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**GENETIC VARIABILITY AND CORRELATION STUDIES IN
RABI SORGHUM (*Sorghum bicolor* (L.) Moench) FOR
DROUGHT TOLERANCE**

BY
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DISSERTATION

Submitted to the

*Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani
in partial fulfilment of the
requirement for the degree of*

**MASTER OF SCIENCE
(Agriculture)**

IN

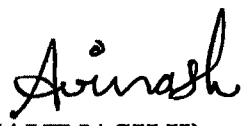
GENETICS AND PLANT BREEDING

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(GENETICS AND PLANT BREEDING)
VASANTRAO NAIK MARATHWADA KRISHI VIDYAPEETH,
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2016**

CANDIDATE'S DECLARATION

*I hereby declare that this dissertation
Or part thereof has not been
Previously submitted by me
For a degree of any
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Institute*

Place: PARBHANI
Date: 30 / 05 / 2016


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CERTIFICATE-I

This is to certify that dissertation entitled "**GENETIC VARIABILITY AND CORRELATION STUDIES IN RABI SORGHUM (*Sorghum bicolor* (L.) Moench) FOR DROUGHT TOLERANCE**" submitted to Vasantrya Naik Marathwada Krishi Vidyapeeth, Parbhani in partial fulfillment of the requirement for the award of degree of **MASTER OF SCIENCE (AGRICULTURE)** in the subject of **AGRICULTURAL BOTANY (GENETICS AND PLANT BREEDING)** embodies the results of bonafide research carried out by **Mr. AVINASH K.**, under my guidance and supervision and that no part of this dissertation has been submitted for any degree or diploma.

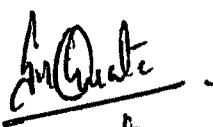
The assistance and help received during the course of this investigation have been fully acknowledged.

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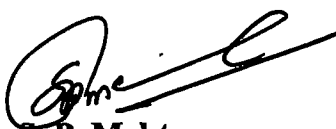
This is to certify that the dissertation entitled "**GENETIC VARIABILITY AND CORRELATION STUDIES IN *RABI* SORGHUM (*Sorghum bicolor* (L.) Moench) FOR DROUGHT TOLERANCE**" submitted by Mr. AVINASH K., to the Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani in partial fulfilment of the requirement for the degree of **MASTER OF SCIENCE (AGRICULTURE)** in the subject of **AGRICULTURAL BOTANY (GENETICS AND PLANT BREEDING)** has been approved by the student's advisory committee after oral examination in collaboration with the external examiner.


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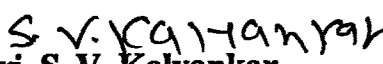
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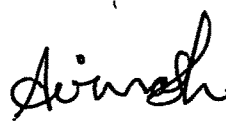
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Place : Parbhani

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(AVINASH K.)

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ABBREVATIONS

R	=	residual effect
r	=	correlation coefficient
Σ	=	summation
MSS	=	mean sum of square
mm	=	millimeter(s)
b.s.	=	broad sense
EMS	=	error mean sum of square
etc.	=	etceteras
h^2	=	heritability
d.f.	=	degree of freedom
cm	=	centimeter(s)
m	=	meter(s)
mg	=	milligram
viz.,	=	videlicet (namely)
σ^2	=	variance
<i>et al.</i>	=	and other
Fig.	=	Figure
g	=	gram (s)
GCV	=	genotypic coefficient of variation
GM	=	General mean
%	=	per cent
kg	=	kilogram(s)
ha	=	hectare(s)
/	=	per
SE	=	Standard error
CD	=	Critical difference
CV	=	Coefficient of variation
pp	=	pages
P	=	phenotypic correlation
PCV	=	phenotypic coefficient of variation
No.	=	number



Introduction



CHAPTER-I

INTRODUCTION

Sorghum (*Sorghum bicolor* (L.) Moench) is an often cross pollinating crop with chromosome number $2n=20$. It is one of the main staple food for the world's poorest and most food insecure people across the semi-arid tropics (DSR Vision 2030). It is the fifth most important cereal crop following Rice, Wheat, Maize, and Barley (Reddy *et al.*, 2010). It is considered as the king of millets and extensively grown in Africa, China, USA, Mexico and India. Africa and India accounts for largest share (>70%) of global sorghum area (Ashok kumar *et al.*, 2011). It has multiple uses as a food, fodder, fuel and fibre crop (Paterson *et al.*, 2009). Sorghum has been classified under family *Poaceae*, subfamily *Panicoidae*, tribe *Andropogonae* sub tribe *Sorghastrae* and genus *Sorghum* (Price *et al.*, 2005).

Recent FAO statistics indicates a world production of 60 million tonnes of grain sorghum from 44 million hectare of land with productivity of 1238 kg/ ha (FAO stat 2013). In India sorghum is being grown in both *kharif* (rainy) and *rabi* (post rainy) seasons. Area under sorghum in India is 9.1 million hectare with 6.7 million tonnes of production and 783 kg productivity per hectare (e-stat 2014-15).

In India the major sorghum growing state is Maharashtra which contributes 49.14 per cent of area and 42.07 per cent production and other sorghum growing states are Karnataka, Tamil Nadu, Andhra Pradesh, Rajasthan and Madhya Pradesh (Anonymous 2014). In Maharashtra, sorghum is grown in the districts viz., Solapur, Beed, Parbhani, Osmanabad and Latur with an area of 28.58 lakh hectares, production of 25.07 lakh tonnes and productivity of 1971 kg/ha (Anonymous 2015).

Grain sorghum is one of the most important dietary sources of calories for the world's population. The nutrient composition of sorghum

indicates that it is a good source of energy, proteins, carbohydrates, vitamins and minerals (Afify *et al.*, 2011). Sorghum has an ability to cope up with many types of stresses, including heat, drought, salinity and flood. It performs better under adverse soil and weather conditions as compared to other crops. This makes the crop to minimize the risk and enables to fit to sustainable and economically profitable dry land production system.

In India, the productivity of *rabi* sorghum is very low, and highly variable from year to year mainly due to post flowering drought but *rabi* sorghum is highly valued because of its good grain quality. This crop is usually affected by water stress at both pre and post-flowering stages of development and has the most adverse effect on yield (Kebede *et al.*, 2001). Drought tolerance is defined as the relative yield of a genotype compared with other genotypes subjected to same drought stress (Hall, 1993). Drought tolerance depends on the plant developmental stage at the onset of the stress condition, which may happen in sorghum during the early vegetative seedling stage, during panicle development and in post-flowering, in the period between grain filling and physiological maturity. Drought tolerance in sorghum is a complex trait influenced by many genes coding for various traits contributing towards tolerance (Tesfamichael *et al.*, 2015).

Identification of superior cultivars/lines for drought tolerance is important from the point of view of stabilizing the production. This is especially true for *rabi* sorghum as it is grown primarily under receding soil moisture regimes of the post monsoon period. Knowledge about the nature and extent of genetic variability present in the material is very important in planning and executing breeding programme successfully. The presence of significant genetic variability among sorghum genotypes suggests an opportunity for improvement of grain yield and drought tolerance through hybridization of genotypes related to divergent groups and subsequent selection from the segregating generations. Success for breeding under drought stress depends on understanding of genetic basis of drought tolerance in crop plants

based on various morpho-physiological traits to evolve superior genotype (Mitra, 2001).

Correlation coefficient helps in determining the direction of selection and number of characters to be considered in improving the grain yield under drought condition. Whereas, path analysis is used to determine the amount of direct and indirect effect of the causal components on the effect component (Ali *et al.*, 2009a).

Hence, the present investigation entitled “Genetic variability and correlation studies in *rabi* sorghum (*Sorghum bicolor* (L.) Moench) for drought tolerance” was therefore undertaken with following objectives.

- 1) To study the variability in *rabi* sorghum germplasm lines for grain yield, fodder yield and drought tolerance parameters.
- 2) To estimate direct and indirect phenotypic and genotypic effects on grain yield and fodder yield.

*Review of
Literature*

CHAPTER-II

REVIEW OF LITERATURE

This chapter deals with the presentation of relevant literature on related studies done by previous workers

2.1 Genetic variability

An insight into the magnitude of the variability present in a crop species is of almost importance as it provides the basis for effective selection. Progress in any breeding programme depends upon magnitude of useful variability present in the population and the extent to which the desirable characters are heritable.

Shinde *et al.* (1979) evaluated 20 sorghum lines during *rabi* season for genetic variability. Coefficient of variation was large for plant height, 1000 grain weight and grain yield. A wide range of variation was observed for plant height, panicle weight and grain yield. All characters except number of leaves expressed a high percentage of heritability. Genetic advance was very high for plant height and moderate for panicle length and moderate for panicle weight and grain yield. However expected genetic advance was quite high for grain yield which was encourage.

Singh and Makne (1980) recorded high genotypic and phenotypic variation for plant height and test weight in sorghum. Estimates of heritability were high for plant height, days to 50 per cent flowering and number of days to maturity. Estimated genetic advance was high for plant height, grain yield per plant and test weight.

Seetharama *et al.* (1990) revealed that great variability was found among genotypes for days to 50 per cent flowering and drought stress caused 5 days delay in flowering. Early flowering genotypes can be useful in escaping late season drought.

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

Veerabadhiran and Kennedy (2001) studied genetic variability in 75 genotypes of *Sorghum bicolor*. Observations were recorded for 50 per cent flowering days to maturity, 100 grain weight and grain yield. The characters 100 grain weight and grain yield showed high GCV and PCV. The highest heritability was recorded in grain yield per plant (99.98) followed by days to 50 per cent flowering (96.98).

Date (2002) studied genetic variability in F₂ families of *rabi* sorghum and reported high genotypic coefficient of variability for number of secondaries, fodder yield, grain number per panicle, grain yield per plant, panicle weight. High heritability coupled with high expected genetic advance was observed for grain number per panicle, number of secondaries, fodder yield, grain yield per plant and leaf area.

Sanchez *et al.* (2002) revealed that plant height showed highly significant differences among the genotypes. Drought stress reduced plant height by 14 per cent and growth rate by 19 per cent.

Kumar and Sahib (2003) evaluated 24 genotypes of sorghum and reported that higher differences in PCV and GCV. And they were observed for total tiller per plant, dry leaf weight per plant, leaf number per plant and over other characters. High heritability and genetic advance were observed for leaf width, dry stem weight per plant and dry fodder yield per plant.

Arunkumar *et al.* (2004) studied 138 genotypes of *rabi* sorghum under rainfed conditions during *rabi* 2000. High phenotypic coefficient of variation and genotypic coefficient of variation were observed for grain yield

per plant (g/plant), plant height (cm), earhead length (cm), number of primaries/earhead and leaves per plant.

Tesfaye *et al.* (2005) studied genetic diversity among drought tolerant sorghum genotypes. The most resistant accessions in these studies were all from the East Africa. Therefore, an analysis of genetic diversity was conducted to evaluate the pattern of genetic relationships among the full set of drought tolerant lines.

Amanullah *et al.* (2007) conducted an experiment to know growth characters and fodder productivity of 10 sorghum varieties during summer season 1999-2000. Differences among the plant heights of the sorghum varieties were significant with maximum plant height of 218 cm noted in the plots of variety JS-88, while the minimum plant height of 88 cm was recorded in variety PARC-SS-II. Leaves per tiller of the different varieties ranged significantly from a minimum of 5.3 (NO.1863) to a maximum of 8.7 (JS-88). Average leaf area varied significantly between 140 and 247 cm². Maximum leaf area of 247cm² recorded for variety JS-88, followed by 219 cm² for variety S-9601, while the minimum of 140 cm² recorded for the variety Tandojam local.

Channappagoudar *et al.* (2007) conducted an experiment with 22 *rabi* sorghum genotypes to understand genetic variations for drought tolerance in different genotypes. The genotype SPV 913 which gave a maximum grain yield was attributed to moderate accumulation of TDM (total dry matter) and ear weight at maturity with maximum HI (49.4%) and test weight (31.9 g) followed by SPV-504 which was mainly attributed to higher TDM and higher ear weight and sheath weight at maturity rather than HI (28.3%) whereas, genotype Nizamabad's highest yield was mainly due to higher HI (31.8%) followed by moderate accumulation of TDM.

Pawar (2007) conducted field experiments during *rabi* 2004-05 and 2005-06 to study the physiological indices for higher productivity under

receding soil moisture situation on various morpho-physiological, yield and yield components in sorghum. Among the genotypes, RSLG-262, Phule Yoshodha, PBS-2 and CRS-4 recorded maximum leaf, stem, panicle and total dry matter at all the stages. The genotypes RSLG-262 and Phule Yoshodha maintained higher photosynthetic rate and lower transpiration rate indicating their drought tolerance nature. The relative water content (RWC) was more in the genotypes RSLG-262, Phule Yoshodha, PBS-2 and CRS-4 which indicated their drought tolerance nature. These genotypes also recorded higher yield and yield components.

Ali *et al.* (2009a) evaluated 10 sorghum genotypes including one check (JS-2002) at seedling and post anthesis stage for drought tolerance based on morpho-physiological traits. Flag leaf area exhibited the highest phenotypic and genotypic variance followed by specific leaf area and excised leaf weight loss.

Ali *et al.* (2009b) studied various morpho-physiological traits to sort out drought tolerant local land races (LLRs) of sorghum. Dry root weight exhibited the highest genotypic coefficient of variation among seedling traits while excise leaf weight loss among the flag leaf related characters. Considerable variation was observed for relative water content (RWC) which was upper most for FJSS-5 followed by FJSS-9 and FJSS-1. Most of the landraces showed more RWC as compared to the control Chakwal sorghum.

Kusalkar *et al.* (2009) showed that high estimates of GCV were recorded for grain yield, leaf width, number of leaves per plant and earhead length, while low estimates of GCV were recorded for earhead width, days to 50 per cent flowering, days to maturity, plant height, leaf length and number of internodes per plant. High estimates of PCV were recorded for grain yield, leaf width, number of leaves per plant and earhead length while low estimates of PCV were recorded for days to 50 per cent flowering, days to maturity and leaf length.

Bibi *et al.* (2012) evaluated 20 different accessions of sorghum for their genetic potential to drought tolerance at seedling stage. Significant differences were observed among the accessions, treatments and their interactions for evaluated plant traits suggesting a great amount of variability for drought tolerance in sorghum. Shoot related traits were most sensitive against the water stress. Proportional contribution of root length, shoot length, fresh shoot weight, dry shoot weight, fresh root weight and dry root weight was 56.6, 20.2, 10.5, 8.5, 3.5 and 0.7 per cent respectively to drought stress as measured by principle component analysis.

Tariq *et al.* (2012) evaluated 25 sorghum genotypes under irrigated and rainfed conditions. Highest genotypic and phenotypic variances were observed for plant height, fresh weight per plant and green fodder yield. Green fodder yield, dry matter yield, fresh weight per plant and dry weight per plant depicted high heritability estimates along with high expected genetic advance.

Kapanidowda *et al.* (2012) evaluated 70 inbred lines and parents at different water regime (40 and 80% of field capacity) with 4 replications. Genotype had a significant effect on CO₂ assimilation rate ($P < 0.0001$ and $P < 0.0001$), transpiration rate ($P < 0.002$ and $P < 0.007$) and CO₂ assimilation: transpiration rate ($P < 0.0001$ and $P < 0.0001$) under 80 per cent and 40 per cent field capacity respectively. Genetic variability among genotypes for gas exchange rates (A, E and A:E) at pre-flowering in sorghum suggesting scope for improved water use efficiency (WUE) and productivity.

Arunkumar (2013) showed that GCV played a major role for the expression of the traits. Fodder yield/plant (34.08) had high GCV, followed by grain yield/ha (29.88), grain yield/plant (28.48), earhead length (12.89), test weight (11.04), seed set % (10.25), plant height (9.05), days to 50 per cent flowering (8.35) and earhead breadth (8.27). Heritability in narrow sense ranged from 50.30 (earhead breadth) to 92.20 (grain yield). High genetic

advance observed for grain yield (1376.74) coupled with high heritability (92.20).

Patil *et al.* (2013) studied nine generations of a cross between drought susceptible parent, SPV 1587 and drought tolerant parent, Phule Maulee under natural receding soil moisture regime during winter season of 2006-07. Phule Maulee recorded higher relative leaf water content, chlorophyll stability index and grain yield per plant. Stomata frequencies were less on both surfaces in the drought tolerant parent.

Techale *et al.* (2014) evaluated 11 wild type sorghum accessions to pre-flowering moisture stress by studying 11 morphological characters and observed significant variation for leaf rolling, root length, leaf drying, plant height and flag leaf width. However, the remaining traits showed non-significant difference among treatments due to moisture stress at ($p \leq 0.05$). Accession TS217 and DA119 shown superior pre-flowering drought tolerance followed by accession TS211 compared with the check B35.

Chittapur and Biradar (2015) evaluated one hundred *rabi* sorghum Germplasm lines of diverse origin for 15 quantitative traits during *rabi* season. High phenotypic coefficient of variation was observed for grain yield, panicle weight, panicle length, number of primaries and dead heart percentage. High heritability coupled with high genetic advance were observed for the characters days to flowering, dead heart percentage, panicle weight panicle length, number of primaries per panicle, testweight and grain yield per plant indicating that additive gene effects were operating for these traits and selection for superior genotype was possible to bring genetic improvement in desired direction.

Tesfamichael *et al.* (2015) evaluated 25 sorghum accessions at post-flowering stage under well watered and drought stress conditions using split plot design. High PCV and GCV were recorded for majority of the characters studied except for days to flowering, days to maturity and number of

leaves. However, plant height gave rise to the highest coefficients of variation (both PCV and GCV) followed by harvest index and panicle length. On the other hand parameters such as grain yield, total biomass, panicle weight over all agronomic score and stay-green trait showed moderate phenotypic and genotypic coefficients of variation.

Dhutmal *et al.* (2015a) evaluated 16 drought tolerant germplasm of *rabi* sorghum under moisture deficit condition at sorghum research station, Parbhani during *rabi* 2012. Results revealed that GCV ranged from 2.867 to 26.20 per cent and PCV from 4.74 to 40.93 per cent. It was observed that the leaf dry weight (26.19 g), seed vigor (22.45), stem dry weight (17.20 g), panicle dry weight per plant (17.12 g), grain yield per plant (13.98 g) and total biomass per plant (13.60 g) exhibited high to moderate genotypic coefficient of variation. However, low genotypic coefficients of variation were observed for days to 50 per cent flowering (7.73), test weight (7.62), plant height (6.21), days to physiological maturity (4.58), SCMR (8.90), relative water content (3.75) and leaves per plant (2.86). On the other hand, phenotypic coefficient of variation also exhibited similar trend of high, moderate and low variations with slightly higher values.

Khandelwal *et al.* (2015) evaluated 224 sorghum genotypes for various morphological and yield components. High magnitude of phenotypic and genotypic coefficient of variation was observed for harvest index, grain yield per plant, dry and fresh weight per plant and panicle length whereas low magnitude phenotypic and genotypic coefficient of variation was observed for days to flowering and days to maturity.

2.2 Correlation

Shahane and Borikar (1982) showed that grain yield had positive correlation with days to 50 per cent flowering and grain size.

Nimbalkar *et al.* (1988) studied interrelationship and path coefficient for grain yield and its attributes in sorghum and reported positive and highly significant correlation coefficient between grain yield per plant, panicle weight and panicle breadth. While it was negatively significant between grain yield and days to 50 per cent flowering and plant height indicating there is feasibility of developing medium tall and early plant types with high grain yield.

Cheralu and Rao (1989) reported that grain yield showed significant positive association with ear head weight, number of primaries, number of secondaries and total dry matter in winter sorghum. In respect of earhead length showed significant negative correlation with harvest index.

Bakheit (1990) observed 22 sorghum genotypes under drought conditions. The evaluation of 5 yield components revealed that considerable amount of variability existed between genotypes for all 5 characters. Plant height was highly and positively correlated with grain yield per plant and 1000 grain weight. The trait 1000 grain weight was positively correlated with plant height and grain yield per plant. Plant height and 1000 grain weight were thought to be useful selection criteria for high grain yield.

Mohammed *et al.* (1993) studied 54 varied sorghum genotypes under irrigated and dry conditions. It was found that fodder yield was positively correlated with plant height and days to maturity, but negatively correlated with crude protein content and harvest index. The overall harvest index had a negative correlation with flowering days and plant height.

Potadukhe *et al.* (1994) gave information on correlation of different traits with yield from the data on ten yield related characters in 42 genotypes and observed that grain yield was positive and significantly correlated at the genotypic and phenotypic level with panicle length, panicle weight and 1000 grain weight.

Nguyuen-Day (1998) studied the genotypic correlation and path coefficients on seven traits for thirteen genotypes of sorghum and reported that harvest index and its components had a high positive correlation with grain yield and these had direct or indirect effects on grain yield.

Can and Yoshida (1999) reported that harvest index had a negative correlation with plant height and positive correlation with grain yield at phenotypic and genotypic level. Thus correlation analysis may provide useful information in the selection of sorghum genotypes with high yield and plant height for a double cropping system.

Borrell *et al.* (2000) studied nine closely related hybrids varying in rate of leaf senescence were grown under two water-limiting regimes, post-flowering water deficient and terminal (pre and post-flowering) water deficit, and a fully irrigated control. Under terminal water deficit, grain yield was correlated positively with green leaf area at maturity ($r = 0.75^{**}$) negatively with rate of leaf senescence ($r = -0.74^{**}$) and grain yield also increased by 0.35 mg/ha every day that onset of leaf senescence was delayed beyond 76 days after emergence in water-limited treatments. Stay green hybrids produced 47 per cent more post-anthesis biomass than their senescent counterparts.

Shivalli (2000) observed that the genotype IS21340 recorded higher plant height and yield indicating their positive association. This indicates that plant height is also an important parameter for increasing productivity similarly, SPV 1090 and SPV 1217 recorded higher plant height, which was correlated with grain yield under receding soil moisture.

Iyanar *et al.* (2001) carried out genotypic correlation coefficient and path coefficient analysis in 54 genotypes and observed that seed yield was significantly and positively correlated with panicle weight and panicle length.

Kadam *et al.* (2002) revealed that high leaf area index and leaf area duration of a genotype which produced high dry matter could be considered as indicator of grain yield.

Awari *et al.* (2003) reported that the difference in grain and fodder yield in different genotypes of sorghum mainly due to variation in morphological and physiological characters viz., plant height, number of leaves, leaf breadth and length, leaf area index, leaf area duration, total dry matter per plant, crop growth, earhead length and girth, 1000 grain weight and grain number per plant. These characters were highly positively and significantly correlated with grain and fodder yield.

Umakant *et al.* (2004) carried out correlation studies and showed that selection could be practiced for head weight, plant height, panicle length, number of primaries per panicle and 100 seed weight as these characters manifested positive and significant correlation with grain yield.

Anjana (2006) observed that grain yield per plant significantly positively correlated with harvest index.

Hemlata Sharma *et al.* (2006) observed that grain yield per plant significant positively correlated with 100 seed weight.

Khairnar (2007) studied 30 genotypes with 2 checks. The characters plant height, panicle length, test weight, primary branches/panicle, grains/primary branches, harvest index were positively correlated with grain yield/plant and had positive direct effect.

Ali *et al.* (2009a) evaluated 10 sorghum genotypes including one check (JS-2002) at seedling and post-anthesis stage for drought tolerance based on morpho-physiological traits. The coefficient of correlation among the different morpho-physiological characters showed that root length revealed significant positive association with root:shoot ratio, flag leaf area and grain yield. Leaf dry matter revealed significant positive correlation with grain yield

and relative water content was positively associated with relative dry weight, which advocated that selection of genotypes with considerable water and more accumulation of osmotic in flag leaves could be possible, which in turn will help the plant to cope with drought stress conditions at reproductive stage.

Ali *et al.* (2011b) studied 44 sorghum accessions at seedling stage and natural incidence of water stress at post anthesis stage. Fresh shoot weight displayed significant positive relationship with dry shoot weight and relative water content whereas negative with root:shoot ratio head width, head weight and grain yield per plant. Flag leaf area revealed positive relationship with specific flag leaf area and leaf dry matter. Relative water content revealed negative association with residual transpiration.

Tariq *et al.* (2012) evaluated 25 sorghum genotypes under irrigated and rainfed conditions for fodder yield and quality traits. They were strong positive genotypic and phenotypic correlation between green fodder yield and number of tillers per plant, stem thickness, fresh weight per plant, dry weight per plant and dry matter yield.

Ghorade *et al.* (2013) revealed that grain yield per plant was positively and significantly correlated with all the growth parameters related with drought viz., chlorophyll content at 75 DAS, proline content, specific leaf weight and leaf area ratio at 75 DAS. This indicated that increase in grain yield in *rabi* sorghum under drought condition may be because of increase in one or more of these growth parameters.

Khodarahmpour (2013) showed that root:shoot ratio was significant and positively correlated with root length and seedling length also it was positively correlated with germination percent and mean germination time.

Nirmal *et al.* (2013) identified a sorghum variety Phule Anuradha as drought tolerant because of its superior physiological traits under receding soil moisture condition during *rabi*. The grain yield was positively correlated

with relative water content of leaves, leaf area index (LAI), biomass at harvest, grain number per panicle, test weight, stay-green at maturity, per day production of grain with fodder and fodder yield and negatively correlated with transpiration and stomatal frequency under drought stress.

Devkumar *et al.* (2014) evaluated 20 sorghum genotypes during *rabi* 2012-13. Photosynthetic rate and stomatal resistance at 15 and 30 days after flowering were positively and significantly correlated with grain yield while the transpiration rate at 15 and 30 days after flowering exhibited negative correlation with grain yield. SPAD chlorophyll meter reading (15 and 30 days after flowering) and chlorophyll content at 30 days after flowering had positively significant correlation with grain yield.

