SCREENING AND VALIDATION OF PUTATIVE HEAT TOLERANT CHICKPEA (*Cicer arietinum* L.) GENOTYPES

Hanumantu Sirisha

Thesis

Master of Science in Agriculture

(Genetics and Plant Breeding)

DEPARTMENT OF GENETICS AND PLANT BREEDING

COLLEGE OF AGRICULTURE

RANI LAKSHMI BAI CENTRAL AGRICULTURAL UNIVERSITY

JHANSI – 284 003 UTTAR PRADESH, INDIA

August, 2023

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Thesis

Submitted to the

Rani Lakshmi Bai Central Agricultural University

Jhansi -284003, Uttar Pradesh, India

By

HANUMANTU SIRISHA

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF

Master of Science in Agriculture

(Genetics and Plant Breeding)

August, 2023

College of Agriculture
Rani Lakshmi Bai Central Agricultural University
Jhansi -284003

(Genetics and Plant Breeding)

CERTIFICATE

Certified that **Ms. Hanumantu Sirisha,** ID. No. **RLBCAU/AG/PG/053/21** has satisfactorily pursued her course of research for not less than IV semesters and that the thesis entitled **"Screening and validation of putative heat tolerant chickpea (*Cicer arietinum* L.) genotypes"** submitted by her to the Rani Lakshmi Bai Central Agricultural University, Jhansi 284003 (U.P.) in partial fulfilment of the requirements for the award of the degree of Master of Science in Agriculture in the subject of Genetics and Plant Breeding is the result of original research work conducted by her under my supervision and is sufficiently of a high standard to warrant its presentation to the examination.

I also certify that the thesis or part thereof has not been previously submitted by her for a degree/diploma of any University.

Date: 11/02/2023

Anshuman Singh

Dr. Anshuman Singh

Chairperson

COLLEGE OF AGRICULTURE
RANI LAKSHMI BAI CENTRAL AGRICULTURAL UNIVERSITY
JHANSI – 284003

(GENETICS AND PLANT BREEDING)

CERTIFICATE-II

This is to certify that the thesis entitled "**Screening and validation of putative heat tolerant chickpea (*Cicer arietinum* L.) genotypes**" submitted by **Ms. Hanumantu Sirisha**, ID. No. **RLBCAU/AG/PG/053/21** to the Rani Lakshmi Bai Central Agricultural University, Jhansi, 284003 (U.P.) for partial fulfilment of the requirements for the award of the degree of Master of Science in Agriculture in the subject of Genetics and Plant Breeding has been approved by the Student's Advisory Committee after the viva voce examination.

Student Advisory Committee

Date: 16/09/2023

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Acknowledgement

First and foremost, I am grateful to God for being the constant source of all inspiration and being by my side in every moment of difficulty. I would like to express my genuine purity, immense gratitude and sincere appreciation to my advisor and chairman of my advisory committee, **Dr. Anshuman Singh**, Scientist (Sr. scale) (Genetics and Plant Breeding), Rani Lakshmi Bai Central Agricultural University, Jhansi, for his valuable assistance, insightful suggestions, continual support, and vigilant scrutiny throughout every phase of this work, which enhanced the research effort.

Throughout the research process, I am thankful to all members of the advisory committee, **Dr. Rakesh Choudhary**, Scientist (Genetics and Plant Breeding), RLBCAU, Jhansi, **Dr. Sharwan Kumar Shukla**, Assistant Professor (Agricultural Biochemistry), RLBCAU, Jhansi and **Dr. Tejveer Singh**, Senior Scientist, Crop Improvement Division, ICAR-IGFRI, Jhansi for their productive guidance, helpful cooperation, timely suggestions, and encouragement.

I would like to offer my sincere gratitude to **Dr. A.K. Singh**, hounrable Vice-Chancellor, RLBCAU, Jhansi, **Dr. Anil Kumar**, (Director of Education), **Dr. Bijay Kumar Behera** (Dean of Fisheries) and **Dr. S. K. Chaturvedi**, former Dean (College of Agriculture) and **Dr. P. P. Jambulkar**, Head of the department (Plant Pathology) for their assistance and encouragement in the present study.

I am thankful to **Dr. Rumana Khan**, Assistant Professor, **Dr. M.K. Singh**, Assistant Professor and **Dr. A. Nishant Bhanu**, former Teaching cum Research Associate (Genetics and Plant Breeding), RLBCAU, Jhansi for their valuable suggestions and motivation throughout the research work.

I am equally grateful to **Dr. Piyoosh Babele** and **Dr. Shailendra Kumar** Teaching cum Research Associate (Agricultural Statistics) for their continuous support and help in accomplishing the entire research project.

*Nonetheless, I'd appreciate it to, my former senior **S. Bharath** & **Neeraj Kumar** and my present seniors **D. Keerthana Reddy**, **Sajan Kumar and P. Pavan** for their guidance and co-operation, as well as my fellow batchmates **Aneesha, Nikhil and Gupta** and also all my girls **Dharini, Sneha, Priyanka, Rupa and Thulasi** for their continuous love and support, moreover, all of the enjoyment, we had together over the past two years in particular, on top of respect their efforts and for being with me through thick and thin.*

*I am also thankful to all of my lovely juniors especially Mitali, Chetna, Bidyalaxmi, Asif, Shivam, Nikhila, Alekhya, Sumanjali, Tanmay, Sibani, Anuvarna, Athira**,** Varsha, Surbhi, Rohith, Rakshit, Bharti, Hari as well as my UG friends **Anweshita, Soumya and Bhagyalaxmi**, for their endless love and support.*

*A special thanks to all of the GPB department's technical assistant **Mr. Kartikey Sootrakar, Mr. Birendra Kumar and Ms. Jyoti** for their forever contributions, support, and assistance in executing the research work.*

I also express my sincere thanks to the Central Library RLBCAU, Jhansi for the facilities provided and grateful to all teaching and non-teaching staff of RLBCAU, Jhansi for my relaxed and comfortable study and stay at RLBCAU, Jhansi.

*At last but not the least, warmest, heartfelt and sincere admirations to my respected Amma **Smt. H. Santoshi** & Naanna **Shri H. Rama Rao**, and also my beloved Ammama **Smt. T. Laxmi** for their everlasting affection, loyalty, blessings and valuable suggestions throughout every phase of my life.*

RLBCAU, Jhansi ***(Hanumantu Sirisha)***

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LIST OF SYMBOLS AND ABBREVIATIONS

Symbols	Abbreviations	Symbols	Abbreviations
%	Per cent	LS	Late sown condition
/	Per	Mha	million hectare
<	Less than	NPP	Number of pods per plant
>	more than	NPB	Number of primary branches
°C	Degrees Celsius	NSP	Number of seed per pod
ANOVA	Analysis of variance	NSB	Number of secondary branches
CAT	Catalase	PCV	Phenotypic coefficient of variation
CC	Chlorophyll content	PV	Pollen viability
CF	Chlorophyll fluorescence	PH	Plant height
Cm	Centimeter	PP	Plant population
DFF	Days to 50% flowering	PR	Protein content
DFPI	Days to first pod initiation	PS	Pod set
DFP	Days to 50 % pod stage	R	correlation coefficient
DM	Days to maturity	RP	Rate of photosynthesis
et al.	Co-workers	ROS	Reactive oxygen species
GCV	Genotypic coefficient of variation	SC	Stomatal conductance
GAM	Genetic advance over mean	SOD	Superoxide dismutase
h^2bs	Heritability in broad sense	SYPP	Seed yield per plant
Ha	Hectare	TR	Transpirational rate
100-SW	Hundred seed weight	Viz.,	Namely

INTRODUCTION

Chapter I

INTRODUCTION

Chickpea is a self-pollinated crop of major global significance and is receiving increasing attention worldwide due to its nutritional value and resilience to harsh environmental circumstances (Devasirvatham & Tan *et al*., 2018). Based on the shape of the seeds, chickpea has two market classes: Kabuli and Desi (Madurapperumage & Amod, *et al*., 2021). Chickpeas have one of the highest nutritional compositions of any dry edible legumes. The average nutritional content of chickpea is 22 % protein, 67 % total carbohydrates, 47 % starch, 5 % fat, and 8 % crude fibre (https://www.usapulses.org/). Raw chickpea seeds have a nutritional value of 5 mg of iron, 4.1 mg of zinc, 160 mg of calcium, and 138 mg of magnesium per 100 g (Jukanti *et al*., 2012).

It is usually grown as a *Rabi* crop in various parts of the world including India, West Asia, East Africa, North America and Latin America (Rani *et al*., 2020). Chickpea is pronounced with different names such as Gram, Bengal gram, Garbanzo bean, Chana etc. India accounts production share of 65% globally and stands first which is followed by Australia with 14% share (Merga & Haji, 2019). According to FAOSTAT, 2021-22 with a total area of 10.94 million hectares and an approximate production of 11.91 million tonnes, chickpeas are one of India's most significant pulse crops. It is largely grown as a rainfed crop with minimal external input. As per E&S Division, DA&FW(2021-22), a total 0.49 Mha area in Bundelkhand region contributed 0.48 million tones production leads to the productivity of 843kg/ha. According to DA & FW, Fourth Advance Estimates Production of Food grains targets 13.75 million tonnes gram production in the year 2022-23.

Bengal gram is an annual legume crop that belongs to the tribe *Cicereae*, family *Fabaceae*, and genus *Cicer*. It is an autogamous diploid species with a genomic size of about 738 mega base pairs and sixteen chromosomes in the somatic cells.

Due to changing cropping systems and intensive cropping practices particularly after long duration of paddy often sowing of chickpea is delayed. As a result, the extremely sensitive chickpea reproductive stage encounters high temperatures (Krishnamurthy *et al*., 2011). The reproductive systems of both males and females have been significantly affected, resulting in inviable pollen, inviable ovules, and a lack of stigma receptivity. High temperatures shorten the lifespan of the crop because they enhance up rate of maturation (Summerfield *et al*., 1984). Under late sown condition, chickpea plants' establishment become difficult due to slow growth where as high temperature at the reproductive stage limits pod formation and grain development. When flowering meet high temperatures, the pollen becomes empty, shriveled, and shrunken, which reduces its functionality. Such sterile pollen accelerates flower drop and does not result in fertilization. Negative effects on pollen germination and pollen tube expansion are also noted (Devasirvatham *et al*., 2012).

Heavy yield losses occur when plants are exposed to temperatures higher than 35°C during the flowering and podding stages. Even a 1°C increase in temperature over the threshold has been reported to occur in significant losses in chickpea production (Devi *et al*., 2022).

When compared to other abiotic stresses, heat stress initially received less attention, but in recent years, that interest has been quietly growing as farmers are allocating more area to chickpea after paddy harvest due to better returns. Of all the stages of the crop, reproductive stage is the most sensitive and highly affecting the yield of the crop.

First reason for heat stress during reproductive period is shift in cultivation of chickpea from growing during cool seasons for long duration to warm seasons for short duration. The second reason can be attributed to high cropping intensity as a consequence chickpea is sown late in the season. The third reason is due to unappealing climate changes (Gaur *et al*., 2018).

Over the coming decades, the global climate change will have a significant impact on the biological functions of plants, and the current trends in warming have already commenced to have an effect on a variety of crop species and agriculture. The chickpea grows best between 10 to 30 °C and production of chickpeas may be significantly impacted by higher temperatures, such as those around 35° C, during the flowering stage (Kumari *et al*., 2020).

The chickpea crop's germination and establishment have been significantly impeded during sowing. The ideal temperature range for chickpea seed germination is between 15 and 35°C. Chickpea seeds exhibited decreased germination frequency at a temperature of 40 °C. The chickpea seedling that has already germinated may suffer from increased heat stress as well. For the development of chickpea seedlings, temperatures over 30 to 35 °C proved stressful, while temperatures above 40 °C had a fatal effect on seedling length(Kumari *et al*., 2020).

The detrimental effects of heat stress not only affecting the morphological traits but also leads in alterations of physiological and biochemical traits. In order to identify, develop, and discover thermo tolerant cultivars, it is necessary to comprehend how heat stress affects several physiological variables. The flow of water ions and inorganic solutes, photosynthesis, and respiration may all be affected by the membrane disruption caused through high temperatures. Therefore, the degree of electrolyte leakage determines the cell membrane's thermo stability (Jain, 2014).

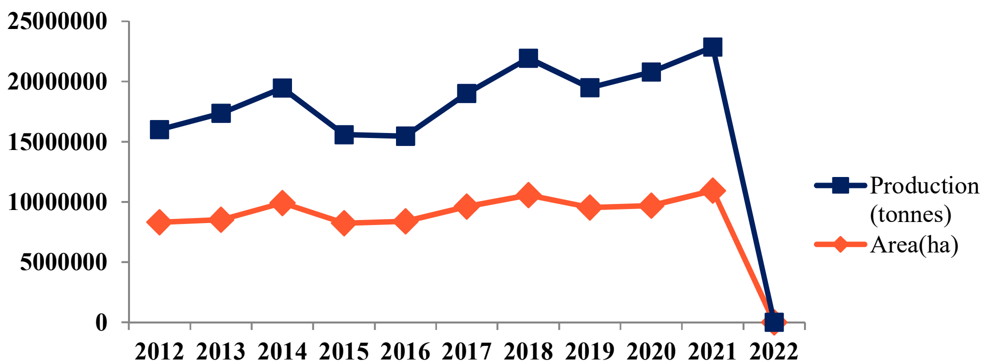


Fig.1.1 Area and Production of chickpea from 2012-2022 in India

FAO, 2022. PFAOSTAT: Production: Crops and livestock products

https://www.fao.org/faostat/en/#data/QCL

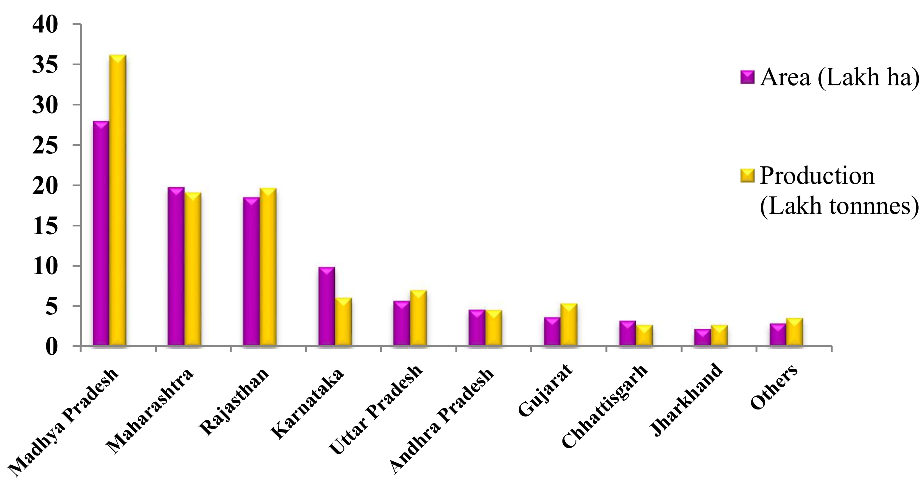


Fig. 1.2 Area and production of chickpea under different states in India

Annual Report [2021-22] - Directorate of Pulses Development, Bhopal

https://dpd.gov.in/Annual%20Report%20(2021-22).pdf

An effective technique to assess the harm caused by stress on PSII is to measure the chlorophyll fluorescence parameter such as Fv/Fm or the maximal quantum efficiency of PSII (photo system II). Compared to sensitive chickpeas, heat-tolerant chickpeas experienced greater Fv/Fm, better photosynthetic rates, and higher grain yields (Zhou *et al*., 2020).

Furthermore, in hot, dry climates, high temperatures are related to water stress which leads to physiological and biochemical changes that serve as adaptive mechanisms. Compatible solutes like proline, sugars, and polyols are frequently thought of as a fundamental approach for ensuring the development and survival of chickpea plants under abiotic stress as they accumulate low-molecular-weight chaperones. Through the excessive formation of reactive oxygen species (ROS) such superoxide radicals (O_2), hydroxyl (OH), singlet oxygen, and hydrogen peroxide (H_2O_2), such unfavourable circumstances also induced oxidative metabolism in plants (Harsh et al., 2016). A high temperature can disrupt enzymes regulations and metabolic pathways, which increases the number of potentially harmful reactive oxygen species (ROS). As many physiological processes governed by enzymes that are subject to varying degrees of heat stress, ROS causes oxidative damage to membrane lipids, proteins, and DNA.

Heat stress has a direct impact on photosynthesis, especially PS II, in chickpea. To conserve water, plants cultivated in high-stress conditions such as high temperatures decrease stomatal conductance. As a result, CO_2 uptake is decreased and photosynthetic rate falls, which causes less assimilate generation for plant growth and yield (Kumar *et al*., 2020).

The best method for estimating the relationships between significant yield components is path coefficient analysis paired with correlation. These methods will be implemented in the breeding process to maximise the yield potential for raising chickpea productivity as well as developing better high yielding varieties. Correlation, which is the mutual link between the variables, helps researchers choose the best methods for choosing superior genotypes. Breeding techniques would be extremely effective when there is a positive connection between the primary yield components, but selecting would be very challenging in a reversed scenario. Due to the reciprocal cancellation of the component features, the estimations of correlation coefficients alone can frequently be deceptive. Therefore, a path analysis together with correlation is a more useful tool when considering aspects that contribute to yield (Agrawal *et al*., 2018).

Simultaneously the study of genetic divergence is also crucial in order to evaluate genetic variability, correlate multiple variables to yield, and identify high-yielding genotypes with superior architecture under heat stress conditions (Yücel *et al*., 2006).

Research gap

The current chickpea germplasm need to be evaluated and validated in order to find out the genotypes that are heat tolerant and the underlying processes since information regarding genotypic diversity in terms of particular morpho-physiological and reproductive features in chickpea is rarely available. In order to identify heat-tolerant chickpea genotypes under conditions in the field, this study established an efficient, clear, and reliable screening approach with well-defined attributes. The screening procedure can be utilised to find the chickpea germplasm with improved heat tolerance for introduction into commercial breeding programmes. The present study entitled **"Screening and validation of putative heat tolerant chickpea (*Cicer arietinum* L.) genotypes" was performed under the following objectives –**

i) Phenotyping of chickpea germplasm accessions for identification of heat tolerant genotypes.

ii) Validation of promising heat tolerant genotypes based on morpho-physiological and biochemical traits.

iii) Assessing character association and genetic divergence in chickpea germplasm.

REVIEW

OF

LITERATURE

Chapter II

REVIEW OF LITERATURE

In this chapter a brief review of work done by different scientists among all over the globe has been reported based on the current research programme entitled **"Screening and validation of putative heat tolerant chickpea (*Cicer arietinum* L.) genotypes"** under the following subheads –

2.1 Morphological Traits

2.1.1 Genetic variability

2.1.2 Heritability and genetic advance

2.1.3 Correlation and path analysis

2.1.4 Genetic divergence

2.2 Physiological and Biochemical Traits

2.1 Morphological Traits

2.1.1 Genetic variability

The tendency of individual genotypes in a population to differ from one another is known as genetic variability. The degree of variability present in the germplasm may be determined using genetic factors like genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) which can be used for future breeding programme.

Bharathi *et al.* (2022) analysed twenty six chickpea genotypes and found that biological yield per plant had high PCV and GCV depicted significant genetic variability for these properties in the material.

Dhopre, Pavan, (2022) analysed 25 chickpea genotypes at Sehore, Madhya Pradesh. He observed that high GCV and PCV have been noted for the number of seeds per plant, number of pods per plant, biological yield per plant, seed yield per plant, number of unfilled pods per plant, and hundred seed weight under late-sown conditions.

Katkani *et al.* (2022) screened 42 advanced chickpea breeding lines and noticed that number of effective pods per plant had the highest GCV (%) and PCV (%) (30.2% and

48.1%, respectively), followed by total number of pods per plant (26.0% and 40.2%), seed yield per plant (24.1% and 32.7%), and 100 seed weight (21.7% and 25.7%).

Nikhitha and Walia (2022) carried out an experiment on twenty seven chickpea genotypes conducted in RBD. Moderate was observed for plant height, number of pods per plant, principal branches, and yield per plant, harvest index, and test weight.

Perumalla *et al.* (2022) evaluated twenty three genotypes of chickpea and found that high GCV and PCV were identified for the number of pods per plant, root dry weight, and nodule dry weight, but moderate GCV and PCV were observed for the number of seeds per plant, yield of seeds per plant, and nodule fresh weight.

S. Kumar *et al.* (2020) carried out experiment in fifty chickpea germplasm and observed the highest phenotypic and genotypic coefficients of variation (PCV and GCV) for 100-seed weight, biological yield per plant, grain yield per plant, and number of primary branches per plant.

Jain *et al.* (2020) evaluated 40 chickpea genotypes under late sown condition. He concluded that the number of pods per plant had the highest PCV and GCV.

A. Kumar *et al.*(2019) conducted an experiment on forty five genotypes of chickpea and noticed that high levels of phenotypic and genotypic coefficients of variation were observed for 100 seed weight and the number of pods per plant. Yield and the factors that contributed to it had genotypic coefficients of variation that varied from 0.46 to 26.09. Plant height, yield of grains per plot, and number of pods per plant all showed moderate genotypic coefficients of variation.

Gediya *et al.* (2019) examined genetic variability in fifty seven chickpea genotypes. Secondary branches per plant, pods per plant, seeds per pod, seeds per plant, hundred seed weight, seed yield per plant, and harvest index all had higher PCVs than GCVs.

Aswathi & Jayamani, (2019) conducted an experiment based on fifty two desi chickpea genotypes. The yield per single plant showed the highest PCV and GCV, followed by the hundred seed weight, number of secondary branches, number of pods per plant, number of seeds per plant, and the height of the first pod.

Paul *et al.* (2018) evaluated a set of two hundred and ninety six F8–9 recombinant inbred lines (RILs) of the cross ICC 4567 (heat sensitive) × ICC 15614 (heat tolerant) under field conditions at ICRISAT, Patancheru, India and showed significant genotypic coefficient of variation (GCV) (23.29–30.22%) and phenotypic coefficient of variation

(PCV) (25.69–32.44%) for the traits such as FPod(number of filled pods), TS(total number of seeds), %pod set and grain yield.

Thakur *et al.*(2018) screened twenty chickpea germplasm and observed that seed index (19.17) and seeds consistent with pod (18.30) exhibited largest GCV while for PCV, the biological weight (21. 55) and the seed index (21.99) were also noted.

Thakur *et al.* (2018) screened hundred chickpea germplasm lines and noticed that seed yield per plant (32.76%), number of secondary branches (32.6%), test weight (31.28%), total number of seed per plant (28.68%), and number of pods per plant (25.7%) exhibited highest GCV.

Chopdar *et al.* (2017) studied twenty chickpea genotypes and found that traits such as seed yield per plant, and 100- seed weight all exhibited high genotypic coefficient of variation.

Kumar *et al*. (2017a) analysed twenty nine chickpea genotypes sown under heat stress environment and found that the number of pods per plant, the weight of 100 seeds, and grain yield all showed elevated GCV and PCV.

Kumar *et al.* (2017b) studied thirty six desi chickpea genotypes sown at Bihar Agricultural University, Sabour and noticed that biological yield, effective pods per plant, total pods per plant, 100-seed weight, and primary branches per plant, grain yield per plot observed as the highest GCV and PCV.

Devasirvatham *et al.* (2015) assessed genetic variability for heat tolerance in one hundred and sixty genotypes of chickpea grown in two environments (heat stressed/late sown and non-stressed/optimal sowing time) at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India and observed that phenology, growth, yield components, and grain yield all showed significant genetic variation.

Babbar (2014) examined twelve promising chickpea lines sown under normal and late conditions. In both normal and late sown conditions, high PCV and GCV accounted for the attributes seed yield per plant, number of effective pods per plant, number of total pods per plant, seed size, and harvest index.

Kuldeep, Rajkumar, (2014) studied hundred advanced breeding lines grown under heat stress conditions at Jabalpur and observed that seed yield per plant, 100-seed weight, harvest index, number of pods per plant, overall number of pods per plant, and number of secondary branches exhibited high GCV and PCV.

Yucel *et al.* (2006) studied fifteen chickpea genotypes and revealed that the 1000 seed weight had the strongest genotypic variation, followed by the number of seeds produced per yield.

2.1.2 Heritability and genetic advance

Heritability can be defined as proportion of phenotypic variance among individuals in a population due to genetic variance. High heritability along with high genetic advance results in additive gene action which reflects the degree of gain in a character act as selection criteria for breeder helps in identifying promising suitable genotypes.

Bharathi *et al. (*2022) carried out an experiment on twenty six chickpea varieties along with one check and found that high heritability was observed high heritability along with high genetic advance as a percent of mean for the traits of biological yield per plant, seed index, harvest index, number of pods per plant, seed yield per plant, and plant height, indicating that these characteristics were primarily controlled by additive gene effects

Dhopre, Pavan, (2022) analysed 25 chickpea genotypes at Sehore, Madhya Pradesh and revealed that plant height, total seeds per plant, total pods per plant, number of empty pods per plant, 100 seed weight per plant, harvest index, and seed yield per plant under late sown environments were traits with high heritability coupled with high genetic advance as a percentage of mean. These traits can potentially be considered as positive amenities for improvement through selection.

Nikhitha and Walia (2022) carried out an experiment on 27 chickpea genotypes conducted in RBD and observed for plant height, number of pods per plant, primary branches, yield per plant, harvest index, and test weight, with good heritability and high genetic advance. Several characteristics, such harvest index, number of pods per plant, primarily branches, plant height, and test weight, showed a significant positive correlation with seed yield per plant, whereas harvest index followed by biological weight in terms of immediate effects had a much greater effect on seed yield per plant.

Katkani *et al.* (2022) screened 42 advanced chickpea breeding lines and noticed that significant heritability combined with high genetic advances as a percentage of mean observed for 100 seed weight. The promising lines with high seed yield per plant were identified as JG 2020-26 (28.06 g), JG 2020-27 (27.08 g), and JG 2020-31 (26.51) performing superior in high temperature stressed environment.

Jain *et al.* (2020) evaluated forty chickpea genotypes under late sown condition and found that days to maturity had the highest broad sense heritability (h^2b), followed by days to 50% flowering and 100-seed weight.

S. Kumar *et al.* (2020) carried out experiment in fifty chickpea germplasm. 100 seed weight, biological yield per plant, primary branches per plant, grain yield per plant, effective pods per plant, total number of pods per plant, secondary branches per plant, plant height, days to 50% flowering, and days to maturity all showed high heritability combined with high genetic advance as a percentage of mean indicating that these characteristics can be considered as favourable attributes for selection.

Aswathi & Jayamani, (2019) conducted an experiment based on fifty two desi chickpea genotypes. For single plant yield, hundred seed weight, number of secondary branches, pods per plant, number of seeds per plant, and initial pod height, strong heritability and a high estimate of genetic advance expressed as a percentage of mean were observed.

A. Kumar *et al.* (2019) conducted an experiment on forty five genotypes of chickpea and noticed days to 50% flowering, 100 seed weight, and number of pods per plant all showed high heritability. The 100 seed weight, number of pods per plant, and grain yield per plot all showed strong heritability along with high genetic advance.

Paul *et al.* (2018) evaluated a set of of two hundred and ninty six F8–9 recombinant inbred lines (RILs) of the cross ICC 4567 (heat sensitive) × ICC 15614 (heat tolerant) under field conditions at ICRISAT, Patancheru, India and found that FPod(number of filled pods), TS(total number of seeds),%Pod Set, and GY(grain yield) have strong heritabilities (80.89-86.89%) in all heat stress environments.

Thakur *et al.* (2018a) screened hundred chickpea germplasm lines and noticed that seed yield, number of secondary branches, number of pods per plant, test weight, and total number of seed per plant exhibited significantly higher heritability in percent with high genetic advance in percentage of mean.

Thakur *et al.*(2018b) screened twenty chickpea germplasm and observed that the best heritability was found with respect to number of seeds consistent with plant, followed by number of pods consistent with plant, variety of seeds per pod, and harvest index.

Chopdar *et al.* (2017) studied twenty chickpea genotypes and found that traits such as seed yield per plant, and 100- seed weight all exhibited high heritability along with genetic advance over mean values and were discovered to be more heavily regulated by additive gene action.

Kumar *et al.* (2017a) analysed twenty nine chickpea genotypes sown under heat stress environment. He observed number of pods per plant and 100-seed weight had high heritability with high genetic advance as a percentage of mean.

Kumar *et al.* (2017b) studied thirty six desi chickpea genotypes sown at Bihar Agricultural University, Sabour. He noticed that plant height, number of primary branches per plant, number of secondary branches per plant, total number of pods per plant, effective pods per plant, biological yield, 100 seed weight, grain yield per plant, and grain yield per plot all had high heritability and genetic advance over the mean.

Babbar (2014) examined twelve promising chickpea lines sown under normal and late conditions. Flower initiation (days) and 50% flowering (days) exhibited high heritability, as well as high genetic advance as a percentage of mean.

Kuldeep, Rajkumar, (2014) studied 100 advanced breeding lines grown under heat stress conditions at Jabalpur. Seed yield per plant had a high heritability with a high genetic advance as a percentage of the mean, followed by 100-seed weight, harvest index, number of effective pods per plant, and total number of pods per plant was observed.

Kaloki (2012) examined one hundred and ten chickpea genotypes under field conditions and found that Days to 50% flowering, days to 75% maturity and 100 seed mass all have high heritability estimates as a result, these traits can be effectively improved by selection.

Canci and Toker (2009) screened three hundred and seventy seven chickpea accessions and found that two desi chickpea varieties ACC 316 and ACC 317 showed heat resistance under field conditions. He concluded that seed weight was the trait with the highest heritability and least affected by adverse external conditions, and it should be exploited in early breeding selections.

Yucel *et al*. (2006) studied fifteen chickpea genotypes and found that seed number, 1000-seed weight, and number of full pods had higher heritability than the other traits.

2.1.3 Correlation and path coefficient analysis

In order to understand the nature of the correlations between grain yield and the factors that contribute to it, as well as determine the factors that have the greatest influence on yield and should be considered when making selections, path coefficient analysis has been widely employed in crop breeding programmes. The direct and indirect impacts of cause factors on effect variables are shown through path analysis.

Ningwal *et al.* (2023) examined 57 chickpea genotypes grown in *Rabi* 2021-22. Correlation analyses indicated that biological yield, number of secondary branches per plant, and number of pods per plant were all positively and substantially correlated with the yield of seeds per plant. The path analysis revealed that biological seed yield per plant had the most positive direct influence on seed yield per plant and so may be regarded as important characteristics for chickpea yield improvement.

Bharathi *et al.* (2022) carried out an experiment on twenty six chickpea varieties along with one check and found that biological yield per plant and seed production per plant both had a significant direct impact on grain yield per plant at the phenotypic level resulting in the highest contributions to yield per plant

Dhopre, Pavan, (2022) analysed 25 chickpea genotypes at Sehore, Madhya Pradesh. Plant height, total seeds per plant, total pods per plant, number of empty pods per plant, 100 seed weight per plant, harvest index, and seed yield per plant under late sown environments were traits with high heritability coupled with high genetic advance as a percentage of mean. These traits can potentially be considered as positive amenities for improvement through selection.

Katkani *et al.* (2022) screened 42 advanced chickpea breeding lines and noticed that TNPPP (total number of pods per plant), BYPP (biological yield per plant) and 100 seed weight showed significant positive and direct effect on SYPP (seed yield per plant) in early sown and NEPPP(number of effective pods per plant) and BYPP(biological yield per plant) in late sown condition.

Nikhitha and Walia (2022) carried out an experiment on 27 chickpea genotypes conducted in RBD and found that several characteristics, such harvest index, number of pods per plant, primarily branches, plant height, and test weight, showed a significant positive correlation with seed yield per plant, whereas harvest index followed by biological weight in terms of immediate effects had a much greater effect on seed yield per plant.

Perumalla *et al*. (2022) evaluated twenty three genotypes of chickpea. The correlation coefficient study revealed a substantial positive phenotypic and genotypic relationship between seed yield per plant and harvest index (0.84 and 0.87), biomass (0.52 and 0.50), and number of seeds per pod (0.36 and 0.34), as well as biomass and number of seeds per pod. The path analysis results showed that seed yield was positively and directly influenced by harvest index, biological yield, shoot fresh weight, number of seeds per pod, number of pods per plant, and seed index.

Jain *et al.* (2020) evaluated forty chickpea genotypes under late sown condition. Path coefficient analysis revealed that the following nine independent factors number of seeds per pod, number of pods per plant, number of primary branches per plant, plant height from ground to first pod (cm), and days to 50% flowering had a positive and direct impact on grain yield.

S. Kumar *et al.* (2020) carried out experiment in fifty chickpea germplasm. The study of path coefficients for grain yield per plant determined that biological yield, harvest index, secondary branches, canopy temperature during vegetative stage, and effective pods per plant had a major effect on yield per plant.

A. Kumar *et al.* (2019) conducted an experiment on forty five genotypes of chickpea and noticed that according to path analysis, the number of pods per plant, plant height, and days to 50% flowering factors exhibited significantly maximum impact on grain yield.

Gediya *et al.* (2019) examined genetic variability in fifty seven chickpea genotypes and observed that pods per plant (0.198), seeds per plant (0.672), harvest index (0.170), and 100 seed weight (0.665) all had a significant direct influence on seed yield per plant according to the path coefficient analysis.

A. Kumar *et al.*(2019) conducted an experiment on forty five genotypes of chickpea and noticed that according to path analysis, the number of pods per plant, plant height, and days to 50% flowering factors exhibited significantly maximum impact on grain yield.

Omer & Karadavut (2018) studied a total of 22 chickpea genotypes including both registered varieties (18) and domestic populations (4). Correlation analysis revealed positive and significant relationships between the number of pods per plant and the number of seeds per plant (r=0.934**), the number of seeds per plant and the 100-seed weight (r=0.826**), the number of seeds per plant and the yield per plant (r=0.908**), and the seed yield per plant and the 100-seed weight (0.614**), yield (0.602**). According to the path analysis, the direct influence of plant height on yields was found to be negative with -0.124, but the direct effects of first pod height, number of pods per plant, and number of seeds per plant were found to be positive with 0.096, 0.079, and 0.841, respectively.

Paul *et al.* (2018) evaluated a set of two hundred and ninety six F8–9 recombinant inbred lines (RILs) of the cross ICC 4567 (heat sensitive) × ICC 15614 (heat tolerant) under field conditions at ICRISAT, Patancheru, India. The path analysis results revealed that TS (total number of seeds) was the major direct contributor to GY(grain yield) and FPod (number of filled pods) was the major indirect contributor to GY in heat stress environments.

Thakur *et al.* (2018a) screened hundred chickpea germplasm lines and noticed that test weight (0.728), harvest index (0.439), total number of pods per plant (0.436), total number of secondary branches (0.391), and total number of seeds per plant (0.366) all had highly significant positive correlations with seed yield per plant.

Thakur *et al.* (2018b) screened twenty chickpea germplasm and observed the genotypic and phenotypic levels of seed yield were directly and favourably influenced by the number of branches, variety of plant pods, number of plant seeds, organic yield, and harvesting index, which had the greatest effect on plant yield.

Kumar *et al.* (2017a) analysed twenty nine chickpea genotypes sown under heat stress. The path analysis showed that the plant stand at harvest and the number of pods per plant had the significant direct impact on seed yield. On the basis of seed yield, Phule G-13110 (2080 kg/ha), RKG 11-155 (2038 kg/ha), PBC 501 (1920 kg/ha), and CSJ (1907 kg/ha) were indicated as potential heat tolerant genotypes.

Chopdar *et al.* (2017) studied twenty chickpea genotypes and found that days to maturity, primary branches per plant, biomass per plant, harvest index, protein content, and number of seeds per pod were key factors impacting seed yield both directly and indirectly.

Kumar *et al.* (2017b) studied thirty six desi chickpea genotypes sown at Bihar Agricultural University, Sabour. According to the path analysis, the chlorophyll index, effective pods per plant, and 100-seed weight had the maximum direct impact on seed yield. IPC2010-62, BRC-2, Sabour chana-1, and GNG2215 were identified as potential heat tolerance genotypes based on seed yield.

Devasirvatham *et al.* (2015) assessed genetic variability for heat tolerance in 167 genotypes of chickpea grown in two environments (heat stressed/late sown and non-stressed/optimal sowing time) at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India. He observed that plant biomass, pod number, filled pod number, and seed number per plant were positively correlated where as phenology (as measured by days to first flower, days to 50% flowering, and days to first pod) was negatively correlated with grain yield at high temperatures.

Kuldeep, Rajkumar, (2014) studied 100 advanced breeding lines grown under heat stress conditions at Jabalpur. According to the path analysis, the number of effective pods per plant and 100-seed weight had the greatest direct effect on seed yield. Heat tolerant lines have been identified based on seed yield as ICCV 84251, ICCV 04303, ICCV 06108, ICCV 03209, and ICCV 04312.

Babbar (2014) examined 12 promising chickpea lines sown under normal and late conditions. The number of effective pods per plant had the maximum significant influence on seed yield, according to path coefficient analysis. KAK 2, JGK 2, ICCV 07311 and ICCV 06301 have been determined as heat tolerant lines based on minimal yield loss %.

Kaloki (2012) examined one hundred and ten chickpea genotypes under field conditions and found that the number of pods per plant had the highest significant influence on grain yield according to path coefficient analysis**.**

Yucel *et al.* (2006) studied fifteen chickpea genotypes and revealed that the path coefficient analysis using seed yield per plant as a dependent variable indicated that all other variables, with the exception of days to flowering, initial pod height, and total pod number, indicated strong positive direct impacts.

2.1.4 Genetic divergence

Genetic divergence studies gives insight into the genetic variation of the available genotypes, thus becomes the major goal in assessment of efficient germplasm lines in any breeding program. If the significance of the genotype x environment (G E) interaction is unclear, plant breeders can utilise cluster analysis to identify patterns of genotypic performance and environmental productivity.

Qulmamatova, (2023) analyzed seventy one genotypes based on morphological and yield traits and revealed that on the basis of cluster analysis chickpea genotypes were grouped into six clusters. Clusters I and VI had the maximum yield, whereas clusters II and III had taller genotypes. These findings may be useful in future breeding programmes which include chickpea hybridization for yield enhancement.

Tanwar *et al.* (2022) analyzed sixty genotypes in RBD design based on eleven morpho-physiological traits under both timely and late sown condition. Based on cluster analysis the germplasm lines grouped into eight and seven clusters under normal sown and late sown condition respectively. Under timely sown conditions, the highest inter-cluster distance was recorded between clusters IV and VII. However, it was noticed between clusters VI and VII under late conditions. This demonstrated that genotypes in this cluster group were substantially divergent from one another, signifying a high level of variation within and across groups that may be utilised in breeding strategies.

Aswathi & Jayamani, (2019) conducted an experiment based on fifty two desi chickpea genotypes. According to cluster analysis, cluster I was determined to be the highest with respect to 16 genotypes, whereas clusters VI and VIII found to be smallest with respect to one single genotype each(CB PLS 5433 and CB RC 110-2).

