009) studied 176 F₅ generation B lines along with local checks, reported that plant height, panicle dry weight, grain yield per plant exhibited high heritability coupled with high genetic advance. GCV and PCV were high for plant height, panicle dry weight and grain yield per plant.

Chavan *et al.* (2010) documented that high genetic advance was observed for number of grains per panicle (1,286.80) and low for panicle width (3.14 cm). High heritability coupled with high genetic advance was observed for number of grains per panicle, plant height and grain yield per panicle. Whereas, high heritability combined with low genetic advance was recorded by panicle width, panicle length and test weight.

Ali *et al.* (2011 a) demonstrated that fresh root shoot weights, dry shoot weight and root to shoot ratio were important selection criteria for drought tolerance as well as higher grain yield at seedling stage. Similarly, higher flag leaf area, leaf dry matter, relative water contents and cell membrane stability along with lower values of specific flag leaf weight, excise leaf weight loss and residual transpiration could be exploited as morpho-physiological markers for drought tolerance and higher grain yield at late growth stage.

Mahajan *et al.* (2011) conducted experiment on 20 F₅ families of sorghum along with four checks, noticed that high heritability coupled with high genetic advance was observed for plant height, grain yield per panicle. Significant variations were recorded among the genotypes for various morphological and yield traits studied. High values for phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) were recorded for grain yield per plant, number of grains per panicle and plant height.

Venkata *et al.* (2011) studied sixteen parents and 48 F₁ hybrid combinations of rice, estimated highest magnitude of genotypic and phenotypic variance for number of grains per panicle and amylose content.

Gedifew (2012) studied twenty-five sorghum genotypes including the local checks, reported that highest PCV and GCV for plant height trait. Higher ratios of the phenotypic variance to genotypic variance were recorded plant height, head length, head width, head weight and grain yield indicating that the traits were highly influenced by the environment. Broad sense heritability estimates for the traits ranged from 45.1 per cent (for head weight) to 99.8 per cent (for single leaf area).

Puspitasari *et al.* (2012) observed genetic variability for productivity and grain quality characters among ten genotypes, such as plant height, panicle length, grain yield per plant and 100 seed weight. The broad sense heritability for productivity characters were estimated which ranged from medium to high.

Nirmal *et al.* (2013) reported that grain yield was positively correlated with LAI, biomass at maturity, stomatal resistance, PAR, harvest index %, grains /panicle, 1,000-grain weight., RLWC %, ear head exertion, stay green at physiological maturity, per day production of grain and fodder yield and negatively correlated with leaf temperature and transpiration rate, CSI, stomatal frequency and stomatal conductance.

Abraha *et al.* (2015) analyzed variance for seedling vigor, number of leaves, leaf area, stay green, peduncle exertion, panicle length and width, plant height, days to flowering and maturity, grain yield, biomass and harvest index under drought stress and irrigated conditions. High magnitude of phenotypic and genotypic coefficient of variations for plant height, harvest index and biomass as well as high heritability for

days to flowering, panicle length, days to maturity and over all agronomic score were recorded.

Shepon *et al.* (2015) studied growth, morpho-physiological, yield and yield contributing characters of twenty sorghum genotypes. The experiment was consisted of twenty genotypes of sorghum among the genotypes, BD 725 showed significantly the best performance on growth, yield and morpho-physiological characters compare to other genotypes at harvest, due to its genetic makeup and regional adaptability, while BD728 was less efficient among those genotypes.

2.2 Correlation studies

The correlation coefficient analysis helps to determine the nature and degree of relationship between any two measurable characters. It resolves the complex relationships between events into simple forms of association. Association between quantitative characters statistically determined by Pearson's correlation coefficient (r) has been quite useful as basis for selection.

The association of characters can be measured as the coefficient of correlation. The basic concept of correlation was elaborated and discussed by Fisher (1918) and Wright (1921) for plant breeding programmes. The main purpose of correlation in crop plants has been the detailed understanding of complex characters, such as yield per plant. Yield is the multiplicative end product of many factors (Grafius, 1959). Yield being dependent on physico-morphological features of the plant, it is desirable to know the individual contribution of these characters along with grain quality characters for developing effective selection strategies.

Esechie (1983) field and laboratory studies were carried out in 1981 and 1982 to investigate the relationship of stalk morphology and chemical composition to lodging resistance in maize in the rainforest zone of Nigeria. Morphological characters correlated with lodging were plant height, thickness and length of basal internode, thickness of rind and weight of 5 cm basal section. Lodging was negatively correlated with grain yield and with the per cent of total nonstructural carbohydrate, protein and potassium in the stalks. Premature stalk senescence and rot were common in varieties

susceptible to lodging. Lodging had no relationship with leaf area and number of days from sowing to flowering.

Resistance to *M. phaseolina* in each environment and across environments, related to maturity and the stalk disintegration scores were significantly negatively correlated both phenotypically and genotypically (Bramel *et al.*, 1988).

Das and Prabhakar (2003) concluded that many morphological and anatomical characters of sorghum stalk are associated with lodging and plants ability to withstand invasion of stalk-rot pathogens. Morphological characters namely, plant height and stalk thickness and anatomical characters namely, number of vascular bundle and positioning of vascular bundle in stalk play significant role in determining stalk strength, lodging resistance and charcoal rot intensity in sorghum.

Patil *et al.* (2003) reported Among the yield components, highest correlation coefficient was observed between ear mass and grain mass per plant (0.931), followed by grain mass per plant and grains per ear (0.924), ear length and ear thickness (0.915 cm) and ear mass and ear thickness (0.894 cm)

Ravi *et al.* (2003) reported that stover quality traits crude protein content and *in-vitro* digestibility in *rabi* sorghum were significantly inversely associated with grain yield in varieties as well as in hybrids. The inverse associations between stover quality traits and grain yield might be due to severe competition for protein and carbohydrates under most commonly observed water stress in *rabi* season growing conditions. More work is required to investigate grain-stover relationships under on-farm conditions where water and nutrient inputs tend to be more restricted than in experimental fields of crop improvement programs. Nevertheless, genotypes do already exist that provide substantially higher digestible stover yield than others under diverse levels of grain production.

Arunkumar *et al.* (2004) revealed that close association between number of primaries and grain yield per plant. Selection for more number of primaries would lead to increase in number of secondaries and number of grains, there by improvement in grain yield is expected. Test weight was associated strongly and positively with grain

yield per plant. More stress should be given for selection of more number of primaries and increased thickness of panicle for improving the grain yield in *rabi* sorghum.

Mallinath *et al.* (2004) documented that positive correlation observed among days to 50 % flowering, plant height, number of leaves, panicle weight, number of primaries and fodder yield per plant indicated that grain yield is largely a function of these five attributes.

Rekha and Biradar (2006) revealed that correlation studies revealed that grain yield had positive and highly significant association with plant height, panicle weight, number of primaries per panicle and test weight, where as it had negative and highly significant correlation with seed fat content and seed protein content.

Negative and significant association has been observed between length of infection and seed weight both at genotypic and phenotypic level (Rajkumar *et al.*, 2007).

Das *et al.* (2008) reported that thicker stalk facilitated the spread of lesions more than did a thinner one. A stalk with densely packed vascular bundles inhibited lesion advancement. It was concluded that anatomical characters of sorghum stalk, especially bundle- number, along with yield parameters played an important role in determining the extent of stalk damage by charcoal rot in *rabi* sorghum.

Reddy *et al.* (2008) also reported significant positive correlation between plant height and % lodging. Resulted that number of internodes crossed by the charcoal rot had significant positive correlation with length of infection at phenotypic and genotypic level. Similarly, Srinivasa *et al.* (2008) observed that plant height was positively correlated with per cent lodging both at genotypic and phenotypic levels.

Esechie *et al.* (2009) Studies were conducted in two consecutive years at Mead, Nebraska, to investigate the relationship between lodging, certain morphological characters and grain yield of sorghum. Morphological characters correlated with lodging were plant height, length of pre peduncle internode and rind thickness. Lodging was negatively correlated with number of days from sowing to 50 per cent bloom and grain yield but was not correlated with grain weight of the head.

Lodhi (2009) carried out correlation analysis for fodder yield traits among fifty genotypes of oat under normal and late sown conditions and observed that genotypic correlation coefficients were higher in magnitude as compared to their corresponding phenotypic correlation coefficients under both the conditions. The characters namely plant height, stem thickness, number of leaves per plant, leaf length and leaf breadth had significant and positive correlation with green and dry fodder yields at genotypic and phenotypic levels.

Highly significant and positive association between plant height and per cent lodging both at phenotypic and genotypic level has also been reported by Patil (2009).

Singh *et al.* (2009) estimated correlation among fodder yield traits in thirty two diverse genotypes of forage sorghum and found that genotypic correlations were of higher magnitude as compared to their corresponding phenotypic correlations for most of the character combinations. Green fodder yield was found to be positive and significantly correlated with green fodder yield per day, days to 50 per cent flowering, days to milking stage, leaf length, nodes per plant and plant height. Stem girth and leaf breadth showed positive non-significant association, whereas crude protein had negative non-significant association with green fodder yield.

Jasmina *et al.* (2010) reported that protein content had low genetic correlation coefficient ($r_g=0.21$) with yield of seed. Highest coefficient of phenotypic correlation obtained between grain yield and protein content ($r_p=0.20$).

Ali *et al.* (2011 b) reported the correlation analysis revealed that selection for long roots; higher root/shoot ratio, leaf area and leaf dry matter could be performed simultaneously. There was positive association between relative water contents and cell membrane stability but both of these traits were negatively correlated with residual transpiration and excised leaf weight loss. The results concluded that morpho-physiological diversity in the studied material is structured by genotypes and this diversity could be utilized for cultivar breeding and germplasm conservation programs aimed at improving drought tolerance in sorghum.

Panicle weight (g) had highly significant and positive correlation with plant height, number of heads per plot, while it had highly significant and negative correlation

with 100 grain weight, at the two locations. Grain yield per hectare had high significant positive correlation with number of grain per panicle and number of panicles per unit area observed among eight indigenous grain sorghum genotypes Ahmed *et al.* (2012).

Correlation studies revealed significant and positive association of green fodder yield with early vigour, days to 50 per cent flowering, plant height, leaf length, stem weight, stem girth, biomass per plant and dry fodder yield. Therefore, these characters could be used as criteria for selection of genotypes with high fodder yield reported by Radhika and Bharathi (2012).

Jain and Patel (2012) studied the interrelationship between forage yield and its related traits in 102 land races of forage sorghum. The results revealed that, fodder yield had significant and positive association with number of leaves per plant, leaf length, leaf width and plant height.

Vijaya *et al.* (2012) conducted experiment on 25 *rabi* sorghum genotypes to assess the association of grain yield components on grain yield per plant, significant and positively correlated was found with panicle weight, harvest index, 100-seed weight and panicle length. Similarly, Bahaa *et al.* (2013) conducted experiment on twenty sorghum landraces noticed that positive and highly significant correlation between grains yield per panicle and panicle length, panicle width, thousand seed weight.

Charcoal rot incidence was found to have mixed response to nodal colonization. In resistant variety E 36-1 and in susceptible check SPV-86 charcoal rot incidence had Positive significant correlation with number of nodes colonized, $r = 0.740$ and $r = 0.828$ respectively. The positive relationship indicated that increase in incidence of charcoal rot would also concomitantly increase nodal colonization. In other varieties M-35-1, CSV-22 and Maulee, the relationship ($r = 0.357$ to 0.472) was fairly positive yet non-significant. In CSH-15 R charcoal rot incidence has not affected nodal colonization as shown by negative correlation ($r = -0.213$) reported by Ashok *et al.* (2013).

Manjeet and Umesh (2014) reported that yield losses showed a positive correlation between disease rating and % loss in the grain yield *i.e.* per cent loss in dry weight increased in direct proportion to the increase in disease rating. The disease rating 4.9 showed maximum loss 46 % in yield coupled with infection of all the internodes

with complete wilting and lodging of plants. On the contrarily the disease rating 3.2 showed minimum loss of 14 % coupled with confinement of the process of infection up to two internodes with slit drying.

Correlation estimates indicated significant positive correlation between root traits, such as root weight and root length (0.53), root volume and root length (0.36), dry root weight and root length (0.47). While, some of the other root traits (RL, SR and FRW/DRW) were significantly negatively correlated with disease contributing traits (CRL, MNC and MLS). Seed and fodder yield were also positively correlated (0.46), while fodder yield was negatively correlated with number of seminal roots (0.21) as reported by Girish *et al.* (2016)

3. MATERIAL AND METHODS

The present investigation involved 236 sorghum minicore accessions and four checks. This material was used for the field evaluation of charcoal rot disease, fodder quality traits, yield and their component traits. The details of material used and the methodologies adopted in the present investigation are presented under following headings.

3.1 Location

3.2 Climate

3.3 Experimental details

3.4 Statistical analysis used in assessing genetic variability, correlation and path coefficient analysis

3.1 Location

The experiment was carried out at Botany Garden, Department of Genetics and Plant Breeding, Main Agricultural Research Station, University of Agricultural Sciences, Dharwad during *rabi* 2016-17. The experiment site is located in the agro-climatic zone-8 (Northern Transition Zone) of Karnataka state. Geographically, Dharwad is located at latitude of 15°17'N and longitude of 75°07'E and altitude of 678 meters above mean sea level (MSL).

3.2 Climate

The data on rainfall, ambient temperature (maximum and minimum) and relative humidity that prevailed during the crop growth period at Main Agricultural Research Station, Dharwad are presented in Appendix I.

3.3 Experimental details

3.3.1 Experimental material

A collection of 236 accessions of minicore of sorghum was obtained from the Genetic Resources Division, ICRISAT, Patancheru, India. The minicore included all

five basic races [*bicolor*, *caudatum*, *durra*, *guinea* and *kafir*] and intermediate races [*caudatum-bicolor*, *durrabicolor*, *durra-caudatum*, *guinea-bicolor*, *guinea-caudatum*, *guineadurra*, *guinea-kafir*, *kafir-bicolor*, *kafir-caudatum* and *kafir-durra*]. The details are given in Table 1.

3.3.2 Experimental layout

Experiment was laid out in Randomized Complete Block Design (RCBD) and sowing was done during second week of October (*rabi* season of 2016-17). The trial was laid out with a spacing of 45 X 15 cm and other recommended packages of practices were followed to raise a good crop. To create epiphytotic conditions for charcoal rot incidence, tooth pick method (Edmunds, 1964) was employed. In tooth pick method, individual plants were inoculated with *Macrophomina phaseolina* cultured on tooth picks in honey peptone medium after 15 days of flowering of genotype.

3.3.3 Tooth pick method

Macrophomina phaseolina was cultured on tooth picks using honey peptone medium as described by Rao *et al.* (1978). Honey peptone medium was prepared by dissolving one g of peptone in 5 ml of honey and 94 ml of distilled water. Tooth picks were boiled in water for two hours to remove toxic substances that may inhibit the growth of fungi. After boiling, they were washed thoroughly in fresh tap water. When tooth picks became dry, about 10 tooth picks were placed in 100 ml flasks in such a way that the, pointed end of tooth picks faced away from the base and was sterilized at 1.1 kg cm⁻² for 20 min. The honey peptone broth was sterilized at 1.1 kg cm⁻² for 15 min in sixty 100 ml flasks. After cooling, *M. phaseolina* isolate (D₅) was inoculated to two 100 ml flasks and a rich suspension was made. This suspension was poured into two tooth pick flasks to cover lower one third of the tooth picks.

The flasks were incubated for seven days at 30 °C by the time, tooth picks were covered with the fungal growth and were ready for inoculation. A pointed iron needle (1-2 mm thickness) with a wooden handle was used to make a hole at the base of the stem, to facilitate tooth pick insertion. Tooth picks were introduced obliquely into the sorghum stalk at the second internode 15 days after flowering. Five plants from each accession were inoculated.

Table 1: Description of sorghum minicore accessions used in the study

Sl. No.	IS No.	Origin	Race	Sl. No.	IS No.	Origin	Race
1	602	United states of America	<i>Bicolor</i>	30	5295	India	<i>Guinea</i>
2	603	United states of America	<i>Bicolor</i>	31	5301	India	<i>Guinea-caudatum</i>
3	608	United states of America	<i>Bicolor</i>	32	5386	India	<i>Durra</i>
4	995	United states of America	<i>Caudatum-bicolor</i>	33	5667	India	<i>Durra</i>
5	1004	India	<i>Durra</i>	34	5919	India	<i>Durra</i>
6	1041	India	<i>Durra</i>	35	6351	India	<i>Durra</i>
7	1212	China	<i>Kafir-durra</i>	36	6354	India	<i>Durra</i>
8	1233	China	<i>Bicolor</i>	37	6421	India	<i>Durra</i>
9	2379	South Africa	<i>Caudatum</i>	38	7131	Uganda	<i>Durra-caudatum</i>
10	2382	South Africa	<i>Caudatum</i>	39	7250	Nigeria	<i>Guinea</i>
11	2389	South Africa	<i>Kafi</i>	40	7305	Nigeria	<i>Caudatum</i>
12	2397	South Africa	<i>Kafi</i>	41	7310	Nigeria	<i>Guinea</i>
13	2413	Iran	<i>Bicolor</i>	42	7679	Nigeria	<i>Guinea</i>
14	2426	Afghanistan	<i>Caudatum-bicolor</i>	43	7957	Nigeria	<i>Guinea-bicolor</i>
15	2864	South Africa	<i>Caudatum</i>	44	7987	Nigeria	<i>Guinea</i>
16	2872	Egypt	<i>Caudatum-bicolor</i>	45	8012	Japan	<i>Guinea-bicolor</i>
17	2902	Nigeria	<i>Caudatum-bicolor</i>	46	8348	Pakistan	<i>Durra</i>
18	3971	India	<i>Durra</i>	47	8774	South Africa	<i>Kafi</i>
19	4060	India	<i>Durra-bicolor</i>	48	8777	Uganda	<i>Caudatum-bicolor</i>
20	4092	India	<i>Caudatum</i>	49	8916	Uganda	<i>Guinea-caudatum</i>
21	4360	India	<i>Durra</i>	50	9108	Kenya	<i>Caudatum</i>
22	4372	India	<i>Guinea-durra</i>	51	9113	Kenya	<i>Caudatum</i>
23	4515	India	<i>Durra</i>	52	9113	Kenya	<i>Caudatum</i>
24	4581	India	<i>Durra</i>	53	9745	Sudan	<i>Caudatum</i>
25	4613	India	<i>Durra</i>	54	10302	Thailand	<i>Caudatum</i>
26	4613	India	<i>Durra</i>	55	10757	Chad	<i>Caudatum</i>
27	4698	India	<i>Durra</i>	56	10867	Chad	<i>Guinea-caudatum</i>
28	4951	India	<i>Guinea</i>	57	10969	USA	<i>Guinea-caudatum</i>
29	5094	India	<i>Durra</i>	58	11026	Ethiopia	<i>Durra</i>

Table 1: Contd.....

Sl. No.	IS No.	Origin	Race	Sl. No.	IS No.	Origin	Race
59	11473	Ethiopia	<i>Caudatum</i>	89	16151	Cameroon	<i>Guinea-bicolor</i>
60	11619	Ethiopia	<i>Durra-bicolor</i>	90	16382	Cameroon	<i>Guinea</i>
61	11919	Ethiopia	<i>Durra-bicolor</i>	91	16528	Cameroon	<i>Guinea</i>
62	12302	Zimbabwe	<i>Caudatum</i>	92	17941	India	<i>Caudatum</i>
63	12447	Sudan	<i>Durra-caudatum</i>	93	17980	India	<i>Durra</i>
64	12697	Australia	<i>Bicolor</i>	94	18039	India	<i>Durra-bicolor</i>
65	12706	United States of America	<i>Caudatum-bicolor</i>	95	19153	sudan	<i>Guinea-caudatum</i>
66	12735	Saudi Arabia	<i>Caudatum-bicolor</i>	96	19262	sudan	<i>Guinea-caudatum</i>
67	12804	Turkey	<i>Bicolor</i>	97	19389	Bangladesh	<i>Caudatum</i>
68	12883	India	<i>Durra</i>	98	19445	Botswana	<i>Kafir</i>
69	12937	Ethiopia	<i>Kafir</i>	99	19450	Botswana	<i>Guinea-kafir</i>
70	12937	Nicaragua	<i>Kafir</i>	100	19676	Zimbabwe	<i>Kafir</i>
71	12937	Cuba	<i>Caudatum</i>	101	19859	India	<i>Durra</i>
72	13294	Venezuela	<i>Caudatum-bicolor</i>	102	19975	Senegal	<i>Guinea</i>
73	13549	Mexico	<i>Caudatum-bicolor</i>	103	20195	Niger	<i>Bicolor</i>
74	13782	South Africa	<i>Kafir-durra</i>	104	20298	Niger	<i>Caudatum-bicolor</i>
75	13893	South Africa	<i>Kafir-caudatum</i>	105	20625	USA	<i>Durra-caudatum</i>
76	13919	South Africa	<i>Kafir-caudatum</i>	106	20632	USA	<i>Caudatum</i>
77	13971	South Africa	<i>Caudatum</i>	107	20679	USA	<i>Guinea-caudatum</i>
78	14010	South Africa	<i>Caudatum-bicolor</i>	108	20697	USA	<i>Caudatum</i>
79	14090	Argentina	<i>Caudatum</i>	109	20713	USA	<i>Guinea-caudatum</i>
80	14290	Botswana	<i>Kafir-durra</i>	110	20727	USA	<i>Bicolor</i>
81	14779	Cameroon	<i>Caudatum</i>	111	20740	USA	<i>Bicolor</i>
82	14861	Cameroon	<i>Caudatum</i>	112	20743	USA	<i>Bicolor</i>
83	15170	Cameroon	<i>Caudatum</i>	113	20816	USA	<i>Bicolor</i>
84	15466	Cameroon	<i>Caudatum</i>	114	20956	Indonesia	<i>Durra-caudatum</i>
85	15478	Cameroon	<i>Guinea-caudatum</i>	115	21083	Kenya	<i>Caudatum</i>
86	15744	Cameroon	<i>Durra-caudatum</i>	116	21512	Malawi	<i>Guinea</i>
87	15931	Cameroon	<i>Guinea</i>	117	21645	Malawi	<i>Guinea</i>
88	15945	Cameroon	<i>Guinea-caudatum</i>	118	21863	Syria	<i>Bicolor</i>

Table 1: Contd.....

Sl. No.	IS No.	Origin	Race	Sl. No.	IS No.	Origin	Race
119	21863	Botswana	<i>Kafir</i>	149	25301	Ethiopia	<i>Durra-bicolor</i>
120	22294	Botswana	<i>Kafir</i>	150	25548	Rwanda	<i>Caudatum</i>
121	22609	Sri Lanka	<i>Caudatum</i>	151	25732	Mali	<i>Durra</i>
122	22616	Myanmar	<i>Bicolor</i>	152	25836	Mali	<i>Durra</i>
123	22720	Somalia	<i>Durra</i>	153	25910	Mali	<i>Guinea</i>
124	22799	Somalia	<i>Durra</i>	154	25989	Mali	<i>Guinea</i>
125	22986	Sudan	<i>Caudatum</i>	155	26025	Mali	<i>Guinea</i>
126	23216	Zambia	<i>Caudatum-bicolor</i>	156	26025	Mali	<i>Guinea</i>
127	23514	Ethiopia	<i>Caudatum</i>	157	26222	Togo	<i>Guinea-caudatum</i>
128	23521	Ethiopia	<i>Guinea-caudatum</i>	158	26484	Benin	<i>Guinea</i>
129	23579	Ethiopia	<i>Guinea-caudatum</i>	159	26617	Madagascar	<i>Caudatum-bicolor</i>
130	23586	Ethiopia	<i>Guinea-caudatum</i>	160	26694	South Africa	<i>Caudatum</i>
131	23590	Ethiopia	<i>Guinea-caudatum</i>	161	26701	South Africa	<i>Caudatum-bicolor</i>
132	23644	Gambia	<i>Guinea</i>	162	26737	South Africa	<i>Kafi</i>
133	23684	Mozambique	<i>Guinea</i>	163	26749	South Africa	<i>Kafi</i>
134	23891	Yemen	<i>Durra</i>	164	27034	Sudan	<i>Durra</i>
135	23992	Yemen	<i>Caudatum</i>	165	27557	Burkina Faso	<i>Guinea</i>
136	24139	Tanzania	<i>Guinea</i>	166	27697	Sierra Leone	<i>Guinea</i>
137	24175	Tanzania	<i>Guinea</i>	167	27786	Morocco	<i>Durra-bicolor</i>
138	24218	Tanzania	<i>Guinea</i>	168	27887	South Africa	<i>Caudatum-bicolor</i>
139	24348	India	<i>Caudatum</i>	169	27912	South Africa	<i>Kafi</i>
140	24453	South Africa	<i>Caudatum-bicolor</i>	170	28141	Yemen	<i>Durra-caudatum</i>
141	24462	South Africa	<i>Caudatum-bicolor</i>	171	28313	Yemen	<i>Durra-caudatum</i>
142	24463	South Africa	<i>Kafi</i>	172	28389	Yemen	<i>Durra-caudatum</i>
143	24492	South Africa	<i>Kafi</i>	173	28449	Yemen	<i>Guinea-caudatum</i>
144	24503	South Africa	<i>Bicolor</i>	174	28451	Yemen	<i>Guinea-caudatum</i>
145	24939	Zambia	<i>Bicolor</i>	175	28614	Yemen	<i>Durra-caudatum</i>
146	24953	Zambia	<i>Guinea- caudatum</i>	176	28747	Yemen	<i>Durra-caudatum</i>
147	25089	Ghana	<i>Guinea</i>	177	28849	Yemen	<i>Durra-caudatum</i>
148	25249	Ethiopia	<i>Durra-bicolor</i>	178	29091	Yemen	<i>Durra-caudatum</i>

Table 1: Contd.....