Dhutmal *et al.* (2014) evaluated 48 genotypes involving 25 land races, 20 advanced breeding lines and 3 varieties, for post flowering drought tolerance of post rainy sorghum (*Sorghum bicolor* (L.) Moench) and observed significant and positive association of grain yield per plant with panicle dry weight, days to 50 per cent flowering and total biomass. Grain yield per plant was strongly correlated with plant height, SCMR, leaf dry weight, 1000 grain weight, RLWC and number of leaves per plant.

Jain and Patel (2014) revealed that the seed yield per plant showed positive and significant correlation with plant height, number of leaves per plant, 100 seed weight and dry fodder yield per plant. While the dry fodder yield per plant showed positive and significant correlation with days to maturity, plant height, number of leaves per plant, leaf length, leaf width, 100-seed weight and seed yield per plant.

Chittapur and Biradar (2015) revealed that grain yield had positive and highly significant association with plant height, panicle weight, number of primaries, panicle weight and test weight, whereas negative and highly significant correlation with seed fat content and protein content.

Dhutmal *et al.* (2015b) evaluated 13 advanced breeding lines and three check varieties of sorghum for correlation studies during *rabi* season of 2012 under soil moisture deficit condition. SPAD chlorophyll meter reading (0.319) showed significant ($P < 0.05$) and positive association with grain yield. Whereas, panicle dry weight (0.369) and relative water content (0.391) exhibited highly significant ($P < 0.01$) association with grain yield at phenotypic level. At genotypic level, total number of leaves (0.296), and SPAD chlorophyll meter reading (0.308) exhibited positive significant ($P < 0.05$) association with grain yield while panicle weight (0.368), relative water content (0.472) showed strong positive ($P < 0.01$) association with grain yield.

Khandelwal *et al.* (2015) evaluated 224 sorghum genotypes for various morphological and yield components. Grain yield per plant was significantly and positively correlated with harvest index, 1000 seed weight, panicle length, fresh weight per plant and leaf area.

2.3 Path analysis

Sriram and Rao (1983) examined 9 genotypes and found harvest index, panicle dry weight and grains per panicle add the maximum direct effect on grain yield. Panicle weight was strongly associated with yield, especially at flowering stage.

Wankhede *et al.* (1985) studied correlation and path analysis and reported negative direct effect of plant height on grain yield. Days to 50 per cent flowering though possessing low correlation with grain yield acted in a minor way directly influencing the grain yield and also through positive indirect effect *via.*, panicle girth and panicle weight.

Bohra *et al.* (1986) analysed data for fourty genotypes for twelve yield related traits. Path coefficient revealed that plant height, 100 grain weight had high and positive direct effect on grain yield per plant. It was concluded

that harvest index, flag leaf area and 100 seed grain weight should be emphasized while selecting for improved grain yield per plant.

Potadukhe *et al.* (1992) studied 44 diverse sorghum genotypes and found that plant height, days to 50 per cent flowering, leaf area index, stem girth, panicle weight and grain weight had a positive direct or indirect effect on yield. Panicle weight had a greatest direct effect on yield and influenced most of the other traits indirectly.

Patel *et al.* (1993) revealed that the path coefficient analysis showed that panicle weight had maximum positive direct effect on grain yield followed by days to 50 per cent flowering, days to maturity and test weight.

Lamani *et al.* (1997) evaluated four sorghum genotypes (M-35-1, 9-13, GRS-1 and A-1) for 11 characters during late *rabi* season of 1995-96. Path analysis revealed higher positive direct effect of harvest index (0.782) and total dry matter at harvest (0.388) and negative direct effect of photosynthetic rate (0.112) and transpiration rate (0.001).

Veerabhadhiran and Kennedy (2001) carried out correlation and path analysis studies in 75 sorghum genotypes and revealed that estimation of direct and indirect effect of yield per plant showed that 100 grain weight contributed high direct effect towards grain yield and this was followed by days to 50 percent flowering.

Hemlata Sharma *et al.* (2006) revealed that path analysis for grain yield indicated highest direct effect of days to 50 per cent flowering followed by 100 seed weight.

Ali *et al.* (2011a) showed that path coefficient analysis of physiological traits with grain yield as dependent variable demonstrated that leaf dry matter and relative dry weight had positive direct effects on grain yield. On the other hand flag leaf area, specific flag leaf area and residual transpiration exhibited negative direct influence on grain yield.

Aml *et al.* (2012) revealed that path analysis showed that panicle length had a low but positive direct effect on grain yield, whereas days to flowering, plant height, panicle length, panicle width and panicle internodes had positive indirect effect while leaf area and kernel weight had negative indirect effect.

Dhutmal *et al.* (2014) Showed that total biomass had highest direct effect (28.33) on grain yield, followed by stem dry weight, panicle dryweight, leaf dry weight and days to 50 per cent flowering. Indirect effect on grain yield/plant were also estimated it was found that panicle dryweight showed maximum indirect effect via., total biomass while indirect effect of total biomass was also positive via., stem weight and panicle dry weight.

Jain and Patel (2014) revealed that the characters, 100- seed weight, plant height, number of leaves per plant and leaf width had exerted positive and high direct effects on seed yield per plant and dry fodder yield per plant.

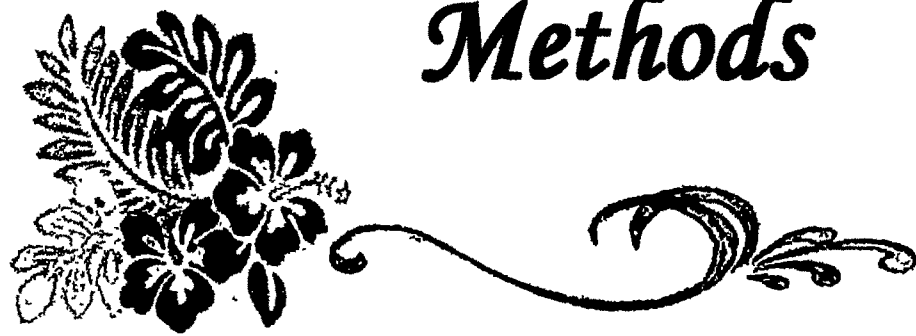
Dhutmal *et al.* (2015b) evaluated 13 advanced breeding lines and three check varieties of sorghum for path analysis studies during *rabi* season of 2012 under soil moisture deficit condition. Total biomass (37.10) had a highest direct effect on grain yield, followed by panicle dry weight (21.10), stem dry weight (21.17) and leaf dry weight (7.40). SCMR had positive direct effect on grain yield (0.589), while its indirect effect was via., stem dry weight, relative water content and total biomass.

Khandelwal *et al.* (2015) evaluated 224 sorghum genotypes for various morphological and yield components. Path coefficient analysis revealed positive correlation as well as high or moderate direct effects of harvest index, dry weight per plant and 1000 seed weight on grain yield per plant. Positive correlation and low direct effects of panicle length and leaf area on grain yield was observed. Fresh weight per plant showed positive correlation with grain yield but it produced low negative direct effect,

indicating that the reason for this correlation was due to low positive indirect effect through harvest index and indirect effect for fresh weight per plant via., leaf area and number of leaves per plant was also high.



Materials and Methods



CHAPTER-III

MATERIALS AND METHODS

The investigation entitled “Genetic variability and correlation studies in *rabi* sorghum (*Sorghum bicolor* (L.) Moench) for drought tolerance” was undertaken at Sorghum Research Station V.N.M.K.V. Parbhani during *rabi* 2015. The experimental details regarding materials and methods are described below.

3.1 Experimental materials

Forty germplasm lines of *rabi* sorghum along with 3 checks (M-35-1, CSV-22R and Phule suchitra) were sown at Sorghum Research Station V.N.M.K.V. Parbhani. The experiment was conducted during *rabi* 2015. The details of germplasm lines included in experiment have been shown in Table 3.1.

3.2 Experimental details.

1. Experimental design : Randomized Block Design
2. Genotypes : 37+3=40
3. Number of replications : Three
4. Spacing : 45 cm × 15 cm
 - a) Row to Row : 45 cm
 - b) Plant to plant : 15 cm
5. Plot size : Single row of 3 m length
6. Fertilizer dose : 80 : 40 : 40 NPK kg/ha

3.3 Cultural practices.

Sowing was done by dibbling on 5th October, 2015. The crop was given an uniform basal dose of 40N : 40P : 40K kg/ha. Seed treatment with 70 % thiamethoxam @ 2.5g per kg of seed was given to protect the crop from shoot fly infestation. The agronomic and plant protection measures were

followed as and when required during the period of crop growth. Top dressing with 40 kg N/ha with urea was given at 30 days after sowing.

Table 3.1: List of germplasm lines of *rabi* sorghum used for the study

Sr. No.	Name of genotypes
1	RSV 1345
2	RSV 1516
3	RSV 1542
4	RSV 1611
5	RSV 1749
6	RSV 1767
7	RSV 1772
8	RSV 1785
9	RSV 1786
10	RSV 1850
11	SLV 166
12	SLV 168
13	SLV 169
14	SLV 171
15	SLV 181
16	SLV 182
17	SLV 184
18	SLV 188
19	SLV 190
20	SLV 193
21	BRJ 3121
22	BRJ 40813
23	BRJ 29914
24	BRJ 4951
25	SSRK 13-1
26	SSRK 13-2
27	SSRK 13-4
28	SSRK 13-5
29	SSRK 13-6
30	SSRK 13-7
31	SSRK 13-8
32	SSRK 13-10
33	SSRK 13-11
34	SSRK 13-14
35	SSRK 13-15
36	SSRK 13-17
37	SSRK 13-20
38	M-35-1(C)
39	CSV-22R (C)
40	Phule suchitra (C)

3.4 Observations

Observations were recorded on five randomly selected plants in each line from each replication. Observations were recorded for the following twenty seven characters.

3.4.1 Days to flower initiation

Number of days required from sowing to flower initiation were recorded.

3.4.2 Days to 50 per cent flowering

Number of days from sowing to 50 per cent flowering of panicle were recorded

3.4.3 Days to physiological maturity

Days required from the date of sowing to the day of maturity of grains were recorded

3.4.4 Plant height (cm)

The height was measured in centimetres from the base of the plant to the top of the panicle at the time of maturity, from five randomly selected plants in each entries/ replication.

3.4.5 Number of leaves per plant

Numbers of leaves on five selected plants per replication were counted and average was reported as number of leaves per plant.

3.4.6 Third leaf area (cm²)

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

Breadth : Breadth of third leaf from the top was measured at broadest region in cm after emergence of panicle.

Area : Area of leaf was calculated by following formula given by Kemp (1960).

$$\text{Leaf area (cm}^2\text{)} = L \times B \times K$$

L- Maximum average length of leaf (cm)

B- Maximum average breadth of leaf (cm)

K- Leaf area constant (0.75)

3.4.7 Flag leaf area (cm²)

Length : Length of flag leaf was measured from base to tip in cm after panicle emergence.

Breadth : Breadth of third leaf area from the top was measured at broadest region in cm after emergence panicle.

Area : Area of leaf was calculated by following formula given by Kemp (1960).

$$\text{Leaf area (cm}^2\text{)} = L \times B \times K$$

L- Maximum average length of leaf (cm)

B- Maximum average breadth of leaf (cm)

K- Leaf area constant (0.75)

3.4.8 Leaf area index

The leaf area index was calculated by formula

$$\text{LAI} = \frac{\text{Leaf area in sq. cm}}{\text{Ground area covered by the plant in sq. cm}}$$

Leaf area was estimated by taking maximum length and breadth of all leaves multiplied by factor 0.75 (length $\times$ breadth $\times$ 0.75) as suggested by Sticker and Pauli (1961).

3.4.9 Leaf dry weight (g)

At days to 50 per cent flowering all the leaves from five randomly selected plants were collected and were kept in oven at $80 \pm 2^\circ\text{C}$ for 72 hours. The oven dried samples were weighed.

3.4.10 Stem dry weight (g)

At days to 50 per cent flowering stem of five randomly selected plants were collected and were kept in oven at $80 \pm 2^\circ\text{C}$ for 72 hours. The oven dried stem samples weights were recorded.

3.4.11 Panicle dry weight (g)

At days to 50 per cent flowering panicle of five randomly selected plants were collected and were kept in oven at $80 \pm 2^\circ\text{C}$ for 72 hours. The oven dried samples were weighed.

3.4.12 Total dry weight (g)

At days to 50 per cent flowering five randomly selected plants were collected and its parts were detached and were kept separately in oven at $80 \pm 2^{\circ}\text{C}$ for 72 hours. Total dry weight of the plant was recorded by adding weights of detached parts.

3.4.13 Chlorophyll content

Chlorophyll content was measured by the chlorophyll SPAD meter which gives automatic reading when leaf pressed in machine.

3.4.14 Relative water content (%)

Relative water content (RWC) of leaves was estimated at flowering stage as per method suggested by Smart (1974) using formula

$$\text{RWC} = \frac{\text{Fresh weight} - \text{dry weight}}{\text{Turgid weight} - \text{dry weight}} \times 100$$

3.4.15 Transpiration index

Transpiration index was measured by cobalt chloride method. Here square stripes of filter paper were soaked in 3 per cent cobalt chloride solution then paper stripes were placed in hot air oven at $40-50^{\circ}\text{C}$ and time taken for cobalt chloride paper standardization was recorded (change of colour from white to blue). In field paper stripes were placed on both surface of leaf with the help of glass slide and clips then time required to change the blue colour of cobalt chloride paper stripe into pink was recorded. Finally transpiration index was calculated by formula.

$$\text{TI} = \frac{\text{Time taken for cobalt chloride paper standardization (seconds)}}{\text{Time taken for cobalt chloride paper colour change on leaf (seconds)}}$$

3.4.16 Stay-green score at maturity (1 to 9)

Here all the genotypes were scored with the help of stay-green score as per description given by Mahalakshmi and Bidinger (2002) at maturity on the basis of greenness of leaves, where 1 indicates full green top six leaves and 9 indicates fully senescent top six leaves at maturity.

3.4.17 Root: Shoot ratio

The root and shoot length of five randomly selected seedlings were recorded and root:shoot ratio was computed by following formula and expressed in percentage.

$$\text{Root: Shoot ratio} = \frac{\text{Root length (cm)}}{\text{Shoot length (cm)}} \times 100$$

3.4.18 Stomatal Count

The leaf samples were collected from five randomly selected genotypes then blue or red correction fluid is applied on lower surface of leaves and with slight pressure film from the leaf was removed and numbers of stomata were counted using microscope at 40X magnification.

3.4.19 Panicle length (cm)

Panicle length was measured in centimetre from the base of the panicle to the tip of the panicle.

3.4.20 Panicle width (cm)

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

3.4.21 Panicle weight (g)

Weight of dried panicles was recorded after harvest.

3.4.22 Number of primary branches per panicle

Total numbers of primaries on rachis of the panicle were measured from lowest node of rachis to tip of head.

3.4.23 Fodder yield per plant (g)

After harvest fodder yield per plant was recorded in gram.

3.4.24 Biological yield per plant (g)

The biological yield was calculated with following formula

$$\text{Biological yield} = \text{Grain yield} + \text{Fodder yield}$$

3.4.25 100 Seed weight (g)

Weight of randomly sampled 100 seeds from each of the entry was recorded.

3.4.26 Harvest index (%)

$$\text{Harvest index (\%)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

3.4.27 Grain yield per plant (g)

Observational plant panicles were threshed and grain yield per plant was recorded in gram.

3.5 Statistical analysis

The mean values of all the traits under consideration were used for statistical analysis. The data were subjected to following statistical analysis.

1. Analysis of variance
2. Estimation of mean and range
3. Estimation of genetic variability parameters
4. Heritability and genetic advance
5. Correlation
6. Path analysis

3.5.1 Analysis variance

Analysis of variance was performed to test the significance of difference between the lines for all the characters as per the method described by Panse and Sukhatme (1985). The analysis of variance is set out under ANOVA Table.

$$Y_{ij} = m + G_j + E_{ij}$$

Where,

- | | | |
|----------|---|---|
| Y_{ij} | = | observed value of j^{th} genotype in i^{th} replication. |
| m | = | general mean |
| G_j | = | effect of j^{th} genotypes |
| E_{ij} | = | uncontrolled variation associated with j^{th} genotype in i^{th} replication. |

Sr. No.	Source of variation	D.F.	Mean sum of squares		Variance ratio 'F' observed	Table 'F'
			Observed	Expected		
1.	Replication	(r-1)	RMS	$\sigma^2_e + \sigma^2_r$		
2.	Treatment	(t-1)	TRMS	$\sigma^2_e + r\sigma^2_g$		
3.	Error	(r-1) (t-1)	EMS	σ^2_e		
	Total	(rt-1)				

Where,

r = number of replications

t = number of treatments

σ^2_e = error variance

σ^2_g = genotype variance

σ^2_r = replication variance

The mean squares were tested against error variance by usual 'F' test. The standard error of difference for comparing any two genotypic means was estimated by formula.

$$\text{Standard Error (SE)}_{\pm} = \sqrt{\text{EMSS}/r}$$

Where,

EMSS = error mean sum of squares

r = number of replications

$$\text{Critical difference (CD)} = \text{SE} \times \sqrt{2} \times t$$

Where,

t = Table value of 't' as error d.f. at 5 or 1 per cent level of significance

3.5.2 Estimation of mean and range

The mean values of all the treatments for the characters under study were worked out by dividing the total by corresponding number of observations.

$$\text{Mean } (\bar{X}) = \frac{1}{n} \sum_{i=1}^n X_i$$

Where,

$\bar{X}$ = Mean of character

X_i = i^{th} observation of population

n = Number of observation per replication

Range = The lowest and highest values of mean of each character represented by range.

3.5.3 Estimation of genetic variability parameters

Various parameters of genetic variability were calculated by using appropriate formulae.

1. Phenotypic and genotypic variances

The genotypic and phenotypic variance were calculated by using the respective mean squares from variance table (Burton 1952).

Genotypic variance (σ^2_g)

$$\sigma^2_g = \frac{\text{TRMSS} - \text{EMSS}}{r}$$

Error variance = $\sigma^2_e - \text{EMSS}$

Phenotypic variance (σ^2_p)

$$\sigma^2_p = \sigma^2_g + \sigma^2_e$$

Where,

TRMSS = Treatment mean sum of squares

EMSS = Error mean sum of squares

r = Number of replication

2. Phenotypic and genotypic coefficient of variation

The genotypic and phenotypic coefficients of variance (GCV and PCV) were calculated according to method suggested by Burton (1952).

Genotypic coefficient of variation (GCV)

$$\text{GCV (\%)} = \frac{\sqrt{\sigma^2_g}}{\bar{x}} \times 100$$

Phenotypic coefficient of variation (PCV)

$$\text{PCV (\%)} = \frac{\sqrt{\sigma^2_p}}{\bar{x}} \times 100$$

Where,

σ^2_g = Genotypic variance

σ^2_p = Phenotypic variance

$\bar{x}$ = General or grand mean of character

GCV and PCV were classified into 0-10 %: Low, 10-20 %: Moderate, 20 % and above: High as suggested by Sivasubramanian and Menon (1973).

3.5.4 Heritability and genetic advance

1. Heritability (Broad sense) was calculated according to the method suggested by Allard (1960).

$$\text{Heritability (h}^2\text{) (b.s) (\%)} = \frac{\sigma^2_g}{\sigma^2_p} \times 100$$

σ^2_g = Genotypic variance

σ^2_p = Phenotypic variance

Heritability was classified as suggested by Robinson *et al* (1949) and described as 0-30 %: Low, 30 -60 %: Moderate, 60 % and above; High.

2. The genetic advance (at 5 per cent selection intensity) was calculated for each character using the formula suggested by Johnson *et al.* (1955).

$$\text{Genetic advance} = h^2 \times k \times \sqrt{\sigma^2_p}$$

Where,

h^2 (b.s) = heritability (Broad sence)

K = Selection difference at 5 per cent selection intensity, the value of K = 2.06

σ_p = Phenotypic standard deviation

3. The expected genetic advance (EGA) in percentage of mean was calculated as

$$\text{EGA} = \frac{\text{GA}}{\bar{x}} \times 100$$

Where,

GA = Genetic advance

$\bar{x}$ = General or grand mean of character

The genetic advance as per cent of mean was categorized into 0-10 %: Low, 10-20 %: Moderate, 20 % and above: High as suggested by Johnson *et al.* (1955).

3.5.5 Correlation

In order to study the extent of association between different traits the genotypic and phenotypic simple correlation coefficient were worked out from the respective variance and covariances. The formula as suggested by Johnson *et al.* (1955) were used for calculating simple correlation coefficient as given below.

1. Genotypic correlation coefficient ($r_{g_{xy}}$)

$$(r_{g_{xy}}) = \frac{\text{Cov}(g_x \times g_y)}{\sqrt{\sigma^2 g_x \times \sigma^2 g_y}}$$

Where,

$\text{Cov}(g_x \times g_y)$ = Genotypic covariance between character x and y

$\sigma^2 g_x$ and $\sigma^2 g_y$ = Genotypic variance of character x and y, respectively.

Similarly,

2. Phenotypic correlation coefficient ($r_{p_{xy}}$)

$$(r_{p_{xy}}) = \frac{\text{Cov}(p_x \cdot p_y)}{\sqrt{\sigma^2 p_x \cdot \sigma^2 p_y}}$$

Where,

$\text{Cov}(p_x \cdot p_y)$ = Phenotypic covariance between character x and y

$\sigma^2 p_x$ and $\sigma^2 p_y$ = Phenotypic variance of character x and y, respectively.

Significance of correlation coefficient was determined from the Fisher and Yates table at 5 and 1 per cent level of significance. The 'r' values were compared against (n-2) degrees of freedom.

3.5.6 Path analysis

The genotypic correlation coefficient between yield and its components were further partitioned into direct and indirect effects with the help of path coefficient analysis originally suggested by Sewall Wright (1921) and further outlined by Dewey and Lu (1959).

The first step in path analysis is to prepare the path diagram based on cause and effect relationship in the present study, path diagram was prepared by taking yield as effect i.e. the function of various components like X_1 , X_2 , X_3 and these components show following type of association with each other.

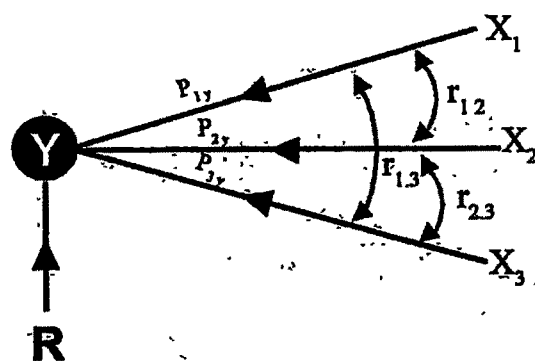


Fig. 3.1 : A path diagram

In path diagram the grain yield is the result of X_1, X_2, X_3 and same other undefined factors designated by R. the double arrowed lines indicates mutual association as measured by correlation coefficient (r_{ij}) and the single arrowed line present direct influence as measured by path coefficient (P_{ij}).

Direct and indirect contribution of eight variable to grain yield were calculated by solving a set of simultaneous equations of the form as per Dewey and Lu (1959).

$$mny = pny + m_2p_2y + m_3p_3y + \dots$$

Where,

mny = represents correlation coefficient between one component and grain yield

m_2 = represents correlation coefficient between that character and each of other components

pny = represents path coefficient between that characters and grain yield.

Matrix - A

Martrix-B

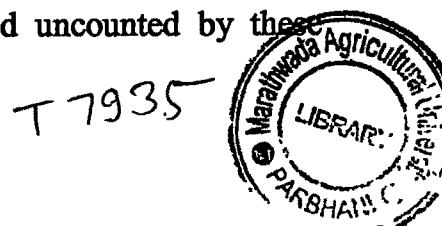
$$\begin{bmatrix} r_{1,y} \\ r_{2,y} \\ \vdots \\ m.y \end{bmatrix} \begin{bmatrix} p_1 \\ p_2 \\ \vdots \\ p_n \end{bmatrix} \begin{bmatrix} r_{1,1} & r_{1,2} & \dots & r_{1,n} \\ r_{2,1} & r_{2,2} & \dots & r_{2,n} \\ \vdots & \vdots & \ddots & \vdots \\ m,1 & m,2 & \dots & 1 \end{bmatrix}$$

The B matrix was inverted (B^{-1}) and path coefficient (p_{ij}) were obtained as

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

The coefficient $p_1, p_2, \dots, p_n$ are estimate of direct effect of character while the indirect effects of i^{th} character on grain yield character through j^{th} character is $r_{ij}p_{ij}$.

The residual factor i.e. variation in yield uncounted by these associations was calculated from the following formula.



$$\text{Residual factor (Rx)} = \sqrt{1-R^2}$$

Where,

$$R^2 = (P1y, r1y + p2y, r2y + \dots + Pny, rny)$$

Where,

$$P1y, P2y, \dots, Pny, = \text{Path values}$$

$$r1y, r2y, \dots, rny, = \text{Correlation coefficient}$$



Results

CHAPTER - IV

RESULTS

The present investigation on “Genetic variability and correlation studies in *rabi* sorghum (*Sorghum bicolor* (L.) Moench) for drought tolerance” was conducted using forty genotypes during *rabi* 2015. The results of present investigation are reported under the following headings.

4.1 Analysis of variance

4.2 Mean performance

4.3 Genetic parameters

4.4 Correlation

4.5 Path analysis

4.1 Analysis of variance

The results of analysis of variance for forty genotypes in *rabi* sorghum are furnished in Table 4.1. Highly significant differences among the genotypes were observed for all the twenty seven characters indicating presence of sufficient amount of variability in all the characters studied.

4.2 Mean performance

Forty genotypes of *rabi* sorghum were analyzed to find out the performance of genotypes for twenty seven characters. The values of mean for different traits are presented in Table 4.2

4.2.1 Days to flower initiation

Days to flower initiation ranged from 60.33 to 77.66 days with a general mean of 70.67 days. Among the genotypes BRJ 40813 (60.33 days), RSV 1345 (63.00 days), RSV 1542 (64.00 days), SSRK 13-1 (64.00 days) and RSV 1850 (66.33 days) were found earlier for days to flower initiation than other genotypes and checks M-35-1 (71.00 days), Phule suchitra (72.00 days) and CSV-22R (73.00 days). While, genotype SLV 168 (77.66 days) was found late for days to flower initiation.