Jha *et al.* (2018) evaluated seventy eight chickpea genotypes for the identification of heat tolerant genotypes. Higher to moderate heat tolerance was demonstrated by RVG 203, RSG 888, JAKI 9218, GNG 469, and IPC 06-11. According to cluster analysis, the most effective and efficient selection indices for determining a heat resistant genotype, are MP, YI, GMP, and SSI.

Jha, Uday Chand, (2017) screened forty two genotypes under both normal and heat stress condition grouped all the genotypes into 4 groups based on cluster analysis and identified four genotypes named GNG1958, ICC 15955, IPC 09-102 and ICC15104 tolerant to HS.

Pandey, (2015) conducted an experiment on hundred promising chickpea genotypes and revealed that 100 genotypes were grouped into sixteen clusters. The cluster I consisted of maximum 29 genotypes, followed by Cluster II, cluster V and cluster VI, which had 26, 13 and 12 genotypes, respectively.

Krishnamurthy *et al.* (2011) screened the reference collection of chickpea germplasm for high temperature tolerance in two locations in India (Patancheru and Kanpur) grouped into 5 clusters based on HTI(Heat Tolerance Index) and reported stable tolerant (n = 18), tolerant only at Patancheru (n = 34), tolerant exclusively at Kanpur (n = 23), moderately tolerant (n = 120), and stable sensitive (n = 82).

2.2 Physiological and Biochemical traits

Changes in physiological activities in response to temperature are significant across a temperature range of 10-35°C, although exposure to temperatures below or above this range may cause damage to the photosynthetic system. Furthermore, various activation of antioxidant enzymes during heat stress can also occur due to over accumulation of reactive oxygen species under stressed conditions leads to adaptation and survival of plant growth and development.

Arslan, (2023) examined the impact of heat stress on the physiological and biochemical reactions of heat-acclimated and non-acclimated cultivars of chickpea (*Cicer arietinum* L.; Diyar and Küsmen-99) and proved that by increasing the amount of anthocyanins and flavonoids and the activity of antioxidant enzymes (SOD and POD) under heat stress, the cultivars made an effort to reduce reactive oxygen species (ROS). Seedlings acclimated to higher temperatures were more resistant in terms of ChlF characteristics, and Diyar had superior PSII photochemical activity.

Sharma *et al.* (2023) studied two heat susceptible(HS) and two heat tolerant(HT) chickpea genotypes and revealed that the greater expression of peroxidase, superoxide dismutase, and catalase in HT genotypes influences the tolerance responses, according to biochemical characterisation of HS and HT genotypes. The resistant genotypes showed consistent and non-significant reductions in chlorophyll content, whereas the susceptible genotypes had a substantial decline.

Devi *et al.* (2022) analyzed thirty ninety chickpea genotypes grown in both normal and late sown condition based on 7 physiological traits and 4 yield and yield related traits. Out of these, GNG1969, GNG1488, PantG186, RSG888, CSJ315, and GNG1499 showed higher heat tolerance, as evidenced by small reductions in pollen viability, pollen germination, and pod set%, as well as high seed yield plant-1 and less damage to membranes, photosynthetic ability, leaf water status, and oxidative processes occurred on both the environments.

Bindra, Shayla, *et al*. (2021) evaluated 6 chickpea genotypes including 21 interspecific derivatives (from the cross C. arietinum ICCV96030 × C. pinnatifidum IC525200), their parents, 10 elite genotypes, and three checks (drought tolerant, heat tolerant, drought and heat susceptible) under three conditions: timely sowing with irrigation, timely sowing with drought stress, and late sowing leading to heat stress where he revealed thet one derivative line (GLW669) showed tolerance to heat and GLW605 was identified as a promising donor for both drought and heat tolerance based on estimated stress susceptibility indices for seed yield.

Koskosidis *et al*. (2021) conducted an experiment in two different seasons and examined five genotypes under field condition where he revealed Amorgos seemed to be a promising variety with high nutritional value, as it demonstrated the greatest values in terms of bioactive characteristics and antioxidant activity in both sowing periods and high protein content during the off-season planting.

Kumar *et al.* (2020) investigated four genotypes namely BG 240 and JG 14 (relatively heat tolerant), SBD 377 (moderately tolerant), and ICC 1882 genotypes (relatively heat sensitive). Heat tolerant genotypes BG 240 and JG 14 maintained a higher level of quantum yield of PS II (Fv/Fm ratio) under heat stress conditions, indicating the involvement of xanthophyll cycle pigments in chickpea heat tolerance.

Makonya *et al.* (2019) examined four chickpea genotypes by using chlorophyll fluorescence, chlorophyll concentrations, gas exchange and grain yield and found that two genotypes were resilient to heat, with a Fv/Fm of 0.83-0.85 at the warmer location along with higher photosynthetic activity, whereas the two sensitive genotypes had a lower Fv/Fm of 0.78-0.80. He reported that chlorophyll fluorescence and leaf carbohydrates are effective techniques for field selection of heat-tolerant chickpea genotypes.

Meena *et al.* (2014) conducted an experiment based on three genotypes of chickpeas—Pusa 256, RSG 888, and JG 11 to examine how high temperature stress affected several physiological and biochemical parameters. High temperature stress reduced RWC(relative water content), MSI(membrane stability index), chlorophyll content, dry matter, and leaf area in all chickpea genotypes while increasing the activity of antioxidant enzymes including POX (Peroxidase), GR (Glutathione reductase), and SOD (Superoxide dismutase). Compared to Pusa 256 and JG 11, RSG 888 had improved seedling development parameters under high temperatures.

MATERIALS

AND

METHODS

Chapter- III

MATERIALS AND METHODS

In the present study entitled "**Screening and validation of putative heat tolerant Chickpea (*Cicer arietinum* L.) genotypes**" a total of 18 heat tolerant genotypes were validated in both timely sown and late sown condition based on agro-morphological, physiological and biochemical traits. With respect to this, the current study was also carried out for screening and evaluation of 500 germplasm accessions based on agro-morphological and physiological traits. Both the experiments were carried out in F-Block, research farm of Rani Lakshmi Bai Central Agricultural University, Jhansi, Uttar Pradesh. This chapter "Materials and Methods" contains information related to experimental material and a procedure for recording observations on various traits to access the variability present in both the research experiments consisting of validation of 18 entries and screening of 500 germplasm accessions respectively.

3.1 Experimental Material

3.1.1 Site of the experiment

The research programme was conducted at F-block during the year 2022-23 for both the experiments at the University research farm of the Rani Lakshmi Bai Central Agricultural University, Jhansi, Uttar Pradesh. All the necessary facilities are sufficiently available at the research farm for the smooth conduct of experiment.

3.1.2 Climate and weather

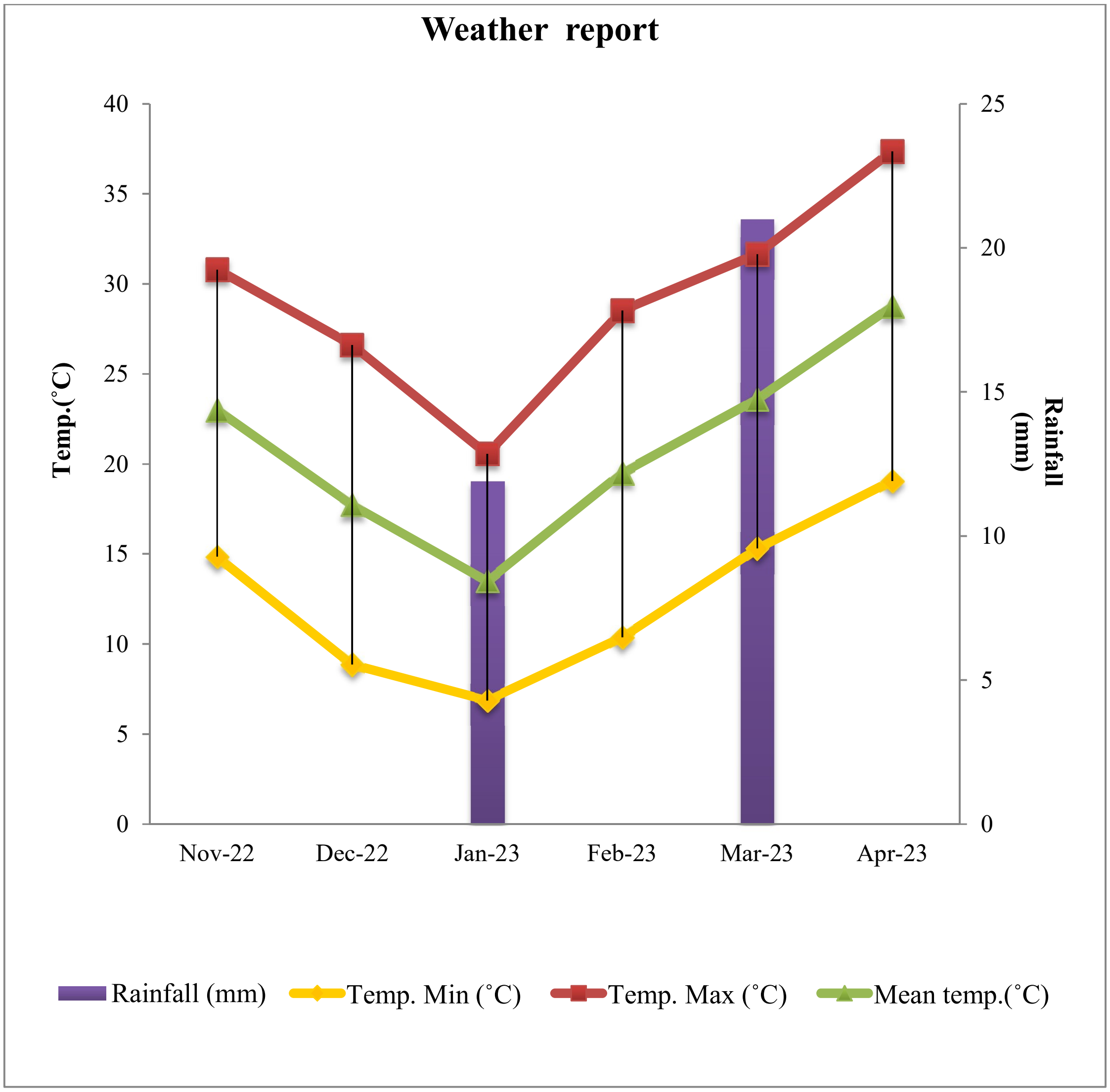
The University farm, RLBCAU, Jhansi is located in the central plateau zone of Uttar Pradesh's Bundelkhand area, as well as the Northern scarp of the Vindhyan plains of two agro-climatic sub-zone of Bundelkhand, between North longitudes 24°11′ and 25°57′and East latitudes 78°10′and 79°25 at a height of 284 metres above mean sea level. The weather is often dry and subject to dramatic weather and temperature fluctuations throughout the year. The winter season lasts from October to January, with temperatures as low as 2 ˚C in December. In Jhansi, the average annual rainfall is 900 mm. Peak summers are very scorching, with temperatures reaching 45-47 ˚C and an average daily temperature of 36 ˚C with very high humidity. However, during the research period, the weather was ideal for the experiment during the growth of crop.

3.1.3 Meteorological data

Table no. 3.1: Meteorological weather data 2022-23

Month	Std. Met.Week	Temp.(˚C)			Relative Humidity(RH)		Rainfall (mm)	Evaporation (mm)
		Max.	Min.	Mean	I	II		
Nov-22	1.	32.7	16.9	25	86	32	0	3.7
	2.	32.8	17.1	25	87	42	0	3.0
	3.	30.0	13.6	22	86	34	0	3.3
	4.	27.7	11.8	20	84	45	0	2.8
Dec-22	5.	26.9	11.1	19	86	39	0	2.5
	6.	25.7	9.6	18	84	38	0	2.3
	7.	26.4	9.8	18	86	39	0	2.3
	8.	25.4	6.3	16	79	44	0	2.0
	9.	25.9	7.5	17	73	46	0	2.1
Jan-23	10.	16.1	4.3	10	91.3	77.4	0	1.3
	11.	25.5	6.9	16	85.5	47.8	0	2
	12.	20	4.4	12	80.8	49	0	2.3
	13.	20.6	11.9	16	90.6	76	11.9	1.4
Feb-23	14.	23.7	9.2	16	80.3	35	0	2.7
	15.	29.4	9.9	20	74.2	40	0	3.3
	16.	28	9.4	19	81	40.2	0	3.6
	17.	33	13	23	79.5	38.4	0	3.6
Mar-23	18.	31.6	15.4	24	81.2	35.5	0	4.1
	19.	30.3	14.9	23	82	41.5	3.8	4.1
	20.	32.8	15.9	24	81	33	0.2	4.5
	21.	29.1	15.5	22	82.6	36.3	17	3.7
	22.	34.5	14.8	25	86	32	0	5.1
Apr-23	23.	34.8	17.8	26	69.8	27	0	6.8
	24.	38.6	20.7	30	68.3	29	0	7.3
	25.	40.3	20.9	31	63.8	32	0	9.1
	26.	35.8	21.1	28	76.8	42	0	6.7

The meteorological data necessary for the study was recorded during the growing period from November, 2022 to May, 2023. The data has collected from the institute ICAR-IGFRI's meteorological observation unit. The following table 3.1 shows the weather information.



(***Source***: ICAR-IGFRI, Jhansi)

Fig. 3.1: Graphical representation of maximum, minimum and mean temperatures along with rainfall during the crop season from 1st week of November, 2022 to last week of April, 2023.

3.1.4 Experimental material

A total of 500 genotypic accessions received from NIPGR/ICRISAT along with 3 checks JG-14, RLBGK-1 and IPC-2006-77 were screened and evaluated against the temperature extremities based on different agro-morphological and physiological traits to identify heat tolerant donors and also to assess genetic variability among different 500 germplasm accessions. The details of the experiment given in table 3.2

Table 3.2: Experimental details of research conducted during *Rabi*, 2022-23 (Augmented design)

1st Objective	**Phenotyping of chickpea germplasm accessions for identification of heat tolerant genotypes**
Location	University Seed and Research Farm, RLBCAU, Jhansi
Year of commencement	*Rabi*, 2023
Date of sowing	18th January, 2023
No. of entries	500
No. of checks	3
Name of the checks	JG14, RLBGK-1, IPC 2006-77
Experimental design	Augmented design
No. of replications	Un-replicated
No. of rows per plant	Single row (on ridges)
Length of each row	2 m
Row to row spacing	90 cm

A total 18 putative heat-tolerant genotypes along with two heat tolerant check varieties JG-14 and IPC-2006-77 and heat susceptible check varieties JG-62 and BG-3062 were validated during timely sown and late sown condition based on agro-morphological, physiological and biochemical traits for the selection of suitable high heat-tolerant genotypes and also to assess genetic variability among all the 18 entries. The following details of this experiment are given in table no. 3.3.

Table 3.3: Experimental details of research conducted during *Rabi*, 2022-23 (RBD)

2nd Objective	**Validation of promising heat tolerant genotypes based on morpho-physiological and biochemical traits**.
Location	University Seed and Research Farm, RLBCAU, Jhansi
Year of commencement	*Rabi*, 2022-23
Date of sowing	
Timely Sowing	7th November, 2022
Late sowing	20th January, 2023
No. of entries	18
No. of checks	4 (2 heat tolerant + 2 heat susceptible)
Heat tolerant	JG-14, IP-2006-77
Heat susceptible	JG-62, BG-3062
Experimental Design	RBD
No. of replications	3
No. of rows per plot	4
Length of each row	3m

3.2 Recording Observations:

For validation of promising heat tolerant genotypes based on morpho-physiological and biochemical traits, the parameters used for recording observations on different traits are described as follows:-

3.2.1 Agro-morphological traits:

3.2.1.1 Plant population:

Total numbers of fully germinated plants were counted at 30 days after sowing in each row of all entries in each replication.

3.2.1.2 Days to 50% flowering:

Number of days was recorded from the date of sowing to the date at which 50% plants in each genotype had been flowered.

3.2.1.3 Leaflet size:

The leaflet size was measured from the middle of the plant using a 30 centimetre scale.

3.2.1.4 Plant height:

The plant height was measured from the bottom to the top- most pod present on the single plant during fully developed pod stage of all the entries.

3.2.1.5 Days to 1st pod initiation:

Number of days were recorded from the date of sowing to the date at which first pod in each genotype per replication had developed.

3.2.1.6 Days to 50% pod stage:

Numbers of days were recorded from the date of flowering to the date at which 50% pods in each genotype of each replication had developed.

3.2.1.7 Number of pods per plant:

Total numbers of pods per plant were counted at the time of maturity of all the entries.

3.2.1.8 Number of seeds per pod:

Total numbers of seeds per pod were counted at the time of maturity of all the entries.

3.2.1.9 Number of primary branches (per plant):

Total number of branches arising directly from the main shoot were counted and recorded at the time of maturity.

3.2.1.10. Number of secondary branches (per plant):

Total number of branches arising from all primary branches were counted and recorded at the time of maturity of all the entries.

3.2.1.11. Days to maturity:

Total numbers of days required for the development of all the mature pods of entire accession from the date of sowing were recorded.

3.2.1.12. Seed yield per plant (g):

After threshing, winnowing and grain clearing, seeds produced from a single plant were weighed using electronic weighing balance (g).

3.2.1.13. 100-seed weight (g):

A sample of 100 seeds from each entry in all replications has weighed by using electric weighing balance.

3.2.2 Physiological traits:

3.2.2.1. Pollen viability:

Flowers from each entry of each replication were collected and the pollen viability test was carried out by staining the pollen grains on slide with the help of 2% acetocarmine chemical solution and observed the slides under digital microscope. Viable pollen stained deep in colour where as non-viable or less viable pollen took no or little stain.

3.2.2.2. Pod set:

Pod set was observed at 50% of flowering, and for the next 10 consecutive days post this date by tagging 5 flowers daily. Pod set was recorded for each flower seven days after anthesis.

3.2.2.3. Chlorophyll content:

The amount of chlorophyll content present in all the entries was measured with the help of a device known as SPAD meter (Chlorophyll meter).

3.2.2.4. Chlorophyll fluorescence:

The photochemical efficiency measured as chlorophyll fluorescence of all the accessions was recorded by using device Chlorophyll fluorometer.

3.2.2.5 Rate of transpiration, stomatal conductance and rate of photosynthesis:

All of these three traits were recorded for all the genotypes of each and every replication by using an instrument known as IRGA (Infra Red Gas Analyser).

3.2.3 Biochemical traits:

Crude extract preparation:

Leaf samples were stored at -20°C for the enzyme extraction. At the time of extraction, the same leaf samples had washed twice with distilled water. A 6g of leaf sample was taken and homogenized in 15ml of 50mM sodium phosphate buffer (pH 7.0) and 0.5% (w/v) polyvinylpyrrolidone (PVP) for 5 min at 4°C with the help of mortar and pestle. Then the homogenate was centrifuged for 15min. at 8000rpm, 0°C. Finally the supernatant was collected and stored at 4°C to avoid enzyme degradation.

3.2.3.1 Total Protein assay:

Total protein estimation assay was carried out by Bradford method. A caliberated standard curve was prepared by using BSA (0.5mg/ml) as standard mixed with Bradford working reagent. Four different concentrations such as 15µl, 20µl, 25µl and 30µl of Bovine serum albumin (0.5mg/ml) were taken in eppendorf tubes. Then each of this tube was mixed with 85µl, 80µl, 75µl and 70µl of 0.15M NaCl respectively to become 100µl concentration each. Finally these solutions are mixed with 1ml of Bradford reagent and used as standards. A blank was prepared containing 1ml of Bradford reagent. Similarly 100µl of crude extract was mixed with 1ml of Bradford reagent and used as unknown working sample solution. The absorbance was recorded at 595nm (UV-Visible spectrophotometer) for both the standards and unknown sample against a blank sample and concentration of protein for each sample was calculated.

3.2.3.2 Superoxide dismutase (SOD) activity assay:

Superoxide dismutase (SOD) activity can be determined by measuring the inhibition in photo reduction of nitro blue tetrazolium (NBT) by SOD enzyme. A reaction mixture was prepared containing 3.5ml of 50mM sodium phosphate buffer (pH 7.6), 0.3ml of crude extract, 0.5ml of 25mM NBT (Nitro blue tetrazolium), 0.2ml of 0.1mM EDTA, 0.2ml of 50mM sodium carbonate and 0.3ml of 13mM L-methionine to make final volume up to 3ml. Then this reaction mixture was treated with 0.1ml of 2mM Riboflavin and exposed to 15W fluorescent light for 10-15min. The absorbance was recorded at 560nm (UV-Visible spectrophotometer) for all the unknown samples against a blank sample containing reaction mixture except crude extract treated with riboflavin. The specific SOD activity was calculated as units per mg of protein using the formula –

$$\text{Percent inhibition (\%)} = \frac{[(\Delta ODs(min^{-1}) - \Delta ODo(min^{-1})])X\ 100}{\Delta ODsmin^{-1}}$$

Increase in absorbance (Uninhibited) per min (ΔODs min^{-1}) at 560 nm

Inhibition of absorbance per min (ΔODo min^{-1}) by the sample at 560 nm

$$\text{SOD activity (U mg}^{-1}\text{ protein)} = \frac{Percent\ inhibition\ X\ df}{50\%\ X\ Sample\ volume(ml) X\ Protein(\text{U mg}^{-1}\text{ protein})}$$

3.2.2.3 Catalase (CAT) activity assay:

Catalase activity can be demonstrated by the existence of catalase, an enzyme that catalyses the release of oxygen from hydrogen peroxide (H_2O_2). A reaction mixture was prepared containing 3ml of 200mM hydrogen peroxide, 0.3ml crude extract and 1.7ml of 50mM sodium phosphate buffer (pH 7.0). The absorbance was recorded at 410nm for

3min. against a blank sample.

$$\text{CAT activity} = \frac{OD\ min^{-1} X\ df\ X\ Total\ volume(ml)}{0.0436\ X\ Sample\ volume(ml) X\ Protein(\text{U mg}^{-1}\ \text{protein})\text{X length(cm)}}$$

For phenotyping of 500 chickpea germplasm accessions for identification of heat tolerant genotypes, the following parameters recorded for screening are as follows –

Plant population, Anthocyanin pigment, Days to 50% flowering, Days to 50% pod stage, Plant height (cm), Number of primary branches, Number of secondary branches, Number of pods per plant, Number of seeds per pod, Days to maturity, Seed yield per plant (g), 100-seed weight (gm), Chlorophyll content and Pollen viability test [description related to these traits have mentioned already above (see 3.2.1 and 3.2.2).

3.3 Statistical Analysis:

Data recorded on various characters has been subjected to following statistical analysis:

3.3.1 Analysis of variance in randomized block design (RBD)

Randomised block design is an experimental design in which the experimental units are organised into groups known as blocks. The treatments are assigned at random to the experimental units within each block. We have a totally randomised block design when all treatments occur at least once in each block.

Data collected for the validation of 18 entries along with check varieties based on all the parameters were subjected to following RBD analysis-

Table no. 3.4 Analysis of variance for randomized block design

S.N.	Source of variation	Degree of freedom	Sum of squares	Mean sum of squares	F-value
1.	Replication	r-1	SSR	MSSR	Fr = MSSR/MSSE
2.	Treatments	t-1	SST	MSST	Ft = MSST/MSSR
3.	Error	(r-1) (t-1)	SSE	MSSE	
4.	Total	rt-1	TSS		

Whereas,

SSR = Sum of square due to replication

SST = Sum of squares due to treatment

SSE = Sum of squares due to error

MSST = Mean sum of squares due to treatment

MSSR = Mean sum of squares due to replication

MSSE = Mean sum of squares due to error

Test of significance was done by referring the "F" tabulated values given by Fisher and Yates (1936).

3.3.2 Analysis of variance in an augmented design

Augmented design is an ideal experimental design and efficiently used in plant breeding programme. It is used when seeds are available in limited quantity and wants to evaluate as many as genotypes possible on a limited piece of land. Germplasm lines are randomly allocated to each block once and only once. It provides an estimate of standard error that can be used for comparisons among the genotypes or between the genotypes and check varieties. The ANOVA was performed using the Federer's approach (1956).

Data recorded for screening of all 500 germplasm accessions along with the check varieties based on all the parameters were subjected to following statistical analysis –

Table no. 3.5 Analysis of variance (ANOVA) for augmented design

S.N.	**Source of variation**	**Degree of freedom**	**Sum of squares**	**Mean sum of squares**	**F-value**
1.	Blocks	b-1	SSb	MSSb	MSSb/MSSE
2.	Entries	e-1	SSe	MSSe	MSSe/MSSR
A.	Genotypes	g-1	SSg	MSSg	MSSg/MSSE
B.	Check	v-1	SSv	MSSv	MSSv/MSSE
3.	Genotypes/check	[g+(v-1)]	SSgv	MSSgv	MSSgv/MSSE
4.	Error	(b-1)(v-1)	SSE	MSSE	
	Total	N-1	TSS		

Whereas,

b = Number of blocks

e = Number of total entries

g = Number of germplasm accession tested

SSb = Sum of squares due to block

SSv = Sum of squares due to germplasm lines/accessions

SSE = Sum of square due to error

MSS = Mean sum of square

MSSE = Mean sum of square due to error and test of significance was done by referring the "F" tabulated values given by Fisher and Yates (1936).

3.3.3 Genetic variance:

It is the inherent variation which remains unaltered by the environment. It is variation due to genotypes. It is denoted by Vg & is calculated using the formula-

$$Vg = MSSt - MSSe / r$$

Where, MSSt = Mean sum of square due to treatment

MSSe = Mean sum of square due to error

r = number of replications

3.3.4 Coefficient of variation:

Three components viz., phenotypic, environmental, and genotypic were used to estimate the coefficient of variation at both genotypic and phenotypic level for the traits under study by using the formula given by Burton (1953).

3.3.4.1 Phenotypic coefficient of variation (PCV):

It is defined as the ratio of phenotypic standard deviation to the mean, expressed as % and can be calculated using the formula

$$PCV\% = \frac{\sqrt{Vp}}{\bar{x}} \times 100$$

Where, $\sqrt{Vp}$ = Phenotypic standard deviation

$\bar{x}$ = grand mean of the character under study

3.3.4.2 Genotypic coefficient of variation (GCV):

GCV is the ratio of genotypic standard deviation to the mean expressed as% and is calculated using the formula

$$GCV\% = \frac{\sqrt{Vg}}{\overline{x}} \text{ X } 100$$

Where, $\sqrt{Vg}$ = Phenotypic standard deviation

$\overline{x}$ = grand mean of the character under study

Sivasubromonium and Madhavarmenon (1973) classified GCV and PCV into three groups:

S.N.	Range	Value
1.	Low	$< 10\%$
2.	Moderate	$10 - 20\ \%$
3.	High	$> 30\%$

3.3.5 Estimation of heritability (broad sense) and genetic advance:

3.3.5.1 Broad sense heritability:

Heritability (in the broad sense) is calculated as the ratio of genotypic variance to phenotypic variance.

$$H^2 = \frac{Vg}{Vp} \text{ x } 100$$

Where, Vg = Genotypic variance

Vp = Phenotypic variance

Scales of broad sense heritability classified into 4 groups

S.N.	**Range**	**Value**
1.	Low	$< 40\%$
2.	Moderate	$40\% - 60\ \%$
3.	High	$60\% - 80\%$
4.	Very high	$> 80\%$

3.2.5.2 Genetic advance:

It is a measure of genetic gain under selection. It refers to the improvement of near genotype value of selection lines and families over the base population.

$$GA = K \times h^2 \times \sqrt{Vp}$$

Where, K = Selection differential at 5% selection intensity (2.06)

$\sqrt{Vp}$ = Phenotypic standard deviation

h^2 = Heritability

3.3.5.3 Genetic advance over mean:

Genetic advance as percentage of mean for each trait was worked out by adopting the formula given by Johnson *et al.,* (1955).

$$\text{Genetic advance as per cent of mean (\%)} = \frac{\textit{Genetic advance}}{\textit{Geenral population over mean}}\ x\ 100$$

3.2.6 Correlation analysis:

This is done to measure the mutual relationship between various plant character pairs and determines the component characters on which selection can be based for improvement in the yield.

$$r\,(x,y) = \frac{cov\,(x.y)}{\sqrt{Var\ x\,.Var\ y}}$$

Where, r (x, y) = correlation between x and y

Cov (x.y) = covariance between x and y

Var x = variance of x

Var y = variance of y

The correlation coefficient’s significance was determined at an adequate level of significance. The correlation coefficient (r) significant values were assessed at (n-2) degree of freedom.

3.2.7 Path coefficient analysis:

It is given by Sewall Wright (1921) and first applied by Lu and Dewey (1959) for plant selection in crested wheat grass. It is basically the dissociation of correlation coefficients into measurements of direct and indirect effects of a set of independent factors on the dependent variable using standardised partial regression coefficients. It is often referred to as a cause and effect relationship.

rny = Pny + rn2P2Y + rn3P3Y +.......+rnxPxY

Where; rny = correlation coefficient between one independent character and yield.

Pny = path coefficients between the independent character and yield.

rn2,rn3,...........rnx = correlation between the independent character and yield

Residual effect: It is estimated according to the following formula.

1 = R^2+P1y2 +P2y2+.................+[P(n-1)y]2 + 2{P1y P2y r12 + P1y P3y r13 + P1y P4y r14 + ...+ P(n-2)y P(n-1)y r(n-2)]

1 = R^2 + X

Where, X is equal to the sum of all the terms mentioned in the above equation.

3.2.8 Genetic divergence:

The goal of applying cluster analysis on matrices of pairwise distance measurements among a set of genotypes, similar to PCA, is to separate the observations into discrete groups.

Non-hierarchical Euclidean cluster analysis described by Beale (1969) and elaborated by Spark (1973) was used to study the genetic divergence among genotypes. According to Beale (1969) initially each observation is located to the closest cluster centre. The means of the cluster were then calculated and taken to the new cluster centres. At the same time, the sum of squared deviation of the observations from their respective cluster centre was computed. The observation were then checked in turn to see if a shift to a different cluster centre results in a decrease in the total sum of squares. This assumes that $d_j^2 < dK^2$, where, $d_j$is the distance from the centre of cluster i.e. however, a more effective criterion involves reassigning the observation, if cluster i, was less than that from centre of cluster *k*, even when the cluster centre were simultaneously reposition that was when:

$$\frac{ni}{ni+1}d_i^2\frac{nk}{nk+1}d_k^2$$

Where, *ni* is the number of observation in cluster *i.*

In delimiting cluster usually average among a subset of 'm' point is considered, not the individual i_2m *(m-l)* deviances. If the i^th^ variable on the j^th^ member is X_{ij} average of the means deviance of set of 'm' is as follows:

$$=\frac{1}{m(m-1)}\sum_{i=1}^{D}\sum_{i=1}^{-M}\sum_{k=1}^{-M}(x_{ij}-x_{jk})^2$$

$$=\frac{1}{m(m-1)}\sum_{i=1}^{D}\sum_{j=1}^{-M}\sum_{k=1}^{-M}[(x_{ij}-x_i)-(x_{ik}-x_i)]$$

Where, x_i is the mean of x_i over m members

$$\frac{1}{m(m-1)}\Sigma[\sum_j\sum_k(x_{ij}-x_i)+\sum_j\sum_k(x_{ik}-x_i)^2-2\sum_j\sum_k(x_{ij}-x_j)(x_{ik}-x_i)]$$

The cross product term vanishes and other two are equal:

Average deviation= $\frac{2}{m-1}\sum_{i=1}^{m}\sum_{j=1}^{D}[x_{ij}-x_i]^2$

Thus, Now, instead of calculating 1/m (m-1) deviance, 'm' deviation from the centre of gravity was calculated.

Thus assumption in this method were that the Euclidean distances 'D' separating 'n' point in a 'p' dimensional space are proportional to the dissimilarities between the objects, and secondary, that no object belongs simultaneously to two clusters.

RESULTS

AND

DISCUSSIONS

Chapter IV

RESULTS AND DISCUSSIONS

The current study entitled "Screening and validation of putative heat tolerant chickpea genotypes" was conducted to screen 500 chickpea germplasm based on agro-morphological and physiological traits in augmented design and simultaneously this study was conducted to validate 18 heat tolerant chickpea genotypes along with two heat-tolerant and heat-susceptible checks in Randomized block design (RBD) based on agro-morphological, physiological and biochemical traits during 2022-23 at the RLBCAU research farm in order to fulfil the following objectives.

i) Phenotyping of chickpea germplasm accessions for identification of heat tolerant genotypes.

ii) Validation of promising heat tolerant genotypes based on morpho-physiological and biochemical traits.

iii) Assessing character association and genetic divergence in chickpea germplasm.

Objective one is fulfilled by agro-morphological characterization and by estimating mean performance, analysis of variance and genetic variability parameters viz., phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability and genetic advance over mean (GAM). Objective two is fulfilled by characterization of agro-morphological, physiological and biochemical traits based on estimation of mean performance and genetic variability parameters viz., phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability and genetic advance over mean (GAM). Objective three is fulfilled by assessing correlation and path analysis of various traits studied under both the objectives mentioned above and finally by conducting cluster analysis among 500 chickpea germplasm accessions.

4.1 Phenotyping of chickpea germplasm accessions for identification of heat tolerant genotypes.

Out of 500 genotypes, 486 genotypes germinated, 484 genotypes set flower, 440 genotypes set pods due to heat extremities. The experimental findings have been mentioned under the following subsections.

4.1.1 Morphological characterization

4.1.2 Analysis of variance

4.1.3 Mean performance

4.1.4 Genetic variability parameters

4.1.4.1 Genotypic and phenotypic coefficient of variation

4.1.4.2 Heritability and genetic advance over mean

4.1.5 Correlation coefficient analysis

4.1.6 Path coefficient analysis

4.1.7 Cluster analysis

4.1.1 Morphological Characterization

The relevance of morphological characteristics in quality seed production certification procedures should be emphasised. Rouging of off-types is typically reasonable in large seed production operations to assure the genetic purity of the seed produced based on stable morphological features determined by qualitative genes.

For all accessions, floral characteristics such as flower colour were recorded. The genotypes were divided into two groups based on flower colour variance, namely white (62) and pink (378). Based on this feature, chickpea genotypes were categorized into desi (378) and kabuli (62) types. Therefore, the frequency distribution of kabuli and desi types was 14.09 % and 85.9 % respectively.

Based on seed colour characteristics, genotypes are classified into four categories via brown (340), white (62), black (29) and green (9). Therefore, the frequency distributions of these four categories were 77.27 %, 14.09 %, 6.59 % and 2.04 % respectively.

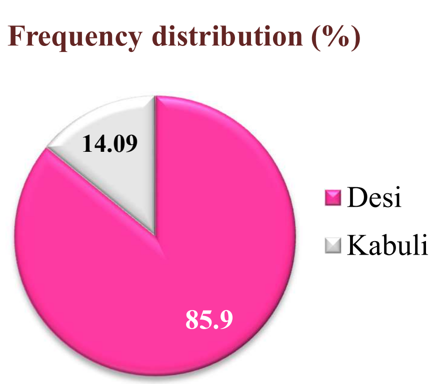


Fig. 4.1 Kabuli and desi type

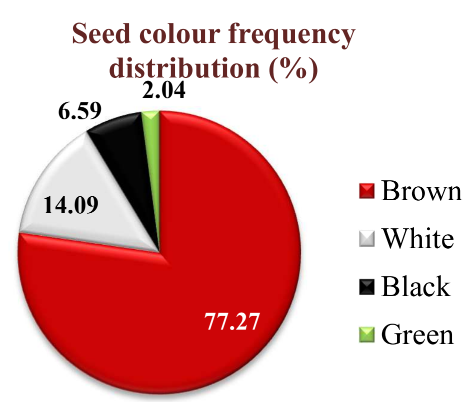


Fig. 4.2 Seed colour characteristics

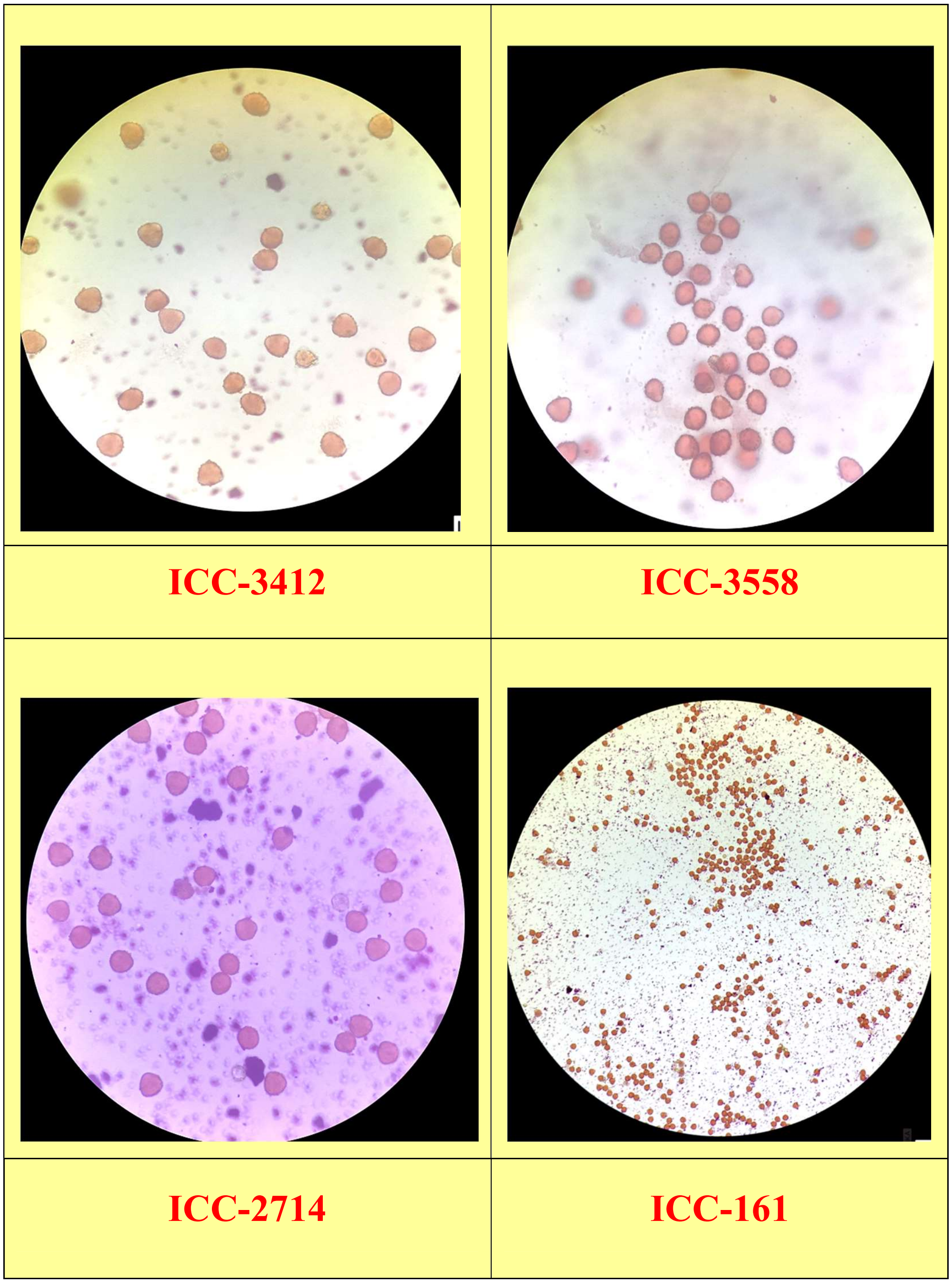
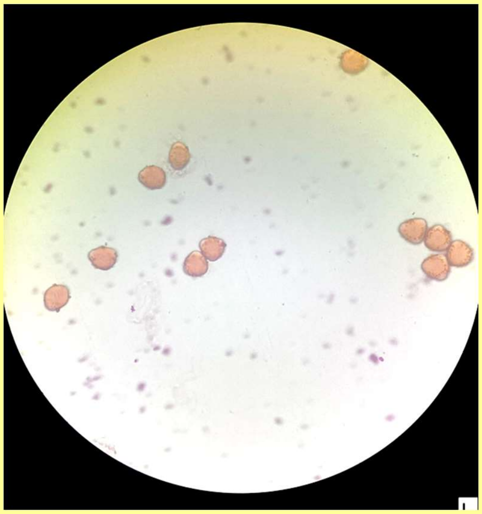
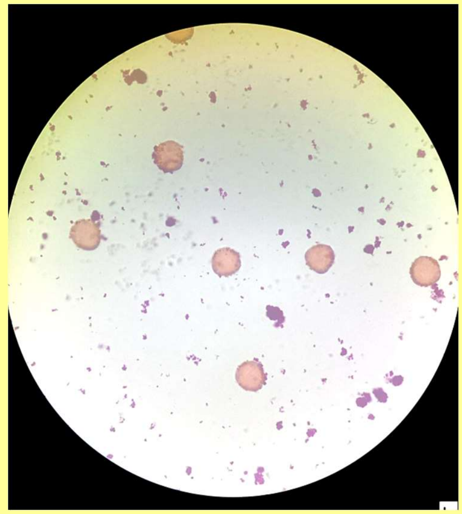


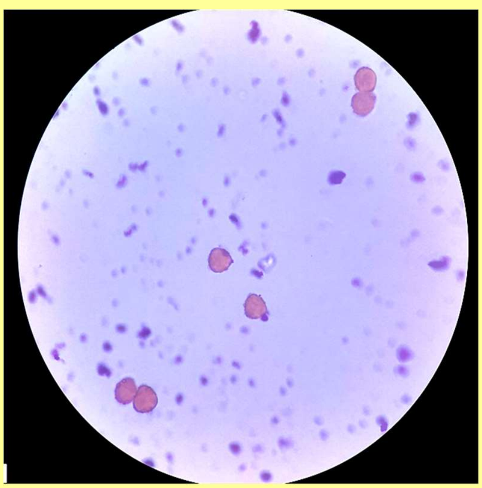
Fig. 4.3 Heat tolerant accessions showing more viable pollen



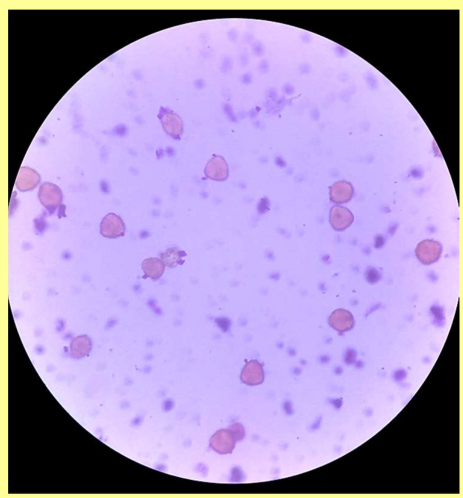
ICC-1228



ICC-829



ICC-3025



ICC-2338

Fig. 4.4 Heat sensitive accessions showing less viable pollen

4.1.2 Analysis of variance

Table no. 4.1 showed the results of the analysis of variance for augmented design using quantitative data obtained on 500 accessions along with three checks that finished the life cycle and generated yield. In this study, the analysis of variance (ANOVA) demonstrated significant variations in seed yield and attributes between chickpea accessions. These substantial variations demonstrated that there was an extensive degree of diversity across the germplasm for the characteristics examined viz., plant population, days to 50% flowering, days to 50% pod stage, chlorophyll content, plant height, number of pods per plant, number of seeds per pod, number of primary branches, number of secondary branches, 100-seed weight, days to maturity and seed yield per plant.