Sl. No.	IS No.	Origin	Race	Sl. No.	IS No.	Origin	Race
179	29100	Yemen	<i>Durra-caudatum</i>	209	30400	China	<i>Caudatum-bicolor</i>
180	29187	Swaziland	<i>Guinea-caudatum</i>	210	30417	China	<i>Caudatum-bicolor</i>
181	29239	Swaziland	<i>Zila</i>	211	30443	China	<i>Caudatum-bicolor</i>
182	29241	Swaziland	<i>Kafi</i>	212	30450	China	<i>Caudatum-bicolor</i>
183	29269	Swaziland	<i>Guinea-caudatum</i>	213	30451	China	<i>Caudatum-bicolor</i>
184	29304	Swaziland	<i>Guinea-kafir</i>	214	30460	China	<i>Caudatum</i>
185	29314	Swaziland	<i>Durra-caudatum</i>	215	30466	China	<i>Caudatum-bicolor</i>
186	29326	Swaziland	<i>Caudatum-bicolor</i>	216	30507	Korea	<i>Caudatum-bicolor</i>
187	29335	Swaziland	<i>Caudatum</i>	217	30508	Korea	<i>Caudatum-bicolor</i>
188	29358	Lesotho	<i>Kafir</i>	218	30533	Korea	<i>Caudatum-bicolor</i>
189	29392	Lesotho	<i>Kafir</i>	219	30536	Korea	<i>Caudatum-bicolor</i>
190	29441	Lesotho	<i>Kafir</i>	220	30562	Korea	<i>Bicolor</i>
191	29468	Lesotho	<i>Guinea-caudatum</i>	221	30572	Cameroon	<i>Guinea-caudatum</i>
192	29519	Lesotho	<i>Kafir</i>	222	30838	Cameroon	<i>Guinea</i>
193	29565	Lesotho	<i>Guinea-caudatum</i>	223	31043	Uganda	<i>Caudatum</i>
194	29568	Lesotho	<i>Kafir</i>	224	31186	Uganda	<i>Guinea-caudatum</i>
195	29582	Lesotho	<i>Kafir</i>	225	31446	Uganda	<i>Guinea-caudatum</i>
196	29606	South Africa	<i>Kafir</i>	226	31557	Burundi	<i>Caudatum</i>
197	29627	South Africa	<i>Durra-caudatum</i>	227	31651	Zaire	<i>Caudatum</i>
198	29654	China	<i>Kafir</i>	228	31681	Algeria	<i>Bicolor</i>
199	29689	Zimbabwe	<i>Kafir</i>	229	31706	Yemen	<i>Durra</i>
200	29714	Zimbabwe	<i>Kafir-durra</i>	230	31714	Yemen	<i>Durra-caudatum</i>
201	29733	Zimbabwe	<i>Kafir-durra</i>	231	32245	Yemen	<i>Durra-caudatum</i>
202	29772	Zimbabwe	<i>Guinea-caudatum</i>	232	32349	India	<i>Guinea</i>
203	29914	Zimbabwe	<i>Caudatum</i>	233	32439	India	<i>Guinea</i>
204	29950	Zimbabwe	<i>Guinea-caudatum</i>	234	32787	Somalia	<i>Durra</i>
205	30079	Zimbabwe	<i>Durra-caudatum</i>	235	33023	Tanzania	<i>Guinea</i>
206	30092	Zimbabwe	<i>Durra-caudatum</i>	236	33090	Honduras	<i>Durra</i>
207	30231	Zimbabwe	<i>Kafir</i>	237	33353	Kenya	<i>Caudatum</i>
208	30383	China	<i>Caudatum-bicolor</i>				

Table 2: Salient features including pedigree information and distinguishing traits of checks used for field evaluation.

Sl. No	Entries	Pedigree / origin	Salient features and other details
1	M 35-1	Land race selection from Maldandi bulk at Mohol, Maharastra	It is an improved cultivar from Maharashtra released more than 50 years ago. Most of the area is still occupied by this single cultivar. Most popular <i>rabi</i> sorghum variety with excellent grain quality. Susceptible to charcoal rot.
2	BJV-44	(CSV 216R X DSV 5) X CSV 216R	Seeds are cream coloured and bold and charcoal rot and shoot fly tolerant.
3	SPV-86	R24 x R16 IIMR, Hyderabad	High yielding variety, highly susceptible to charcoal rot, moderately tolerant to shoot fly, leaves yellowish green, medium drooping, more leaf sheath waxyness, semi compact cylindrical ear, seeds round, bold and creamy, grain texture of endosperm is half vitreous
4	E-36-1	<i>Guinea-Caudatum</i> hybrid race with Ethiopian origin	Resistance to drought, and charcoal rot, striga susceptible and stay-green type, bold and white colour seeds covered with glumes. Leaves dark green, medium height with compact panicle.



Plate 1: General field view of experimental plot



Plate 2: *M. phaseolina* cultured on tooth picks using honey peptone medium



Plate 3: Tooth pick method of inoculation



Plate 4: Charcoal rot symptoms caused by *Macrophomina phaseolina* in stalk

3.3.4 Method of sampling

Five plants were tagged at random in each genotype to take observations on quantitative traits like yield and yield components. The crop stand and growth were satisfactory.

3.3.5 Evaluation of genotypes of minicore collection for charcoal rot component traits

3.3.5.1 Per cent lodging (Frezi and Teyssandier, 1980).

Score	Phenotype (Reaction)
1.	No damage (Highly resistant)
2.	1-10 % plants damaged (Resistant)
3.	11-25 % plants damaged (Moderately resistant)
4.	26-40 % plants damaged (Susceptible)
5.	More than 40 % plants damaged (Highly susceptible)

3.3.5.2 Spreading of the fungus

At the time of harvesting, the stem of each plant was split opened and length of spread of the fungus in terms of discoloration was measured in cm.

3.3.5.3 Number of internodes crossed by fungus

At harvest, the stem of individual plants was split opened and the number of internodes crossed by fungus was measured.

3.3.5.4 Per cent disease incidence

Number of infected plants and non-infected plants were counted and expressed in percentage.

3.3.6 Evaluation of fodder quality parameters

Observation on stalk and anatomical characters was recorded.

3.3.6.1 Stem girth

To record the stem girth, third internode from the bottom was considered and girth was measured using vernier caliper and expressed in centimeters (cm).

3.3.6.2 Brix per cent at maturity

Measured with the help of Refractometer at physiological maturity and expressed in percentage.

3.3.6.3 Glossiness

Recorded at ten days after emergence of seedlings and scored as below.

- i. Most glossy.
- ii. Least glossy.

3.3.6.4 Serration

Serration on leaf margins and leaf sheath were observed and recorded.

3.3.6.5 Pubescence

It was observed at nodes and categorized as glabrous and appressed pubescence.

3.3.6.6 Bloom

Heavy white wax coat or white powdery wax appearance on the leaf surface was categorized as waxy bloom and non-wax as bloomless

3.3.6.7 Chlorophyll content at flag leaf and maturity stage

A device developed to measure light attenuation at 430 nm (the peak wavelength for chlorophyll a and b absorption) and that at 750 nm (near infra-red) with no transmittance. The unit less values measured by chlorophyll meter (SPAD-502) termed

as SCMR (SPAD Chlorophyll Meter Reading), is a good estimate of chlorophyll content. This SPAD meter is a simple hand end equipment which operates with De power and is portable. SCMR values were recorded in plants at

- i. Flag leaf stage
- ii. Maturity stage

The third fully expanded leaf from the apex was used for the SCMR determination both at flag leaf and maturity stage. Several measurements were made on each plant at top and middle and average to make an appropriate estimate of leaf chlorophyll.

3.3.6.8 Number of leaves per plant

Total number of leaves per plant at the time of maturity were counted and expressed in numbers.

3.3.7 Evaluation of productivity traits.

3.3.7.1 Days to 50 % flowering

Number of days taken from sowing up to the day of 50 % of the panicle in which anthesis is noticed was recorded for each plant and expressed in days.

3.3.7.2 Days to maturity

Number of days taken from sowing up to the physiological maturity of the panicle was recorded for each plant and expressed in days.

3.3.7.3 Plant height

Plant height was recorded from base of the plant to the tip of panicle at the time of harvest and expressed in centimeters (cm).

3.3.7.4 Panicle length

Length from the base of panicle to its tip was measured and expressed in centimeters (cm).

3.3.7.5 Panicle width

Width of panicle was measured at the broadest point and expressed in centimeters (cm).

3.3.7.6 Number of primaries per panicle

Total number of primaries per panicle at the time of maturity were counted and expressed in numbers.

3.3.7.7 Panicle weight

Unthreshed panicle dried to 12 % moisture was weighed and recorded in grams (g)

3.3.7.8 100-seed weight

From each of the tagged plant, 100 grains were counted at random and weighed in grams (g).

3.3.7.9 Fodder yield per plot

Excluding two border plants of the row, all the plants were cut and dried. Weight was recorded and expressed in kilograms (kg).

3.3.7.10 Grain yield per plant

The weight of grains obtained after threshing the fully dried panicle was taken as grain yield per plant and expressed in grams (g).

3.4 Statistical analysis used in assessing genetic variability, correlation and path coefficient analysis

The data was analyzed using a computer with package WINDOSTAT at Computer Section of University of Agricultural Sciences, Dharwad. Statistical analysis of the data on individual character was carried out on the mean value of five plants with the help of below mentioned parameters

3.4.1 Analysis of variance (ANOVA)

The data on mean values of all characters for 236 genotypes along four checks was analyzed for variance following Randomized Block Design. The analysis of variance and covariance for individual character and for the character pairs respectively were carried out using the mean values of each plot following the method given by Panse and Sukhatme (1967). The significance of the differences among all the genotypes was tested by F-test using the error variance.

Source of variation	Degrees of freedom	Sum of squares	MSS	F ratio
Replications	(r-1)	rSS	rMSS	rMSS/eMSS
Genotypes	(g-1)	gSS	gMSS	gMSS/eMSS
Error	(g-1) (r-1)	eSS	eMSS	
Total	N-1	TSS		

Where,

r = number of replication

g = number of genotypes

The significance of F value was tested by comparing the computed value with the Table value as given by Fisher and Yates (1963).

3.4.2 Mean

The mean value for each character was worked out by using formula

$$\bar{y} = \frac{1}{n} \sum_{i=1}^n y_i$$

Where,

Sy_i = Sum total of the character

n = Number of observations

3.4.3 Range

The lowest and highest values for each character was recorded as range

3.4.4 Estimation of genetic parameters

In order to identify and ascertain the genetic variability among genotypes and to assess the extent of environmental effect on various characteristics, different genetic parameters were estimated by following formulae.

3.4.5 Estimation of variance components

$$\text{Variance} = \frac{1}{n-1} \sum_{i=1}^n \{Y_i - \bar{Y}\}^2$$

Where,

Y_i = Individual value

$\bar{Y}$ = Population mean

$$\text{Standard deviation (SD)} = \sqrt{\text{variance}} = \frac{\sqrt{\sum d^2}}{N}$$

Where,

d = Deviation of individual value from mean

N = Number of observations

Genotypic and phenotypic components of variance were estimated with the help of following formulae.

$$\text{Genotypic variance (s}^2\text{g)} = v\text{MSS} - e\text{MSS} \div r$$

Where,

$v\text{MSS}$ = mean sum of squares of varieties or genotypes

$e\text{MSS}$ = error mean sum of squares

r = number of replications

$$\text{Phenotypic variance } (s_p^2) = \sigma_g^2 + \text{eMSS}$$

Where,

$$\sigma_g^2 = \text{genotypic variance}$$

eMSS = error mean sum of squares

3.4.5.1 Coefficient of variability

Both genotypic and phenotypic coefficients of variability were computed for each character as per method suggested by Burton and Devane (1953)

$$\text{a. Genotypic Coefficient of Variation (GCV) \%} = \frac{\sigma_g}{\bar{X}} \times 100$$

$$\text{b. Phenotypic Coefficient of Variation (PCV) \%} = \frac{\sigma_p}{\bar{X}} \times 100$$

Where

σ_g = Genotypic standard deviation

σ_p = Phenotypic standard deviation

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

GCV and PCV values were categorized as low, moderate and high as indicated by Sivasubramanian and Menon (1973) which is as follows :

0 – 10.0 % : Low

10.1 – 20.0 % : Moderate

20.1 % and above : High

3.4.5.2 Heritability in broad sense

Heritability (h_{bs}^2) was computed for each character as the ratio of genetic variance to the total variance as suggested by Hanson *et al.* (1956).

$$\text{Heritability } (h^2_{bs}) (\%) = \frac{s^2_g}{s^2_p} \times 100$$

Where,

(σ^2_g) and (σ^2_p) are genotypic and phenotypic variances, respectively.

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

0 – 30.0 % : Low

30.1 – 60.0 % : Moderate

60.1 % and above : High

3.4.5.3 Genetic advance

Genetic advance for each character was computed by adopting the formula given by Johnson *et al.* (1955).

$$\text{Genetic advance} = h^2 \cdot k \cdot \sigma_p$$

Where

k = selection differential and is 2.06 at 5 % (Lush, 1949)

σ_p = phenotypic standard deviation

h^2 = heritability

The expected genetic advance as % of mean (GAM) was estimated as given below

$$\text{Expected GAM } (\%) = (GA \div \overline{X}) \times 100$$

Where

GA = Genetic advance

$\overline{X}$ = General mean

The genetic advance as per cent mean was categorized as suggested by Johnson *et al.* (1955) and the same is given below:

0-10.0 %	: Low
10.1-20.0 %	: Moderate
20.1 % and above	: High

3.4.5.4 Correlation studies

The correlation coefficients were worked out to determine the degree of association of a character with yield and also among the yield components. Such correlations were calculated only for the best location data.

Genotypic and phenotypic correlations were computed by using the formula given by Weber and Moorthy (1952).

$$r_p = \text{Cov (X Y)}_p / \sqrt{X^2_p \times Y^2_p}$$

Where,

r_p = Phenotypic correlation

Cov (X Y)_p = Phenotypic covariance between the characters 'X' and 'Y',

X^2_p and Y^2_p = Phenotypic variance of the characters 'X' and 'Y' respectively.

$$r_g = \text{Cov X Y}_g / \sqrt{X^2_g \times Y^2_g}$$

Where,

r_g = Genotypic correlation

Cov (X Y)_g = Genotypic covariance between the characters 'X' and 'Y',

X^2_g and Y^2_g = Genotypic variance of the characters 'X' and 'Y' respectively.

Estimated correlation coefficients were compared against r values given in Fisher and Yates (1963) table at $(n - 2)$ degrees of freedom at the probability levels of 0.05 to test their significance.

4. EXPERIMENTAL RESULTS

Charcoal rot is a complex disease often coincides with post-flowering drought stress which makes it difficult to employ a precise scoring of the disease reaction in sorghum. Therefore, multiple trait evaluations are essential to get an accurate account of the reaction of the genetic material and to compute the genetic contributions towards resistance. The sorghum minicore accessions were sown at Botany Garden, Department of Genetics and Plant Breeding, University of Agricultural Sciences, Dharwad during *rabi* season of 2016-17 for phenotypic evaluation.

The present study was intended to estimate the nature and magnitude of genetic variability involving different quantitative and qualitative traits including charcoal rot component parameters, fodder quality, yield and their component traits among 236 *rabi* sorghum minicore accession along with four checks. The results of various experiments of the study are presented under the following headings.

- 4.1 Estimates of genetic variability for component traits of charcoal rot, fodder quality parameters, yield and their component traits among *rabi* sorghum minicore accessions.
 - 4.2 Estimates of correlation co-efficient between component traits of charcoal rot, yield and their component traits in minicore accessions.
 - 4.3 Estimates of correlation co-efficient between component traits of charcoal rot, fodder yield and quality traits in minicore accessions.
- 4.1 Estimates of Genetic variability for component traits of charcoal rot resistance, fodder quality parameters, yield and their component traits among sorghum minicore accessions in *rabi* season.**

The analysis of variance for charcoal rot parameters, fodder quality traits, yield and yield-related component traits computed among the minicore accessions are presented in Table 3. Analysis of variance revealed a high and significant difference in the minicore set of germplasm for charcoal rot resistance component traits viz., per cent lodging, number of internodes crossed by fungus, spreading of fungus, fodder yield and quality traits, yield and it's related traits. The mean, range, genotypic and phenotypic

Table 3: Mean sum of squares of sorghum minicore accessions for charcoal rot, fodder quality, grain yield and their component traits

Components	Replications	Genotypes	Error	S. Em. $\pm$	C. D. at 5 %	C. D. at 1 %	C. V. (%)
Degrees of freedom	1	236	236	-	-	-	-
Lodging percentage	63.87	1810.3*	20.94	3.220	9.010	11.80	16.22
Spread of fungus (cm)	4.480	1992.8*	3.910	1.390	3.890	5.130	5.290
Number of internodes crossed	1.400	4.72*	0.160	0.280	0.790	1.040	17.67
Percent incidence	274.9	1698.3*	120.5	7.740	21.63	28.50	16.66
Days to 50 % flowering	222.8	122.13*	28.07	3.730	10.43	13.75	7.340
Days to maturity	236.3	207.84*	68.56	5.840	16.31	21.50	6.200
Plant height (cm)	393.2	3199.86*	216.15	10.37	28.96	38.17	7.640
Earhead length (cm)	10.06	77.75*	9.740	2.200	6.140	8.100	14.62
100 seed weight (g)	0.550	1.180*	0.140	0.270	0.760	1.000	11.78
Number of primaries per panicle	35.65	314.06*	13.48	2.590	7.230	9.530	8.290
Earhead width (cm)	1.850	7.070*	0.560	0.530	1.480	1.950	10.64
Panicle weight (g)	25.00	989.9*	13.94	2.630	7.350	9.690	7.620
SPAD value at flag leaf stage	41.97	86.10*	16.48	2.860	7.990	10.54	7.670
SPAD value at maturity stage	38.37	317.39*	13.10	2.550	7.130	9.390	13.80
Stem girth (cm)	0.090	0.190*	0.030	0.120	0.350	0.460	13.49
Brix % at maturity	3.360	63.03*	1.500	0.860	2.410	3.180	12.59
Number of leaves per plant	1.020	4.450*	0.750	0.610	1.710	2.260	11.54
Fodder yield per plot (kg)	0.008	0.170*	0.003	0.040	0.110	0.140	13.65
Grain yield per plant (g)	21.45	671.8*	32.16	4.000	11.17	14.72	14.79

Table 4: Estimates of genetic variability parameters in sorghum minicore accessions for charcoal rot, fodder quality, yield and their component traits

Traits	Range		Grand Mean	PCV (%)	GCV (%)	Heritability (%)	Genetic advance	GA as % of mean
	Minimum	Maximum						
Spread of fungus (cm)	0.000	138.0	37.39	84.50	84.33	99.61	65.10	173.4
Number of internodes crossed	0.000	7.040	2.26	68.90	66.59	93.42	3.020	132.6
Per cent lodging	0.000	100.0	28.35	106.7	105.50	97.71	61.22	214.8
Per cent incidence	0.000	100.0	63.74	47.30	44.06	86.74	53.70	84.53
Days to 50 % flowering	54.50	98.00	72.10	12.01	9.51	62.62	11.16	15.50
Days to maturity	110.0	158.0	133.5	8.80	6.25	50.39	11.51	9.14
Plant height (cm)	87.60	328.1	192.3	21.49	20.09	87.34	74.29	38.67
Panicle length (cm)	6.400	51.00	21.33	31.00	27.33	77.74	10.63	49.64
100 seed weight (g)	1.450	5.71	3.27	24.89	21.92	77.59	1.29	39.78
Number of primaries per panicle	19.00	87.75	44.27	28.90	27.69	91.76	23.99	54.64
Panicle width (cm)	2.320	14.00	7.07	27.63	25.50	85.17	3.004	48.48
Panicle weight (g)	10.10	154.8	48.97	45.74	45.10	97.22	44.93	91.61
Chlorophyll content at flag leaf stage (SPAD value)	35.01	61.19	50.82	13.53	11.14	67.86	10.04	18.91
Chlorophyll content at maturity stage (SPAD value)	5.880	57.90	26.21	49.03	47.05	92.07	24.48	93.00
Stem girth (cm)	0.500	2.430	1.32	25.41	21.54	71.82	0.407	37.60
Brix per cent at maturity	0.200	28.00	9.73	58.37	56.99	95.34	11.22	114.6
Number of leaves per plant	3.830	13.00	7.54	21.38	18.00	70.78	2.363	31.22
Fodder yield per plot (kg)	0.100	1.530	0.42	69.88	68.53	96.18	0.564	138.5
Grain yield per plant (g)	8.400	132.4	38.34	48.99	46.71	90.89	35.07	91.73

variances, genotypic and phenotypic coefficient of variability, heritability estimates in broad sense, genetic advance and genetic advance as per cent mean for the characters studied are presented in Table 4 and depicted in Fig. 1 and Fig. 2. The data on mean values of individual genotypes for all the characters under study are presented in Table 7, 8 and 9.

4.1.1 Per cent lodging

It was observed that the minicore accessions differed significantly for the per cent lodging due to charcoal rot disease, where in, a mean average value of 28.35 % and a high variation ranged with a minimum 0 and maximum value of 100 % was recorded. The accessions IS27557, IS30536, IS20632, IS24218, IS23644, IS12945, IS12735 *etc.* recorded zero per cent lodging while, accessions IS25836, IS20727, IS19859, IS4581, IS24503, IS19676, IS13549, IS602, IS20816, IS28451 and IS20740 recorded 100 % lodging.

High PCV of 106.73 and GCV of 105.50 with high heritability of 97.71 % with an associated genetic advance as per cent mean of 214.8 recorded for this trait among the minicore accessions.

4.1.2 Number of internodes crossed

A significant difference was recorded for the number of internodes crossed by the pathogen among the minicore accessions. The mean value of the number of internodes crossed was recorded as 2.26 ranging from 0 to 7.04. IS7987, IS4360, IS31446, IS30460, IS32787, IS26617, IS30417, IS23514, IS1212, IS27887, IS22294, IS32349, IS602 and IS4372 recorded least number of internodes crossed by pathogen. The accessions *viz.*, IS21083 (7.04) and IS16151 (6.1) recorded highest value of number of internodes crossed by fungus.

The PCV and GCV of 68.90 and 66.59 respectively with a moderate heritability of 93.42 % and genetic advance 132.6 % over the mean were recorded.

4.1.3 Length of spreading of the fungus

Minicore accessions displayed significant variation for spreading of the fungus, with a mean average value of 37.39 cm. A significant wide range of fungal spreading

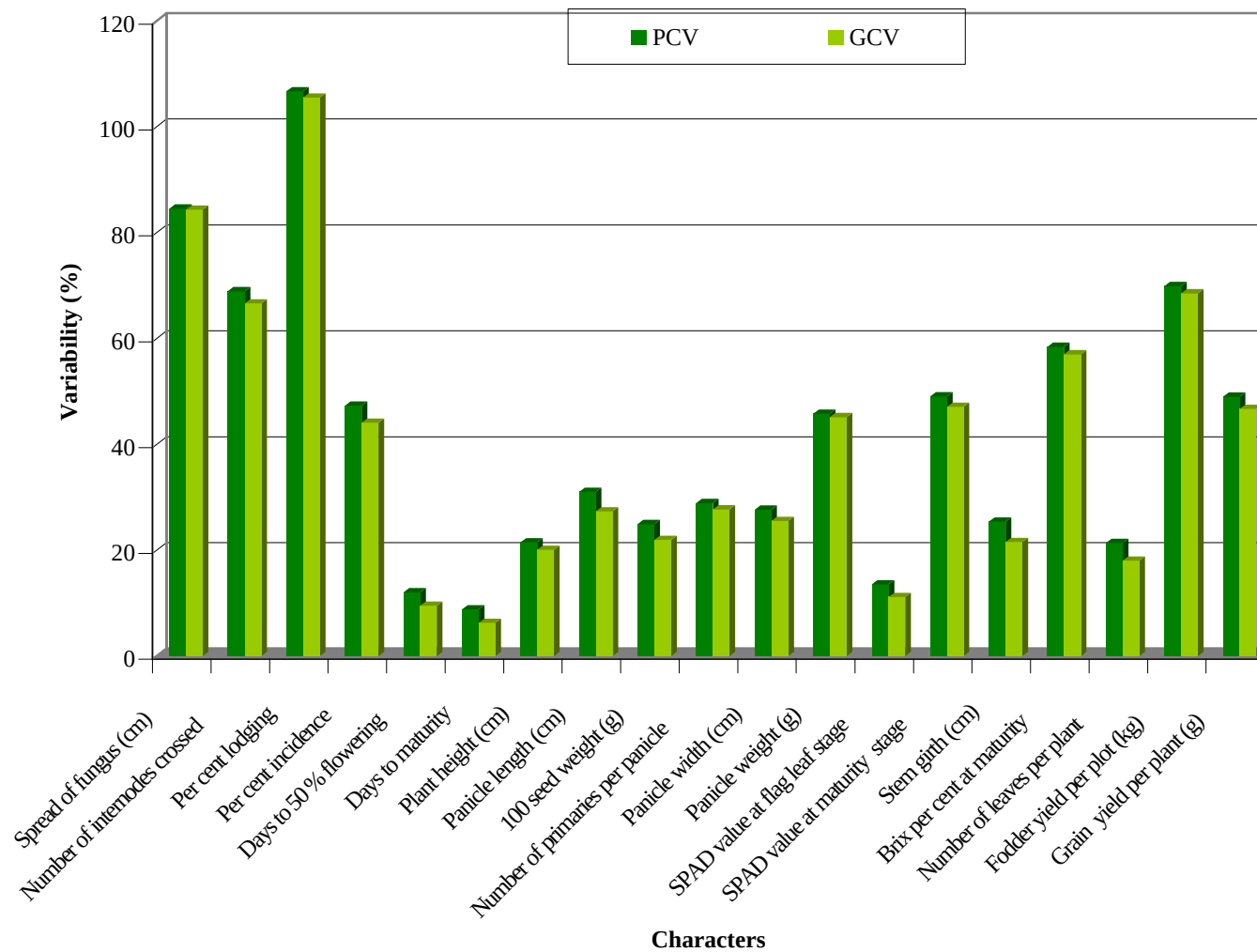


Fig. 1: Genotypic and phenotypic coefficient of variation for nineteen quantitative characters in sorghum

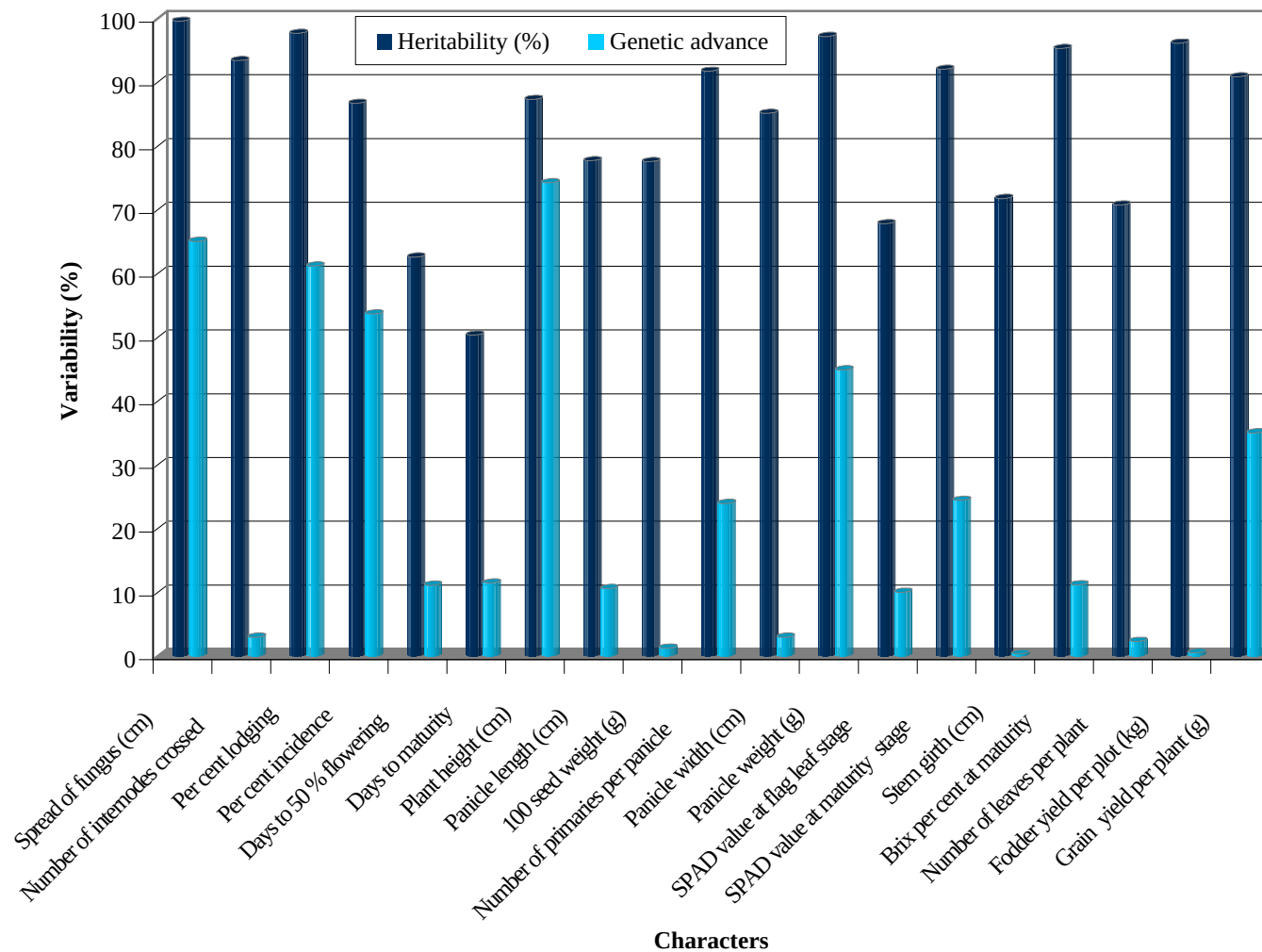


Fig. 2: Broad sense heritability and genetic advance as per cent mean for nineteen quantitative characters in 236 minicore accessions of sorghum

varied from 0 to 138 cm. IS7987, IS4360, IS31446, IS30460, IS32787, IS26617, IS30417, IS23514, IS1212, IS27887, IS22294, IS32349, IS602 and IS4372 recorded length of spread by fungus, while accessions IS21083 (138 cm) and IS25836 (133 cm) recorded highest value of spreading of fungus.

