IDENTIFICATION OF CHICKPEA (*Cicer arietinum* L.) GENOTYPES UNDER RICE BASED CROPPING SYSTEM FOR LATE SOWN CONDITION

M. Sc. (Ag.) Thesis

By

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DEPARTMENT OF GENETICS AND PLANT BREEDINGCOLLEGE OF AGRICULTURE
INDIRA GANDHI KRISHI VISHWAVIDYALAYA
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CERTIFICATE-I

This is to certify that the thesis entitled **Identification of chickpea (*Cicer arietinum* L.) genotypes under rice based cropping system for late sown condition** submitted in partial fulfilment of the requirements for the degree of Master of Science in Agriculture of the Indira Gandhi Krishi Vishwavidyalaya, Raipur, is a record of the bonafide research work carried out by **Rupsingh Netam** under our guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee and the Director of Instructions.

No part of the thesis has been submitted for any other degree or diploma or has been published/ published part has fully acknowledged. All the assistance and help received during the course of the investigations have been duly acknowledged by him.

Date: 4-7-2022

Ritu Rani Saxena.
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This is to certify that the thesis entitled **Identification of chickpea (*Cicer arietinum* L.) Genotypes under rice based cropping system for late sown condition** submitted by **Rupsingh Netam** to the Indira Gandhi Krishi Vishwavidyalaya, Raipur (CG) in partial fulfilment of the requirements for the degree of **Master of Science (Ag)** in the **Department of Genetics and Plant Breeding** has been approved by the external evaluator and students Advisory Committee after oral examination, under the chairmanship of head of the department.

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Approved/Not approved

Director of Instructions ……………………

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Date 04-07-2022 *Rupsingh Netam*

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF NOTATIONS/SYMBOLS

%	Percentage
∑	Summation
cm	Centimetre
DF	Degree of freedom
et al.	And co-worker/and others
Fig.	Figure
g	Gram
h^2bs	Heritability broad sense
ha	Hectare
i.e.	That is
kg	Kilogram
m^2	Square meter
mm	Milli meter
$^{\circ}C$	Degree Celsius
S. No.	Serial number
viz.	Namely
Mt	million ton
Km/hr	Kilometer
RF	Rainfall
MSR	Mean sum of square
MST	Treatment means sum of square
MSE	Error means sum of square

LIST OF ABBREVIATIONS

ANOVA	Analysis of variance
DTF	Days to flowering
DM	Days to maturity
PH	Plant height
HOFP	Height of first pod
PB	Primary branches
SB	Secondary branches
PPP	Pods per plant
SPP	Seeds per pod
HSW	Hundred seed weight
BY	Biological yield
SYP	Seed yield per plant
HI	Harvest index
PLYG	Plot yield
GA	Genetic Advance
GAM	Genetic Advance as percentage of mean
PCV	Phenotypic Coefficient of Variation
GCV	Genotypic Coefficient of Variation
MSS	Mean Sum of Squares

THESIS ABSTRACT

a)Title of the Thesis	:	**Identification of chickpea (*Cicer arietinum* L.) genotypes under rice based cropping system for late sown condition**
b) Full name of the student	:	Rupsingh Netam
c) Major Subject	:	Genetics and Plant Breeding
d) Name and Address of the Major Advisor	:	Dr. Ritu R. Saxena Principal Scientist, Department of Genetics and Plant Breeding, College of Agriculture, IGKV, Raipur
e) Degree to be Awarded	:	M.Sc. (Agriculture)

Signature of the Student

Ritu Rani Saxena.

Signature of Major Advisor

Date: 4-7-2022

Signature of Head of the Department

ABSTRACT

The experiment entitled "**Identification of chickpea (*Cicer arietinum* L.) genotypes under rice based cropping system for late sown condition**" was conducted using thirty-seven desi chickpea genotypes. Observations on quantitative traits had been noted on five plants which were chosen from every plot and replications at different growth stages. Variance analysis relates to observable variations for any trait in individuals. The mean sum of squares due to genotypes studied for all the yield characters reveal that the seed yield and its component

traits seem to have considerable genetic variability which can be utilized in selection. Parameters of genetic variability were recorded on thirteen quantitative traits.