Table 4.1 Analysis of Variance for twenty seven characters of *rabi* sorghum.

Sr. No	Sources of variation	d.f	Days to flower initiation	Days to 50 % flowering	Days to physiological maturity	Plant height (cm)	No. of leaves per plant	Third leaf area (cm ²)	Flag leaf area (cm ²)	Leaf area index	Leaf dry weight (g)	Stem dry weight (g)	Panicle dry weight (g)	Total dry weight (g)	Chlorophyll content	Relative water content
1	Replication	2	4.300	2.008	2.308	22.843	0.817	2.277	0.512	0.118	1.326	21.058	1.504	13.628	6.177	3.190
2	Treatment	39	44.008**	41.934**	27.148**	2369.134**	3.8333*	6259.333**	1530.126**	2.629**	18.471**	1283.551*	14.912**	1604.633**	54.353**	221.171**
3	Error	78	1.428	0.991	0.872	10.411	0.408	16.829	2.557	0.053	1.426	8.981	0.897	17.279	4.185	3.988

** Significant at 1 per cent level.

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Sr. No	Sources of variation	d.f	Transpiration index	Stay green score	Root:Shoot ratio (%)	Stomatal count	Panicle length (cm)	Panicle width (cm)	Panicle weight (cm)	No. of primary branches	Fodder yield (g/plant)	Biological yield (g/plant)	100-seed weight (g)	Harvest index	Grain yield (g/plant)
1	Replication	2	0.003	0.660	1.636	2.605	4.667	0.351	30.685	7.318	17.885	46.537	0.016	1.375	7.072
2	Treatment	39	0.049**	0.577**	115.373**	15.328**	10.977**	0.914**	422.860**	178.890**	289.069**	497.727**	0.605**	55.068**	67.258**
3	Error	78	0.004	0.296	9.186	1.494	1.606	0.125	11.394	11.112	7.954	16.893	0.008	3.107	3.464

** Significant at 1 per cent level.

Table 4.2 The Mean performances of twenty seven characters studied in *rabl* sorghum.

Sr. No	Genotypes	Days to flower initiation	Days to 50 % flowering	Days to physiological maturity	Plant height (cm)	No. of leaves per plant	Third leaf area (cm ²)	Flag leaf area (cm ²)	Leaf area index	Leaf dry weight (g)
1	RSV 1345	63.00	65.66	108.33	186.00	9.55	266.06	223.31	3.76	11.40
2	RSV 1516	72.33	75.66	117.33	156.33	10.33	279.07	214.66	4.27	11.76
3	RSV 1542	64.00	67.33	109.33	183.89	9.11	266.68	251.28	3.60	18.86
4	RSV 1611	72.00	75.66	116.33	188.77	10.44	260.87	223.05	4.03	10.26
5	RSV 1749	69.33	72.66	111.00	181.33	8.22	257.11	233.73	3.13	12.37
6	RSV 1767	68.00	71.33	111.33	174.66	9.78	295.11	231.12	4.27	10.45
7	RSV 1772	69.00	72.66	114.00	167.77	10.22	317.46	237.26	4.80	15.37
8	RSV 1785	70.00	73.66	116.33	173.77	8.88	227.91	214.24	3.00	20.08
9	RSV 1786	68.33	72.66	116.66	179.33	9.66	323.69	245.12	4.63	15.04
10	RSV 1850	66.33	69.33	109.66	156.44	9.66	267.28	220.88	3.82	14.36
11	SLV 166	72.00	74.66	116.33	164.66	10.11	253.45	214.36	3.79	11.15
12	SLV 168	77.66	81.00	120.00	147.88	9.66	322.23	224.51	4.61	11.78
13	SLV 169	76.00	78.66	117.00	161.89	10.33	308.15	209.97	4.72	14.16
14	SLV 171	74.33	76.66	116.33	162.00	9.33	260.11	202.78	3.59	14.15
15	SLV 181	74.33	78.33	118.66	179.89	9.66	327.57	255.38	4.69	13.78
16	SLV 182	74.00	75.66	115.66	181.44	11.66	324.02	240.02	5.59	10.04
17	SLV 184	69.33	72.33	113.33	175.88	9.89	334.10	233.00	4.89	13.10
18	SLV 188	70.33	73.66	115.00	190.33	9.89	264.30	223.06	3.91	12.66
19	SLV 190	70.66	73.66	117.66	169.00	9.77	389.19	214.39	5.63	11.83
20	SLV 193	68.66	72.00	115.33	161.44	9.11	303.27	246.18	4.09	10.74
21	BRJ 3121	71.66	74.00	115.66	129.33	7.55	265.60	213.59	2.97	11.15
22	BRJ 40813	60.33	63.66	109.66	106.66	7.33	242.11	221.33	2.63	14.18
23	BRJ 29914	72.00	74.33	115.33	172.11	9.55	326.57	244.97	4.62	11.96
24	BRJ 4951	68.33	71.33	112.33	156.11	8.33	214.44	200.83	2.64	11.26
25	SSRK 13-1	64.00	66.33	109.33	118.33	8.44	257.90	214.65	3.22	9.12
26	SSRK 13-2	68.00	71.00	110.33	142.33	7.44	257.23	224.69	2.83	15.15
27	SSRK 13-4	68.66	72.33	113.00	151.77	9.66	275.29	234.76	3.94	8.77
28	SSRK 13-5	73.00	75.66	116.33	162.11	9.44	265.33	215.84	3.71	11.06
29	SSRK 13-6	70.00	74.00	116.33	133.89	10.00	313.52	253.19	4.64	12.10
30	SSRK 13-7	68.33	71.66	111.66	102.00	8.00	222.08	203.23	2.63	13.07
31	SSRK 13-8	71.33	74.66	114.33	139.66	8.99	181.88	169.72	2.42	9.10
32	SSRK 13-10	76.00	78.33	118.33	99.00	6.44	164.38	153.91	1.57	10.15
33	SSRK 13-11	74.66	77.00	117.00	125.33	10.00	249.19	214.85	3.69	9.10
34	SSRK 13-14	74.33	77.66	117.66	155.88	9.11	271.77	247.03	3.66	12.00
35	SSRK 13-15	77.33	80.33	118.66	92.66	7.33	202.40	200.84	2.19	9.66
36	SSRK 13-17	74.00	76.66	117.00	103.44	7.55	191.21	181.07	2.13	8.50
37	SSRK 13-20	69.33	72.00	113.66	170.89	9.65	268.54	197.71	3.89	13.06
38	M-35-1(C)	71.00	74.00	115.33	196.00	10.22	233.55	213.32	3.53	13.00
39	CSV-22R (C)	73.00	75.33	115.66	180.00	10.88	272.85	246.82	4.40	12.33
40	Phule suchitra (C)	72.00	74.66	116.00	183.77	10.89	280.90	254.65	4.53	13.20
	Mean	70.67	73.70	114.73	156.60	9.30	270.11	221.63	3.76	12.28
	SE $\pm$	0.69	0.57	0.53	1.86	0.36	2.36	0.92	0.13	0.68
	CD at 5%	1.94	1.61	1.51	5.24	1.03	6.66	2.59	0.37	1.94

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Sr. No	Genotypes	Stem dry weight (g)	Panicle dry weight (g)	Total dry weight (g)	Chlorophyll content	Relative water content	Transpiration index	Stay-green score	Root:Shoot ratio (%)	Stomatal count
1	RSV 1345	113.33	14.66	139.40	55.02	74.26	1.19	6.33	59.95	16.86
2	RSV 1516	110.33	12.50	134.60	43.55	77.09	1.04	5.66	72.42	18.80
3	RSV 1542	96.33	11.13	126.33	43.59	63.80	1.38	5.16	61.61	16.89
4	RSV 1611	88.33	10.26	108.86	47.08	74.35	1.23	5.33	69.36	18.89
5	RSV 1749	76.00	7.33	95.70	42.50	65.30	1.17	5.73	70.14	17.37
6	RSV 1767	77.66	10.36	98.48	47.21	58.76	1.20	5.33	56.40	17.79
7	RSV 1772	67.66	7.43	90.47	54.88	83.86	1.04	6.33	64.44	18.47
8	RSV 1785	115.00	11.00	146.08	44.04	61.03	1.15	5.26	60.23	18.08
9	RSV 1786	88.66	12.33	116.04	51.80	83.08	1.20	5.06	67.20	19.42
10	RSV 1850	92.00	11.33	117.70	47.94	88.22	1.19	5.40	58.80	19.90
11	SLV 166	53.00	7.86	72.01	44.42	78.31	1.27	5.40	62.19	22.52
12	SLV 168	104.66	14.06	130.52	57.62	86.36	0.99	5.66	56.65	17.55
13	SLV 169	108.66	7.66	130.50	49.96	81.24	1.14	5.33	70.30	21.35
14	SLV 171	102.66	10.33	127.15	53.88	74.35	1.10	5.66	63.23	20.42
15	SLV 181	104.66	15.06	133.51	54.89	72.37	0.96	5.33	61.30	16.05
16	SLV 182	115.33	8.43	133.80	44.61	83.82	1.12	5.66	58.28	20.58
17	SLV 184	94.00	10.10	117.20	39.96	84.05	1.13	6.00	49.67	17.51
18	SLV 188	98.66	10.50	121.83	49.16	82.75	1.10	6.00	47.65	19.23
19	SLV 190	102.66	8.40	122.90	43.88	68.28	1.00	5.33	58.62	18.69
20	SLV 193	68.33	11.30	90.37	46.90	87.50	0.89	5.46	53.01	18.00
21	BRJ 3121	70.66	10.83	92.65	43.78	70.99	1.11	5.66	55.94	18.63
22	BRJ 40813	57.66	8.03	79.88	50.62	76.20	0.96	5.40	63.12	17.12
23	BRJ 29914	107.66	6.50	126.12	50.58	81.64	1.03	5.66	65.34	20.95
24	BRJ 4951	78.33	9.50	99.09	47.20	83.51	0.96	5.86	61.31	17.32
25	SSRK 13-1	71.00	8.66	88.78	50.09	79.56	1.06	5.55	59.80	16.82
26	SSRK 13-2	66.66	8.33	90.15	51.32	57.72	1.25	5.89	51.29	23.40
27	SSRK 13-4	74.33	8.00	91.11	51.86	81.04	1.17	5.73	48.89	21.40
28	SSRK 13-5	60.00	8.00	79.06	43.16	77.48	1.32	5.66	52.05	21.63
29	SSRK 13-6	96.66	8.00	116.77	40.55	71.81	1.16	6.33	56.39	19.59
30	SSRK 13-7	73.33	8.36	94.77	48.49	67.63	1.36	5.13	59.93	22.06
31	SSRK 13-8	69.33	7.50	85.93	49.09	65.98	1.02	5.33	59.21	20.73
32	SSRK 13-10	60.33	8.16	78.65	43.72	76.69	1.22	5.33	53.11	18.15
33	SSRK 13-11	64.66	8.16	81.94	44.42	67.26	1.10	5.33	66.79	20.46
34	SSRK 13-14	55.66	6.16	73.83	47.19	82.43	1.08	5.33	53.68	19.59
35	SSRK 13-15	43.33	6.66	59.66	45.02	85.37	1.55	5.66	57.63	25.59
36	SSRK 13-17	51.66	8.33	68.50	47.70	73.91	1.12	4.86	59.71	18.06
37	SSRK 13-20	62.00	7.16	82.23	46.40	66.88	1.27	4.86	65.25	23.15
38	M-35-1(C)	95.33	9.96	118.30	47.62	87.34	1.16	4.86	66.33	20.02
39	CSV-22R (C)	103.66	11.66	127.66	51.45	85.74	1.09	4.23	68.99	24.11
40	Phule suchitra (C)	103.00	11.66	127.86	52.92	86.72	1.14	4.80	60.32	22.50
	Mean	83.58	9.54	105.41	47.90	76.37	1.14	5.47	60.16	19.64
	SE ±	1.73	0.54	2.39	1.18	1.15	0.03	0.31	1.74	0.70
	CD at 5%	4.87	1.53	6.75	3.32	3.24	0.10	0.88	4.92	1.98

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Sr. No	Genotypes	Panicle length (cm)	Panicle width (cm)	Panicle weight (cm)	No. of primary branches	Fodder yield (g/plant)	Biological yield (g/plant)	100-seed weigh(g)	Harvest index	Grain yield (g/plant)
1	RSV 1345	16.91	5.12	58.88	56.30	64.53	90.62	3.29	28.75	26.09
2	RSV 1516	15.65	4.90	65.54	55.66	47.82	69.95	3.07	31.66	22.13
3	RSV 1542	15.88	4.69	50.11	58.85	53.75	76.46	3.13	29.69	22.71
4	RSV 1611	14.35	4.68	62.95	57.55	56.57	77.47	3.16	26.96	20.89
5	RSV 1749	17.73	4.65	52.85	65.55	48.36	73.68	2.77	34.36	25.31
6	RSV 1767	17.54	4.61	64.85	61.55	56.84	82.46	3.08	31.06	25.61
7	RSV 1772	12.75	4.86	56.20	42.22	53.67	77.22	2.94	30.52	23.54
8	RSV 1785	18.65	4.67	82.88	61.63	65.45	94.36	2.74	30.63	28.91
9	RSV 1786	17.79	4.46	73.95	54.33	48.66	81.07	3.44	40.03	32.41
10	RSV 1850	14.73	4.83	73.95	63.67	38.34	62.86	3.24	38.96	24.51
11	SLV 166	15.16	4.74	59.98	56.44	61.79	84.02	2.58	26.45	22.22
12	SLV 168	14.68	5.03	100.15	64.04	64.72	101.17	3.02	36.04	36.44
13	SLV 169	12.45	4.68	87.63	46.66	63.38	84.02	3.37	24.57	20.64
14	SLV 171	10.78	5.04	71.08	56.33	51.21	70.52	2.56	27.38	19.31
15	SLV 181	15.56	4.89	80.18	53.00	58.08	79.56	3.50	26.99	21.48
16	SLV 182	14.25	5.37	82.30	49.62	65.15	92.97	3.07	29.92	27.82
17	SLV 184	15.25	4.40	93.29	56.82	54.11	76.61	3.30	29.36	22.49
18	SLV 188	15.35	4.76	69.06	59.89	50.13	68.08	3.14	26.35	17.95
19	SLV 190	12.41	5.11	62.66	48.42	57.02	78.19	3.45	27.09	21.16
20	SLV 193	14.60	4.82	79.02	55.11	45.28	67.75	2.92	33.14	22.46
21	BRJ 3121	15.23	4.80	70.90	60.22	43.65	61.59	1.90	29.12	17.93
22	BRJ 40813	16.82	4.18	57.80	48.49	36.70	55.38	2.28	33.72	18.68
23	BRJ 29914	16.49	4.40	71.03	61.42	57.41	80.16	2.77	28.36	22.75
24	BRJ 4951	12.36	4.47	58.45	50.44	35.33	54.66	2.54	35.38	19.32
25	SSRK 13-1	14.64	3.63	65.08	48.29	40.33	56.80	2.58	28.99	16.47
26	SSRK 13-2	16.77	4.33	56.36	50.66	41.04	66.17	2.92	37.87	25.12
27	SSRK 13-4	15.60	5.39	73.56	56.66	47.25	76.35	3.06	38.04	29.09
28	SSRK 13-5	11.30	4.95	62.14	60.00	53.67	76.24	2.78	29.56	22.57
29	SSRK 13-6	11.66	4.86	63.37	40.44	56.96	77.74	2.79	26.68	20.78
30	SSRK 13-7	16.49	4.23	64.25	35.33	28.81	46.89	2.63	38.49	18.07
31	SSRK 13-8	17.37	4.16	67.61	40.00	65.11	85.80	2.37	24.11	20.69
32	SSRK 13-10	14.65	2.67	58.18	46.77	31.57	46.41	2.27	31.92	14.84
33	SSRK 13-11	15.43	3.73	54.95	48.11	54.76	78.38	2.58	30.09	23.61
34	SSRK 13-14	17.26	3.86	56.20	50.22	48.40	64.33	2.29	24.71	15.92
35	SSRK 13-15	16.91	3.61	52.45	41.11	37.22	52.21	2.00	28.66	14.98
36	SSRK 13-17	16.89	3.62	51.19	39.78	50.05	66.05	1.74	24.20	16.00
37	SSRK 13-20	13.21	4.00	70.25	46.00	47.31	71.16	3.31	33.54	23.85
38	M-35-1(C)	15.75	4.51	75.76	56.85	60.32	83.81	3.38	28.02	23.48
39	CSV-22R (C)	15.57	5.10	83.84	60.66	61.65	91.25	3.12	32.43	29.60
40	Phule suchitra (C)	14.27	4.74	75.16	59.66	54.74	82.14	3.43	33.38	27.40
	Mean	15.18	4.54	67.90	53.12	51.43	74.06	2.86	30.68	22.63
	SE $\pm$	0.73	0.20	1.94	1.92	1.62	2.37	0.05	1.01	1.07
	CD at 5%	2.06	0.57	5.48	5.41	4.58	6.68	0.14	2.86	3.02

4.2.2 Days to 50 per cent flowering

Number of days to 50 per cent flowering ranged from 63.66 to 81.00 days with a mean of 73.70 days. The genotype BRJ 40813 (63.66 days) was found early for days to 50 per cent flowering followed by RSV 1345 (65.66 days), SSRK 13-1 (66.33 days) RSV 1542 (67.33 days) and RSV 1850 (69.33 days). While, genotype SLV 168 (81.00 days) found late for days to 50 per cent flowering.

4.2.3 Days to physiological maturity

The mean values for days to physiological maturity were varied from 108.33 to 120.00 days with mean of 114.73 days. The genotypes RSV 1345 (108.33 days), RSV 1542 (109.33 days), SSRK 13-1 (109.33 days), RSV 1850 (109.66 days), BRJ 40813 (109.66 days) and SSRK 13-2 (110.33) were found earliest for days to physiological maturity as compared to other genotypes and checks M-35-1 (115.33 days), CSV-22R (115.66 days) and Phule suchitra (116.00 days). While, genotype SLV 168 (120.00 days) exhibited late maturity.

4.2.4 Plant height (cm)

Wide variation for plant height ranged from 92.66 to 196.00 cm with a general mean of 156.60 cm. The check M-35-1(196.00 cm) recorded highest plant height followed by SLV 188 (190.33 cm), RSV 1611 (188.77), RSV 1345 (186.00 cm) and RSV 1542 (183.89 cm) than other genotypes and checks CSV-22R (180.00 cm) and Phule suchitra (183.77 cm). While, genotype SSRK 13-15 (92.66 cm) was found shortest among the genotypes studied.

4.2.5 Number of leaves per plant

The mean value for number of leaves ranged from 6.44 to 11.66 with a general mean of 9.30. Among the genotypes SLV 182 (11.66) was found to have more number of leaves than other genotypes and checks M-35-1 (10.22), CSV-22R (10.88) and Phule suchitra (10.89). While, genotype SSRK 13-10 (6.44) recorded lowest number of leaves.

4.2.6 Third leaf area (cm²)

Third leaf area ranged from 164.38 to 389.19 with a mean value of 270.11. The genotype SLV 190 (389.19) recorded highest third leaf area followed by SLV 184 (334.10), SLV 181 (327.57) and BRJ 29914 (326.57). While, genotype SSRK 13-10 (164.38) exhibited least third leaf area.

4.2.7 Flag leaf area (cm²)

Flag leaf area ranged from 153.91 to 255.38 with a general mean value of 221.63. The genotype SLV 181 (255.38) recorded significantly higher flag leaf area compared to other genotypes and checks M-35-1 (213.32), CSV-22R (246.82) and Phule suchitra (254.65). The genotypes SSRK 13-6 (253.19), RSV 1542 (251.28) and SSRK 13-14 (247.03) were also recorded higher flag leaf area. The genotype SSRK 13-10 (153.91) recorded least flag leaf area.

4.2.8 Leaf area index

The mean value for leaf area index ranged from 1.57 to 5.63 with a general mean of 3.76. The genotypes SLV 190 (5.63), SLV 182 (5.59), SLV 184 (4.89) and RSV 1772 (4.80) recorded highest leaf area index over other genotypes and checks. The genotype SSRK 13-10 (1.57) exhibited lowest leaf area index.

4.2.9 Leaf dry weight (g)

Significant differences were observed for leaf dry weight among the genotypes. Range of variation for leaf dry weight was from 8.50 to 20.08. The genotype RSV 1785 (20.08) recorded significant highest leaf dry weight followed by RSV 1542 (18.86), RSV 1772 (15.37) and SSRK 13-2 (15.15). Whereas, lowest leaf dry weight was recorded by genotype SSRK 13-17 (8.50).

4.2.10 Stem dry weight (g)

Range of variation for stem dry weight was from 43.33 to 115.33 with a general mean value of 83.58. The genotype SLV 182 (115.33) recorded significant highest stem dry weight followed by RSV 1785 (115.00), RSV 1345

(113.33), RSV 1516 (110.33) and SLV 169 (108.66). The lowest stem dry weight was recorded by the genotype SSRK 13-15 (43.33).

4.2.11 Panicle dry weight (g)

The mean value for panicle dry weight ranged from 6.16 to 15.06 with a general mean of 9.54. The genotype SLV 181 (15.06) recorded significant highest panicle dry weight followed by RSV 1345 (14.66), SLV 168 (14.06), RSV 1516 (12.50) and RSV 1786 (12.33). While, lowest panicle dry weight was recorded by genotype SSRK 13-14 (6.16).

4.2.12 Total dry weight (g)

The mean value for total dry weight ranged from 59.66 to 146.08 with a general mean of 105.41. The genotypes RSV 1785 (146.08), RSV 1345 (139.40), RSV 1516 (134.60), SLV 182 (133.80) and SLV 181 (133.51) recorded highest total dry weight over other genotypes and checks. While, SSRK 13-15 (59.66) exhibited lowest total dry weight.

4.2.13 Chlorophyll content

The chlorophyll content among the genotypes ranged from 39.96 to 57.62 with over all mean of 47.90. The genotype SLV 168 (57.62) exhibited highest chlorophyll content compared to other genotypes and checks followed by genotypes RSV 1345 (55.02), SLV 181 (54.89), RSV 1772 (54.88) and SLV 171 (53.88). Whereas, SLV 184 (39.96) exhibited lowest chlorophyll content.

4.2.14 Relative water content (%)

Range of variation for relative water content was from 57.72 to 88.22 with a general mean value of 76.37. The genotype RSV 1850 (88.22) recorded significantly higher relative water content compared to other genotypes and checks M-35-1 (87.34), CSV-22R (85.74) and Phule suchitra (86.72) and it was followed by SLV 168 (86.36), SSRK 13-15 (85.37) and SLV 184 (84.05). The genotype SSRK 13-2(57.72) recorded lowest relative water content.

4.2.15 Transpiration index

The transpiration index ranged from 0.89 to 1.55 with a general mean of 1.14. The genotype SLV 193 (0.89) recorded significantly lower transpiration index followed by BRJ 4951 (0.96), SLV 181 (0.96), BRJ 40813 (0.96), SLV 168 (0.99) and SLV 190 (1.00). While, genotype SSRK 13-15 (1.55) exhibited higher transpiration index followed by RSV 1542 (1.38), SSRK 13-7 (1.36) and SSRK 13-5 (1.32).

4.2.16 Stay green score at maturity at maturity (1-9)

The mean value for stay green score at maturity at maturity ranged from 4.23 to 6.33 with a general mean of 5.47. All the genotypes recorded higher stay green score at maturity compared to checks CSV-22R (4.23), Phule suchitra (4.80) and M-35-1 (4.86) except genotypes SSRK 13-20 (4.86) and SSRK 13-17 (4.86) which were recorded similar stay green score at maturity as check M-35-1 (4.86). While, genotype RSV 1772 (6.33) recorded higher stay green score at maturity.

4.2.17 Root:Shoot ratio (%)

The root:shoot ratio among the genotypes ranged from 47.65 to 72.42 with a general mean of 60.16. The genotypes RSV 1516 (72.42), SLV 169 (70.30), RSV 1749 (70.14) and RSV 1611 (69.36) recorded maximum root:shoot ratio than other genotypes and checks. The genotypes SLV 188 (47.65), SSRK 13-4 (48.89) and SLV 184 (49.67) recorded lower root:shoot ratio.

4.2.18 Stomatal count

The number of stomata among the genotypes ranged from 16.05 to 25.59 with a general mean of 19.64. The genotype SLV 181 (16.05) recorded lower number of stomata followed by SSRK 13-1 (16.89), RSV 1345 (16.86), RSV 1542 (16.86) and BRJ 40813 (17.12). While, more number of stomata was recorded in the genotype SSRK 13-15 (25.59).

4.2.19 Panicle length (cm)

The panicle length in genotypes ranged from 10.78 to 18.65 with general mean of 15.18. The genotype RSV 1785 (18.65) exhibited maximum panicle length which was closely followed by RSV 1786 (17.79), RSV 1749 (17.73), RSV 1767 (17.54) and SSRK 13-8 (17.37). Whereas, genotype SLV 171 (10.78) exhibited minimum panicle length.

4.2.20 Panicle width (cm)

The panicle width ranged from 2.67 to 5.39 with a general mean of 4.54. The genotype SSRK 13-4 (5.39) recorded significantly highest panicle width followed by SLV 182 (5.37), RSV 1345 (5.12) and SLV 190 (5.11). The genotype SSRK 13-10 (2.67) recorded lowest panicle width.

4.2.21 Panicle weight (g)

Significant differences were observed for panicle weight among the genotypes. Range of variation for panicle weight was from 50.11 to 100.15 with general mean of 67.90. The genotype SLV 168 (100.15) recorded significant highest panicle weight followed by genotypes SLV 184 (93.29), SLV 169 (87.63) and check CSV-22R (83.84). While, genotype RSV 1542 (50.11) recorded lowest panicle weight.