High PCV and GCV of 84.50 and 84.33, respectively were recorded for this trait. High heritability of 99.61 % and genetic advance of 173.4 % over the mean were found.

4.1.4 Per cent disease incidence

Minicore accessions displayed significant variation for per cent incidence disease, with a mean value of 63.74 % and a high variation ranged from 0 to 100 % was recorded. Least per cent incidence disease was recorded for IS7987, IS4360, IS31446, IS30460, IS32787, IS26617, IS30417, IS23514, IS1212, IS27887, IS22294, IS32349, IS602 and IS4372 while, IS21083, IS25836, IS30536, IS27786, IS19262, IS11919, IS14090, IS33023, IS29187 *etc.* recorded 100 per cent disease incidence.

High PCV (47.30) and GCV (44.06) coupled with high heritability (86.74) and moderate genetic advance over the mean (84.53) was recorded.

4.1.5 Plant height

The minicore accessions greatly differed for the plant height. The mean plant height of the minicore accessions was noticed as 192.3 cm with a significant variation ranging from 87.6 to 328.1 cm. The accession IS23586 (87.6 cm), IS29519 (104.95 cm) were relatively dwarf in stature while, the accessions IS8777 (328.1 cm) and IS12447 (301.2 cm) were tall.

High phenotypic and genotypic coefficients of variation recorded for plant height (21.49 and 20.09 %, respectively), with a high heritability of 87.34 % together with high per cent genetic advance of 38.67 % over the mean.

4.1.6 Panicle length

It was noticed that the panicle length in the minicore accessions varied from 6.40 to 51.0 cm with a mean of 21.33 cm. The genotype IS7957 (6.4 cm) followed by

IS15170 (9.2 cm) had shortest panicle length, while IS24503 (51 cm) had longest panicle length.

The phenotypic and genotypic coefficients of variation recorded for this trait were 31.00 and 27.33 % respectively. High heritability of 77.74 % with a moderate genetic advance over mean of 49.64 % was recorded for this trait.

4.1.7 Panicle width

High level of variation was observed for the trait panicle width with a grand mean of 7.07 cm. It was noticed that the panicle width among the accessions ranged from 2.32 cm to 14 cm. The line IS4372 (2.32 cm) had shortest panicle width, while, IS10302 (14 cm) had longest panicle width.

The high phenotypic and genotypic coefficients of variation (27.63 PCV and 25.50 GCV) and higher heritability (85.17) was observed for this trait. High genetic advance (48.48) over mean was recorded for this trait.

4.1.8 Number of primaries per panicle

The mean value of 44.27 was recorded for the number of primaries per panicle. The accession IS27912 (19) had minimum number of primaries per panicle followed by IS22239 (21.5), while, IS31043 (87.75) had maximum number of primaries per panicle followed by IS23590 (84.91).

Moderate phenotypic and genotypic coefficients of variation 28.90 and 27.69 % were recorded respectively. A relatively high heritability of 91.76 % with genetic advance over mean of 54.64 % was recorded for this trait.

4.1.9 Days to 50 per cent flowering

The mean value of 72.10 days was obtained for 50 per cent flowering among the minicore set of germplasm with a wide range from 54.5 days to 98 days. The line IS19859 (54.5 days) was the earliest to reach 50 per cent flowering followed by IS29627 (57 days), IS17941 (58 days), IS20298, IS26025 (59 days) while, IS29772 (98 days) was late to reach 50 % flowering followed by IS24492 (95 days).

The phenotypic and genotypic coefficients of variation observed for the same trait was in the moderate range of 12.01 and 9.51 % respectively. A relatively higher level of heritability estimated (62.62 %) along with low GAM (15.50) was recorded for this trait.

4.1.10 Days to maturity

The grand mean value of days to maturity among the minicore set of germplasm was recorded as 133.5 days with a range from 110 days to 158 days. The accessions viz., IS24503 and IS14090 (110) matured early followed by IS12706 (114.5 days). While, IS29568 matured very late (158 days) followed by IS31446 (157 days).

The phenotypic and genotypic coefficients of variation observed for this trait was in the low range of 8.80 and 6.25 % respectively with a heritability of 50.39 % coupled with low genetic advance over the mean (9.14 %).

4.1.11 100 -seed weight

The trait 100-seed weight found significantly varying from 1.45 and 5.70 g across the minicore accessions with a mean value of 3.27 g. The accessions IS11619 (1.45 g) and IS33023 (1.66 g) recorded the lowest 100-seed weight. While, IS29689 (5.71 g) followed by IS4360 (5.62 g) recorded highest 100-seed weight.

The percentage of the phenotypic and genotypic coefficients of variability for this trait was relatively moderate at 24.89 and 21.92 %, respectively. A higher heritability value of 77.59 % coupled with GAM of 39.78 was recorded for this trait.

4.1.12 Panicle weight

The trait panicle weight found significantly varying range from 10.10 to 154.8 g across the minicore accessions with a grand mean of 48.97 g. The accession IS31651 (10.10 g) has lowest panicle weight followed by IS31714 (12 g) while, IS7987 (154.7 g) has highest panicle weight followed by IS995 (111.6 g).

The phenotypic and genotypic coefficients of variability for this trait was relatively high at 45.74 and 45.10 % respectively. A higher heritability value of 97.22 % with genetic advance over mean of 91.61 % was recorded for this trait.

4.1.13 Chlorophyll content at flag leaf stage

The trait chlorophyll content at flag leaf stage found significantly varying between a range of 35.01 and 61.19 with a mean of 50.82. The accession IS8916 (35.01) had lowest chlorophyll content at flag leaf stage followed by IS12697 (35.13) while, IS12302 (64.13) had highest chlorophyll content at flag leaf stage followed by IS1004 (61.19).

The PCV and GCV for this trait was relatively high at 13.53 and 11.14 % respectively. A higher heritability value of 67.86 % with genetic advance over the mean of 18.91 % was recorded for this trait.

4.1.14 Chlorophyll content at maturity stage

The recorded mean value for the chlorophyll content at maturity stage was 26.21. The accession IS8916 (5.88) registered lowest chlorophyll content at maturity stage followed by IS26701 (6.98) while accession IS29241 (57.90) followed by IS29914 (56.65) recorded highest chlorophyll content at maturity stage.

The moderate value of phenotypic (49.03) and genotypic coefficients (47.05) of variability was recorded. High heritability of 92.07 % with genetic advance over mean of 93.0 % was recorded for this trait.

4.1.15 Brix per cent at maturity

The mean value of brix per cent among the minicore set of germplasm was recorded as 9.73 with a range from 0.2 (IS29241) to 28 (IS23891).

The PCV and GCV observed for this trait was in the moderate range of 58.37 and 56.99 % respectively. High heritability (95.34 %) along with high genetic advance over mean (114.64 %) was recorded.

4.1.16 Number of leaves per plant

The range for the number of leaves per plant among minicore accessions varied from 5 to 14 with an average of 7.54 leaves per plant. The accession IS23586 (3.83)

recorded lowest number of leaves per plant while, IS25836 (13) recorded highest number of leaves per plant among minicore accession.

The PCV and GCV for this trait were 21.38 and 18.00 %, respectively. For the number of leaves per plant, high heritability of 70.78 % with moderate genetic advance over the mean of 31.22 % was recorded.

4.1.17 Stem girth

A higher level of variation was observed for stem girth among the minicore accessions. The range varied from 0.5 cm to the maximum 2.43 cm. A grand mean of stem girth among the minicore observed was 1.32 cm. The line IS25836 (0.5) and IS12965 (0.61) has recorded lowest stem girth. While, IS7987 (2.43) and IS25910 (2.21) recorded highest value of stem girth among accessions.

For the same trait, a moderate PCV and GCV was recorded (25.41 and 21.54 respectively) with heritability of 71.82 % and moderate genetic advance over the mean (37.60 %).

4.1.18 Fodder yield per plot

The mean value of fodder yield per plot among the minicore set of germplasm was recorded as 0.42 kg with range varying from 0.1 to 1.53. The line IS25089 (0.10 kg) recorded lowest fodder yield per plot while, IS25989 (1.53 kg) recorded highest fodder yield per plot.

The PCV and GCV observed for this trait was in the moderate range of 69.88 and 68.53 % respectively. High heritability (96.18 %) along with high genetic advance over mean (138.5 %) was recorded.

4.1.19 Grain yield per plant

Grain yield per plant significantly differed among the accessions of *rabi* sorghum minicore. A highly variable range with a minimum and maximum of 8.4 to 132.4 g respectively was recorded with a mean grain yield per plant of 38.34 g. The accession IS4372 (8.4 g) exhibited lowest grain yield per plant followed by IS26046

(8.5 g), IS31714 (10.0 g). While, IS7987 (132.3 g) recorded highest grain yield per plant followed by IS14290 (95.5 g).

The phenotypic and genotypic coefficients of variability were 48.99 and 46.71 respectively for this trait. The heritability estimated was high with 90.89 % coupled with a high genetic advance over mean (91.73 %).

4.2 Estimates of correlation co-efficient for component traits of charcoal rot resistance and yield traits among *rabi* sorghum minicore accessions

The phenotypic and genotypic correlations among all traits were computed to understand the nature of association and possible interactions among all the accessions of *rabi* sorghum minicore which lead to record highly varied degree of phenotypes for host resistance responses with *Macrophomina phaseolina* pathogenicity under the condition of charcoal rot manifestation. The results are presented in Table 5.

4.2.1 Length of spreading of the *M. phaseolina*

A significant positive correlation for this trait was observed with the number of internodes crossed by *M. phaseolina* (0.765, 0.789), per cent disease incidence (0.457, 0.493), plant height (0.145, 0.155), panicle length (0.103, 0.111), panicle weight (0.098, 0.100) and grain yield per plant (0.116, 0.119) both at phenotypic and genotypic level. However, this trait recorded negative correlation with number of primaries per plant (-0.014, -0.013) both at phenotypic and genotypic level respectively.

4.2.2 Number of internode crossed by fungus

This trait exhibited significant positive correlation with length of spreading of the fungus (0.765, 0.789), per cent lodging (0.094, 0.099) and per cent disease incidence (0.490, 0.549) both at phenotypic and genotypic level respectively. However, it recorded negative correlation with 100-seed weight (-0.028, -0.022) and number of primaries per plant (-0.002, -0.002) both at phenotypic and genotypic level respectively.

Table 5: Estimates of phenotypic correlation and genotypic correlation coefficients for charcoal rot, grain yield and it's component traits in sorghum minicore accessions

Traits		SP	NIC	LD %	PDI	DFF	DM	PH	PL	HSW	NPP	PW	PWE	GYP
SP	P	1.00	0.76 **	0.05	0.46 **	0.02	0.05	0.14 **	0.10*	0.07	-0.01	0.08	0.10 *	0.12*
	G	1.00	0.79**	0.05	0.49**	0.02	0.07	0.15**	0.11*	0.08	-0.01	0.08	0.10*	0.12*
NIC	P		1.00	0.09*	0.49**	0.03	0.01	0.055	0.03	-0.03	-0.002	0.03	0.05	0.04
	G		1.00	0.10*	0.55**	0.03	0.02	0.07	0.03	-0.02	-0.002	0.03	0.06	0.05
LD %	P			1.00	-0.03	-0.15**	-0.09	0.12**	0.08	-0.19**	-0.02	-0.08	-0.20**	-0.24**
	G			1.00	-0.02	-0.18**	-0.12**	0.13**	0.01	-0.22**	-0.02	-0.09	-0.21**	-0.25**
PDI	P				1.00	-0.03	0.07	0.07	0.06	0.07	-0.002	-0.04	0.11 *	0.11*
	G				1.00	-0.08	0.13**	0.08*	0.08	0.09	-0.02	-0.02	0.11**	0.12*
DFF	P					1.00	0.04	0.12 **	-0.03	-0.04	0.04	-0.002	0.19 **	0.10*
	G					1.00	0.03	0.15**	-0.07	-0.06	0.07	0.03	0.22**	0.11*
DM	P						1.00	-0.07	-0.01	0.01	-0.04	-0.01	-0.001	-0.02
	G						1.00	-0.06	-0.03	0.01	-0.07	-0.01**	-0.02	-0.01
PH	P							1.00	0.34**	0.13 *	0.15**	0.19**	0.42**	0.32**
	G							1.00	0.42**	0.16**	0.17**	0.22**	0.46**	0.35**
PL	P								1.00	-0.09*	-0.09	0.19**	0.09 *	0.05
	G								1.00	-0.13**	-0.08	0.24*	0.10*	0.04
HSW	P									1.00	0.05	0.09	0.32 **	0.38**
	G									1.00	0.06	0.14*	0.36**	0.44**
NPP	P										1.00	0.04	0.30 **	0.28**
	G										1.00	0.05	0.32**	0.31**
PW	P											1.00	0.08	0.08
	G											1.00	0.08	0.09*
PWE	P												1.00	0.84**
	G												1.00	0.866**

Where, SP- length of spread of infection by fungus , NIC- number of internodes crossed by fungus, LD %- percent lodging, PDI- per cent disease incidence, DFF- days to 50 per cent flowering, DM- days to maturity, PH- plant height, , PL- panicle length, HSW-100 seed weight, NPP- number of primaries per panicle, PW- panicle width, PWE- panicle weight and GYP- grain yield per plant.

*, ** indicates significant at 5 per cent and 1 per cent level of probability, respectively.

Table 6: Estimates of phenotypic and genotypic correlation coefficients for charcoal rot, fodder yield and it's quality traits in sorghum minicore accessions

Traits		SP	NIC	LD %	%PDI	SPAD1	SPAD2	SG	TSS	NL	FY
SP	P	1.00	0.76 **	0.05	0.46 **	0.01	-0.02	0.12**	-0.12 **	0.05	-0.05
	G	1.00	0.79**	0.05	0.49**	0.01	-0.02	0.15**	-0.13**	0.06	-0.05
NIC	P		1.00	0.09 *	0.49**	-0.03	-0.06	0.06	-0.11*	0.05	-0.07
	G		1.00	0.10*	0.55**	-0.03	-0.07	0.09*	-0.13**	0.05	-0.07
LD %	P			1.00	-0.03	-0.04	-0.04	-0.07	-0.19 **	-0.19**	-0.12**
	G			1.00	-0.02	-0.04	-0.04	-0.08	-0.19**	-0.23**	-0.12**
%PDI	P				1.00	-0.01	-0.06	0.03	0.004	-0.07	-0.07
	G				1.00	-0.002	-0.07	0.06	0.01	-0.07	-0.06
SPAD1	P					1.00	0.36**	0.02	-0.11 *	-0.02	0.06
	G					1.00	0.46**	0.06	-0.13**	-0.04	0.07
SPAD2	P						1.00	0.07	-0.07	0.06	0.13*
	G						1.00	0.07	-0.08	0.07	0.13**
SG	P							1.00	-0.10*	0.18**	0.09*
	G							1.00	-0.11**	0.31**	0.11**
TSS	P								1.00	-0.03	0.01
	G								1.00	-0.04	0.02
NL	P									1.00	0.21 **
	G									1.00	0.26**
FY	P										1.00
	G										1.00

Where,

r_p - phenotypic correlation, r_g - genotypic correlation, SP- Length of Spread of fungus , NIC- Number of nodes crossed, LD %- Per cent lodging, PDI- Per cent disease incidence, SPAD1- chlorophyll content at flag leaf stage, SPAD 2- chlorophyll content at maturity, SG- Stem girth, TSS- Total soluble solids at maturity, NL- Number of leaves per plant and FY- Fodder yield per plot.

*, ** indicates significant at 5 per cent and 1 per cent level of probability, respectively.

4.2.3 Per cent lodging

Highly significant and positive correlation was observed both at the phenotypic and genotypic level with number of internodes crossed by fungus (0.094, 0.099) and plant height (0.116, 0.131). However, significant negative correlation was recorded with 100 seed weight (-0.193, -0.225) days to 50 per cent flowering (-0.15, -0.131), panicle weight (-0.20, -0.21) and grain yield per plant (-0.2391, -0.253) both at phenotypic and genotypic level among the minicore accessions.

4.2.4 Per cent disease incidence

High positive significant correlation was found with number of internodes crossed, length of spreading of the fungus (0.457, 0.493), number of internodes crossed by fungus (0.490, 0.549), panicle weight (0.106, 0.111) and grain yield per plant (0.108, 0.118) both at phenotypic and genotypic level respectively. While, negatively correlated with per cent lodging (-0.027, -0.019), days to 50 % flowering (-0.0297, -0.0837), number of primaries per plant (-0.0021, -0.0183) and panicle width (-0.0412, -0.0192) both at phenotypic and genotypic level respectively.

4.2.5 Days to 50 % flowering

Days to 50 % flowering recorded highly significant and negative correlation with per cent lodging (-0.1508, -0.1834) both at phenotypic and genotypic level, respectively. While, this trait was recorded non-significant negative association with 100-seed weight (-0.036, -0.0606), panicle length (-0.0285, -0.075) and per cent disease incidence (-0.029, -0.084) both at phenotypic and genotypic level respectively. But in contrast, significant positive correlation with plant height (0.119, 0.151), panicle weight (0.186, 0.225) and grain yield per plant (0.101, 0.111) was exhibited both at phenotypic and genotypic level respectively.

4.2.6 Days to maturity

Days to maturity showed non-significant and negative correlation with plant height (-0.0661, -0.0590), panicle length (-0.0105, -0.0325), number of primaries per plant (-0.0382, -0.0697), panicle weight (-0.0146, -0.0240), lodging % (-0.0860, -0.1211), panicle width (-0.009, -0.0097) and grain yield per plant (-0.0197, -0.0111)

both at phenotypic and genotypic level. While, this trait recorded positive correlation with days to 50 per cent flowering (0.0368, 0.0300), 100-seed weight (0.0124, 0.0015), length of spread of fungus (0.0483, 0.0683) and per cent disease incidence (0.0709, 0.1266) both at phenotypic and genotypic level respectively.

4.2.7 Plant height

A significant positive correlation was recorded with length of the spread by fungus (0.145, 0.155), per cent lodging (0.116, 0.131), days to 50 per cent flowering (0.119, 0.151), panicle weight (0.420, 0.225), panicle length (0.34, 0.421) number of primaries per panicle (0.152, 0.170), 100-seed weight (0.1289, 0.156), panicle width (0.1871, 0.223) and grain yield per plant (0.3169, 0.352) both at the phenotypic and genotypic level, respectively. Whereas, this trait exhibited negative association with days to maturity both at phenotypic and genotypic level respectively.

4.2.8 Panicle length

Highly significant and positive correlation was observed both at the phenotypic and genotypic level with length of spread of fungus (0.103, 0.111), plant height (0.340, 0.421), panicle width (0.223, 0.197) and panicle weight (0.1009, 0.089) respectively. But in contrast it recorded negative and significant correlation with 100-seed weight (-0.093, -0.128) both at phenotypic and genotypic level. However, this trait showed negative non-significant correlation with days to 50 per cent flowering (-0.0285, -0.075), days to maturity (-0.0105, -0.0325) and number of primaries per panicle (-0.0875, -0.0811) both at phenotypic and genotypic level respectively.

4.2.9 Panicle width

This trait showed positive and significant correlation with plant height (0.1871, 0.223), 100-seed weight (0.0934, 0.1419) and panicle length (0.1965, 0.2432) both at the phenotypic and genotypic level, respectively. Negative non-significant correlation with % lodging (-0.0761, -0.0883), % disease incidence (-0.0412, -0.0192) and days to maturity (-0.009, -0.009) both at the phenotypic and genotypic level respectively.

4.2.10 100-seed weight

This trait was found to be highly significant and positively correlated with panicle weight (0.325, 0.360), plant height (0.129, 0.156), panicle width (0.093, 0.142) and grain yield per plant (0.3711, 0.438) both at phenotypic and genotypic level. However, it was found to be significant and negatively correlated with per cent lodging (-0.193, -0.225) and panicle length (-0.093, -0.128) both at phenotypic and genotypic level.

4.2.11 Number of primaries per panicle

This character showed highly significant and positive correlation with plant height (0.152, 0.170), panicle weight (0.304, 0.325) and grain yield per plant (0.2799, 0.314) both phenotypic and genotypic level respectively while, exhibited negative correlation with panicle length (-0.0875, -0.0811), days to maturity (-0.0382, -0.0697), length of the spread of the fungus (-0.0136, -0.0130), number of internodes crossed by fungus (-0.0022, -0.0024), per cent disease incidence (-0.0021, -0.0183) and per cent lodging (-0.0171, -0.018) both at the phenotypic and genotypic level, respectively.

4.2.12 Panicle weight

Panicle weight was significantly and positively correlated with length of spread of fungus (0.0983, 0.100), per cent disease incidence (0.106, 0.111), days to 50 per cent flowering (0.186, 0.225), plant height (0.420, 0.457), panicle length (0.089, 0.1009), 100 seed weight (0.325, 0.360), number of primaries per panicle (0.304, 0.322) and grain yield per plant (0.8365, 0.866). But in contrast, significant negative correlation with per cent lodging (-0.20, -0.21) was registered both at the phenotypic and genotypic level respectively.

4.2.13 Grain yield per plant

Grain yield per plant was significant and positively correlated with spreading of fungus (0.1158, 0.119), per cent disease incidence (0.1076, 0.118), 100-seed weight (0.3816, 0.438), number of primaries per panicle (0.2799, 0.314), days to 50 per cent flowering (0.1012, 0.111), plant height (0.3169, 0.352) and panicle weight (0.8365, 0.866) both at the phenotypic and genotypic level respectively. In contrast, significant negative correlation with per cent lodging (-0.239, -0.253) was noticed both at the phenotypic and genotypic level, respectively.

4.3 Estimates of Correlation co-efficient between component traits of charcoal rot, fodder yield and fodder quality traits in minicore accessions

The phenotypic and genotypic correlations between charcoal rot disease parameters and fodder yield and quality traits were computed to understand the nature of association and possible interactions among all the accessions of *rabi* sorghum minicore accessions. The results are presented in Table 6.

4.3.1 Length of spreading of the *M. phaseolina*

A significant positive correlation was observed with the number of internodes crossed by *M. phaseolina* (0.765, 0.788), per cent disease incidence (0.457, 0.493) and stem girth (0.124, 0.149) both at phenotypic and genotypic level. However, significantly negative correlation with brix per cent at maturity (-0.118, -0.128) both at phenotypic and genotypic level was recorded. Length of spread of fungus exhibited negative but non-significant correlation with chlorophyll content at maturity stage (-0.0219, -0.0239) and fodder yield per plot (-0.0536, -0.0537) both at phenotypic level and genotypic level respectively.

4.3.2 Number of internode crossed by fungus

This trait exhibited significant positive correlation with length of spreading of the fungus (0.765, 0.789), per cent lodging (0.094, 0.099) and per cent disease incidence (0.490, 0.549) both at phenotypic and genotypic level respectively. However, it recorded significant negative correlation with brix percentage (-0.1126, -0.134) both at phenotypic and genotypic level respectively. Number of internodes crossed by fungus exhibited positive and non-significant correlation with number of leaves per plant (0.0497, 0.0028) and negative but non-significant association with fodder yield per plot (-0.069, -0.066) both at phenotypic level and genotypic level, respectively.

4.3.3 Per cent lodging

Highly significant and positive correlation was observed both at the phenotypic and genotypic level with number of internodes crossed by fungus (0.094, 0.099).

However, significantly negative correlation was recorded with fodder yield per plot (-0.117, -0.124,) brix percentage (-0.189, -0.195) and number of leaves per plant (-0.193, -0.228) both at phenotypic and genotypic level among the minicore accessions. On the other hand, negative non-significant correlation with per cent disease incidence, chlorophyll content at flag leaf stage, chlorophyll content at maturity stage and stem girth was noticed at the phenotypic and genotypic Level.

4.3.4 Per cent disease incidence (PDI)

This trait exhibited strong and positive significant correlation with number of internodes crossed, length of spreading of the fungus (0.457, 0.493) and number of internodes crossed by fungus (0.490, 0.549), both at phenotypic and genotypic level respectively. While, it was negatively correlated with number of leaves per plant, fodder yield per plot, chlorophyll content at flag leaf stage and chlorophyll content at maturity stage both at phenotypic and genotypic level.

4.3.5 Chlorophyll content at flag leaf stage

It was found that chlorophyll content at flag leaf stage recorded positive significant and correlation with chlorophyll content at maturity stage (0.360, 0.458) while, it recorded negative and significant correlation with total soluble solids (-0.108, -0.131) both at phenotypic and genotypic level. However, it recorded negative correlation with number of internodes crossed by fungus (-0.027, -0.032), per cent lodging (-0.043, -0.043), per cent incidence (-0.015, -0.002) and number of leaves per plant (-0.017, -0.038) both at phenotypic and genotypic level, respectively.