Out of 37 genotypes studied, two genotypes namely, RKG 21-4 (37.00) and PBC 626 (39.33) showed extra early flowering (<40 Days) whereas, five genotypes *viz*., BG 4032 (86.00); RSGD-984 (86.33); BG 372 (ch) (87.67); RKG 21-3 (88.33); RKG 21-4 (89.00) recorded early maturity (<90 days) under late sown condition in rice based cropping system; genotypes, GNG-2555 (30.40); BRC-8 (30.47); NBeG 1634 (31.73); GL18148 (34.53); IPC 2017-373 (40.13) possessed height of first pod *i.e.*, more than 30 cm. Twenty genotypes had very small hundred seed weight (< 25g), 15 genotypes had small hundred seed weight (20-25 g), and two genotypes had medium hundred seed weight (26-35 g). For high seed yield per plant, entries RVG 203 (ch) (26.67g); IPC 2006-77 (ch) (24.67g); Phule G 1314-3-27 (20.00g); NDG 17-6-3 (20.00g) possessed high yield.

PCV values are higher than GCV values show that there is variability among genotypes. High magnitude of PCV coupled with GCV was exhibited by secondary branches, pods per plant, harvest index and plot yield in grams.

Days to flowering and plant height were the two traits which showed high heritability with high genetic advance.

Plot yield in grams showed significant and positive association with seed yield per plant, harvest index and pods per plant both at phenotypic and genotypic level. Biological yield, harvest index and pods per plant exhibited positive direct effect on seed yield per plant. The correlation values of these three traits also confirm the results as they possess the positive and highly significant association with seed yield per plant.

थीसिस सार

a) थीसिस का शीर्षक : देर से बोई गई स्थिति के लिए धान आधारित फसल प्रणाली के तहत चना (*सिसर एरीटिनम* एल.) किस्मों की पहचान

b) छात्र का पूरा नाम : रूपसिंह नेताम

c) प्रमुख विषय : आनुवंशिकी और पादप प्रजनन

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प्रमुख सलाहकार के हस्ताक्षर

दिनांक: 4-7-2022

विभागाध्यक्ष के हस्ताक्षर

सार

"देरी से बोई गई स्थिति के लिए धान आधारित फसल प्रणाली के तहत चना (*सिसर एरीटिनम* एल.) किस्मों की पहचान" शीर्षक वाला प्रयोग सैंतीस देसी चना किस्मों का उपयोग करके आयोजित किया गया था। मात्रात्मक लक्षणों को पांच पौधों पर अंकित किया गया था, जिन्हें प्रत्येक भूखंड से चुना गया था और विभिन्न विकास चरणों में प्रतिकृतियां थीं। प्रसरण विश्लेषण प्रत्येक जीनोटाइप में

किसी भी लक्षण के लिए देखने योग्य भिन्नताओं से संबंधित है। सभी उपज लक्षणों के लिए अध्ययन किए गए जीनोटाइप के कारण वर्गों के औसत योग से पता चलता है कि बीज उपज और इसके घटक लक्षणों में काफी आनुवंशिक विविधता है जिसका उपयोग चयन में किया जा सकता है। तेरह मात्रात्मक लक्षणों पर आनुवंशिक विविधता के मापदंड दर्ज किए गए थे।

अध्ययन किए गए 37 जीनोटाइप में से, दो जीनोटाइप्स, RKG 21-4 (37.00) और PBC 626 (39.33) ने अतिशीघ्र फूल खिलना (<40 दिन) दिखाया, जबकि, पांच जीनोटाइप्स जैसे, BG 4032 (86.00); RSGD-984 (86.33); BG 372 (ch) (87.67); RKG 21-3 (88.33); RKG 21-4 (89.00) ने धान आधारित फसल प्रणाली में देर से बुवाई की स्थिति के तहत शीघ्र परिपक्वता (<90 दिन) दर्ज की; जीनोटाइप, GNG-2555 (30.40); BRC-8 (30.47); NBeG 1634 (31.73); GL18148 (34.53); IPC 2017-373 (40.13) की पहली फली की ऊँचाई यानी 30 सेंटीमीटर से अधिक है। बीस जीनोटाइप में बहुत कम सौ बीज वजन (<25 ग्राम) था, 15 जीनोटाइप में लघु सौ बीज वजन (20-25 ग्राम) था, और दो जीनोटाइप में मध्यम सौ बीज वजन (26-35 ग्राम) था। प्रति पौधे उच्च बीज उपज के लिए, प्रविष्टियाँ RVG 203 (ch) (26.67g); IPC 2006-77 (ch) (24.67g); Phule G 1314-3-27 (20.00g); NDG 17-6-3 (20.00g) में पाया गया।

पी सी वी मान जी सी वी मान से अधिक हैं, जोकि यह दर्शाता है कि जीनोटाइप के बीच विविधता है। जी सी वी के साथ मिलकर पी सी वी के उच्च परिमाण को माध्यमिक शाखाओं, प्रति पौधे फली, फसल सूचकांक और प्लॉट उपज ग्राम में प्रदर्शित किया गया था।