4.2.22 Number of primary branches

Number of primary braches in a panicle ranged from 35.33 to 65.55 with general mean of 53.12. The maximum number of primary branches was recorded in genotype RSV 1749 (65.55) followed by SLV 168 (64.04), RSV 1850 (63.66), RSV 1785 (61.63) and RSV 1767 (61.55). While, minimum number of primary branches was recorded in SSRK 13-7 (35.33).

4.2.23 Fodder yield per plant (g)

Fodder yield per plant ranged from 28.81 to 65.45 with a mean of 51.43. The genotype RSV 1785 (65.45) recorded maximum fodder yield among the genotypes followed by SLV 182 (65.15), SSRK 13-8 (65.11), SLV

168 (64.72) and RSV 1345 (64.53). The minimum fodder yield per plant was recorded in the genotype SSRK 13-7 (28.81).

4.2.24 Biological yield per plant (g)

The mean value for biological yield ranged from 46.41 to 101.17 with general mean of 74.06. The genotypes SLV 168 (101.17), RSV 1785 (94.36) and SLV 182 (92.97) recorded maximum biological yield per plant than other genotypes and checks. While, genotype SSRK 13-10 (46.41) recorded minimum biological yield per plant.

4.2.25 100 seed weight (g)

The mean value for 100 seed weight ranged from 1.74 to 3.50 with general mean of 2.86. The genotypes SLV 181 (3.50), SLV 190 (3.45) and RSV 1786 (3.44) recorded maximum 100 seed weight than other genotypes and checks Phule suchitra (3.43), M- 35-1 (3.38) and CSV-22R (3.12). Whereas, genotype SSRK 13-17 (1.74) recorded minimum 100 seed weight.

4.2.26 Harvest index (%)

Harvest index ranged from 24.11 to 40.03 with a mean of 30.68. The genotype RSV 1786 (40.03) recorded maximum harvest index among the genotypes followed by RSV 1850 (38.96), SSRK 13-7 (38.49), SSRK 13-4 (38.04) and SSRK 13-2 (37.87). The minimum harvest index was recorded in the genotype SSRK 13-8 (24.11).

4.2.27 Grain yield per plant (g)

Significant differences were observed for grain yield per plant among genotypes. It ranged from 14.84 to 36.44 with general mean of 22.63. The genotypes SLV 168 (36.44) and RSV 1786 (32.41) recorded maximum grain yield per plant than other genotypes and checks CSV-22R (29.60), Phule suchitra (27.40) and M- 35-1 (23.48) followed by SSRK 13-4 (29.09), RSV 1785 (28.91) and SLV 182 (27.82). While, genotype SSRK 13-10 (14.84) recorded minimum grain yield per plant.

4.3 Genetic parameters

The data was analyzed for estimation of variability i.e. phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability, genetic advance and genetic advance as per cent of mean. The results are presented in Table 4.3 revealed that genetic variance and GCV were lower than phenotypic variance and PCV, respectively. The details of these variability parameters are presented below.

4.3.1 Days to flower initiation

The genotypic coefficient of variation (GCV) was 5.33 per cent and phenotypic coefficient of variation (PCV) was 5.59 per cent. High heritability (90.86 %), low genetic advance (7.39) and moderate genetic advance as per cent of mean (10.46) observed for the trait days to flower initiation.

4.3.2 Days to 50 per cent flowering

Days to 50 per cent flowering showed 5.01 per cent genotypic coefficient of variation (GCV) and 5.19 per cent phenotypic coefficient of variation (PCV). High heritability (93.23%), low genetic advance (7.34) and low genetic advance as per cent of mean (9.96) estimates were recorded.

4.3.3 Days to physiological maturity

The genotypic coefficient of variation (GCV) was 2.57 per cent and phenotypic coefficient of variation (PCV) was 2.70 per cent. Days to physiological maturity showed high heritability (90.94 %), low genetic advance (5.81) and low genetic advance as per cent of mean (5.06).

4.3.4 Plant height (cm)

The plant height showed 17.90 per cent genotypic coefficient of variation (GCV) and 18.02 per cent phenotypic coefficient of variation (PCV). Very high heritability (98.69 %), high genetic advance (57.38) and high genetic advance as per cent of mean (36.64) were observed.

4.3.5 Number of leaves per plant

The genotypic coefficient of variation (GCV) was 11.48 per cent and phenotypic coefficient of variation (PCV) was 13.37 per cent. Number of leaves per plant showed high heritability (73.64 %), very low genetic advance (1.88) and high genetic advance as per cent of mean (20.29).

4.3.6 Third leaf area (cm²)

The genotypic coefficient of variation (GCV) for third leaf area was 16.88 per cent. Whereas, the phenotypic coefficient of variation (PCV) was 16.95 per cent. The very high heritability (99.20 %), very high genetic advance (93.59) and high genetic advance as per cent of mean (34.64) were observed.

4.3.7 Flag leaf area (cm²)

The genotypic coefficient of variation (GCV) was 10.18 per cent. While, the phenotypic coefficient of variation (PCV) was 10.20 per cent. The highest heritability (99.50%), very high genetic advance (46.36) and high genetic advance as per cent of mean (20.92) were observed for the trait flag leaf area.

4.3.8 Leaf area index

The genotypic coefficient of variation (GCV) for leaf area index was 24.57 per cent. Whereas, phenotypic coefficient of variation (PCV) was 25.33 per cent. This trait showed high amount of heritability (94.10 %) coupled with very low genetic advance (1.85) and high genetic advance as per cent of mean (49.11).

4.3.9 Leaf dry weight (g)

Leaf dry weight showed 19.40 per cent genotypic coefficient of variation (GCV) and 21.70 per cent phenotypic coefficient of variation (PCV). High amount of heritability (79.93 %), low genetic advance (4.38) and high genetic advance as per cent of mean (35.73) were observed for leaf dry weight.

Table 4.3 Genetic Variability Parameters for twenty seven characters studied in *rabi* sorghum

Sr.No.	Characters	Range		MEAN	σ^2 (g) (Genotypic variance)	σ^2 (p) (Phenotypic variance)	GCV (%)	PCV (%)	h^2 b.s.(%)	GA	GA as % of mean
		minimum	maximum								
1	Days to flower initiation	60.33	77.66	70.67	14.19	15.62	5.33	5.59	90.86	7.39	10.46
2	Days to 50 % flowering	63.66	81.00	73.70	13.64	14.63	5.01	5.19	93.23	7.34	9.96
3	Days to physiological maturity	108.33	120.00	114.73	8.75	9.63	2.57	2.70	90.94	5.81	5.06
4	Plant height (cm)	92.66	196.00	156.60	786.24	796.65	17.90	18.02	98.69	57.38	36.64
5	No. of leaves per plant	6.44	11.66	9.30	1.14	1.55	11.48	13.37	73.64	1.88	20.29
6	Third leaf area (cm ²)	164.38	389.19	270.11	2080.83	2097.66	16.88	16.95	99.20	93.59	34.64
7	Flag leaf area (cm ²)	153.91	255.38	221.63	509.18	511.74	10.18	10.20	99.50	46.36	20.92
8	Leaf area index	1.57	5.63	3.76	0.85	0.91	24.57	25.33	94.10	1.85	49.11
9	Leaf dry weight (g)	8.50	20.08	12.28	5.68	7.10	19.40	21.70	79.93	4.38	35.73
10	Stem dry weight (g)	43.33	115.33	83.58	424.85	433.83	24.66	24.91	97.93	42.01	50.27
11	Panicle dry weight (g)	6.16	15.06	9.54	4.67	5.56	22.64	24.72	83.89	4.07	42.72
12	Total dry weight (g)	59.66	146.08	105.41	529.11	546.39	21.82	22.17	96.84	46.63	44.23
13	Chlorophyll content	39.96	57.62	47.90	16.72	20.90	8.53	9.54	79.98	7.53	15.72
14	Relative water content	57.72	88.62	76.37	72.39	76.38	11.14	11.44	94.78	17.06	22.34
15	Transpiration index	0.89	1.55	1.14	0.01	0.02	10.79	12.19	78.33	0.22	19.68
16	Stay-green score	4.23	6.33	5.47	0.08	0.38	5.38	11.31	22.68	0.28	5.28
17	Root:Shoot ratio (%)	47.65	72.42	60.16	35.39	44.58	9.88	11.09	79.39	10.92	18.15
18	Stomatal count	16.05	25.59	19.64	4.61	6.10	10.93	12.57	75.52	3.84	19.56
19	Panicle length (cm)	10.78	18.65	15.18	3.12	4.73	11.64	14.32	66.03	2.95	19.48
20	Panicle width (cm)	2.67	5.39	4.54	0.26	0.38	11.28	13.71	67.69	0.86	19.13
21	Panicle weight (cm)	50.11	100.15	67.90	137.15	148.54	17.24	17.94	92.33	23.18	34.13
22	No. of primary branches	35.33	65.55	53.12	55.92	67.03	14.07	15.41	83.42	14.07	26.48
23	Fodder yield (g/plant)	28.81	65.45	51.43	93.70	101.65	18.82	19.60	92.17	19.14	37.22
24	Biological yield (g/plant)	46.41	101.17	74.06	160.27	177.17	17.09	17.97	90.46	24.80	33.49
25	100-seed weight (g)	1.74	3.50	2.86	0.19	0.20	15.55	15.88	95.97	0.90	31.39
26	Harvest index	24.11	40.03	30.68	17.32	20.42	13.56	14.73	84.79	7.89	25.72
27	Grain yield (g/plant)	14.84	36.44	22.63	21.26	24.72	20.37	21.97	85.99	8.80	38.91

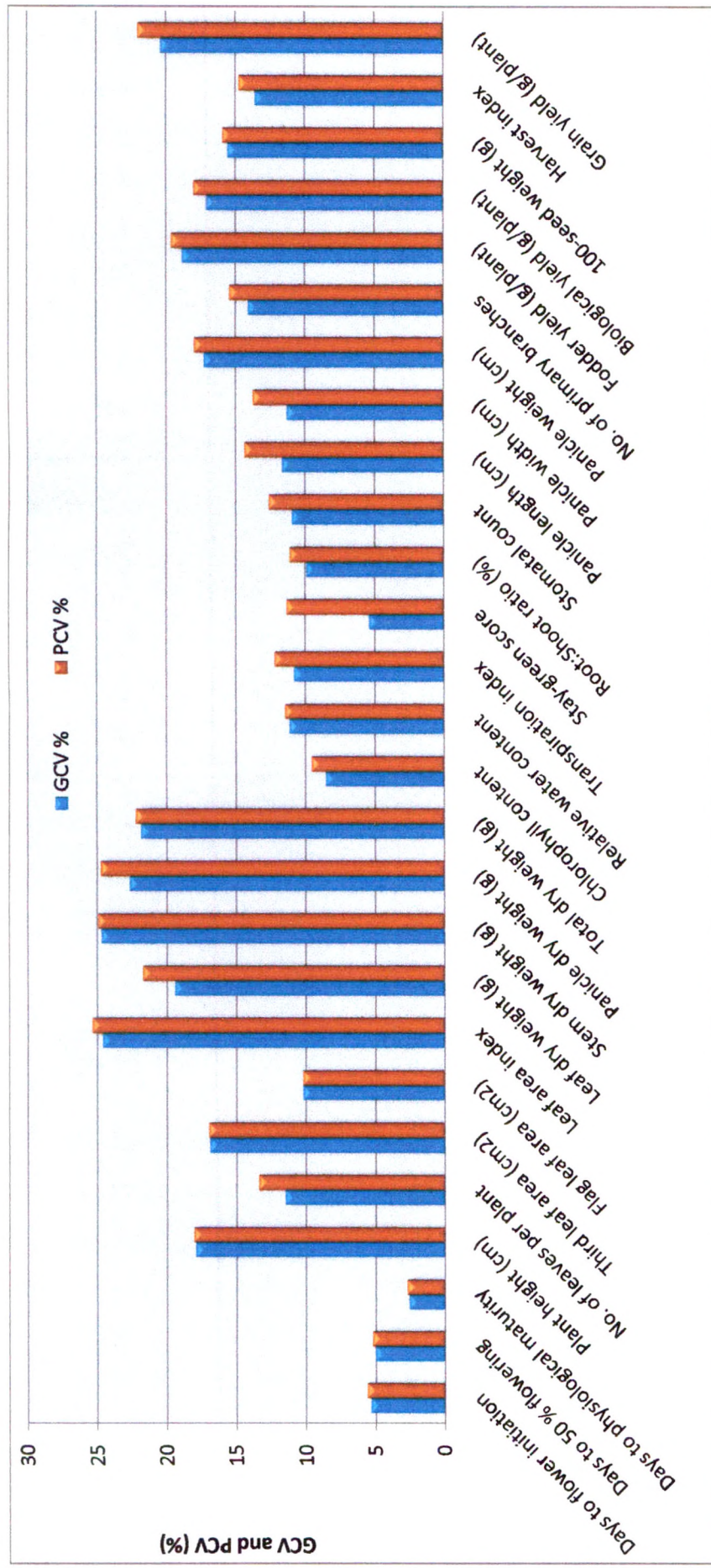


Fig 4.1. Genotypic and phenotypic coefficient of variation for yield and yield contributing characters in *rabi* sorghum

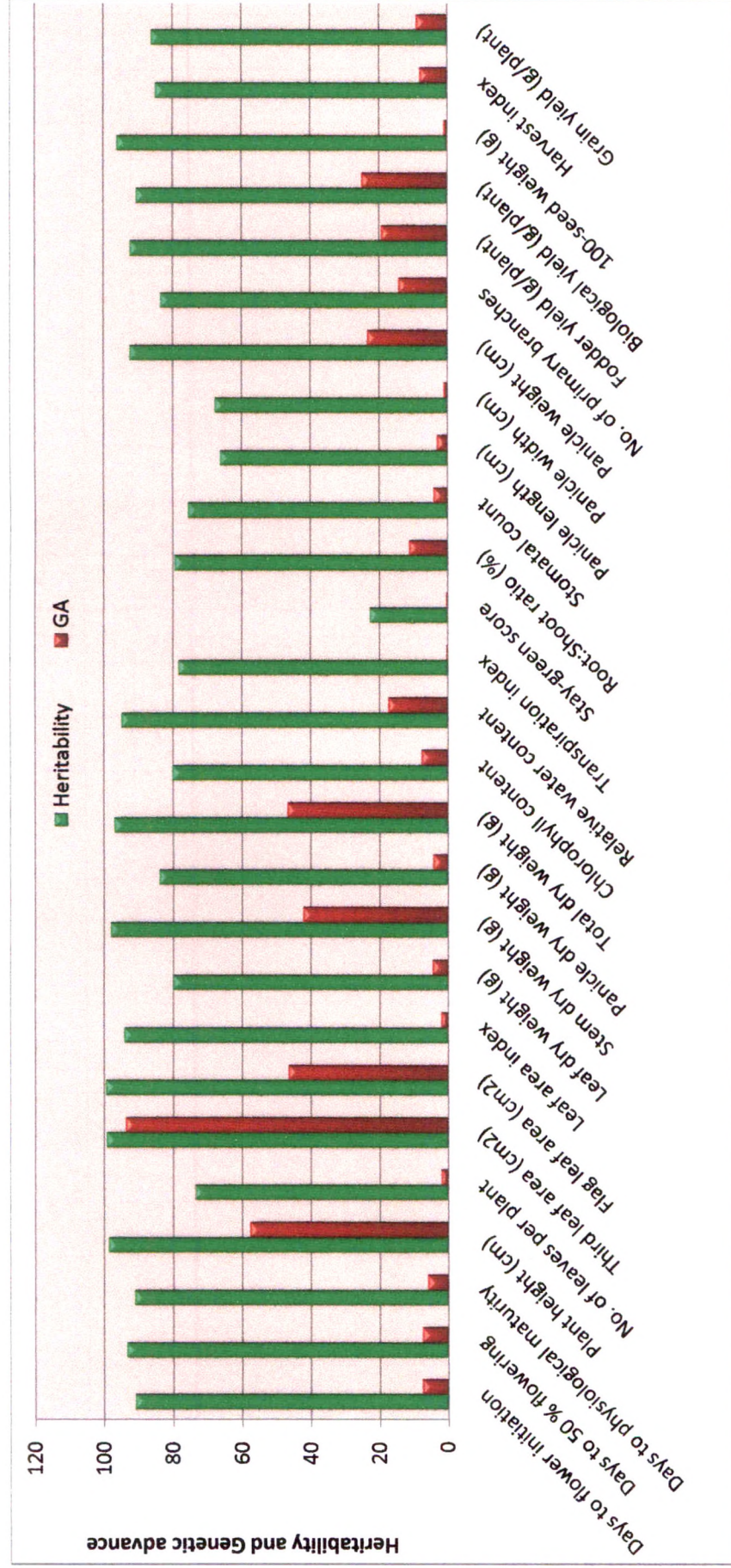


Fig 4.2. Graphical comparison of Heritability and Genetic Advance of twenty seven characters in *rabi* sorghum

4.3.10 Stem dry weight (g)

The genotypic coefficient of variation (GCV) for stem dry weight was 24.66 per cent. Whereas, phenotypic coefficient of variation (PCV) was 24.91 per cent. This trait showed high heritability (97.93 %) coupled with high genetic advance (42.01) and high genetic advance as per cent of mean (50.27).

4.3.11 Panicle dry weight (g)

The genotypic coefficient of variation (GCV) was 22.64 per cent and phenotypic coefficient of variation (PCV) was 24.72 per cent. High amount of heritability (83.89 %) coupled with low genetic advance (4.07) and high genetic advance as per cent of mean (42.72) were observed for the trait panicle dry weight.

4.3.12 Total dry weight (g)

Genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) was 21.82 and 22.17 per cent, respectively. This trait showed high heritability (96.84 %) along with high genetic advance (46.63) and high genetic advance as per cent of mean (44.23).

4.3.13 Chlorophyll content

Chlorophyll content showed 8.53 per cent genotypic coefficient of variation (GCV) and 9.54 per cent phenotypic coefficient of variation (PCV). High amount of heritability (79.98%) coupled with low genetic advance (7.53) and moderate genetic advance as per cent of mean (15.72) estimates were recorded.

4.3.14 Relative water content

The genotypic coefficient of variation (GCV) was 11.14 per cent and phenotypic coefficient of variation (PCV) was 11.44 per cent. This trait showed high amount of heritability (94.78%) coupled with moderate genetic advance (17.06) and high genetic advance as per cent of mean (22.34).

4.3.15 Transpiration index

Transpiration index showed 10.79 per cent genotypic coefficient of variation (GCV) and 12.19 per cent phenotypic coefficient of variation (PCV). High heritability (78.33 %), very low genetic advance (0.22) and moderate genetic advance as per cent of mean (19.68) were observed.

4.3.16 Stay green score at maturity (1-9)

The genotypic coefficient of variation (GCV) for stay green score at maturity was 5.38 per cent. Whereas, phenotypic coefficient of variation (PCV) was 11.31 per cent. This trait showed low heritability (22.68 %) coupled with very low genetic advance (0.28) and low genetic advance as per cent of mean (5.28).

4.3.17 Root:Shoot ratio (%)

The genotypic coefficient of variation (GCV) was 9.88 per cent and phenotypic coefficient of variation (PCV) was 11.09 per cent. High amount of heritability (79.39 %) coupled with moderate genetic advance (10.92) and moderate genetic advance as per cent of mean (18.15) were observed for root:shoot ratio. .

4.3.18 Stomatal count

The genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) was 10.93 and 12.57 per cent, respectively. High heritability (75.52 %), low genetic advance (3.84) and moderate genetic advance as per cent of mean (19.56) were observed.

4.3.19 Panicle length (cm)

The genotypic coefficient of variation (GCV) for panicle length was 11.64 per cent and phenotypic coefficient of variation (PCV) was 14.32 per cent. High heritability (66.03%) coupled with low genetic advance (2.95) and moderate genetic advance as per cent of mean (19.48) were observed for the trait panicle length.

4.3.20 Panicle width (g)

Genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) was 11.28 and 13.71 per cent, respectively. This trait showed high amount of heritability (67.69%) along with very low genetic advance (0.86) and moderate genetic advance as per cent of mean (19.48).

4.3.21 Panicle weight (g)

Panicle weight showed 17.24 per cent genotypic coefficient of variation (GCV) and 17.94 per cent phenotypic coefficient of variation (PCV). High heritability (92.33%) coupled with high genetic advance (23.18) and high genetic advance as per cent of mean (34.13) were observed for the trait panicle weight.

4.3.22 Number of primary branches

Genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) was 14.07 and 15.41 per cent, respectively. High heritability (83.42%), moderate genetic advance (14.07) and high genetic advance as per cent of mean (26.48) were observed for number of primary branches.

4.3.23 Fodder yield per plant (g)

In case of fodder yield per plant the genotypic coefficient of variation (GCV) was 18.82 per cent and phenotypic coefficient of variation (PCV) was 19.60 per cent. This trait showed high amount of heritability (92.17%) coupled with moderate genetic advance (19.14) and high genetic advance as per cent of mean (37.22).

4.3.24 Biological yield per plant (g)

The genotypic coefficient of variation (GCV) for biological yield per plant was 17.09 per cent and phenotypic coefficient of variation (PCV) was 17.97 per cent. High heritability (90.46%) along with high genetic advance (24.80) and high genetic advance as per cent of mean (33.49) were observed for the trait biological yield per plant.

4.3.25 100 Seed weight (g)

The genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were 15.55 and 15.88 per cent, respectively. High heritability (95.97%), low genetic advance (0.90) and high genetic advance as per cent of mean (31.39) were observed for 100 seed weight.

4.3.26 Harvest index (%)

The genotypic coefficient of variation (GCV) for harvest index was 13.56 per cent. Whereas, phenotypic coefficient of variation (PCV) was 14.73 per cent. This trait showed high heritability (84.79 %) coupled with low genetic advance (7.89) and high genetic advance as per cent of mean (25.72).

4.3.27 Grain yield per plant (g)

The trait grain yield per plant showed 20.37 per cent genotypic coefficient of variation (GCV) and 21.97 per cent phenotypic coefficient of variation (PCV). High heritability (85.99%), low genetic advance (8.80) and high genetic advance as per cent of mean (38.91) were observed for the trait grain yield per plant.

4.4 Correlation

The correlation coefficient was studied in order to find out inter relationship between yield and its components at genotypic and phenotypic levels. The genotypic and phenotypic correlation coefficients for twenty seven characters are presented in Table 4.4 and 4.5 respectively.

4.4.1 Yield and yield contributing characters

Grain yield per plant has recorded significant and positive association with plant height ($G=0.537$, $P=0.494$), number of leaves per plant ($G=0.560$, $P=0.454$), third leaf area ($G=0.444$, $P=0.412$), flag leaf area ($G=0.467$, $P=0.432$), leaf area index ($G=0.529$, $P=0.471$), leaf dry weight ($G=0.301$, $P=0.214$), stem dry weight ($G=0.494$, $P=0.446$), panicle dry weight ($G=0.460$, $P=0.445$), total dry weight ($G=0.511$, $P=0.477$), chlorophyll content

($G=0.365$, $P=0.288$), panicle width ($G=0.617$, $P=0.499$), panicle weight ($G=0.544$, $P=0.518$), number of primary branches ($G=0.550$, $P=0.462$), fodder yield ($G=0.512$, $P=0.497$), biological yield ($G=0.756$, $P=0.749$), 100-seed weight ($G=0.596$, $P=0.554$) and harvest index ($G=0.510$, $P=0.483$) at both genotypic and phenotypic level.

The characters days to flower initiation ($G=-0.039$, $P=-0.040$), days to 50 per cent flowering ($G=-0.009$, $P=-0.018$), days to physiological maturity ($G=-0.007$, $P=-0.004$) and transpiration index ($G=-0.078$, $P=-0.134$) showed negative and non significant correlation with grain yield per plant at both genotypic and phenotypic level. While, characters relative water content ($G=0.069$, $P=0.071$), stay green score at maturity ($G=0.167$, $P=0.055$), root:shoot ratio ($G=0.146$, $P=0.128$), stomatal count ($G=0.049$, $P=0.039$) and panicle length ($G=0.160$, $P=0.100$) showed non significant and positive correlation with grain yield per plant at both genotypic and phenotypic level.

4.4.1.1 Days to flower initiation

Days to flower initiation has recorded significant and positive association with days to 50 per cent flowering ($G=0.995$, $P=0.977$), days to physiological maturity ($G=0.894$, $P=0.862$), stomatal count ($G=0.376$, $P=0.332$), fodder yield per plant ($G=0.262$, $P=0.235$), panicle weight ($G=0.257$, $P=0.253$) and relative water content ($G=0.219$, $P=0.202$) at both genotypic and phenotypic level. Flag leaf area ($G=-0.214$, $P=-0.205$), leaf dry weight ($G=-0.311$, $P=-0.270$) and harvest index ($G=-0.362$, $P=-0.301$) were significant but negatively associated with days to flower initiation at both level.

Biological yield per plant ($G=0.185$) has recorded positive and significant association with days to flower initiation at genotypic level. Whereas, stay green score at maturity ($G=-0.271$) and panicle length ($G=-0.224$) showed significant but negative association with days to flower initiation.