Analysis of variance revealed non-significant differences between blocks for all the traits evaluated at 0.05 and 0.01 level of significance. The variation among three checks resulted significant differences for the following traits such as plant height, number of pods per plant, 100-seed weight at 0.01 level of significance and seed yield per plant at 0.05 level of significance. The variation due to treatments found to be significant for the characteristics such as plant height, number of pods per plant, number of secondary branches at 5% level of significance where as plant population, days to 50% flowering, days to 50% pod stage, plant height, 100-seed weight, days to maturity and seed yield per plant at 1% level of significance. The occurrence of substantial variability, as demonstrated by ANOVA, indicates that there is ample scope to enhance desirable characteristics through chickpea breeding programmes.

Similar findings have been reported **by (Ningwal *et al*., 2023) (Jha *et al*., 2017), (Jha *et al*., 2018),** (**Nikhitha & Walia, 2022**), **(Chopdar *et al.*, 2017)**

Table no. 4.1 ANOVA for augmented design

ANOVA, Treatment Adjusted Mean sum of squares													
Source	**df**	**PP**	**DFF**	**DFP**	**CC**	**PH**	**NPP**	**NSP**	**NPB**	**NSB**	**SW100**	**DM**	**SYPP**
Block (ignoring Treatments)	6	27.20 **	231.38 **	230.49 **	0.11 ns	90.11 **	1106.30 **	0.15 ns	4.02 **	46.90 **	116.55 **	156.97 **	63.36 **
Treatment (eliminating Blocks)	442	3.36 *	29.96 **	28.47 **	0.10 ns	8.97 **	140.77 *	0.07 ns	0.31 ns	4.20 ns	7.36 **	29.51 **	5.37 **
Treatment: Check	2	3.48 ns	0.19 ns	0.43 ns	0.00 ns	67.09 **	1364.36 **	0.17 ns	0.25 ns	3.73 ns	23.98 **	4.43 ns	3.39 *
Treatment: Test and Test vs. Check	440	3.36 *	30.10 **	28.60 **	0.10 ns	8.71 **	135.21 *	0.07 ns	0.31 ns	4.20 ns	7.28 **	29.62 **	5.38 **
Residuals	12	1.42	1.08	1.87	0.06	2.37	57.59	0.05	0.19	1.91	1.25	2.48	0.78
ANOVA, Block Adjusted **Mean sum of squares**													
Source	**df**	**PP**	**DFF**	**DFP**	**CC**	**PH**	**NPP**	**NSP**	**NPB**	**NSB**	**SW100**	**DM**	**SYPP**
Treatment (ignoring Blocks)	442	3.68 *	33.10 **	31.59 **	0.10 ns	10.15 **	154.98 *	0.08 ns	0.37 ns	4.83 *	8.92 **	31.53 **	6.19 **
Treatment: Check	2	3.48 ns	0.19 ns	0.43 ns	0.00 ns	67.09 **	1364.36 **	0.17 ns	0.25 ns	3.73 ns	23.98 **	4.43 ns	3.39 *
Treatment: Test	439	3.66 *	26.29 **	24.84 **	0.09 ns	9.91 **	149.75 *	0.08 ns	0.37 ns	4.79 *	8.33 **	23.02 **	6.00 **
Treatment: Test vs. Check	1	13.84 **	3089.89 **	3057.07 **	1.91 **	0.18 ns	34.28 ns	0.00 ns	0.31 ns	27.33 **	241.03 **	3825.51 **	92.94 **
Block (eliminating Treatments)	6	3.78 ns	0.41 ns	1.11 ns	0.07 ns	3.32 ns	59.17 ns	0.03 ns	0.14 ns	0.29 ns	1.22 ns	7.94 *	3.23 *
Residuals	12	1.42	1.08	1.87	0.06	2.37	57.59	0.05	0.19	1.91	1.25	2.48	0.78

P > 0.05: ns; significance at ** P < 0.01, * P < 0.05

PP-Plant population ; DFF-Days to 50 % flowering ; DFP-Days to 50 % pod stage ; CC-Chlorophyll content ; PH-Plant height ; NPP-Number of pods per plant ; NSP-Number of seed per pod ; NPB-Number of primary branches ; NSB-Number of secondary branches ; SW100-Hundred seed weight ; DM-Days to maturity ; SYPP-Seed yield per plant

4.1.3 Mean Performances

Among the set of parameters studied, there was a broad range of differences in mean performance among all chickpea genotypes demonstrated in **table 4.2**. The goal of this study was to figure out if there was any evidence of any genetic variation between chickpea accessions for 12 characteristics in the Bundelkhand area.

4.1.3.1 Plant population

The trait plant population ranged from 2.67 to 12.33 with the average value of 7.49.The genotypes which showed good plant population were ICC-176, ICC-273, ICC-301, ICC-353, ICC-583, ICC-1035, ICC-1084, ICC-1122, ICC-1127, ICC-1161, ICC-1172, ICC-1193, ICC-1265, ICC-1272, ICC-1398, ICC1424, ICC-1507, ICC-1560, ICC-1579, ICC-1876, ICC-1923, ICC-2078, ICC-2135, ICC-2204, ICC-2508, ICC-2516, ICC-2555, ICC-2884, ICC-3025, ICC-3232, ICC-3317, ICC-3325, ICC-3421 along with best check IPC-2006-77 (12).

4.1.3.2 Days to 50 % flowering

The trait days taken to 50% flowering showed a wide range of variance, ranging from 52.76 to 74.1, with an average of 66.45. ICC-796, ICC-812, ICC-1018, ICC-1397, ICC-2773, ICC-2836 and all of the check varieties displayed early flowering to 50% flowering (53days).

4.1.3.3 Days to 50% pod stage

The trait days taken to 50% pod stage showed a large range of variation, ranging from 60.67 to 82.33, with an average value of 74.3. Early days to 50% pod stage were observed in ICC-796, ICC-812, ICC-1018, and ICC-1397 (61 days) along with best check (60 days).

4.1.3.4 Chlorophyll content

The trait chlorophyll content had an estimated average value of 2 varying from 1.2 to 3.28. The genotypes noticed higher chlorophyll content were ICC-1579 (3.19), ICC-668 (3.02), ICC-1891 (3.0), ICC-2355 (2.99) performed better than check variety (2.73).

4.1.3.5 Plant height

Plant height ranged from 26.74 to 42.08 with the average value of 33.98. Erect type genotypes were observed for ICC-552 and ICC-731 (42.67) followed by ICC-905 and ICC-931 (42.33) which are taller than best check variety RLBGK-1 (39.22).

4.1.3.6 Number of pods per plant

The trait number of pods per plant varied from 25.23 to 83.86 with the mean value of 52.72. ICC-2709 (77.67) followed by ICC-1093 and ICC-2078 (75.67), ICC-3558 and ICC-3596 (75.33), ICC-2720 (75), ICC-95 (74.67) produced maximum number of pods per plant than the check variety JG-14 (73.67) and IPC-2006-77 (72).

4.1.3.7 Number of seeds per pod

The trait number of seeds per pod varied from 1.12 to 2.45 with the mean value of 1.55. ICC-168 (2.33) exhibited highest number of seed per pod when compared to check variety IPC-2006-77 (2.0).

4.1.3.8 Number of primary branches

The number of primary branches per plant ranged from 2.74 to 5.85 with the average value of 3.86. ICC-797 and ICC-3406 (5.67) showed highest number of primary branches compared to check variety JG-14 and RLBGK-1 (4.33).

4.1.3.9 Number of secondary branches

The trait number of secondary branches had an estimated average value of 12.35 ranging from 8 to 18.28. The genotypes viz., ICC-3406 (18.33) followed by ICC-3558 (18.0), ICC-1000 (17.67) observed higher number of secondary branches than check variety JG-14 (16.33).

4.1.3.10 100-seed weight

The trait 100- seed weight had a mean value of 12.35 ranging from 7.53 to 22.21. ICC-1355 22.2) followed by ICC-2698 (20.66), ICC-3567 (20.64), ICC-2773 20.09) exhibited maximum 100-seed weight when compared to the check variety JG-14 (19.2).

4.1.3.11 Days to maturity

The trait days taken to maturity observed the minimum of 90.38 to maximum 116.71 with average of 108.53. The genotype ICC-2589 along with the check RLBGK-1 (91 days) matured early.

4.1.3.12 Seed yield per plant

The maximal and minimal value for seed yield per plant found to be 4.37 and 16.43 respectively with an average value of 10.45. The genotypes ICC-574 (15.95) and ICC-3558 (15.88) obtained higher seed yield per plant than the check variety IPC-2006-77 (15.85).

Table no. 4.2 Mean and range performances of different traits

Trait	Range		Mean
	Min	Max	
PP	2.67	12.33	7.49
DFF	52.76	74.1	66.45
DFP	60.67	82.33	74.3
CC	1.2	3.28	2
PH	26.74	42.08	33.98
NPP	25.23	83.86	52.72
NSP	1.12	2.45	1.55
NPB	2.74	5.85	3.86
NSB	8	18.28	12.13
100-SW	7.53	22.21	12.35
DM	90.38	116.71	108.53
SYPP	4.37	16.46	10.45

PP-Plant population ; DFF-Days to 50 % flowering ; DFP-Days to 50 % pod stage ; CC-Chlorophyll content ; PH-Plant height ; NPP-Number of pods per plant ; NSP-Number of seed per pod ; NPB-Number of primary branches ; NSB-Number of secondary branches ; SW100-Hundred seed weight ; DM-Days to maturity ; SYPP-Seed yield per plant

4.1.4 Genetic variability parameters

4.1.4.1 Genotypic and phenotypic coefficient of variation

In order to evaluate genetic variation and determine the degree of overall variance, the coefficient of variation was estimated using the outcomes of analysis of variance for all of the examined characteristics. The significant differences between GCV and PCV demonstrated the favourable influence of the environment as well as the genotypes' genetic composition.

Highest GCV(**fig. 4.2**) observed in the trait seed yield per plant (21.87) (**Kuldeep *et al*., 2014**) followed by 100-seed weight (21.55), plant population (19.97), number of pods per plant (18.21), number of secondary branches (13.99), number of primary branches (10.94), number of seeds per pod (10.04), chlorophyll content (9.26), plant height (8.08), days to 50% flowering (7.56), days to 50% pod stage (6.45) and days to maturity (4.18)

High PCV (**fig. 4.2**) estimate was found in the trait plant population (25.53) followed by seed yield per plant (23.44), 100-seed weight (23.37), number of pods per plant (23.21), number of secondary branches (18.04), number of seeds per pod (17.65), number of primary branches (15.68), chlorophyll content (15.26), plant height (9.27), days to 50% flowering (7.72), days to 50% pod stage (6.71) and days to maturity (4.42).

In the current study, most of the characters evaluated had greater PCV than GCV (fig. 4.2). It signifies that the environment has a significant impact on the inheritance and full expression of the characteristic.

The lesser magnitude of the difference between PCV and GCV indicated that the particular characteristic was less impacted by environment in the manifestation of these traits viz., number of pods per plant, 100-seed weight, number of secondary branches, days to 50% flowering, days to 50% pod stage, days to maturity and seed yield per plant. It indicates that certain features are less susceptible to environmental variations, and therefore further consideration should be geared towards these traits during breeding of cultivars from current source material (**Kumar *et al*., 2017)**.

Similar findings have been reported by **Chopdar *et al*. (2017), Thakur *et al.* (2018) Gediya *et al*. (2019), Tsehaye *et al*. (2020), Katkani *et al.* (2022), Perumalla *et al*. (2022)**

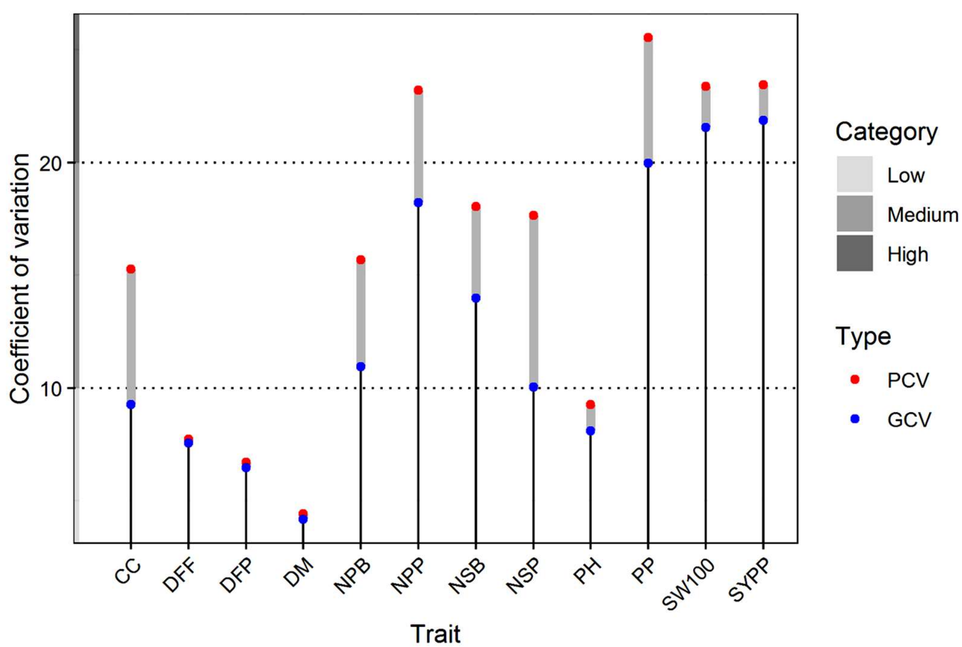


Fig.4.5 GCV and PCV of different traits

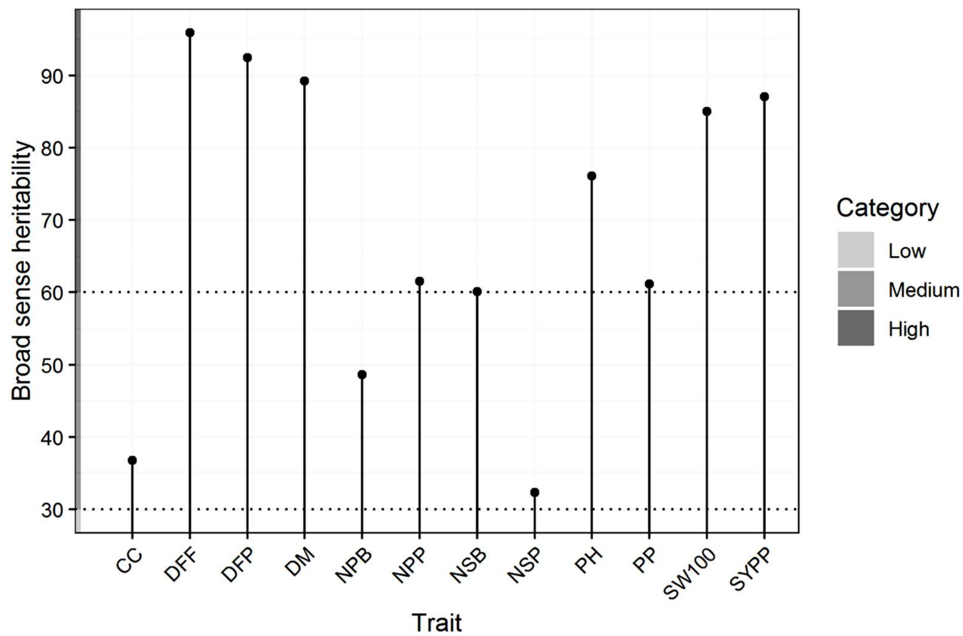


Fig.4.6 Heritability (broad sense) values of different traits

PP-Plant population ; DFF-Days to 50 % flowering ; DFP-Days to 50 % pod stage ; CC-Chlorophyll content ; PH-Plant height ; NPP-Number of pods per plant ; NSP-Number of seed per pod ; NPB-Number of primary branches ; NSB-Number of secondary branches ; SW100-Hundred seed weight ; DM-Days to maturity ; SYPP-Seed yield per plant

4.1.4.2 Heritability and genetic advance over mean

Heritability is a key genetic attribute that refers to the amount of genetic variation in a character's genetic composition as well as the way it is transmitted among genotypes. It depicts genotype breeding values for specific characteristics, representing a percentage of total variation carried from parents to offspring.

Heritability and genetic advance (GA) are significant biometric methods for studying variance in populations with the goal of performing selection and evaluating suitable germplasm for development through breeding processes.

Under selection pressures, genetic advance is defined as a shift in allele frequency towards the superior direction, and it is often stated as a percentage of the mean (genetic gain). Genetic advance measures the degree of variation that responds to selection. Because genetic variety is important in selection, it demonstrates additive variance, which quantifies additive gene expression and is crucial for genetic gain under selection.

High heritability (**fig.4.3**) observed for the trait days to 50% flowering (95.89%) (**A. Kumar *et al*., 2019)** followed by days to 50% pod stage (92.46%), days to maturity (89.21%), seed yield per plant (87.05%), 100-seed weight (85.02%), plant height (76.12%), number of pods per plant (61.54%), plant population (61.67%), number of secondary branches (60.11 %), number of primary branches (48.65%), chlorophyll content (36.77%) and number of seeds per pod (32.36).

High genetic advance over mean (**fig.4.4**) had noticed for the trait seed yield per plant (42.1%) (**Ningwal *et al*., 2023**) followed by 100-seed weight (41%), plant population (32.22%), number of pods per plant (29.47%), number of secondary branches (22.38%), number of primary branches (15.74%), days to 50% flowering (15.26%), plant height (14.55), days to 50% pod stage (12.79), number of seed per pod (11.78%), chlorophyll content (11.58%) and days to maturity (8.13%).

The traits viz., seed yield per plant, 100-seed weight, numbers of pods per plant were observed as high heritability broad sense coupled with high genetic advance indicated the presence of role of additive gene action and these traits can be improved by effective selection measure.
Similar findings were reported by **Nikhitha and Walia, (2022), Katkani *et al.* (2022), Bharathi *et al.* (2022).**

High heritability broad sense along with low genetic advance over mean had been noticed for the traits viz., days to 50% flowering, days to 50% pod stage and days to maturity indicating additive gene action might be expressing by these characters, could be improved by adoption of effective plant breeding programmes.
These results were in close agreement with the findings of **Solanki *et al*. (2019), Tsehaye *et al*. (2020) and Kumar *et al*. (2020)**.

The traits exhibiting moderate heritability broad sense and low genetic advance were chlorophyll content, number of seeds per pod and number of primary branches indicating the presence of non-additive gene action could be restricted by implementing effective plant breeding strategies.

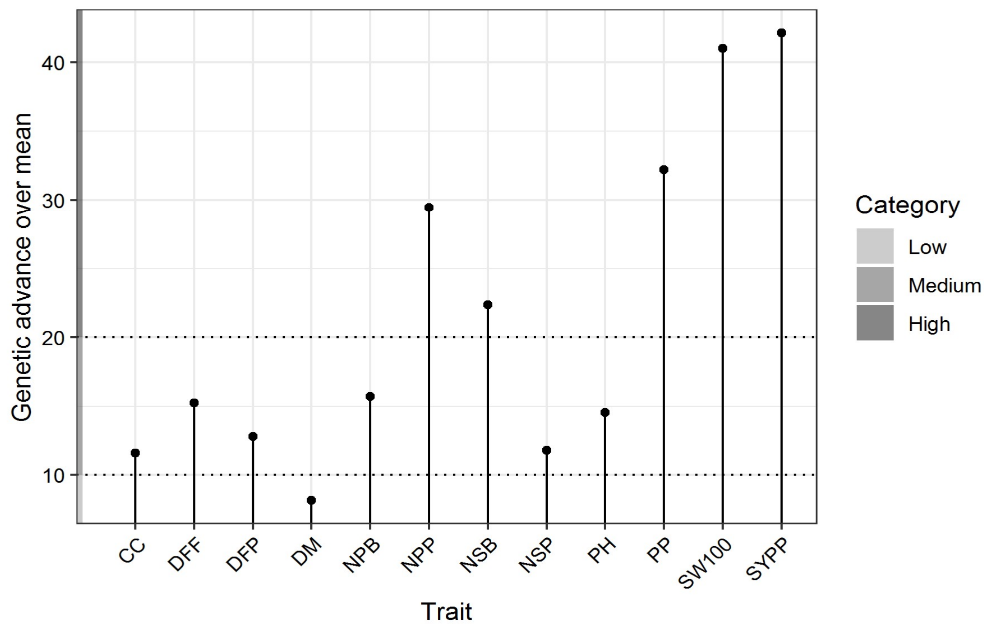


Fig.4.7 Genetic Advance over Mean values of different traits

PP-Plant population; DFF-Days to 50 % flowering; DFP-Days to 50 % pod stage; CC-Chlorophyll content; PH-Plant height; NPP-Number of pods per plant; NSP-Number of seed per pod; NPB-Number of primary branches; NSB-Number of secondary branches; SW100-Hundred seed weight; DM-Days to maturity; SYPP-Seed yield per plant

4.1.5 Correlation coefficient analysis

In plant breeding, changes in one variable are generally followed by changes in another. The total number of pods and clusters per plant impact seed production in pulses, and these characteristics are considered to be related. Knowing the degree of correlation might prove useful for improving the seed and its essential features.

The correlation is due to the combined or net influence of segregating genes, which modified both the gene and its expression. Some genes increase both variables, resulting in a positive correlation, whereas others increase only one of them, resulting in a negative correlation.

It is always necessary to have information on the nature of the relation between traits and economic yield to facilitate the selection method. The correlation coefficient (r) varied from -1 to +1.

4.1.5.1 Seed yield per plant

The trait seed yield per plant (**table 4.3**) showed significant positive correlation with number of pods per plant (0.258**), number of seed per pod (0.252**), chlorophyll content (0.173**), number of primary branches (0.229**), number of secondary branches (0.401**), and 100-seed weight (0.115*) where as it exhibited presence of negative and significant correlation with days to 50% flowering (-0.232**), days to 50% pod stage (-0.234**) and days to maturity (-0.249**).

4.1.5.2 Days to maturity

The number of days to maturity observed positive and significant correlation with to 50% flowering (0.923**) and days to 50% pod stage (0.924**) while noticed significant negative correlation with number of pods per plant (-0.147**) and 100-seed weight (-0.125**).

4.1.5.3 100-seed weight

The trait 100-seed weight revealed positive and significant correlation with chlorophyll content (0.157**), number of pods per plant (0.217**) and number of secondary branches (0.166**) and also showed negative correlation with days to 50% flowering (-0.155**) and days to 50% pod stage (-0.149**).

4.1.5.4 Number of secondary branches

The significant positive correlation for number of secondary branches had noticed with plant population (0.245**), chlorophyll content (0.199**), number of pods per plant (0.515**), number of seeds per pod (0.335**) and number of primary branches (0.34**) while it observed negative correlation with days to 50% flowering (-0.241**), days to 50% pod stage and days to maturity (-0.242**).

4.1.5.5 Number of primary branches

The trait number of primary branches exhibited positive significant correlation with chlorophyll content (0.107*), plant height (0.21**), number of pods per plant (0.31**) and number of seeds per pod (0.243**) where as it showed negative significant correlation with days to 50% flowering (-0.104**), days to 50% pod stage (-0.102*) and days to maturity (-0.125**).

4.1.5.6 Number of pods per plant

The traits viz., plant population (0.259**), chlorophyll content (0.248**), number of secondary branches (0.515**), 100-seed weight (0.217**) and seed yield per plant

(0.258**) revealed positive and significant correlation with the trait number of pods per plant where as it had noticed negative and significant correlation with days to 50% flowering (-0.195**), days to 50% pod stage (-0.187**).

4.1.5.7 Numbers of seed per pod

The characteristics such as plant population (0.149**), chlorophyll content (0.103*), plant height (0.122**), number of pods per plant (0.271**) revealed positive and significant correlation with the trait number of seed per pod while it showed significant negative correlation with days to 50% flowering (-0.158**), days to 50% pod stage (-0.159**), and days to maturity (-0.112**).

4.1.5.8 Plant height

The height of plant showed significant positive correlation with chlorophyll content (0.093*), number of pods per plant (0.12*), number of seeds per pod (0.122**), number of primary branches (0.21**), number of secondary branches (0.112**) and seed yield per plant (0.099*) where as it exhibited negative and significant correlation with days to 50 % flowering (-0.105*) and days to 50 % pod stage (-0.103*).

4.1.5.9 Chlorophyll content

The trait chlorophyll content was positively and significantly correlated with plant population (0.146**), number of pods per plant (0.248**), number of secondary branches (0.199**), seed yield per plant (0.173**) where as it was significant negatively correlated with days to 50% flowering (-0.202**) and days to 50 % pod stage (-0.203**).

4.1.5.10 Days to 50 % pod stage

The number of days to 50 % pod stage observed significant positive correlation with days to 50 % flowering (0.994**) and days to maturity (0.923**) where as it showed negative and significant correlation to plant population (-0.167**), number of pods per plant (-0.187**) and seed yield per plant (-0.234**)

4.1.5.11 Days to 50 % flowering

The number of days to 50 % flowering exhibited positive and significant correlation with days to 50 % pod stage (0.994**) and days to maturity (0.923**) while it observed significant negative correlation with number of pods per plant (-0.195**), 100-seed weight (-0.155**), seed yield per plant (-0.232**).

4.1.5.12 Plant population

The traits viz., chlorophyll content (0.146**), number of pods per plant (0.259***), number of secondary branches (0.245**), 100-seed weight (0.147**) exhibiting positive and significant correlation with the trait plant population.

The result findings have been reported by **Thakur *et al.* (2018)** where it had noticed total number of pods per plant, total number of secondary branches and total number of seeds per plant all had highly significant positive correlations with seed yield per plant. **(Nikhitha & Walia, 2022)** also revealed days to 50% flowering showed positive significant correlation with days to maturity and showed negative correlation with number of secondary branches per plant.

Similar findings were reported by **Ningwal *et al.* (2023), Jain *et al.* (2020), Omer & Karadavut (2018), Devasirvatham *et al.* (2015)**.

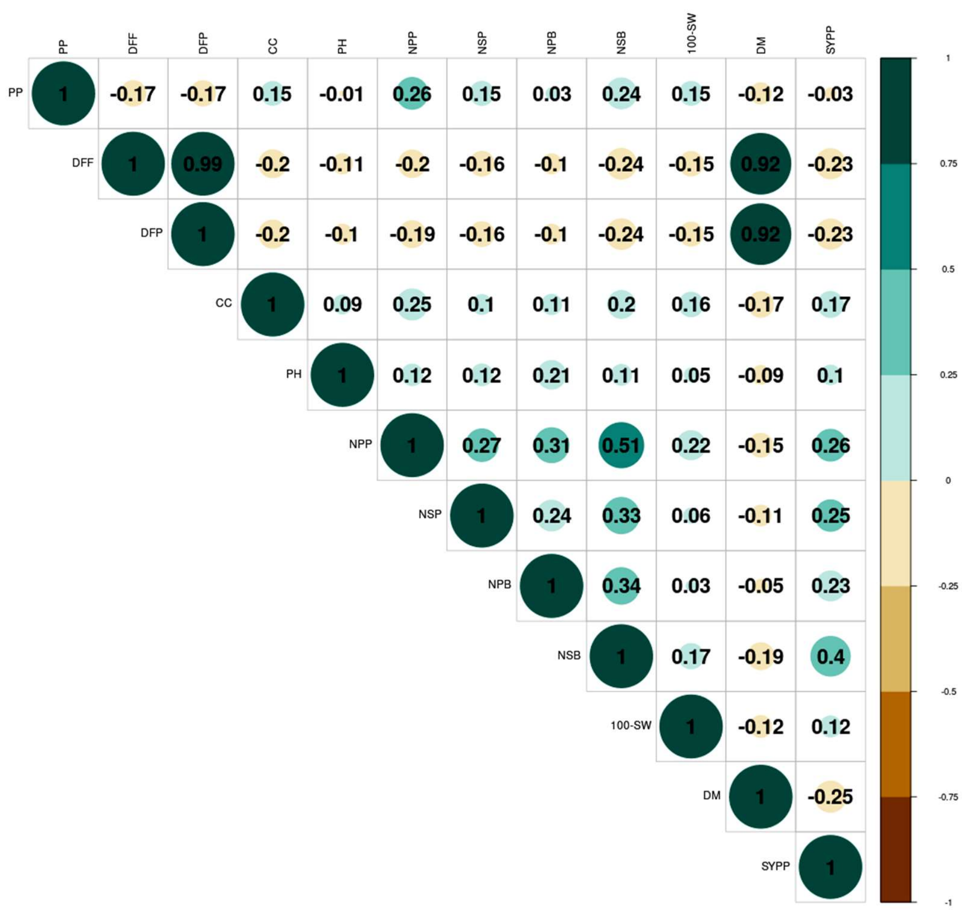


Fig. 4.8 Correlogram depicting correlation between different traits

Table 4.3 Correlation coefficient analysis

	PP	DFF	DFP	CC	PH	NPP	NSP	NPB	NSB	100-SW	DM	SYPP
PP	1	-0.168**	-0.167**	0.146**	-0.008	0.259**	0.149**	0.033	0.245**	0.147**	-0.117*	-0.032
DFF		1	0.994**	-0.202**	-0.105*	-0.195**	-0.158**	-0.104*	-0.241**	-0.155**	0.923**	-0.232**
DFP			1	-0.203**	-0.103*	-0.187**	-0.159**	-0.102*	-0.242**	-0.149**	0.924**	-0.234**
CC				1	0.093*	0.248**	0.103*	0.107*	0.199**	0.157**	-0.17**	0.173**
PH					1	0.12*	0.122**	0.21**	0.112*	0.05	-0.091	0.099*
NPP						1	0.271**	0.31**	0.515**	0.217**	-0.147**	0.258**
NSP							1	0.243**	0.335**	0.059	-0.112*	0.252**
NPB								1	0.34**	0.027	-0.046	0.229**
NSB									1	0.166**	-0.187**	0.401**
100-SW										1	-0.125**	0.115*
DM											1	-0.249**
SYPP												1

P > 0.05: non-significance; significance at P < 0.01, * P < 0.05**

PP-Plant population; DFF-Days to 50 % flowering; DFP-Days to 50 % pod stage; CC-Chlorophyll content; PH-Plant height; NPP-Number of pods per plant; NSP-Number of seed per pod; NPB-Number of primary branches; NSB-Number of secondary branches; SW100-Hundred seed weight; DM-Days to maturity; SYPP-Seed yield per plant

4.1.6 Path coefficient analysis

Path coefficient analysis was applied to determine the indirect and direct contributions of each characteristic to seed yield per plant. Wright (1921) established this path co-efficient analysis approach, which isolates the variables of correlation and analyses the possible contributions of direct and indirect effects of the independent variable on the dependent variable.

Yield per plant is a complex feature that is linked to a higher number of correlated yield attributing variables; their dependency generally influences their relationship with yield by rendering correlation impossible. Path coefficient analysis is a method for determining the direct and indirect effects of several independent characters on the dependent characters

Table 4.4 displays the path coefficient values for the direct and indirect impacts of quantitative features on yield per plant. **Figure 4.6** depicts a representation of the path coefficient study on the interaction of characteristics with yield of seeds per plant.

4.1.6.1 Plant population

Plant population exerted negative direct effect on seed yield per plant (-0.010) where as the positive indirect direct effects were observed by chlorophyll content (0.061), number of pods per plant (0.033) and 100-seed weight (0.015).

4.1.6.2 Days to 50 % flowering

The number of days to 50 % flowering had positive direct impact on seed yield per plant (0.738) and observed negative indirect effects by days to 50 % pod stage (-0.387), number of secondary branches (-0.047), days to maturity (-0.352).

4.1.6.3 Days to 50 % pod stage

The number of days to 50 % pod stage had negative direct effect on seed yield per plant (-0.391) and noticed negative indirect effects through days to maturity (-0.352) where as observed positive indirect effects through number of pods per plant (0.012) and 100-seed weight (0.012).

4.1.6.4 Number of primary branches

The trait number of primary branches exerted direct and positive impact on seed yield per plant (0.075), where as indirect effects due to number of secondary branches (0.081), number of pods per plant (0.034), have observed positive via days to 50 %

flowering noticed as negative.

4.1.6.5 Number of secondary branches

The trait number of secondary branches contributed direct and positive impact on seed yield per plant (0.094). The indirect effect of traits such as number of pods per plant (0.100), 100-seed weight (0.022) are showed as positive via day to 50 % flowering (-0.118) observed as negative.

4.1.6.6 Number of pods per plant

The trait number of pods per plant contributed direct positive influence on seed yield per plant (0.044). The indirect positive effects were due to the traits viz., number of seeds per pod (0.061), 100-seed weight (0.020), number of primary (0.028) and secondary branches (0.214) where as negative indirect effects noticed due to day to 50 % flowering (-0.162).

4.1.6.7 Number of seed per pod

Number of seed per pod revealed positive and direct impact on seed yield per plant (0.157) where as indirect positive effects exhibited due to number of pods per plant (0.023), number of secondary branches (0.083), plant height (0.011) and negligible effect of 100-seed weight (0.002).

4.1.6.8 Plant height

The height of plant had exerted direct and positive influence on seed yield per plant (0.084) where as the traits viz., chlorophyll content (0.008), number of primary branches (0.010) and 100-seed weight (0.008) exhibited negligible indirect effects.

4.1.6.9 Days to maturity

The number of days to maturity had negative and direct effect on seed yield per plant (-0.053). The indirect positive effects observed by chlorophyll content (0.015), number of pods per plant (0.038), number of seed per pod (0.011) and 100-seed weight (0.013) via negative indirect effects showed by day to 50 % flowering (-0.044) and days to 50 % pod stage (-0.020).

4.1.6.10 100-seed weight

The trait 100-seed weight contributed highest direct positive effect on seed yield per plant (0.103) while the occurrence of indirect effects were due to number of secondary branches (0.041), number of pods per plant (0.021) observed as positive via days to 50 % flowering (-0.103) indicating negative indirect effect.

Gediya *et al.* (2019) also observed that total number of pods per plant (0.044), seeds per pod and 100 seed weight (0.665) all had a significant direct influence on seed yield per plant where as **Omer & Karadavut (2018)** also revealed the significant indirect influence of the number of seeds per plant on the number of pods per plant depicts that the number of pods in the plant will increase as the number of seeds in the plant increases, and hence increases the yield.