4.3.6 Chlorophyll content at maturity stage

This trait showed significant positive correlation with chlorophyll content at flag leaf stage (0.360, 0.458) and fodder yield per plot (0.127, 0.134) both at phenotypic and genotypic level. However, it recorded negative correlation with brix per cent and disease parameters viz., per cent lodging (-0.039, -0.042), length of spreading of the fungus (-0.021, -0.024) and number of internode crossed by fungus (-0.065, -0.072) and per cent disease incidence (-0.064, -0.071) among the *rabi* minicore accessions both at phenotypic and genotypic level, respectively.

4.3.7 Brix per cent at maturity

Brix per cent at maturity recorded highly significant and negative correlation with chlorophyll content at flag leaf stage (-0.108, -0.131), stem girth (-0.101, -0.112) and disease parameters viz., per cent lodging (-0.189, -0.195), length of spreading of the fungus (-0.118, -0.128) and number of internode crossed by fungus (-0.113, -0.134) both at phenotypic and genotypic level respectively. While, it trait was recorded negative but non-significant association with chlorophyll content at maturity stage (0.360, 0.458) and numbers of leaves per plant (-0.027, -0.040) both at phenotypic and genotypic level, respectively. Positive but non-significant correlation (0.015, 0.017) between brix per cent and fodder yield per plot both at phenotypic and genotypic level, respectively.

4.3.8 Stem girth

Stem girth showed significant positive correlation with length of spread of fungus (0.124, 0.149), number of leaves per plant (0.179, 0.313) and fodder yield per plot (0.095, 0.113) both at phenotypic and genotypic level, respectively. In contrast, this trait was correlated negatively with charcoal rot component character viz., per cent lodging (-0.069, -0.082) both at phenotypic and genotypic level, respectively. However, a negative and significant correlation was observed with brix per cent (-0.101, -0.112) both at phenotypic level and genotypic, respectively.

4.3.9 Number of leaves per plant

Highly significant and positive correlation was observed both at phenotypic and genotypic level with stem girth (0.179, 0.313) and fodder yield per plot (0.215, 0.264) respectively. In contrast, this trait exhibited significant negative correlation with per cent lodging (-0.193, -0.228) both at phenotypic and genotypic level respectively. On the other hand, it recorded positive and non-significant correlation with length of spreading by fungus (0.051, 0.056), number of internodes crossed by fungus (0.047,

0.049) and chlorophyll content at maturity stage (0.057, 0.069) both at phenotypic and genotypic level, respectively.

4.3.10 Fodder yield per plot

Fodder yield per plot recorded highly significant and positive correlation with chlorophyll content at maturity (0.127, 0.134), number of leaves per plant (0.215, 0.264) and stem girth (0.095, 0.113) both at phenotypic and genotypic level, respectively. While, this trait recorded negative but non-significant association with disease parameters viz., per cent disease incidence (-0.066, -0.065), length of spreading of the fungus (-0.054, -0.054) and number of internodes crossed by fungus (-0.069, -0.066) both at phenotypic and genotypic level, respectively. This trait was found to be highly significant and negatively correlated with per cent lodging (-0.117, -0.124) both at phenotypic and genotypic level, respectively.

Table 7: Comparative mean performance of sorghum minicore accessions for the component traits of charcoal rot resistance

Sl. No	AC	LD (%)	PLS	SP	NIC	PDI	Sl. No.	AC	LD (%)	PLS	SP	NIC	PDI
1	IS22986	0.000	1.00	22.00	1.46	70.00	29	IS29241	10.00	2.00	10.00	1.02	20.00
2	IS25989	50.00	5.00	2.500	0.25	20.00	30	IS2413	30.00	3.00	20.00	1.00	33.33
3	IS7305	30.00	4.00	36.00	1.99	66.60	31	IS4631	0.000	1.00	38.40	3.67	100.0
4	IS29269	60.00	5.00	20.00	5.66	70.00	32	IS23891	60.00	5.00	97.33	5.33	100.0
5	IS29772	50.00	5.00	70.30	1.00	50.00	33	IS7957	0.000	1.00	34.60	4.00	60.00
6	IS16151	50.00	5.00	110.0	6.10	60.00	34	IS1233	0.000	1.00	48.00	2.50	60.00
7	IS608	20.00	3.00	30.00	3.67	20.00	35	IS28451	100.0	2.00	77.50	5.00	100.0
8	IS30450	55.00	5.00	21.50	3.50	66.60	36	IS25732	30.00	3.00	94.25	5.00	80.00
9	IS24348	30.00	4.00	36.60	2.33	80.00	37	IS8012	0.000	1.00	44.00	2.75	50.00
10	IS30460	70.00	5.00	0.000	0.00	0.00	38	IS9745	0.000	1.00	14.25	1.25	100.0
11	IS20816	100.0	5.00	38.60	2.67	70.00	39	IS5094	70.00	5.00	60.00	2.25	40.00
12	IS22616	100.0	5.00	250.0	3.67	60.00	40	IS33844	0.000	1.00	63.60	3.00	100.0
13	IS32787	40.00	4.00	0.000	0.00	20.00	41	IS28747	0.000	1.00	12.80	0.80	20.00
14	IS26617	0.000	1.00	0.000	0.00	0.00	42	IS20740	100.0	5.00	32.60	2.10	80.00
15	IS30417	40.00	4.00	0.000	0.00	0.00	43	IS4515	20.00	3.00	68.00	3.60	100.0
16	IS29468	10.00	2.00	69.40	6.00	20.00	44	IS2872	30.00	4.00	27.60	2.50	100.0
17	IS23514	50.00	5.00	0.00	0.00	0.00	45	IS31043	40.00	4.00	73.33	3.34	100.0
18	IS30466	0.000	1.00	24.00	1.40	40.00	46	IS11026	50.00	5.00	60.33	3.50	66.66
19	IS1212	20.00	3.00	0.00	0.00	20.00	47	IS2389	20.00	3.00	3.670	0.33	33.33
20	IS30451	80.00	5.00	26.60	1.33	70.00	48	IS26737	0.00	1.00	35.00	1.00	60.00
21	IS24953	40.00	4.00	0.000	4.00	0.00	49	IS995	20.00	3.00	37.66	2.05	66.67
22	IS28614	40.00	4.00	23.10	4.00	70.00	50	IS12883	70.00	5.00	9.670	0.67	28.33
23	IS27887	20.00	3.00	0.000	0.00	0.00	51	IS20697	20.00	3.00	112.0	4.60	80.00
24	IS30507	0.000	1.00	41.50	3.00	100.0	52	IS12706	20.00	3.00	77.50	3.50	100.0
25	IS25910	70.00	5.00	40.20	2.20	100.0	53	IS8777	0.000	1.00	75.00	3.16	70.00
26	IS7987	70.00	5.00	0.000	0.00	0.000	54	IS22720	60.00	5.00	8.80	2.50	33.33
27	IS7679	30.00	4.00	32.30	1.25	70.00	55	IS23590	0.000	1.00	24.00	1.40	80.00
28	IS20743	0.000	1.00	44.60	1.21	66.60	56	IS4360	0.000	1.00	0.000	0.00	0.000

Table 7: Contd.....

Sl. No	AC	LD (%)	PLS	SP	NIC	PDI	Sl. No.	AC	LD (%)	PLS	SP	NIC	PDI
57	IS20713	0.000	1.00	30.00	1.28	70.00	89	IS30443	20.00	3.00	65.15	2.67	66.66
58	IS22294	0.000	1.00	7.200	0.00	40.00	90	IS9133	60.00	5.00	30.00	2.00	70.00
59	IS15744	30.00	4.00	10.00	0.42	40.00	91	IS4060	0.000	1.00	6.660	1.09	80.00
60	IS32439	0.000	1.00	90.00	4.50	100.0	92	IS4613	40.00	4.00	38.00	2.20	60.00
61	IS21512	20.00	3.00	21.00	1.20	70.00	93	IS29654	0.000	1.00	20.00	1.50	100.0
62	IS4092	0.000	1.00	79.60	4.20	100.0	94	IS324453	0.000	1.00	15.00	1.05	60.00
63	IS31714	50.00	5.00	35.20	2.50	50.00	95	IS473	80.00	5.00	16.66	2.00	65.00
64	IS25249	80.00	5.00	17.00	1.00	50.00	96	IS4951	70.00	5.00	73.40	4.00	60.00
65	IS31186	60.00	5.00	29.00	1.03	50.00	97	IS29358	70.00	5.00	7.500	0.50	0.000
66	IS23684	0.000	1.00	43.20	2.08	50.00	98	IS19389	0.000	1.00	27.00	1.64	66.67
67	IS31446	0.000	1.00	0.000	0.00	0.000	99	IS12447	0.000	1.00	33.00	1.75	100.0
68	IS1041	20.00	3.00	51.00	2.20	100.0	100	IS29335	60.00	5.00	23.25	2.50	70.00
69	IS2426	0.000	1.00	0.000	2.50	100.0	101	IS33353	70.00	5.00	22.60	1.28	60.00
70	IS18039	30.00	4.00	65.50	3.25	80.00	102	IS20195	80.00	5.00	21.66	4.00	66.66
71	IS16382	100.0	5.00	45.00	2.97	60.00	103	IS602	100.0	5.00	0.000	0.00	0.000
72	IS16151	0.000	1.00	32.00	1.23	60.00	104	IS29733	50.00	5.00	47.50	2.50	100.0
73	IS17941	40.00	4.00	24.00	1.40	66.60	105	IS7131	90.00	5.00	8.750	0.60	50.00
74	IS2379	20.00	3.00	67.00	4.02	100.0	106	IS13971	60.00	5.00	124.0	5.52	100.0
75	IS19676	100.0	5.00	24.00	1.65	60.00	107	IS26484	20.00	5.00	39.66	2.52	80.00
76	IS18758	60.00	5.00	78.30	3.33	75.00	108	IS29627	0.000	1.00	37.00	1.85	100.0
77	IS26046	60.00	5.00	7.330	0.67	66.60	109	IS24463	20.00	3.00	118.5	6.01	100.0
78	IS1004	60.00	5.00	44.00	3.00	80.00	110	IS33090	20.00	3.00	25.00	1.75	70.00
79	IS26694	60.00	5.00	37.30	2.33	66.60	111	IS29392	0.000	1.00	17.00	1.25	50.00
80	IS29314	10.00	2.00	73.40	4.75	100.0	112	IS30533	50.00	5.00	5.100	0.33	20.00
81	IS8916	0.000	1.00	75.00	4.00	100.0	113	IS29914	0.000	1.00	54.80	2.70	60.00
82	IS32349	20.00	3.00	0.000	0.00	0.000	114	IS31446	50.00	5.00	100.4	4.27	100.0
83	IS5667	0.000	1.00	15.10	2.06	100.0	115	IS19450	40.00	4.00	65.00	3.37	60.00
84	IS29326	0.000	1.00	8.100	0.63	25.00	116	IS13919	0.000	1.00	20.00	1.40	33.33
85	IS13549	100.0	5.00	28.10	1.90	100.0	117	IS28313	30.00	4.00	10.10	0.60	20.00
86	IS995	60.00	5.00	99.90	5.30	100.0	118	IS5386	20.00	3.00	70.25	3.60	100.0
87	IS5301	0.000	1.00	44.00	4.84	100.0	119	IS5919	90.00	5.00	37.15	2.00	80.00
88	IS4698	20.00	3.00	94.80	5.30	100.0	120	IS33023	0.000	1.00	62.00	2.80	100.0

Table 7: Contd.....

Sl. No	AC	LD (%)	PLS	SP	NIC	PDI	Sl. No.	AC	LD (%)	PLS	SP	NIC	PDI
121	IS2902	40.00	4.00	37.00	2.00	50.00	152	IS23586	50.00	5.00	7.800	3.40	100.0
122	IS5919	90.00	5.00	20.00	1.00	70.00	153	IS20956	20.00	3.00	6.500	3.40	80.00
123	IS33023	60.00	5.00	61.00	3.80	100.0	154	IS4581	100.0	5.00	9.800	5.66	100.0
124	IS2902	20.00	3.00	13.30	1.00	66.60	155	IS22239	0.000	1.00	12.70	3.63	100.0
125	IS29187	40.00	4.00	41.20	4.75	100.0	156	IS19445	60.00	5.00	6.300	2.80	80.00
126	IS30466	90.00	5.00	12.50	1.00	66.60	157	IS29568	0.000	1.00	8.100	2.50	50.00
127	IS14290	20.00	3.00	20.00	0.67	66.60	158	IS29304	60.00	5.00	18.30	2.50	60.00
128	IS27034	80.00	5.00	23.30	2.00	80.00	159	IS23579	20.00	3.00	9.100	2.75	80.00
129	IS6421	20.00	3.00	24.00	1.75	70.00	160	IS28389	60.00	5.00	11.30	2.75	50.00
130	IS24175	0.000	1.00	20.00	1.50	80.00	161	IS24939	60.00	5.00	24.20	4.67	66.67
131	IS29091	0.000	1.00	16.00	0.80	40.00	162	IS24503	100.0	5.00	5.700	1.55	50.00
132	IS10969	0.000	1.00	26.50	1.75	70.00	163	IS23216	25.00	3.00	8.600	3.07	100.0
133	IS19859	100.0	5.00	25.40	1.80	80.00	164	IS7310	0.000	1.00	4.700	1.00	50.00
134	IS26025	40.00	4.00	12.50	0.60	20.00	165	IS15466	20.00	3.00	5.200	2.00	40.00
135	IS30400	0.000	1.00	21.00	1.60	80.00	166	IS29689	0.000	1.00	14.40	1.00	50.00
136	IS31714	20.00	3.00	10.00	1.00	33.30	167	IS15945	20.00	3.00	25.80	2.40	80.00
137	IS2864	20.00	3.00	45.20	2.60	100.0	168	IS14010	60.00	5.00	49.50	4.00	70.00
138	IS22239	20.00	3.00	22.60	2.00	60.00	169	IS29606	20.00	3.00	9.200	1.40	60.00
139	IS16528	20.00	3.00	9.000	1.00	20.00	170	IS30572	0.000	1.00	15.40	2.27	66.66
140	IS20298	0.000	1.00	7.400	1.00	50.00	171	IS11473	0.000	1.00	18.50	1.49	80.00
141	IS30838	20.00	3.00	0.000	0.00	0.000	172	IS31706	0.000	1.00	6.500	1.79	90.00
142	IS14861	90.00	5.00	24.50	1.33	33.30	173	IS30079	20.00	3.00	14.20	3.50	75.00
143	IS4372	0.000	1.00	0.000	0.00	0.00	174	IS28849	40.00	4.00	14.40	2.80	66.66
144	IS15931	0.000	1.00	15.00	1.00	50.00	175	IS2413	20.00	3.00	21.10	1.80	60.00
145	IS19153	0.000	1.00	20.00	1.20	50.00	176	IS25089	0.000	1.00	17.80	1.80	60.00
146	IS24492	0.000	1.00	8.750	1.00	25.00	177	IS6351	40.00	4.00	8.300	1.25	33.33
147	IS24139	0.000	1.00	7.500	0.75	50.00	178	IS29239	20.00	3.00	20.60	0.40	35.00
148	IS24462	0.000	1.00	21.50	1.50	70.00	179	IS3971	40.00	4.00	7.200	0.60	25.00
149	IS21863	60.00	5.00	51.60	5.11	33.30	180	IS8774	0.000	1.00	8.900	3.00	70.00
150	IS29441	20.00	3.00	21.20	1.75	70.00	181	IS21645	0.000	1.00	6.000	2.67	66.66
151	IS26749	0.000	1.00	6.000	2.10	79.00	182	IS23992	80.00	5.00	34.00	4.00	70.00

Table 7: Contd.....

Sl. No.	AC	LD (%)	PLS	SP	NIC	PDI	Sl. No.	AC	LD (%)	PLS	SP	NIC	PDI
183	IS15170	40.00	4.00	65.00	1.42	80.00	212	IS27557	0.000	1.00	16.15	1.75	60.00
184	IS23521	80.00	5.00	75.80	3.75	100.0	213	IS30536	00.00	1.00	45.20	2.40	100.0
185	IS603	40.00	4.00	108.7	3.33	81.60	214	IS30383	20.00	3.00	10.00	0.80	20.00
186	IS29100	80.00	5.00	65.00	1.65	50.00	215	IS31651	20.00	3.00	6.670	0.67	66.67
187	IS5295	20.00	3.00	34.80	4.00	100.0	216	IS29519	40.00	4.00	35.00	1.80	100.0
188	IS7250	0.000	1.00	29.40	3.33	66.60	217	IS20632	0.000	1.00	25.60	2.00	80.00
189	IS8348	0.000	1.00	34.50	2.00	100.0	218	IS28449	20.00	3.00	36.00	2.60	100.0
190	IS12937	60.00	5.00	38.70	2.00	75.00	219	IS24218	0.000	1.00	0.000	0.00	0.00
191	IS27912	0.000	1.00	50.00	1.80	100.0	220	IS12804	50.00	5.00	12.51	0.75	100.0
192	IS25301	20.00	3.00	83.30	3.50	75.00	221	IS2382	20.00	3.00	37.51	1.76	50.00
193	IS20625	40.00	4.00	14.50	1.75	66.60	222	IS23644	0.000	1.00	21.67	1.01	33.33
194	IS12697	0.000	1.00	57.50	1.60	40.00	223	IS12945	0.000	1.00	17.51	1.02	60.00
195	IS10757	0.000	1.00	15.60	3.03	100.0	224	IS17980	20.00	3.00	31.76	2.26	50.00
196	IS11619	40.00	4.00	26.00	2.50	50.00	225	IS12735	0.000	1.00	12.01	1.02	70.00
197	IS26701	40.00	4.00	63.00	2.67	60.00	226	IS9108	0.000	1.00	15.00	1.00	50.00
198	IS19975	0.000	1.00	83.70	4.00	66.60	227	IS21083	20.00	3.00	56.63	7.04	100.0
199	IS25836	100.0	5.00	133.0	5.20	33.30	228	IS14090	50.00	5.00	38.00	2.60	100.0
200	IS20727	100.0	5.00	29.00	1.20	80.00	229	IS29627	20.00	3.00	32.00	1.60	80.00
201	IS10867	30.00	4.00	24.70	2.15	80.00	230	IS25548	0.000	1.00	24.50	2.00	80.00
202	IS12302	0.000	1.00	23.00	2.52	70.00	231	IS28141	20.00	3.00	21.33	1.33	33.37
203	IS12965	0.000	1.00	57.00	2.68	60.00	232	IS15478	30.00	4.00	22.00	1.42	60.00
204	IS14779	20.00	3.00	58.70	2.50	66.60	233	IS13294	0.000	1.00	18.00	1.50	20.00
205	IS27786	40.00	4.00	23.00	1.50	100.0	234	IS22799	30.00	4.00	2.500	1.38	20.00
206	IS19262	20.00	3.00	35.00	1.40	100.0	235	IS11919	40.00	4.00	30.16	1.92	100.0
207	IS10302	0.000	1.00	15.00	1.75	60.00	236	IS29565	20.00	3.00	23.87	1.88	100.0
208	IS13893	0.000	1.00	52.00	2.80	100.0	237	M-35-1	20.00	3.00	24.28	2.36	30.00
209	IS29714	20.00	3.00	29.00	3.50	100.0	238	BJV-44	20.00	3.00	20.25	2.15	30.00
210	IS32245	50.00	5.00	4.200	0.50	50.00	239	SPV86	40.00	4.00	111.5	5.00	100.0
211	IS2397	0.000	1.00	23.15	2.50	75.00	240	E-36-1	10.00	2.00	13.79	1.09	10.00

AC – accessions, LD – per cent lodging, PLS- per cent lodging score (1-5 scale), SP – spreading of fungus, NIC – number of internodes crossed, PDI – percent disease incidence.

Table 8: Visual scoring and mean performance of minicore accessions of sorghum for fodder yield and quality traits

Sl. No	Accessions	Glossiness	Bloom	Serration	Pubescence	Chlorophyll content -1	Chlorophyll content-2	SG	BRIX %	NLP	FY
1	IS22986	1.00	medium	serration	Appressed	45.19	55.67	1.10	9.20	9.750	0.915
2	IS25989	5.00	medium	non-serration	Appressed	49.83	49.34	0.75	6.00	6.250	1.525
3	IS7305	6.00	medium	non-serration	Appressed	46.97	47.87	0.95	1.90	10.25	0.645
4	IS29269	3.00	medium	serration	Appressed	46.79	36.03	1.00	3.00	9.000	1.035
5	IS29772	6.00	Low	serration	Appressed	46.55	37.36	1.42	2.30	5.750	1.035
6	IS16151	6.00	medium	non-serration	Appressed	49.26	39.70	1.10	4.70	7.000	0.375
7	IS608	3.00	Low	serration	Appressed	52.22	35.10	1.15	3.40	9.000	0.645
8	IS30450	4.00	medium	serration	Appressed	51.19	50.65	1.21	7.10	8.750	0.645
9	IS24348	3.00	Low	serration	Appressed	51.57	28.40	0.97	1.10	6.500	0.412
10	IS30460	4.00	High	serration	Appressed	49.91	35.53	1.05	1.00	6.500	0.401
11	IS20816	4.00	Low	non-serration	Appressed	49.19	20.85	1.06	4.30	6.750	0.850
12	IS22616	3.00	High	non-serration	Appressed	49.03	26.80	1.95	4.30	10.00	0.401
13	IS32787	1.00	High	serration	Appressed	56.93	21.35	1.45	13.60	6.500	0.401
14	IS26617	7.00	High	Serration	Appressed	48.09	17.00	1.30	10.30	8.000	0.309
15	IS30417	6.00	High	serration	Appressed	51.99	9.30	1.26	10.30	7.670	0.415
16	IS29468	3.00	Low	serration	Glabrous	49.01	14.00	1.05	2.10	9.000	0.220
17	IS23514	4.00	Low	serration	Glabrous	47.9	17.87	1.35	3.20	9.000	0.740
18	IS30466	3.00	Low	serration	Appressed	48.71	7.650	0.86	3.20	7.830	0.220
19	IS1212	9.00	Low	serration	Appressed	48.78	14.07	1.08	2.20	7.250	0.740
20	IS30451	9.00	medium	serration	Appressed	57.14	10.32	1.71	6.30	7.250	0.225
21	IS24953	1.00	medium	serration	Appressed	48.67	11.02	0.96	17.70	8.000	0.645
22	IS28614	9.00	Low	serration	Appressed	51.56	16.60	1.30	23.10	8.000	0.645
23	IS27887	1.00	medium	serration	Appressed	50.18	10.50	1.23	9.00	7.420	0.551

Table 8 contd.....

Sl. No	Accessions	Glossiness	Bloom	Serration	Pubescence	Chlorophyll content -1	Chlorophyll content-2	SG	BRIX %	NLP	FY
24	IS30507	5.00	medium	serration	Appressed	57.36	9.60	1.06	6.10	5.500	0.553
25	IS25910	5.00	Low	serration	Appressed	48.72	29.40	2.21	7.20	9.000	0.345
26	IS7987	4.00	Low	non-serration	Appressed	48.72	36.32	2.43	5.90	11.83	0.740
27	IS7679	4.00	Low	serration	Appressed	47.98	23.82	1.12	12.10	6.250	1.230
28	IS20743	3.00	medium	non-serration	Appressed	51.76	14.45	0.70	17.9	5.250	0.305
29	IS29241	9.00	High	serration	Appressed	53.97	70.1	1.89	0.20	7.500	0.250
30	IS2413	1.00	medium	serration	Appressed	54.88	38.87	1.32	7.80	7.750	0.415
31	IS4631	7.00	medium	serration	Appressed	57.6	26.25	1.49	4.30	5.250	0.645
32	IS23891	2.00	High	serration	Appressed	59.34	29.45	1.21	0.50	7.250	0.250
33	IS7957	8.00	medium	non-serration	Appressed	57.94	28.75	1.38	3.30	7.830	0.420
34	IS1233	7.00	Low	non-serration	Appressed	52.28	25.77	1.60	5.20	8.500	1.430
35	IS28451	8.00	medium	serration	Appressed	60.69	8.77	1.72	2.80	7.500	0.255
36	IS25732	7.00	High	serration	Appressed	52.25	10.13	1.40	5.50	6.670	0.255
37	IS8012	8.00	medium	serration	Appressed	50.61	19.95	1.25	3.00	6.670	0.745
38	IS9745	1.00	High	serration	Appressed	50.26	10.45	1.77	1.70	8.500	0.320
39	IS5094	7.00	High	serration	Appressed	49.21	18.12	1.29	3.00	7.830	0.213
40	IS33844	1.00	medium	non-serration	Appressed	38.25	11.8	1.65	2.40	9.500	0.745
41	IS28747	5.00	High	serration	Appressed	55.05	10.35	1.44	15.1	6.170	0.305
42	IS20740	8.00	medium	serration	Appressed	48.76	18.3	1.51	0.90	6.750	0.320
43	IS4515	1.00	medium	serration	Glabrous	52.76	16.62	1.48	7.00	9.330	0.795
44	IS2872	1.00	medium	serration	Appressed	53.17	18.52	1.33	7.60	6.500	0.430
45	IS31043	1.00	High	serration	Appressed	56.22	26.12	1.65	9.60	6.750	0.390
46	IS11026	3.00	High	serration	Appressed	50.01	25.67	1.43	6.80	8.500	0.520
47	IS2389	4.00	High	serration	Appressed	50.49	65.15	1.68	7.30	8.750	0.610

Table 8 contd.....