Table 4.4 Genotypic Correlation Coefficient for twenty seven characters studied in *rabt* sorghum

Characters	Days to flower initiation	Days to 50 % flowering	Days to physiological maturity	Plant height (cm)	No. of leaves per plant	Third leaf area (cm ²)	Flag leaf area (cm ²)	Leaf area index	Leaf dry weight(g)	Stem dry weight(g)	Panicle dry weight(g)	Total dry weight(g)	Chlorophyll content	Relative water content
Days to flower initiation	1.000	0.995**	0.894**	-0.096	0.163	-0.021	-0.214*	0.088	-0.311**	0.016	-0.102	-0.026	-0.052	0.219*
Days to 50 % flowering		1.000	0.915**	-0.076	0.161	0.001	-0.171	0.101	-0.261**	0.018	-0.069	-0.016	-0.028	0.202*
Days to physiological maturity			1.000	-0.052	0.211*	0.131	-0.100	0.210*	-0.188*	0.062	0.019	0.040	-0.064	0.267**
Plant height (cm)				1.000	0.763**	0.518**	0.549**	0.654**	0.383**	0.621**	0.404**	0.634**	0.123	0.106
No. of leaves per plant					1.000	0.643**	0.554**	0.857**	0.061	0.637**	0.258**	0.595**	0.145	0.331**
Third leaf area (cm ²)						1.000	0.698**	0.943**	0.195*	0.515**	0.251**	0.506**	0.131	0.176
Flag leaf area (cm ²)							1.000	0.680**	0.332**	0.394**	0.310**	0.416**	0.169	0.198*
Leaf area index								1.000	0.137	0.620**	0.265**	0.593**	0.136	0.274**
Leaf dry weight (g)									1.000	0.400**	0.283**	0.491**	0.093	-0.207*
Stem dry weight (g)										1.000	0.596**	0.994**	0.209*	0.105
Panicle dry weight (g)											1.000	0.651**	0.423**	0.110
Total dry weight (g)												1.000	0.242**	0.081
Chlorophyll content													1.000	0.257**
Relative water content														1.000
Transpiration index														
Stay-green score														
Root:Shoot ratio (%)														
Stomatal count														
Panicle length (cm)														
Panicle width (cm)														
Panicle weight (cm)														
No. of primary branches														
Fodder yield (g/plant)														
Biological yield (g/plant)														
100-seed weight (g)														
Harvest index														
Grain yield (g/plant)														

* Significant at 5 per cent level, ** Significant at 1 per cent level.

Contd..

Characters	Transpiration index	Stay-green score	Root:Shoot ratio (%)	Stomatal count	Panicle length (cm)	Panicle width (cm)	Panicle weight (cm)	No. of primary branches	Fodder yield (g/plant)	Biological yield (g/plant)	100-seed weight(g)	Harvest index	Grain yield (g/plant)
Days to flower initiation	0.043	-0.271**	0.044	0.376**	-0.224*	-0.130	0.257**	-0.079	0.262**	0.185*	-0.165	-0.362**	-0.039
Days to 50 % flowering	0.036	-0.221*	0.039	0.345**	-0.191*	-0.102	0.264**	-0.086	0.262**	0.197*	-0.131	-0.330**	-0.009
Days to physiological maturity	-0.125	-0.295**	0.058	0.207*	-0.228*	-0.078	0.300**	-0.098	0.294**	0.221*	-0.091	-0.374**	-0.007
Plant height (cm)	-0.155	-0.051	0.208*	-0.128	-0.080	0.693**	0.361**	0.646**	0.623**	0.671**	0.771**	-0.068	0.537**
No. of leaves per plant	-0.182*	-0.110	0.287**	0.156	-0.354**	0.740**	0.498**	0.333**	0.747**	0.777**	0.736**	-0.156	0.560**
Third leaf area (cm ²)	-0.350**	0.293**	0.025	-0.163	-0.315**	0.654**	0.451**	0.282**	0.408**	0.474**	0.648**	0.020	0.444**
Flag leaf area (cm ²)	-0.162	0.144	0.022	-0.095	0.042	0.610**	0.241**	0.429**	0.297**	0.398**	0.509**	0.151	0.467**
Leaf area index	-0.311**	0.146	0.132	-0.035	-0.380**	0.731**	0.520**	0.299**	0.588**	0.642**	0.746**	-0.059	0.529**
Leaf dry weight (g)	-0.082	-0.115	0.185*	-0.133	0.091	0.260**	0.159	0.267**	0.114	0.190*	0.376**	0.211*	0.301**
Stem dry weight (g)	-0.291**	0.059	0.248**	-0.225*	-0.133	0.664**	0.594**	0.436**	0.560**	0.605**	0.664**	-0.038	0.494**
Panicle dry weight (g)	-0.226*	-0.096	0.067	-0.436**	0.091	0.490**	0.458**	0.524**	0.248**	0.356**	0.476**	0.209*	0.460**
Total dry weight (g)	-0.264**	0.040	0.246**	-0.253**	-0.102	0.673**	0.590**	0.470**	0.535**	0.592**	0.676**	0.011	0.511**
Chlorophyll content	-0.334**	-0.097	0.090	-0.031	0.040	0.219*	0.264**	0.034	0.138	0.242**	0.233*	0.200*	0.365**
Relative water content	-0.230*	0.005	-0.044	0.124	-0.285**	0.134	0.395**	0.125	-0.031	0.003	0.130	0.058	0.069
Transpiration index	1.000	-0.135	-0.056	0.555**	0.155	-0.260**	-0.348**	-0.121	-0.194*	-0.177	-0.077	0.088	-0.078
Stay-green score		1.000	-0.503**	-0.515**	-0.367**	0.281**	-0.214*	-0.083	-0.045	-0.090	-0.096	-0.190*	0.167
Root:Shoot ratio (%)			1.000	0.041	0.017	0.048	-0.064	0.002	0.219*	0.227*	0.177	-0.044	0.146
Stomatal count				1.000	-0.101	-0.069	0.002	-0.240**	-0.042	-0.014	-0.047	0.082	0.049
Panicle length (cm)					1.000	-0.333**	-0.125	0.119	-0.020	0.045	-0.196*	0.162	0.160
Panicle width (cm)						1.000	0.457**	0.502**	0.546**	0.649**	0.602**	0.079	0.617**
Panicle weight (cm)							1.000	0.378**	0.426**	0.522**	0.489**	0.131	0.544**
No. of primary branches								1.000	0.297**	0.432**	0.379**	0.199*	0.550**
Fodder yield (g/plant)									1.000	0.954**	0.417**	-0.494**	0.512**
Biological yield (g/plant)										1.000	0.537**	-0.193*	0.756**
100-seed weight (g)											1.000	0.225*	0.596**
Harvest index												1.000	0.510**
Grain yield (g/plant)													1.000

* Significant at 5 per cent level, ** Significant at 1 per cent level.

Table 4.5. Phenotypic Correlation Coefficient for twenty seven characters studied in *rabi* sorghum

Characters	Days to flower initiation	Days to 50 % flowering	Days to physiological maturity	Plant height (cm)	No. of leaves per plant	Third leaf area (cm ²)	Flag leaf area (cm ²)	Leaf area index	Leaf dry weight (g)	Stem dry weight (g)	Panicle dry weight (g)	Total dry weight (g)	Chlorophyll content	Relative water content
Days to flower initiation	1.000	0.977**	0.862**	-0.097	0.111	-0.019	-0.205*	0.069	-0.270**	0.018	-0.102	-0.026	-0.028	0.202*
Days to 50 % flowering		1.000	0.890**	-0.078	0.123	0.004	-0.163	0.088	-0.234*	0.024	-0.073	-0.013	-0.028	0.192*
Days to physiological maturity			1.000	-0.055	0.147	0.127	-0.091	0.177	-0.191*	0.063	0.007	0.032	-0.044	0.250**
Plant height (cm)				1.000	0.660**	0.513**	0.544**	0.635**	0.333**	0.615**	0.372**	0.623**	0.112	0.103
No. of leaves per plant					1.000	0.536**	0.479**	0.826**	0.046	0.537**	0.262**	0.522**	0.079	0.280**
Third leaf area (cm ²)						1.000	0.693**	0.909**	0.174	0.508**	0.224*	0.494**	0.113	0.163
Flag leaf area (cm ²)							1.000	0.660**	0.299**	0.389**	0.279**	0.410**	0.149	0.194*
Leaf area index								1.000	0.124	0.594**	0.258**	0.573**	0.103	0.256**
Leaf dry weight (g)									1.000	0.361**	0.202*	0.452**	0.078	-0.177
Stem dry weight (g)										1.000	0.549**	0.987**	0.185*	0.105
Panicle dry weight (g)											1.000	0.625**	0.301**	0.122
Total dry weight (g)												1.000	0.196*	0.088
Chlorophyll content													1.000	0.229*
Relative water content														1.000
Transpiration index														
Stay-green score														
Root:Shoot ratio (%)														
Stomatal count														
Panicle length (cm)														
Panicle width (cm)														
Panicle weight (cm)														
No. of primary branches														
Fodder yield (g/plant)														
Biological yield (g/plant)														
100-seed weight (g)														
Harvest index														
Grain yield (g/plant)														

* Significant at 5 per cent level, ** Significant at 1 per cent level.

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Characters	Transpiration index	Stay-green score	Root:Shoot ratio (%)	Stomatal count	Panicle length (cm)	Panicle width (cm)	Panicle weight (cm)	No. of primary branches	Fodder yield (g/plant)	Biological yield (g/plant)	100-seed weight(g)	Harvest index	Grain yield (g/plant)
Days to flower initiation	0.039	-0.097	0.046	0.332**	-0.172	-0.091	0.253**	-0.059	0.235**	0.164	-0.164	-0.301**	-0.040
Days to 50 % flowering	0.035	-0.107	0.048	0.291**	-0.138	-0.078	0.252**	-0.060	0.245**	0.177	-0.132	-0.296**	-0.018
Days to physiological maturity	-0.111	-0.120	0.053	0.203*	-0.180*	-0.020	0.269**	-0.073	0.269**	0.203*	-0.095	-0.312**	-0.004
Plant height (cm)	-0.140	-0.018	0.186*	-0.111	-0.063	0.568**	0.344**	0.581**	0.592**	0.634**	0.752**	-0.063	0.494**
No. of leaves per plant	-0.177	-0.055	0.253**	0.094	-0.216*	0.506**	0.431**	0.233*	0.612**	0.631**	0.655**	-0.137	0.454**
Third leaf area (cm ²)	-0.302**	0.146	0.018	-0.140	-0.256**	0.536**	0.435**	0.257**	0.393**	0.452**	0.626**	0.020	0.412**
Flag leaf area (cm ²)	-0.147	0.058	0.021	-0.083	0.035	0.508**	0.231*	0.392**	0.287**	0.378**	0.498**	0.134	0.432**
Leaf area index	-0.270**	0.066	0.121	-0.047	-0.281**	0.572**	0.495**	0.254**	0.545**	0.589**	0.717**	-0.060	0.471**
Leaf dry weight (g)	0.118	-0.012	0.140	-0.092	0.061	0.186*	0.144	0.204*	0.061	0.137	0.319**	0.201*	0.214*
Stem dry weight (g)	-0.253**	0.037	0.028*	-0.197*	-0.102	0.539**	0.564**	0.404**	0.527**	0.570**	0.643**	-0.029	0.446**
Panicle dry weight (g)	-0.244**	-0.038	0.057	-0.362**	0.101	0.347**	0.417**	0.421**	0.249**	0.354**	0.446**	0.183*	0.445**
Total dry weight (g)	-0.254**	0.020	0.227*	-0.228*	-0.072	0.528**	0.566**	0.421**	0.505**	0.569**	0.660**	0.007	0.477**
Chlorophyll content	-0.245**	0.012	0.105	0.045	0.019	0.207*	0.212*	0.104	0.101	0.177	0.208*	0.207*	0.288**
Relative water content	-0.203*	0.001	-0.019	0.095	-0.215*	0.112	0.372**	0.122	-0.027	0.003	0.136	0.059	0.071
Transpiration index	1.000	-0.055	-0.078	0.437**	0.102	-0.145	-0.315**	-0.072	-0.189*	-0.192*	-0.092	0.114	-0.134
Stay-green score		1.000	-0.271*	-0.118	-0.117	0.170	-0.102	0.005	-0.050	-0.063	-0.048	0.047	0.055
Root:Shoot ratio (%)			1.000	0.017	0.017	0.037	-0.042	0.022	0.198*	0.188*	0.161	-0.030	0.128
Stomatal count				1.000	-0.066	0.018	0.001	-0.122	-0.020	-0.001	-0.036	0.120	0.039
Panicle length (cm)					1.000	-0.175	-0.109	0.126	-0.186*	0.019	-0.149	0.131	0.100
Panicle width (cm)						1.000	0.366**	0.448**	0.450**	0.518**	0.478**	0.128	0.499**
Panicle weight (cm)							1.000	0.319**	0.409**	0.506**	0.463**	0.104	0.518**
No. of primary branches								1.000	0.272**	0.370**	0.353**	0.206*	0.462**
Fodder yield (g/plant)									1.000	0.936**	0.397**	-0.454**	0.497**
Biological yield (g/plant)										1.000	0.505**	-0.162	0.749**
100-seed weight (g)											1.000	0.200*	0.554**
Harvest index												1.000	0.483**
Grain yield (g/plant)													1.000

* Significant at 5 per cent level, ** Significant at 1 per cent level.



Fig 4.3. Genotypic and phenotypic correlation coefficient of different characters with grain yield per plant

4.4.1.2 Days to 50 per cent flowering

Association of days to 50 per cent flowering was highly significant and positive with days to physiological maturity ($G=0.915$, $P=0.890$), relative water content ($G=0.202$, $P=0.192$), stomatal count ($G=0.345$, $P=0.291$), panicle weight ($G=0.264$, $P=0.252$) and fodder yield ($G=0.262$, $P=0.245$) at both level. Leaf dry weight ($G=-0.261$, $P=-0.234$) and harvest index ($G=-0.330$, $P=-0.296$) showed significant but negative association with days to 50 per cent flowering at both level.

Biological yield per plant ($G=0.197$), recorded significant positive association at genotypic level. Whereas, stay green score at maturity ($P=-0.221$) and panicle length ($P=-0.191$) exhibited significant and negative association with days to 50 per cent flowering at phenotypic level.

4.4.1.3 Days to physiological maturity

The characters relative water content ($G=0.267$, $P=0.250$), stomatal count ($G=0.207$, $P=0.203$), panicle weight ($G=0.300$, $P=0.269$), fodder yield ($G=0.294$, $P=0.269$) and biological yield ($G=0.221$, $P=0.203$) were significant and positively correlated with days to physiological maturity at both level. Whereas, leaf dry weight ($G=-0.188$, $P=-0.191$), panicle length ($G=-0.228$, $P=-0.180$) and harvest index ($G=-0.374$, $P=-0.312$) has recorded negative significant association with days to physiological maturity at both genotypic and phenotypic level.

Number of leaves per plant ($G=0.211$) and leaf area index ($G=0.210$) exhibited significant and positive association with days to physiological maturity at genotypic level. While, stay green score at maturity ($G=-0.295$) has significant but negative correlation with days to physiological maturity at genotypic level.

4.4.1.4 Plant height

Association of plant height was highly significant and positive with number of leaves per plant ($G=0.763$, $P=0.660$), third leaf area ($G=0.518$, $P=0.513$), flag leaf area ($G=0.549$, $P=0.544$), leaf area index ($G=0.654$,

P=0.635), leaf dry weight (G=0.383, P=0.333), stem dry weight (G=0.621, P=0.615), panicle dry weight (G=0.404, P=0.372), total dry weight (G=0.634, P=0.623), root:shoot ratio (G=0.208, P=0.186), panicle width (G=0.693, P=0.568), panicle weight (G=0.361, P=0.344), number primary branches (G=0.646, P=0.581), fodder yield (G=0.623, P=0.592), biological yield (G=0.671, P=0.634), 100 seed weight (G=0.771, P=0.752) and grain yield (G=0.537, P=0.494) at both genotypic and phenotypic level.

Transpiration index (G=-0.155, P=-140) and stomatal count (G=-0.128, P=-0.111) has non-significant negative association with plant height at both genotypic and phenotypic level.

4.4.1.5 Number of leaves per plant

Number of leaves per plant has recorded significant and positive correlation with third leaf area (G=0.643, P=0.536), flag leaf area (G=0.554, P=0.479), leaf area index (G=0.857, P=0.826), stem dry weight (G=0.637, P=0.537), panicle dry weight (G=0.258, P=0.262), total dry weight (G=0.595, P=0.522), relative water content (G=0.331, P=0.280), root:shoot ratio (G=0.287, P=0.253), panicle width (G=0.740, P=0.506), panicle weight (G=0.498, P=0.431), number of primary branches (G=0.333, P=0.233), fodder yield (G=0.747, P=0.612), biological yield (G=0.777, P=0.631) and 100- seed weight (G=0.736, P=0.655) at both level.

The trait panicle length (G=-0.354, P=-0.216) was significant but negatively associated with number of leaves per plant at both genotypic and phenotypic level. While, transpiration index (G=-0.182) recorded negative but significant association with number of leaves per plant at genotypic level.

4.4.1.6 Third leaf area (cm²)

Third leaf area showed significant and positive association with flag leaf area (G=0.698, P=0.693), leaf area index (G=0.943, P=0.909), stem dry weight (G=0.515, P=0.508), panicle dry weight (G=0.251, P=0.224), total dry weight (G=0.506, P=0.494), panicle width (G=0.654, P=0.536), panicle weight (G=0.451, P=0.435), number of primary branches (G=0.282, P=0.257),

fodder yield ($G=0.408$, $P=0.393$), biological yield ($G=0.474$, $P=0.452$) and 100- seed weight ($G=0.648$, $P=0.626$) at both level.

Transpiration index ($G=-0.350$, $P=-0.302$) and panicle length ($G=-0.315$, $P=-0.256$) recoded significant negative association at both level. Whereas, leaf dry weight ($G=0.195$) and stay green score at maturity ($G=0.293$) recorded positive and significant association with third leaf area at genotypic level.

4.4.1.7 Flag leaf area (cm²)

The characters leaf area index ($G=0.680$, $P=0.660$), leaf dry weight ($G=0.332$, $P=0.299$), stem dry weight ($G=0.394$, $P=0.389$), panicle dry weight ($G=0.310$, $P=0.279$), total dry weight ($G=0.416$, $P=0.410$), relative water content ($G=0.198$, $P=0.194$), panicle width ($G=0.610$, $P=0.508$), panicle weight ($G=0.241$, $P=0.231$), number of primary branches ($G=0.429$, $P=0.392$), fodder yield ($G=0.297$, $P=0.287$), biological yield ($G=0.398$, $P=0.378$) and 100-seed weight ($G=0.509$, $P=0.498$) were positively and significantly associated with flag leaf area at both level.

Transpiration index ($G=-0.162$, $P=-0.147$) and stomatal count ($G=-0.095$, $P=-0.083$) showed non significant and negative association with flag leaf area.

4.4.1.8 Leaf area index

Association of leaf area index was significant and positive with stem dry weight ($G=0.620$, $P=0.594$), panicle dry weight ($G=0.265$, $P=0.258$), total dry weight ($G=0.593$, $P=0.573$), relative water content ($G=0.274$, $P=0.256$), panicle width ($G=0.731$, $P=0.572$), panicle weight ($G=0.520$, $P=0.495$), number of primary branches ($G=0.299$, $P=0.254$), fodder yield ($G=0.588$, $P=0.545$), biological yield ($G=0.642$, $P=0.589$) and 100-seed weight ($G=0.746$, $P=0.717$) at both genotypic and phenotypic level.

The characters transpiration index ($G=-0.311$, $P=-0.270$) and panicle length ($G=-0.380$, $P=-0.281$) recoded significant negative association with leaf area index at both level.

4.4.1.9 Leaf dry weight (g)

Leaf dry weight was positively and significantly correlated with stem dry weight ($G=0.400$, $P=0.361$), panicle dry weight ($G=0.283$, $P=0.202$), total dry weight ($G=0.491$, $P=0.452$), panicle width ($G=0.260$, $P=0.186$), number of primary branches ($G=0.267$, $P=0.204$), 100-seed weight ($G=0.376$, $P=0.319$) and harvest index ($G=0.211$, $P=0.201$) at both genotypic and phenotypic level.

The characters root:shoot ratio ($G=0.185$) and biological yield ($G=0.190$) recorded significant positive association. Whereas, relative water content ($G=-0.207$) showed significant negative association with leaf dry weight at genotypic level.

4.4.1.10 Stem dry weight (g)

Highly significant and positive correlation of stem dry weight was observed with panicle dry weight ($G=0.596$, $P=0.549$), total dry weight ($G=0.994$, $P=0.987$), chlorophyll content ($G=0.209$, $P=0.185$), root:shoot ratio ($G=0.248$, $P=0.228$), panicle width ($G=0.664$, $P=0.539$), panicle weight ($G=0.594$, $P=0.564$), number of primary branches ($G=0.436$, $P=0.404$), fodder yield ($G=0.560$, $P=0.527$), biological yield ($G=0.605$, $P=0.570$) and 100-seed weight ($G=0.664$, $P=0.643$) at both genotypic and phenotypic level.

Transpiration index ($G=-0.291$, $P=-0.253$) and stomatal count ($G=-0.225$, $P=-0.197$) were significantly but negatively correlated at both level. While, stay green score at maturity ($G=0.059$, $P=0.037$) and relative water content ($G=0.105$, $P=0.105$) showed non significant positive association with stem dry weight at both level.

4.4.1.11 Panicle dry weight (g)

The characters total dry weight ($G=0.651$, $P=0.625$), chlorophyll content ($G=0.423$, $P=0.301$), panicle width ($G=0.490$, $P=0.347$), panicle weight ($G=0.458$, $P=0.417$), number of primary branches ($G=0.524$, $P=0.421$), fodder yield ($G=0.248$, $P=0.249$), biological yield ($G=0.356$, $P=0.356$) 100-seed

weight ($G=0.476$, $P=0.446$) and harvest index ($G=0.209$, $P=0.183$) recorded significant and positive association with panicle dry weight.

Association of transpiration index ($G=-0.226$, $P=-0.244$) and stomatal count ($G=-0.436$, $P=-0.362$) were significantly but negatively correlated with panicle dry weight at both genotypic and phenotypic level.

4.4.1.12 Total dry weight (g)

Total dry weight has recorded significant and positive association with chlorophyll content ($G=0.242$, $P=0.196$), root:shoot ratio ($G=0.246$, $P=0.227$), panicle width ($G=0.673$, $P=0.528$), panicle weight ($G=0.590$, $P=0.566$), number of primary branches ($G=0.470$, $P=0.421$), fodder yield ($G=0.535$, $P=0.505$), biological yield ($G=0.592$, $P=0.569$) and 100-seed weight ($G=0.676$, $P=0.660$) at both level.

Transpiration index ($G=-0.264$, $P=-0.254$) and stomatal count ($G=-0.253$, $P=-0.228$) recorded significant but negative correlation with total dry weight at both genotypic and phenotypic level.

4.4.1.13 Chlorophyll content

Association of chlorophyll content with relative water content ($G=0.257$, $P=0.229$), panicle width ($G=0.219$, $P=0.207$), panicle weight ($G=0.264$, $P=0.212$), 100-seed weight ($G=0.233$, $P=0.208$) and harvest index ($G=0.200$, $P=0.207$) was positive and significant at both level.

Chlorophyll content showed significant but negative association with transpiration index ($G=-0.334$, $P=-0.245$) at both level. While, biological yield ($G=0.242$) recorded significant positive association with chlorophyll content at genotypic level.

4.4.1.14 Relative water content

Relative water content recorded positive and significant association with panicle weight ($G=0.395$, $P=0.372$) at both genotypic and phenotypic level.

The traits transpiration index ($G=-0.230$, $P=-0.203$) and panicle length ($G=-0.285$, $P=-0.215$) showed negative but significant association with relative water content at both genotypic and phenotypic level.

4.4.1.15 Transpiration index

The character transpiration index was significantly and negatively correlated with panicle weight ($G=-0.348$, $P=-0.315$) and fodder yield ($G=-0.194$, $P=-0.189$) at both level. Stomatal count ($G=0.555$, $P=0.437$) was significant and positively associated with transpiration index at both level.

Panicle width ($G=-0.260$) and biological yield ($P=-0.192$) showed significant but negative association with transpiration index at genotypic and phenotypic level respectively.

4.4.1.16 Stay green score at maturity (1-9)

Association of stay green score at maturity was significant and negative with root:shoot ratio ($G=-0.503$, $P=-0.271$) and stomatal count ($G=-0.515$, $P=-0.118$) at both level. Whereas, panicle length ($G=-0.367$), panicle weight ($G=-0.214$) and harvest ($G=-0.190$) were significant but negatively correlated only at genotypic level.

Panicle width ($G=0.281$) recorded positive and significant association with stay green score at maturity at genotypic level. While, panicle width ($P=0.170$) showed non significant positive association at phenotypic level.

4.4.1.17 Root:Shoot ratio

The characters fodder yield ($G=0.219$, $P=0.198$) and biological yield ($G=0.227$, $P=0.188$) showed positive and significant association with root:shoot ratio at genotypic and phenotypic level.

Association of root:shoot ratio was non significant and negative with panicle weight ($G=-0.064$, $P=-0.042$) and harvest index ($G=-0.044$, $P=-0.030$) at both level.

4.4.1.18 Stomatal count

Stomatal count was non significant and negatively correlated with panicle length ($G=-0.101$, $P=-0.066$), fodder yield ($G=-0.042$, $P=-0.020$), biological yield ($G=-0.014$, $P=-0.001$) and 100 seed weight ($G=-0.047$, $P=-0.036$) at both level. While, panicle width ($G=-0.069$) was non significant and negatively correlated only at genotypic level.

The trait number primary branches ($G=-0.240$, $P=-0.122$) was significantly and negatively correlated at genotypic level and non significantly negatively associated with stomatal count at phenotypic level respectively.

4.4.1.19 Panicle length (cm)

The characters panicle width ($G=-0.333$) and 100 seed weight ($G=-0.196$) were significantly and negatively correlated at genotypic level. While, fodder yield ($P=-0.186$) was significantly and negatively correlated with panicle length at phenotypic level.

Panicle length has recorded non significant but positive association with number of primaries ($G=0.119$, $P=0.126$), biological yield ($G=0.045$, $P=0.019$) and harvest index ($G=0.162$, $P=0.131$) at both genotypic and phenotypic level.