फूल आने के दिन और पौधे की ऊंचाई दो लक्षण थे जो उच्च आनुवंशिक प्रगति के साथ उच्च आनुवंशिकता दिखाते थे।

चना में प्लॉट की उपज ने प्रति पौधे बीज उपज, फसल सूचकांक और फली प्रति पौधे दोनों के साथ फेनोटाइपिक और जीनोटाइपिक स्तर पर महत्वपूर्ण और सकारात्मक संबंध दिखाया। जैविक उपज, फसल सूचकांक और प्रति पौधे फली ने प्रति पौधे बीज उपज पर सकारात्मक प्रत्यक्ष प्रभाव प्रदर्शित किया। इन तीन लक्षणों के सहसंबंध मूल्य भी परिणामों की पुष्टि करते हैं क्योंकि वे प्रति पौधे बीज उपज के साथ सकारात्मक और अत्यधिक महत्वपूर्ण संबंध रखते हैं।

CHAPTER-I
INTRODUCTION

Chickpeas (*Cicer arietinum* (L.) 2n = 2x = 16] belong to the *Cicer* genus, Cicereae tribe, Leguminosae and subfamily Papilionaceae. Commonly known as gram, Bengal gram or chickpeas, they are the most important cold-season edible grain legumes in the world after common beans (*Phaseolus vulgaris* L.) and peas (*Pisum sativum* L.). It originated in south-eastern Turkey (Ladizinsky, 1975). It is an annual, self-pollinated diploid legume crop.

According to seed size and colour, there are two types of cultivated chickpeas: *kabuli* type and *desi* type (Cubero, 1975). Macrosperma (*kabuli* type) is large seed size (100 seeds weight >25 g), round or punched, and cream colour. The plant is medium to tall, with large small leaves, white flowers, and does not contain anthocyanin. The *desi* type is small seed size and angular in shape. The seed colour varies in the range of cream, black, brown, yellow and green. There are 2-3 ovules pod^{-1}, but on average 1-2 seed pod^{-1} are produced. The plant is short, with small leaves and purple flowers, and contains anthocyanin.

As a grain legume, it plays an important role in nutrition, providing protein-rich supplements for grain-based diets, especially for vegetarians and subsistence. Seeds are the main edible part of plants, containing about 17-24% protein, 64% carbohydrates, 47% starch, 3.8-10.2% fat, 1.7-10.7% fibre and 6% soluble sugar. It is also rich in essential amino acids lysine, but lacks sulphur-containing amino acids, methionine and cysteine as protein content. Like other legumes, chickpeas also fix atmospheric nitrogen through a symbiotic relationship with rhizobium species, thereby helping to improve the soil fertility of subsequent crops.

Chickpea (*Cicer arietinum* L.) is the most important legume crop during the *Rabi* season, and it is mainly grown in semi-arid and warm temperate regions in our country. It may have the highest protein content in legume grains other than peanuts and soybeans. The high nutritional value makes chickpeas an important food, especially in famine-prone areas in the world. Grain legumes such as chickpeas contain high-quality protein and are suitable for both animal feed and human diets.

In Indian agriculture, chickpea crops have played a significant role. They are high in protein and help to keep cropping system productive. India leads the world in both area and yield of pulses, but there is still a large disparity between demand and supply. On a per capita basis, we require roughly 38 kg of pulses each year. Despite the pact that overall pulse output reached 18.24 million tonnes in 2012-13 (anonymous, 2013), it was insufficient to fulfil the growing demand for pulses due to rising population and better living standards.

Legume crops capacity to utilise atmospheric nitrogen through biological nitrogen fixation is more cost-effective and ecologically friendly. When legume are grown along with cereals their nitrogen fixation is boosted even more because the extra nitrate in the root zone that legumes fix is used by cereals (Fujita *et al*. 1998). On the contrary, mono-cropping legumes accumulate too much nitrate in the root zone, which reduces nitrogen fixation (Anil *et al*. 1998).

Chickpeas are the third most important edible legume crop in the world. They are grown rain-fed in cool and dry climates in semi-arid regions. In the past few decades, due to the increasing demand of the world's growing population for food, this largely depends on the protection and utilization of the world's surplus plant genetic resources.

Chickpeas rank third in the global legumes category, with India being the main producer, followed by Pakistan and Turkey (source: FAO) as the main producing countries. This is the most widely grown legume crop in India, accounting for 40% of total production (source: FAO), making it the world's leading producer of chickpeas. India produces about 6 million tons of chana (source: FAO), accounting for a major share of about 70% of the world's total production (source: Farmer Portal, farmer.gov.in).