Sl. No	Accessions	Glossiness	Bloom	Serration	Pubescence	Chlorophyll content -1	Chlorophyll content-2	SG	BRIX %	NLP	FY
48	IS26737	9.00	High	non-serration	Appressed	52.43	50.3	1.36	6.50	8.500	1.510
49	IS995	9.00	High	non-serration	Appressed	53.89	28.1	1.35	4.80	6.750	0.390
50	IS12883	7.00	High	serration	Appressed	54.39	33.3	1.28	9.90	6.500	0.213
51	IS20697	2.00	High	serration	Glabrous	53.55	49.27	1.65	19.7	10.00	0.645
52	IS12706	1.00	Medium	serration	Appressed	50.5	16	1.63	5.00	11.75	0.230
53	IS8777	8.00	Medium	non-serration	Appressed	52.5	38.35	1.6	8.80	11.50	0.795
54	IS22720	9.00	Medium	serration	Appressed	51.73	40.87	1.225	12.4	8.830	0.301
55	IS23590	7.00	Low	serration	Appressed	45.43	35.45	1.30	17.3	10.00	1.260
56	IS4360	3.00	medium	serration	Appressed	50.5	49.25	1.69	7.00	11.25	0.515
57	IS20713	7.00	medium	serration	Appressed	53.04	48.48	1.11	5.30	8.25	0.310
58	IS4360	1.00	medium	serration	Glabrous	49.95	57.90	1.33	12.20	9.67	0.284
59	IS15744	1.00	medium	serration	Appressed	49.07	28.63	1.45	15.30	7.50	0.310
60	IS32439	8.00	medium	non-serration	Appressed	44.95	45.35	1.70	0.60	5.50	0.310
61	IS21512	9.00	medium	non-serration	Glabrous	57.78	33.25	1.45	3.70	9.75	0.475
62	IS4092	9.00	High	serration	Appressed	53.74	33.25	1.45	0.80	8.25	0.475
63	IS31714	9.00	High	serration	Appressed	54.93	38.08	0.75	25.80	6.50	0.227
64	IS25249	1.00	High	serration	Appressed	48.54	14.48	1.65	5.50	7.00	0.320
65	IS31186	1.00	Low	serration	Glabrous	53.47	48.95	1.22	14.80	6.00	0.150
66	IS23684	3.00	Low	serration	Appressed	53.82	11.50	1.27	6.90	9.00	0.620
67	IS31456	1.00	Low	serration	Appressed	44.26	24.43	1.30	10.20	9.25	0.890
68	IS1041	8.00	medium	serration	Appressed	53.89	41.10	1.15	5.90	8.08	0.225
69	IS2426	7.00	medium	serration	Appressed	53.9	29.08	0.99	8.20	7.00	0.220
70	IS18039	4.00	medium	serration	Glabrous	44.37	21.50	1.51	13.50	7.58	0.230
71	IS16382	1.00	medium	non-serration	Appressed	47.41	19.78	1.75	3.06	7.00	0.210

Table 8 contd.....

Sl. No	Accessions	Glossiness	Bloom	Serration	Pubescence	Chlorophyll content -1	Chlorophyll content-2	SG	BRIX %	NLP	FY
72	IS16151	1.00	medium	non-serration	Appressed	52.21	32.35	1.23	17.20	6.67	0.895
73	IS17941	2.00	Low	serration	Appressed	51.19	32.98	1.24	3.50	8.00	0.310
74	IS2379	9.00	medium	serration	Appressed	58.42	44.30	1.18	14.50	6.25	0.225
75	IS19676	8.00	High	serration	Appressed	60.18	41.40	0.76	7.00	5.58	0.110
76	IS18758	7.00	Low	serration	Appressed	51.88	18.90	1.33	9.50	7.75	0.415
77	IS26046	8.00	medium	serration	Appressed	52.56	11.35	1.40	7.30	6.50	0.210
78	IS1004	1.00	High	serration	Appressed	61.19	51.03	1.35	10.90	7.42	0.825
79	IS26694	7.00	High	serration	Appressed	51.66	13.58	1.55	5.30	7.75	0.315
80	IS29314	1.00	High	serration	Appressed	52.13	11.00	1.20	6.10	7.75	0.410
81	IS8916	5.00	Low	serration	Glabrous	35.01	5.88	1.46	5.40	8.25	0.210
82	IS32349	8.00	Low	serration	Appressed	48.03	32.28	1.44	3.60	12.50	0.175
83	IS5667	1.00	Low	serration	Appressed	44.95	33.03	1.54	17.60	9.50	1.100
84	IS29326	9.00	High	serration	Appressed	47.6	12.78	1.37	6.20	5.50	0.250
85	IS13549	1.00	High	serration	Appressed	51.48	18.65	1.84	5.80	8.58	0.153
86	IS995	1.00	High	serration	Appressed	47.75	39.88	1.93	15.40	9.50	0.395
87	IS5301	8.00	medium	serration	Appressed	47.63	33.38	1.83	4.90	9.17	0.815
88	IS4698	1.00	medium	non-serration	Appressed	44.28	19.78	1.89	16.90	6.75	0.210
89	IS30443	3.00	medium	serration	Glabrous	45.80	12.83	1.43	9.40	6.50	0.153
90	IS9133	5.00	High	non-serration	Appressed	53.90	30.50	1.42	5.85	6.50	0.754
91	IS4060	8.00	medium	serration	Appressed	50.32	33.80	1.35	10.10	7.50	0.150
92	IS4613	8.00	High	serration	Glabrous	49.70	25.20	1.55	4.80	9.25	0.152
93	IS29654	9.00	medium	non-serration	Appressed	48.77	28.28	1.05	12.70	9.00	0.315
94	IS324453	3.00	medium	serration	Appressed	57.30	15.70	1.35	18.70	10.00	0.720
95	IS473	5.00	medium	non-serration	Appressed	49.05	15.70	1.25	12.00	5.75	0.210

Table 8 contd.....

Sl. No	Accessions	Glossiness	Bloom	Serration	Pubescence	Chlorophyll content -1	Chlorophyll content-2	SG	BRIX %	NLP	FY
96	IS4951	5.00	High	serration	Appressed	47.77	33.83	1.00	3.10	6.58	0.425
97	IS29358	3.00	medium	serration	Appressed	55.90	45.90	1.50	2.21	5.50	1.050
98	IS19389	4.00	High	serration	Appressed	54.32	20.08	1.44	7.60	7.25	0.730
99	IS12447	1.00	High	non-serration	Appressed	42.57	11.25	1.48	17.30	9.75	1.330
100	IS29335	3.00	Low	serration	Glabrous	52.90	15.93	1.25	13.30	7.50	0.425
101	IS33353	4.00	medium	non-serration	Appressed	50.08	15.93	1.17	17.80	8.08	0.425
102	IS20195	4.00	medium	non-serration	Appressed	53.00	27.30	1.64	5.00	6.75	0.215
103	IS602	6.00	Low	non-serration	Appressed	57.73	17.68	1.45	13.95	6.50	0.150
104	IS29733	4.00	High	non-serration	Appressed	56.73	48.50	1.34	7.00	6.75	0.310
105	IS7131	6.00	Low	serration	Glabrous	54.22	36.90	1.49	6.50	7.25	0.205
106	IS13971	5.00	Medium	serration	Appressed	55.12	37.50	1.24	7.30	8.00	0.250
107	IS26484	4.00	Medium	non-serration	Appressed	51.97	14.80	1.5	8.70	8.00	0.205
108	IS29627	5.00	High	serration	Appressed	57.43	41.35	1.18	13.80	8.00	0.430
109	IS24463	8.00	Medium	serration	Appressed	52.77	10.43	1.57	9.60	6.00	0.300
110	IS33090	4.00	Medium	non-serration	Appressed	48.85	10.20	1.40	15.00	6.50	0.205
111	IS29392	1.00	High	non-serration	Appressed	51.90	37.03	1.40	7.30	7.25	0.125
112	IS30533	1.00	Low	serration	Appressed	50.33	33.73	0.81	5.10	7.25	0.350
113	IS29914	1.00	High	serration	Appressed	49.08	67.88	1.32	14.50	5.25	0.265
114	IS31446	9.00	Medium	serration	Appressed	49.82	52.95	1.40	13.20	6.00	0.125
115	IS19450	5.00	Low	non-serration	Appressed	50.33	34.85	1.15	6.70	7.42	0.125
116	IS13919	4.00	Low	non-serration	Appressed	44.52	29.93	1.23	10.90	6.75	0.205
117	IS28313	3.00	Low	serration	Appressed	50.33	32.65	1.55	10.10	8.83	0.125
118	IS5386	5.00	Medium	serration	Appressed	51.97	21.13	1.30	16.00	6.67	0.615
119	IS5919	9.00	Medium	serration	Appressed	50.47	29.88	1.50	6.00	6.83	0.205

Table 8 contd.....

Sl. No	Accessions	Glossiness	Bloom	Serration	Pubescence	Chlorophyll content -1	Chlorophyll content-2	SG	BRIX %	NLP	FY
120	IS33023	9.00	Low	serration	Appressed	51.97	25.28	1.49	6.00	8.17	0.430
121	IS2902	5.00	Low	non-serration	Glabrous	40.12	9.65	0.66	7.80	7.50	0.125
122	IS5919	3.00	Low	non-serration	Appressed	49.35	20.25	1.09	6.50	7.50	0.530
123	IS33023	5.00	High	serration	Appressed	49.93	18.33	1.37	9.80	8.00	0.320
124	IS2902	5.00	Low	non-serration	Appressed	45.77	20.18	0.68	12.70	6.00	0.215
125	IS29187	4.00	Medium	non-serration	Appressed	53.15	26.35	1.42	6.30	8.75	0.140
126	IS30466	4.00	Low	serration	Appressed	53.15	13.20	1.26	8.10	7.25	0.125
127	IS14290	1.00	Low	serration	Appressed	46.55	14.70	1.20	18.30	6.50	0.750
128	IS27034	1.00	Low	serration	Appressed	50.95	20.95	1.23	9.10	6.50	0.205
129	IS6421	4.00	Medium	serration	Glabrous	53.03	22.95	1.48	11.30	10.00	1.080
130	IS24175	4.00	Medium	serration	Appressed	54.93	17.40	1.59	24.20	8.50	0.355
131	IS29091	2.00	Medium	serration	Appressed	50.18	23.50	1.33	5.70	6.67	0.430
132	IS10969	3.00	High	non-serration	Appressed	54.93	26.23	1.47	8.60	9.50	0.300
133	IS19859	9.00	High	non-serration	Appressed	58.05	14.15	1.33	4.70	5.58	0.230
134	IS26025	9.00	Medium	serration	Appressed	56.52	18.78	1.13	5.20	6.50	0.755
135	IS30400	7.00	Low	serration	Appressed	55.17	33.38	1.46	14.40	7.50	0.800
136	IS31714	8.00	High	serration	Appressed	48.88	28.58	1.30	25.80	9.00	0.805
137	IS2864	9.00	Low	non-serration	Appressed	50.18	11.00	1.48	9.50	8.17	0.210
138	IS22239	1.00	Medium	non-serration	Appressed	48.30	17.80	1.50	9.20	6.25	0.295
139	IS16528	1.00	Medium	non-serration	Appressed	52.70	12.75	1.35	15.40	7.00	0.210
140	IS20298	8.00	Medium	non-serration	Appressed	51.25	29.95	0.74	18.50	7.75	0.210
141	IS30838	9.00	Low	serration	Appressed	59.48	21.18	1.32	6.50	6.25	0.110
142	IS14861	5.00	Medium	non-serration	Appressed	58.17	28.75	1.23	14.20	5.50	0.330
143	IS4372	3.00	Low	non-serration	Appressed	51.50	27.53	1.43	14.40	6.50	0.374

Table 8 contd.....

Sl. No	Accessions	Glossiness	Bloom	Serration	Pubescence	Chlorophyll content -1	Chlorophyll content-2	SG	BRIX %	NLP	FY
144	IS15931	1.00	Medium	non-serration	Appressed	50.52	24.40	1.64	21.10	7.50	0.110
145	IS19153	8.00	Low	serration	Appressed	49.88	16.20	1.31	17.80	7.83	0.210
146	IS24492	1.00	Medium	non-serration	Appressed	50.52	41.73	1.74	8.30	6.50	0.805
147	IS24139	3.00	Low	non-serration	Appressed	51.02	20.35	1.31	20.60	7.75	0.805
148	IS24462	3.00	Medium	non-serration	Appressed	50.57	18.63	1.30	7.20	6.50	0.510
149	IS21863	1.00	Low	non-serration	Appressed	51.57	15.15	1.25	8.90	6.25	0.510
150	IS29441	3.00	Low	non-serration	Appressed	48.40	13.40	1.78	9.40	8.75	0.855
151	IS26749	1.00	Medium	non-serration	Appressed	48.02	44.58	1.07	7.50	7.83	0.605
152	IS23586	9.00	Low	non-serration	Appressed	48.12	32.85	1.12	8.90	3.83	0.210
153	IS20956	3.00	Medium	serration	Appressed	48.87	18.53	0.84	9.40	4.83	0.115
154	IS4581	4.00	Low	non-serration	Appressed	51.10	28.58	1.14	11.80	5.50	0.115
155	IS22239	9.00	Medium	serration	Appressed	50.77	26.70	1.43	14.30	5.67	0.210
156	IS19445	1.00	Medium	serration	Appressed	52.15	32.40	1.36	20.60	6.17	0.520
157	IS29568	2.00	Medium	serration	Appressed	53.05	22.48	1.25	9.30	7.25	0.520
158	IS29304	2.00	Low	non-serration	Appressed	49.80	11.93	1.23	8.90	7.00	0.405
159	IS23579	1.00	Medium	serration	Appressed	51.10	18.80	1.26	13.80	5.50	0.310
160	IS28389	7.00	Low	non-serration	Appressed	54.92	23.60	1.22	12.70	8.75	0.325
161	IS24939	7.00	High	serration	Appressed	57.60	12.90	1.51	7.40	6.75	0.405
162	IS24503	3.00	Low	serration	Appressed	45.42	19.73	1.43	16.60	7.00	0.115
163	IS23216	7.00	Low	non-serration	Appressed	52.18	12.88	1.07	11.50	6.00	0.115
164	IS7310	1.00	Low	serration	Appressed	48.03	19.65	1.12	24.90	9.50	0.120
165	IS15466	2.00	Medium	serration	Appressed	56.35	11.00	1.13	22.20	5.08	0.510
166	IS29689	9.00	Low	serration	Appressed	45.82	20.95	1.18	4.90	7.50	0.115
167	IS15945	9.00	High	serration	Appressed	49.40	21.65	1.37	10.80	8.83	0.205

Table 8 contd.....

Sl. No	Accessions	Glossiness	Bloom	Serration	Pubescence	Chlorophyll content -1	Chlorophyll content-2	SG	BRIX %	NLP	FY
168	IS14010	1.00	Medium	serration	Appressed	56.35	10.75	1.58	5.30	10.00	0.205
169	IS29606	1.00	Medium	serration	Appressed	48.55	22.25	1.35	3.40	11.42	0.420
170	IS30572	8.00	Medium	serration	Appressed	51.52	21.80	1.33	18.60	8.50	0.520
171	IS11473	2.00	Medium	non-serration	Appressed	53.63	39.25	1.37	10.60	10.25	0.315
172	IS31706	1.00	Low	serration	Appressed	41.08	31.93	1.22	6.60	6.08	0.210
173	IS30079	3.00	Low	serration	Appressed	55.28	22.55	1.37	7.50	7.25	0.115
174	IS28849	1.00	Low	serration	Appressed	41.97	20.03	1.18	20.30	9.42	0.415
175	IS2413	9.00	Low	serration	Appressed	53.57	25.23	1.21	21.80	6.42	0.320
176	IS25089	3.00	Low	serration	Appressed	42.92	18.88	1.13	13.70	6.25	0.100
177	IS6351	6.00	Low	serration	Appressed	52.52	56.65	1.44	11.10	7.25	0.115
178	IS29239	3.00	Low	non-serration	Appressed	61.00	33.48	0.87	9.60	8.33	0.210
179	IS3971	3.00	Low	serration	Appressed	50.78	35.18	1.36	5.70	8.58	0.235
180	IS8774	8.00	Low	serration	Appressed	42.65	33.50	1.36	14.60	7.50	0.515
181	IS21645	1.00	medium	serration	Appressed	37.97	36.35	1.29	10.70	6.50	0.510
182	IS23992	8.00	Medium	serration	Appressed	43.95	21.68	1.42	5.60	6.50	0.510
183	IS15170	1.00	Low	non-serration	Appressed	46.83	46.25	1.28	5.90	7.58	0.510
184	IS23521	3.00	Low	non-serration	Glabrous	46.97	22.55	1.49	14.70	7.25	0.210
185	IS603	6.00	Medium	non-serration	Appressed	48.02	15.40	1.39	6.40	7.75	0.210
186	IS29100	1.00	Low	Serration	Appressed	51.67	21.73	0.72	11.00	5.25	0.510
187	IS5295	1.00	Low	Serration	Appressed	40.88	13.55	1.44	8.10	7.75	0.510
188	IS7250	1.00	Low	Serration	Appressed	43.47	36.43	1.08	9.70	8.75	0.350
189	IS8348	9.00	Medium	Serration	Appressed	51.42	22.25	1.18	11.40	6.00	0.835
190	IS12937	3.00	Medium	Serration	Appressed	52.55	23.15	0.85	6.70	6.50	0.510
191	IS27912	4.00	Medium	Serration	Appressed	52.53	42.13	1.39	4.40	6.00	0.245

Table 8 contd.....

Sl. No	Accessions	Glossiness	Bloom	Serration	Pubescence	Chlorophyll content -1	Chlorophyll content-2	SG	BRIX %	NLP	FY
192	IS25301	9.00	Medium	Serration	Appressed	41.87	15.30	1.59	7.80	8.00	0.510
193	IS20625	1.00	Medium	Serration	Appressed	35.13	16.85	1.39	9.50	8.00	0.355
194	IS12697	1.00	Medium	Serration	Appressed	35.13	12.88	1.58	18.20	10.08	0.220
195	IS10757	7.00	Medium	Serration	Appressed	53.37	17.03	1.46	18.60	9.75	1.235
196	IS11619	8.00	Medium	Serration	Appressed	53.42	13.88	0.88	8.50	7.50	0.835
197	IS26701	7.00	Medium	Serration	Appressed	55.45	6.98	1.39	7.00	6.42	0.620
198	IS19975	6.00	Medium	Serration	Appressed	46.83	14.85	1.08	8.70	8.50	0.525
199	IS25836	6.00	Low	Serration	Appressed	60.37	20.63	0.50	11.30	13.00	0.620
200	IS20727	5.00	Low	non-serration	Appressed	52.38	20.50	0.93	10.20	7.08	0.515
201	IS10867	7.00	Medium	Serration	Appressed	43.53	15.45	1.44	3.80	9.00	0.105
202	IS12302	4.00	Medium	Serration	Appressed	64.13	20.63	0.99	16.00	7.75	0.120
203	IS12965	8.00	Low	Serration	Appressed	48.12	17.73	0.61	15.20	8.50	0.410
204	IS14779	9.00	Medium	Serration	Appressed	54.90	26.18	1.06	4.20	6.50	0.330
205	IS27786	4.00	Medium	non-serration	Appressed	50.32	19.90	1.36	24.40	7.50	0.215
206	IS19262	1.00	Medium	serration	Appressed	53.77	32.90	1.10	9.60	7.00	0.215
207	IS10302	7.00	Medium	serration	Glabrous	56.18	18.08	1.18	7.50	6.17	0.215
208	IS13893	8.00	Medium	serration	Appressed	55.30	22.60	1.28	9.20	5.50	0.115
209	IS29714	1.00	Medium	serration	Appressed	55.08	19.28	1.68	8.00	11.75	0.115
210	IS32245	4.00	Low	Serration	Appressed	51.38	23.33	1.06	4.20	6.75	0.214
211	IS2397	8.00	Medium	Serration	Appressed	43.62	16.25	1.13	5.10	7.50	0.110
212	IS27557	1.00	Medium	Serration	Appressed	56.88	8.33	1.40	10.15	6.00	0.215
213	IS30536	2.00	Low	serration	Appressed	52.77	8.33	1.01	11.50	6.83	0.310
214	IS30383	1.00	Medium	Serration	Appressed	49.22	22.55	1.16	20.80	8.25	0.215
215	IS31651	7.00	Medium	Serration	Appressed	53.12	21.03	0.88	10.30	5.75	0.105

Table 8 contd.....

Sl. No	Accessions	Glossiness	Bloom	Serration	Pubescence	Chlorophyll content -1	Chlorophyll content-2	SG	BRIX %	NLP	FY
216	IS29519	7.00	Medium	serration	Appressed	55.00	25.98	0.94	28.00	4.92	0.510
217	IS20632	9.00	Low	Serration	Appressed	53.10	11.30	0.93	7.80	7.08	0.215
218	IS28449	2.00	Low	Serration	Appressed	45.60	15.05	1.15	5.70	8.17	0.624
219	IS24218	2.00	Medium	Serration	Appressed	50.85	15.73	0.93	19.50	7.50	0.310
220	IS12804	9.00	Medium	Serration	Appressed	47.83	31.25	1.55	5.81	6.75	0.515
221	IS2382	9.00	Medium	Serration	Appressed	49.57	14.15	1.29	5.91	7.25	0.215
222	IS23644	1.00	Medium	non-serration	Appressed	45.10	17.78	1.28	12.61	7.00	0.215
223	IS12945	3.00	Medium	Serration	Appressed	49.65	20.48	1.18	15.81	6.25	0.250
224	IS17980	1.00	Medium	non-serration	Appressed	55.18	41.20	1.48	9.61	8.75	0.215
225	IS12735	1.00	Medium	Serration	Appressed	53.45	30.78	1.07	8.31	6.25	0.215
226	IS9108	5.00	Medium	Serration	Appressed	54.03	35.33	1.47	22.90	6.25	0.212
227	IS21083	1.00	High	non-serration	Appressed	52.58	37.30	1.20	16.90	7.00	0.31
228	IS14090	4.00	Medium	serration	Appressed	50.85	42.83	1.61	3.30	6.50	0.215
229	IS29627	8.00	Medium	serration	Appressed	47.07	51.49	1.61	15.90	7.17	0.310
230	IS25548	9.00	Medium	serration	Appressed	54.03	26.03	1.81	6.00	6.50	0.130
231	IS28141	1.00	Medium	serration	Appressed	54.48	41.30	1.18	6.30	6.50	0.130
232	IS15478	1.00	Medium	serration	Appressed	49.57	27.05	1.60	9.50	5.83	0.205
233	IS13294	8.00	Medium	non-serration	Appressed	49.90	55.38	1.15	6.40	6.75	0.42
234	IS22799	9.00	Medium	serration	Appressed	45.77	37.65	1.41	3.45	6.75	0.130
235	IS11919	1.00	Low	non-serration	Appressed	46.03	33.50	0.87	13.36	6.50	0.205
236	IS29565	1.00	Low	serration	Appressed	51.37	24.95	1.31	6.43	6.00	0.510
237	M-35-1	1.00	High	serration	Appressed	50.08	28.06	1.89	8.50	8.50	1.100
238	BJV-44	1.00	medium	serration	Appressed	58.07	37.89	1.76	8.20	8.75	1.260
239	SPV86	9.00	medium	serration	Appressed	49.70	28.13	1.76	11.50	9.50	1.100
240	E-36-1	1.00	High	serration	Appressed	67.03	40.3	3.53	14.20	7.25	0.750

AC – Accessions, chlorophyll content-1 – chlorophyll content at flag leaf stage, chlorophyll content -2 -chlorophyll content at maturity, SG-stem girth, BRIX %-total soluble solids in percentage,

NLP-number of leaves per plant and FY- fodder yield plot

Table 9: Comparative mean performance of sorghum minicore accessions for the grain yield and its component traits

Sl. No	AC	DFF	DM	PH	PL	HSW	NPP	PW	PWE	GYP
1	IS22986	86.00	141.5	179.0	16.40	3.62	55.58	6.62	63.95	48.15
2	IS25989	72.00	118.5	110.4	13.60	3.25	40.00	5.87	24.95	16.95
3	IS7305	65.00	150.0	238.0	31.25	2.20	61.00	7.50	67.35	58.55
4	IS29269	77.50	137.0	184.0	16.33	2.13	40.50	7.10	38.95	19.20
5	IS29772	98.00	133.5	162.0	20.00	2.73	56.75	6.85	30.00	22.66
6	IS16151	69.00	118.5	177.2	28.00	2.61	48.58	10.00	41.80	29.00
7	IS608	81.50	130.0	178.0	28.00	2.01	60.37	9.38	20.00	19.85
8	IS30450	81.50	120.5	219.8	29.00	3.05	42.00	6.65	65.00	25.00
9	IS24348	61.50	118.5	203.0	26.00	3.35	46.91	6.75	41.80	32.40
10	IS30460	84.50	132.0	167.4	28.00	1.67	31.49	5.80	24.25	14.30
11	IS20816	70.00	127.0	189.6	28.33	2.46	38.25	8.50	32.25	22.85
12	IS22616	79.00	140.0	287.6	31.00	4.31	29.75	10.00	44.25	35.25
13	IS32787	71.50	124.5	185.8	30.25	3.50	46.62	6.25	62.85	45.05
14	IS26617	80.50	129.0	186.6	24.00	2.62	47.12	7.50	47.65	33.25
15	IS30417	74.50	117.5	156.4	25.20	2.83	47.25	5.12	41.85	31.85
16	IS29468	80.50	131.0	208.8	15.00	4.81	53.16	8.57	33.95	29.95
17	IS23514	74.50	128.5	209.0	11.00	1.70	61.50	5.22	34.95	22.55
18	IS30466	63.50	127.0	148.0	18.80	2.82	53.50	8.25	63.15	62.95
19	IS1212	66.50	119.0	159.2	22.00	3.68	47.50	3.77	18.75	14.55
20	IS30451	63.00	120.5	242.4	24.20	3.02	51.50	5.92	28.20	23.40
21	IS24953	89.50	118.0	198.2	20.33	2.63	33.33	5.50	20.60	17.40
22	IS28614	67.00	128.0	260.0	17.88	2.93	45.20	4.75	29.80	29.75
23	IS27887	65.50	130.0	200.8	16.60	2.82	32.58	6.10	54.20	54.25
24	IS30507	66.00	132.0	151.2	25.15	2.35	72.50	5.13	60.20	47.40
25	IS25910	90.50	137.5	260.6	37.65	2.81	63.25	8.50	76.55	43.75
26	IS7987	79.50	120.5	252.0	11.00	4.62	31.58	6.63	154.7	132.30
27	IS7679	66.00	118.5	198.2	24.00	3.35	42.75	8.37	44.95	27.70
28	IS20743	63.50	131.5	192.5	26.00	2.61	34.50	7.20	28.35	27.95
29	IS29241	68.00	150.0	228.4	31.75	3.50	61.83	5.95	87.35	70.75
30	IS2413	67.50	122.0	284.7	27.00	3.34	30.00	8.65	70.00	52.66
31	IS4631	63.50	139.0	139.1	30.00	2.07	43.83	5.82	47.55	35.35
32	IS23891	66.00	131.5	167.3	20.00	3.53	42.00	4.80	45.65	37.55
33	IS7957	64.00	144.0	175.9	6.40	3.06	31.66	5.20	33.15	28.75
34	IS1233	72.00	117.5	270.0	28.75	3.74	41.25	5.62	96.95	82.93
35	IS28451	72.00	144.0	179.7	18.75	2.55	37.33	6.95	54.60	42.40
36	IS25732	67.50	137.5	166.0	20.20	3.08	41.87	7.87	41.20	33.10
37	IS8012	66.50	128.0	211.5	24.50	3.48	53.00	7.50	78.00	58.40
38	IS9745	79.50	133.0	194.0	27.50	4.04	36.50	7.38	52.00	35.94
39	IS5094	74.00	133.0	205.4	24.00	3.22	36.58	6.60	42.20	31.96
40	IS33844	64.00	136.5	275.0	39.40	3.35	33.17	7.97	72.60	63.20
41	IS28747	63.00	154.0	136.4	25.20	2.94	36.50	7.40	43.60	35.00
42	IS20740	71.50	155.5	209.5	25.00	3.11	65.83	4.85	72.60	58.50
43	IS4515	68.00	135.0	229.4	16.60	3.98	49.41	7.87	76.60	77.60
44	IS2872	69.50	143.0	190.0	17.25	4.66	40.50	6.00	58.00	49.35
45	IS31043	67.50	134.5	196.6	14.00	3.47	87.75	6.57	42.48	32.71
46	IS11026	73.00	146.0	220.0	14.00	3.24	48.83	7.55	53.35	41.86
47	IS2389	77.50	139.0	226.6	24.00	3.35	41.58	6.45	74.15	59.35
48	IS26737	69.50	149.5	211.7	26.25	3.10	55.16	5.70	70.15	51.75
49	IS995	75.50	140.5	160.1	20.66	2.46	47.75	6.62	46.48	26.15

Table 9 contd.....