4.4.1.20 Panicle width (cm)

Association of panicle width was positive and significant with panicle weight ($G=0.457$, $P=0.366$), number of primary branches ($G=0.502$, $P=0.448$), fodder yield ($G=0.546$, $P=0.450$), biological yield ($G=0.649$, $P=0.518$) and 100 seed weight ($G=0.602$, $P=0.478$) at both genotypic and phenotypic level. While, harvest index ($G=0.079$, $P=0.128$) was non significant and positively correlated with panicle width at both level.

4.4.1.21 Panicle weight (g)

Number of primary branches ($G=0.378$, $P=0.319$), fodder yield ($G=0.426$, $P=0.409$), biological yield ($G=0.522$, $P=0.506$) and 100 seed weight ($G=0.489$, $P=0.463$) recorded positive and significant association with panicle

weight at both genotypic and phenotypic. While, it was non significant and positively correlated with harvest index ($G=0.131$, $P=0.104$) at both level.

4.4.1.22 Number of primary branches

At both genotypic and phenotypic level, number of primary branches was positively and significantly correlated with fodder yield ($G=0.297$, $P=0.272$), biological yield ($G=0.432$, $P=0.370$), 100 seed weight ($G=0.379$, $P=0.353$) and harvest index ($G=0.199$, $P=0.206$).

4.4.1.23 Fodder yield per plant (g)

Association of fodder yield per plant was positive and significant with biological yield ($G=0.954$, $P=0.936$) and 100 seed weight ($G=0.417$, $P=0.397$) at both level. Whereas, harvest index ($G=-0.494$, $P=-0.454$) was significant but negatively correlated with fodder yield per plant at both genotypic and phenotypic level.

4.4.1.24 Biological yield per plant (g)

The trait 100 seed weight ($G=0.537$, $P=0.505$) was significant and positively associated with biological yield at both level. Harvest index ($G=-0.193$) showed significant but negative association at genotypic level. Whereas, at phenotypic level harvest index ($P=-0.162$) showed non significant negative association.

4.4.1.25 100 seed weight (g)

Hundred seed weight has recorded significant and positive association with harvest index ($G=0.225$, $P=0.200$) at both genotypic and phenotypic level.

4.5 Path analysis

The correlation studies did not show the exact picture of direct and indirect effects of yield contributing characters. Path analysis was carried out to find out the direct and indirect contribution of each character towards the grain yield per plant. Direct and indirect effects of yield components and

Table 4.6 Direct and indirect effects (genotypic level) of yield components on grain yield

Characters	Days to flower initiation	Days to 50 % flowering	Days to physiological maturity	Plant height (cm)	No. of leaves per plant	Third leaf area (cm ²)	Flag leaf area (cm ²)	Leaf area index	Leaf dry weight (g)	Stem dry weight (g)	Panicle dry weight (g)	Total dry weight (g)	Chlorophyll content	Relative water content
Days to flower initiation	0.6026	0.6000	0.5392	-0.0579	0.0987	-0.0132	-0.1289	0.0535	-0.1874	0.0098	-0.0617	-0.0158	-0.0315	0.1321
Days to 50 % flowering	-0.5100	-0.5122	-0.4689	0.0392	-0.0828	-0.0019	0.0880	-0.0518	0.1340	-0.0095	0.0357	0.0085	0.0147	-0.1039
Days to physiological maturity	0.0665	0.0680	0.0743	-0.0039	0.0157	0.0097	-0.0075	0.0156	-0.0140	0.0047	0.0014	0.0030	-0.0048	0.0199
Plant height (cm)	0.0331	0.0264	0.0180	-0.3449	-0.2634	-0.1788	-0.1894	-0.2259	-0.1322	-0.2144	-0.1397	-0.2190	-0.0424	-0.0368
No. of leaves per plant	-0.1306	-0.1288	-0.1687	-0.6088	-0.7972	-0.5132	-0.4418	-0.6837	-0.0492	-0.5085	-0.2059	-0.4748	-0.1156	-0.2639
Third leaf area (cm ²)	0.0283	-0.0023	-0.1702	-0.6722	-0.8346	-1.2965	-0.9056	-1.2230	-0.2531	-0.6682	-0.3254	-0.6562	-0.1702	-0.2281
Flag leaf area (cm ²)	-0.0059	-0.0047	-0.0027	0.0150	0.0152	0.0911	0.0274	0.0186	0.0091	0.0108	0.0085	0.0114	0.0047	0.0054
Leaf area index	0.1630	0.1858	0.3868	1.2021	1.5743	1.7316	1.2497	1.8357	0.2531	1.1394	0.4875	1.089	0.2512	0.5044
Leaf dry weight (g)	0.0969	0.0815	0.0589	-0.1194	-0.0192	-0.0609	-0.1305	-0.0430	-0.3117	-0.1249	-0.0885	-0.1533	-0.0290	0.0648
Stem dry weight (g)	-0.0531	-0.0604	-0.2051	-2.025	-2.0788	-1.6796	-1.2839	-2.0227	-1.3060	-3.2589	-1.9452	-3.2396	-0.6838	-0.3429
Panicle dry weight (g)	0.0637	0.0433	-0.0119	-0.2519	-0.1606	-0.1561	-0.1930	-0.1652	-0.1766	-0.3713	-0.6221	-0.4055	-0.2635	-0.0688
Total dry weight (g)	-0.0917	-0.0582	0.1407	2.2212	2.0835	1.7707	1.4560	2.0770	1.7203	3.4777	2.2803	3.4985	0.8480	0.2857
Chlorophyll content	-0.0070	-0.0038	-0.0086	0.0165	0.0194	0.0176	0.0228	0.0183	0.0125	0.0281	0.0567	0.0325	0.1339	0.0345
Relative water content	0.0148	0.0137	0.0181	0.0072	0.0223	0.0119	0.0134	0.0185	-0.0140	0.0071	0.0075	0.0055	0.0174	0.0675
Transpiration index	0.0067	0.0057	-0.0197	-0.0243	-0.0285	-0.0549	-0.0254	-0.0488	0.0129	-0.0457	-0.0355	-0.0414	-0.0523	-0.0361
Stay-green score	0.0631	0.0515	0.0168	0.0120	0.0258	-0.0683	-0.0336	-0.0342	0.0269	-0.0138	0.0224	-0.0095	0.0227	-0.0012
Root:Shoot ratio (%)	-0.0028	-0.0025	-0.0037	-0.0132	-0.0182	-0.0016	-0.0014	-0.0084	-0.0117	-0.0157	-0.0043	-0.0156	-0.0057	0.0028
Stomatal count	-0.1450	-0.1332	-0.0801	0.0494	-0.0601	0.0629	0.0368	0.0135	0.0513	0.0869	0.1683	0.0977	0.0122	-0.0481
Panicle length (cm)	-0.0307	-0.0263	-0.0312	-0.0110	-0.0485	-0.0432	0.0057	-0.0521	0.0125	-0.0182	0.0125	-0.0140	0.0055	-0.0391
Panicle width (cm)	-0.0668	-0.0524	-0.0403	0.3554	0.3797	0.3354	0.3129	0.3750	0.1136	0.3404	0.2516	0.3451	0.1125	0.0689
Panicle weight (cm)	-0.0222	-0.0228	-0.0259	-0.0312	-0.0430	-0.0390	-0.0208	-0.0449	-0.0137	-0.0513	-0.0396	-0.0509	-0.0228	-0.0341
No. of primary branches	-0.0119	-0.0130	-0.0146	0.0963	0.0497	0.0421	0.0641	0.0446	0.0398	0.0650	0.0782	0.0701	0.0051	0.0188
Fodder yield (g/plant)	0.0245	0.0245	0.0274	0.0582	0.0698	0.0382	0.0278	0.0550	0.0106	0.0523	0.0232	0.0500	0.0129	-0.0029
Biological yield (g/plant)	0.1290	0.1375	0.1541	0.4670	0.5402	0.3296	0.2768	0.4469	0.1323	0.4212	0.2480	0.4119	0.1684	0.0021
100-seed weight (g)	-0.0433	-0.0344	-0.0239	0.2017	0.1924	0.1695	0.1331	0.1951	0.0984	0.1737	0.1246	0.1768	0.0611	0.0340
Harvest index	-0.2109	-0.1922	-0.2179	-0.0398	-0.0910	0.0121	0.0882	-0.0346	0.1232	-0.0225	0.1222	0.0065	0.1165	0.0343

Residual effect 0.149

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Characters	Transpiration index	Stay-green score	Root:Shoot ratio (%)	Stomatal count	Panicle length (cm)	Panicle width (cm)	Panicle weight (cm)	No. of primary branches	Fodder yield (g/plant)	Biological yield (g/plant)	100-seed weight(g)	Harvest index	Grain yield (g/plant)
Days to flower initiation	0.0259	-0.1636	0.0266	0.2268	-0.1351	-0.0786	0.1552	-0.0481	0.1583	0.1119	-0.0998	-0.2182	-0.0394
Days to 50 % flowering	-0.0186	0.1135	-0.0204	-0.1772	0.0983	0.0524	-0.1353	0.0445	-0.1345	-0.1013	0.0673	0.1690	-0.0093
Days to physiological maturity	-0.0093	-0.0220	0.0044	0.0154	-0.0169	-0.0058	0.0223	-0.0073	0.0218	0.0165	-0.0068	-0.0278	-0.0073
Plant height (cm)	0.0535	0.0178	-0.0718	0.0443	0.0278	-0.2392	-0.1246	-0.2228	-0.2149	-0.2317	-0.2662	0.0236	0.5372
No. of leaves per plant	0.1451	0.0884	-0.2293	-0.1244	0.2824	-0.5907	-0.3974	-0.2659	-0.5960	-0.6196	-0.5870	0.1246	0.5609
Third leaf area (cm ²)	0.4543	-0.3809	-0.0329	0.2116	0.4090	-0.8486	-0.5855	-0.3662	-0.5298	-0.6147	-0.8410	-0.0270	0.4442
Flag leaf area (cm ²)	-0.0044	0.0040	0.0016	-0.0026	0.0011	0.0167	0.0066	0.0118	0.0082	0.0109	0.0139	0.0041	0.4678
Leaf area index	-0.5724	0.2695	0.2435	-0.0643	-0.6991	1.3431	0.9557	0.5495	1.0809	1.1802	1.3704	-0.1090	0.5293
Leaf dry weight (g)	-0.0256	0.0361	-0.0579	0.0415	0.0285	-0.0812	-0.0496	-0.0832	-0.0355	-0.0593	-0.1174	-0.0659	0.3010
Stem dry weight (g)	0.9500	-0.1932	-0.8085	0.7359	0.4343	-2.1645	-1.9378	-1.4215	-1.8251	-1.9747	-2.1658	0.1261	0.4940
Panicle dry weight (g)	0.1411	0.0598	-0.0419	0.2717	-0.0566	-0.3053	-0.2854	-0.3262	-0.1546	-0.2219	-0.2965	-0.1305	0.4605
Total dry weight (g)	-0.9246	0.1422	0.8639	-0.8876	-0.3572	2.3556	2.0646	1.6452	1.8721	2.0729	2.3666	0.0393	0.5118
Chlorophyll content	-0.0447	-0.0131	0.0121	-0.0043	0.0054	0.0294	0.0354	0.0046	0.0185	0.0324	0.0313	0.0268	0.3650
Relative water content	-0.0156	0.0013	-0.0030	0.0084	-0.0193	0.0091	0.0267	0.0085	-0.0021	0.0012	0.0088	0.0040	0.0692
Transpiration index	0.1567	-0.0211	-0.0089	0.0871	0.0244	-0.0408	-0.0546	-0.0190	-0.0305	-0.0279	-0.0121	0.0138	-0.0787
Stay-green score	0.0314	-0.2326	0.1171	0.1198	0.0854	-0.0655	0.0498	0.0195	0.0106	0.0211	0.0223	0.0443	-0.1677
Root:Shoot ratio (%)	0.0036	0.0318	-0.0632	-0.0026	-0.0011	-0.0031	0.0041	-0.0011	-0.0139	-0.0144	-0.0112	0.0028	0.1465
Stomatal count	-0.2141	0.1984	-0.0161	-0.3852	0.0392	0.0266	-0.0019	0.0928	0.0163	0.0054	0.0181	-0.0318	0.0499
Panicle length (cm)	0.0213	-0.0502	0.0023	-0.0139	0.1368	-0.0456	-0.0172	0.0164	-0.0029	0.0062	-0.0268	0.0222	0.1609
Panicle width (cm)	-0.1335	0.1444	0.0250	-0.0354	-0.1707	0.5125	0.2345	0.2578	0.2801	0.3329	0.3088	0.0405	0.6179
Panicle weight (cm)	0.0301	0.0185	0.0056	-0.0012	0.0108	-0.0395	-0.0863	-0.0327	-0.0368	-0.0451	-0.0422	-0.0114	0.5442
No. of primary branches	-0.0181	-0.0125	0.0013	-0.0359	0.0179	0.0750	0.0565	0.1491	0.0443	0.0644	0.0566	0.0297	0.5500
Fodder yield (g/plant)	-0.0182	-0.0042	0.0205	-0.0040	-0.0020	0.0510	0.0398	0.0277	0.0934	0.0892	0.0390	-0.0462	0.5127
Biological yield (g/plant)	-0.1236	-0.0632	0.1578	-0.0098	0.0313	0.4515	0.3633	0.3004	0.6637	0.6951	0.3738	-0.1342	0.7568
100-seed weight (g)	-0.0202	-0.0251	0.0464	-0.0123	-0.0512	0.1575	0.1278	0.0993	0.1091	0.1405	0.2613	0.0588	0.5964
Harvest index	0.0514	-0.1108	-0.0258	-0.0481	0.0943	0.0460	0.0767	0.1160	-0.2881	-0.1124	0.1311	0.5825	0.5102

Residual effect 0.149

Table 4.7 Direct and indirect effects (phenotypic level) of yield components on grain yield

Characters	Days to flower initiation	Days to 50 % flowering	Days to physiological maturity	Plant height (cm)	No. of leaves per plant	Third leaf area (cm ²)	Flag leaf area (cm ²)	Leaf area index	Leaf dry weight(g)	Stem dry weight(g)	Panicle dry weight(g)	Total dry weight (g)	Chlorophyll content	Relative water content
Days to flower initiation	-0.0798	0.0578	0.0410	0.0078	-0.0089	0.0016	0.0164	-0.0055	0.0216	-0.0015	0.0082	0.0021	0.0023	-0.0162
Days to 50 % flowering	0.0578	0.0592	0.0423	-0.0047	0.0073	0.0003	-0.0097	0.0052	-0.0139	0.0014	-0.0043	-0.0008	-0.0017	0.0114
Days to physiological maturity	0.0410	0.0423	0.0475	-0.0026	0.0070	0.0060	-0.0044	0.0084	-0.0091	0.0030	0.0004	0.0015	-0.0021	0.0119
Plant height (cm)	-0.0011	-0.0009	-0.0006	0.0114	0.0075	0.0058	0.0062	0.0072	0.0038	0.0070	0.0042	0.0071	0.0013	0.0012
No. of leaves per plant	0.0032	0.0035	0.0042	0.0186	0.0282	0.0151	0.0135	0.0233	0.0013	0.0152	0.0074	0.0147	0.0022	0.0079
Third leaf area (cm ²)	-0.0012	0.0003	0.0075	0.0304	0.0318	0.0592	0.0411	0.0538	0.0103	0.0301	0.0133	0.0293	0.0067	0.0097
Flag leaf area (cm ²)	-0.0080	-0.0064	-0.0036	0.0212	0.0187	0.0270	0.0390	0.0257	0.0117	0.0152	0.0109	0.0160	0.0058	0.0076
Leaf area index	-0.0060	-0.0076	-0.0154	-0.0551	-0.0717	-0.0788	-0.0572	-0.0867	-0.0108	-0.0516	-0.0224	-0.0497	-0.0090	-0.0223
Leaf dry weight (g)	0.0531	0.0460	0.0377	-0.0655	-0.0091	-0.0343	-0.0589	-0.0244	-0.1964	-0.0710	-0.0397	-0.0889	-0.0155	0.0349
Stem dry weight (g)	-0.0228	-0.0305	-0.0795	-0.7715	-0.6740	-0.6369	-0.4885	-0.7455	-0.4531	-1.2533	-0.6889	-1.2371	-0.2324	-0.1318
Panicle dry weight (g)	0.0163	0.0116	-0.0012	-0.0592	-0.0417	-0.0356	-0.0444	-0.0410	-0.0321	-0.0873	-0.1588	-0.0993	-0.0479	-0.0195
Total dry weight (g)	-0.0370	-0.0180	0.0446	0.8573	0.7180	0.6796	0.5642	0.7883	0.6219	1.3567	0.8595	1.3745	0.2694	0.1219
Chlorophyll content	-0.0001	-0.0010	-0.0017	0.0041	0.0029	0.0042	0.0055	0.0038	0.0029	0.0068	0.0111	0.0072	0.0368	0.0084
Relative water content	-0.0013	-0.0012	-0.0016	-0.0007	-0.0018	-0.0010	-0.0012	-0.0016	0.0011	-0.0007	-0.0008	-0.0006	-0.0015	-0.0064
Transpiration index	0.0011	0.0010	-0.0031	-0.0039	-0.0049	-0.0084	-0.0041	-0.0075	0.0033	-0.0070	-0.0068	-0.0071	-0.0068	-0.0056
Stay-green score	0.0014	0.0016	0.0018	0.0003	0.0008	-0.0022	-0.0009	-0.0010	0.0002	-0.0006	0.0006	-0.0003	-0.0002	0.0000
Root:Shoot ratio (%)	0.0003	0.0003	0.0003	0.0011	0.0015	0.0001	0.0001	0.0007	0.0008	0.0014	0.0003	0.0014	0.0006	-0.0001
Stomatal count	-0.0150	-0.0132	-0.0092	0.0050	-0.0043	0.0063	0.0038	0.0022	0.0042	0.0089	0.0164	0.0103	-0.0021	-0.0043
Panicle length (cm)	0.0016	0.0013	0.0017	0.0006	0.0020	0.0024	-0.0003	0.0027	-0.0006	0.0010	-0.0010	0.0007	-0.0002	0.0020
Panicle width (cm)	0.0005	0.0005	0.0001	-0.0033	-0.0029	-0.0031	-0.0029	-0.0033	-0.0011	-0.0031	-0.0020	-0.0030	-0.0012	-0.0006
Panicle weight (cm)	0.0103	0.0103	0.0110	0.0140	0.0176	0.0177	0.0094	0.0202	0.0059	0.0230	0.0170	0.0231	0.0086	0.0152
No. of primary branches	-0.0020	-0.0020	-0.0024	0.0192	0.0077	0.0085	0.0130	0.0084	0.0067	0.0134	0.0139	0.0139	0.0035	0.0040
Fodder yield (g/plant)	-0.0738	-0.0770	-0.0846	-0.1859	-0.1923	-0.1236	-0.0901	-0.1711	-0.0193	-0.1655	-0.0781	-0.1587	-0.0317	0.0085
Biological yield (g/plant)	0.1808	0.1952	0.2233	0.6958	0.6932	0.4965	0.4155	0.6468	0.1510	0.6261	0.3916	0.6222	0.1952	0.0034
100-seed weight (g)	0.0014	0.0011	0.0008	-0.0064	-0.0056	-0.0053	-0.0042	-0.0061	-0.0027	-0.0055	-0.0038	-0.0056	-0.0018	-0.0012
Harvest index	-0.1600	-0.1572	-0.1655	-0.0337	-0.0730	0.0108	0.0713	-0.0318	0.1066	-0.0156	0.0973	0.0040	0.1101	0.0313

Residual effect 0.199

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Characters	Transpiration index	Stay-green score	Root:Shoot ratio (%)	Stomatal count	Panicle length (cm)	Panicle width (cm)	Panicle weight (cm)	No. of primary branches	Fodder yield (g/plant)	Biological yield (g/plant)	100-seed weight(g)	Harvest index	Grain yield (g/plant)
Days to flower initiation	-0.0031	0.0078	-0.0037	-0.0265	0.0137	0.0073	-0.0202	0.0047	-0.0188	-0.0131	0.0131	0.0241	-0.0401
Days to 50 % flowering	0.0021	-0.0064	0.0029	0.0172	-0.0082	-0.0046	0.0149	-0.0036	0.0145	0.0105	-0.0079	-0.0175	-0.0189
Days to physiological maturity	-0.0053	-0.0057	0.0026	0.0097	-0.0086	-0.0010	0.0128	-0.0035	0.0128	0.0097	-0.0045	-0.0148	-0.0040
Plant height (cm)	-0.0016	-0.0002	0.0021	-0.0013	-0.0007	0.0065	0.0039	0.0066	0.0067	0.0072	0.0086	-0.0007	0.4944
No. of leaves per plant	-0.0050	-0.0016	0.0072	0.0027	-0.0061	0.0143	0.0122	0.0066	0.0173	0.0178	0.0185	-0.0039	0.4540
Third leaf area (cm ²)	-0.0179	0.0087	0.0011	-0.0083	-0.0152	0.0318	0.0258	0.0152	0.0233	0.0268	0.0371	0.0012	0.4120
Flag leaf area (cm ²)	-0.0057	0.0023	0.0008	-0.0032	0.0014	0.0198	0.0090	0.0153	0.0112	0.0148	0.0194	0.0052	0.4320
Leaf area index	0.0234	-0.0058	-0.0105	0.0041	0.0244	-0.0496	-0.0429	-0.0220	-0.0473	-0.0511	-0.0622	0.0052	0.4711
Leaf dry weight (g)	-0.0233	0.0025	-0.0275	0.0181	-0.0120	-0.0366	-0.0283	-0.0401	-0.0121	-0.0270	-0.0628	-0.0395	0.2142
Stem dry weight (g)	0.3179	-0.0475	-0.2863	0.2471	0.1282	-0.6756	-0.7078	-0.5068	-0.6611	-0.7152	-0.8069	0.0368	0.4466
Panicle dry weight (g)	0.0388	0.0061	-0.0092	0.0575	-0.0161	-0.0552	-0.0663	-0.0670	-0.0395	-0.0567	-0.0709	-0.0292	0.4457
Total dry weight (g)	-0.3493	0.0281	0.3121	-0.3137	-0.1001	0.7264	0.7781	0.5797	0.6591	0.7794	0.9082	0.0104	0.4771
Chlorophyll content	-0.0090	0.0004	0.0039	0.0017	0.0007	0.0076	0.0078	0.0038	0.0037	0.0065	0.0077	0.0076	0.2885
Relative water content	0.0013	0.0000	0.0001	-0.0006	0.0014	-0.0007	-0.0024	-0.0008	0.0002	0.000	-0.0009	-0.0004	0.0712
Transpiration index	0.0278	-0.0015	-0.0022	0.0121	0.0029	-0.0041	-0.0088	-0.0020	-0.0052	-0.0054	-0.0026	0.0032	-0.1346
Stay-green score	0.0008	-0.0147	0.0040	0.0017	0.0017	-0.0025	0.0015	-0.0001	0.0007	0.0009	0.0007	-0.0007	-0.0559
Root:Shoot ratio (%)	-0.0005	-0.0016	0.0060	0.0001	0.0001	0.0002	-0.0003	0.0001	0.0012	0.0011	0.0010	-0.0002	0.1280
Stomatal count	-0.0198	0.0054	-0.0008	-0.0452	0.0030	-0.0008	-0.0001	0.0055	0.0009	0.0000	0.0016	-0.0054	0.0396
Panicle length (cm)	-0.0010	0.0011	-0.0002	0.0006	-0.0094	0.0017	0.0010	-0.0012	0.0002	-0.0002	0.0014	-0.0012	0.1001
Panicle width (cm)	0.0008	-0.0010	-0.0002	-0.0001	0.0010	-0.0058	-0.0021	-0.0026	-0.0026	-0.0030	-0.0028	-0.0007	0.4999
Panicle weight (cm)	-0.0128	-0.0042	-0.0017	0.0001	-0.0044	0.0149	0.0407	0.0130	0.0167	0.0206	0.0189	0.0043	0.5180
No. of primary branches	-0.0002	0.0002	0.0007	-0.0040	0.0042	0.0148	0.0106	0.0330	0.0090	0.0122	0.0117	0.0068	0.4621
Fodder yield (g/plant)	0.0593	0.0157	-0.0621	0.0063	0.0058	-0.1415	-0.1286	-0.0854	-0.3137	-0.2939	-0.1247	0.1424	0.4971
Biological yield (g/plant)	-0.2116	-0.0694	0.2068	-0.0006	0.0214	0.5684	0.5558	0.4070	1.0280	1.0973	0.5547	-0.1780	0.7492
100-seed weight (g)	0.0008	0.0004	-0.0014	0.0003	0.0013	-0.0041	-0.0039	-0.0030	-0.0034	-0.0043	-0.0085	-0.0017	0.5543
Harvest index	0.0605	0.0251	-0.0163	0.0637	0.0697	0.0682	0.0555	0.1095	-0.2407	-0.0860	0.1064	0.5310	0.4833

Residual effect 0.199

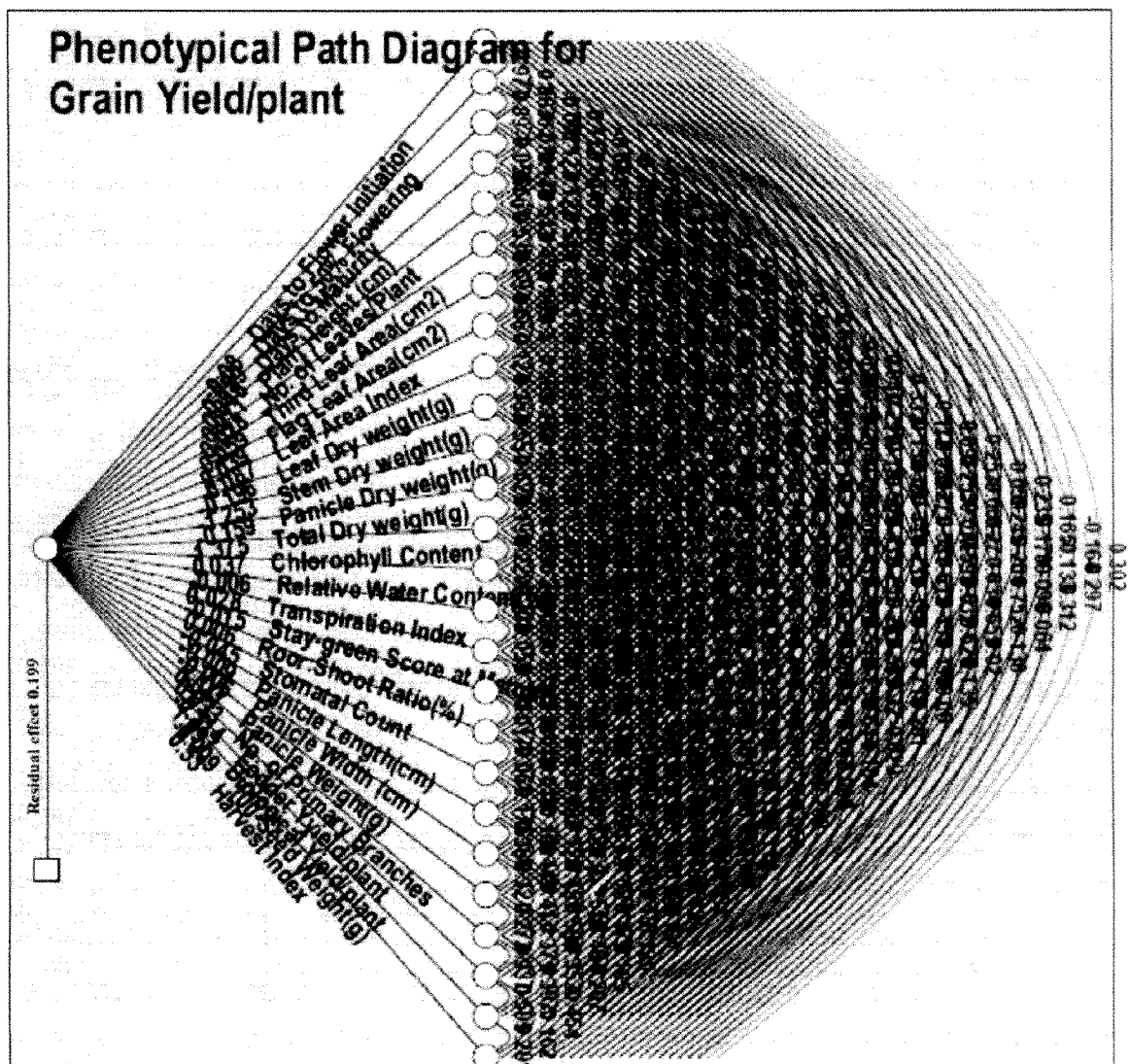


Fig. 4.5. Phenotypic path diagram for grain yield per plant

their genotypic and phenotypic correlation with grain yield are presented in Table 4.6 and 4.7 respectively.