Similar results have been reported by others **Jain *et al.* (2020), Paul *et al.* (2018), Kumar *et al.* (2017), Chopdar *et al.* (2017).**

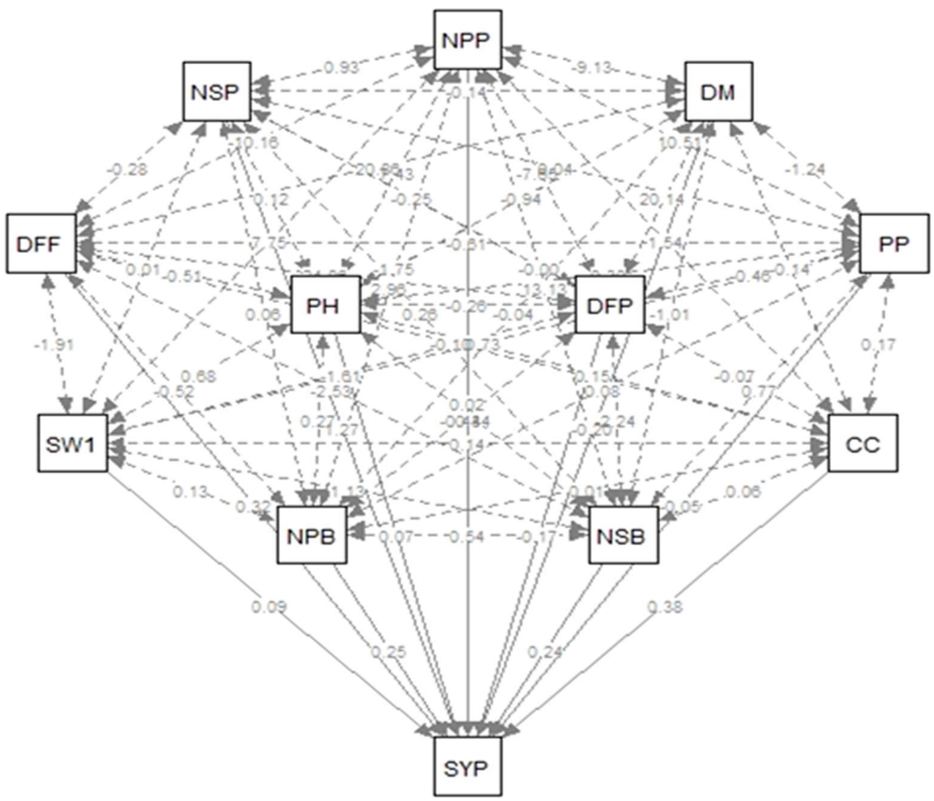


Fig.4.9 Path diagram

PP-Plant population; DFF-Days to 50 % flowering; DFP-Days to 50 % pod stage; CC-Chlorophyll content; PH-Plant height; NPP-Number of pods per plant; NSP-Number of seed per pod; NPB-Number of primary branches; NSB-Number of secondary branches; SW100-Hundred seed weight; DM-Days to maturity; SYPP-Seed yield per plant

Table 4.4 Path coefficient analysis

	PP	DFF	DFP	CC	NPB	NSB	NPP	NSP	PH	DM	SW100
PP	**-0.010**	-0.037	0.016	0.061	0.004	0.017	0.033	-0.003	0.011	0.033	0.015
DFF	0.002	**0.738**	-0.387	-0.003	-0.012	-0.047	-0.015	-0.028	-0.003	-0.352	-0.014
DFP	0.002	0.731	**-0.391**	-0.002	-0.010	-0.045	-0.012	-0.027	-0.002	-0.352	-0.012
CC	0.005	0.635	-0.336	**-0.005**	-0.001	-0.021	-0.014	-0.016	-0.005	-0.409	-0.013
NPB	-0.002	-0.118	0.055	0.003	**0.075**	0.081	0.034	0.050	0.012	0.004	0.007
NSB	-0.015	-0.111	0.047	0.020	0.025	**0.094**	0.100	0.036	0.015	0.057	0.022
NPP	-0.007	-0.162	0.082	0.005	0.028	0.214	**0.044**	0.061	0.005	0.041	0.020
NSP	-0.003	-0.133	0.066	-0.001	0.024	0.083	0.023	**0.157**	0.011	0.041	0.002
PH	-0.002	-0.022	0.008	0.008	0.010	0.013	0.018	0.020	**0.084**	0.025	0.008
DM	-0.040	-0.044	0.020	0.015	0.004	0.036	0.038	0.011	0.004	**0.053**	0.013
SW100	-0.005	-0.103	0.047	0.009	0.005	0.041	0.021	0.003	0.007	0.053	**0.103**

Residual Effect^2 = 0.77

PP-Plant population; DFF-Days to 50 % flowering; DFP-Days to 50 % pod stage; CC-Chlorophyll content; PH-Plant height; NPP-Number of pods per plant; NSP-Number of seed per pod; NPB-Number of primary branches; NSB-Number of secondary branches; SW100-Hundred seed weight; DM-Days to maturity; SYPP-Seed yield per plant

4.1.7 Euclidean cluster analysis

Different crop species have successfully employed the choice of parents based on the level of genetic difference. In this context, the idea of genetic divergence has been demonstrated to be quite beneficial in distinguishing groups of individuals.

The genetic divergence for augmented block design was assessed using Euclidean Cluster Analysis. The distances between and among the clusters were calculated using Euclidean distances. This investigation was performed on experimental material consisting of 500 genotypes along with three checks. The following subheadings have been used to explain genetic divergence in further detail:

4.1.7.1 Group constellation

All 440 genotypes had been grouped under six clusters **(Qulmamatova, 2023)** in such a way that average intra cluster distance remained minimum. Table no. 4.8 represented clustering pattern of genotypes which consist of 43 genotypes under cluster-I, cluster-II had maximum number of genotypes viz., 129, 59 genotypes under cluster-III, cluster-IV had 63 genotypes, cluster-V comprised of 119 genotypes and cluster-VI had 30 genotypes.

4.1.7.2 Average inter-cluster distances

The pattern of genotype distribution into distinct groups revealed significant genetic difference. The maximum inter cluster distance (**table 4.5**) existed between cluster-IV and cluster-VI (38.090) followed by cluster-III and cluster-VI (33.529), cluster-II and cluster-III (33.235), cluster-II and cluster-IV (31.671).

It represent a measure of genetic diversity between clusters which results into rational selection of suitable donors from various clusters. The greater the distance between clusters, the greater the possibility of transgressive segregants. The greatest genetic distance had been identified between cluster-IV and cluster-VI in this study, followed by cluster-III and cluster-VI, cluster-II and cluster-III, cluster-II and cluster-IV. As a result, crossings between genotypes from these cluster pairings may result in desirable transgressive segregants.

Table no. 4.5 Inter cluster distances

Distances between Final Cluster Centres						
Cluster	**I**	**II**	**III**	**IV**	**V**	**VI**
I	1	23.985	15.712	25.379	16.841	19.062
II		1	**33.235**	**31.671**	16.290	14.776
III			1	14.820	18.573	**33.529**
IV				1	15.713	**38.090**
V					1	23.267
VI						1

4.1.7.3 Cluster mean values for different traits

Table 4.6 displays the cluster means for every parameter evaluated in chickpea accessions. Detailed information related to all the attributes varied under various clusters had been demonstrated below

Maximum mean value for the trait chlorophyll content was observed in cluster III (2.1559) followed by cluster-IV (2.1049) and cluster-III (2.0550). The genotypes under cluster-I (58.2800) took minimum days to 50 % flowering followed by cluster-III (60.6293) and cluster-VI (60.8940). The genotypes under cluster-I (66.29) took minimum number of days to 50 % pod stage followed by cluster-III (68.85) and cluster-VI (68.98). Cluster-I (101.28) revealed the genotypes categorized under this group matured early when compared to cluster-III (68.85) followed by cluster-VI (103.79). The trait number of primary branches exhibited highest cluster mean for cluster-III (4.2878) genotypes followed by cluster-IV (4.1521) and cluster-VI (3.8593). The genotypes under cluster-IV (70.2621) produced maximum number of pods per plant followed by cluster-III (68.4585) and cluster-V (54.8374). The trait number of secondary branches showed maximum mean value for cluster-III (13.5408) genotypes followed by cluster-IV (12.8770) and cluster-I (12.7626). Maximum number of erect genotypes grouped under cluster-IV (35.1486) followed by cluster-VI (34.7210) and cluster-III (34.3459). The genotypes noticed for greater value of 100-seed weight categorized under cluster-III (13.3000) followed by cluster-I (13.1474) and cluster-IV (12.8702).

The genotypes grouped under cluster –III (11.5951) produced higher seed yield per plant followed by cluster-IV (11.1071) and cluster-I (10.5512).

It had been concluded that the genotypes grouped under cluster-III were moderately maturing and observed maximum chlorophyll content, exhibiting higher number of primary and secondary branches leads to the production of higher seed yield per plant and 100-seed weight.

Similar findings were reported by **Qulmamatova,(2023**), **Tanwar *et al.* (2022), Aswathi & Jayamani, (2019), Jha *et al.*(2018), Jha, Uday Chand, (2017), Pandey, (2015), Krishnamurthy *et al. (*2011)**

Table no. 4.6 Cluster mean values for different traits

Final Cluster Centres						
	Cluster					
	I	**II**	**III**	**IV**	**V**	**VI**
CC	1.9547	1.8706	2.1559	2.1049	2.0550	1.8730
DFF	58.2800	69.6146	60.6293	69.7610	68.5045	60.8940
DFP	66.29	77.21	68.85	77.77	76.26	68.98
DM	101.28	111.44	103.99	111.17	110.03	103.79
NPB	3.8484	3.6494	4.2878	4.1521	3.7351	3.8593
NPP	53.5437	38.8050	68.4585	70.2621	54.8374	35.1490
NSB	12.7626	10.8456	13.5408	12.8770	12.4156	11.2093
NSP	1.5721	1.4631	1.7475	1.5762	1.5477	1.5057
PH	33.9079	33.3419	34.3459	35.1486	33.7010	34.7210
PP	7.07	6.71	8.76	8.18	7.69	6.72
SW100	13.1474	11.5852	13.3000	12.8702	12.1661	12.2123
SYPP	10.5512	9.8401	11.5951	11.1071	10.3332	9.7757

PP-Plant population ; DFF-Days to 50 % flowering ; DFP-Days to 50 % pod stage ; CC-Chlorophyll content ; PH-Plant height ; NPP-Number of pods per plant ; NSP-Number of seed per pod ; NPB-Number of primary branches ; NSB-Number of secondary branches ; SW100-Hundred seed weight ; DM-Days to maturity ; SYPP-Seed yield per plant

Table no. 4.7 Identification of donors based on cluster mean of different traits

S.N.	Traits	Total cluster mean	Genetic donors
1.	Days to maturity	106.95	ICC-153, ICC-168, ICC-219, ICC-383, ICC-494, ICC-512, ICC-553, ICC-734, ICC-1196, ICC-1402, ICC-1510, ICC-1569, ICC-2072, ICC-2172, ICC-2210, ICC-2595, ICC-2711, ICC-3575
2.	Chlorophyll content	2.00	ICC-562, ICC-618, ICC-701, ICC-731, ICC-751, ICC-1070, ICC-1136, ICC-1173, ICC-1265, ICC-1555, ICC-1614, ICC-2070, ICC-2072, ICC-2096, ICC-2206, ICC-2211, ICC-2567, ICC-2625, ICC-2664, ICC-2669, ICC-2933, ICC-3142, ICC-3245, ICC-3337, ICC-3421, ICC-3425, ICC-3432, ICC-3540, ICC-3567
3.	Number of primary branches	3.92	ICC-15, ICC-26, ICC-80, ICC-92, ICC-143, ICC-169, ICC-184, ICC-237, ICC-255, ICC-273, ICC-315, ICC-317, ICC-350, ICC-398, ICC-437, ICC-455, ICC-515, ICC-542, ICC-553, ICC-579, ICC-693, ICC-711, ICC-751, ICC-755, ICC-796, ICC-812, ICC-871, ICC-950, ICC-952, ICC-1033, ICC-1049, ICC-1083, ICC-1097, ICC-1128, ICC-1246, ICC-1397, ICC-1445, ICC-1505, ICC-1594, ICC-2030, ICC-2104, ICC-2172, ICC-2210, ICC-2211

4.	**Number of secondary branches**	**12.27515**	ICC-92, ICC-315, ICC-343, ICC-353, ICC-542, ICC-618, ICC-668, ICC-1194, ICC-1822, ICC-2023, ICC-2030, ICC-2497, ICC-2509, ICC-2836, ICC-2957, ICC-3089, ICC-3594
5.	**Number of pods per plant**	**53.50**	ICC-1180, ICC-1312, ICC-3362
6.	**Hundred-seed weight**	**12.54**	ICC-1049, ICC-1278, ICC-2233, ICC-3581
7.	**Seed yield per plant**	**10.53**	ICC-708, ICC-875, ICC-1127, ICC-2204, ICC-2349, ICC-2411, ICC-2610, ICC-3325, ICC-3388, ICC-3458

Table no. 4.8 Genotypes grouped under six clusters

I	43	**JG-14**								
		ICC-169	ICC-273	ICC-437	ICC-494	ICC-701	ICC-729	ICC-755	ICC-793	ICC-797
		ICC-929	ICC-931	ICC-943	ICC-946	ICC-1030	ICC-1032	ICC-1097	ICC-1201	ICC-1237
		ICC-1285	ICC-1345	ICC-1355	ICC-1359	ICC-1449	ICC-1520	ICC-1569	ICC-1911	ICC-2078
		ICC-2206	ICC-2211	ICC-2353	ICC-2410	ICC-2915	ICC-3232	ICC-3277	ICC-3284	ICC-3506
		ICC-3542	ICC-3575	ICC-3581	ICC-3582	ICC-3596	ICC-111			
II	**129**	ICC-45	ICC-75	ICC-80	ICC-86	ICC-143	ICC-219	ICC-301	ICC-311	ICC-324
		ICC-338	ICC-342	ICC-344	ICC-455	ICC-477	ICC-482	ICC-552	ICC-562	ICC-583
		ICC-643	ICC-684	ICC-685	ICC-708	ICC-734	ICC-925	ICC-961	ICC-987	ICC-1009
		ICC-1036	ICC-1049	ICC-1066	ICC-1070	ICC-1071	ICC-1078	ICC-1083	ICC-1084	ICC-1092
		ICC-1093	ICC-1118	ICC-1121	ICC-1122	ICC-1127	ICC-1128	ICC-1136	ICC-1161	ICC-1163
		ICC-1164	ICC-1172	ICC-1181	ICC-1193	ICC-1196	ICC-1204	ICC-1205	ICC-1229	ICC-1240
		ICC-1250	ICC-1263	ICC-1360	ICC-1392	ICC-1402	ICC-1431	ICC-1498	ICC-1505	ICC-1507
		ICC-1555	ICC-1609	ICC-1614	ICC-1629	ICC-1710	ICC-1715	ICC-1740	ICC-1770	ICC-1789
		ICC-1793	ICC-1817	ICC-1822	ICC-1876	ICC-1889	ICC-1891	ICC-1897	ICC-1964	ICC-1970
		ICC-1996	ICC-2014	ICC-2065	ICC-2066	ICC-2072	ICC-2080	ICC-2107	ICC-2172	ICC-2177
		ICC-2195	ICC-2202	ICC-2210	ICC-2349	ICC-2352	ICC-2402	ICC-2486	ICC-2507	ICC-2514
		ICC-2515	ICC-2546	ICC-2555	ICC-2589	ICC-2593	ICC-2606	ICC-2629	ICC-2878	ICC-3207
		ICC-3217	ICC-3266	ICC-3274	ICC-3312	ICC-3325	ICC-3326	ICC-3366	ICC-3391	ICC-3425
		ICC-3426	ICC-3432	ICC-3453	ICC-3485	ICC-3521	ICC-3539	ICC-3540	ICC-3558	ICC-3568
		ICC-3571	ICC-3528							
III	59	**IPC-2006-77**								
		ICC-136	ICC-190	ICC-218	ICC-255	ICC-257	ICC-440	ICC-591	ICC-606	ICC-618
		ICC-652	ICC-792	ICC-796	ICC-871	ICC-875	ICC-898	ICC-905	ICC-932	ICC-968
		ICC-1000	ICC-1033	ICC-1157	ICC-1232	ICC-1295	ICC-1315	ICC-1337	ICC-1338	ICC-1443

		ICC-1445	ICC-1699	ICC-2023	ICC-2083	ICC-2096	ICC-2104	ICC-2142	ICC-2166	ICC-2240
		ICC-2564	ICC-2600	ICC-2669	ICC-2672	ICC-2675	ICC-2694	ICC-2695	ICC-2703	ICC-2720
		ICC-2773	ICC-2782	ICC-2906	ICC-2938	ICC-2957	ICC-2969	ICC-3024	ICC-3025	ICC-3029
		ICC-3056	ICC-3205	ICC-3331	ICC-3337					
IV	63	ICC-237	ICC-317	ICC-504	ICC-637	ICC-742	ICC-751	ICC-791	ICC-1098	ICC-1278
		ICC-1356	ICC-1419	ICC-1574	ICC-1579	ICC-1815	ICC-1895	ICC-1896	ICC-1915	ICC-1932
		ICC-2184	ICC-2220	ICC-2223	ICC-2233	ICC-2270	ICC-2299	ICC-2342	ICC-2355	ICC-2358
		ICC-2490	ICC-2492	ICC-2500	ICC-2508	ICC-2509	ICC-2520	ICC-2565	ICC-2570	ICC-2576
		ICC-2628	ICC-2630	ICC-2697	ICC-2698	ICC-2711	ICC-2714	ICC-2737	ICC-2796	ICC-2808
		ICC-2829	ICC-2859	ICC-2884	ICC-2893	ICC-2919	ICC-2927	ICC-2933	ICC-3048	ICC-3059
		ICC-3089	ICC-3093	ICC-3142	ICC-3230	ICC-3410	ICC-3421	ICC-3497	ICC-261	
V	119	ICC-95	ICC-153	ICC-166	ICC-168	ICC-219	ICC-299	ICC-315	ICC-337	ICC-343
		ICC-350	ICC-353	ICC-383	ICC-398	ICC-448	ICC-553	ICC-574	ICC-579	ICC-619
		ICC-668	ICC-698	ICC-709	ICC-711	ICC-738	ICC-752	ICC-760	ICC-764	ICC-812
		ICC-839	ICC-950	ICC-951	ICC-952	ICC-963	ICC-991	ICC-1018	ICC-1026	ICC-1035
		ICC-1043	ICC-1052	ICC-1059	ICC-1102	ICC-1173	ICC-1180	ICC-1194	ICC-1272	ICC-1291
		ICC-1296	ICC-1297	ICC-1312	ICC-1384	ICC-1397	ICC-1398	ICC-1414	ICC1424	ICC-1510
		ICC-1560	ICC-1594	ICC-1600	ICC-1616	ICC-1707	ICC-1751	ICC-1774	ICC-1806	ICC-1884
		ICC-1903	ICC-1913	ICC-1923	ICC-1929	ICC-1950	ICC-1990	ICC-2013	ICC-2030	ICC-2070
		ICC-2113	ICC-2114	ICC-2122	ICC-2126	ICC-2127	ICC-2135	ICC-2171	ICC-2183	ICC-220
		ICC-2263	ICC-2397	ICC-2411	ICC-2489	ICC-2497	ICC-2503	ICC-2511	ICC-2516	ICC-2518
		ICC-2567	ICC-2580	ICC-2591	ICC-2595	ICC-2608	ICC-2610	ICC-2625	ICC-2635	ICC-2648
		ICC-2664	ICC-2709	ICC-2836	ICC-2844	ICC-2845	ICC-2861	ICC-3245	ICC-3257	ICC-3313
		ICC-3330	ICC-3388	ICC-3404	ICC-3406	ICC-3412	ICC-3415	ICC-3440	ICC-3458	ICC-3512
		ICC-3567	ICC-3593							

VI	30	**RLBGK-1** ICC-92 ICC-161 ICC-176 ICC-184 ICC-442 ICC-512 ICC-513 ICC-515 ICC-531 ICC-542 ICC-549 ICC-693 ICC-731 ICC-811 ICC-1246 ICC-1265 ICC-1422 ICC-2086 ICC-2561 ICC-2613 ICC-2679 ICC-2748 ICC-2997 ICC-3267 ICC-3317 ICC-3362 ICC-3532 ICC-3594 ICC-42

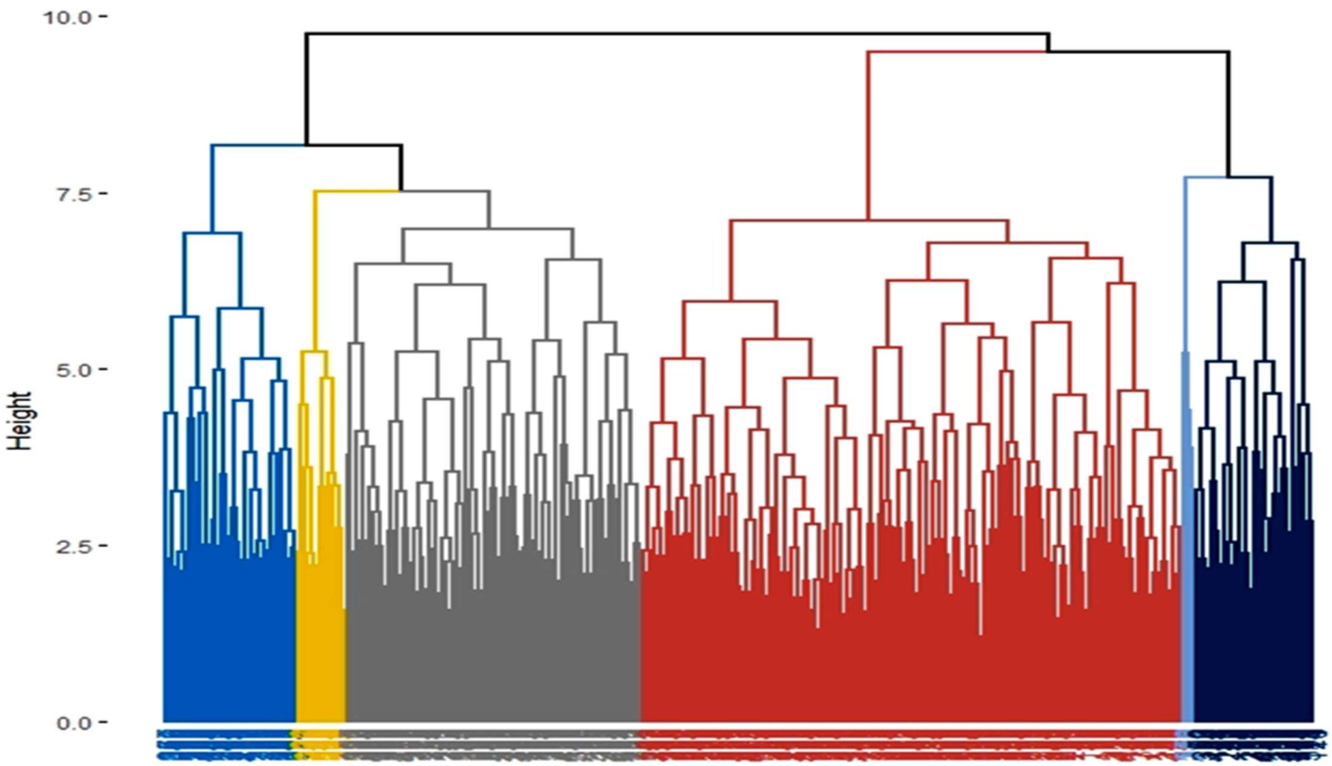


Fig.4.10 Cluster Dendrogram

Table no. 4.9 List of heat tolerant (bold) and heat susceptible lines along with check varieties

Entries	PP	DFF	DFP	CC	PH	NPB	NSB	NPP	NSP	100-SW	DM	SYPP
ICC-161	**9**	**62**	**70**	**2.43**	**35.37**	**3.67**	**14.00**	**71.33**	**1.67**	**8.92**	**105**	**14.27**
ICC-176	**11**	**57**	**65**	**2.17**	**34.13**	**3.67**	**14.67**	**67.33**	**2.00**	**10.42**	**100**	**13.51**
ICC-273	**11**	**58**	**66**	**2.70**	**35.67**	**4.00**	**13.67**	**72.33**	**1.67**	**9.72**	**100**	**11.35**
ICC-299	**10**	**56**	**64**	**2.40**	**37.67**	**5.00**	**12.67**	**63.67**	**1.33**	**11.88**	**101**	**10.93**
ICC-301	**11**	**57**	**65**	**2.50**	**30.00**	**4.67**	**13.33**	**69.67**	**2.00**	**9.92**	**99**	**12.67**
ICC-494	**9**	**63**	**71**	**2.43**	**31.50**	**4.33**	**16.00**	**60.33**	**2.00**	**8.42**	**106**	**12.85**
ICC-583	**11**	**58**	**66**	**2.21**	**34.33**	**3.67**	**17.39**	**71.33**	**2.00**	**8.07**	**101**	**13.72**
ICC-1000	**9**	**71**	**79**	**2.40**	**35.50**	**3.67**	**17.67**	**57.00**	**1.67**	**19.35**	**114**	**12.89**
ICC-2096	**9**	**67**	**75**	**2.00**	**31.17**	**4.67**	**15.67**	**64.33**	**2.00**	**13.3**	**110**	**13.14**
ICC-2714 *	**6**	**68**	**76**	**2.27**	**38.17**	**4.67**	**13.33**	**56.33**	**2.00**	**15.08**	**111**	**13.91**
ICC-3326	**10**	**59**	**67**	**2.27**	**37.17**	**4.33**	**16.67**	**73.67**	**2.00**	**18.37**	**102**	**12.51**
ICC-3406	**10**	**64**	**72**	**2.57**	**35.17**	**5.67**	**18.33**	**67.67**	**1.67**	**14.41**	**107**	**14.45**
ICC-3410 *	**7**	**62**	**70**	**2.17**	**34.67**	**5.33**	**11.23**	**66.00**	**2.00**	**17.55**	**105**	**13.69**
ICC-3412 *	**7**	**69**	**77**	**2.17**	**38.67**	**5.00**	**12.67**	**64.67**	**2.00**	**14.75**	**112**	**12.74**
ICC-3421	**11**	**70**	**78**	**2.00**	**40.33**	**5.00**	**16.33**	**65.67**	**1.67**	**17.37**	**113**	**10.83**
ICC-3497	**10**	**61**	**69**	**2.03**	**34.17**	**4.33**	**17.00**	**72.33**	**1.67**	**15.65**	**104**	**13.80**
ICC-3558	**10**	**61**	**69**	**2.20**	**36.50**	**5.33**	**18.00**	**75.33**	**1.67**	**10.6**	**104**	**15.88**
ICC-829	5	81	88	2.10	28	3.67	11.00	0.00	0	0	116	0.00
ICC-1228	8	64	71	1.30	33	3.67	10	0.00	0	0	99	0.00
ICC-1824	5	68	75	1.37	23.25	3	10	0.00	0	0	103	0.00
ICC-2216	7	72	80	1.27	26.75	3.67	9	0.00	0	0	107	0.00
ICC-2338	5	79	87	1.35	30.75	3.33	10	0.00	0	0	114	0.00
ICC-3025	8	65	74	1.97	38.67	3	8	0.00	0	0	100	0.00
RLBGK-1	**9.14**	**54**	**61.85**	**2.31**	**37.68**	**3.59**	**12.68**	**51.84**	**1.21**	**13.99**	**94**	**11.93**
JG-14	**7.85**	**54**	**61.85**	**2.3**	**32.66**	**3.95**	**14.09**	**57.19**	**1.57**	**17.68**	**95.97**	**12.55**
IPC-2006-77	**8**	**54.28**	**62.28**	**2.2**	**32.03**	**3.67**	**13.03**	**66.38**	**1.71**	**15.61**	**94.57**	**13.46**

Fig. 4.11 Differentiation of genotypes based on maturity

4.2 Validation of promising heat tolerant genotypes based on morpho-physiological and biochemical traits.

Total 18 promising heat tolerant genotypes have been validated along with two heat tolerant checks viz., JG-14 and IPC-2006-77 and two heat susceptible checks viz., JG-62 and BG-3062 under both timely sown and late sown condition for the selection of superior heat tolerant genotypes. The experimental findings have been reported under the following subsections

4.2,1 Analysis of variance

4.2.2 Mean performance

4.2.3 Genetic variability parameters

4.2.3.1 Genotypic and phenotypic coefficient of variation

4.2.3.2 Heritability and genetic advance over mean

4.2.4 Correlation coefficient analysis

4.2.5 Path coefficient analysis

4.2.1 Analysis of variance

The analysis of variance (**table 4.10**) was performed based on RBD by collecting quantitative data of eighteen genotypes along with four checks to verify the substantial significant differences in genetic variation among different germplasm accessions under both timely and late sown condition on the basis of different characteristics taken to this study. This study confirmed that a lot of variation had appeared across the germplasms for the parameters evaluated such as plant population, seedling vigour index (SVI), days to 50% flowering, leaflet size, plant height, days to first pod initiation, days to 50% pod stage, number of primary branches, number of secondary branches, number of pods per plant, number of seeds per pod, days to maturity, hundred-seed weight, days to pod set, chlorophyll content, chlorophyll fluorescence, transpiration rate, stomatal conductance, rate of photosynthesis, protein content, superoxide dismutase activity and catalase activity.

The variation between blocks or replications found to be non-significant during timely and late sown condition except leaflet size, plant height, number of secondary branches, pod set, chlorophyll content, rate of photosynthesis and chlorophyll fluorescence were found significant difference at 0.05% significance level under timely sown condition and leaflet size, number of primary branches, pod set, and superoxide dismutase activity are significantly differed at 0.05% and 0.1% significance level during late sown condition.

Among the chickpea germplasm accessions, it revealed significant differences for all the traits evaluated under both timely and late sown condition indicating the presence of sufficient variability for exploration.Similar findings are reported by following researchers **Devi et *al.* (2022), Kumar et *al.*, (2017), Thakur *et al.* (2018).**

4.2.2 Mean Performances

A wide range of variation in mean performance (**table no. 4.11**) was noticed in all 18 promising heat tolerant genotypes under both timely and late sown condition for the group of variables examined. The purpose of this research was to find out difference of any genetic variability in 18 heat tolerant chickpea accessions for 22 traits in the Bundelkhand region.

4.2.1.1 Plant population

During timely sown condition, plant population ranged from 11 to 37 with the average of 21.28. Highest mean value of plant population was observed for the genotype ICC-6368 (25.67) where as for check variety JG-14 (32.67) was found to be the maximum.

During late sown condition, plant population ranged from 12 to 33 with the average of 20.92. Highest mean value of plant population was observed for the genotype ICC-3508 (22.33) where as for check variety JG-62 (31.33) was found to be the maximum.

4.2.1.2 Seedling vigour index (SVI)

A large amount of variation was observed for the trait SVI ranged from 82.5 to 210 with the mean of 148.41 High SVI was observed in ICC-6944 (204.17) almost similar to check JG-14(205) followed by the ICC-3528 (197.83) which is also being similar to check IPC-2006-77 (198.67) in timely sown condition.

Similarly, a lot of variation was observed during late sown condition ranged from 90 to 207.5 with the average of 155.04. Maximum SVI was found to be in ICC-3528 (196.67) compared to check JG-62 (197.67).

4.2.1.3 Days to 50% flowering

In timely sown condition, a large amount of variation was noticed in the trait days taken to 50% flowering with the minimum of 52 to maximum 82 showing average of 71.71. ICC-3528 (61.33) and all the check varieties showed early days to 50% flowering.

Similarly during late sown condition a range from 58 to 85 with mean value of 70.46 was observed and ICC-3528 (56) followed by ICC-3439 (62) along with all the check varieties.

Table no. 4.10 ANOVA for Randomized block design (RBD) for both timely and late sown condition

ANOVA (Mean sum of squares) - TIMELY SOWN														
		PP	**SVI**	**DFF**	**LS**	**PH**	**DFPI**	**DFP**	**NPB**	**NSB**	**NPP**	**NSP**	**DM**	**100-SW**
Replication	**T**	10.13	121.40	7.23	0.20*	126.56*	127.91*	17.59	0.07	1.82*	79.49	0.00	4.61	1.91
Treatment	**T**	149.02**	4887.4**	326.5**	0.41**	235.33**	347.6**	333.37**	0.49**	6.89**	258.48**	0.148**	583.81**	30.54**
Error	**T**	4.86	53.90	2.97	0.14	27.01	6.81	6.20	0.08	0.47	36.02	0.02	1.96	2.23
		PS	**CC**	**CF**	**TR**	**SC**	**RP***	**PR**	**SOD**	**CAT**	**SYPP**			
Replication	**T**	20.93*	0.12*	0.00351*	0.29	0.01	2.56	0.97	0.02	8.99	8.08			
Treatment	**T**	327.05**	0.17**	0.0068**	1.33**	0.055**	121.71**	28.95**	4.76**	2720.57**	22.38**			
Error	**T**	5.17	0.04	0.00	0.12	0.00	0.91	0.08	0.01	2.85	2.43			
ANOVA (Mean sum of squares) - LATE SOWN														
		PP	**SVI**	**DFF**	**LS**	**PH**	**DFPI**	**DFP**	**NPB**	**NSB**	**NPP**	**NSP**	**DM**	**100-SW**
Replication	**L**	6.47	162.09	0.81	0.22*	14.32	0.17	0.97	0.96*	0.89	3.93	0.002	2.96	0.43
Treatment	**L**	74.60**	2828.13**	194.33**	0.15*	24.94**	191.22**	201.26**	0.17*	2.21**	306.34**	0.073**	82.6**	28**
Error	**L**	4.12	111.83	1.55	0.09	4.78	1.51	1.28	0.07	0.42	3.36	0.02	2.08	0.37
		PS	**CC**	**CF**	**TR**	**SC**	**RP**	**PR**	**SOD**	**CAT**	**SYPP**			
Replication	**L**	21.73	0.11*	0.00	0.06	0.00	0.10	0.39	0.045*	9.88	0.30			
Treatment	**L**	177.84**	0.096**	0.0041*	1.92**	0.0064**	9.01**	24.64**	5.38**	1280.95**	21.84**			
Error	**L**	10.61	0.02	0.00	0.10	0.00	0.66	0.19	0.01	0.96	1.18			

P > 0.05 : ns ; significance at *** P < 0.001, P < 0.01, * P < 0.05**

PP-Plant population ; SVI-Seedling vigour index ; DFF-Days to 50 % flowering ; LS-Leaflet size ; PH-Plant height ; DFPI-Days to first pod initiation ; DFP-Days to 50 % pod stage ; NPB- Number of primary branches ; NSB-Number of secondary branches ; NPP-Number of pods per plant ; NSP-Number of seed per pod ; DM-Days to maturity ; 100SW-Hundred seed weight ; PS-Days to pod set ; CC-Chlorophyll content ; SYPP-Seed yield per plant ; CF-Chlorophyll fluorescence content ; TR-Rate of transpiration ; SC-Stomatal conductance ; RP-Rate of photosynthesis ; PR-Protein content ; SOD-Superoxide dismutase ; CAT-Catalase

4.2.1.4 Leaflet size (cm)

The trait leaflet size varied from 4.18 to 6.36 with the average of 5.13 in timely sown condition. The genotypes ICC-3439 (5.64) followed by ICC-4939 (5.57), ICC-6708 (5.55) showed large size of leaflet compared to the check JG-14 (5.83)

In late sown condition it varied from 2.74 to 4.24 with the mean value of 3.42 and large leaflet size was observed in ICC- 3508 (3.71) followed by ICC -3439 (3.8) compared to the check JG-62 (3.87).

4.2.1.5 Plant height (cm)

Plant height ranged from 45.70 to 86 with the average value of 66.52 under timely sown condition. The genotypes ICC-6368(75.63), followed by ICC-4925 (75.10) and ICC-6708(74.67) showed maximum plant height than the check varieties JG-14 (74.33), and BG-3062 (65.60)

In late sown condition, it ranged from 24.30 to 40.90 with the mean value of 32.37. The genotypes ICC-3528 (36) and ICC-3439 (34.3) showed maximum plant height than the **check variety BG-3062 (28.03).**

4.2.1.6 Days to first pod initiation

In timely sown condition, a large amount of variation was noticed in the trait days taken to first pod initiation with the minimum of 49 to maximum 87 having average value of 71.62. ICC-3528 (60.67) and all the check varieties showed early days to first pod initiation.

Similarly during late sown condition a range from 58 to 87 with mean value of 70.69 was observed and ICC-3528 (58.33) followed by ICC-3439 (64.33) along with all the check varieties showed early days to first pod initiation.

4.2.1.7 Days to 50% pod stage

A wide range of variation was observed in the trait days taken to 50% podding with the minimum of 60 to maximum 92 having average value of 79.28 during timely sown condition. ICC-3528 (60.67) and all the check varieties showed early days to 50% podding.

Similarly during late sown condition a range from 65 to 93 with mean value of 70. The genotype ICC-3528 (68.33) showed early days to 50% podding than the check variety JG-62 (71.33).

4.2.1.8 Number of primary branches

The number of primary branches per plant ranged from 3.8 to 5.4 with the average value of 4.55 under timely sown condition. The genotypes ICC-3528 and ICC-3439 along with the check JG-14 had showed highest primary branches (5.13).

The number of primary branches per plant ranged from 3.8 to 5.4 with the average value of 4.55 under timely sown condition. The genotypes ICC-3528 and ICC-3439 along with the check JG-14 had showed highest primary branches (5.13).

Similarly, during late sown condition the number of primary branches per plant also ranged from 2.8 to 4.6 with the mean value of 3.61. The genotypes ICC-1749 (3.93) followed by ICC-6368 (3.87) and ICC-6818 (3.87) had showed highest number of primary branches along with the check variety JG-14 and IPC-2006-77 (3.93).

4.2.1.9 Number of secondary branches

The number of primary branches per plant ranged from 8 to 15 with the average value of 11.76 under timely sown condition. The genotype ICC-1749(14.07) showed maximum number of secondary branches followed by ICC-4956(12.9) compared to the check variety (14.53).

Similarly during late sown condition, it also ranged from 7.6 to 12 with the mean value of 10.07. The genotype ICC-6818 showed maximum number of genotypes along with the check variety JG-14 (12.13).

4.2.1.10 Number of pods per plant

The trait number of pods per plant varied from 71 to 114 with the mean value of 91.38 and also ranged from 52.20 to 95.60 with the average value of 76.06 under both timely and late sown condition respectively.

ICC-6368 (100.7) produced highest number of pods per plant when compared to check variety (106.7) under timely sown condition where as in late sown condition ICC-6858 (93.97) fulfilled this condition compared to the check variety (92.33).

4.2.1.11 Number of seeds per pod

The trait number of seeds per pod varied from 1.2 to 2.4 with the mean value of 1.66 and also ranged from 1.4 to 2 with the average value of 1.64 under both timely and late sown condition respectively.

ICC-3439 produced highest number of seeds per pod under both timely (2.4) and late sown condition (2.13) than the check variety JG-14 (1.8).

4.2.1.12 Days to maturity

The trait days taken to maturity observed the minimum of 102 to maximum 144 with average of 128.68 and also ranged from 90 to 113 with mean value of 100.46 under both timely and late sown condition respectively.