Sl. No	AC	DFE	DM	PH	PL	HSW	NPP	PW	PWE	GYP
51	IS20697	69.50	144.0	235.1	24.60	3.41	38.83	7.68	50.20	43.64
52	IS12706	79.00	114.5	210.1	20.50	3.23	46.25	6.50	59.00	46.63
53	IS8777	69.00	135.5	328.1	40.00	4.21	51.58	10.25	93.20	78.90
54	IS22720	70.00	143.5	187.1	14.40	3.22	68.25	6.38	48.80	38.60
55	IS23590	60.50	136.5	185.0	14.80	3.64	84.91	7.58	69.00	54.20
56	IS4360	89.50	141.0	181.0	14.00	5.62	46.58	7.23	110.0	83.40
57	IS20713	88.00	128.5	186.2	25.00	3.40	49.00	7.25	42.00	32.20
58	IS22294	71.50	115.0	177.0	19.85	3.26	38.00	7.45	46.20	43.70
59	IS15744	81.50	130.0	189.0	21.05	3.40	44.50	7.13	47.80	38.02
60	IS32439	74.50	129.0	170.0	31.10	3.62	40.00	6.38	57.60	61.62
61	IS21512	72.00	127.0	199.0	26.45	2.37	47.00	5.05	74.00	44.98
62	IS4092	79.00	118.5	169.8	25.45	2.78	50.00	4.85	72.20	56.82
63	IS31714	69.00	135.5	160.0	26.10	3.29	30.00	5.00	46.20	55.66
64	IS25249	65.00	131.5	163.7	26.60	4.35	75.00	7.13	58.40	42.40
65	IS31186	73.50	131.5	177.5	15.35	3.69	38.00	4.53	36.40	33.25
66	IS23684	87.50	117.5	232.5	21.60	4.45	62.00	8.48	95.60	81.80
67	IS31446	75.00	151.5	227.5	14.85	3.21	49.75	7.25	68.50	55.00
68	IS1041	73.00	135.0	294.6	32.85	2.29	50.50	6.95	38.33	17.06
69	IS2426	65.00	122.5	172.5	19.85	3.42	37.25	7.43	24.60	20.96
70	IS18039	74.50	133.0	228.0	20.85	1.85	36.00	7.35	52.40	43.62
71	IS16382	74.50	130.0	147.5	17.85	2.52	54.25	4.98	38.00	35.34
72	IS16151	71.00	141.0	152.2	17.20	2.50	39.50	7.20	57.20	52.40
73	IS17941	58.00	128.0	206.2	18.60	4.08	38.50	6.25	24.50	16.00
74	IS2379	60.50	126.0	212.2	23.00	3.32	50.00	6.88	39.00	29.96
75	IS19676	66.00	137.0	196.3	24.00	2.29	47.75	11.00	29.80	39.40
76	IS18758	69.00	141.0	268.7	20.05	3.75	48.50	6.25	43.25	30.06
77	IS26046	64.00	133.5	228.3	20.30	2.38	52.00	6.50	16.60	8.50
78	IS1004	73.00	137.5	213.7	26.90	2.51	58.25	6.25	54.60	43.70
79	IS26694	80.50	135.0	199.9	20.70	2.50	61.00	6.85	85.40	65.74
80	IS29314	62.50	131.5	192.4	16.95	3.65	43.00	5.50	30.80	21.80
81	IS8916	78.50	140.0	193.3	20.70	2.97	31.25	6.63	27.33	19.33
82	IS32349	78.50	134.0	226.6	15.70	2.36	51.76	7.25	57.60	41.40
83	IS5667	88.50	119.5	221.5	15.45	2.30	51.75	6.38	70.50	44.46
84	IS29326	63.50	122.5	155.0	18.75	2.97	51.87	7.20	38.00	43.64
85	IS13549	72.50	129.0	232.0	25.40	4.05	33.00	5.00	108.00	74.40
86	IS995	75.00	131.0	255.6	31.25	3.43	45.00	6.35	111.60	79.20
87	IS5301	80.50	137.0	228.9	26.80	2.44	45.41	6.35	75.60	53.80
88	IS4698	75.00	126.5	199.4	26.50	3.95	65.16	6.98	68.40	56.80
89	IS30443	68.50	138.5	185.6	18.33	2.75	29.25	5.75	31.55	26.35
90	IS9133	66.00	122.5	185.0	21.00	2.82	43.00	5.50	33.05	27.55
91	IS4060	74.50	131.5	173.3	13.00	3.28	62.16	8.50	54.55	45.25
92	IS4613	75.00	128.5	216.0	14.40	2.89	75.87	4.70	66.55	43.75
93	IS29654	66.50	142.0	265.0	17.66	3.70	63.00	7.30	63.05	56.65
94	IS324453	73.50	125.0	265.0	25.00	4.44	66.50	10.88	68.65	55.85
95	IS473	73.00	120.5	145.0	13.33	2.79	40.75	6.88	20.00	13.60
96	IS4951	67.50	139.0	176.4	23.60	2.83	45.87	9.63	39.25	31.00
97	IS29358	66.00	134.0	114.6	12.50	2.82	35.00	6.00	23.50	19.50
98	IS19389	70.50	142.5	196.4	15.75	2.68	53.50	9.75	50.70	42.55
99	IS12447	76.50	134.5	301.2	22.20	4.15	59.62	5.63	97.35	78.55
100	IS29335	66.50	115.0	238.7	14.25	3.94	44.50	6.88	46.35	37.15

Table 9 contd.....

Sl. No	AC	DFE	DM	PH	PL	HSW	NPP	PW	PWE	GYP
101	IS33353	64.00	122.5	221.0	16.60	3.44	37.00	6.95	41.15	19.75
102	IS20195	75.50	138.5	145.0	16.66	3.21	63.08	7.00	63.05	40.60
103	IS602	67.00	138.0	137.5	30.30	2.73	46.75	5.13	45.35	24.18
104	IS29733	67.50	126.0	150.7	26.25	3.93	34.50	7.30	53.25	41.85
105	IS7131	70.00	144.0	159.9	10.00	2.75	32.12	5.08	49.85	45.85
106	IS13971	66.00	126.0	227.4	23.33	3.69	39.75	7.18	71.60	59.24
107	IS26484	66.00	134.5	250.0	28.50	2.95	34.00	7.63	19.10	15.05
108	IS29627	67.50	137.0	240.0	26.75	4.43	41.75	7.70	70.35	15.05
109	IS24463	83.00	136.0	145.0	15.00	4.87	59.16	7.30	80.05	71.71
110	IS33090	76.00	142.5	155.0	14.25	2.66	37.91	9.25	45.55	34.45
111	IS29392	67.00	137.5	203.8	17.50	4.49	42.12	6.03	50.05	39.25
112	IS30533	66.50	144.0	213.3	23.66	3.61	27.75	3.13	16.25	10.45
113	IS29914	68.00	143.5	132.0	26.00	2.89	41.83	6.63	38.05	34.05
114	IS31446	74.50	157.0	172.0	26.25	3.83	25.00	4.85	45.45	22.05
115	IS19450	78.00	115.0	155.0	14.60	4.27	64.66	7.00	73.50	62.30
116	IS13919	71.00	137.0	144.0	23.40	3.65	30.00	9.50	18.95	10.90
117	IS28313	88.50	141.5	146.6	21.20	4.05	59.50	11.13	61.10	52.90
118	IS5386	77.50	134.6	158.0	19.80	3.66	54.50	5.00	49.45	41.70
119	IS5919	62.00	142.0	131.0	11.00	3.19	29.75	5.98	48.75	17.40
120	IS33023	67.00	141.0	179.0	13.00	4.29	34.62	6.50	48.75	69.00
121	IS5386	65.50	138.5	207.5	20.00	2.99	61.75	5.50	26.66	19.40
122	IS5919	68.50	142.5	227.5	22.50	4.08	38.00	7.50	57.00	40.20
123	IS33023	66.00	136.5	221.0	27.00	1.66	34.25	10.75	18.66	11.00
124	IS2902	69.50	152.0	175.0	18.33	2.82	50.00	6.98	57.20	31.80
125	IS29187	82.00	130.5	272.5	28.75	3.00	29.75	7.78	107.70	73.55
126	IS30466	63.00	136.0	222.5	22.50	2.69	45.25	6.50	21.20	13.75
127	IS14290	74.00	125.0	222.9	25.00	5.14	56.50	7.65	107.80	95.50
128	IS27034	63.00	147.5	189.5	21.66	3.78	36.75	7.25	18.75	14.60
129	IS6421	68.50	121.5	205.8	16.50	4.32	59.00	7.10	85.20	51.20
130	IS24175	78.50	142.0	182.0	16.00	2.76	32.25	4.28	65.40	53.00
131	IS29091	66.00	121.0	189.5	18.40	4.03	42.50	3.78	39.28	30.00
132	IS10969	82.50	133.5	260.0	19.75	3.36	64.00	7.25	77.40	30.80
133	IS19859	54.50	139.5	145.0	25.00	2.62	43.25	6.48	44.00	31.80
134	IS26025	59.00	117.5	148.5	19.40	2.30	49.94	7.10	32.80	30.00
135	IS30400	71.00	144.0	196.0	25.00	3.51	49.25	10.87	32.00	21.40
136	IS31714	75.50	134.5	230.0	17.50	2.46	25.50	6.25	12.00	10.00
137	IS2864	88.50	152.0	208.6	24.00	2.66	36.58	7.25	34.25	31.00
138	IS22239	66.00	136.0	149.9	15.50	2.86	38.00	7.25	37.20	31.40
139	IS16528	66.00	143.5	184.9	18.00	2.93	38.00	4.50	22.60	20.60
140	IS20298	59.00	129.0	179.9	23.25	3.49	52.25	4.88	20.25	23.00
141	IS30838	70.00	135.0	201.6	37.33	2.92	29.75	11.20	24.20	23.40
142	IS14861	66.00	138.0	176.6	21.00	1.75	69.00	6.83	32.00	22.50
143	IS4372	86.50	137.5	161.6	20.00	2.30	46.75	2.33	50.40	8.40
144	IS15931	78.50	139.5	187.5	17.50	3.62	57.78	10.25	31.80	25.80
145	IS19153	87.00	126.5	212.8	16.00	3.48	38.75	7.10	53.20	48.00
146	IS24492	95.00	152.0	192.5	17.50	2.54	55.37	6.68	39.25	29.20
147	IS24139	89.50	133.5	198.7	14.50	3.75	45.75	6.88	44.20	42.40
148	IS24462	69.00	124.0	174.2	19.75	3.48	29.25	7.08	20.00	22.40
149	IS21863	64.00	136.5	143.3	17.00	2.93	51.50	6.75	42.75	26.00
150	IS29441	72.00	143.0	176.2	20.00	2.70	31.75	6.70	37.40	29.20

Table 9 contd.....

Sl. No	AC	DFE	DM	PH	PL	HSW	NPP	PW	PWE	GYP
151	IS26749	71.00	124.5	149.0	16.20	3.43	47.75	7.00	41.40	44.50
152	IS23586	66.00	132.5	87.6	19.58	2.30	35.00	9.50	24.25	20.00
153	IS20956	62.50	120.5	131.0	21.58	2.82	27.75	4.50	25.00	16.40
154	IS4581	69.00	119.5	163.3	23.48	4.33	42.00	6.20	24.80	16.40
155	IS22239	67.50	148.0	135.0	21.23	2.53	21.50	9.00	35.20	26.60
156	IS19445	70.50	138.5	171.0	17.58	3.29	33.75	7.50	46.84	40.84
157	IS29568	69.50	158.0	182.5	19.25	4.66	49.50	6.98	54.04	40.84
158	IS29304	64.00	119.5	185.0	26.50	2.56	37.50	6.23	19.44	15.54
159	IS23579	88.00	137.0	138.7	20.25	2.05	38.97	6.00	30.44	23.04
160	IS28389	83.00	120.5	187.5	25.75	2.18	39.75	6.88	34.24	28.64
161	IS24939	66.00	120.5	136.6	10.33	3.89	35.25	5.63	60.40	47.95
162	IS24503	68.00	110.0	272.5	51.00	2.55	25.50	7.50	23.60	20.00
163	IS23216	64.00	124.5	138.8	11.75	2.77	45.00	4.20	24.80	15.60
164	IS7310	66.00	127.5	205.0	26.00	2.12	39.75	7.08	38.60	35.00
165	IS15466	65.50	131.0	122.0	21.75	3.12	39.00	5.13	45.25	29.50
166	IS29689	69.00	129.5	167.5	15.00	5.71	44.25	7.55	84.40	71.80
167	IS15945	79.00	143.5	202.6	24.42	2.38	50.00	8.38	69.80	59.40
168	IS14010	80.00	143.0	220.0	25.27	2.02	27.00	7.83	65.00	37.60
169	IS29606	70.50	122.5	259.0	37.62	2.72	42.75	11.50	76.80	43.40
170	IS30572	74.00	127.0	175.0	21.52	2.58	26.43	6.20	37.40	38.80
171	IS11473	70.00	120.5	253.8	33.77	4.92	46.00	6.60	85.00	73.80
172	IS31706	73.50	139.0	217.1	25.85	3.72	31.12	9.63	65.20	41.50
173	IS30079	70.00	121.0	167.5	10.50	5.04	54.00	6.48	43.00	51.80
174	IS28849	76.50	131.5	179.0	13.40	3.98	51.75	6.00	50.80	45.40
175	IS2413	66.00	139.5	174.0	13.00	3.80	48.12	7.25	31.80	27.80
176	IS25089	69.00	128.0	180.0	24.20	3.52	41.50	6.58	26.60	22.40
177	IS6351	72.00	135.5	185.0	16.20	4.93	36.25	7.00	40.33	29.66
178	IS29239	63.50	125.5	176.0	15.40	2.61	30.00	4.03	25.78	16.80
179	IS3971	63.00	133.5	227.0	20.00	2.82	33.76	7.70	19.20	17.66
180	IS8774	78.50	132.5	163.8	21.60	2.87	42.87	6.38	40.80	33.00
181	IS21645	77.00	141.0	166.7	21.00	3.17	32.88	7.53	39.50	30.00
182	IS23992	75.50	143.0	171.3	12.50	2.89	25.50	4.95	42.42	30.00
183	IS15170	72.00	116.0	172.6	9.20	2.76	35.00	8.08	85.02	37.22
184	IS23521	78.00	133.0	186.3	17.25	3.35	51.72	10.12	36.77	25.80
185	IS603	75.50	138.5	217.0	20.67	3.44	24.50	9.13	89.40	28.82
186	IS29100	67.50	138.0	177.5	20.50	3.06	44.35	6.50	28.36	41.17
187	IS5295	77.00	141.5	213.3	18.33	3.19	49.25	6.08	74.96	25.01
188	IS7250	82.00	141.0	200.0	13.00	3.01	80.00	7.00	50.36	62.56
189	IS8348	78.00	137.0	142.5	17.50	4.23	37.00	7.40	33.20	37.36
190	IS12937	80.00	123.0	158.7	11.00	3.72	24.00	4.13	33.20	81.60
191	IS27912	66.00	155.5	127.5	22.50	4.49	19.00	7.03	48.60	15.75
192	IS25301	73.50	132.0	197.5	20.00	2.29	55.50	5.75	29.80	51.00
193	IS20625	72.50	143.5	208.0	22.25	2.74	77.00	6.20	74.75	25.80
194	IS12697	87.50	140.5	247.0	23.00	3.65	28.75	11.45	73.60	50.00
195	IS10757	82.00	142.0	253.3	20.67	3.10	44.50	7.88	32.00	31.60
196	IS11619	66.00	121.5	167.5	15.50	1.46	48.50	8.25	39.60	22.00
197	IS26701	85.50	127.5	154.4	20.60	3.44	53.00	5.08	44.20	40.75
198	IS19975	73.00	134.0	226.6	28.33	3.44	46.25	6.18	50.00	39.60
199	IS25836	80.00	124.5	260.0	25.00	4.58	42.00	5.00	59.00	38.80
200	IS20727	63.50	121.5	161.4	19.40	3.15	38.25	6.45	18.20	35.00

Table 9 contd.....

Sl. No	AC	DFF	DM	PH	PL	HSW	NPP	PW	PWE	GYP
201	IS10867	74.50	152.0	211.6	25.00	3.81	34.80	6.45	49.60	23.66
202	IS12302	76.50	131.5	180.7	16.50	3.63	30.75	5.25	51.50	49.00
203	IS12965	87.50	147.5	155.0	12.20	3.41	41.75	8.38	31.40	32.68
204	IS14779	90.50	138.5	181.2	25.00	3.59	25.75	8.35	26.00	26.80
205	IS27786	66.00	145.0	196.2	21.25	3.74	30.00	6.13	45.00	22.20
206	IS19262	80.50	137.0	194.0	15.80	3.50	40.00	6.20	41.00	39.60
207	IS10302	64.50	134.5	206.6	29.40	3.48	27.00	14.00	20.60	36.68
208	IS13893	63.00	152.5	126.7	16.66	3.63	40.00	8.13	37.00	23.90
209	IS29714	88.50	116.0	270.5	28.75	2.02	36.00	12.62	33.50	35.60
210	IS32245	66.00	131.5	161.25	33.75	3.48	36.50	8.75	30.00	20.86
211	IS2397	70.50	142.5	133.75	13.75	3.87	59.00	7.13	52.00	35.80
212	IS27557	66.00	156.0	124.00	38.60	3.32	28.00	6.50	38.60	31.00
213	IS30536	66.00	128.0	161.00	12.00	3.15	45.50	5.50	51.20	41.88
214	IS30383	66.00	148.5	147.60	17.00	3.55	26.00	10.25	29.80	26.26
215	IS31651	75.00	122.5	159.00	17.33	2.67	28.25	5.38	10.10	25.19
216	IS29519	76.00	133.0	104.95	17.80	3.05	33.00	5.13	12.97	15.83
217	IS20632	75.00	134.0	199.00	17.80	3.83	50.00	6.43	45.17	38.97
218	IS28449	72.50	146.5	233.00	27.00	3.60	29.50	8.50	64.57	43.93
219	IS24218	66.00	143.5	175.00	17.50	3.22	33.00	4.83	49.19	46.25
220	IS12804	66.50	143.0	196.51	18.50	4.75	51.00	7.88	47.24	50.49
221	IS2382	72.50	130.5	201.30	24.25	3.39	57.00	5.63	47.79	55.33
222	IS23644	73.50	152.0	221.72	25.00	4.12	43.00	7.00	48.20	26.20
223	IS12945	63.00	137.0	175.65	20.50	4.33	39.50	9.25	52.33	37.34
224	IS17980	76.50	135.0	225.00	21.75	2.75	49.25	5.25	81.50	48.00
225	IS12735	64.00	137.5	170.80	23.00	4.81	32.00	9.50	45.20	39.02
226	IS9108	64.00	137.0	157.50	20.00	4.88	33.50	9.13	33.20	30.70
227	IS21083	70.00	142.0	168.00	15.60	3.69	38.50	5.13	33.50	27.35
228	IS14090	68.50	110.0	164.00	25.00	3.90	34.50	7.63	56.00	46.66
229	IS29627	57.00	128.0	197.00	21.00	2.43	52.50	7.00	74.00	60.24
230	IS25548	83.00	120.5	178.70	16.25	3.42	33.75	5.00	61.50	20.78
231	IS28141	72.50	146.5	188.30	23.33	3.45	38.00	9.75	36.00	16.52
232	IS15478	90.50	130.5	159.00	21.00	2.23	35.50	6.75	57.00	37.38
233	IS13294	70.50	140.5	162.50	22.20	3.73	26.50	8.50	28.80	26.36
234	IS22799	71.00	115.0	203.33	25.00	2.92	50.50	7.38	48.80	39.00
235	IS11919	66.00	128.0	211.66	21.67	3.21	33.00	5.50	39.80	38.60
236	IS29565	73.00	151.0	178.70	28.25	2.86	47.75	6.45	38.40	43.80
237	M-35-1(c)	67.33	123.0	230.9	16.40	4.30	60.45	16.75	68.4	60.6
238	BJV-44(c)	69.83	116.0	244.6	19.43	4.69	68.58	12.62	74.1	65.8
239	SPV86(c)	63.50	142.0	236.0	20.50	3.47	44.37	8.62	49.24	36.58
240	E-36-1(c)	62.30	103.0	175.5	21.80	3.36	56.56	13.27	56.4	43.70

AC – Accessions, DFF- Days to 50 % Flowering, DM- Days to maturity, PH- plant height, PL- panicle length, HSW-100 Seed weight, NPP- Number of Primaries per panicle, Ear head width, PW- panicle width and GYP- grain yield per plant.

5. DISCUSSION

Sorghum is an important staple food for more than 300 million people and feed for cattle living in Asia and Africa. It is being cultivated both in *kharif* and *rabi* seasons. Rabi sorghum is highly valued because of its excellent grain and fodder quality. Among cereals, sorghum has a higher potential of well adaptation to adverse environmental condition like drought for a prolonged period than most other cereals for which it is popularly known as ‘camel of cereals’ (Sanderson *et al.*, 1992).

Breeding for host plant resistance is also equally important in *rabi* sorghum, particularly with respect to major biotic stresses viz., charcoal rot, prevailing in sorghum grown areas of North Karnataka including Vijayapur district (Balikai *et al.*, 2008). Breeding for resistance to biotic stresses like charcoal rot and shoot fly is a continuous process in sorghum that often requires the knowledge of inheritance pattern of the traits determining resistance in the genetic material developed.

Breeding for resistance to pests and diseases in sorghum began three decades ago (Rao *et al.*, 1980; Rosenow and Frederiksen, 1980 and Mukuru, 1993). Several genes conferring resistance have been identified and transferred to other agronomically promising cultivars through conventional breeding methods. However, control of biotic stresses through host genetic manipulation has been slower for an important sorghum pest like shoot fly (due to limited resistant sources) and also for charcoal rot as gene effects were small compared to downy mildew and leaf blight in which gene effects are large (Thakur *et al.*, 1997).

Charcoal rot in sorghum is caused by the soil borne fungi, *Macrophomina phaseolina*, which is more pronounced under drought and heat stress condition and manifests itself during post flowering drought at terminal stage of the crop that eventually reduces the yield and the quality of the grain by rendering the plants to excessive lodging. This co-occurrence makes charcoal rot a complex phenomena as resistance to charcoal rot is governed by many different gene interactions (Patil, 2009).

Further, studies on reaction of different sorghum genotypes to charcoal rot suggested the involvement of both dominant and recessive genes (Rosenow, 1984, Bramel *et al.*, 1988 and Tenkouano *et al.*, 1993) and involvement of many genes each

with little effect and highly influenced by the environment. These observations suggested that traits like stay-green, which can delays leaf senescence under drought stress condition during physiological maturity has been proven useful to improve charcoal rot resistance (Rosenow *et al.*, 1983, Duncan, 1984 and Woodfin *et al.*, 1988). Moreover, drought tolerance in sorghum is reported positive association to charcoal rot tolerance both at the phenotypic and genotypic level (Rosenow, 1984, Rajkumar, 2004). Therefore, breeding programmes for increasing charcoal rot resistance have been focusing primarily on improving drought tolerance (Hausmann *et al.*, 2002 and Patil, 2011).

In the present investigation, the sorghum minicore set of 236 germplasm accessions along with four checks were evaluated and characterized for the components of charcoal rot disease, fodder quality traits, yield and yield related traits. The results obtained on these studies are discussed below under the following headings:

- 5.1 Analysis of variance
- 5.2 Genetic variability, heritability in broad sense and genetic advance
- 5.3 Correlation analysis for components traits of charcoal rot, yield and yield contributing traits in minicore collection.
- 5.4 Correlation analysis for components traits of charcoal rot, fodder yield and quality traits in minicore collection.
- 5.5 Identification of superior genotypes among the minicore accessions

5.1 Analysis of variance

In the present investigation, 236 accessions of minicore along with four checks exhibited highly significant differences for all the traits *viz.*, spreading of fungus, number of internodes crossed by fungus, per cent lodging, per cent incidence disease, days to 50 per cent flowering, days to maturity, plant height, panicle length, panicle width, 100-seed weight, number of primaries per panicle, panicle weight, chlorophyll content at flag leaf stage, chlorophyll content at maturity stage, stem girth, brix per cent at maturity, number of leaves per plant, fodder yield per plot and grain yield per plant

both at 5 and 1 per cent level of probability. This indicates that, the minicore collections were genetically diverse for most of the traits under study. Non significant variation was observed for replication which indicated less influence of environment on the genotypic performance.

5.2 Genetic variability, heritability in broad sense and genetic advance

Analysis of variance may not reveal the absolute variability and this could be accessed through standardizing the phenotypic and genotypic variances by obtaining coefficients of variability. Thus, the components of variation such as genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were computed. Further, it is essential to separate out the environmental influence from the total variability for effective selection. This indicates the accuracy with which a genotype can be identified by its phenotypic performance. The estimates of heritability alone fail to indicate the response to selection. Therefore, the heritability estimates appeared to be more meaningful when accompanied by estimates of genetic advance. The genetic advance as per cent mean (GAM) was also estimated.

The minicore accessions in the present investigation displayed considerable differences among the entries with respect to most of the morphological traits studied. This is evident from the highly significant mean sum of squares for each of these traits. The analyzed data has shown that phenotypic coefficient of variation (PCV) was higher than genotypic coefficient of variation (GCV) for all the characters studied indicating these traits had polygenic inheritance under high environmental influence. Similar results have been reported by Sindagi *et al.* (1970). Both the estimates of variation were within a narrow range for most of the traits which, implied that phenotypic variability can be used as reliable measure of genotypic variability.

High values of GCV and PCV were found for the traits such as length of spread of *Macrophomina phaseolina*, per cent lodging, per cent disease incidence, number of internodes crossed by fungus, plant height, panicle length, panicle width, 100-seed weight, panicle weight, number of primaries per panicle, stem girth, chlorophyll content at maturity, brix percentage, fodder yield per plot and grain yield per plant which

indicated variation for these characters and their contribution towards total genetic variability. The similar result for the plant height was also observed in previous studies of Bello *et al.* (2007) and Godbharle *et al.* (2010). The present result for the panicle length is in concordance with the findings of Aba *et al.* (2001) and Bello *et al.* (2007). Higher PCV and GCV for panicle width were also in agreement with the studies of Bapat and Shinde (1980); Tiwari *et al.* (2003); Chavan *et al.* (2010) and Arunkumar *et al.* (2004).