4.5.1 Days to flower initiation

At genotypic level, days to flower initiation had a positive direct effect (0.6026) on grain yield per plant. It had maximum positive indirect effect on grain yield through days to 50 per cent flowering (0.6000) followed by days to physiological maturity (0.5392), stomatal count (0.2268), fodder yield (0.1583) and panicle weight (0.1552). While, maximum negative indirect effect on grain yield was exerted by harvest index (-0.2182) followed by leaf dry weight (-0.1874), stay green score at maturity (-0.1636) and panicle length (-0.1351).

At phenotypic level, days to flower initiation had a negative direct effect (-0.0798) on grain yield per plant. It had maximum positive indirect effect on grain yield through harvest index (0.0241), leaf dry weight (0.0216) and flag leaf area (0.0164). While, characters days to 50 per cent flowering (-0.0780), days to physiological maturity (-0.0688) and stomatal count (-0.0265) recorded maximum negative indirect effect on grain yield per plant.

4.5.2 Days to 50 per cent flowering

Negative direct effect (-0.5122) on grain yield was exerted by days to 50 per cent flowering and it had maximum positive indirect effect on grain yield through harvest index (0.1690) followed by leaf dry weight (0.1340), stay green score at maturity (0.1135) and panicle length (0.0983). While, characters days to flower initiation (-0.5100), days to physiological maturity (-0.4689), stomatal count (-0.1772) and panicle weight (-0.1353) exerted maximum negative indirect effect on grain yield per plant at genotypic level.

At phenotypic level, days to 50 per cent flowering had shown positive direct effect (0.0592) on grain yield per plant. While it recorded maximum negative indirect effect via., harvest index (-0.0175) followed by leaf

dry weight (-0.0139) and flag leaf area (-0.0097). While, days to flower initiation (0.0578), days to physiological maturity (0.0527), stomatal count (0.0172) and panicle weight (0.0149) had shown maximum positive indirect effect on grain yield per plant.

4.5.3 Days to physiological maturity

At genotypic level, days to physiological maturity recorded positive direct effect (0.0743) on grain yield per plant. Its maximum positive indirect effect on grain yield was exerted through days to 50 per cent flowering (0.0680) followed by days to flower initiation (0.0665), panicle weight (0.0223) and fodder yield per plant (0.0218). Whereas, harvest index (-0.0278), stay green score at maturity (-0.0220) and panicle length (-0.0169) showed maximum negative indirect effect on grain yield per plant.

Days to physiological maturity had shown positive direct effect (0.0475) on grain yield per plant. The characters days to 50 per cent flowering (0.0423) and days to flower initiation (0.0410) recorded maximum positive indirect effect on grain yield per plant. Whereas, days to physiological maturity had maximum negative indirect effect on grain yield per plant through harvest index (-0.0148), leaf dry weight (-0.0091) and panicle length (-0.0086) at phenotypic level.

4.5.4 Plant height (cm)

Plant height had shown the negative direct effect (-0.3449) on grain yield per plant. It had maximum positive indirect effect on grain yield through transpiration index (0.0535), stomatal count (0.0443), days to flower initiation (0.0331) and panicle length (0.0278). While, maximum negative indirect effect was exerted through 100 seed weight (-0.2662) followed by number of leaves per plant (-0.2634), panicle width (-0.2392) and biological yield per plant (-0.2317) at genotypic level.

At phenotypic level, plant height recorded positive direct effect (0.0114) on grain yield per plant. It had shown maximum positive indirect effect through 100 seed weight (0.0086) and number of leaves per plant

(0.0075). While, characters transpiration index (-0.0016), stomatal count (-0.0013) and days to flower initiation (-0.0011) had shown maximum negative indirect effect on grain yield per plant.

4.5.5 Number of leaves per plant

The character number of leaves per plant showed negative direct effect (-0.7972) on grain yield per plant. It recorded maximum positive indirect effect on grain yield through panicle length (0.2824), transpiration index (0.1451), harvest index (0.1246) and stay green score at maturity (0.0884). The highest negative indirect effect was observed through leaf area index (-0.6837), biological yield (-0.6196), plant height (-0.6088) and fodder yield per plant (-0.5960) at genotypic level.

At phenotypic studies, number of leaves per plant exerted positive direct effect (0.0282) on grain yield per plant. It had maximum positive indirect effect on grain yield per plant via., leaf area index (0.0233) followed by plant height (0.0186) and 100 seed weight (0.0185). While, it had shown maximum negative indirect effect through panicle length (-0.0061).

4.5.6 Third leaf area (cm²)

At genotypic level, third leaf area recorded negative direct effect (-1.2965) on grain yield per plant and it exerted maximum positive indirect effect on grain yield per plant through transpiration index (0.4543) followed by panicle length (0.4090), stomatal count (0.2116) and days to flower initiation (0.0283). Whereas, maximum negative indirect effect on grain yield was recorded through leaf area index (-1.2230), flag leaf area (-0.9056) panicle width (-0.8486) and 100 seed weight (0.8410).

Third leaf area had shown positive direct effect (0.0592) on grain yield per plant. The traits leaf area index (0.0538), flag leaf area (0.0411) and 100 seed weight (0.0371) recorded maximum positive indirect effect. While, transpiration index (-0.0179) and panicle length (-0.0152) had shown highest negative indirect effect on grain yield per plant at phenotypic level.

4.5.7 Flag leaf area (cm²)

Flag leaf area exerted positive and direct effect (0.0274) on grain yield per plant. The traits third leaf area (0.0911), leaf area index (0.0186) and panicle width (0.0167) through which flag leaf area recorded maximum positive indirect effect on grain yield per plant. While, flag leaf area had maximum negative indirect effect on grain yield per plant via., days to flower initiation (-0.0059) at genotypic level.

The character flag leaf area recorded positive direct effect (0.0390) on grain yield per plant. The maximum positive indirect effect on grain yield per plant was exerted through third leaf area (0.0270), leaf area index (0.0257) and plant height (0.0212). Whereas, it had shown maximum negative indirect effect via., days to flower initiation (-0.0080) and days to 50 per cent flowering (-0.0064) at phenotypic level.

4.5.8 Leaf area index

Leaf area index had shown positive direct effect (1.8357) on grain yield per plant. The maximum positive indirect effect on grain yield was exerted through third leaf area (1.7316), number of leaves per plant (1.5743), 100 seed weight (1.3704) and panicle width (1.3431). Its highest negative indirect effect on grain yield was recorded through panicle length (-0.6991) and transpiration index (-0.5724) at genotypic level.

At phenotypic level, leaf area index recorded negative direct effect (-0.0867) on grain yield per plant. It had maximum positive indirect effect on grain yield per plant through panicle length (0.0244) and transpiration index (0.0234). While, third leaf area (-0.0788) had shown highest negative indirect effect on grain yield per plant.

4.5.9 Leaf dry weight (g)

At genotypic level, leaf dry weight recorded negative direct effect (-0.3117) on grain yield per plant and it had maximum negative indirect effect on grain yield through total dry weight (-0.1533), flag leaf area (-0.1305), stem dry weight (-0.1249) and plant height (-0.1194). While, leaf dry weight had

shown highest positive indirect effect on grain yield through days to flower initiation (0.0969) followed by days to 50 per cent flowering (0.0815), relative water content (0.0648) and days to physiological maturity (0.0589).

The character leaf dry weight exerted negative direct effect (-0.1964) on grain yield per plant. The maximum positive indirect effect on grain yield per plant was observed through days to flower initiation (0.0531) followed by days to 50 per cent flowering (0.0460) and days to physiological maturity (0.0377). While, total dry weight (-0.0889) had recorded highest negative indirect effect on grain yield per plant at phenotypic level.

4.5.10 Stem dry weight (g)

Stem dry weight had shown maximum negative direct effect (-3.2859) on grain yield per plant. The character stem dry weight exerted maximum positive indirect effect on grain yield per plant through transpiration index (0.9500) followed by stomatal count (0.7349) and panicle length (0.4343). It had maximum negative indirect effect through total dry weight (-3.2396), 100 seed weight (-2.1658), panicle width (-2.1645) and number of leaves per plant (-2.0788) at genotypic level.

The character stem dry weight recorded highest negative direct effect (-1.2533) on grain yield per plant. It had maximum positive indirect effect on grain yield per plant through transpiration index (0.3179) and stomatal count (0.2471). While, it had shown highest negative indirect effect on grain yield per plant via., total dry weight (-1.2371) at phenotypic level.

4.5.11 Panicle dry weight (g)

At genotypic level, the character panicle dry weight exerted negative direct effect (-0.6221) on grain yield per plant. However, it had maximum positive indirect effect on grain yield through stomatal count (0.2717) followed by transpiration index (0.1411) and days to flower initiation (0.0637). Whereas, its maximum negative indirect effect on grain yield was observed via, total dry weight (-0.4055), stem dry weight (-0.3713), number primary branches (-0.3262) and panicle width (-0.3053).

At phenotypic level, panicle dry weight had shown negative direct effect (-0.1588) on grain yield per plant. It had maximum positive indirect on grain yield per plant through stomatal count (0.0575) followed by transpiration index (0.0388), days to flower initiation (0.0163) and days to 50 per cent flowering (0.0116). While, total dry weight (-0.0993) had exerted highest negative indirect effect on grain yield per plant.

4.5.12 Total dry weight

The trait total dry weight exerted highest positive direct effect (3.4985) on grain yield among all the characters studied. Whereas, it had maximum positive indirect effect on grain yield through stem dry weight (3.4777) followed by 100 seed weight (2.3666), panicle width (2.3556) and panicle dry weight (2.2803). The maximum negative indirect effect on grain yield was recorded through transpiration index (-0.9246), stomatal count (-0.8876) and panicle length (-0.3572) at genotypic level.

Total dry weight had shown highest positive direct effect (1.3745) on grain yield per plant. It had maximum positive indirect effect on grain yield per plant via., stem dry weight (1.3567) followed by 100 seed weight (0.9082), panicle dry weight (0.8595) and leaf area index (0.7883). Whereas, it had shown maximum negative indirect effect through transpiration index (-0.3493) and stomatal count (-0.3137) at phenotypic level.

4.5.13 Chlorophyll content

Chlorophyll content recorded positive direct effect (0.1339) on grain yield per plant. It had exerted highest positive indirect effect on grain yield per plant through panicle dry weight (0.0567), panicle weight (0.0354), relative water content (0.0345), biological yield per plant (0.0324) and total dry weight (0.0325). Whereas, it had maximum negative indirect effect on grain yield via, transpiration index (-0.0447) and stay green score at maturity (-0.0131) at genotypic level.

At phenotypic level, chlorophyll content recorded positive direct effect (0.0368) on grain yield per plant. However, it had maximum positive

indirect effect on grain yield through panicle dry weight (0.0111) and relative water content (0.0084). While, transpiration index (-0.0090) recorded maximum negative indirect effect on grain yield per plant.

4.5.14 Relative water content

At genotypic level, the relative water content showed positive direct effect (0.0675) on grain yield per plant. It had maximum positive indirect effect on grain yield through panicle weight (0.0267), number of leaves per plant (0.0223), leaf area index (0.0185), days to physiological maturity (0.0181) and chlorophyll content (0.0174). While, It had shown maximum negative indirect effect on grain yield per plant through panicle length (-0.0193), transpiration index (-0.0156) and leaf dry weight (-0.0140).

At phenotypic level, relative water content had shown negative direct effect (-0.0064) on grain yield per plant. It showed maximum positive indirect effect on grain yield per plant through panicle length (0.0014), transpiration index (0.0013) and leaf dry weight (0.0011). While, panicle weight (-0.0024) exerted maximum negative indirect effect on grain yield per plant.

4.5.15 Transpiration index

Transpiration index exerted positive direct effect (0.1567) on grain yield per plant. It had maximum positive indirect effect on grain yield through stomatal count (0.0871), panicle length (0.0244) and harvest index (0.0138). Whereas, maximum negative indirect effect was exerted through third leaf area (-0.0549) followed by chlorophyll content (-0.0523), leaf area index (-0.0488) and stem dry weight (-0.0457) at genotypic level.

At phenotypic level, transpiration index recorded positive direct effect (0.0278) on grain yield per plant. The traits stomatal count (0.0121), leaf dry weight (0.0033), harvest index (0.0032) and panicle length (0.0029) through which transpiration index recorded maximum positive indirect effect on grain yield per plant. While, panicle weight (-0.0088) had exerted highest negative indirect effect on grain yield per plant.

4.5.16 Stay green score at maturity (1-9)

Stay green score at maturity recorded negative direct effect (-0.2326) on grain yield per plant. The traits stomatal count (0.1198), root:shoot ratio (0.1171), panicle length (0.0854) and days to flower initiation (0.0631) through which stay green score at maturity exerted maximum positive indirect effect on grain yield. While, it recorded maximum negative indirect effect on grain yield through third leaf area (-0.0683) followed by panicle width (-0.0655), leaf area index (-0.0342) and flag leaf area (-0.0336) at genotypic level.

The character stay green score at maturity had shown negative direct effect (-0.0147) on grain yield per plant. It had maximum positive indirect effect on grain yield per plant via., root:shoot ratio (0.0040) followed by days to physiological maturity (0.0018) and stomatal count (0.0017). Whereas, traits panicle width (-0.0025), third leaf area (-0.0022) and leaf area index (-0.0010) had observed maximum negative indirect effect on grain yield per plant at phenotypic level.

4.5.17 Root:Shoot ratio

At genotypic level, the trait root:shoot ratio exhibited negative direct effect (-0.0632) on grain yield per plant. It had positive indirect effect on grain yield through stay green score at maturity (0.0318) and panicle weight (0.0041). Whereas, it had maximum negative indirect effect through number of leaves per plant (-0.0182) followed by stem dry weight (-0.0157), total dry weight (-0.0156) and biological yield per plant (-0.0144).

The character root:shoot ratio recorded positive direct effect (0.0060) on grain yield per plant. It had maximum positive indirect effect on grain yield per plant through number of leaves (0.0015), stem dry weight (0.0014) and total dry weight (0.0014). While, it had highest negative indirect effect on grain yield per plant via., stay green score at maturity (-0.0016) at phenotypic level.

4.5.18 Stomatal count

Stomatal count exhibited negative direct effect (-0.3852) on grain yield per plant and it had maximum positive indirect effect on grain yield through stay green score at maturity (0.1984) followed by panicle dry weight (0.1683), total dry weight (0.0977) and number of primary branches (0.0928). While, it showed maximum negative indirect effect on grain yield through transpiration index (-0.2141), days to flower initiation (-0.1450), days to 50 per cent flowering (-0.1332) and days to physiological maturity (-0.0801) at genotypic level.

The character stomatal count showed negative direct effect (-0.0452) on grain yield per plant. It had recorded maximum positive indirect effect on grain yield per plant through panicle dry weight (0.0164) followed by total dry weight (0.0103) and stem dry weight (0.0089). Whereas, it had shown maximum negative indirect effect through transpiration index (-0.0198) followed by days to flower initiation (-0.0150), days to 50 per cent flowering (-0.0132) and days to physiological maturity (-0.0092) at phenotypic level.

4.5.19 Panicle length (cm)

At genotypic level, panicle length had shown positive direct effect (0.1368) on grain yield per plant. The characters harvest index (0.0222), transpiration index (0.0213), number of primary branches (0.0164), leaf dry weight (0.0125) and panicle dry weight (0.0125) through which panicle length exerted maximum positive indirect effect on grain yield. While, it had shown maximum negative indirect effect through leaf area index (-0.0521) followed by stay green score (-0.0502), number of leaves per plant (-0.0485) and panicle width (-0.0456).

Panicle length exhibited negative direct effect (-0.0094) on grain yield per plant. It had maximum positive indirect effect on grain yield per plant via., leaf area index (0.0027), third leaf area (0.0024), number leaves per plant (0.0020) and relative water content (0.0020). Whereas, it had shown maximum

negative indirect effect through number of primary branches (-0.0012) and harvest index (-0.0012) at phenotypic level.

4.5.20 Panicle width (cm)

Panicle width had shown positive direct effect (0.5125) on grain yield per plant. It had maximum positive indirect effect on grain yield per plant through number of leaves per plant (0.3797), leaf area index (0.3750), plant height (0.3554) and total dry weight (0.3451). It had maximum negative indirect effect on grain yield per plant through panicle length (-0.1707) followed by transpiration index (-0.1335), days to flower initiation (-0.0668) and days to 50 per cent flowering (-0.0524) at genotypic level.

The character panicle width recorded negative direct effect (-0.0058) on grain yield per plant. The traits panicle length (0.0010) and transpiration index (0.0008) through which panicle width exhibited maximum positive indirect effect on grain yield per plant. While, panicle width had shown maximum negative indirect effect on grain yield per plant through plant height (-0.0033) followed by third leaf area (-0.0031) and stem dry weight (-0.0031) at phenotypic level.

4.5.21 Panicle weight (g)

At genotypic level, the trait panicle weight exhibited negative direct effect (-0.0863) on grain yield per plant. The characters transpiration index (0.0301), stay green score at maturity (0.0185) and panicle length (0.0108) through which panicle weight exerted maximum positive indirect effect on grain yield and it had shown maximum negative indirect effect through stem dry weight (-0.0513), total dry weight (-0.0509), biological yield per plant (-0.0451) and leaf area index (-0.0449).

The character panicle weight had shown positive direct effect (0.0407) on grain yield per plant. It had maximum positive indirect effect on grain yield per plant through total dry weight (0.0231), stem dry weight (0.0230) and biological yield per plant (0.0206). While, it had shown maximum negative indirect effect on grain yield per plant via., transpiration index (-

0.0128) followed by panicle length (-0.0044), stay green score at maturity (-0.0042) and root:shoot ratio (-0.0017) at phenotypic level.

4.5.22 Number of primary branches

Number of primary branches had a positive direct effect (0.1491) on grain yield per plant. It showed a maximum positive indirect effect through characters viz., plant height (0.0963), panicle dry weight (0.0782), panicle width (0.0750) and total dry weight (0.0701). While, it showed maximum negative indirect effect through stomatal count (-0.0359) followed by transpiration index (-0.0181), days to physiological maturity (-0.0146) and days to 50 per cent flowering (-0.0130) at genotypic level.

The character number of primary branches showed positive direct effect (0.0330) on grain yield per plant. It exhibited maximum positive indirect effect on grain yield per plant via., plant height (0.0192) followed by panicle width (0.0148), panicle dry weight (0.0139) and total dry weight (0.0139). Whereas, it had shown maximum negative indirect effect on grain yield per plant through stomatal count (-0.0040) followed by days to physiological maturity (-0.0024), days to 50 per cent flowering (-0.0020) and days to flower initiation (-0.0020) at phenotypic level.

4.5.23 Fodder yield per plant (g)

At genotypic level, the character fodder yield per plant showed positive direct effect (0.0934) on grain yield per plant. Its indirect effect on grain yield per plant through biological yield per plant (0.0892), number of leaves per plant (0.0698), plant height (0.0582) and leaf area index (0.0550) was positive. Whereas, it was negative through harvest index (-0.0462), transpiration index (-0.0182), stay green score at maturity (-0.0042) and stomatal count (-0.0040).

At phenotypic level, fodder yield per plant had shown negative direct effect (-0.3137) on grain yield per plant. It had recorded maximum positive indirect effect on grain yield per plant through harvest index (0.1424), transpiration index (0.0593) and stay green score at maturity (0.0157). While,

trait biological yield per plant (-0.2939) had recorded highest negative indirect effect on grain yield per plant.

4.5.24 Biological yield per plant (g)

Biological yield per plant had shown positive direct effect (0.6951) on grain yield per plant. It exerted maximum negative indirect effect through characters viz., harvest index (-0.1342), transpiration index (-0.1236) and stay green score at maturity (-0.0632). Whereas, it shown maximum positive indirect effect through fodder yield per plant (0.6637) followed by number of leaves per plant (0.5402), panicle width (0.4515), leaf area index (0.4469), stem dry weight (0.4212) and total dry weight (0.4119) at genotypic level.

At phenotypic level, biological yield per plant exhibited positive direct effect (1.0973) on grain yield per plant. The traits fodder yield per plant (1.0280), plant height (0.6958) and number of leaves per plant (0.6932) through which fodder yield per plant exhibited maximum positive indirect effect on grain yield per plant. While, transpiration index (-0.2116) recoded highest negative indirect effect on grain yield per plant.

4.5.25 100 seed weight (g)

At genotypic level, the character 100 seed weight recorded positive direct effect (0.2613) on grain yield per plant. The characters plant height (0.2017), leaf area index (0.1951), number of leaves per plant (0.1924) and total dry weight (0.1768) showed maximum positive indirect effect on grain yield per plant. Whereas, the traits panicle length (-0.0512), days to flower initiation (-0.433), days to 50 per cent flowering (-0.0344) and stay green score at maturity (-0.0251) recorded maximum negative indirect effect on grain yield per plant.

The character 100 seed weight had recorded negative direct effect (-0.0085) on grain yield per plant. It had shown maximum positive indirect effect on grain yield per plant through days to flower initiation (0.0014) followed by panicle length (0.0013) and relative water content (0.0012). While,

it had maximum negative indirect effect on grain yield per plant via., plant height (-0.0064), leaf area index (-0.0061) and number of leaves per plant (-0.0056) at phenotypic level.

4.5.26 Harvest index

Harvest index showed positive direct effect (0.5825) on grain yield per plant. Harvest index recorded maximum negative indirect effect on grain yield per plant through fodder yield per plant (-0.2881) followed by days to physiological maturity (-0.2179), days to flower initiation (-0.2109) and days to 50 per cent flowering (-0.1922). Whereas, the traits 100 seed weight (0.1311), leaf dry weight (0.1232), panicle dry weight (0.1222), number of primary branches (0.1160) showed maximum positive indirect effect on grain yield per plant at genotypic level.

At phenotypic level, harvest index had recorded positive direct effect (0.5310) on grain yield per plant. The traits chlorophyll content (0.1101), number of primary branches (0.1095), leaf dry weight (0.1066) and 100 seed weight (0.1064) through which harvest index recorded maximum positive indirect effect on grain yield per plant. While, it had shown maximum negative indirect effect on grain yield per plant through fodder yield per plant (-0.2407) followed by days to physiological maturity (-0.1655), days to flower initiation (-0.1600) and days to 50 percent flowering (-0.1572) at phenotypic level.

4.5.27 Residual effect

The genotypic residual effect was 0.149 whereas, phenotypic residual effect was 0.199.



Discussion

CHAPTER - V

DISCUSSION

Sorghum (*Sorghum bicolor* (L.) Moench) is a multipurpose crop grown for food, animal feed and industrial purpose. It is cultivated in both rainy (*kharif*) and winter (*rabi*) season in Maharashtra.

The present study was undertaken to study the genetic variability, association of characters and their direct and indirect effects on grain yield under drought condition. Plant breeding deals with the management of genetic variability present in a population. It's assessment in available germplasm is of immense importance for further crop improvement and to identify the superior genotypes. Selection on the basis of *per se* performance for plant yield does not give fruitful result because yield is a complex character. While association of various characters with yield and among themselves, would provide criteria for indirect selection through different components for improvement in *rabi* sorghum. Simple correlation coefficients were of limited value in selecting superior plants and hence, it is important to study the cause and effect relationship between yield and its components. The results of the present investigation for genetic variability, correlation and path analysis are briefly discussed in following headings.