ICC-3528 matured early under both timely (123) and late sown condition (93) and the best check varieties were JG-14 and IPC-2007-77.

4.2.1.13 100- seed weight (g)

The trait 100- seed weight had a mean value of 14.69 ranging from 9.2 to 23.24 under timely sown condition and also had a mean value of 100.46 ranging from 9.29 to 21.72 under late sown condition.

The highest value of 100-seed weight was observed for ICC-3439 (18.54) under timely sown condition along with the best check variety JG-14 (22.4). Similarly during late sown condition ICC-3528 (15.8) was observed as maximum value along with the best check JG-62 (20.64).

4.2.1.14 Days to pod set

The trait days taken for pod setting had mean value of 79.24 ranging from 59.8 to 90.8 during timely sown condition and also had a mean value of 77.34 varying from 64.6 to 93.6 during late sown condition. Early pod setting was observed in ICC-3528 (68.87) during both timely and late sown condition along with the best check variety JG-14.

4.2.1.15 Chlorophyll content

The trait chlorophyll content had an estimated average value of 2.14 varying from 1.72 to 3.54 and also had a mean value of 1.92 varying from 1.38 to 2.34 under both timely and late sown condition respectively.

The maximum chlorophyll content was observed for ICC-1749 (2.42) during timely sown condition where as in late sown, ICC-3528 exhibited the highest value. The best checks for this trait were BG-3062 (2.79) and JG-14 (2.24) respectively.

4.2.1.16 Chlorophyll fluorescence content

A large amount of variation was observed for the trait chlorophyll fluorescence content, each having an estimated mean value of 0.66 but ranging from 0.53 to 0.78 and also been ranging from 0.57 to 0.8 under both timely and late sown condition respectively.

The maximum chlorophyll fluorescence content was observed for ICC-3528 (0.74) during timely sown condition where as in late sown, ICC-3439 exhibited the highest value. The best checks for this trait were JG-62 (0.78) and JG-14 (0.78) respectively.

4.2.1.17 Transpiration rate

The trait rate of transpiration was observed ranging from 1.16 to 5.75 with an average value of 3.57 and also had an average value of 3.83 varying from 2.3 to 5.34 under both timely and late sown condition respectively.

Higher transpiration rate was observed in ICC-3439 (5.01) than the check variety JG-62 (4.42) and also observed in ICC-3528 (4.8) under both timely and late sown conditions respectively.

4.2.1.18 Stomatal conductance

The trait stomatal conductance ranged from 0.11 to 0.59 having an average value of 0.32 during timely sown condition and also been ranged from 0.05 to 4.32 with an average value of 0.15 during late sown condition.

Maximum level of stomatal conductance was observed for ICC-3528 under both timely and late sown condition performed better than the check variety IPC-2006-77.

4.2.1.19 Rate of photosynthesis

A wide range of variation had been observed for the trait photosynthetic rate ranging from 8.73 to 29.51 with an average value of 17.53 and also from 4.9 to 12.92 having a mean value of 8.93 under both timely and late sown condition respectively.

The maximal values of photosynthetic rates for both timely and late condition were observed for ICC-6944 (22.9) and ICC-6933 (10.2) respectively. The best performance of check was JG-14.

4.2.1.20 Protein content

A large amount of variation had been found in case of protein content estimation ranging from 10.13 to 21.67 with a mean value of 16.17 during timely sown condition and also been varying from 10.08 to 22.14 having an average value of 16.53 during late sown condition.

A good source of protein was found in ICC-3528 (20.25) and ICC-6944 (19.51) under both timely and late sown condition respectively when compared to the best check variety JG-14.

4.2.1.21 Superoxide dismutase (SOD) activity

A high range of SOD activity had been observed with an estimated mean value of 1.34 ranging from 0.25 to 2.73 during timely sown condition and also been varied from 0.05 to 4.32 with a mean value of 1.79 during late sown condition.

A rapid increase in level of SOD activity was observed in ICC-3528 (4.06) under late sown condition followed by ICC-3508 (2.8) compared to timely sown and performed better than check varieties.

4.2.1.22 Catalase (CAT) activity

A high range of CAT activity had been observed with an estimated mean value of 54.19 ranging from 23.75 to 98.20 during timely sown condition and also been varied from 32.27 to 110.6 with a mean value of 60.01 during late sown condition.

A significant increase in level of CAT activity was found in ICC-6368 (80.12) under late sown condition followed by ICC-3528 (71.8) compared to timely sown and performed better than check varieties

4.2.1.23 Seed yield per plant (g)

The trait number of pods per plant varied from 7.91 to 19.87 with a mean value of 12.50 and also been ranged from 6.44 to 17.93 with an average value of 11.22 under both timely and late sown condition respectively.

The highest seed yield per plant was noticed in ICC-6701 under both timely and late sown condition when compared to the check varieties viz., JG-14 under both timely sown and under late sown condition.

Table no. 4.11: Estimation of range and mean performance of the genotypes under timely and late sown condition

Trait	T / L	Range		Grand Mean
		Max	Min	
PP	**T**	37.00	11.00	21.28
	L	33.00	12.00	20.92
SVI	**T**	210.00	82.50	148.41
	L	207.50	90.00	155.04
DFF	**T**	82.00	52.00	71.71
	L	85.00	58.00	70.46
LS	**T**	6.36	4.18	5.13
	L	4.24	2.74	3.42
PH	**T**	86.00	45.70	66.52
	L	40.90	24.30	32.37

DFPI	**T**	87.00	49.00	71.62
	L	87.00	58.00	70.69
DFP	**T**	92.00	60.00	79.28
	L	93.00	65.00	77.29
NPB	**T**	5.40	3.80	4.55
	L	4.60	2.80	3.61
NSB	**T**	15.00	8.00	11.76
	L	12.40	7.60	10.07
NPP	**T**	114.60	71.60	91.38
	L	95.60	52.20	76.06
NSP	**T**	2.40	1.20	1.66
	L	2.20	1.40	1.64
DM	**T**	144.00	102.00	128.68
	L	113.00	90.00	100.46
100-SW	**T**	23.24	9.20	14.69
	L	21.72	9.29	13.13
PS	**T**	90.80	59.80	79.24
	L	93.60	64.60	77.34
CC	**T**	3.54	1.72	2.14
	L	2.34	1.38	1.92
CF	**T**	0.78	0.53	0.66
	L	0.80	0.57	0.66
TR	**T**	5.75	1.16	3.57
	L	5.24	2.30	3.83
SC	**T**	0.59	0.11	0.32
	L	0.26	0.06	0.15
RP	**T**	29.51	8.73	17.53
	L	12.92	4.90	8.93
PR	**T**	21.67	10.13	16.17
	L	22.14	10.08	16.53
SOD	**T**	2.73	0.25	1.34
	L	4.32	0.05	1.79
CAT	**T**	98.20	23.75	54.19
	L	110.60	32.27	60.01
SYPP	**T**	19.87	7.91	12.50
	L	17.93	6.44	11.22

4.2.3 Genetic variability parameters

4.2.3.1 Genotypic and phenotypic coefficient of variation

Genetic measures such as genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) can be used to assess the degree of diversity in germplasm. Although the phenotypic coefficient of variation (PCV) for all characters was consistently found to be greater than the genotypic coefficient of variation (GCV), the variations in magnitude were modest. It indicates that the environment has lesser impact on the characters expression.

During timely sown condition, the highest GCV and PCV (**table 4.12**) were observed for the trait SOD activity followed by stomatal conductance, CAT activity, rate of photosynthesis, plant population, seedling vigour index, transpiration rate, hundred-seed weight, seed yield per plant, protein content, number of seeds per pod, chlorophyll content, days to first pod initiation, plant height, days to 50% flowering, days to 50% podding, number of secondary branches, days to pod set, number of pods per plant, leaflet size, days to maturity, number of primary branches, chlorophyll fluorescence.

During late sown condition, maximum level of GCV and PCV were noticed for the trait SOD activity followed by CAT activity, stomatal conductance, plant population, hundred-seed weight, rate of photosynthesis, seedling vigour index, transpiration rate, protein content, number of pods per plant, number of seeds per pod, days to first pod initiation, days to 50% podding, days to pod set, plant height, number of secondary branches, leaflet size, number of primary branches, chlorophyll fluorescence, days to maturity.

The results similar to this experiment were reported by. **Arslan, (2023), Devi *et al.* (2022)**, **Katkani *et al.* (2022), Perumalla *et al.* (2022), Jain *et al.* (2020), Devasirvatham *et al.* (2015)**

4.2.3.2 Heritability and genetic advance over mean

Heritability indicates that genotypes which are more closely associated are more likely to resemble one another than compared to distant ones. Estimates of heritability help breeders to set up the resources essential to select for desirable characteristics efficiently and achieve maximal genetic gain with limited time and resources.

The degree of gain acquired in a character under a certain selection pressure is explained by genetic advance. High genetic advance combined with high heritability estimates provides the ideal conditions for selection. It also demonstrates the existence of additive genes in the trait, implying consistent crop improvement through trait selection. Individual consideration of the parameters is less trustworthy and informative than estimates of heritability with genetic advancement.

Genetic variability components such as heritability and genetic advance (GA) are important biometric tools for analysing dissimilarity in populations with the aim to perform selection and evaluate viable germplasm for development through breeding procedures. Higher PCV and GCV for yield and yield-related characteristics in putative heat tolerant lines were investigated, indicating the relevance of genetic diversity in plant selection.

During timely sown condition, days to maturity (98) had the highest heritability followed by rate of photosynthesis (97), days to 50% flowering (96), CAT activity (96), seedling vigour index (96) found to be maximum where as greater genetic advance over mean noticed in the trait SOD activity (86.75) followed by CAT activity (77.56), stomatal conductance (75.57), rate of photosynthesis (66.92) found to be higher compared to other variables.

The largest value of heritability viewed in the trait SOD and CAT activity (99) followed by protein content (97), days to maturity (90), seedling vigour index (89) appeared higher than the other parameters validated under late sown condition. Genetic advance over mean was found greater in the trait SOD (88.83) followed by CAT activity (70.83), stomatal conductance (54.12) compared to other characteristics.

High heritability coupled with high genetic advance (**table 4.12**) over mean observed maximum in SOD and CAT activity under both timely and late sown condition. Comparatively, it was noticed higher during late sown rather than timely sown condition indicated association of genetic progress aids in selection and identification of desirable heat tolerant donors.

The similar result findings have been reported by **Sharma *et al.* (2023), Bharathi *et al.* (2022)**, **Devi *et al.* (2022), S. Kumar *et al.* (2020), Makonya *et al*. (2019), Aswathi & Jayamani, (2019), Chopdar *et al*.(2017), Meena *et al.* (2014)**

Table no. 4.12 Estimation of genetic variability parameters under timely and late sown condition

Traits		GCV %	PCV %	h^2 (Broad sense) %	GA %	GAM %
PP	**T**	27.37	29.31	87	11.20	52.64
	L	23.17	25.12	85	9.21	44.02
SVI	**T**	25.11	25.66	96	75.11	50.61
	L	19.41	20.57	89	58.48	37.72
DFF	**T**	12.73	12.99	96	18.44	25.71
	L	10.28	11.16	85	13.74	19.50
LS	**T**	5.89	9.42	39	0.39	7.58
	L	4.44	9.87	20	0.14	4.11
PH	**T**	10.63	13.48	62	11.49	17.27
	L	8.01	10.48	58	4.08	12.61
DFPI	**T**	13.04	13.60	92	18.44	25.76
	L	10.34	11.29	84	13.78	19.50
DFP	**T**	11.54	12.02	92	18.11	22.84
	L	9.97	10.73	86	14.74	19.07
NPB	**T**	6.69	9.16	53	0.46	10.07
	L	5.19	9.02	33	0.22	6.16
NSB	**T**	10.23	11.97	73	2.12	18.01
	L	7.67	10.01	59	1.22	12.09
NPP	**T**	8.24	10.70	80	16.11	17.63
	L	13.21	13.43	77	16.20	21.30
NSP	**T**	11.56	15.19	58	0.30	18.12
	L	7.82	11.89	43	0.17	10.60
DM	**T**	9.22	9.29	98	24.25	18.85
	L	4.97	5.25	90	9.73	9.68
100-SW	**T**	20.55	23.12	79	5.53	37.63
	L	23.11	23.57	75	4.78	36.40
PS	**T**	11.47	11.86	93	18.09	22.83
	L	9.65	10.53	84	14.10	18.23
CC	**T**	9.99	13.68	53	0.32	15.02
	L	8.27	11.19	55	0.24	12.58
CF	**T**	6.97	7.90	78	0.08	12.67
	L	4.25	7.37	33	0.03	5.05
TR	**T**	21.82	23.57	86	1.49	41.64
	L	16.16	18.72	75	1.10	28.75

SC	**T**	38.88	41.21	89	0.24	75.57
	L	28.38	30.65	86	0.08	54.12
RP	**T**	32.98	33.49	97	11.73	66.92
	L	18.68	20.77	81	3.09	34.62
PR	**T**	18.06	18.15	99	5.99	37.02
	L	17.27	17.46	97	5.81	35.16
SOD	**T**	48.60	50.29	93	1.29	96.75
	L	74.89	75.10	99	2.75	153.83
CAT	**T**	38.43	39.23	96	42.03	77.56
	L	34.42	34.46	99	42.50	70.83
SYPP	**T**	19.61	22.24	78	4.46	35.64
	L	23.38	25.31	85	4.99	44.49

.

PP-Plant population ; SVI-Seedling vigour index ; DFF-Days to 50 % flowering ; LS-Leaflet size ; PH-Plant height ; DFPI-Days to first pod initiation ; DFP-Days to 50 % pod stage ; NPB- Number of primary branches ; NSB-Number of secondary branches ; NPP-Number of pods per plant ; NSP-Number of seed per pod ; DM-Days to maturity ; 100SW-Hundred seed weight ; PS-Days to pod set ; CC-Chlorophyll content ; SYPP-Seed yield per plant ; CF-Chlorophyll fluorescence content ; TR-Rate of transpiration ; SC-Stomatal conductance ; RP-Rate of photosynthesis ; PR-Protein content ; SOD-Superoxide dismutase ;CAT-Catalase

4.1.5 Correlation coefficient analysis

The degree of relationships between different variables is measured using correlation coefficients. A Pearson correlation coefficient, the most popular, evaluates the degree and direction of a linear association between two distinct variables. The correlation coefficient is evaluated on a scale ranging from + 1 to - 1. When a particular variable rises as the other increases, the correlation is positive; when one falls as the other rises, the correlation is negative.

4.1.5.1 Seed yield per plant (SYPP)

Seed yield per plant exhibited highest and significant correlation with 100-seed weight (0.862**) followed by SOD (0.592**) and CAT (0.793**) activity, SVI (0.576**), rate of photosynthesis (0.544**), number of pods per plant (0.445**), number of secondary branches (0.445**) whereas it showed negative correlation to days to 50% flowering (-0.763**), days to first pod initiation (-0.764**), days to 50% pod stage (-0.713**), days to maturity (-0.572**) under late sown condition.

During timely sown condition, it showed significant positive and negative correlation to all the respective traits mentioned under late sown condition nearly in similar way except SOD (0.13) and CAT (-0.312*) activity.

4.1.5.2 Catalase activity (CAT)

CAT activity revealed positive and significant correlation with SOD (0.698**), rate of photosynthesis (0.512**), stomatal conductance (0.34**), transpiration rate (0.349**), 100-seed weight (0.705**), number of pods per plant (0.537**) where as observed negative correlation to days to 50% flowering(-0.733**), days to first pod initiation (-0.72**), days to 50% podding (-0.696**), days to maturity(-0.582**) under late sown condition.

At the timely sown condition CAT activity exhibited positive and significant correlation only to SOD (0.456**) activity.

4.1.5.3 Superoxide dismutase activity (SOD)

SOD activity revealed positive and significant correlation with rate of photosynthesis (0.538**), stomatal conductance (0.501**) transpiration rate (0.369**), 100-seed weight (0.678**), number of pods per plant (0.419**) where as observed negative correlation to days to 50% flowering(-0.733**), days to first pod initiation (-0.72**), days to 50% pod stage (-0.696**), days to maturity(-0.662**) under late sown condition.

In timely sown condition it showed positive and significant correlation with seedling vigour index (0.361**), plant population (0.277*), chlorophyll content (0.412**) and rate of photosynthesis (0.291*).

4.1.5.4 Protein content

During late sown condition, the trait protein content noticed as positive and significant correlation with plant population (0.618**), seedling vigour index (0.783**), number of secondary branches (0.453**), number of pods per plant (0.501**), 100-seed weight (0.538**), chlorophyll content (0.506**), chlorophyll fluorescence content (0.36**), transpiration rate (0.427**), stomatal conductance (0.46***) and rate of photosynthesis (0.592**).

During timely sown condition, it showed significantly positive correlation to all the respective traits mentioned under late sown condition nearly in similar way in addition of trait number of primary branches per plant (0.315*).

4.1.5.5 Rate of photosynthesis

The trait rate of photosynthesis observed positive and significant correlation with plant population (0.84**) seedling vigour index (0.877**), number of primary branches (0.43**) number of pods per plant (0.391**), 100-seed weight (0.617**), chlorophyll content (0.543**), chlorophyll fluorescence content (0.419**), transpirational rate (0.278*), stomatal conductance (0.647**) under timely sown condition.

During late sown condition, it showed significant positive to all the respective traits mentioned under timely sown condition nearly in similar way in addition of trait number of secondary branches per plant (0.453**).

4.1.5.6 Stomatal conductance

The trait stomatal conductance found to be positive significant correlation with seedling vigour index (0.433**), hundred seed weight (0.248*), chlorophyll content (0.567**), chlorophyll fluorescence content (0.28*), transpiration rate (0.477**) under late sown condition.

In timely condition, it showed positively significant correlation with plant population (0.43**), seedling vigour index (0.681**), chlorophyll content (0.245*), chlorophyll fluorescence content (0.452**), transpiration rate (0.612**).

4.1.5.7 Rate of transpiration

During late sown condition, the trait transpiration rate revealed positively significant correlation with plant population (0.265*), seedling vigour index (0.434**), number of pods per plant (0.353**), 100-seed weight (0.394**), chlorophyll content (0.323**), chlorophyll fluorescence content (0.306*)

Under the timely sown condition, it showed positively significant correlation with seedling vigour index (0.352**), number of seeds per pod (0.404**), chlorophyll fluorescence content (0.257*).

4.1.5.7 Chlorophyll content

In timely sown condition, the trait chlorophyll content observed positive and significant correlation with plant population (0.384**), seedling vigour index (0.486***) and 100-seed weight (0.392**).

During late sown condition, it showed significantly positive correlation to all the respective traits mentioned under timely sown condition in similar way in addition to the trait number of pods per plant (0.319**).

4.1.5.8 Days to pod set

The trait days to pod set showed positive and significant correlation to days to 50% flowering (0.784**), days to first pod initiation (0.797**), days to 50% podding stage (0.828**) and days to maturity (0.762**) under late sown condition.

Also under timely sown, this trait was positively and significantly correlated with all the respective traits observed under late sown in a similar condition.

4.1.5.9 100-seed weight

The trait 100-seed weight was positively and significantly correlated with plant population (0.47**) seedling vigour index (0.44**), number of primary branches (0.481**), number of pods per plant (0.354**) and number of seeds per pod (0.429**).

During late sown condition, this trait was positively and significantly correlated with plant population (0.641**), seedling vigour index (0.618**), number of secondary branches (0.276**) and number of pods per plant (0.337**).

4.1.5.10 Days to maturity

The trait days to maturity showed positive and significant correlation to days to 50% flowering (0.76**), days to first pod initiation (0.776**) and days to 50% pod stage (0.768**) and also showed negative and significant correlation to number of secondary branches (-0.38**) and number of pods per plant (-0.579**) under late sown condition.

During timely sown condition, it revealed positive and significant correlation to days to 50% flowering (0.931**), days to first pod initiation (0.891**) and days to 50% podding stage (0.925**).

4.1.5.11 Number of seeds per pod

The trait number of seeds per pod observed significant positive correlation with leaflet size (0.267*), number of primary branches (0.334**) and number of pods per plant (0.399**) under timely sown condition where as in late sown condition, it found to be non-significant for all these traits.

4.1.5.12 Number of pods per plant

Under timely sown condition, the trait number of pods per plant revealed significant positive correlation with plant population (0.381**), seedling vigour index (0.351**), number of primary branches (0.315*), number of secondary branches (0.43***) where as in late sown condition, it showed significantly positive correlation to all the respective traits mentioned under timely sown condition in similar way.

4.1.5.13 Number of secondary branches

During timely sown condition, number of secondary branches exhibited positive and significant correlation with number of pods per plant (0.312**) where as in late sown condition, it showed positive and correlation with plant population (0.333**), seedling vigour index (0.359**) number of primary branches (0.255*).

4.1.5.14 Number of primary branches

The trait number of primary branches per plant had observed positive and significant correlation with number of pods per plant (0.315*) and number of secondary branches (0.255*) at late sown condition where as in timely sown condition, it showed positive and significant correlation with plant population (0.4**), seedling vigour index (0.401**), rate of photosynthesis (0.43**) and seed yield per plant (0.491**).

4.1.5.15 Days to 50% pod stage

The trait days to 50% podding stage had revealed positive and significant correlation with days to 50% flowering (0.76**), days to first pod initiation (0.776**) and showed negative and significant correlation with number of pods per plant (-0.456**), 100-seed weight (-0.788**), SOD (-0.73***) and CAT (-0.696**) activity where as in timely sown condition it fulfilled the similar results for all the respective traits mentioned under late condition.

4.1.5.16 Days to first pod initiation

The trait days to first pod initiation observed positive and significant correlation with days to 50% flowering (0.993**) and showed negative and significant correlation with chlorophyll content (-0.434**), chlorophyll fluorescence content (-0.409**), transpiration rate (-0.43**), stomatal conductance (-0.413**) and rate of photosynthesis (-0.626**) under late sown condition.

In timely sown condition it showed negative and significant correlation with number of pods per plant (-0.412**), number of seeds per pod (-0.37**), stomatal conductance (-0.374**), rate of photosynthesis (-0.679**) and protein content (-0.606**) and noticed positive and significant correlation with days to pod set (0.979**).

4.1.5.17 Plant height

During late sown condition, the trait plant height revealed positive and significant correlation with seedling vigour index (0.447**), number of pods per plant (0.41**), SOD

(0.353**) and CAT (0.467**) activity whereas in timely sown condition, it was positively and significantly correlated with number of secondary branches (0.266*) and SOD activity (0.254*).

4.1.5.18 Leaflet size

The trait leaflet size was positively and significantly correlated with chlorophyll content (0.268*) and chlorophyll fluorescence content (0.38**) under late sown condition where as in timely sown condition it showed positive and significant correlation with number of seeds per pod (0.267*), 100-seed weight (0.336**) and seed yield per plant (0.3*).

4.1.5.19 Days to 50% flowering

Under late sown condition, the trait days to 50% flowering exhibited positive and significant correlation with days to first pod initiation (0.993**), days to 50% pod stage (0.984**), days to maturity (0.76**) and observed negative significant correlation with number of pods per plant (-0.499**), 100-seed weight (-0.821**), chlorophyll content (-0.426**), chlorophyll fluorescence content (-0.409**), rate of transpiration (-0.422**), photosynthetic rate (-0.64**) and stomatal conductance (-0.401**), SOD (-0.724**) and CAT activity (-0.733**).

During timely sown condition, the trait days to 50% flowering showed positive and significant correlation days to first pod initiation (0.968**), days to 50% podding stage (0.984**) and days to maturity (0.931**) where as it had revealed negative significant correlation with number of pods per plant (-0.411**), number of seeds per pod (-0.378**), chlorophyll content (-0.49**), chlorophyll fluorescence content (-0.408**), protein content (-0.64**), stomatal conductance (-0.405**) and CAT activity (0.439**).

4.1.5.20 Seedling vigour index (SVI)

The trait seedling vigour index was positively and significantly correlated with plant population (0.774**), number of pods per plant (0.351**), 100-seed weight (0.618**), chlorophyll content (0.467**), chlorophyll fluorescence content (0.317**), rate of transpiration (0.434**), photosynthetic rate (0.605**) and stomatal conductance (0.433**), SOD (0.733**) and CAT activity (0.624**) under late sown condition.

During timely sown condition, it showed significant positive correlation with plant population (0.83**), number of pods per plant (0.356**), 100-seed weight (0.44**), chlorophyll content (0.486**), chlorophyll fluorescence content (0.548**), rate of transpiration (0.352**), photosynthetic rate (0.877**), stomatal conductance (0.681**) and SOD (0.361**) activity.

4.1.5.21 Plant population

The trait plant population was positively and significantly correlated with number of pods per plant (0.438**), 100-seed weight (0.47**), chlorophyll content (0.384**), chlorophyll fluorescence content (0.38**), stomatal conductance (0.43***), rate of photosynthesis (0.84**) and SOD (0.277*) activity under timely sown condition.

During late sown condition, the trait plant population showed positive and significant correlation with number of pods per plant (0.381**), 100-seed weight (0.641**), rate of transpiration (0.265*), rate of photosynthesis (0.68**), SOD (0.65**) and CAT (0.635**) activity.

The similar observations also being noted by following researchers **Ningwal *et al.* (2023)**, **Nikhitha and Walia (2022), Omer & Karadavut (2018), Thakur *et al.* (2018), Devasirvatham *et al.* (2015)**, **Meena *et al.* (2014)**

4.1.6 Path coefficient analysis

Path coefficient analysis is a reliable statistical technique for categorising correlation coefficients into direct or indirect effects. It assesses the interconnection between multiple yield-relevant variables. A path analysis can be carried out in the form of a hierarchical (sequential) multiple regression analysis. For each endogenous variable, a multiple regression analysis will be executed to predict that variable (Y) from all other factors that are hypothesised to have direct impacts on Y. It was developed by Sewall Wright. Dewey and Lu (1959) used it for the first time in plants in order to differentiate between direct and indirect effects of climate.

Table no. 4.13 Correlation coefficient analysis during timely sown condition

TS	PP	SVI	DFF	LS	PH	DFPI	DFP	NPB	NSB	NPP	NSP	DM	100.SW	PS	CC	CF	TR	SC	RP	PR	SOD	CAT	SYPP
PP	1.00	0.83**	-0.663**	0.37**	0.24	-0.583**	-0.61**	0.4**	0.18	0.438**	0.23	-0.733**	0.47**	-0.63**	0.384**	0.38**	0.13	0.43**	0.84**	0.655**	0.277*	-0.305*	0.562**
SVI		1.00	-0.602**	0.18	0.18	-0.541**	-0.571**	0.401**	0.05	0.356**	0.20	-0.663**	0.44**	-0.599**	0.486**	0.548**	0.352**	0.681**	0.877**	0.761**	0.361**	-0.18	0.513**
DFF			1.00	-0.286*	-0.02	0.968**	0.984**	-0.463**	-0.262*	-0.411**	-0.378**	0.931**	-0.741**	0.987**	-0.49**	-0.408**	-0.21	0.405**	-0.739**	-0.644**	-0.10	0.439**	-0.718**
LS				1.00	0.05	-0.264*	-0.281*	0.21	0.03	0.23	0.267*	-0.319**	0.336**	-0.263*	0.17	0.16	-0.14	-0.04	0.22	0.07	0.12	-0.18	0.3*
PH					1.00	-0.01	-0.01	0.07	0.266*	0.11	-0.15	-0.14	-0.05	0.00	-0.06	-0.19	-0.282*	-0.03	0.18	0.11	0.254*	-0.08	0.04
DFPI						1.00	0.978**	-0.496**	-0.288*	-0.412**	-0.37**	0.891**	-0.732**	0.979**	-0.449**	-0.374**	-0.20	-0.374**	-0.679**	-0.606**	-0.01	0.459**	-0.711**
DFP							1.00	-0.45**	-0.263*	-0.395**	-0.336**	0.925**	-0.715**	0.991**	-0.494**	-0.397**	-0.21	-0.387**	-0.707**	-0.61**	-0.06	0.448**	-0.704**
NPB								1.00	0.17	0.4**	0.334**	-0.384**	0.481**	-0.475**	-0.02	0.06	0.3*	0.3*	0.43**	0.427**	-0.09	-0.345**	0.491**
NSB									1.00	0.312*	0.01	-0.339**	0.23	-0.255*	0.16	-0.04	-0.23	-0.11	0.08	0.09	-0.22	-0.23	0.399**
NPP										1.00	0.399**	-0.393**	0.354**	-0.39**	0.22	-0.02	0.01	0.18	0.391**	0.315*	0.17	-0.21	0.511**
NSP											1.00	-0.257*	0.429**	-0.349**	0.11	-0.05	0.404**	0.18	0.20	0.23	0.00	-0.05	0.326**
DM												1.00	-0.68**	0.918**	-0.568**	-0.367**	-0.08	-0.386**	-0.788**	-0.593**	-0.22	0.376**	-0.715**
100SW													1.00	-0.737**	0.392**	0.21	0.13	0.24	0.617**	0.515**	0.07	-0.262*	0.791**
PS														1.00	-0.492**	-0.421**	-0.245*	-0.424**	-0.734**	-0.651**	-0.05	0.453***	-0.713**
CC															1.00	0.282*	-0.06	0.245*	0.543**	0.362**	0.412**	-0.07	0.506**
CF																1.00	0.257*	0.452**	0.419**	0.424**	0.02	-0.262*	0.16
TR																	1.00	0.612**	0.278*	0.427**	-0.23	-0.01	0.03
SC																		1.00	0.647**	0.665**	0.18	-0.03	0.22
RP																			1.00	0.815**	0.291*	-0.303*	0.656**
PR																				1.00	0.03	-0.434**	0.513**
SOD																					1.00	0.456**	0.13
CAT																						1.00	-0.312*
SYPP																							1.00

P > 0.05: ns; significance at ** P < 0.01, * P < 0.05

PP-Plant population ; SVI-Seedling vigour index ; DFF-Days to 50 % flowering ; LS-Leaflet size ; PH-Plant height ; DFPI-Days to first pod initiation ; DFP-Days to 50 % pod stage ; NPB-Number of primary branches ; NSB-Number of secondary branches ; NPP-Number of pods per plant ; NSP-Number of seed per pod ; DM-Days to maturity ; 100SW-Hundred seed weight ; PS-Days to pod set ; CC-Chlorophyll content ; SYPP-Seed yield per plant ; CF-Chlorophyll fluorescence content ; TR-Rate of transpiration ; SC-Stomatal conductance ; RP-Rate of photosynthesis ; PR-Protein content ; SOD-Superoxide dismutase ; CAT-Catalase

Table no. 4.14 Correlation coefficient analysis during late sown condition

LS	PP	SVI	DFF	LS	PH	DFPI	DFP	NPB	NSB	NPP	NSP	DM	100.SW	PS	CC	CF	TR	SC	RP	PR	SOD	CAT	SYPP
PP	1.00	0.774**	-0.705**	0.05	0.351**	-0.687**	-0.659**	0.00	0.333**	0.381**	0.07	-0.602**	0.641**	-0.493**	0.396**	0.328**	0.265*	0.19	0.68**	0.618**	0.65**	0.635**	0.712**
SVI		1.00	-0.632**	0.01	0.447**	-0.623**	-0.61**	0.05	0.359**	0.351**	0.00	-0.593**	0.618**	-0.439**	0.467**	0.317**	0.434**	0.433**	0.605**	0.783**	0.733**	0.624**	0.576**
DFF			1.00	-0.09	-0.499**	0.993**	0.984**	-0.05	-0.355**	-0.499**	-0.07	0.76**	-0.821**	0.784**	-0.426**	-0.409**	-0.422**	-0.401**	-0.64**	-0.583**	-0.724**	-0.733**	-0.763**
LS				1.00	0.07	-0.10	-0.10	0.13	0.01	0.05	0.22	-0.24	0.13	-0.245*	0.268*	0.38**	0.04	0.16	0.15	0.04	0.05	0.15	0.02
PH					1.00	-0.472**	-0.475**	0.04	0.279*	0.41**	-0.13	-0.517**	0.478**	-0.415**	0.17	0.387**	0.325**	0.24	0.413**	0.303*	0.353**	0.467**	0.418**
DFPI						1.00	0.987**	-0.04	-0.33**	-0.493**	-0.10	0.776**	-0.82**	0.797**	-0.434**	-0.409**	-0.43**	-0.413**	-0.626**	-0.597**	-0.746**	-0.72**	-0.764**
DFP							1.00	-0.03	-0.303*	-0.456**	-0.09	0.768**	-0.788**	0.828**	-0.42**	-0.417**	-0.434**	-0.445**	-0.602**	-0.584**	-0.73**	-0.696**	-0.713**
NPB								1.00	0.255*	0.315*	0.16	-0.10	-0.05	-0.01	0.20	0.22	0.09	0.15	0.11	0.23	0.06	0.17	-0.12
NSB									1.00	0.43**	0.15	-0.38**	0.276*	-0.257*	0.22	0.344**	0.20	0.15	0.509**	0.453**	0.271*	0.329**	0.326**
NPP										1.00	0.11	-0.579**	0.337**	-0.302*	0.319**	0.23	0.353**	0.17	0.526**	0.501**	0.419**	0.537***	0.445**
NSP											1.00	-0.13	0.02	-0.13	0.07	0.14	0.14	0.05	0.02	0.21	0.09	0.10	0.03
DM												1.00	-0.56*	0.762**	-0.619**	-0.47**	-0.329**	-0.564**	-0.768**	-0.566**	-0.662**	-0.582**	-0.572**
100.SW													1.00	-0.591**	0.33**	0.413**	0.394**	0.248*	0.477**	0.538**	0.678**	0.705**	0.862**
PS														1.00	-0.441**	-0.44**	-0.22	-0.535**	-0.595**	-0.502**	-0.669**	-0.569**	-0.544**
CC															1.00	0.423**	0.323**	0.567**	0.533**	0.506**	0.441**	0.401**	0.299*
CF																1.00	0.306*	0.28*	0.367**	0.36**	0.271*	0.409**	0.321**
TR																	1.00	0.477***	0.286*	0.427***	0.369**	0.349**	0.28*
SC																		1.00	0.515***	0.46***	0.501***	0.34**	0.13
RP																			1.00	0.592***	0.538***	0.512***	0.544***
PR																				1.00	0.81***	0.59***	0.47***
SOD																					1.00	0.698***	0.592***
CAT																						1.00	0.703***
SYPP																							1.00

P > 0.05 : ns ; significance at *** P < 0.001, P < 0.01, * P < 0.05**

PP-Plant population ; SVI-Seedling vigour index ; DFF-Days to 50 % flowering ; LS-Leaflet size ; PH-Plant height ; DFPI-Days to first pod initiation ; DFP-Days to 50 % pod stage ; NPB-Number of primary branches ; NSB-Number of secondary branches ; NPP-Number of pods per plant ; NSP-Number of seed per pod ; DM-Days to maturity ; 100SW-Hundred seed weight ; PS-Days to pod set ; CC-Chlorophyll content ; SYPP-Seed yield per plant ; CF-Chlorophyll fluorescence content ; TR-Rate of transpiration ; SC-Stomatal conductance ; RP-Rate of photosynthesis ; PR-Protein content ; SOD-Superoxide dismutase ; CAT-Catalase

Table no. 4.15 Path coefficient analysis of timely sown condition

TS	PP	SVI	DFF	LS	PH	DFPI	DFP	NPB	NSB	NPP	NSP	DM	100-SW	PS	CC	CF	TR	SC	RP	PR	SOD	CAT
PP	**-0.84**	1.10	0.92	0.02	0.17	-0.14	-0.48	-0.11	-0.03	0.35	-0.13	-0.14	0.52	0.15	0.26	-0.13	0.03	-0.08	-0.05	-0.38	-0.20	-0.02
SVI	-0.79	**1.25**	0.63	0.02	0.16	-0.09	-0.30	-0.13	-0.02	0.31	-0.12	-0.09	0.51	0.10	0.30	-0.20	0.05	-0.12	-0.05	-0.44	-0.24	-0.01
DFF	0.56	-0.54	**-1.22**	-0.02	0.01	0.20	0.66	0.09	0.03	-0.25	0.09	0.16	-0.55	-0.20	-0.21	0.12	0.00	0.04	0.03	0.20	0.00	0.04
LS	-0.49	0.66	0.66	**0.05**	0.09	-0.11	-0.33	-0.14	-0.02	0.47	-0.24	-0.08	0.77	0.10	0.26	-0.10	0.04	-0.04	-0.04	-0.31	-0.25	0.00
PH	-0.40	0.51	-0.03	0.01	**0.38**	0.02	0.05	-0.03	-0.03	0.18	0.02	-0.03	0.04	-0.01	0.04	0.05	-0.01	-0.02	-0.02	-0.20	-0.26	0.00
DFPI	0.52	-0.47	-1.22	-0.01	0.03	**0.20**	0.67	0.09	0.03	-0.24	0.10	0.16	-0.56	-0.20	-0.20	0.11	0.00	0.03	0.03	0.19	-0.05	0.04
DFP	0.54	-0.48	-1.23	-0.01	0.02	0.20	**0.67**	0.08	0.03	-0.22	0.08	0.16	-0.53	-0.20	-0.21	0.12	0.00	0.03	0.03	0.17	-0.03	0.04
NPB	-0.59	1.00	0.76	0.03	0.08	-0.14	-0.37	**-0.21**	-0.03	0.51	-0.32	-0.09	0.82	0.12	0.18	-0.09	0.09	-0.11	-0.05	-0.50	-0.05	-0.02
NSB	-0.28	0.27	0.45	0.01	0.12	-0.08	-0.24	-0.05	**-0.09**	0.18	-0.03	-0.09	0.35	0.07	0.11	0.05	0.01	-0.01	-0.01	-0.17	0.07	-0.01
NPP	-0.57	0.71	0.67	0.03	0.13	-0.11	-0.32	-0.16	-0.03	**0.56**	-0.24	-0.09	0.60	0.10	0.19	0.02	0.04	-0.07	-0.04	-0.36	-0.21	-0.01
NSP	-0.39	0.49	0.44	0.03	-0.03	-0.08	-0.21	-0.18	-0.01	0.45	**-0.35**	-0.03	0.71	0.07	0.12	-0.03	0.06	-0.07	-0.02	-0.28	-0.08	0.01
DM	0.59	-0.54	-1.12	-0.01	-0.05	0.19	0.62	0.07	0.04	-0.23	0.04	**0.17**	-0.45	-0.18	-0.25	0.11	0.02	0.02	0.03	0.13	0.05	0.04
100-SW	-0.53	0.72	0.91	0.03	0.02	-0.15	-0.47	-0.16	-0.04	0.37	-0.23	-0.11	**0.92**	0.15	0.33	-0.10	0.04	-0.06	-0.04	-0.37	-0.09	-0.01
PS	0.55	-0.52	-1.20	-0.01	0.02	0.20	0.65	0.09	0.03	-0.24	0.09	0.16	-0.54	**-0.20**	-0.21	0.13	0.00	0.04	0.03	0.19	-0.04	0.04
CC	-0.60	0.96	0.80	0.02	0.04	-0.12	-0.42	-0.08	-0.03	0.26	-0.09	-0.13	0.76	0.13	**0.44**	-0.14	0.02	-0.08	-0.05	-0.38	-0.41	0.00
CF	-0.44	0.98	0.70	0.01	-0.07	-0.11	-0.37	-0.06	0.02	-0.04	-0.03	-0.10	0.35	0.12	0.22	**-0.21**	0.06	-0.12	-0.04	-0.41	-0.12	-0.01
TR	-0.28	0.69	-0.01	0.01	-0.03	-0.01	0.03	-0.17	-0.01	0.23	-0.21	0.05	0.38	0.00	0.09	-0.19	**0.10**	-0.13	-0.03	-0.36	0.10	0.01
SC	-0.48	0.94	0.37	0.01	0.05	-0.05	-0.16	-0.12	-0.01	0.24	-0.13	-0.03	0.35	0.06	0.21	-0.20	0.07	**-0.15**	-0.04	-0.39	-0.13	0.00
RP	-0.79	1.12	0.85	0.02	0.12	-0.13	-0.43	-0.13	-0.02	0.35	-0.12	-0.12	0.64	0.14	0.33	-0.16	0.04	-0.11	**-0.06**	-0.45	-0.19	-0.02
PR	-0.67	1.07	0.57	0.02	0.15	-0.09	-0.27	-0.17	-0.04	0.39	-0.16	-0.05	0.64	0.09	0.29	-0.21	0.06	-0.12	-0.05	**-0.58**	-0.07	-0.02
SOD	-0.28	0.48	0.00	0.01	0.16	0.02	0.04	-0.01	0.01	0.19	-0.04	-0.02	0.13	-0.01	0.25	-0.05	-0.01	-0.03	-0.02	-0.05	**-0.57**	0.04
CAT	0.22	-0.12	-0.69	0.00	0.00	0.12	0.39	0.05	0.01	-0.06	-0.02	0.09	-0.16	-0.12	0.02	0.03	0.01	-0.01	0.01	0.14	-0.28	**0.08**