In case of 100-seed weight and grain yield per plant, results in the present study found similar with the earlier reported results by; Sindagi *et al.* (1970); William *et al.* (1987); Sharma *et al.* (2006); Bello *et al.* (2007) and Chavan *et al.* (2010). The disease parameters of charcoal rot resistance like length of infection and per cent lodging, which have not been studied widely so far, were found to be similar to the report of Patil (2009).

However, moderate values of PCV and GCV observed for traits such as, chlorophyll content at flag leaf stage and number of leaves per plant and indicated that these characters are amenable for improvement. In case of numbers of leaves per plant, the results in the present investigation were in agreement with studies of Kukadia *et al.* (1983), Kanure (1993); Asthana *et al.* (1995), Reddy *et al.* (1996), Prabhakar (2001), Punnuri (2004), Reddy *et al.* (2006), Rajkumar *et al.* (2007) and Chavan *et al.* (2010). A wide range of variation was observed for brix per cent. A similar results noticed by Jadav *et al.* (2011) and Radhika and Bharathi (2012).

In case of charcoal rot component traits viz., length of spread by fungus, PCV was higher than the GCV. Although there are not much evidence as little studies on charcoal rot parameters have been done so far, a higher degree of variability of these trait has been reported by Patil (2009). Low estimates of PCV and GCV were recorded for days to 50 per cent flowering and days to maturity in minicore accessions indicating low variability for these traits. Similar observations were noticed by Desai (1998), Patel *et al.* (1980b), Raja and Parikh (1980), Nimbalkar *et al.* (1988), Bheemashankar (2007) and Sunil and Sajjanar (2013).

Panicle weight recorded high magnitude of PCV and GCV in the present study. These results were similar to the reports of Asthana *et al.* (1995), Biradar *et al.* (1996)

and Rao and Patil (1996). Among minicore accessions, high values of PCV and GCV were obtained for grain yield per plant and fodder yield which indicates presence of high degree of variability and low environmental influences on the expression of these characters and hence, these characters can be relied upon simple selection. Similar results were reported by Mukuru (1993) and Biradar *et al.* (1996a).

Variability is pre requisite for selection to be effective, although the coefficient of variation indicates the extent of variability for different characters but do not indicate the heritability portion. This could be ascertained from the heritability estimates. Therefore, Johnson *et al.* (1955) suggested that heritability in conjunction with genetic advance is more effective and reliable in predicting resultant effect of selection. Heritability suggest the level of additive and non-additive gene action that determines the phenotypic expression of particular traits and also the effectiveness of selection for a trait depends on the relative level of genetic and non-genetic variation. Therefore studying heritability of quantitative parameters provides the role of genetic and environmental factors that determine the expression of a particular character (Allard, 1999). Effective selection can be achieved only when the targeted trait is under the control of additive effects more than environmental effects. Heritability on the higher side for any traits also reflects that they will remain stable under varied environmental conditions.

In the present study, high estimates of broad sense heritability noticed for majority of the characters viz., length of spread of fungus, per cent lodging, number of internodes crossed by *M. phaseolina*., per cent disease incidence, plant height, panicle weight, panicle length, panicle width, number of primaries per panicle, numbers of leaves per plant, days to 50 per cent flowering, 100-seed weight, chlorophyll content at flag leaf stage, chlorophyll content at maturity, brix per cent at maturity, fodder yield per plot and grain yield per plant. These results are in accordance with previous reports of Punhuri (2004), Reddy *et al.* (2006), Rajkumar *et al.* (2007) and Patil (2011). The high heritability observed for these traits indicated that these traits are less influenced by environmental factors and the selection would be effective.

Girish *et al.* (2016) reported high heritability along with high genetic advance over mean for length of spread of fungus, per cent lodging, mean node crossed and seed

yield. Moderate heritability was observed for the traits viz., stem girth, days to maturity and fodder yield per plot. These observations are in agreement with earlier studies reported by Halalli *et al.* (1983) and Patil (2011) in sorghum.

Broad sense heritability alone is less reliable as these values are prone to alter with change in the environment and experimental material (Swarup and Chagule, 1962). Therefore, the use of heritability values coupled with genetic advance would be more reliable than heritability alone. High heritability coupled with genetic advance indicates that additive gene effects are operating and selection would be effective.

In the present study, high heritability coupled with high genetic advance over mean was observed for the traits viz., plant height, length of spread of infection by fungus, number of internodes crossed by fungus, per cent lodging, per cent disease incidence, panicle length, number of primaries per panicle, panicle weight, 100 seed weight, panicle width, chlorophyll content at maturity, stem girth, brix per cent, number of leaves per plant, fodder yield per plant and grain yield per plant. This reveals that these characters would respond to the selection as these are more likely to be controlled by additive gene effects. Similar results for the traits, plant height, 100 seed weight and grain yield per plant were observed earlier by Biradar *et al.* (1996), Reddy *et al.* (1996), Nguyen *et al.* (1998), Mallinath *et al.* (2004), Arunkumar *et al.* (2004), Mukri (2007) and Chavan *et al.* (2010).

High heritability coupled with moderate genetic advance for days to 50 per cent flowering and chlorophyll content at flag leaf stage indicate that these traits are more likely controlled by both additive and non-additive gene actions. These results are in line with earlier results of Arunkumar *et al.* (2004) and Sunil and Sajjanar (2013). The high heritability coupled with moderate genetic advance noticed for these traits indicates the possibility of further improvement through recombination breeding. The high heritability coupled with low genetic advance for days to maturity indicate that this trait was more likely controlled by non-additive gene action. Warkad *et al.* (2008) reported similar trend for this trait.

5.3 Correlation analysis for components traits of charcoal rot, fodder quality traits, yield and yield contributing traits in minicore collections

Charcoal rot is a complex disease governed by polygenic inheritance in sorghum whose phenotypic expression depends on interplay of several component characters. Attempts of resistance breeding to this disease must be such that the ultimate goal of higher yield should not be hampered considered. Yield is a very complex trait and there are no genes as such governing yield (Griffing, 1956). Therefore, to improve the yield breeders often try to select on the basis of component characters which are less complex as compared to yield.

Correlation studies provide information on the nature and extent of association between any two pairs of metric characters. From this, it would be possible to bring about genetic up gradation in one character by selection of the other of a pair. To assess the extent and nature of association between component traits of charcoal rot disease, fodder quality parameters, yield and yield contributing traits, both genotypic and phenotypic correlations were done. It was noticed that genotypic correlation coefficients were higher than the phenotypic coefficient for all traits. High genotypic correlation indicates inherent relationship between characters which can be useful for the further crop improvement programme.

Among the charcoal rot parameters, length of spread of fungus found to be highly significant and positive association with numbers of internode crossed by fungus, per cent lodging, per cent incidence and other agronomical traits viz., plant height, panicle length, panicle weight and grain yield per plant both at genotypic and phenotypic level, respectively. Plant height was positively correlated with length of spreading by fungus indicating that disease development is directly proportional to plant height. This was also confirmed earlier by Bazzalo *et al.* (1991).

On the contrary, spread of infection by fungus had non-significant and negative association with number of primaries per panicle both at phenotypic and genotypic level. Similar observations were made by Esechia *et al.* (1977) and Rajkumar (2004).

A strong association of grain yield with length of spread of fungus might be related to the post-flowering carbohydrate translocation pattern. Higher the grain yield means greater is the carbohydrate requirement of developing grains and translocation of the same from stalk to grain leading to a condition of physiological stress that results in greater susceptibility of stalk tissue to the invasion by *M. phaseolina*. Therefore, a highly energy-efficient genotype is required to develop a high grain yield with charcoal rot resistance genotype that can produce both the high yield and simultaneously maintain stalk strength till maturity (physiologically and metabolically active stalk).

The number of internodes crossed by the fungus exhibited strong and significant positive correlation with length of infection both at genotypic and phenotypic level. A similar kind of observation was also reported by Srinivasa *et al.* (2011). Further, this trait showed negative association with 100-seed weight and number of primaries per plant both at genotypic and phenotypic level, indicating more the length of spread of fungus lesser is the translocation of photosynthates from source to sink.

Among the charcoal rot parameters per cent lodging found to be positively associated with numbers of internode crossed, length of spreading of the fungus as well as other agronomical trait viz., plant height. This indicates that spread of the fungus and more number of internodes crossed weakens the stem at the base. This coupled with tallness enhance lodging and affect the total fodder quality. Hence, a combination of medium height, medium thick stem, large panicle and resistance to charcoal rot disease are desirable traits in productive genotypes. These results are supported by Esechie *et al.* (1977) and Rajkumar *et al.* (2007).

Per cent lodging showed negative and significant association with days to 50 per cent flowering, 100-seed weight, panicle weight and grain yield per plant both at phenotypic and genotypic level. Similar results were also obtained by Sunil and Sajjanar (2013).

The significant negative association of per cent lodging with grain yield per plant was observed. However, other two disease resistance components viz., spread of the fungus and per cent incidence were found positively correlated with grain yield per

plant both at genotypic and phenotypic level. These results were supported by the earlier reported by Patil (2011) in sorghum.

Among the yield component traits the perusal of phenotypic and genotypic correlation revealed that, grain yield per plant had highly significant positive phenotypic and genotypic correlation with panicle weight, plant height, 100-seed weight, number of primaries per panicle and 50 per cent flowering indicating grain yield is largely a function of these five attributes and the importance may be given for these traits in yield improvement programme. Similar results were reported by Mahajan *et al.* (2011). They reported that grain yield per panicle had showed positive significant association both at phenotypic and genotypic levels with plant height and 100-seed weight. However, it had positive non-significant correlation with panicle width at genotypic level.

High positive correlation of plant height with grain as well as fodder yield indicates, it is most important trait in developing dual purpose *rabi* sorghum cultivars. Earlier workers also opined similarly (Thombre and patil, 1985, Sankarapandian *et al.*, 1994 and Scapim *et al.*, 1998).

Panicle weight showed positive and significant association with plant height, panicle length, number of primaries per panicle, 100-seed weight, panicle width, days to 50 per cent flowering and grain yield per plant both at the phenotypic and genotypic level. Days to 50 per cent flowering showed positive and significant association with plant height, panicle weight and grain yield per plant both at genotypic and phenotypic level. Number of primaries per panicle showed highly significant and positive correlation with plant height, panicle weight and grain yield per plant. Therefore, inter relation among traits indicate that these traits could be utilized for the crop improvement which could enhance the genetic constituent for the upliftment of traits of interest to express better phenotype as there is no negative relationships. Several workers have also reported positive significant association of grain yield with panicle weight viz., Veerbadhiran and Kennedy (1994), Pawar and Jadhav (1996), Jayaprakash *et al.* (1997) and Ivanar *et al.* (2001).

The trait 100-seed weight was found to be significantly and positively correlated with grain yield per plant, suggesting that 100-seed weight as an important attribute

with immense contribution in determining grain yield. Similar results were reported by Vijaya *et al.* (2012).

5.4 Correlation analysis for components traits of charcoal rot, fodder yield and quality traits in minicore collection

Fodder yield, being a complex character, is the cumulative and interactive effect of a number of component traits. Direct selection for yield per se generally results in low genetic gain because of its low heritability in general may suggest the plant breeders to realize the importance of component traits. However, inclusion of all the component traits in selection scheme is impractical because of obvious reasons and here the knowledge of association of various characters comes to the rescue in formulating an effective and efficient selection scheme. Therefore, a sound knowledge of character association forms an integral part of a programme for making improvements in complex characters like fodder yield.

In minicore, the association between chlorophyll content and charcoal resistance traits was negative. The results indicate the importance of stay-green in reducing the charcoal rot incidence. Mahalaksmi *et al.* (2002) revealed that stay green genotypes in sorghum are less susceptible to lodging and charcoal rot. The stay-green trait appears to have some resistance to charcoal rot because the length of spread by fungus in the stay-green cultivar were about 27 per cent shorter than the non stay-green line (Burgess *et al.*, 2009). Rosenow and Fredenksen (1980) also reported significant correlations between non-senescence, lodging resistance and charcoal rot resistance.

Although, the results of present study indicate the role of stay-green in reducing the incidence of charcoal rot, but low magnitude of correlation coefficients between stay green and charcoal rot resistance, indicate that stay-green alone cannot be used as selection criteria in breeding for charcoal rot resistance. This view is supported by Tenkouano *et al.* (1993), who opined that both charcoal rot resistance and non-senescence were controlled by dominant and recessive epistatic interactions between two gene loci and a third locus with modifying effects. They proposed that non-senescence should not be used as a sole criteria for resistance to charcoal rot in sorghum.

Positive and significant association was found between stay-green with 100 seed weight and grain yield. These results are supported by Borrell *et al.* (2000) and they proclaimed that retention of photosynthetic capacity under water-limited conditions ensures continued availability of new assimilates and is associated with increased N uptake during grain filling potentially improving grain size. Hence, stay-green can potentially increase grain yield by enhancing grain filling.

Stem girth exhibited positive and significant association with number of leaves per plant, spreading of fungus and fodder yield per plot both at phenotypic and genotypic level. However, a negative and significant correlation was observed with brix per cent both at phenotypic and genotypic level. There was a highly significant correlation between stem thickness and length of spread of fungus. These association pattern indicate thicker stalks will have less brix, consequently allowing spread of fungus. Hence it is suggested to select for medium thick stem for enhancing fodder yield and quality. Similar results were reported for many of these associations by Rana *et al.* (1976), Paroda *et al.* (1975), Yadav *et al.* (2003), Shukla and Parihar (2004), Borad *et al.* (1996) and Iyanar *et al.* (2010).

Further, these observations are in agreement with Das *et al.* (2008), where they had observed longer spreading of pathogen in thick-stalked genotypes compared to thinner ones when sorghum genotypes were inoculated with *M. phaseolina*.

Brix per cent recorded highly significant and negative correlation with chlorophyll content at flag leaf stage, stem girth and disease parameters viz., per cent lodging, length of spreading of the fungus and number of internode crossed both at genotypic and phenotypic level. These results indicate quantity of sugar in the stalk appears to have an effect on disease symptoms with higher the sugar content in resistant genotypes than the susceptible ones. Similar results were also reported by Gill *et al.* (2005) for total soluble sugars. Harleen *et al.* (2008) suggested that higher protein content, phenols, total sugars and reducing sugars coupled with other biochemical components in cultivars might be responsible for inducing the resistance to charcoal rot.

There was significant and positive correlation observed both at phenotypic and genotypic level for fodder yield per plot with number of leaves per plant, chlorophyll content at maturity stage and stem girth which indicated that these characters are

important components of the fodder yield.. Hence, selection for these characters will help in selecting genotypes with high fodder yield. Iyanar *et al.* (2010) observed that fodder yield exhibited high correlation with number of leaves. However, when we scan interrelationship of stem thickness with charcoal rot parameters it is better not to opt for thick stem instead select for thin or medium thick stem.

Based on the present study, it may be opined that, to enhance fodder yield and quality, the breeder may have to focus on medium thick stem, more number of leaves higher chlorophyll content at flag leaf and maturity and high brix percentage. These traits would reduce the charcoal rot disease there by enhancing quality of the fodder.

5.5 Identification of superior genotypes among minicore accessions

Promising genotypes are those genotypes which have many yield attributing traits that are potential for future use as varieties or donors. Since crossing with them leads to increased accumulation of favourable genes. A gene pool comprising of such genotypes can be used as source population to evolve superior lines, varieties and hybrids.

An attempt was made to identify superior genotypes for each of trait over population mean and C. D. value in minicore accessions. Identified genotypes + checks along with their mean values is presented in Table 11 and 12.

There were as many as 41 accessions which recorded significantly higher grain yield per plant over population mean. Among them IS7987, IS14290, IS4360, IS1233 and IS23684 were even significantly superior over all the checks. Similarly 26 accessions performed superior over population mean for 100-seed weight and out of them IS29689, IS4360, IS-14290, IS30079 and IS6351 were superior genotypes over M-35-1 and BJV-44. For the trait number of primaries per panicle 56 accessions were found to be superior over population mean and among them the accessions viz., IS31043, IS23590 and IS7250 were superior over all the checks. Similarly, 71 accessions exhibited superior performance over mean for panicle weight, out of them IS7987, IS995, IS4360, IS13549 and IS14290 were superior genotypes over all the checks used.

Table 10: Grouping of sorghum minicore accessions into resistance and susceptibility types based on number of internodes crossed by fungus score (1-5) (Rosenow, 1980)

Sl. No.	Group	No. of Accession.	List of Accession in different groups
1	HR	59	IS25989, IS29772, IS30460, IS32787, IS26617, IS30417, IS2413, IS7987, IS28747, IS23514, IS1212, IS24953, IS2389, IS26737, IS27887, IS12883, IS4360, IS22294, IS29326, IS26046, IS32349, IS15744, IS25249, IS31186, IS31446, IS31446, IS324453, IS29358, IS602, IS7131, IS30533, IS28313, IS5919, IS2902, IS30466, IS14290, IS29091, IS26025, IS31714, IS16528, IS20298, IS30838, IS4372, IS15931, IS24492, IS24139, IS7310, IS29689, IS29239, IS3971, IS32245, IS30383, IS31651, IS24218, IS12804, IS23644, IS12945, IS12735, IS9108, E-36-1.
2	R	73	IS22986, IS7305, IS608, IS30466, IS30451, IS7679, IS20743, IS29241, IS9745, IS995, IS23590, IS20713, IS21512, IS19676, IS23684, IS16151, IS17941, IS5667, IS13549, IS12447, IS9133, IS4060, IS29627, IS33353, IS19389, IS33090, IS29654, IS473, IS29392, IS13919, IS5919, IS2902, IS22239, IS27034, IS6421, IS24175, IS10969, IS19859, IS30400, IS14861, IS19153, IS24462, IS24503, IS15466, IS29606, IS11473, IS31706, IS2413, IS15170, IS25089, IS29100, IS6351, IS8348, IS12937, IS27912, IS20625, IS12697, IS20727, IS29519, IS27786, IS19262, IS10302, IS27557, IS20632, IS2382, IS29627, IS25548, IS28141, IS15478, IS13294, IS22799, IS11919, IS29565.
3	MR	49	IS24348, IS20816, IS30507, IS25910, IS1233, IS8012, IS5094, IS33844, IS20740, IS2872, IS22720, IS31714, IS1041, IS2426, IS16382, IS1004, IS26694, IS30443, IS19445, IS2397, IS4613, IS2864, IS33023, IS29335, IS29733, IS26484, IS29914, IS29568, IS29304, IS23579, IS28389, IS15945, IS30572, IS26701, IS28849, IS11619, IS8774, IS8774, IS21645, IS10867, IS12302, IS12965, IS14779, IS13893, IS2397, IS30536, IS28449, IS17980, IS14090, M-35-1, BJV-44.
4	S	32	IS30450, IS22616, IS28614, IS4631, IS7957, IS4515, IS8916, IS31043, IS18758, IS18039, IS11026, IS12706, IS8777, IS19450, IS4951, IS5386, IS33023, IS23586, IS20956, IS22239, IS23216, IS14010, IS5295, IS30079, IS23992, IS23521, IS7250, IS603, IS25301, IS10757, IS19975, IS29714.
5	HS	23	IS29269, IS16151, IS29468, IS23891, IS28451, IS25732, IS20697, IS29314, IS32439, IS4092, IS2379, IS995, IS5301, IS20195, IS4698, IS13971, IS24463, IS31446, IS29187, IS4581, IS24939, IS25836, IS21083, SPV86.

HR- highly resistance, 1 = less than one internode invaded.

HS – Highly susceptible, 5 = >4 internodes invaded

R- Resistance, 2 = 1.1 – 2.0, internodes invaded.

S- Susceptible, 4 = 3.1 – 4.0, internodes invaded.

MR- Moderately resistance, 3 = 2.1 – 3.0, internodes invaded.

Table 11: Top five superior performing genotypes identified for grain yield and their component traits in minicore collections of sorghum (Rabi 2016-17)

SI. No.	Days to 50 per cent flowering	Days to maturity	Plant height (cm)	Panicle length(cm)	100 seed weight (g)	Number of primaries per panicle	Panicle width (cm)	Panicle weight (g)	Grain yield per plant (g)
1	IS19859 (54.5)**	IS14090, IS24503 (110)**	IS8777 (328.1)**	IS24503 (51)**	IS29689 (5.71)**	IS31043 (87.75)**	IS10302 (14)**	IS7987 (154.7)**	IS7987 (132.3)**
2	IS29627 (57)**	IS12706 (114.5)*	IS12447 (301.2)**	IS8777 (40)**	IS4360 (5.62)**	IS23590 (84.91)**	IS29714 (12.62)**	IS995 (111.6)	IS14290 (95.5)**
3	IS17941 (58)**	IS22294, IS29335 (115)*	IS1041 (294.6)**	IS33844 (39.4)**	IS14290 (5.14)**	IS7250 (80)**	IS29606 (11.5)**	IS4360 (110)**	IS4360 (83.4)**
4	IS26025, IS20298 (59)*	IS15170, IS29714 (116)*	IS22616 (287.6)**	IS27557 (38.6)**	IS30079 (5.04)**	IS20625 (77)**	IS12697 (11.45)**	IS13549 (108)**	IS1233 (82.93)**
5	IS23590, IS2379 (60.5)*	IS30417 (117.5)	IS33844 (284.7)**	IS25910 (37.65)**	IS6351 (4.93)**	IS4613 (75.87)**	IS30838 (11.2)**	IS14290 (107.8)**	IS23684 (81.8)**
M35-1	67.33	123.0	230.9**	16.40	4.30**	60.45**	16.75**	68.40**	60.6**
BJV-44	69.83	116.0*	244.6**	19.43	4.69**	68.58**	12.62**	74.10**	65.8**
SPV-86	63.50	142.0	236.0**	20.50	3.47	44.37	8.62*	49.24	36.58
E36-1	62.30*	103.0**	175.5	21.80	3.36	56.56**	13.27**	56.40*	43.70
Mean	72.10	133.5	192.3	21.33	3.27	44.27	7.07	48.97	38.34
C. D. at 5 %	10.43	16.31	28.96	6.140	0.760	7.230	1.480	7.350	14.72
C. D. at 1 %	13.75	21.50	38.17	8.100	1.000	9.530	1.950	9.690	14.79

Figure in the parenthesis indicate mean value for the character

*, ** indicates significant at 5 per cent and 1 per cent level of probability, respectively.

Table 12: Top five superior performing genotypes identified for fodder yield and quality traits in minicore collections of sorghum (*Rabi* 2016-17)

SI. No.	Chlorophyll content at flag leaf stage	Chlorophyll content at maturity stage	Stem girth (cm)	Brix % at maturity	Number of leaves per plant	Fodder yield per plot (kg)
1	IS12302 (64.13)**	IS29241 (57.9)**	IS7987 (2.43)**	IS29519 (28)**	IS25836 (13)**	IS25989 (1.525)**
2	IS1004 (61.19)*	IS29914 (56.65)**	IS25910 (2.21)**	IS31714 (25.8)**	IS32349 (12.5)**	IS26737 (1.51)**
3	IS29239 (61.00)*	IS2389 (55.67)**	IS22616 (1.95)**	IS7310 (24.9)**	IS7987 (11.83)**	IS1233 (1.43)**
4	IS28451 (60.69)*	IS22294 (55.38)**	IS995 (1.93)**	IS27786 (24.4)**	IS12706, IS29714 (11.75)**	IS12447 (1.33)**
5	IS25836 (60.37)*	IS6351 (52.95)**	IS29241 (1.89)**	IS24175 (23.1)**	IS8777 (11.5)**	IS23590 (1.26)**
M35-1	50.08	28.06	1.89**	8.50	8.50	1.100**
BJV-44	58.07	37.89**	1.76*	8.20	8.75	1.260**
SPV-86	49.70	28.13	1.76*	11.50*	9.50*	1.100**
E36-1	67.03**	40.3**	3.53**	14.20**	7.25	0.750**
Mean	50.82	26.21	1.32	9.73	7.54	0.42
C. D. at 5 %	7.990	7.130	0.350	2.410	1.710	0.110
C. D. at 1 %	10.54	9.390	0.460	3.180	2.260	0.140

Figure in the parenthesis indicate mean value for the character

*, ** indicates significant at 5 per cent and 1 per cent level of probability, respectively.

For fodder yield and quality traits, 9 accessions recorded significantly superior for chlorophyll content at flag leaf stage over population mean. Among these the best performing genotypes viz., IS12302, IS1004, IS29239, IS28451 and IS25836 were superior over all the checks except E 36-1. The accessions IS29241, IS29914, IS2389, IS22294 and IS6351 were superior for chlorophyll content at maturity stage over population mean and all the checks. Similarly, the accessions viz., IS7979, IS25910, IS22616, IS995 and IS29241 were superior over population mean and checks namely M-35-1, BJV-44 and E 36-1 for stem girth.

The top superior genotypes viz., IS25836, IS32349, IS7987, IS12706 and IS8777 were found significantly superior over mean and checks for the character number of leaves per plant. With respect to brix per cent, 62 accessions were found to be the best ones over mean. Among them accessions viz., IS29519, IS31714 and IS7310 were superior over all the checks used. Similarly, 51 accessions performed superior over mean for fodder yield per plot and out of them IS25989, IS26737, IS1233 and IS12447 were even superior genotypes over checks.

In the present study 236 accessions of sorghum were screened for charcoal rot disease resistance under artificial inoculation of tooth pick method. Accessions viz., IS7987, IS14290, IS4360, IS13549, IS30466, IS31446, IS23590, IS28313, IS31446 and IS12804 showed least number of internodes crossed by fungus and least spreading of fungus with high grain yield per plant. These can be used as promising sources in the breeding programmes to develop better varieties or hybrids against charcoal rot (Table 13).

Jamadar *et al.* (2000) observed that of the 197 germplasms screened, the genotypes IS2243, IS2550, IS18671 and IS33758 were highly resistant with less than one per cent plants infected.

Top five superior performing genotypes identified for important traits in minicore collection of sorghum are presented in Table 14, 15, 16, 17 and 18.