5.1 Analysis of variance

5.2 Mean performance

5.3 Genetic parameters

5.4 Correlation

5.5 Path analysis

5.1 Analysis of variance

The analysis of variance showed significant differences among the genotypes for all the characters. This indicates that wide range of variability among genotypes is present for yield and yield contributing characters in *rabi* sorghum (Table 4.1). Similar results were recorded by Sanchez *et al.* (2002) for

plant height, Amanullah *et al.* (2007) for plant height and leaf area and Pawar (2007) for relative water content and Techale *et al.* (2014) for plant height

5.2 Mean performance

Mean performance of the different characters studied are presented in Table 4.2

On the basis of mean performance, early days to flower initiation was observed in genotypes *viz.*, BRJ 40813, RSV 1345, RSV 1542 and SSRK 13-1. The genotypes BRJ 40813, RSV 1345, SSRK 13-1 and RSV 1542 were found early for days to 50 per cent flowering. While, genotypes RSV 1345, RSV 1542, SSRK 13-1, RSV 1850 and BRJ 40813 were found early for days to physiological maturity.

The check M-35-1 followed by genotypes SLV 188, RSV 1611, RSV 1345 and RSV 1542 were found taller than other genotypes. The highest number of leaves per plant was observed in the genotype SLV 182. The genotype SLV 190, SLV 184, SLV 181 and BRJ 29914 were recorded higher third leaf area. The highest flag leaf area was recorded in the genotypes SLV 181 and check Phule suchitra. While, The genotypes SLV 190, SLV 182, SLV 184 and RSV 1772 recorded highest leaf area index over other genotypes and checks.

The genotypes RSV 1785, RSV 1542, RSV 1772 and SSRK 13-2 recorded highest leaf dry weight. The trait stem dry weight was found maximum in genotypes SLV 182, RSV 1785, RSV 1345, RSV 1516 and SLV 169. Panicle dry weight in genotypes SLV 181, RSV 1345, SLV 168, RSV 1516 and RSV 1786 was found highest. The genotypes RSV 1785, RSV 1345, RSV 1516, SLV 182 and SLV 181 recorded highest total dry weight over other genotypes and checks.

Chlorophyll content in genotypes SLV 168, RSV 1345, SLV 181, RSV 1772 and SLV 171 was observed maximum. The highest relative water content was revealed in the genotypes RSV 1850, SLV 168, SSRK 13-15, SLV 184 and checks M-35-1, CSV-22R and Phule suchitra. The genotypes SLV 193

recorded lower transpiration index followed by BRJ 4951, SLV 181, BRJ 40813, SLV 168 and SLV 190. The genotype RSV 1772 recorded higher stay green score at maturity. The genotypes RSV 1516, SLV 169, RSV 1749 and RSV 1611 recorded maximum root:shoot ratio than other genotypes and checks. The genotype SLV 181 recorded lower number of stomata followed by SSRK 13-1, RSV 1345, RSV 1542 and BRJ 40813.

The genotype RSV 1785 exhibited maximum panicle length followed by RSV 1786, RSV 1749, RSV 1767 and SSRK 13-8. The panicle width was maximum in genotypes SSRK 13-4, SLV 182, RSV 1345 and SLV 190. Whereas, highest panicle weight was recorded in the genotypes SLV 168, SLV 184, SLV 169 and check CSV-22R. The maximum number of primary branches were recorded in genotypes RSV 1749, SLV 168, RSV 1850, RSV 1785 and RSV 1767.

The genotype RSV 1785 recorded maximum fodder yield per plant followed by SLV 182, SSRK 13-8, SLV 168 and RSV 1345. The highest biological yield per plant was recorded in the genotypes SLV 168, RSV 1785 and SLV 182. The genotypes SLV 181, SLV 190 and RSV 1786 recorded maximum 100 seed weight. The highest harvest index was recorded in the genotypes RSV 1786 followed by RSV 1850, SSRK 13-7, SSRK 13-4 and SSRK 13-2. The genotypes SLV 168 and RSV 1786 recorded maximum grain yield per plant.

5.3 Genetic parameters

The knowledge of genetic variability, heritability and genetic advance is pre requisite for initiating appropriate breeding procedure in crop improvement programmes. The heritable variation is masked by non-heritable variation which creates difficulty in exercising selection. So, it becomes necessary to split overall variability into heritable and non-heritable components with the help of certain genetic parameters which may enable the breeder to plan out proper breeding programme. Selection will be effective when the character is controlled by additive gene action.

Thus, the present study was undertaken to acquire the knowledge of genetic parameters like variability, heritability and genetic advance in selected genotypes of *rabi* sorghum for drought tolerance.

5.3.1 Range of variability

In general, wide range of variability was observed for majority of characters. Range of variation on the basis of mean was more for characters viz., days to flower initiation, days to 50 per cent flowering, days to physiological maturity, plant height, number of leaves per plant, third leaf area, flag leaf area, leaf area index, stem dry weight, panicle dry weight, total dry weight, chlorophyll content, relative water content, root: shoot ratio, panicle length, panicle width, panicle weight, number of primary branches, fodder yield per plant, biological yield per plant, 100 seed weight, harvest index and grain yield per plant.

Wide range of variability for different yield contributing characters in sorghum were reported by several workers including Shinde *et al.* (1979) for plant height, panicle weight and grain yield, Veerabhadiran and Kennedy (2001) for 100 seed weight, grain yield per plant and days to 50 per cent flowering, Ali *et al.* (2009b) for relative water content.

5.3.2 Genotypic and phenotypic variance

In the present study, genotypic variance was slightly lower than phenotypic variance for all the characters. Although the phenotypic variance was greater than genotypic variance, the difference between them were of lower magnitude.

High estimates of genotypic and phenotypic variance were observed for the traits days to flower initiation, days to 50 per cent flowering, plant height, third leaf area, flag leaf area, stem dry weight, total dry weight, chlorophyll content, relative water content, panicle length, panicle width, panicle weight, number of primary branches, fodder yield per plant, biological yield per plant, harvest index and grain yield per plant. These results are in agreement with the results reported by Singh and Makne (1980) for plant

height, Seetharama *et al.* (1990) for days to 50 per cent flowering, Ali *et al.* (2009a) for flag leaf area and Tariq *et al.* (2012) for plant height and fodder yield.

5.3.3 Genotypic and phenotypic coefficient of variation

Genotypic coefficient of variation estimates was lower than phenotypic coefficient of variation for all the characters and differences between them were of lower magnitude.

In the present study, moderate to high estimates of genotypic and phenotypic coefficient of variation were recorded for plant height, number of leaves per plant, third leaf area, flag leaf area, leaf area index, leaf dry weight, stem dry weight, panicle dry weight, total dry weight, relative water content, transpiration index, stomatal count, panicle length, panicle width, panicle weight, number of primary branches, fodder yield per plant, biological yield per plant, 100 seed weight, harvest index and grain yield per plant.

These results are in agreement with the results reported by Veerabadhiran and Kennedy (2001), Date (2002), Kumar and Sahib (2003), Arunkumar *et al.* (2004), Ali *et al.* (2009b), Kusalkar *et al.* (2009), Arunkumar (2013), Chittapur and Biradar (2015), Tesfamichael *et al.* (2015), Dhutmal *et al.* (2015a), Khandelwal *et al.* (2015).

5.3.4 Heritability and Genetic Advance

The genotypic coefficient of variation alone does not indicate the proportion of total heritable variation. High heritability indicates the effectiveness of selection based on phenotypic performance but does not necessarily mean a high genetic gain for particular character. The heritability estimates along with expected genetic advance are more useful for predicting yield under phenotypic selection than heritability estimates alone. High heritability accompanied with high genetic advance indicates preponderance of additive gene effect, in such case selection may be effective. High heritability with low genetic advance reveals preponderance of non additive gene action.

In present investigation, heritability ranged from 99.50 to 22.68 per cent while genetic advance ranged from 93.59 to 0.22. The characters plant height, third leaf area, flag leaf area, stem dry weight, total dry weight, chlorophyll content, relative water content, root:shoot ratio, panicle weight, number of primary branches, fodder yield per plant and biological yield per plant expressed high estimate of heritability accompanied with moderate to high genetic advance indicating additive gene action and thus selection for these characters in genetically diverse material would be more effective for desired genetic improvement. Similar results were reported by Shinde *et al.* (1979), Singh and Makne (1980), Ambekar *et al.* (2000), Date (2002), Kumar and Sahib (2003), Tariq *et al.* (2012) and Chittapur and Biradar (2015).

The characters days to flower initiation, days to 50 per cent flowering, days to physiological maturity, number of leaves per plant, leaf area index, leaf dry weight, panicle dry weight, transpiration index, stomatal count, panicle length, panicle width, 100 seed weight, harvest index and grain yield per plant had high heritability with low genetic advance suggesting the variability for these characters is governed by non-additive gene action indicating the limited scope for improving these characters through phenotypic selection. Similar results were reported by Shinde *et al.* (1979) and Dhutmal *et al.* (2015a).

Thus considering the estimates of genetic parameters like GCV, PCV, heritability and genetic advance together, it is evident that the characters which show high values for GCV, PCV, heritability and genetic advance were considered most important and selection of these characters could be more effective for improving grain yield in *rabi* sorghum.

5.4 Correlation

Correlation coefficient is an important statistical constant, which indicates the degree of association among the various characters. The genotypic correlation was generally higher than phenotypic correlation indicating the inherent association between various traits. Yield is a complex character and is

dependent on number of component characters. Therefore, study of relationship between the characters with each other and with yield becomes more important in crop improvement programme.

In the present investigation, significant and positive correlation of grain yield per plant were observed with characters viz., plant height, number of leaves per plant, third leaf area, flag leaf area, leaf area index, leaf dry weight, stem dry weight, panicle dry weight, total dry weight, chlorophyll content, panicle width, panicle weight, number of primary branches, fodder yield per plant, biological yield per plant, 100-seed weight and harvest index at both genotypic and phenotypic level indicating that increase in grain yield is because of increase in one or more of the above characters.

These results are in agreement with the results reported by Cheralu and Rao (1989) for ear head weight, number of primaries and total dry weight, Bakheit (1990) for plant height, Potadukhe *et al.* (1994) and Iyanar *et al.* (2001) for panicle weight, Ngyuyen-Day (1998) for harvest index, Kadam *et al.* (2002) for leaf area index, Awari *et al.* (2003) for plant height, number of leaves, leaf area index and panicle width, Umakanth *et al.* (2004) for panicle weight, plant height, number of primaries and 100 seed weight, Anjana (2006) for harvest index, Sharma *et al.* (2006) for 100 seed weight, Ghorade *et al.* (2013) for chlorophyll content, Dhutmal *et al.* (2014) for panicle dry weight, plant height, chlorophyll content, leaf dry weight and number of leaves per plant, Jain *et al.* (2014) for fodder yield per plant and Khandelwal *et al.* (2015) for harvest index and leaf area.

The characters viz., days to flower initiation, days to 50 per cent flowering, days to physiological maturity and transpiration index showed negative and non significant correlation with grain yield per plant at both genotypic and phenotypic level. Similar results were reported by Nimbalkar *et al.* (1988) for days to 50 per cent flowering, Nirmal *et al.* (2013) and Devkumar *et al.* (2014) for transpiration.

The traits viz., relative water content, stay green score at maturity, root:shoot ratio, stomatal count and panicle length showed non significant positive association with grain yield per plant at both genotypic and phenotypic level. Similar finding have also been reported by Nirmal *et al.* (2013) for relative water content and stay green at maturity, Dhutmal *et al.* (2015b) for relative water content.

The harvest index has recorded negative but significant association with days to flower initiation, days to 50 per cent flowering and days to physiological maturity. Similar results were also recorded by Mohammed *et al.* (1993).

It is important to note that the characters which are significant and positively correlated with grain yield could be considered as important traits for improving yield in *rabi* sorghum.

5.5 Path analysis

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

Direct effect of any component characters on grain yield gives an idea about reliability of indirect selections to be made through that character to bring about improvement in grain yield. If both correlation and the direct effect are high and positive then correlation explains its true relationship and selection for the character will be effective.

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

The present results revealed that days to physiological maturity, flag leaf area, total dry weight, chlorophyll content, transpiration index, number of primary branches, biological yield per plant and harvest index showed positive direct effect on grain yield per plant at both genotypic and phenotypic

level. These results are in agreement with the results reported by Sriram and Rao (1983), Lamani *et al.* (1997) and Khandelwal *et al.* (2015) for harvest index and Dhutmal *et al.* (2015b) for chlorophyll content.

The traits leaf dry weight, stem dry weight, panicle dry weight, stay green score at maturity and stomatal count recorded negative direct effect on grain yield per plant at both level.

Days to flower initiation, leaf area index, relative water content, panicle length, panicle width, fodder yield per plant and 100 seed weight recorded positive direct effect on grain yield per plant only at genotypic level. Similar findings were reported by Bohra *et al.* (1986) and Jain and Patel (2014) for 100 seed weight, Potadukhe *et al.* (1992) for leaf area index, Hemlata Sharma *et al.* (2006) and Veerabadhiran and Kennedy (2001) for 100 seed weight and Aml *et al.* (2012) for panicle length.

The characters days to 50 per cent flowering, plant height, number of leaves per plant, third leaf area, root:shoot ratio and panicle weight showed positive direct effect on grain yield per plant at phenotypic level similar results were reported by Patil *et al.* (1993) for panicle weight and days to 50 per cent flowering.

Days to flower initiation, leaf area index, relative water content, panicle length, panicle width, fodder yield and 100 seed weight showed negative direct effect on grain yield per plant at phenotypic level.

The character days to 50 per cent flowering, plant height, number of leaves per plant, third leaf area, root:shoot ratio and panicle weight showed negative direct effect on grain yield per plant at genotypic level. Similar results were reported by Wankhede *et al.* (1985) for plant height.

*Summary and
Conclusion*

CHAPTER - VI

SUMMARY AND CONCLUSION

The present investigation entitled “Genetic variability and correlation studies in *rabi* sorghum (*Sorghum bicolor* (L) Moench) for drought tolerance” was undertaken at Sorghum Research Station V.N.M.K.V. Parbhani during *rabi* 2015 with the following objectives.

- 1) To study the variability in *rabi* sorghum germplasm lines for grain yield, fodder yield and drought tolerance parameters.
- 2) To estimate direct and indirect phenotypic and genotypic effects on grain yield and fodder yield.

The results are summarized as below

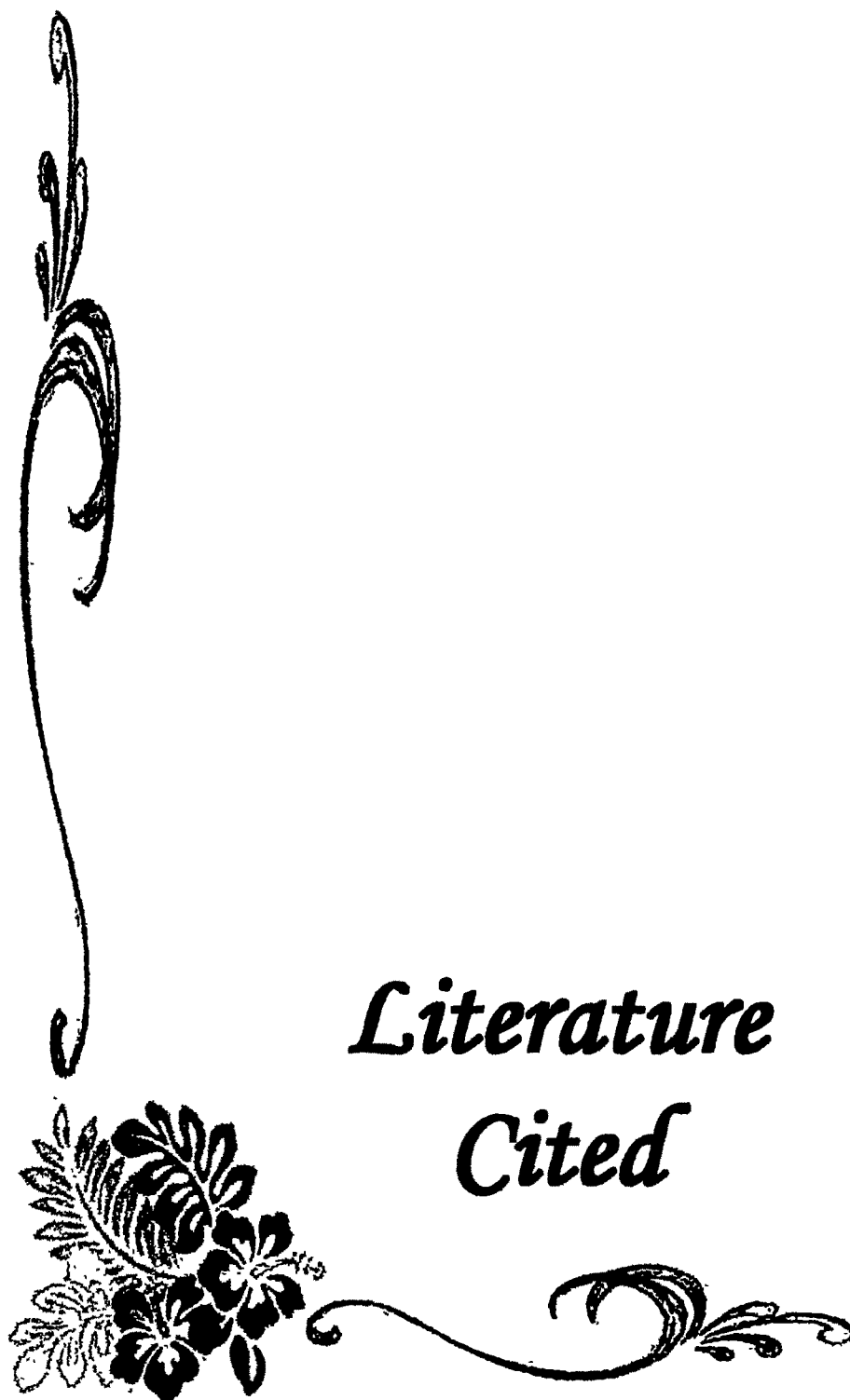
1. Analysis of variance showed significant differences among twenty seven characters, indicating much variability is available and useful for further study.
2. Among the genotypes, early days to flower initiation and early days to 50 per cent flowering was observed in the genotype BRJ 40813. While, genotype RSV 1345 was early to mature. The check M-35-1 followed by genotype SLV 188 recorded highest plant height.
3. Highest number of leaves per plant was observed in the genotype SLV 182. The genotype SLV 190 recorded higher third leaf area and leaf area index. While, the highest flag leaf area was recorded in the genotype SLV 181.
4. The genotype RSV 1785 recorded highest leaf dry weight, total dry weight, panicle length and fodder yield per plant. While, the genotype SLV 182 recorded maximum stem dry weight.
5. The relative water content was more in RSV 1850 and Lower transpiration index was observed in SLV 193.

6. The genotype RSV 1772 recorded higher stay green score at maturity. Maximum root:shoot ratio was observed in RSV 1516. While, lowest stomatal count, maximum panicle dry weight and maximum 100 seed weight were observed in the genotype SLV 181.
7. The genotypes SSRK 13-4 and RSV 1749 recorded maximum panicle width and number of primary branches respectively.
8. The highest chlorophyll content, biological yield per plant, panicle weight and grain yield per plant were observed in the genotype SLV 168. The highest harvest index was recorded in the genotype RSV 1786.
9. High estimates of genotypic and phenotypic coefficient of variation were recorded for leaf area index, stem dry weight, panicle dry weight, total dry weight and grain yield per plant.
10. The characters plant height, third leaf area, flag leaf area, stem dry weight, total dry weight, panicle weight and biological yield per plant expressed high estimates of heritability accompanied with high genetic advance.
11. Grain yield per plant recorded positive and significant association with the characters viz., plant height, number of leaves per plant, third leaf area, flag leaf area, leaf area index, leaf dry weight, stem dry weight, panicle dry weight, total dry weight, chlorophyll content, panicle width, panicle weight, number of primary branches, fodder yield per plant, biological yield per plant, 100-seed weight and harvest index.
12. Path coefficient analysis revealed the maximum contribution of days to physiological maturity, flag leaf area, total dry weight, chlorophyll content, transpiration index, number of primary branches, biological yield per plant and harvest index with grain yield per plant at both genotypic and phenotypic level.
13. The traits days to flower initiation, leaf area index, relative water content, panicle length, panicle width, fodder yield per plant and 100 seed weight recorded positive direct effect on grain yield per plant at genotypic level.

CONCLUSION

This study indicated, there is much scope for a breeder for making the selection of genotypes and improvement in yield can be possible due to positive correlation with yield and yield related drought contributing characters such as days to physiological maturity, flag leaf area, total dry weight, chlorophyll content, transpiration index, number of primary branches, biological yield per plant and harvest index.

The characters which show high GCV, PCV, heritability coupled with high genetic advance and characters showing positive association with yield and drought tolerance parameters could be considered for identifying drought tolerance genotypes. The genotypes BRJ-40813, RSV 1785, SLV 181, SLV 190 and SLV 168 were found superior for different yield contributing and drought tolerance parameters over other genotypes and checks. Hence, these genotypes can be advanced to next generation and can be used for drought tolerance purpose.



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ABSTRACT

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**GENETIC VARIABILITY AND CORRELATION STUDIES IN *RABI*
SORGHUM (*Sorghum bicolor* (L.) Moench) FOR DROUGHT
TOLERANCE**

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THESIS ABSTRACT

The present investigation entitled “Genetic variability and correlation studies in *rabi* sorghum (*Sorghum bicolor* (L.) Moench) for drought tolerance” was carried out at Sorghum Research Station, V.N.M.K.V., Parbhani during *rabi* 2015. Thirty seven genotypes of *rabi* sorghum including 3 checks (M-35-1, Phule suchitra and CSV-22 R) were selected and these genotypes were grown in RBD in three replications. These genotypes were evaluated and data were recorded for twenty seven parameters.

The present investigation revealed that, among the genotypes *viz.*, BRJ-40813, RSV 1785, SLV 181, SLV 190 and SLV 168 were found superior for different yield contributing and drought tolerance parameters over other genotypes and checks. The traits leaf area index, stem dry weight, panicle dry weight, total dry weight and grain yield per plant recorded high estimates of GCV and PCV. While, characters plant height, third leaf area, flag leaf area, stem dry weight, total dry weight, panicle weight and biological yield per plant expressed high estimates of heritability accompanied with high genetic advance.

Grain yield per plant recorded positive and significant association with the characters *viz.*, plant height, number of leaves per plant, third leaf area, flag leaf area, leaf area index, leaf dry weight, stem dry weight, panicle dry weight, total dry weight, chlorophyll content, panicle width, panicle weight, number of primary branches, fodder yield per plant, biological yield per plant,

100-seed weight and harvest index. Whereas, Path analysis revealed that the characters days to physiological maturity, flag leaf area, total dry weight, chlorophyll content, transpiration index, number of primary branches, biological yield per plant and harvest index recorded positive direct effect with grain yield per plant at both genotypic and phenotypic level. Hence, direct selection for the characters which show high GCV, PCV, heritability coupled with high genetic advance and characters showing positive direct association with yield and drought tolerance parameters could be considered for identifying drought tolerance genotypes.



Appendix

APPENDIX-I

Weekly Weather Data 2015-16										
WK	Period	Rainfall (mm)	R.D.	Temperature °C		Humidity (%)		EVP	BSS (Hrs.)	W. V. (Kmph)
				Max.	Min.	AM	PM			
1	01-07 Oct.	1.8	0.0	34.3	20.9	75	44	7.1	7.3	3.6
2	08-14 Oct.	0.0	0.0	35.1	19.4	73	32	7.8	9.0	2.2
3	15-21 Oct.	0.0	0.0	35.7	18.3	70	29	7.8	9.1	3.6
4	22-28 Oct.	0.0	0.0	35.1	19.5	70	31	5.9	8.2	3.0
5	29-0 Nov.	0.0	0.0	33.0	18.9	75	36	5.6	8.1	4.4
6	05-11 Nov.	0.0	0.0	34.0	16.9	68	25	6.1	7.5	4.6
7	12-18 Nov.	0.0	0.0	33.6	14.3	75	23	6.1	8.9	5.3
8	19-25 Nov.	0.0	0.0	32.1	18.4	78	36	6.6	6.4	6.2
9	26-02 Dec.	0.0	0.0	32.9	17.0	79	33	5.6	7.6	3.0
10	03-09 Dec.	0.0	0.0	32.6	13.8	71	26	5.3	9.3	3.1
11	10-16 Dec.	0.0	0.0	33.8	17.7	72	31	5.6	8.9	3.4
12	17-23 Dec.	0.0	0.0	32.9	16.1	71	31	5.8	8.5	4.7
13	24-31 Dec.	0.0	0.0	30.3	8.5	74	24	5.2	7.7	4.8
14	01-07 Jan.	0.0	0.0	32.8	11.11	73	21	5.2	9.4	2.8
15	08-14 Jan.	0.0	0.0	31.5	11.7	67	25	5.3	8.4	2.9
16	15-21 Jan.	0.0	0.0	30.6	13.9	63	28	5.3	8.0	3.9
17	22-28 Jan.	0.0	0.0	30.6	8.4	67	22	5.3	9.4	3.7
18	29-04 Feb.	0.0	0.0	34.4	12.7	67	16	6.3	9.9	3.5
19	05-11 Feb.	0.0	0.0	34.7	15.7	68	18	7.0	9.1	4.2
20	12-18 Feb.	0.0	0.0	34.6	17.6	64	16	7.5	8.5	5.2
21	19-25 Feb.	0.0	0.0	37.4	19.4	65	22	8.0	9.5	4.7
22	26-04 Mar	21.8	2	35.9	19.3	69	30	6.4	8.4	5.1