Residual Effect^2 = 0.10

PP-Plant population ; SVI-Seedling vigour index ; DFF-Days to 50 % flowering ; LS-Leaflet size ; PH-Plant height ; DFPI-Days to first pod initiation ; DFP-Days to 50 % pod stage ; NPB- Number of primary branches ; NSB-Number of secondary branches ; NPP-Number of pods per plant ; NSP-Number of seed per pod ; DM-Days to maturity ; 100SW-Hundred seed weight ; PS-Days to pod set ; CC-Chlorophyll content ; SYPP-Seed yield per plant ; CF-Chlorophyll fluorescence content ; TR-Rate of transpiration ; SC-Stomatal conductance ; RP-Rate of photosynthesis ; PR-Protein content ; SOD-Superoxide dismutase ; CAT-Catalase

Table no. 4.16 Path coefficient analysis during late sown condition

LS	PP	SVI	DFF	LS	PH	DFPI	DFP	NPB	NSB	NPP	NSP	DM	100-SW	PS	CC	CF	TR	SC	RP	PR	SOD	CAT
PP	**0.38**	0.22	-2.29	0.05	-0.21	-0.54	2.02	-0.03	0.17	0.22	-0.02	-0.06	0.81	0.27	0.11	-0.14	0.13	-0.21	0.22	-0.47	-0.02	0.29
SVI	0.34	**0.27**	-1.89	0.06	-0.27	-0.45	1.69	-0.06	0.20	0.22	-0.04	-0.05	0.79	0.21	0.16	-0.18	0.21	-0.36	0.20	-0.59	-0.02	0.29
DFF	-0.27	-0.15	**2.83**	0.01	0.25	0.69	-2.74	-0.04	-0.09	-0.17	-0.02	0.06	-0.72	-0.33	-0.04	0.10	-0.18	0.14	-0.14	0.18	0.01	-0.21
LS	0.11	0.10	0.21	**0.47**	-0.38	0.06	-0.33	-0.41	0.30	0.35	-0.21	0.02	0.87	0.17	0.30	-0.51	0.11	-0.50	0.18	-0.57	-0.01	0.32
PH	0.23	0.19	-2.30	0.17	**-0.31**	-0.54	2.09	-0.12	0.12	0.29	-0.04	-0.09	0.86	0.29	0.16	-0.21	0.16	-0.34	0.18	-0.47	-0.01	0.32
DFPI	-0.26	-0.14	2.83	0.01	0.25	**0.70**	-2.77	-0.05	-0.08	-0.16	-0.01	0.07	-0.71	-0.34	-0.03	0.10	-0.18	0.15	-0.13	0.18	0.01	-0.20
DFP	-0.24	-0.14	2.83	0.02	0.24	0.70	**-2.81**	-0.06	-0.05	-0.13	-0.02	0.07	-0.65	-0.35	-0.02	0.09	-0.18	0.15	-0.12	0.14	0.01	-0.18
NPB	0.08	0.10	0.85	0.42	-0.27	0.25	-1.22	**-0.46**	0.41	0.54	-0.21	0.08	0.46	-0.09	0.31	-0.45	0.24	-0.54	0.17	-0.72	-0.01	0.29
NSB	0.23	0.18	-1.02	0.18	-0.15	-0.22	0.55	-0.24	**0.42**	0.39	-0.12	-0.01	0.69	0.10	0.24	-0.26	0.15	-0.32	0.24	-0.62	-0.01	0.27
NPP	0.20	0.13	-1.26	0.13	-0.25	-0.30	0.96	-0.20	0.26	**0.51**	-0.07	-0.04	0.53	0.10	0.16	-0.18	0.17	-0.22	0.19	-0.46	-0.01	0.27
NSP	0.07	0.07	0.36	0.26	-0.09	0.09	-0.47	-0.25	0.24	0.22	**-0.21**	0.03	0.28	0.03	0.14	-0.22	0.09	-0.24	0.10	-0.45	-0.01	0.16
DM	-0.21	-0.12	1.90	0.03	0.30	0.48	-1.91	-0.12	-0.04	-0.14	-0.04	**0.06**	-0.29	-0.25	0.00	0.06	-0.15	0.11	-0.13	-0.03	0.01	-0.08
100-SW	0.30	0.19	-2.24	0.14	-0.30	-0.54	1.96	-0.07	0.18	0.22	-0.04	-0.03	**1.12**	0.23	0.13	-0.21	0.18	-0.23	0.16	-0.43	-0.02	0.31
PS	-0.22	-0.11	2.25	-0.06	0.22	0.57	-2.31	-0.03	-0.06	-0.09	0.01	0.06	-0.50	**-0.36**	-0.05	0.13	-0.11	0.22	-0.13	0.13	0.01	-0.15
CC	0.26	0.25	-0.73	0.30	-0.36	-0.17	0.42	-0.30	0.41	0.41	-0.11	0.00	0.84	0.14	**0.33**	-0.41	0.29	-0.74	0.31	-0.73	-0.02	0.33
CF	0.28	0.25	-1.81	0.45	-0.39	-0.42	1.47	-0.38	0.38	0.42	-0.16	-0.04	1.15	0.32	0.36	**-0.45**	0.24	-0.64	0.27	-0.86	-0.02	0.45
TR	0.13	0.14	-1.51	0.05	-0.15	-0.37	1.42	-0.10	0.10	0.19	-0.03	-0.04	0.49	0.13	0.12	-0.12	**0.38**	-0.39	0.11	-0.36	-0.01	0.17
SC	0.13	0.15	-0.76	0.14	-0.21	-0.19	0.77	-0.15	0.15	0.16	-0.05	-0.02	0.39	0.17	0.20	-0.20	0.25	**-0.65**	0.18	-0.39	-0.01	0.17
RP	0.34	0.21	-1.79	0.12	-0.26	-0.43	1.53	-0.11	0.27	0.32	-0.06	-0.06	0.68	0.25	0.21	-0.21	0.17	-0.43	**0.28**	-0.50	-0.01	0.26
PR	0.31	0.26	-1.00	0.16	-0.29	-0.24	0.78	-0.20	0.30	0.34	-0.11	0.01	0.77	0.11	0.21	-0.28	0.24	-0.40	0.21	**0.74**	-0.02	0.28
SOD	0.28	0.21	-1.84	0.08	-0.23	-0.46	1.72	-0.07	0.16	0.23	-0.04	-0.04	0.76	0.25	0.13	-0.16	0.18	-0.35	0.17	-0.52	**0.02**	0.28
CAT	0.29	0.19	-1.79	0.14	-0.30	-0.42	1.50	-0.12	0.20	0.30	-0.06	-0.02	0.83	0.19	0.14	-0.22	0.18	-0.27	0.17	-0.43	-0.02	**0.40**

Residual Effect^2 = 0.13

PP-Plant population ; SVI-Seedling vigour index ; DFF-Days to 50 % flowering ; LS-Leaflet size ; PH-Plant height ; DFPI-Days to first pod initiation ; DFP-Days to 50 % pod stage ; NPB- Number of primary branches ; NSB-Number of secondary branches ; NPP-Number of pods per plant ; NSP-Number of seed per pod ; DM-Days to maturity ; 100SW-Hundred seed weight ; PS-Days to pod set ; CC-Chlorophyll content ; SYPP-Seed yield per plant ; CF-Chlorophyll fluorescence content ; TR-Rate of transpiration ; SC-Stomatal conductance ; RP-Rate of photosynthesis ; PR-Protein content ; SOD-Superoxide dismutase ; CAT-Catalase

4.1.6.1 Plant population

During timely sown condition, Plant population had negative direct effect on seed yield per plant (-0.84) where as it showed positive direct effect on seed yield per plant (0.38) during late sown condition with other indirect effects via SVI (0.22), number of pods per plant (0.22), 100-seed weight (0.81).

4.1.6.2 Seedling vigour index (SVI)

The trait seedling vigour index (SVI) exhibited positive direct effects on seed yield per plant under both timely (1.25) and late sown (0.27) condition along with other traits showing maximum indirect effects via 100-seed weight (0.79), rate of transpiration (0.21), rate of photosynthesis (0.20) and CAT (0.29) activity under late sown condition.

4.1.6.3 Days to 50% flowering

The trait days to 50% flowering had observed negative direct effect on seed yield per plant (-1.22) under timely sown condition where as it showed maximum positive direct effect on seed yield per plant (2.83) during late sown condition via indirect effects of other traits such as number of pods per plant (-0.17), 100-seed weight (-0.72), rate of photosynthesis (-0.14) and CAT (-0.21).

4.1.6.4 Leaflet size

During timely sown condition, the trait leaflet size had noticed negligible direct effect on seed yield per plant (0.05) where as it showed high positive direct effect on seed yield per plant (0.47) under late sown condition.

4.1.6.5 Days to 50% pod stage

At timely sown condition, the trait days to 50% pod stage observed positive direct effect on seed yield per plant (0.67) where as it noticed negative direct effect on seed yield per plant (-2.81) under late sown condition via indirect effect of other traits such as stomatal conductance (0.15), protein content (0.14).

4.1.6.6 Number of secondary branches

During late sown condition the trait number of secondary branches had observed positive direct effect on seed yield per plant (0.42) via indirect effect of other traits such as number of pods per plant (0.39), 100-seed weight (0.69) and CAT (0.27) activity compared to timely sown condition where this trait exhibited negligible direct effect on seed yield per plant (-0.09).

4.1.6.7 Number of pods per plant

The trait number of pods per plant had observed positive direct effect on seed yield per plant under both timely (0.56) and late (0.51) sown condition along with indirect effects of other traits such as 100-seed weight (0.53), rate of transpiration (0.17) and rate of photosynthesis (0.19) under late sown condition.

4.1.6.8 Chlorophyll content

During timely sown condition the trait chlorophyll content exhibited positive direct effect on seed yield per plant under both timely (0.44) and late (0.33) sown condition along with indirect effects of other traits such as rate of transpiration (0.29) and rate of photosynthesis (0.31) and CAT (0.33) activity under late sown condition

4.1.6.9 Rate of transpiration

The trait rate of transpiration displayed positive direct effect on seed yield per plant under both timely (0.10) and late (0.38) sown condition along with indirect effects of other traits such as 100-seed weight (0.49), rate of photosynthesis (0.11) and CAT (0.17) activity under late sown condition.

4.1.6.10 Rate of photosynthesis

At late sown condition, the trait rate of photosynthesis exhibited positive direct effect on seed yield per plant (0.28) via indirect effect of other traits such as number of secondary branches (0.27), number of pods per plant (0.32), 100-seed weight (0.68) and CAT (0.26) activity while compared to timely sown condition, this trait exhibited negligible direct effect on seed yield per plant (-0.06).

4.1.6.11 Protein content

During timely sown condition the trait protein content had showed negative direct effect on seed yield per plant (-0.58) where as it observed positive direct effect on seed yield per plant (0.74) via indirect effect of other traits viz., number of pods per plant (0.34), 100-seed weight (0.77) and CAT (0.28) activity.

4.1.6.12 Superoxide dismutase (SOD) activity

The trait SOD activity had noticed positive direct effect on seed yield per plant (0.02) via indirect effect of other traits viz., seedling vigour index (0.21), leaflet size (0.08), number of pods per plant (0.23), 100-seed weight (0.76), chlorophyll content (0.13), transpiration rate (0.18), rate of photosynthesis (0.17) and CAT (0.28) activity under late sown condition where as in timely sown condition, it showed negative direct effect on seed yield per plant (-0.57).

4.1.6.13 Catalase (CAT) activity

The trait CAT activity had observed higher direct and positive effect on seed yield per plant (0.40) under timely sown than late sown condition (0.08) along with indirect effect of other traits viz., rate of photosynthesis (0.17), rate of transpiration (0.18), 100-seed weight (0.83) and seedling vigour index (0.19).

The results closed to these findings were reported by **Arslan, (2023), Devi *et al.* (2022)**, **Dhopre, Pavan, (2022), Katkani *et al.* (2022), Jain *et al.* (2020)**, **Kumar *et al*. (2017), Kumar *et al*. (2017).**

Based on correlation and path coefficient analysis study, it had been confirmed that SOD and CAT activity exhibited highly positive and significant correlation along with positive direct effects on seedling vigour index (SVI), number of pods per plant, 100-seed weight, chlorophyll content, rate of photosynthesis, stomatal conductance and rate of transpiration during heat stress condition when compared to timely sown condition.
SOD and CAT activity can be taken into consideration for categorizing all the promising heat tolerant germplasm accessions under high, moderate and low heat tolerance groups.

Table no. 4.17 Genotypic accessions grouped under different categories of heat stress tolerance level.

Heat stress tolerance	Number of genotypic accessions performed	Name of the accession
High	6	**ICC-3439, ICC-3508, ICC-3528, ICC-6368, ICC-6933, ICC-4939**
Moderate	5	ICC-6944, ICC-6368, **ICC-6701**, ICC-6818, ICC-6858
Low	7	ICC-1723, ICC-1749, ICC-4925, ICC-4956, ICC-6456, ICC-6620, ICC-6708, ICC-6916,

Fig. 4.12 Differentiation of genotypes based on maturity

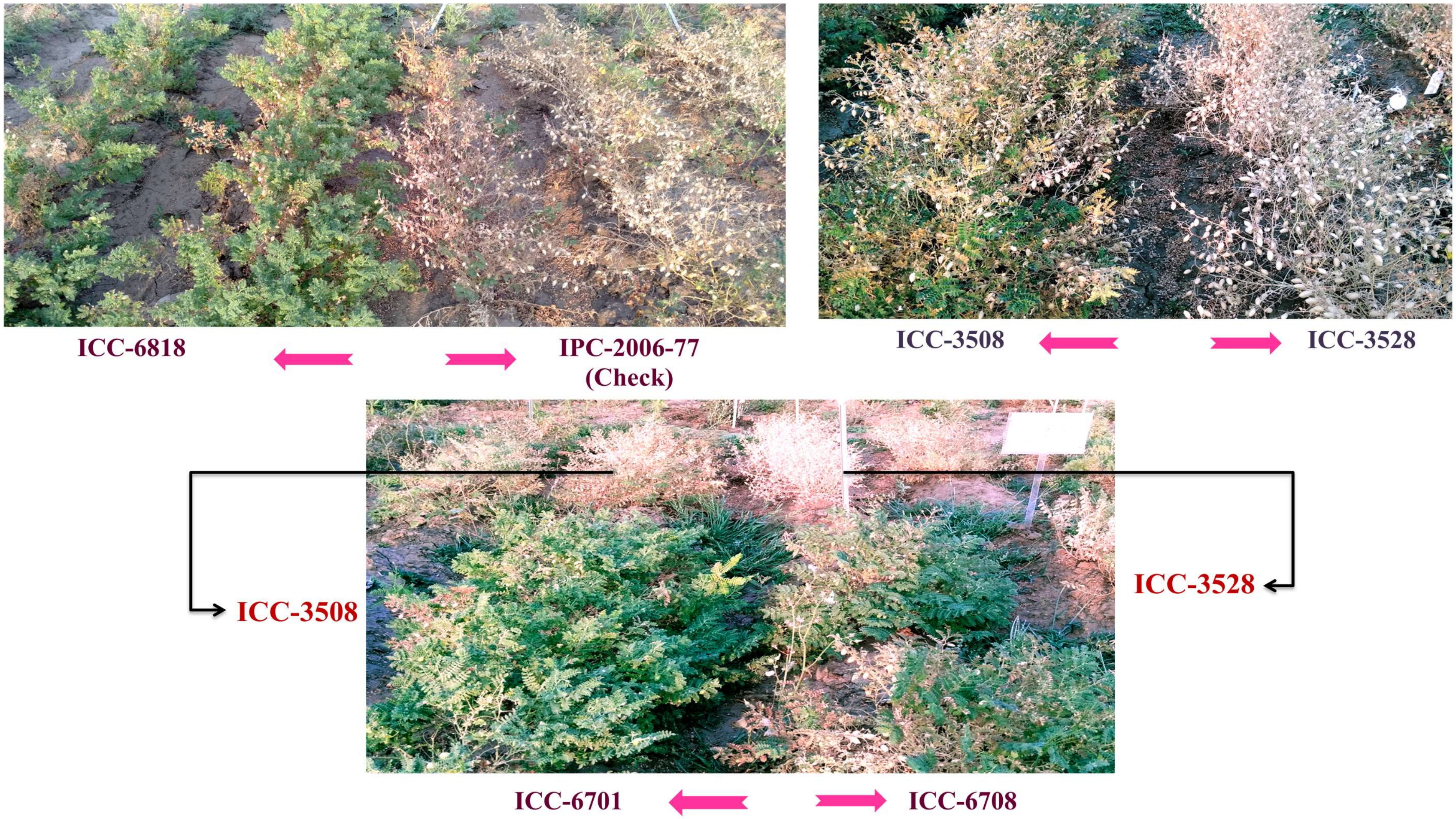


Fig. 4.13 Pollen viability test during timely sown and heat stress condition

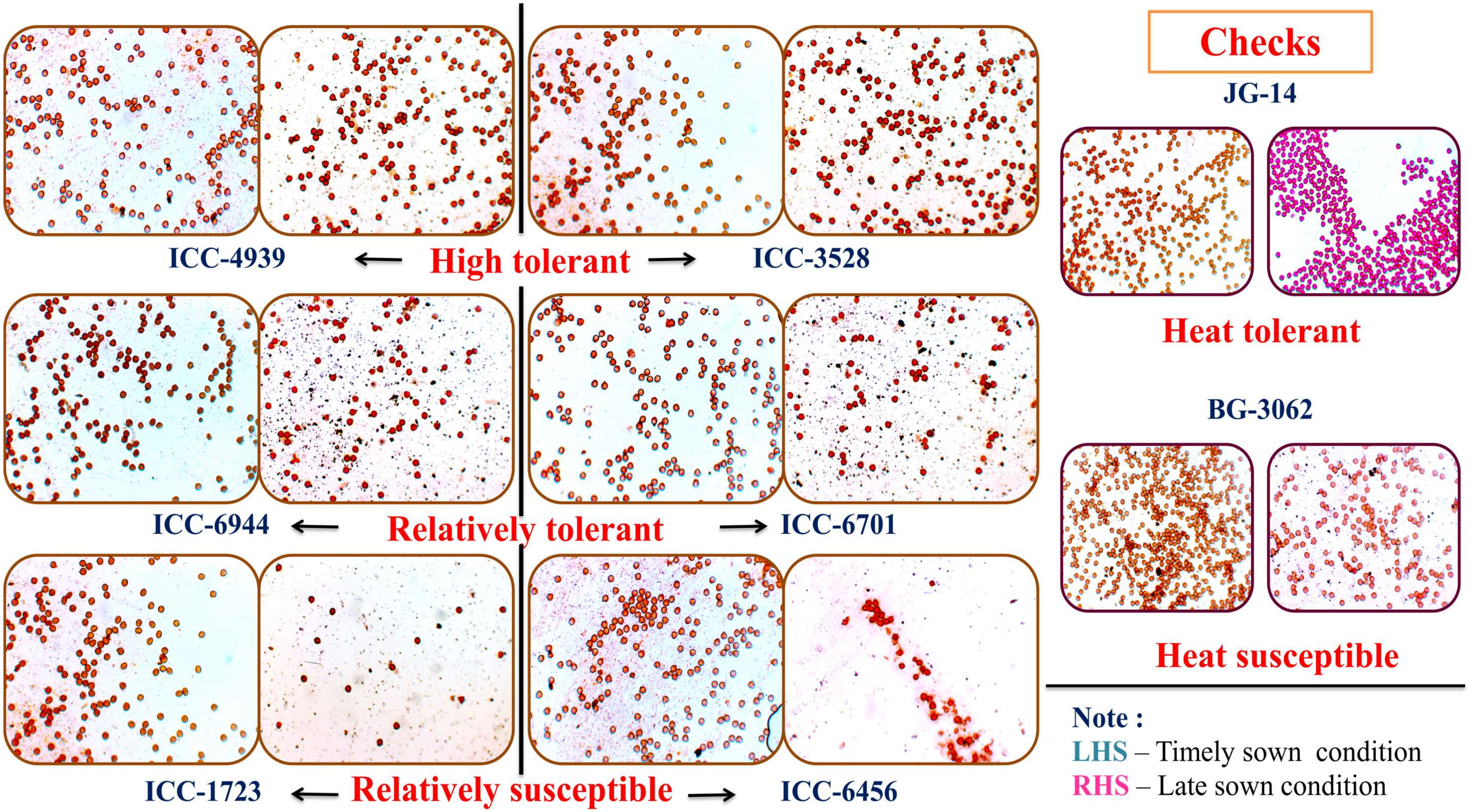


Fig.4.14 Rate of transpiration (TR), Stomatal conductance (SC) and Rate of photosynthesis (PR) activity during TS and LS condition

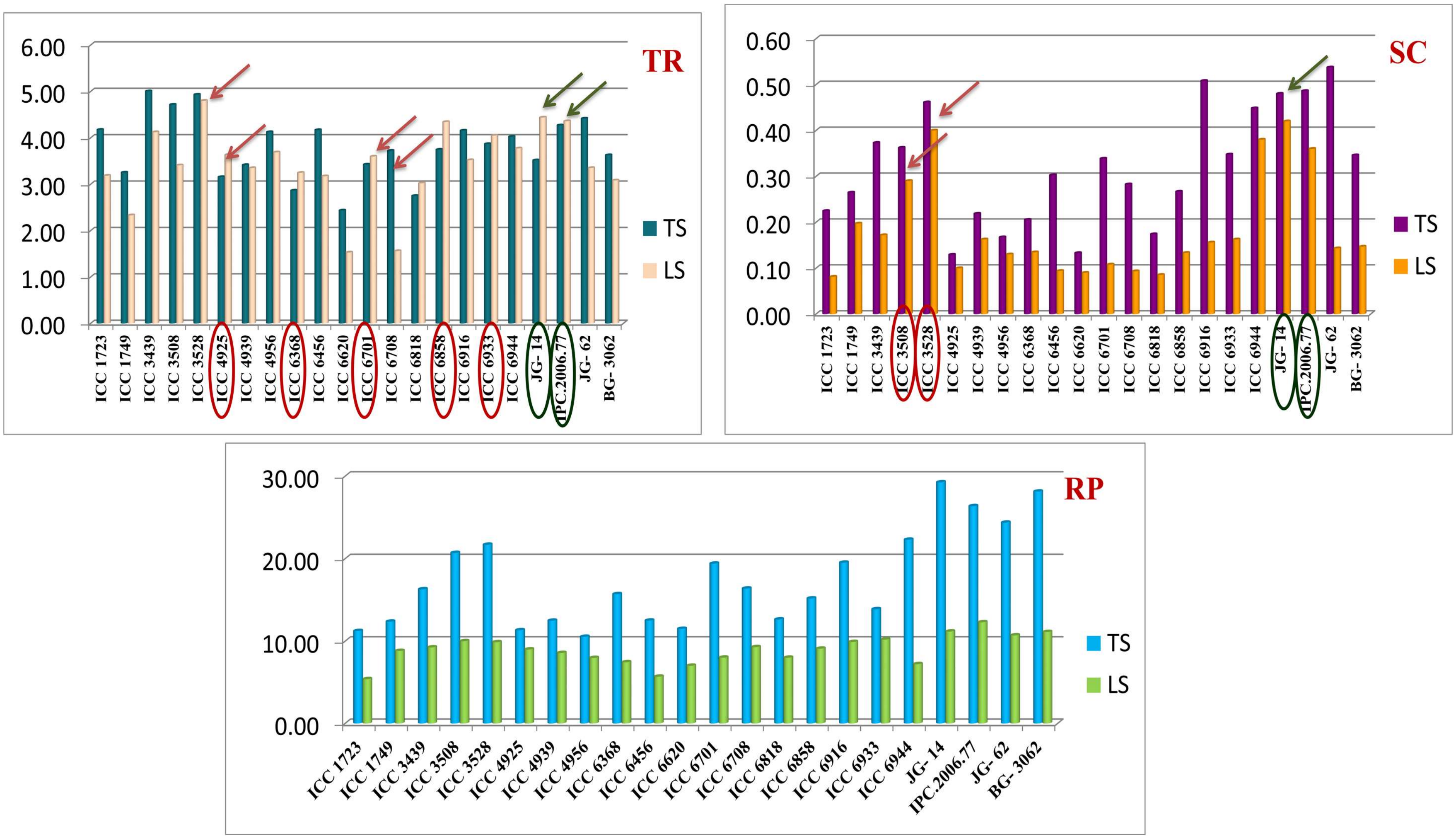


Fig. 4.15 SOD activity during TS and LS condition

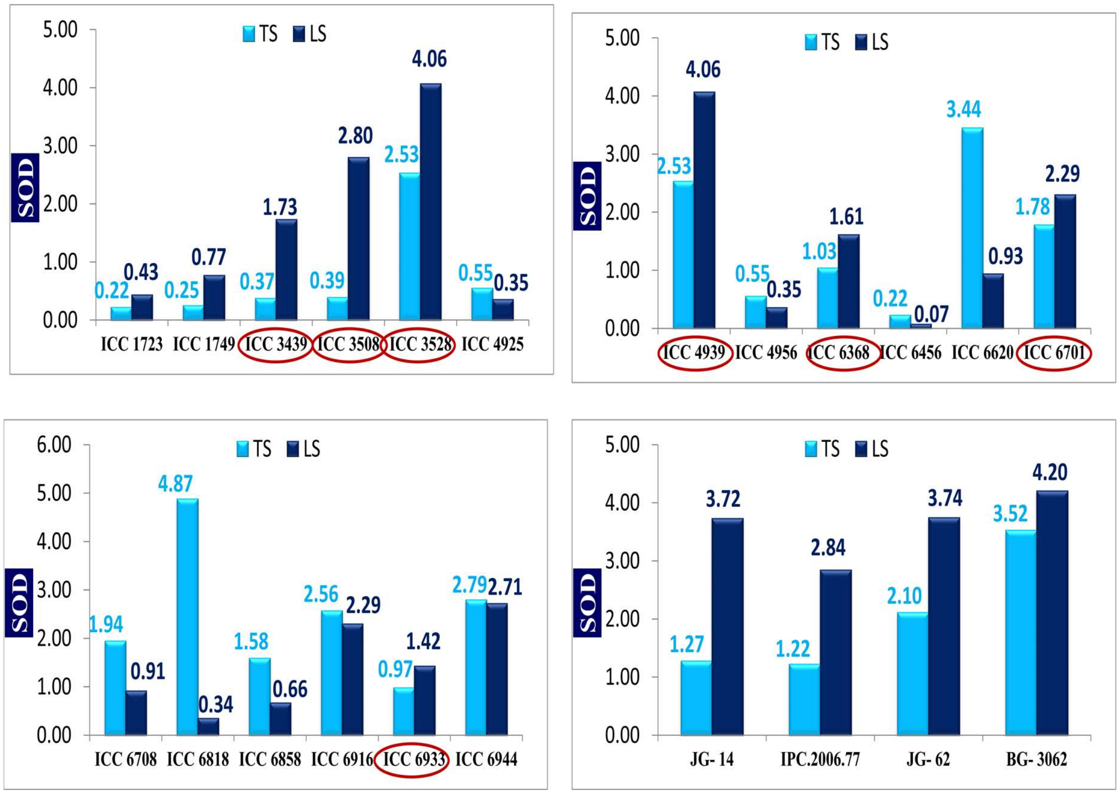
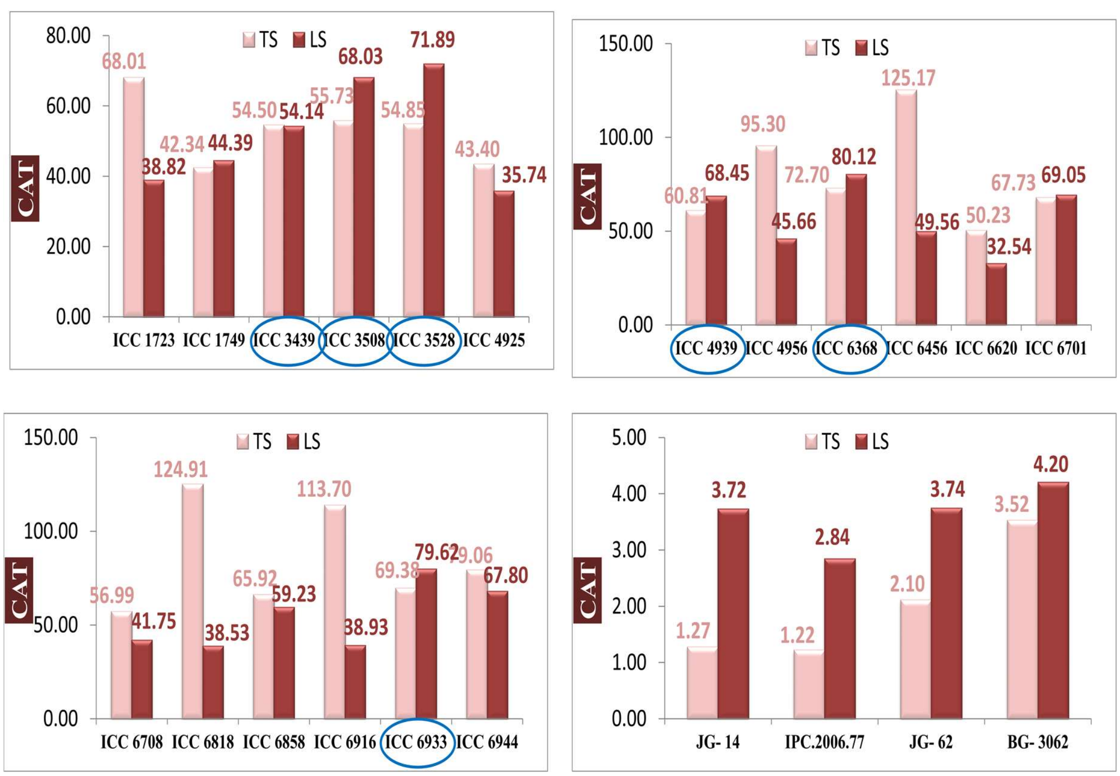


Fig.4.16 CAT activity during TS and LS condition



SUMMARY AND CONCLUSIONS

Chapter V
SUMMARY AND CONCLUSIONS

The current investigation entitled "**Screening and validation of putative heat tolerant chickpea (*Cicer arietinum* L.) genotypes**" was conducted during 2022-23 at the RLBCAU research farm in order to evaluate 500 chickpea germplasm in augmented design for agro-morphological and physiological traits, and simultaneously to validate 18 heat tolerant chickpea genotypes along with two heat-tolerant and heat-susceptible checks in Randomised block design (RBD) for agro-morphological, physiological, and biochemical characteristics to achieve the following objectives

i) Phenotyping of chickpea germplasm accessions for identification of heat tolerant genotypes.

ii) Validation of promising heat tolerant genotypes based on morpho-physiological and biochemical traits.

iii) Assessing character association and genetic divergence in chickpea germplasm.

Phenotyping of chickpea germplasm accessions for identification of heat tolerant genotypes

Total 500 chickpea germplasm were evaluated in the field condition for the selection and identification of desirable genotypes tolerance to heat stress during the reproductive stage. Due to heat extremes, 486 genotypes germinated, 484 genotypes set flower, and 440 genotypes set pods and filled grains out of 500 genotypes. The observations based on various agro-morphological and physiological traits viz., plant population, days to 50% flowering, days to 50% pod stage, chlorophyll content, plant height, number of pods per plant, number of seeds per pod, number of primary branches, number of secondary branches, 100-seed weight (g), days to maturity and seed yield per plant (g) were recorded for all the 440 genotypes along with three checks.

Based on mean performances, the best potential donors were noted for the different traits. ICC-2589 (91) observed as best early maturing genotype along with best check RLBGK-1 (91). The genotypes ICC- 1093 and ICC-2078 (75.67) produced maximum number of pods per plant than best check variety RLBGK-1 (51.84). The trait 100-seed weight (g) found to be higher in ICC-2698 (20.66) followed by ICC-3567 (20.64), ICC-2773 (20.09) than the check variety JG-14 (12.4). The genotypes via ICC-574(15.95) followed by ICC-4998(15.88) exhibited higher seed yield per plant when compared to the check IPC-2006-77 (10.43).

Analysis of variance revealed a significant variation between the treatments for the various traits evaluated viz., plant height, number of pods per plant, number of secondary branches at 5% level of significance where as plant population, days to 50% flowering, days to 50% pod stage, plant height, 100-seed weight, days to maturity and seed yield per plant at 1% level of significance indicating the presence of substantial genetic variation among all the genotypes.

The extent of GCV found to be higher for the trait seed yield per plant (21.87) followed by 100-seed weight (21.55), plant population (19.97) and number of pods per plant (18.21) where as higher PCV was noticed for plant population (25.53) followed by seed yield per plant (23.44), 100-seed weight (23.37), number of pods per plant (23.21). For each and every variable examined, PCV was considerably greater than the GCV value denoting environmental influence had a great role. The occurrence of such a huge amount of variation offers an outline for crop improvement programme.

High heritability broad sense listed for the trait days to 50% flowering (95.89%) followed by days to 50% pod stage (92.46%), days to maturity (89.21%), seed yield per plant (87.05%), 100-seed weight (85.02%) where as high genetic advance over mean recognized for seed yield per plant (42.1%) followed by 100-seed weight (41%), plant population (32.22%), number of pods per plant (29.47%), number of secondary branches (22.38%). High heritability coupled with high genetic advance over mean aids in adoption of favourable selection procedure and signified the role of additive gene action in the expressing character.

The correlation analysis was carried out between the independent variable viz., seed yield per plant and the other dependent variables revealed positive and negative correlation. The trait number of secondary branches (0.401**) followed by total number of pods per plant (0.258**) and 100-seed weight (0.115*) showed maximum significant positive correlation with seed yield per plant. It implies that the degree of relationship between these attributes would be beneficial for increasing the yield and can be employed for the selection and identification of suitable genotypes under heat stress condition.

According to the path coefficient matrix, hundred seed-weight (0.103) and total number of pods per plant (0.044) resulted direct effects on seed yield per plant where as number of secondary branches exerted indirect positive effect on seed yield per plant through the component characters 100-seed weight (0.022) and number of pods per plant (0.100) suggesting that these traits can be considered for direct and indirect selection for yield attribute.

Based on cluster analysis, all 440 genotypes were classified into a total of six clusters, with Cluster- II having the highest number of genotypes (129). The maximum inter cluster distance was noticed between cluster-IV and cluster-VI (38.090) followed by cluster-III and cluster-VI (33.529), cluster-II and cluster-III (33.235), cluster-II and cluster-IV (31.671). It acts as a measure of variation between clusters, which leads to the appropriate selection of suitable donors from different clusters and can be exploited in wide hybridization programme.

The present investigation carried out from January, 2023 to May, 2023 exposed to different temperature variations particularly during the period of reproductive stage which leads to drastic reduction in yield. Based on different parameters examined, the genotypes ICC-161, ICC-176, ICC-273, ICC-299, ICC-30, ICC-494, ICC-583, ICC-1000, ICC-2096, ICC-2714, ICC-3326, ICC-3406, ICC-3410, ICC-3412, ICC-3421, ICC-3497, ICC-3558 performed better than the check varieties RLBGK-1, JG-14 and IPC-2006-77 with respect to the traits number of secondary branches, number of pods per plant, 100-seed weight, seed yield per plant and pollen viability test. These traits can be considered as most reliable traits for an effective screening and identification of desirable genotypes under heat extremities.

Validation of promising heat tolerant genotypes based on morpho-physiological and biochemical traits.

Total 18 promising heat tolerant genotypes had been validated along with two heat tolerant checks viz., JG-14 and IPC-2006-77 and two heat susceptible checks viz., JG-62 and BG-3062 under both timely sown and late sown condition for the various traits viz., plant population, seedling vigour index (SVI), days to 50% flowering, leaflet size, plant height, days to first pod initiation, days to 50% pod stage, number of primary branches, number of secondary branches, number of pods per plant, number of seeds per pod, days to maturity, hundred-seed weight, days to pod set, chlorophyll content, chlorophyll fluorescence, transpiration rate, stomatal conductance, rate of photosynthesis, protein content, superoxide dismutase activity and catalase activity.

Analysis of variance confirmed significant differences for all parameters assessed across chickpea germplasm accessions under both timely and late sown conditions, indicating the availability of adequate variation for investigation.

Based on mean performances, higher SOD activity (U mg^{-1} protein) observed for ICC-3528 (4.06) followed by ICC-3508 (2.8) where as ICC-6368 (80.12) followed by ICC-

3528 (71.8) exhibited higher CAT activity (U mg^{-1} protein) under late sown condition. Higher rate of transpiration, stomatal conductance and rate of photosynthesis noticed for ICC-3439, ICC-3528 and ICC-6944 respectively under both timely and late sown condition. ICC-6858 (93.97) produced maximum number of pods per plant, on the other hand ICC-3528 (15.8) noted for greater value of 100-seed weight under late sown condition.