In the present study, there were many genotypes which were promising across important traits. Among them IS14290 and IS4360 found significantly superior for 100-seed weight, panicle weight, grain yield per plant and also resistant to charcoal rot disease. Similarly IS7987 was superior genotype for panicle weight, grain yield per

Table 13: Promising genotypes showing least number of internodes crossed by fungus and least spreading of fungus identified based on evaluation of minicore accessions during *rabi* 2016-17

Sl. No	Accessions	Grain yield per plant (g)	Spreading of fungus (cm)	Number of internodes crossed by fungus	Per cent lodging	Plant height (cm)	Stem girth (cm)	Brix per cent at maturity
1	IS7987	132.3	0.00	0.00	70.00	252.0	2.43	5.90
2	IS14290	95.50	20.0	0.66	20.00	222.9	1.20	18.30
3	IS4360	83.40	0.00	0.00	0.000	181.0	1.33	12.20
4	IS13549	74.40	28.1	1.90	100.0	232.0	1.84	5.90
5	IS30466	62.95	24.0	1.33	0.000	222.5	1.26	8.10
6	IS31446	55.00	0.00	0.00	0.000	227.5	1.40	13.20
7	IS23590	54.20	24.0	1.44	0.000	185.0	1.30	10.20
8	IS28313	52.90	10.1	0.60	30.00	146.6	1.55	10.10
9	IS31456	50.66	0.00	0.00	0.000	157.0	1.30	10.20
10	IS12804	50.49	12.5	0.75	50.00	196.51	1.55	5.81
11	M35-1	60.60	24.28	2.36	30.00	230.9	1.89	8.50
12	BJV-44	65.80	20.25	2.15	30.00	244.6	1.76	8.20
13	SPV-86	36.58	111.5	5.00	100.0	236.0	1.76	11.50
14	E36-1	43.70	13.79	1.09	10.00	175.5	3.53	14.20

Table 14: Top five superior performing genotypes identified for days to 50 % flowering and their performance for other importance traits in minicore collections of sorghum (Rabi 2016-17)

SI. No.	Days to 50 per cent flowering	Days to maturity	Plant height (cm)	Panicle length(cm)	100 seed weight (g)	Number of primaries per panicle	Panicle width (cm)	Panicle weight (g)	Grain yield per plant (g)
1	IS19859 (54.5)**	139.5	145.0	25.00	2.62	43.25	6.48	44.00	31.80
2	IS29627 (57)**	128.0	197.00	21.00	2.43	52.50	7.00	74.00**	60.24**
3	IS17941 (58)**	128.0	206.2	18.60	4.08	38.50	6.25	24.50	16.00
4	IS26025 (59)*	117.5	148.5	19.40	2.30	49.94	7.10	32.80	30.00
5	IS23590, IS2379 (60.5)*	126.0	212.2	23.00	3.32	50.00	6.88	39.00	29.96
M35-1	67.33	123.0	230.9**	16.40	4.30**	60.45**	16.75**	68.40**	60.6**
BJV-44	69.83	116.0*	244.6**	19.43	4.69**	68.58**	12.62**	74.10**	65.8**
SPV-86	63.50	142.0	236.0**	20.50	3.47	44.37	8.62*	49.24	36.58
E36-1	62.30*	103.0**	175.5	21.80	3.36	56.56**	13.27**	56.40*	43.70
Mean	72.10	133.5	192.3	21.33	3.27	44.27	7.07	48.97	38.34
C. D. at 5 %	10.43	16.31	28.96	6.140	0.760	7.230	1.480	7.350	14.72
C. D. at 1 %	13.75	21.50	38.17	8.100	1.000	9.530	1.950	9.690	14.79

Figure in the parenthesis indicate mean value for the character

*, ** indicates significant at 5 per cent and 1 per cent level of probability respectively.

Table 15: Top five superior performing genotypes identified for chlorophyll content at flag leaf stage and their performance for other importance traits in minicore collections of sorghum (Rabi 2016-17)

SI. No.	Chlorophyll content at flag leaf stage	Chlorophyll content at maturity stage	Number of leaves per plant	Plant height (cm)	Stem girth (cm)	100 seed weight (g)	Panicle weight (g)	Fodder yield per plot (kg)	Grain yield per plant (g)
1	IS12302 (64.13)**	20.63	7.75	180.7	0.99	3.63	51.50	0.120	49.00
2	IS1004 (61.19)*	51.03**	7.42	213.7	1.35	2.51	54.60**	0.825**	43.70
3	IS29239 (61.00)*	33.48*	8.33	176.0	0.87	2.61	25.78	0.210	16.80
4	IS28451 (60.69)*	8.77	7.500	179.7	1.72*	2.55	54.60**	0.255	42.40
5	IS25836 (60.37)*	20.63	13.00**	260.0**	0.50	4.58	59.00**	0.620**	38.80
M35-1	67.33	28.06	8.50	230.9**	1.89**	4.30**	68.40**	1.100**	60.6**
BJV-44	69.83	37.89**	8.75	244.6**	1.76*	4.69**	74.10**	1.260**	65.8**
SPV-86	63.50	28.13	9.50*	236.0**	1.76*	3.47	49.24	1.100**	36.58
E36-1	62.30*	40.3**	7.25	175.5	3.53**	3.36	56.40*	0.750**	43.70
Mean	72.10	26.21	7.54	192.3	1.32	3.27	48.97	0.42	38.34
C. D. at 5 %	10.43	7.130	1.710	28.96	0.350	0.760	7.350	0.110	14.72
C. D. at 1 %	13.75	9.390	2.260	38.17	0.460	1.000	9.690	0.140	14.79

Figure in the parenthesis indicate mean value for the character

*, ** indicates significant at 5 per cent and 1 per cent level of probability, respectively.

Table 16: Top five superior performing genotypes identified for brix per cent at maturity and their performance for other importance traits in minicore collections of sorghum (Rabi 2016-17)

SI. No.	Brix per cent at maturity	Chlorophyll content at flag leaf stage	Chlorophyll content at maturity stage	Number of leaves per plant	Plant height (cm)	Stem girth (cm)	100 seed weight (g)	Panicle weight (g)	Fodder yield per plot (kg)	Grain yield per plant (g)
1	IS29519 (28)**	55.00	25.98	4.92	104.95	0.94	3.05	12.97	0.510	15.83
2	IS31714 (25.8)**	54.93	38.08**	6.50	160.0	0.75	3.29	55.66	0.227	46.20
3	IS7310 (24.9)**	48.03	19.65	9.50*	205.0	1.12	2.12	38.60	0.120	35.00
4	IS27786 (24.4)**	50.32	19.90	7.50	196.2	1.36	3.74	45.00	0.215	22.20
5	IS24175 (23.1)**	54.93	17.40	8.50	182.0	1.59**	2.76	65.40**	0.355	53.00**
M35-1	8.50	50.08	28.06	8.50	230.9**	1.89**	4.30**	68.40**	1.100**	60.6**
BJV-44	8.20	58.07	37.89**	8.75	244.6**	1.76*	4.69**	74.10**	1.260**	65.8**
SPV-86	11.50*	49.70	28.13	9.50*	236.0**	1.76*	3.47	49.24	1.100**	36.58
E36-1	14.20**	67.03**	40.3**	7.25	175.5	3.53**	3.36	56.40*	0.750**	43.70
Mean	9.73	50.82	26.21	7.54	192.3	1.32	3.27	48.97	0.42	38.34
C. D. at 5 %	2.410	7.990	7.130	1.710	28.96	0.350	0.760	7.350	0.110	14.72
C. D. at 1 %	3.180	10.54	9.390	2.260	38.17	0.460	1.000	9.690	0.140	14.79

Figure in the parenthesis indicate mean value for the character

*, ** indicates significant at 5 per cent and 1 per cent level of probability, respectively.

Table 17: Top five superior performing genotypes identified for fodder yield per plot and their performance for other importance traits in minicore collections of sorghum (Rabi 2016-17)

SI. No.	Fodder yield per plot (kg)	Chlorophyll content at flag leaf stage	Chlorophyll content at maturity stage	Stem girth (cm)	Brix per cent at maturity	Number of leaves per plant	100 seed weight (g)	Panicle weight (g)	Grain yield per plant (g)
1	IS25989 (1.525)**	49.83	40.34**	0.75	6.00	6.250	3.25	24.95	16.95
2	IS26737 (1.51)**	52.43	50.3**	1.36	6.50	8.500	3.10	70.15**	51.75**
3	IS1233 (1.43)**	52.28	25.77	1.60	5.20	8.500	3.74	96.95**	82.93**
4	IS12447 (1.33)**	42.57	11.25	1.48	17.30**	9.75	4.15*	97.35**	78.55**
5	IS23590 (1.26)**	45.43	35.45*	1.30	17.3**	10.00	3.64	69.00**	54.20**
M35-1	1.100**	50.08	28.06	1.89**	8.50	8.50	4.30**	68.40**	60.6**
BJV-44	1.260**	58.07	37.89**	1.76*	8.20	8.75	4.69**	74.10**	65.8**
SPV-86	1.100**	49.70	28.13	1.76*	11.50*	9.50*	3.47	49.24	36.58
E36-1	0.750**	67.03**	40.3**	3.53**	14.20**	7.25	3.36	56.40*	43.70
Mean	0.42	50.82	26.21	1.32	9.73	7.54	3.27	48.97	38.34
C. D. at 5 %	0.110	7.990	7.130	0.350	2.410	1.710	0.760	7.350	14.72
C. D. at 1 %	0.140	10.54	9.390	0.460	3.180	2.260	1.000	9.690	14.79

Figure in the parenthesis indicate mean value for the character

*, ** indicates significant at 5 per cent and 1 per cent level of probability, respectively.

Table 18: Top five superior performing genotypes identified for grain yield per plant and their performance for other importance traits in minicore collections of sorghum (Rabi 2016-17)

SI. No.	Grain yield per plant (g)	Days to 50 per cent flowering	Days to maturity	Plant height (cm)	100 seed weight (g)	Brix per cent at maturity	Chlorophyll content at flag leaf stage	Panicle weight (g)	Fodder yield per plot (kg)
1	IS7987 (132.3)**	79.50	120.5	252.0**	4.62**	12.10	48.72	154.7**	0.740**
2	IS14290 (95.5)**	74.00	125.0	222.9*	5.14**	18.30**	46.55	107.80**	0.750**
3	IS4360 (83.4)**	89.50**	141.0	241.0**	5.62**	17.3**	52.28	110.0**	1.260**
4	IS1233 (82.93)**	72.00	117.5	270.0**	3.74	5.20	60.69**	96.95**	1.430**
5	IS23684 (81.8)**	87.50**	117.5	232.5**	4.45**	6.90	53.82	95.60**	0.620**
M35-1	60.6**	67.33	123.0	230.9**	4.30**	8.50	50.08	68.40**	1.100**
BJV-44	65.8**	69.83	116.0*	244.6**	4.69**	8.20	58.07	74.10**	1.260**
SPV-86	36.58	63.50	142.0	236.0**	3.47	11.50*	49.70	49.24	1.100**
E36-1	43.70	62.30*	103.0**	175.5	3.36	14.20**	67.03**	56.40*	0.750**
Mean	38.34	72.10	133.5	192.3	3.27	9.73	50.82	48.97	0.42
C. D. at 5 %	14.72	10.43	16.31	28.96	0.760	2.410	7.990	7.350	0.110
C. D. at 1 %	14.79	13.75	21.50	38.17	1.000	3.180	10.54	9.690	0.140

Figure in the parenthesis indicate mean value for the character

*, ** indicates significant at 5 per cent and 1 per cent level of probability, respectively.

Table 19: List of superior genotypes identified across the traits studied

Sl. No	Accessions	Characters
1	IS7987	Panicle weight, grain yield per plant, stem girth, number of leaves per plant and resistance to charcoal rot disease
2	IS4360	100-seed weight, panicle weight, grain yield per plant and resistance to charcoal rot disease.
3	IS14290	100 seed weight, panicle weight, grain yield per plant and resistance to charcoal rot disease.
4	IS23590	Days to 50 % flowering, number of primaries per panicle and fodder yield per plot.
5	IS29714	Days to maturity, panicle width and number of leaves per plant
6	IS8777	Plant height, panicle length and number of leaves per plant.
7	IS12447	Plant height and fodder yield per plot.
8	IS6351	100-seed weight and chlorophyll content at maturity.
9	IS1233	Grain yield per plant and fodder yield per plot.
10	IS25836	Chlorophyll content at flag leaf stage and number of leaves per plant.
11	IS29241	Chlorophyll content at maturity and stem girth.
12	IS24503	Days to 50 % flowering and panicle length.

plant, stem girth, number of leaves per plant and also resistant to charcoal rot. The accession IS1233 was superior for fodder yield per plot and grain yield per plant indicating this could be further evaluated for grain and fodder (dual purpose). Similarly, IS23590 recorded significantly superior for early maturity, number of primaries per panicle, fodder yield per plot and charcoal rot resistance (Table 19).

Future line of work

1. Among 236 minicore accessions, IS7987 was superior for grain yield per plant and resistance to charcoal rot disease. Hence, it can be used as donor parent for improvement of grain yield and disease resistance.
2. Among accessions of minicore IS24503 and IS14090 were early maturing and could be used as donor for transferring earliness in breeding programme.
3. The genotypes superior for resistance to charcoal rot, fodder quality and grain yield needs to be evaluated over locations to confirm their superiority before using them in breeding programme.
4. The traits like plant height, length of spread of infection by fungus, number of internodes crossed by fungus, per cent lodging, per cent incidence, panicle length, number of primaries per panicle, panicle weight, 100 seed weight, panicle width, chlorophyll content at maturity stage, stem girth, brix per cent, number of leaves per plant, fodder yield per plant and grain yield per plant exhibited moderately high heritability may be considered in future which are amenable for simple phenotypic selection.
5. Genotypes which were identified as resistant to charcoal rot IS7987, IS22720, IS4360, IS27887, IS31446 and IS32787 could be exploited as donors in charcoal rot resistance breeding programmes.
6. In present study, significant positive association of lodging percentage with plant height and negative significant association with 100 seed weight, days to 50 per cent flowering and grain yield per plant was found in minicore. Therefore genotypes with increased height, early flowering, resistant to charcoal rot and high grain yield per plant may be selected and evaluated for further breeding programme.

6. SUMMARY AND CONCLUSIONS

Sorghum [*Sorghum bicolor* (L.) Moench] belongs to C₄ grass family and a diploid (2n=2x=20) with smaller genome size (~730Mb). It is one of the most drought enduring crop and capable of feeding over 500 million resource poor people in semi-arid tropics of the world. In India, sorghum is mainly grown in Northern Dry Zone of Karnataka, Maharashtra and Andhra Pradesh during *rabi* season where the crop usually faces terminal soil moisture stress that provides a favorable condition for charcoal rot disease caused by a soil borne fungus, *Macrophomina phaseolina* (Tassi) Goid. Charcoal rot often causes severe yield loss and equally degrade the quality of fodder.

Exploration of genetic variability is necessary for the improvement of any crop. In the present study, sorghum mini core collections were evaluated for component traits of charcoal rot resistance, fodder quality trait and yield component traits. The experimental results obtained are summarized below.

1. A mini core consisting of 236 accessions were evaluated together with four checks viz., M-35-1 (popular variety), BJV-44 (improved variety), E 36-1 (charcoal rot resistant) and SPV-86 (charcoal rot susceptible) at Botany garden of MARS, Dharwad. Observations on four component traits of charcoal rot resistance viz., per cent lodging, length of infection by fungus, per cent disease incidence and numbers of internode crossed by fungus and fodder grain yield components such as plant height, stem girth, panicle length, panicle width, number of leaves, number of primaries per plants, days to 50 per cent flowering, 100-seed weight, chlorophyll content at flag leaf stage, chlorophyll content at maturity stage, number of leaves per plant, brix percentage, fodder yield per plot and grain yield per plant were recorded. Artificial inoculation of *M. phaseolina* was done at critical stage of the crop to ensure proper charcoal rot disease manifestation.
2. The analysis of variance showed that the variance due to genotype was significant for all the quantitative characters in sorghum mini core collection. This indicated wide genetic diversity among mini core accessions and their

potential to be suitable material in approaches to improve different traits through simple selection.

3. Higher values of PCV over GCV for all the traits indicated polygenic traits having been influenced by G x E interactions. High values of PCV and GCV were observed for major traits such as plant height, panicle exertion, panicle length, panicle width, numbers of leaves, 100-seed weight and grain yield per plant including disease parameters viz., length of infection and per cent lodging, indicating a greater scope for improvement of these traits. However, PCV and GCV values were found to be moderate for traits such as days to 50 % flowering stem thickness, spikelet numbers and the disease parameter viz., number of internodes crossed by the fungus indicating the difficulty in improvement of these traits through simple selection.
4. Narrow difference between phenotypic and genotypic co-efficient of variation were observed for all the characters indicating relatively more role of genetic portion of variation in the expressions of all traits and the possibility to exploit the same in breeding programs.
5. In the present study, high heritability coupled with high genetic advance over mean was observed for the traits viz., plant height, length of spread of infection by fungus, number of internodes crossed by fungus, per cent lodging, per cent disease incidence, panicle length, number of primaries per panicle, panicle weight, 100-seed weight, panicle width, Chlorophyll content at maturity stage, stem girth, brix percentage, number of leaves per plant, fodder yield per plant and grain yield per plant. This reveals that these characters would be more effective for the crop improvement through selection as these are more likely to be controlled by additive portion of the genetic variation.
6. From the results of correlation co-efficient analysis, it could be concluded that panicle weight and 100-seed weight displayed significant positive correlation on grain yield per plant. Hence it would be rewarding to lay stress on these traits in selection programme for increasing the grain yield in sorghum.

7. In mini core accessions, the association between chlorophyll content at flag leaf and maturity stage and charcoal resistance traits (length of spread of infection by fungus, number of internodes crossed by fungus, per cent incidence and per cent lodging) was in negative. This indicates the importance of stay-green reducing the incidence of charcoal rot.
8. Brix per cent at maturity stage recorded highly significant and negative correlation with disease parameters viz., per cent lodging, length of spreading of the fungus and number of internodes crossed both at genotypic and phenotypic level. These suggested that juicy stem with higher carbohydrate level inhibit the development of pathogen in the lower portion of the stem.
9. Occurrence of the disease at grain maturity in tall and productive plants will certainly promote lodging. A combination of medium height, medium thick stem, large panicle, high brix per cent, more number of leaves, high SPAD values and resistance to charcoal rot are desirable traits to develop a cultivar with high quantity and quality of grain and fodder,
10. Among 236 accessions the genotypes viz., IS7987 (132.3 g) followed by IS14290 (95.5 g) recorded highest grain yield per plant. These genotypes needs to be further evaluated across season and location for their stability.
11. Based on the scale for the number of internodes invaded, the mini core accessions were classified into five groups viz., highly resistant (HR), resistant (R), moderately resistant (MR), susceptible (S) and highly susceptible (HS). Group HR consisted of 59 accessions with less than one internode invaded, group R consisted of 73 accessions with 1.1 to 2.0 internodes invaded, 49 moderately resistant accessions with 2.1-3.0 internodes invaded, 32 were susceptible (3.1- 4.0 internodes invaded) and 23 were highly susceptible (>4 internodes invaded). Five internodes were invaded in susceptible check SPV 86, 2.36 internodes invaded in moderately resistant M-35-1 and 2.36 internodes were crossed in BJV-44 and 1.09 internode invaded in resistant check E 36-1.

12. The accession IS7987 not only recorded resistance to charcoal rot but also exhibited with least number of internodes crossed by fungus, least spread of fungus, zero per cent of lodging and zero per cent of disease incidence with highest grain yield per plant of 132.35 g. this genotype appears to be most potential and needs further evaluation.
13. The accession IS22720 recorded highest 100 seed weight of 5.62 g with grain yield of 83.4 g and also showed resistance to charcoal rot disease. This line can be utilized as base material for further enhancing grain size in sorghum.

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Appendix I. Meteorological data recorded during 2016-17 at Main Agricultural Research Station, Dharwad

Std. week	Date and month	Temperature (°C)		Rainfall (mm)	Normal Rainy Days (NRD)	Relative humidity (%)	
		Maximum	Minimum			Morning	Evening
1	1 - 7 Jan	30.3	13.6	0.0	0	51.6	23.0
2	8 - 14 Jan	29.7	12.0	0.0	0	49.3	20.6
3	15 - 21 Jan	28.2	14.5	0.4	0	71.6	41.4
4	22 - 28 Jan	30.7	16.0	0.0	0	63.3	36.0
5	29 Jan - 4 Feb	33.7	14.8	0.0	0	43.6	19.7
6	5 - 11 Feb	32.6	17.0	0.0	0	74.6	34.3
7	12 - 18 Feb	32.0	17.0	0.0	0	59.9	35.3
8	19 - 25 Feb	35.0	20.3	0.0	0	57.4	32.3
9	26 Feb - 4 Mar	34.5	20.2	0.2	0	57.6	27.4
10	5 - 11 Mar	35.7	20.4	0.0	0	51.4	24.1
11	12 - 18 Mar	34.9	19.3	0.0	0	53.0	23.8
12	19 - 25 Mar	38.0	21.4	0.0	0	42.4	20.3
13	26 Mar - 1 Apr	36.7	21.1	2.4	0	75.9	44.1
14	2 - 8 Apr	36.7	21.3	8.6	1	73.4	45.4
15	9 - 15 Apr	38.1	21.7	0.0	0	67.1	33.7
16	16 - 22 Apr	38.8	22.1	4.8	1	71.0	42.0
17	23 - 29 Apr	38.6	21.2	6.8	1	56.7	32.3
18	30 Apr - 6 May	38.7	22.1	0.2	0	75.6	35.7
19	7 - 13 May	38.2	21.4	34.0	1	65.4	35.1
20	14 - 20 May	35.0	21.8	48.8	3	81.3	58.7
21	21 - 27 May	33.3	23.0	0.0	0	80.6	56.7
22	28 May - 3 Jun	34.2	22.2	7.0	1	75.7	50.7
23	4 - 10 Jun	30.2	21.6	34.2	4	87.6	75.0
24	11 - 17 Jun	28.4	21.3	5.8	1	85.7	63.9
25	18 - 24 Jun	28.9	20.8	6.6	1	86.9	75.7
26	25 Jun - 1 Jul	26.4	21.4	23.4	3	88.3	81.9
27	2 - 8 Jul	26.4	21.5	36.4	6	91.3	84.1
28	9 - 15 Jul	25.9	21.1	61.0	5	90.3	83.6
29	16 - 22 Jul	26.7	20.6	27.2	4	91.1	80.9
30	23 - 29 Jul	26.6	20.8	21.6	3	93.1	85.1
31	30 Jul - 5 Aug	24.7	20.4	37.4	3	92.1	83.7
32	6 - 12 Aug	26.1	20.9	26.0	4	92.4	85.0
33	13 - 19 Aug	26.6	20.7	15.8	2	88.7	78.4
34	20 - 26 Aug	27.1	20.3	9.2	1	88.7	75.4
35	27 Aug - 2 Sep	27.3	20.4	28.8	1	91.3	78.7
36	3 - 9 Sep	27.4	19.7	0.4	0	84.7	73.4
37	10 - 16 Sep	27.2	19.9	14.8	2	88.1	81.7

Appendix I contd.....

Std. week	Date and month	Temperature (°C)		Rainfall (mm)	Normal Rainy Days (NRD)	Relative humidity (%)	
		Maximum	Minimum			Morning	Evening
38	17 - 23 Sep	25.6	20.0	11.8	3	90.4	85.1
39	24 - 30 Sep	27.7	20.5	44.0	1	88.9	81.0
40	1 - 7 Oct	27.2	19.5	6.2	1	88.6	70.6
41	8 - 14 Oct	28.9	20.2	38.6	1	88.9	75.3
42	15 - 21 Oct	30.8	16.3	0.0	0	59.3	39.0
43	22 - 28 Oct	31.1	18.5	0.0	0	63.3	39.1
44	29 Oct - 4 Nov	31.5	18.4	0.4	0	65.3	43.0
45	5 - 11 Nov	30.3	12.6	0.0	0	43.0	27.7
46	12 - 18 Nov	31.0	17.2	5.4	1	68.9	45.0
47	19 - 25 Nov	30.1	13.2	0.0	0	55.6	35.1
48	26 Nov - 2 Dec	31.4	13.1	0.0	0	45.7	29.9
49	3 Dec - 9 Dec	29.4	16.2	0.0	0	64.7	44.0
50	10 - 16 Dec	29.0	15.1	0.0	0	61.6	43.6
51	17 - 23 Dec	30.6	13.4	0.0	0	54.3	35.0
52	24 - 31 Dec	30.5	11.8	0.0	0	52.6	25.9
1	1 - 7 Jan	30.0	12.1	0.0	0	48.6	33.1
2	8 - 14 Jan	29.6	13.6	0.0	0	63.9	43.1
3	15 - 21 Jan	29.2	13.4	0.0	0	56.7	35.0
4	22 - 28 Jan	31.3	15.4	0.0	0	63.4	39.0
5	29 Jan - 4 Feb	32.3	15.6	0.0	0	50.6	30.7
6	5 - 11 Feb	32.8	16.1	0.0	0	66.4	24.6
7	12 - 18 Feb	32.3	15.5	0.0	0	45.7	21.6
8	19 - 25 Feb	35.1	17.6	0.0	0	42.4	13.3
9	26 Feb - 4 Mar	35.0	16.9	0.0	0	39.6	15.0
10	5 - 11 Mar	33.9	16.9	0.0	0	39.7	22.4
11	12 - 18 Mar	34.0	17.8	0.0	0	53.4	24.7
12	19 - 25 Mar	36.3	18.4	0.0	0	50.7	22.1
13	26 Mar - 1 Apr	37.0	21.8	0.0	0	77.6	32.0
14	2 - 8 Apr	36.7	21.0	0.2	0	73.3	20.0
15	9 - 15 Apr	38.1	21.6	5.8	1	74.7	19.7

**GENETIC STUDIES ON CHARCOAL ROT RESISTANCE AND FODDER
QUALITY PARAMETERS IN MINICORE COLLECTION OF SORGHUM
(*Sorghum bicolor* (L.) Moench) DURING RABI SEASON**

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2017

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ABSTRACT

Genetic variability, heritability, genetic advance and correlation were estimated for charcoal rot component traits, fodder quality traits, yield and its component traits in 236 minicore accessions of sorghum during *rabi* season of 2016-17 at the Main Agricultural Research Station, University of Agricultural Sciences, Dharwad. High values of PCV and GCV were observed for majority of traits, indicating a greater scope for improvement of these traits. High heritability coupled with high genetic advance over mean was observed for all the traits except for days to 50 per cent flowering and days to maturity. This reveals that these characters would be more effective for further improvement through simple selection as these are more likely to be controlled by additive portion of the genetic variation.

Significant and negative association of lodging per cent with grain yield and fodder yield per plant indicated lodging affects grain yield and fodder yield. The association between stay green and charcoal rot parameters was negative indicating stay green types are tolerant to charcoal rot. Total soluble solids recorded highly significant and negative correlation with charcoal rot component traits. Stem girth exhibited positive and significant association with number of leaves per plant, spreading of fungus and fodder yield per plot both at phenotypic and genotypic level. Based on these results it could be concluded that, to enhance fodder yield and quality, the breeder need to focus on medium thick stem, more number of leaves, higher chlorophyll content at flag leaf and at maturity and high brix percentage. These traits would reduce the charcoal rot disease there by enhancing quality and quantity of the fodder and grain. The accession IS7987 recorded highest grain yield per plant (132.35 g) and resistant to charcoal rot and suggested to use in resistance breeding programme.