Higher extent of genotypic and phenotypic coefficient of variation were observed for SOD activity followed by stomatal conductance, CAT activity, rate of photosynthesis, plant population, seedling vigour index, transpiration rate, hundred-seed weight, seed yield per plant under timely sown condition where as during late sown condition, high GCV and PCV were noticed for SOD activity followed by CAT activity, stomatal conductance, plant population, hundred-seed weight, rate of photosynthesis, seedling vigour index, transpiration rate, protein content, number of pods per plant indicating SOD and CAT activity played a significant role in creation of genetic variation during heat stress condition.

Higher estimate of heritability broad sense coupled with high genetic advance over mean comparatively, exhibited higher during late sown rather than timely sown condition for the traits SOD and CAT activity which implies selection based on these traits would be rewarding and resulting in a large heritable proportions, demonstrating the significance of additive gene action in the acquisition of this attribute.

Correlation coefficient analysis revealed highest significant positive correlation for the trait 100-seed weight (0.862**) followed by CAT (0.703**), SOD (0.592**), rate of photosynthesis (0.544*EE*), number of pods per plant (0.445**) with seed yield per plant during heat stress condition where as SOD and CAT activity found to be non-significant and negative significant correlation respectively with seed yield per plant during timely sown condition resulting no change in both of the biochemical traits activity could be observed in tolerant genotypes.

According to path coefficient analysis, the traits viz., 100-seed weight(1.12) followed by protein content (0.74), number of pods per plant (0.51), number of secondary branches (0.42), CAT activity (0.40) contributed direct positive impact on seed yield per plant where as indirect positive effects on seed yield per plant due to the following component attributes such as rate of transpiration, rate of photosynthesis, seedling vigour index suggesting that these traits could be taken into consideration for direct and indirect selection strategies.

To maintain agricultural production in a scenario of present and future variations in climate, thermo-tolerance demands a multidisciplinary, holistic strategy that incorporates the resultant effects of biochemical, physiological, breeding, and agronomic treatments. During heat stress, plants accumulate an excess of ROS, which causes lipid peroxidation, DNA damage, protein oxidation, and cell death. ROS production has previously been demonstrated to play an important role in the activation of a antioxidant enzymes that eventually leads to plant adaptation to a variety of external stress factors. Changes in physiological activities in response to temperature are significant across a temperature range of 10-35°C, although exposure to temperatures below or above this range may cause damage to the photosynthetic system. In the current study, genotypes cultivated under increased temperature circumstances showed a considerable increase in photosynthetic rate and rate of transpiration in the promising heat tolerant cultivars.

The current study, endured from November, 2022 to May 2023, being subjected to various temperature fluctuations, specifically during the reproductive stage, which resulted in a significant reduction in yield. Based on the performance of antioxidant enzyme activity (SOD and CAT), agro-morphological and physiological trait studies, a total of 6 genotypic accessions viz., ICC-3439, ICC-3508, ICC-3528, ICC-6933 and ICC-4939 categorized under the group of high tolerance level to heat stress conditions where as moderate level of tolerance exhibited by ICC-6944, ICC-6368, ICC-6701, ICC-6818, ICC-6858 and rest of the eight genotypes grouped under the category of low tolerance level.

Out of six highly heat tolerant chickpea genotypes, ICC-3528 matured early while ICC-6933 and ICC-4939 took longer duration to become fully matured. ICC-6701 which showed moderately tolerance to heat stress also noted as wilt resistant genotype.

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ABSTRACT

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Thesis Title: **"Screening and validation of putative heat tolerant chickpea (*Cicer arietinum* L.) genotypes"**

Abstract

Chickpea (*Cicer arietinum* L.) is an autogamous, diploid species and self pollinated crop known for its high nutritional value, when exposed to temperatures higher than 35°C during the reproductive stage leads to occurrence of severe yield losses. The current study entitled "Screening and validation of putative heat tolerant chickpea (*Cicer arietinum* L.) genotypes" carried out at RLBCAU farm, Jhansi endured from November, 2022 to May, 2023 assessed 500 germplasm accessions along with 3 checks in augmented design based on agro-morphological and physiological traits aided favourable selection of desirable genotypes under heat stress condition and simultaneously validated 18 promising heat tolerant lines along with 4 checks in RBD design under timely and late sown conditions for the identification of suitable heat tolerant donors based on agro-morphological, physiological and biochemical traits. Based on extent of GCV and PCV along with high heritability coupled with high GAM, correlation and path analysis studies, the traits viz., number of secondary branches, number of pods per plant and 100-seed weight together with pollen viability test considered as most reliable traits for the effective selection measure. Cluster analysis revealed a total number of 6 clusters where maximum inter cluster distance observed between cluster-IV and cluster-VI (38.090) leads to the ideal selection of candidate donor parents which can be exploited in wide hybridization programmes. Based on statistical procedures and various observations recorded the genotypes ICC-3326, ICC-3497 and ICC-3558 performed better than the check varieties during screening of 500 genotypes. The experiment based on validation of 18 promising heat tolerant lines confirmed that the genotypes ICC-3439, ICC-3508, ICC-3528, ICC-6933 and ICC-4939 categorized under the group of high heat- tolerance level based on the results of statistical analysis, morphological and physiological traits studies and performance of antioxidant enzyme activity (SOD and CAT) under both timely and heat stress condition.

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Hanumantu Sirisha (Student)

Dr. Anshuman Singh (Chairperson)

नाम: हनुमन्तु सिरिशा ID No: RLBCAU/AG/PG/053/21

प्रवेश का वर्ष: 2021-22

डिग्री: स्नातकोत्तर (कृषि) आनुवंशिकी एवं पादप प्रजनन

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शोधग्रंथ शीर्षक:**"अनुमानित उच्च तापमान सहिष्णु चने (सिसर एरीटिनम एल.) के जीन प्ररूपों की स्क्रीनिंग और सत्यापन"**

सारांश

चना (*सिसर एरीटिनम* एल.) एक स्वनिषेचित, द्विगुणित प्रजाति और स्व-परागण वाली फसल है जो अपने उच्च पोषण मूल्य के लिए जानी जाती है, प्रजनन चरण के दौरान 35 डिग्री सेल्सियस से अधिक तापमान के संपर्क में आने से गंभीर रूप से उपज की हानि होती है। आरएलबीसीएयू फार्म, झाँसी में नवंबर, 2022 से मई, 2023 तक किए गए " अनुमानित उच्च तापमान सहिष्णु चने (सिसर एरीटिनम एल.) के जीन प्ररूपों की स्क्रीनिंग और सत्यापन " शीर्षक से वर्तमान अध्ययन में संवर्धित डिजाइन आधारित 3 चेक किस्मों के साथ 500 जर्मप्लाज्म परिग्रहण का आकलन किया गया। कृषि-रूपात्मक और पादप शारीरिक लक्षणों पर ताप तनाव की स्थिति के तहत वांछनीय जीनोटाइप के अनुकूल अन्वेषण में सहायता की गई और साथ ही उपयुक्त उच्च तापमान सहिष्णु संभावित जीनोटाइप की पहचान के लिए, समय पर और देर से बोई गई स्थिति, कृषि-रूपात्मक, पादप शारीरिक लक्षण और जैव रासायनिक लक्षणों के आधार पर आरबीडी डिजाइन में 4 चेक किस्मों के साथ 18 आशाजनक ताप सहनशील लाइनों को मान्य किया गया। उच्च आनुवंशिकता और उच्च जीएएम के साथ जीसीवी और पीसीवी की सीमा तथा सहसंबंध गुणांक और पथ विश्लेषण अध्ययन के आधार पर, माध्यमिक शाखाओं की संख्या, प्रति पौधे फलियों की संख्या और पराग व्यवहार्यता परीक्षण के साथ 100 बीज का वजन को प्रभावी चयन उपाय के लिए सबसे विश्वसनीय लक्षण माना जाता है । क्लस्टर विश्लेषण से कुल 6 क्लस्टरों का पता चला जहां क्लस्टर-IV और क्लस्टर-VI (38.090) के बीच देखी गई अधिकतम अंतर-क्लस्टर दूरी सबसे अच्छा प्रदर्शन करने वाले उपयुक्त जीनोटाइप के आदर्श चयन की ओर ले जाती है जिसका उपयोग व्यापक संकरण कार्यक्रमों में किया जा सकता है।। 500 जीनोटाइप की स्क्रीनिंग के दौरान, सांख्यिकीय प्रक्रियाओं और विभिन्न अवलोकनों के आधार पर देखा गया कि ICC-3326, ICC-3497 और ICC-3558, जीनोटाइप ने चेक किस्मों की तुलना में बेहतर प्रदर्शन किया। 18 अनुमानित ताप सहनशील जर्मप्लाज्म परिग्रहणों के सत्यापन पर आधारित प्रयोग ने पुष्टि की कि जीनोटाइप ICC-3439, ICC-3508, ICC-3528, ICC-6933 और ICC-4939 को कृषि-रूपात्मक और पादप शारीरिक लक्षणों का अध्ययन तथा समय पर और गर्मी तनाव दोनों स्थितियों में एंटीऑक्सीडेंट एंजाइम गतिविधि (एसओडी और सीएटी) का प्रदर्शन परिणामों के आधार पर उच्च ताप-सहिष्णुता स्तर के समूह के अंतर्गत वर्गीकृत किया गया है।

H. Sirisha — Anshuman Singh

हनुमन्तु सिरिशा
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APPENDICES

Appendix I- Mean performances of 18 heat tolerant promising lines under timely sown condition

TS	PP	SVI	DFF	LS	PH	DFPI	DFP	NPB	NSB	NPP	NSP	DM	100-SW	PS	CC	CF	TR	SC	RP	PR	SOD	CAT	SYPP
ICC 1723	12.33	97.00	78.67	4.75	58.23	78.33	85.67	4.47	11.67	75.80	1.60	137.33	14.33	85.80	1.97	0.64	4.17	0.22	11.23	12.71	0.22	68.01	9.96
ICC 1749	15.00	112.50	75.33	5.09	54.87	74.67	82.33	4.20	14.07	95.00	1.60	133.67	14.43	81.93	2.42	0.66	3.25	0.26	12.37	15.61	0.25	42.34	12.78
ICC 3439	21.67	141.33	67.00	5.64	55.33	65.00	75.33	5.13	10.40	99.40	2.40	133.00	18.54	74.47	1.84	0.65	5.01	0.37	16.29	17.56	0.37	54.50	13.16
ICC 3508	22.33	167.33	75.33	4.77	56.87	74.00	82.00	4.67	10.47	93.67	1.67	134.00	12.82	81.73	2.08	0.69	4.72	0.36	20.69	18.65	0.39	65.73	10.56
ICC 3528	21.33	197.83	61.33	4.93	60.93	60.67	69.33	5.13	10.73	92.60	1.60	123.00	16.43	68.87	2.28	0.74	4.93	0.56	21.68	20.25	2.53	54.85	13.82
ICC 4925	17.00	127.50	77.33	4.80	75.10	76.00	84.33	4.40	12.03	75.00	1.53	132.67	13.29	84.80	1.92	0.63	3.16	0.13	11.32	15.40	0.55	43.40	10.89
ICC 4939	14.33	90.83	69.67	5.57	67.83	69.33	75.67	4.00	10.20	81.33	1.47	131.00	13.09	76.60	2.02	0.67	3.42	0.22	12.48	14.54	2.53	60.81	9.62
ICC 4956	19.67	125.17	81.67	5.16	63.10	81.00	88.33	4.40	12.90	83.87	1.47	142.67	10.97	89.00	1.89	0.65	4.12	0.17	10.53	12.45	0.55	95.30	11.07
ICC 6368	25.67	145.83	73.33	5.34	75.63	76.67	83.33	4.27	11.80	100.70	1.67	132.00	12.28	84.27	2.01	0.64	2.86	0.21	15.70	15.18	1.03	72.70	10.87
ICC 6456	16.33	122.50	73.33	4.65	66.03	73.67	81.67	4.47	12.67	95.60	1.87	133.33	16.46	81.00	2.01	0.58	4.17	0.30	12.49	13.40	0.22	125.17	12.79
ICC 6620	18.50	103.75	74.00	4.78	64.10	73.00	81.00	4.30	12.00	88.60	1.40	132.50	11.09	81.80	1.95	0.67	2.44	0.13	11.49	10.46	3.44	50.23	10.84
ICC 6701	19.67	137.50	74.00	5.43	66.67	73.67	82.67	4.80	12.27	92.13	1.53	133.00	17.98	81.67	2.02	0.65	3.42	0.34	19.40	16.59	1.78	67.73	15.86
ICC 6708	20.33	152.50	79.67	5.55	74.67	79.33	86.67	4.60	11.40	96.87	1.47	133.33	12.40	87.40	2.01	0.65	3.72	0.28	16.38	13.39	1.94	56.99	11.70
ICC 6818	17.33	130.00	79.00	5.53	67.90	79.00	86.33	4.47	11.40	93.93	1.73	131.00	13.46	87.20	2.40	0.62	2.75	0.17	12.63	11.49	4.87	124.91	12.15
ICC 6858	16.00	103.33	76.33	4.93	61.60	75.33	83.33	4.60	10.07	96.13	1.73	135.00	12.96	83.60	2.05	0.55	3.75	0.27	15.18	14.49	1.58	65.92	11.88
ICC 6916	20.00	156.67	78.33	4.57	72.90	78.33	86.00	4.13	11.60	83.60	1.53	132.67	11.99	86.33	2.10	0.61	4.16	0.51	19.51	17.34	2.56	113.70	10.25
ICC 6933	18.00	135.00	80.33	4.61	72.37	81.00	88.67	4.33	12.13	89.13	1.40	140.33	10.65	87.07	1.89	0.67	3.87	0.35	13.87	18.48	0.97	69.38	10.01
ICC 6944	26.33	204.17	81.67	4.99	73.37	85.00	90.67	4.40	9.73	86.40	1.60	139.67	12.78	88.53	2.23	0.70	4.02	0.45	22.29	17.60	2.79	79.06	10.61
JG- 14	32.67	205.00	52.67	5.83	74.33	51.33	60.00	5.13	13.73	106.80	1.80	102.33	22.40	60.33	2.50	0.66	3.52	0.28	29.25	21.45	1.27	41.33	19.39
IPC.2006.77	34.00	198.67	55.00	5.23	81.00	54.33	62.33	5.27	14.53	105.13	1.87	104.00	16.39	62.47	2.20	0.66	4.27	0.49	26.36	19.71	1.22	20.59	15.64
JG- 62	28.33	203.33	57.00	5.46	54.30	58.00	64.33	4.40	11.20	86.40	1.73	106.67	16.49	64.20	2.45	0.78	4.42	0.54	24.36	17.54	2.10	82.74	13.42
BG- 3062	30.33	192.33	57.33	5.15	65.60	58.33	64.67	4.47	11.73	91.33	1.67	109.00	20.80	65.00	2.79	0.69	3.63	0.35	28.13	19.67	3.52	58.55	17.22

PP-Plant population ; SVI-Seedling vigour index ; DFF-Days to 50 % flowering ; LS-Leaflet size ; PH-Plant height ; DFPI-Days to first pod initiation ; DFP-Days to 50 % pod stage ; NPB- Number of primary branches ; NSB-Number of secondary branches ; NPP-Number of pods per plant ; NSP-Number of seed per pod ; DM-Days to maturity ; 100SW-Hundred seed weight ; PS-Days to pod set ; CC-Chlorophyll content ; SYPP-Seed yield per plant ; CF-Chlorophyll fluorescence content ; TR-Rate of transpiration ; SC-Stomatal conductance ; RP-Rate of photosynthesis ; PR-Protein content ; SOD-Superoxide dismutase ; CAT-Catalase

Appendix II- Mean performances of 18 heat tolerant promising lines under late sown condition

LS	PP	SVI	DFF	LS	PH	DFPI	DFP	NPB	NSB	NPP	NSP	DM	100-SW	PS	CC	CF	TR	SC	RP	PR	SOD	CAT	SYPP
ICC 1723	13.33	93.33	72.67	3.31	30.10	76.00	88.00	3.73	9.20	63.47	1.53	113.00	12.52	85.20	1.57	0.62	3.19	0.08	5.35	11.81	0.43	38.82	9.00
ICC 1749	14.33	107.50	71.33	3.55	31.00	73.67	85.00	3.93	10.20	72.33	1.67	100.00	10.80	71.53	2.00	0.68	2.33	0.20	8.82	13.58	0.77	44.39	9.38
ICC 3439	21.33	160.00	62.00	3.71	34.30	64.33	75.33	3.67	10.00	73.80	2.13	97.33	14.86	70.07	1.83	0.69	4.12	0.17	9.25	17.34	1.73	54.14	11.23
ICC 3508	22.33	167.50	70.67	3.80	31.33	72.67	83.33	3.73	10.47	73.07	1.80	97.00	10.01	68.20	2.07	0.68	3.41	0.19	10.00	18.39	2.80	65.03	9.84
ICC 3528	20.00	196.67	56.00	3.27	36.00	58.33	68.33	3.60	9.67	85.07	1.40	93.00	15.80	67.07	2.24	0.67	4.80	0.26	9.87	19.66	4.06	71.89	11.21
ICC 4925	19.67	127.50	73.33	3.47	29.17	75.67	87.33	3.40	9.27	62.17	1.53	104.33	11.25	77.40	2.04	0.66	3.63	0.15	9.00	14.73	0.35	35.74	10.01
ICC 4939	19.00	142.50	68.00	3.55	30.27	70.67	80.33	3.53	9.00	71.87	1.73	103.33	10.84	77.07	1.86	0.65	3.35	0.16	8.57	15.82	4.06	58.45	8.54
ICC 4956	19.33	153.83	75.33	3.41	30.90	78.67	90.00	3.33	9.13	52.67	1.47	105.00	12.24	86.33	1.94	0.66	3.69	0.18	7.97	12.48	0.35	45.66	9.15
ICC 6368	16.33	122.50	70.00	3.48	29.50	73.00	84.67	3.87	10.00	81.80	1.60	104.67	11.04	79.80	1.78	0.67	3.25	0.13	7.44	14.62	1.61	80.12	10.16
ICC 6456	17.33	126.67	73.00	3.45	29.43	73.67	85.67	3.53	8.53	75.00	1.73	103.33	12.73	80.27	1.75	0.65	3.17	0.09	5.65	16.88	0.07	49.56	10.71
ICC 6620	19.00	132.50	70.00	2.94	33.42	72.50	83.50	2.90	9.00	65.00	1.40	104.50	9.80	82.00	1.39	0.60	3.53	0.09	7.02	10.15	0.93	32.54	9.92
ICC 6701	18.00	161.00	68.33	3.43	33.73	70.67	83.00	3.40	10.40	73.87	1.67	103.67	15.53	81.53	1.91	0.68	3.60	0.11	8.01	16.56	2.29	69.05	14.01
ICC 6708	17.67	132.50	72.67	3.43	33.20	75.33	88.33	3.40	10.53	75.53	1.53	98.67	10.55	80.13	1.89	0.66	1.56	0.09	9.28	14.39	0.91	41.75	9.09
ICC 6818	22.33	167.50	71.67	3.30	31.53	76.00	86.67	3.87	10.93	81.33	1.60	106.33	10.95	85.60	1.79	0.66	3.02	0.09	8.00	17.29	0.34	38.53	9.09
ICC 6858	19.33	135.00	71.67	3.37	32.40	75.00	88.67	3.73	10.40	93.27	1.73	99.67	10.49	87.53	2.00	0.64	4.34	0.13	9.09	13.56	0.66	59.23	10.98
ICC 6916	23.67	177.50	72.00	3.30	32.67	74.33	86.67	3.47	9.40	76.80	1.47	101.33	12.45	82.87	1.85	0.65	3.52	0.16	9.91	18.44	2.29	38.93	11.32
ICC 6933	18.67	140.00	74.67	3.34	30.77	76.67	89.67	3.73	10.93	86.87	1.67	102.67	12.15	84.40	1.89	0.61	4.05	0.16	10.20	17.37	1.42	49.62	10.89
ICC 6944	19.00	182.50	77.67	3.11	32.20	80.67	93.33	3.80	10.27	66.73	1.73	108.33	10.94	87.40	1.88	0.65	3.77	0.17	7.22	19.51	2.71	67.80	7.99
JG- 14	25.67	192.50	52.00	3.77	36.10	54.67	66.67	3.93	12.13	86.67	1.67	92.67	18.80	65.67	2.24	0.78	5.44	0.20	11.17	21.04	3.72	81.76	14.85
IPC.2006.77	30.67	193.33	53.00	3.13	36.33	56.33	68.00	3.93	10.60	92.33	1.67	93.33	15.26	67.47	2.12	0.71	4.36	0.18	12.29	20.85	2.84	97.12	14.33
JG- 62	31.33	197.67	55.67	3.87	40.20	59.33	71.33	3.53	9.87	85.67	1.53	94.67	20.64	67.27	1.95	0.71	3.35	0.14	10.71	17.58	3.74	109.82	11.03
BG- 3062	31.33	193.33	54.00	3.03	28.03	56.67	69.67	3.20	11.27	74.40	1.67	97.33	18.19	68.20	1.99	0.63	3.08	0.15	11.11	19.60	4.20	81.09	11.71

PP-Plant population ; SVI-Seedling vigour index ; DFF-Days to 50 % flowering ; LS-Leaflet size ; PH-Plant height ; DFPI-Days to first pod initiation ; DFP-Days to 50 % pod stage ; NPB- Number of primary branches ; NSB-Number of secondary branches ; NPP-Number of pods per plant ; NSP-Number of seed per pod ; DM-Days to maturity ; 100SW-Hundred seed weight ; PS-Days to pod set ; CC-Chlorophyll content ; SYPP-Seed yield per plant ; CF-Chlorophyll fluorescence content ; TR-Rate of transpiration ; SC-Stomatal conductance ; RP-Rate of photosynthesis ; PR-Protein content ; SOD-Superoxide dismutase ; CAT-Catalase

Appendix-III Mean performances of 500 germplasm accessions screened under heat stress condition

	Trt	PP	DFF	DFP	CC	PH	NPP	NSP	NPB	NSB	100-SW	DM	SYPP
RLBGK-1	**C1**	9.14	54	61.85	2.31	37.68	3.59	12.68	51.84	1.21	13.99	94	11.93
JG-14	**C2**	7.85	54	61.85	2.3	32.66	3.95	14.09	57.19	1.57	17.68	95.97	12.55
IPC-2006-77	**C3**	8	54.28	62.28	2.2	32.03	3.67	13.03	66.38	1.71	15.61	94.57	13.46
ICC-2	V1	4	68	76	2.05	31.00	71.00	1.50	3.00	12.00	8.88	111	13.25
ICC-15	V2	5	71	79	2.30	31.00	52.00	1.33	4.00	12.00	11.02	114	10.39
ICC-26	V3	6	69	77	1.52	35.00	45.00	1.33	4.00	10.00	9.45	112	8.07
ICC-42	V4	4	70	78	2.45	35.00	34.00	1.50	3.50	10.00	10.17	110	15.00
ICC-45	V5	5	67	75	2.60	36.00	31.00	1.33	3.00	9.00	9.82	110	15.00
ICC-75	V7	4	69	77	1.73	39.17	48.33	1.33	4.33	10.33	9.37	112	9.94
ICC-80	V8	4	68	76	1.53	32.50	42.00	1.33	4.00	10.67	9.88	109	8.44
ICC-86	V9	5	71	79	2.23	37.83	35.33	1.33	5.00	12.67	11.39	114	9.69
ICC-92	V10	7	67	78	1.63	32.67	49.67	1.33	4.00	12.33	8.42	108	9.83
ICC-95	V11	6	58	66	1.67	33.83	74.67	1.33	3.33	14.33	11.2	101	12.84
ICC-111	V12	8	61	69	1.87	34.00	66.67	1.33	3.33	13.00	9.96	104	7.19
ICC-136	V14	7	65	73	1.63	35.17	65.33	1.67	3.33	14.67	9.16	108	9.90
ICC-143	V15	7	68	77	2.03	37.83	70.33	1.33	4.00	14.67	9.62	109	8.47
ICC-153	V16	8	66	74	1.90	39.23	59.33	1.67	4.67	15.33	10.54	106	13.88
ICC-161	V17	9	62	70	2.43	35.37	71.33	1.67	3.67	14.00	8.92	105	14.27
ICC-166	V18	7	57	65	1.53	30.00	60.67	1.33	4.33	14.33	11.72	100	12.23
ICC-168	V19	7	63	71	1.61	32.50	69.00	2.33	5.33	13.33	8.16	106	10.36
ICC-169	V20	9	58	66	1.88	34.33	64.33	2.00	4.00	14.33	10.66	101	13.04
ICC-176	V21	11	57	65	2.17	34.13	67.33	2.00	3.67	14.67	10.42	100	13.51
ICC-184	V22	6	65	73	1.54	32.17	58.33	1.67	4.00	14.00	10.32	108	13.40
ICC-190	V23	7	67	75	1.91	31.38	48.00	1.33	4.67	14.67	13.75	109	13.18
ICC-219	V24	6	70	78	1.77	34.83	74.67	2.00	4.33	15.00	8.99	110	12.90
ICC-218	V25	7	60	68	1.67	32.67	71.33	2.33	4.67	13.67	10.55	103	12.72
ICC-219	V26	6	63	71	1.97	32.83	49.00	1.33	3.67	14.33	9.48	106	14.67

	Trt	PP	DFF	DFP	CC	PH	NPP	NSP	NPB	NSB	100-SW	DM	SYPP
ICC-237	V27	9	62	70	1.57	32.67	68.33	1.33	4.00	15.67	9.26	105	13.52
ICC-255	V28	9	61	69	2.43	37.67	70.67	1.33	4.00	16.00	11.32	104	12.94
ICC-257	V29	9	58	66	2.03	37.67	66.33	1.33	4.33	14.67	8.92	101	13.64
ICC-273	V30	11	58	66	2.70	35.67	72.33	1.67	4.00	13.67	9.72	100	11.35
ICC-299	V31	10	56	64	2.40	37.67	63.67	1.33	5.00	12.67	11.88	101	10.93
ICC-301	V32	11	57	65	2.50	30.00	69.67	2.00	4.67	13.33	9.92	99	12.67
ICC-311	V33	6	69	76	1.70	30.83	39.67	1.33	4.33	11.33	10.06	108	6.06
ICC-315	V34	6	69	77	1.51	36.33	45.67	1.67	4.00	12.33	13.36	112	14.96
ICC-317	V35	7	61	69	1.67	32.33	55.00	1.33	4.00	13.67	12.15	104	11.02
ICC-324	V36	8	68	76	1.69	31.67	50.00	1.33	4.33	15.67	10.12	111	13.69
ICC-337	V37	9	62	70	1.83	30.17	69.67	2.00	4.33	14.33	9.29	105	15.58
ICC-338	V38	8	60	68	2.13	32.83	71.33	1.67	4.67	15.00	11.51	103	13.52
ICC-342	V39	7	60	68	2.50	34.82	59.67	1.33	4.33	15.00	9.02	103	12.06
ICC-343	V40	6	69	77	1.58	33.00	37.67	1.33	3.67	12.33	12.03	112	13.15
ICC-344	V41	9	71	79	1.84	33.67	68.00	1.67	5.00	11.00	11.8	114	12.25
ICC-350	V42	8	65	73	1.66	30.00	49.33	1.67	4.00	11.67	9.59	108	9.11
ICC-353	V43	11	57	65	2.50	31.00	41.67	1.67	3.67	12.33	12.06	100	11.41
ICC-383	V44	8	63	71	1.74	31.67	56.00	2.00	3.00	16.33	9.79	106	13.98
ICC-398	V45	7	55	63	2.20	31.67	33.33	1.33	4.00	10.67	8.34	92	11.70
ICC-437	V46	7	55	63	1.60	31.50	31.00	2.00	4.00	9.00	11.12	93	14.99
ICC-440	V47	7	61	69	1.80	33.50	43.50	1.33	4.50	11.00	18.72	104	10.15
ICC-442	V48	5	68	76	2.03	33.25	48.50	1.33	3.50	11.50	19.21	111	13.56
ICC-448	V49	4	58	66	1.63	33.67	41.00	1.33	5.00	11.00	7.44	101	7.16
ICC-455	V50	6	69	76	1.57	30.67	46.67	1.67	4.00	14.67	11.3	108	12.99
ICC-477	V51	7	61	69	1.93	31.67	57.00	1.67	5.00	14.67	8.52	104	14.21
ICC-482	V52	6	65	73	1.67	31.33	64.67	2.00	4.33	14.33	9.14	108	12.39
ICC-494	V53	9	63	71	2.43	31.50	60.33	2.00	4.33	16.00	8.42	106	12.85

	Trt	PP	DFF	DFP	CC	PH	NPP	NSP	NPB	NSB	100-SW	DM	SYPP
ICC-504	V54	5	65	73	1.77	31.67	32.33	1.67	4.67	13.00	8.63	108	10.14
ICC-512	V55	7	63	71	1.87	38.00	44.33	1.67	3.67	15.00	8.27	106	11.36
ICC-513	V56	7	67	74	1.90	36.00	45.67	1.33	4.67	13.00	9.55	107	11.10
ICC-515	V57	7	57	65	1.67	34.33	58.33	1.33	4.00	13.00	18.1	100	13.11
ICC-531	V58	6	59	67	1.50	30.00	52.67	1.33	3.67	13.33	10.52	102	11.24
ICC-542	V59	4	67	75	1.83	35.33	32.00	1.67	4.00	12.33	10.31	110	14.75
ICC-549	V60	5	68	76	2.43	35.00	59.00	2.00	4.33	13.67	11.61	111	14.98
ICC-552	V61	6	62	70	1.67	42.67	45.67	2.00	3.67	14.67	10.22	105	11.01
ICC-553	V62	7	69	77	2.67	34.33	50.00	2.00	4.00	10.67	10.18	106	12.21
ICC-562	V63	6	70	78	2.00	41.67	45.00	1.67	4.67	14.67	10.55	107	11.08
ICC-574	V64	7	65	72	1.63	40.52	63.00	1.33	3.67	15.00	11.72	104	15.95
ICC-579	V65	6	60	68	2.63	39.00	68.00	2.00	4.00	14.67	12.81	103	15.61
ICC-583	V66	11	58	66	2.21	34.33	71.33	2.00	3.67	17.39	8.07	101	13.72
ICC-591	V67	6	56	64	2.10	39.67	37.00	1.33	3.67	10.33	9.87	94	10.73
ICC-606	V68	6	64	72	2.30	34.17	42.33	2.00	5.33	14.67	9.08	107	14.61
ICC-618	V69	5	67	74	2.00	32.83	53.00	2.00	4.33	12.33	7.38	108	10.95
ICC-619	V70	7	71	79	1.90	31.67	60.00	2.00	4.67	13.00	11.3	114	12.85
ICC-637	V71	7	67	74	2.33	30.33	61.33	2.00	3.67	14.67	9.27	109	15.28
ICC-643	V72	7	69	78	2.07	37.00	69.00	1.33	3.67	13.67	9.18	108	11.63
ICC-652	V73	6	68	76	2.04	31.33	57.33	1.33	3.00	13.67	8.92	107	10.97
ICC-668	V74	7	69	77	3.02	33.83	59.67	1.67	4.67	12.31	10.68	112	11.29
ICC-684	V75	6	70	78	1.63	30.67	65.33	1.33	4.33	15.00	11.11	113	7.39
ICC-685	V76	4	71	79	1.60	33.67	46.33	1.33	3.67	10.33	9.49	114	10.74
ICC-693	V77	6	68	76	1.90	32.33	39.67	1.33	4.00	10.33	7.51	107	10.29
ICC-698	V78	6	66	75	2.10	34.00	35.67	1.67	3.67	13.33	11.28	109	12.76
ICC-701	V79	7	64	72	2.00	40.50	62.67	1.33	4.67	16.00	8.61	109	13.28
ICC-708	V80	8	68	75	1.70	41.67	56.00	1.67	3.67	10.67	7.91	107	10.55

	Trt	PP	DFF	DFP	CC	PH	NPP	NSP	NPB	NSB	100-SW	DM	SYPP
ICC-709	V81	8	70	77	1.77	39.67	38.33	2.00	4.33	16.67	10.42	110	12.91
ICC-711	V82	7	68	78	1.68	36.17	73.00	1.33	4.00	11.33	13.11	109	7.35
ICC-729	V83	6	55	63	1.87	37.17	44.00	2.33	3.67	13.71	10.55	92	13.03
ICC-731	V84	8	69	77	2.00	42.67	62.67	1.33	4.67	10.67	8.46	108	10.22
ICC-734	V85	7	66	74	1.93	40.91	38.88	2.00	4.33	10.67	8.02	106	7.62
ICC-738	V86	6	54	62	2.43	40.83	42.00	2.00	3.67	11.67	9.69	96	6.88
ICC-742	V87	6	74	80	2.17	41.33	38.33	1.33	5.00	11.67	12.28	115	6.97
ICC-751	V88	6	69	77	2.00	40.00	37.33	2.33	4.00	11.33	12.34	109	9.06
ICC-752	V89	5	56	64	2.83	36.00	45.67	1.33	3.33	12.67	10.07	99	12.02
ICC-755	V90	6	73	79	2.10	34.28	51.33	1.33	4.00	9.67	8.22	114	6.18
ICC-760	V91	8	65	73	1.90	30.67	46.33	1.67	5.00	9.67	8.85	108	7.96
ICC-764	V92	7	73	79	2.20	32.33	41.00	1.33	4.33	11.33	8.68	114	8.01
ICC-791	V93	5	62	70	1.66	34.67	50.67	1.33	3.67	9.00	10.13	105	6.35
ICC-792	V94	8	67	75	2.20	30.33	35.00	2.00	4.67	10.33	8.9	110	8.76
ICC-793	V95	4	56	64	2.03	39.17	50.00	2.00	5.00	12.00	8.89	97	12.96
ICC-796	V96	8	53	61	2.33	37.00	57.33	1.33	4.00	11.67	9.98	100	11.81
ICC-797	V97	4	68	74	1.83	30.67	50.67	1.33	5.67	11.67	8.93	107	10.81
ICC-811	V98	7	58	66	1.87	30.17	36.67	1.33	4.33	12.00	13.14	101	10.71
ICC-812	V99	6	53	61	1.97	35.50	49.67	2.00	4.00	14.33	17.45	96	11.97
ICC-839	V101	6	69	77	1.77	34.00	67.33	1.33	5.00	13.00	11.87	112	7.88
ICC-871	V102	5	64	72	1.73	40.33	30.67	1.33	4.00	10.00	10.64	107	6.57
ICC-875	V103	7	74	80	1.57	40.67	34.00	1.33	4.67	11.00	10.45	115	10.54
ICC-898	V104	5	65	73	1.62	40.33	40.00	2.00	4.33	10.78	10.12	108	6.93
ICC-905	V105	7	73	80	2.23	42.33	47.00	1.33	5.00	15.67	11.88	115	11.80
ICC-925	V106	6	74	80	1.67	35.33	39.67	2.00	4.67	13.00	10.14	115	10.77
ICC-929	V107	9	62	70	1.97	38.00	38.33	1.67	4.33	9.67	9.92	105	9.73
ICC-931	V108	6	65	73	2.03	42.33	49.33	2.00	3.33	10.67	11.4	108	12.13

	Trt	PP	DFF	DFP	CC	PH	NPP	NSP	NPB	NSB	100-SW	DM	SYPP
ICC-932	V109	5	58	66	1.71	36.50	46.67	1.67	3.67	11.67	14.65	101	12.99
ICC-943	V110	8	65	73	1.70	41.50	37.67	2.00	3.67	10.00	12.22	108	6.89
ICC-946	V111	9	68	76	1.87	35.67	57.33	1.33	4.67	14.67	15.35	111	12.02
ICC-950	V112	4	64	72	1.80	31.67	31.00	1.33	4.00	9.67	10.76	107	6.33
ICC-951	V113	5	69	77	1.80	33.67	53.00	1.50	4.33	12.00	13.06	112	6.77
ICC-952	V114	6	68	76	2.43	33.00	63.50	1.50	4.00	15.67	19.12	111	14.02
ICC-961	V115	7	58	66	2.03	33.33	55.00	2.00	3.00	13.33	16.65	101	11.85
ICC-963	V116	4	62	70	1.90	31.67	41.00	1.67	5.00	10.67	9.72	105	8.98
ICC-968	V117	4	59	67	2.03	34.17	40.00	1.33	5.00	9.67	11.21	102	14.73
ICC-987	V120	5	68	76	1.87	31.67	33.67	1.33	4.67	10.67	12.31	111	7.81
ICC-991	V121	6	59	67	1.83	31.38	66.00	1.67	3.67	12.67	12.48	102	7.49
ICC-1000	V122	9	71	79	2.40	35.50	57.00	1.67	3.67	17.67	19.35	114	12.89
ICC-1009	V123	7	69	77	2.67	32.93	68.00	1.33	3.67	14.00	13.39	112	10.82
ICC-1018	V125	10	53	61	1.67	31.70	71.67	1.33	3.67	13.67	14.44	98	8.10
ICC-1026	V126	8	59	67	2.07	34.67	64.33	1.33	3.67	9.33	10.6	102	8.58
ICC-1030	V127	8	61	69	1.80	37.17	58.33	1.67	3.33	11.33	13.55	104	6.23
ICC-1032	V128	7	74	81	1.63	32.00	62.00	1.33	3.67	11.00	11.27	113	7.61
ICC-1033	V129	10	65	73	2.13	30.83	46.00	1.33	4.00	11.67	12.84	108	6.83
ICC-1035	V130	11	68	76	1.53	30.67	32.33	1.67	3.33	10.67	9.57	111	9.49
ICC-1036	V131	7	69	75	1.87	32.17	51.33	1.67	3.33	14.00	8.55	110	7.73
ICC-1043	V132	8	74	79	2.07	35.33	67.00	1.33	3.67	16.33	11.6	114	11.84
ICC-1049	V133	7	71	79	2.20	37.33	44.00	1.50	4.00	9.50	12.57	114	9.43
ICC-1052	V134	8	67	75	2.33	36.67	48.33	2.00	3.67	11.67	9.94	110	8.09
ICC-1059	V135	6	69	77	1.80	32.50	41.00	1.33	3.00	12.67	12.14	112	7.74
ICC-1066	V136	8	68	76	1.77	36.44	33.33	1.67	3.33	9.67	7.96	111	8.13
ICC-1070	V137	8	68	76	2.00	33.33	59.33	1.67	3.33	8.67	7.73	108	6.71
ICC-1071	V138	10	65	73	2.47	30.67	37.67	1.67	3.00	12.67	12.28	108	8.28

	Trt	PP	DFF	DFP	CC	PH	NPP	NSP	NPB	NSB	100-SW	DM	SYPP
ICC-1078	V139	10	66	74	2.10	33.78	52.00	1.33	4.33	11.33	7.67	109	7.57
ICC-1083	V140	10	68	75	2.23	32.83	60.67	1.33	4.00	16.97	13.09	109	11.86
ICC-1084	V141	11	68	76	2.23	34.33	60.00	2.00	3.67	16.67	12.8	111	11.03
ICC-1092	V142	7	60	68	1.77	33.33	47.00	1.67	3.00	10.33	13.3	103	6.99
ICC-1093	V143	8	60	68	2.07	39.33	75.67	1.67	3.67	11.33	14.3	103	8.29
ICC-1097	V144	6	61	69	2.37	37.67	31.00	1.33	4.00	8.50	11.92	104	8.50
ICC-1098	V145	8	70	78	2.13	30.33	60.00	2.00	3.67	15.67	11.91	113	11.28
ICC-1102	V146	8	69	77	1.70	31.67	39.00	1.33	3.33	9.67	12.36	112	6.28
ICC-1118	V147	10	67	75	1.70	35.67	40.67	1.33	3.00	11.33	9.27	110	7.39
ICC-1121	V148	10	67	75	2.30	35.00	48.33	1.67	4.33	11.00	10.42	110	9.48
ICC-1122	V149	11	59	67	2.13	32.60	56.33	1.33	3.67	12.00	14	102	8.78
ICC-1127	V150	11	64	72	1.80	37.23	40.67	1.33	3.67	11.33	10.92	107	10.56
ICC-1128	V151	9	62	70	1.57	36.42	43.67	1.67	4.00	9.33	9.82	105	7.05
ICC-1136	V152	4	65	73	2.00	35.00	31.67	1.33	3.67	12.00	13.47	108	10.32
ICC-1157	V156	10	59	67	1.93	30.33	32.50	1.33	3.00	8.50	10.91	102	11.98
ICC-1161	V157	11	61	69	1.73	33.00	41.50	1.33	3.50	10.00	12.13	104	12.06
ICC-1163	V158	8	62	70	1.97	30.00	33.33	1.33	3.67	13.67	12.67	105	7.17
ICC-1164	V159	6	65	73	2.30	37.00	44.67	1.67	3.33	11.33	10.68	108	8.88
ICC-1172	V160	11	68	76	1.80	34.83	45.33	1.67	3.67	13.67	12.07	111	6.18
ICC-1173	V161	10	71	79	2.00	36.33	55.67	2.00	3.67	11.33	11.58	114	7.13
ICC-1180	V162	6	64	72	1.90	38.67	53.33	1.33	4.67	14.33	15.56	107	10.60
ICC-1181	V163	10	74	80	1.70	34.83	39.33	2.00	3.33	10.33	13.07	115	7.94
ICC-1193	V164	11	61	69	2.47	35.17	72.67	2.00	3.67	15.67	11.09	104	8.97
ICC-1194	V165	7	61	69	2.03	36.17	68.00	1.33	3.33	12.33	10.89	104	11.43
ICC-1196	V166	10	63	71	2.63	34.17	68.00	1.67	3.67	16.33	12.65	106	10.34
ICC-1201	V167	7	67	75	2.33	31.17	65.00	1.33	3.67	16.67	13.19	110	11.21
ICC-1204	V168	8	69	77	2.27	38.17	72.67	1.67	3.67	11.67	14.12	112	12.28

	Trt	PP	DFF	DFP	CC	PH	NPP	NSP	NPB	NSB	100-SW	DM	SYPP
ICC-1205	V169	9	69	77	1.57	34.51	32.00	1.33	3.33	9.67	13.01	112	9.03
ICC-1229	V171	10	64	72	2.37	31.80	54.33	1.33	3.33	11.33	17.9	107	10.10
ICC-1232	V172	9	72	80	1.63	31.00	46.33	1.33	3.67	11.33	18.83	115	10.39
ICC-1237	V173	10	74	80	1.67	30.33	38.33	1.67	3.00	11.00	11.95	115	6.96
ICC-1240	V174	6	60	68	1.80	35.83	41.00	1.33	3.33	13.67	19.62	103	10.23
ICC-1246	V175	9	67	75	1.67	36.00	57.33	2.00	4.00	13.00	17.76	110	11.01
ICC-1250	V176	9	61	69	2.17	39.33	51.67	1.33	3.67	11.00	11.52	104	7.01
ICC-1263	V177	10	69	77	1.53	33.33	42.67	1.33	3.33	11.67	11.19	112	9.24
ICC-1265	V178	11	68	76	2.00	31.33	51.33	1.67	3.67	16.33	12.01	111	7.97
ICC-1272	V179	11	65	73	1.60	37.33	51.67	1.33	3.67	10.33	11.2	108	7.25
ICC-1278	V180	9	66	74	1.77	37.67	32.67	1.67	3.33	11.00	12.52	109	6.76
ICC-1285	V181	7	72	80	1.70	38.67	47.33	2.00	4.33	11.33	12.9	115	10.98
ICC-1291	V182	7	69	74	2.50	37.00	53.00	1.33	4.33	11.00	13.07	108	11.82
ICC-1295	V183	9	73	80	1.59	37.67	67.67	1.33	3.33	13.33	14.23	115	10.72
ICC-1296	V184	7	70	76	1.80	34.67	66.67	2.00	3.67	13.33	15.33	110	12.55
ICC-1297	V185	8	73	79	2.07	31.50	61.00	1.33	3.00	11.33	13.83	114	8.52
ICC-1312	V186	7	56	64	1.87	41.50	53.33	1.67	3.33	15.33	13.4	95	12.19
ICC-1315	V187	6	64	72	1.83	35.67	62.33	1.67	3.00	15.00	13.03	107	12.63
ICC-1337	V188	10	69	77	2.10	33.17	53.67	2.00	3.67	12.83	14.04	112	12.32
ICC-1338	V189	9	69	77	2.17	30.17	69.67	1.33	3.00	16.00	14.01	112	11.57
ICC-1345	V190	6	58	66	2.20	31.83	55.00	1.67	3.00	11.67	14.87	101	10.07
ICC-1355	V191	8	59	67	2.07	37.67	69.00	2.00	3.33	15.00	22.2	102	9.80
ICC-1356	V192	10	55	63	1.97	35.83	59.33	1.67	3.33	13.67	16.14	98	9.20
ICC-1359	V193	8	62	70	1.60	38.33	39.34	1.67	3.33	10.33	13.1	105	7.63
ICC-1360	V194	8	65	73	2.50	31.83	49.00	1.33	3.33	13.82	14.5	108	13.06
ICC-1384	V195	9	67	75	2.17	32.00	56.00	1.33	3.33	13.00	12.14	110	9.02
ICC-1392	V196	10	62	70	2.77	34.17	65.33	2.00	3.67	11.00	13.49	105	8.33

	Trt	PP	DFF	DFP	CC	PH	NPP	NSP	NPB	NSB	100-SW	DM	SYPP
ICC-1397	V197	8	53	61	2.07	30.83	71.67	1.33	4.00	10.33	12.19	97	11.43
ICC-1398	V198	11	58	66	1.93	36.00	69.33	2.00	4.33	14.00	15.48	101	11.04
ICC-1402	V199	8	63	71	2.53	40.67	66.00	2.00	3.67	11.67	16.75	106	14.39
ICC-1414	V200	9	61	69	1.83	33.33	53.00	1.33	3.67	11.00	12.08	104	7.10
ICC-1419	V201	7	58	66	2.03	35.80	65.33	1.67	4.33	16.67	13.02	101	14.76
ICC-1422	V202	9	59	67	1.97	31.49	53.67	2.00	3.33	12.67	14.27	102	10.20
ICC1424	V203	11	58	66	1.93	32.67	50.67	1.67	3.67	9.00	11.48	101	8.30
ICC-1431	V204	10	66	74	2.13	31.67	54.33	1.67	3.33	11.92	14.14	109	11.08
ICC-1443	V205	9	72	80	2.07	35.17	52.33	1.33	3.67	11.33	11.38	115	7.98
ICC-1445	V206	6	66	74	1.53	33.17	55.00	1.67	4.00	8.67	19.28	109	7.83
ICC-1449	V207	8	71	78	1.83	34.67	39.00	1.33	5.00	9.00	10.28	109	15.00
ICC-1498	V208	7	73	79	1.97	32.84	56.00	2.00	3.00	11.00	9.14	114	7.90
ICC-1505	V210	7	73	79	1.90	31.33	39.67	1.67	4.00	11.67	12.72	114	6.38
ICC-1507	V211	11	65	73	1.77	33.50	54.00	1.67	3.33	13.00	13.07	108	7.44
ICC-1510	V212	10	63	71	1.73	35.17	68.50	1.67	3.33	13.33	14.6	106	11.93
ICC-1520	V213	9	73	80	2.17	32.48	40.00	1.33	3.67	11.33	12.31	115	8.46
ICC-1555	V215	10	71	79	2.00	34.50	59.67	1.67	3.33	13.33	14.21	114	10.23
ICC-1560	V216	11	64	72	1.87	31.17	57.33	2.00	3.33	13.00	19.27	107	8.42
ICC-1569	V217	8	63	71	1.83	30.00	53.67	1.67	3.33	13.33	14.08	106	7.16
ICC-1574	V218	8	60	68	2.37	31.83	53.00	1.67	3.67	13.67	14.69	103	10.78
ICC-1579	V219	11	61	69	3.19	30.83	61.67	1.67	3.33	14.00	12.22	104	9.98
ICC-1594	V220	7	74	80	1.83	30.67	39.00	1.33	4.00	10.00	13.72	115	6.08
ICC-1600	V221	8	66	74	2.77	31.94	62.33	2.00	3.67	15.67	12.62	109	10.64
ICC-1609	V222	6	73	80	1.93	33.50	43.67	1.33	3.67	10.67	14.09	115	7.84
ICC-1614	V223	8	73	79	2.00	31.00	56.33	2.00	3.67	12.00	11.3	114	12.13
ICC-1616	V224	10	74	80	2.50	31.50	61.67	1.33	3.33	12.67	12.89	115	8.34
ICC-1629	V225	9	72	80	1.77	32.00	36.50	1.33	3.67	10.00	9.13	115	11.94

	Trt	PP	DFF	DFP	CC	PH	NPP	NSP	NPB	NSB	100-SW	DM	SYPP
ICC-1699	V233	10	73	79	1.73	31.67	36.00	1.33	3.67	8.33	9.89	114	8.97
ICC-1707	V234	7	67	74	1.70	30.33	39.33	1.33	3.67	10.33	10.13	107	8.62
ICC-1710	V235	10	72	80	1.67	32.67	47.67	1.33	3.00	10.00	13.02	115	6.58
ICC-1715	V236	7	71	79	2.03	38.00	37.67	1.67	3.33	10.33	14.23	114	9.93
ICC-1740	V237	9	71	79	1.77	32.82	34.50	1.33	3.33	9.33	12.8	114	6.37
ICC-1751	V238	8	71	79	1.83	31.33	40.33	1.33	3.00	11.33	13.25	114	9.45
ICC-1770	V239	9	62	70	1.87	30.17	47.67	1.33	3.33	10.33	13.12	105	10.02
ICC-1774	V240	10	69	77	1.68	34.00	51.67	1.67	3.67	9.00	16.18	112	7.79
ICC-1789	V241	9	71	79	1.82	33.33	45.00	1.33	3.00	10.00	12.17	114	12.59
ICC-1793	V243	6	69	77	1.92	31.28	39.50	1.33	3.00	8.00	10.48	112	6.93
ICC-1806	V244	5	70	77	1.80	34.32	39.33	1.33	3.00	10.67	16.25	108	11.01
ICC-1815	V246	6	70	78	1.67	32.00	40.00	1.33	3.67	10.33	11.48	113	7.08
ICC-1817	V247	7	70	78	1.62	32.67	43.00	1.33	3.00	9.00	10.3	113	15.00
ICC-1822	V248	4	74	80	2.17	36.10	40.00	1.67	3.33	12.33	10.72	115	10.23
ICC-1876	V257	11	69	77	2.07	31.17	40.00	2.00	3.00	10.00	11.21	112	13.94
ICC-1884	V258	5	70	78	1.87	32.50	41.33	1.33	3.67	9.00	12.08	113	10.73
ICC-1889	V259	6	65	73	1.90	34.23	42.00	1.33	3.00	9.00	10.22	108	15.00
ICC-1891	V260	8	66	74	3.00	31.67	52.33	1.33	4.33	12.00	13.29	109	9.02
ICC-1895	V261	9	70	78	2.93	32.17	56.67	1.67	3.33	14.33	10.09	113	10.12
ICC-1896	V262	7	69	77	2.73	35.17	42.50	1.33	5.00	9.50	8.33	112	11.61
ICC-1897	V263	5	70	78	1.87	34.50	39.00	1.33	3.67	9.33	10.2	113	7.52
ICC-1903	V264	6	66	74	1.60	33.67	52.00	1.33	3.67	11.67	11.54	109	9.67
ICC-1911	V265	7	69	77	2.03	36.33	37.33	1.33	3.33	10.33	11.52	112	7.26
ICC-1913	V266	10	58	66	2.03	34.00	61.00	1.67	4.67	15.00	10.22	101	10.02
ICC-1915	V267	6	72	80	1.80	37.75	36.00	1.33	3.00	10.50	11.59	115	10.09
ICC-1923	V268	11	73	79	2.23	31.00	39.00	1.33	3.00	10.00	11.36	114	13.52
ICC-1929	V269	5	67	75	2.33	30.50	44.33	1.33	3.33	11.33	9.64	110	10.21

	Trt	PP	DFF	DFP	CC	PH	NPP	NSP	NPB	NSB	100-SW	DM	SYPP
ICC-1932	V270	7	57	65	1.93	34.67	61.67	1.33	4.33	12.00	14.21	100	10.05
ICC-1950	V271	7	67	75	2.83	31.33	37.00	1.33	3.67	10.00	13.39	110	6.35
ICC-1964	V272	8	60	68	2.23	31.67	38.67	1.33	3.67	10.00	10.27	103	7.01
ICC-1970	V273	8	73	80	1.93	31.00	43.00	1.33	3.00	11.00	9.39	115	15.00
ICC-1990	V274	4	74	80	1.70	30.83	32.00	1.50	3.00	10.50	10.37	115	10.50
ICC-1996	V275	6	64	72	1.93	34.83	38.00	1.33	3.00	11.50	11.37	107	13.66
ICC-2013	V276	9	69	77	1.97	34.83	48.67	1.33	3.33	10.00	9.27	112	6.28
ICC-2014	V277	4	71	79	1.65	34.50	68.00	2.00	5.00	13.82	10.4	114	10.00
ICC-2023	V278	10	56	64	1.80	33.44	63.67	1.67	4.33	12.33	10.54	95	10.36
ICC-2030	V279	7	72	80	2.13	36.17	52.67	1.67	4.00	12.33	10.29	115	9.78
ICC-2065	V280	6	65	73	2.07	35.83	54.33	1.33	3.67	12.00	11.3	108	8.05
ICC-2066	V281	9	66	74	1.90	31.33	52.00	1.33	3.33	12.00	9.02	109	7.10
ICC-2070	V282	6	68	76	2.00	30.17	52.67	1.33	3.67	10.33	11.9	111	10.24
ICC-2072	V283	7	63	71	2.00	31.50	65.33	1.67	4.33	12.00	13.49	106	11.36
ICC-2078	V284	11	62	70	1.97	37.50	75.67	2.33	4.67	10.11	13.94	105	11.53
ICC-2080	V285	9	62	70	1.93	34.83	72.67	2.33	5.00	13.00	10.9	105	13.91
ICC-2083	V286	8	60	68	1.90	31.33	60.00	1.67	3.67	15.67	10.54	103	12.62
ICC-2086	V287	6	58	66	1.87	27.50	57.00	1.33	3.67	13.33	12.87	101	9.95
ICC-2096	V288	9	67	75	2.00	31.17	64.33	2.00	4.67	15.67	13.3	110	13.14
ICC-2104	V290	4	70	78	2.10	31.50	35.00	2.00	4.00	13.00	12.67	113	13.27
ICC-2107	V291	7	72	80	2.67	35.83	53.00	1.33	3.33	9.67	13.11	115	11.13
ICC-2113	V292	7	72	80	1.93	31.83	44.67	1.67	3.67	11.33	14.01	115	10.29
ICC-2114	V293	7	65	73	2.67	28.67	50.00	1.33	3.67	10.00	9.12	108	7.16
ICC-2122	V294	8	73	79	1.73	31.50	49.00	1.33	3.67	9.00	8.14	114	6.82
ICC-2126	V295	7	68	76	2.10	32.00	32.00	1.33	3.67	9.67	9.17	109	6.25
ICC-2127	V296	7	69	77	1.93	27.17	50.33	1.33	4.33	9.00	9.4	109	7.71
ICC-2135	V297	11	73	81	2.03	27.00	63.67	1.67	3.33	11.00	9.13	112	7.04

	Trt	PP	DFF	DFP	CC	PH	NPP	NSP	NPB	NSB	100-SW	DM	SYPP
ICC-2142	V298	10	66	74	1.77	34.00	33.67	1.33	3.00	8.67	15.06	109	10.66
ICC-2166	V299	9	66	74	1.70	28.75	46.00	1.33	3.50	10.00	12.36	109	6.36
ICC-2171	V300	8	64	72	1.90	28.67	59.33	1.67	4.67	11.00	14.13	107	11.93
ICC-2172	V301	5	63	71	2.13	32.83	57.00	1.67	4.00	11.00	11.85	106	11.66
ICC-2177	V302	8	67	74	2.03	27.17	42.00	1.67	3.00	10.33	11.01	108	12.78
ICC-2183	V303	7	71	79	2.30	33.50	34.50	1.33	3.00	9.00	8.71	114	8.83
ICC-2184	V304	5	68	75	1.57	31.50	42.50	1.33	3.50	9.50	11.56	109	10.45
ICC-2195	V305	7	70	76	1.93	33.50	48.50	1.50	3.00	11.00	9.6	107	12.00
ICC-2202	V307	7	64	72	2.67	35.83	55.33	1.67	3.67	13.67	17.16	107	11.82
ICC-2204	V308	11	67	75	1.53	34.00	38.67	1.33	3.33	11.00	12.41	110	10.55
ICC-2206	V309	10	68	76	2.00	36.17	60.00	1.67	3.67	12.67	9.39	111	7.41
ICC-2210	V310	8	74	81	1.77	34.33	64.00	1.33	4.00	9.67	10.4	106	9.79
ICC-2211	V311	8	67	74	2.00	32.83	66.33	1.67	4.00	13.33	14.4	110	11.34
ICC-2220	V313	4	65	73	1.83	30.67	52.00	1.33	3.67	10.00	12.67	107	10.77
ICC-2223	V314	7	68	77	1.87	35.17	51.00	1.33	3.00	10.00	9.78	110	7.93
ICC-2233	V315	8	72	80	1.66	28.25	38.00	1.33	3.50	9.50	12.58	115	10.19
ICC-2240	V316	7	69	78	1.63	31.00	35.00	1.33	3.00	9.00	11.02	109	15.00
ICC-2263	V318	9	74	82	2.07	30.23	47.00	1.33	3.33	10.67	10.44	107	8.79
ICC-2270	V319	8	70	79	1.59	29.67	43.00	1.33	3.00	12.00	12.36	111	12.45
ICC-2299	V320	6	65	73	1.60	29.75	49.00	2.00	4.00	12.00	11.57	107	11.68
ICC-2342	V322	7	74	82	1.67	33.00	40.00	1.33	3.00	11.00	12.24	109	15.36
ICC-2349	V323	10	74	82	1.69	27.50	38.92	1.33	3.50	8.50	13.17	110	10.56
ICC-2352	V324	4	68	75	1.80	32.50	32.00	1.33	3.00	11.00	11.26	109	11.29
ICC-2353	V325	7	74	82	1.75	29.00	47.00	1.33	3.00	9.00	15.85	107	10.78
ICC-2355	V326	4	67	75	2.99	27.75	42.50	1.50	3.50	11.00	11.4	108	10.97
ICC-2358	V327	7	73	81	1.91	34.50	45.00	1.33	3.00	8.50	10.51	103	9.68
ICC-2397	V329	5	73	81	2.13	35.33	40.67	1.33	3.33	10.67	11.33	109	7.88

	Trt	PP	DFF	DFP	CC	PH	NPP	NSP	NPB	NSB	100-SW	DM	SYPP
ICC-2402	V330	8	71	79	1.90	34.17	53.67	1.33	4.33	11.67	17.51	111	7.13
ICC-2410	V331	8	71	78	1.83	35.67	67.67	2.00	4.67	13.67	9.52	110	10.59
ICC-2411	V332	8	72	80	2.05	28.95	37.00	2.00	3.00	9.00	11.49	115	10.58
ICC-2486	V341	6	72	79	2.10	32.00	40.00	1.33	3.00	13.00	10.38	112	10.75
ICC-2489	V343	5	70	78	1.93	37.83	54.00	1.33	4.00	11.33	19.83	110	14.45
ICC-2490	V344	7	74	82	1.87	36.50	38.50	1.50	4.00	10.50	9.66	107	14.55
ICC-2492	V345	5	69	77	1.60	32.83	32.00	1.33	3.50	9.00	10.11	109	9.90
ICC-2497	V346	7	72	80	1.97	35.00	62.67	2.00	4.67	12.33	16.45	115	11.78
ICC-2500	V347	9	73	81	2.27	36.83	61.67	1.33	4.33	13.00	14.37	111	6.61
ICC-2503	V348	6	74	82	1.60	29.00	31.00	1.33	3.00	10.00	11.03	109	9.67
ICC-2507	V349	6	68	76	2.13	35.67	59.00	1.33	3.33	11.33	10.16	109	10.68
ICC-2508	V350	11	72	80	2.47	33.33	51.00	1.67	4.33	11.67	16.44	112	11.87
ICC-2509	V351	8	68	76	1.70	35.67	63.33	2.00	3.67	12.33	16.23	110	11.51
ICC-2511	V352	10	71	78	1.77	32.50	58.33	1.67	4.00	12.67	9.9	111	8.71
ICC-2514	V353	4	72	80	2.53	30.33	49.67	1.67	3.00	11.33	15.23	112	10.98
ICC-2515	V354	6	73	79	2.60	32.33	61.67	1.33	4.67	13.00	14.55	110	15.03
ICC-2516	V355	11	71	80	1.70	30.33	50.67	1.33	3.33	10.00	9.56	113	11.24
ICC-2518	V356	4	73	81	1.60	31.00	41.50	1.33	3.50	10.50	9.88	112	9.78
ICC-2520	V357	6	67	74	1.57	30.67	37.67	1.33	3.67	9.67	10.47	114	6.29
ICC-2546	V359	5	70	78	2.23	27.67	48.00	1.33	3.67	10.00	13.21	109	7.24
ICC-2555	V360	11	74	82	1.97	32.33	57.33	1.33	3.67	10.67	12.63	111	6.64
ICC-2561	V361	7	72	81	1.90	33.67	43.00	1.33	3.67	9.33	18.91	112	9.08
ICC-2564	V362	9	58	66	2.77	35.33	69.33	2.00	3.67	11.67	16.06	101	10.03
ICC-2565	V363	10	65	73	2.20	33.33	56.67	1.67	4.00	13.00	13.65	108	11.96
ICC-2567	V364	10	70	78	2.00	32.33	39.00	1.33	3.67	11.33	14.01	113	9.23
ICC-2570	V365	7	74	82	1.63	30.83	31.00	1.33	3.00	12.67	14.78	114	6.25
ICC-2576	V366	9	68	76	2.30	39.33	62.33	2.00	3.67	16.00	14.07	111	11.36

	Trt	PP	DFF	DFP	CC	PH	NPP	NSP	NPB	NSB	100-SW	DM	SYPP
ICC-2580	V367	7	71	77	1.63	28.00	35.00	1.33	3.00	12.00	14.03	109	11.78
ICC-2589	V368	9	54	62	1.77	33.17	49.67	1.33	3.33	10.67	12.96	91	10.82
ICC-2591	V369	6	67	75	1.67	29.50	37.67	1.33	3.00	11.33	14.36	110	6.99
ICC-2593	V370	10	64	72	2.83	36.17	38.67	1.67	4.00	12.67	16.93	107	9.69
ICC-2595	V371	10	63	71	2.30	34.83	63.67	1.33	5.00	14.00	14.88	106	11.35
ICC-2600	V372	7	62	70	2.10	34.00	64.67	2.00	3.00	12.00	14.18	105	7.76
ICC-2606	V373	4	70	76	2.37	31.00	43.00	1.33	3.50	10.50	19.03	113	12.15
ICC-2608	V374	7	67	75	1.63	33.33	58.67	1.67	3.67	14.67	14.6	110	11.61
ICC-2610	V375	7	73	81	1.83	30.83	54.33	1.33	3.67	11.00	16.75	112	10.53
ICC-2613	V376	7	65	73	2.37	33.17	61.00	2.00	4.67	10.97	16.5	108	13.86
ICC-2625	V377	5	66	74	2.00	31.33	52.33	1.33	3.67	9.33	18.71	109	6.81
ICC-2628	V378	8	66	74	1.87	33.83	60.00	1.33	3.00	12.00	13.21	109	7.01
ICC-2629	V379	6	69	78	2.37	27.67	52.67	1.33	3.67	12.67	14.15	107	7.87
ICC-2630	V380	9	59	67	2.07	31.33	74.33	2.00	4.33	12.93	14.44	102	11.52
ICC-2635	V381	9	64	72	2.10	32.00	53.67	1.33	3.33	9.67	15.82	107	7.18
ICC-2648	V382	8	68	76	1.93	27.17	45.00	1.33	3.33	9.67	15.07	111	8.45
ICC-2664	V384	4	72	80	2.00	31.47	37.67	1.33	3.67	9.67	10.12	110	7.80
ICC-2669	V385	7	72	80	2.00	31.50	58.00	1.33	3.67	11.00	14.08	115	11.28
ICC-2672	V386	7	71	79	2.27	30.83	65.00	1.33	3.33	10.00	11.57	114	8.76
ICC-2675	V387	5	69	77	1.97	28.00	31.00	1.33	3.67	8.67	9.39	112	6.09
ICC-2679	V388	7	74	82	1.53	32.17	47.00	1.33	3.67	9.33	15.28	109	9.84
ICC-2694	V389	8	72	80	2.27	35.67	54.67	1.67	4.33	16.33	19.64	115	15.54
ICC-2695	V390	8	72	80	1.83	33.67	41.33	1.33	3.33	9.67	13.83	115	6.43
ICC-2697	V391	7	61	69	2.07	34.36	59.67	1.67	4.33	15.67	15.08	104	11.58
ICC-2698	V392	7	67	75	2.10	41.50	74.33	1.67	4.33	16.67	20.66	110	13.01
ICC-2703	V393	10	68	76	2.43	33.83	69.67	1.33	4.33	13.92	14.69	111	11.12
ICC-2709	V394	9	71	79	2.17	34.33	77.67	1.67	4.33	12.00	19.65	114	9.73

	Trt	PP	DFF	DFP	CC	PH	NPP	NSP	NPB	NSB	100-SW	DM	SYPP
ICC-2711	V395	10	63	71	2.47	33.67	67.33	2.00	5.00	16.00	14.28	106	10.67
ICC-2714	V396	6	68	76	2.27	38.17	56.33	2.00	4.67	13.33	15.08	111	13.91
ICC-2720	V397	9	71	79	2.37	34.00	75.00	1.33	4.33	16.33	12.4	114	11.45
ICC-2737	V398	7	72	80	1.97	32.67	69.33	1.33	3.33	11.00	11.84	115	8.23
ICC-2748	V399	6	67	75	2.27	32.17	73.67	1.33	3.00	10.33	15.6	110	9.64
ICC-2773	V401	9	53	61	2.13	35.83	63.33	1.33	3.67	10.33	20.09	93	11.23
ICC-2782	V402	6	67	75	2.78	33.00	74.67	1.67	3.67	13.00	15.62	110	12.54
ICC-2796	V403	9	69	77	2.53	35.83	69.67	1.33	5.00	11.67	13.76	112	12.35
ICC-2808	V404	6	70	78	2.27	29.00	49.00	1.33	3.33	9.67	8.47	113	6.82
ICC-2829	V405	7	70	78	1.67	30.67	40.67	1.33	3.67	9.67	11.84	113	8.97
ICC-2836	V406	7	53	61	2.07	37.33	60.33	1.67	4.33	12.31	12.72	97	13.11
ICC-2844	V407	5	65	73	2.13	31.67	48.33	1.33	3.67	10.00	8.28	108	9.61
ICC-2845	V408	6	66	74	1.63	35.00	34.33	1.33	3.33	8.67	12.49	109	10.87
ICC-2859	V409	7	73	81	1.97	36.00	59.67	1.67	3.67	11.67	12.87	114	10.09
ICC-2861	V410	8	72	80	1.87	35.50	71.33	1.33	4.33	11.67	11.99	115	9.28
ICC-2878	V411	6	65	73	1.97	36.50	52.67	1.33	3.67	11.67	18.29	108	10.96
ICC-2884	V412	11	67	75	2.30	35.50	68.67	1.33	4.33	13.67	10.92	110	9.89
ICC-2893	V414	4	69	77	2.10	39.00	59.00	1.33	3.33	9.67	18.04	112	8.84
ICC-2906	V415	5	67	75	1.90	35.00	35.00	1.33	3.67	10.00	13.52	110	6.82
ICC-2915	V416	4	73	81	1.80	34.83	67.00	1.33	3.33	9.67	13.63	110	10.28
ICC-2919	V417	8	71	79	2.17	37.67	64.67	1.33	4.33	11.33	17.58	114	7.15
ICC-2927	V418	6	71	79	2.07	35.50	49.33	1.33	3.67	10.00	11.57	114	7.28
ICC-2933	V419	6	69	77	2.01	34.00	40.33	1.33	3.67	9.33	10.37	112	7.06
ICC-2938	V420	7	74	82	1.97	35.17	56.67	1.33	4.00	13.67	15.34	111	10.91
ICC-2957	V422	7	72	80	2.03	36.67	58.67	1.67	4.00	12.33	14.36	115	9.20
ICC-2969	V423	9	67	75	1.73	34.83	71.00	2.00	4.00	16.39	14.8	108	12.00
ICC-2997	V426	4	70	78	1.62	35.00	38.50	2.00	3.50	9.50	10.22	113	7.62

	Trt	PP	DFF	DFP	CC	PH	NPP	NSP	NPB	NSB	100-SW	DM	SYPP
ICC-3024	V429	10	68	76	2.10	36.50	34.00	1.33	3.33	9.67	9.74	111	9.82
ICC-3025	V430	11	62	70	2.37	34.67	66.00	2.00	5.33	11.33	17.55	116	13.69
ICC-3029	V431	9	69	77	2.17	38.67	64.67	2.00	5.00	12.67	14.75	113	12.74
ICC-3048	V434	4	74	82	1.97	33.50	52.67	1.33	3.33	10.00	8.73	112	12.70
ICC-3056	V435	5	73	81	2.23	37.67	64.67	1.33	3.00	10.00	11.19	108	9.64
ICC-3059	V436	8	74	82	2.03	39.50	58.67	1.33	3.33	9.67	13.75	110	6.01
ICC-3089	V437	6	70	76	1.93	34.50	49.33	1.33	3.33	12.33	8.4	111	10.78
ICC-3093	V438	9	65	73	1.93	37.17	36.67	1.33	3.67	8.67	8.54	108	11.32
ICC-3142	V442	4	68	76	2.00	35.67	35.33	1.33	3.33	10.00	9.27	111	10.87
ICC-3205	V444	7	69	77	1.93	35.17	52.33	1.67	3.67	13.67	10.69	109	9.08
ICC-3207	V445	7	62	70	2.07	36.00	62.00	1.33	3.33	9.00	9.82	105	12.63
ICC-3217	V446	5	71	79	1.67	34.67	33.00	1.33	3.00	9.00	9.33	114	15.00
ICC-3230	V447	6	67	75	2.33	35.33	38.00	1.67	3.33	11.67	9.56	110	12.70
ICC-3232	V448	11	70	78	2.27	37.00	53.00	2.00	5.33	13.54	8.49	113	10.97
ICC-3245	V450	8	71	79	2.00	35.33	45.00	1.33	3.33	13.33	10.2	114	6.81
ICC-3257	V451	7	72	80	2.10	39.00	69.00	2.00	5.00	12.69	11.5	115	15.00
ICC-3266	V452	7	68	76	1.87	35.50	35.67	1.33	3.00	9.67	19.03	111	9.56
ICC-3267	V453	4	74	82	2.10	37.17	72.33	1.67	3.67	11.67	12.43	112	12.12
ICC-3274	V454	5	74	82	1.80	31.50	53.00	1.67	4.00	14.67	10.01	113	13.99
ICC-3277	V455	9	68	76	1.60	29.67	53.67	1.33	3.67	15.67	8.75	112	8.33
ICC-3284	V456	8	69	77	1.77	33.17	49.67	1.67	3.67	14.33	9.7	112	8.58
ICC-3312	V457	10	58	66	2.13	38.17	63.00	1.33	3.67	12.67	18.16	101	8.50
ICC-3313	V458	7	62	70	2.20	36.67	71.33	1.33	4.67	11.13	10.09	105	6.89
ICC-3317	V459	11	61	69	2.37	38.33	59.00	1.33	4.67	15.33	19.88	104	8.46
ICC-3325	V460	11	61	69	2.07	36.50	70.33	1.33	4.33	15.93	10.9	104	10.57
ICC-3326	V461	10	59	67	2.27	37.17	73.67	2.00	4.33	16.67	18.37	102	12.51
ICC-3330	V462	8	68	76	1.83	34.00	68.33	1.33	5.00	13.00	18.37	111	12.06

	Trt	PP	DFF	DFP	CC	PH	NPP	NSP	NPB	NSB	100-SW	DM	SYPP
ICC-3331	V463	10	71	79	2.10	31.50	73.33	1.67	4.33	14.00	13.01	114	12.47
ICC-3337	V464	7	65	73	2.00	35.17	55.33	1.33	4.33	12.67	13.78	108	10.71
ICC-3362	V465	5	69	77	1.90	33.17	53.33	1.33	3.67	9.67	8.76	112	9.28
ICC-3366	V466	8	69	77	1.97	35.17	63.33	1.33	3.67	10.67	11.66	112	9.78
ICC-3388	V467	9	70	78	1.83	35.00	65.00	1.67	4.00	10.33	10.02	113	10.54
ICC-3391	V468	7	59	67	1.87	35.33	68.00	1.33	4.33	9.67	12.26	102	10.85
ICC-3404	V469	7	68	76	1.87	36.67	65.67	1.33	4.00	11.67	11.09	111	11.22
ICC-3406	V470	10	64	72	2.57	35.17	67.67	1.67	5.67	18.33	14.41	107	14.45
ICC-3410	V471	7	62	70	2.17	34.67	66.00	2.00	5.33	11.23	17.55	105	13.69
ICC-3412	V472	7	69	77	2.17	38.67	64.67	2.00	5.00	12.67	14.75	112	12.74
ICC-3415	V473	6	69	77	1.97	29.83	69.00	2.33	4.67	15.33	12.34	112	14.21
ICC-3421	V474	11	70	78	2.00	40.33	65.67	1.67	5.00	16.33	17.37	113	10.83
ICC-3425	V475	10	67	75	2.00	28.17	54.33	1.67	4.33	16.00	13.96	110	9.68
ICC-3426	V476	10	65	73	2.03	35.50	52.67	1.33	4.67	16.67	12.11	108	11.62
ICC-3432	V477	8	68	76	2.00	35.50	52.67	1.33	4.67	13.67	12.46	111	11.39
ICC-3440	V478	7	70	78	1.93	34.00	60.67	1.33	4.33	15.33	12.26	113	10.71
ICC-3453	V479	9	71	79	1.93	30.17	50.67	2.00	3.67	13.00	13.61	114	8.21
ICC-3458	V480	9	74	82	1.67	27.83	61.00	1.67	4.67	15.00	16.38	108	10.55
ICC-3485	V481	7	69	77	1.93	34.17	67.33	1.67	4.67	16.33	19.76	112	13.31
ICC-3497	V482	10	61	69	2.03	34.17	72.33	1.67	4.33	17.00	15.65	104	13.80
ICC-3506	V483	4	59	67	2.07	36.67	47.33	1.33	3.67	9.33	14.05	102	10.66
ICC-3512	V484	8	68	76	2.23	36.83	63.67	1.33	5.33	10.33	12.34	111	11.15
ICC-3521	V485	9	65	73	2.37	36.00	67.67	1.33	4.67	14.67	9.74	108	10.92
ICC-3532	V486	6	69	77	2.20	38.00	58.67	1.67	3.33	10.67	14.58	112	7.73
ICC-3539	V487	9	61	69	2.20	35.50	59.00	2.00	4.33	16.67	11.81	104	11.88
ICC-3540	V488	7	61	69	2.00	32.00	59.33	1.67	5.00	16.33	12.1	104	14.54
ICC-3542	V489	8	61	69	1.93	27.83	58.33	1.67	4.67	13.25	14.3	104	13.69

ICC-3558	V490	10	61	69	2.20	36.50	75.33	1.67	5.33	18.00	10.6	104	15.88
ICC-3567	V491	9	64	72	2.00	34.67	62.67	2.00	5.33	13.12	20.64	107	13.82
ICC-3568	V492	8	65	73	2.57	34.50	56.00	1.33	3.67	10.67	11.83	108	7.04
ICC-3571	V493	7	67	75	2.13	38.50	72.67	1.67	4.67	13.00	13.93	110	11.23
ICC-3575	V494	7	63	71	2.50	41.83	67.76	1.33	5.00	11.76	20.04	106	14.73
ICC-3580	V495	10	67	75	2.27	37.17	62.33	2.00	3.67	14.00	12.06	110	11.01
ICC-3581	V496	6	71	79	2.13	32.00	62.00	2.00	4.50	13.50	12.59	114	7.85
ICC-3582	V497	6	68	76	2.03	36.67	71.00	1.33	3.67	11.67	7.98	111	11.68
ICC-3593	V498	7	70	78	1.93	36.83	63.00	1.33	4.67	13.33	10.96	113	12.09
ICC-3594	V499	6	58	66	2.03	34.83	72.00	1.33	3.67	12.33	9.81	101	14.30
ICC-3596	V500	8	69	77	1.97	40.67	75.33	1.67	4.00	13.00	11.27	112	11.34

PP-Plant population ; DFF-Days to 50 % flowering ; DFP-Days to 50 % pod stage ; CC-Chlorophyll content ; PH-Plant height ; NPP-Number of pods per plant ; NSP-Number of seed per pod ; NPB-Number of primary branches ; NSB-Number of secondary branches ; SW100-Hundred seed weight ; DM-Days to maturity ; SYPP-Seed yield per plant

CURRICULUM VITAE

Name: Hanumantu Sirisha

Father's Name: Mr. Hanumantu Rama Rao

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E-mail: hsirisha03@gmail.com

Phone Number: 9668305095

Personal Profile:

Date of Birth : 01/08/1998

Gender : Female

Category : GEN

Nationality : Indian

Academic Qualification:

Qualification	OGPA / %	University / Board	Year of Passing
X	9.6	Central Board of Secondary Education, Odisha	2014
XII	88.8 %	Central Board of Secondary Education, Odisha	2016
B. SC. (Hons.) Agriculture	8.58	OUAT, Odisha	2021
M. Sc. Agriculture (Genetics and Plant Breeding)	8.67	RLBCAU, Jhansi	2023

DECLARATION

I do hereby declare that all information given above is true to the best of my knowledge and belief.

Place: Jhansi

(Hanumantu Sirisha)