The world's area, output and productivity are respectively 13.7Mha, 14.24 MT, and 1038.4 Kg/ha (FAOSTAT, 2019). Compared with Kabuli, India mainly produces desi chickpeas. The area, yield, and productivity of chickpeas in India are 9.5 trillion hectares, 9.93 tons, and 1041.1 kg/ha (source: FAOSTAT, 2019). The current area and yield of Chhattisgarh is 293,000 hectares and 203,000 tons (Source: Ministry of Agriculture and FW, Government of India, 2018).

Genetic variation is the first prerequisite of any crop improvement program because it provides the opportunity to choose the ideal plant type. It helps to select better yield attributes for selection or hybridization. The lack of utilization of variability is considered to be one of the main limitations to increasing the productivity of chickpeas. Analysis of variance provides estimates of phenotype, genotype, and environmental variance, which are used to estimate their respective coefficients of variation. This relative value of the coefficient of variation gives an idea of the degree of variation that exists in the population. They also indicate whether choosing improved roles will pay off. The phenotypic coefficient of variation, genotype coefficient of variation, genetic advancement and heritability play an important role in the development of chickpea excellent genotypes.

The analysis is done to understand the amount of genetic diversity present in the population. A successful hybridization program requires the selection of genetically diverse parents because it provides a better opportunity for plant breeders to select superior lines.

Yield is a complex polygenic trait that is affected by a large number of quantitative and qualitative traits. There may not be a gene for yield itself; although there may be genes that control the inheritance of yield characteristics. Any breeding program needs information about the correlation between yield and yield characteristics. This association is usually determined by calculating the correlation coefficient (Grafius, 1959). The further division of the genotype correlation coefficient gives the value of the path coefficient, which reveals the direct and indirect effects of yield traits on yield.

Path analysis helps to divide the correlation coefficient between yield components and seed yield into direct and indirect effects to ensure the actual contribution of attributes and their influence through other traits. The path coefficient analysis suggested by Dewey and Lu (1959) proves to be helpful. It divides the correlation coefficient into a set of measures of the direct and indirect effects of independent variables on dependent variables. If the correlation is caused by a direct effect, it reflects a true and perfect relationship, and such traits can be selected to increase yield.

Rice based cropping system is a major cropping system practiced in India, which include the rotation of crops involving rice, pulses, oil seed, cotton, sugarcane, green manures, vegetables, etc. Most people depend on pulses for their daily dietary protein needs.

Chickpea crop is taken after *Kharif* crops (mainly rice) in India. This type of cropping system is known as rice based cropping system. Paddy is the main crop of Chhattisgarh which is cultivated in large area. The rice crop is planted in different periods, namely early, mid and late, according to soil type and water availability. Generally, early rice is harvested in the last week of October, medium duration rice is harvested in the second week of November, and late-maturing rice is harvested in the first week of December. In the late maturity field of paddy or in the late sown rice field, farmers can sow the late sown varieties of chickpea (which matures early). So that the field will not remain fallow in winter season and the farmer will also get good income.

The yield of chickpea during the fallow period of rice mainly depends on the time of rice harvest. Chickpeas grown after rice harvest of different durations behave differently. Therefore, there is an urgent need to develop chickpea varieties and also to develop chickpea varieties that perform well under late sowing conditions.

Based on the above considerations, an experiment was conducted the entitled"Identification of chickpea (*Cicer arietinum* L.) Genotypes under rice based cropping system for late sown condition" was carried out during Rabi 2021-2022 with the following objectives:

- Phenotyping of yield and yield related traits under rice based cropping system for late sown condition.
- Association analysis between yields related traits.
- Estimation of direct and indirect effects of yield attributing traits on seed yield.

CHAPTER-II

REVIEW OF LITERATURE

Plant breeding's major goal is to improve the producing ability as well as the quality of produce in any crop variety. Crop improvement is determined by the degree of genetic diversity and the heritability of desirable traits. Germplasm is the foundation for agricultural development, thus collecting, evaluating, and categorising it is critical for a dynamic crop improvement programme.

The available literature on the research topic is in the following heads:

2.1 Genetic parameters

2.2 Correlation

2.3 Path analysis

2.1 Genetic parameters

A major prerequisite of every crop development effort is the presence of genetic variation. The degree of genetic variety present in the plant population has a big impact on selection efficiency. As a result, the effectiveness of genetic improvement in any character is determined by the type of variability present in that character's gene pool. As a result, a plant breeder's understanding of the level of diversity contained in a crop species' gene pool is critical for launching a successful plant breeding program. The mean, range, standard deviation, coefficient of variation, heritability, and genetic progress are all examples of genetic variability parameters. The following is a list of related literature on chickpea genetic variability:

2.1.1. Genetic variability

The occurrence of variations among the individuals in a plant population is referred to as variability. Variability arises as a consequence of variances in the genetic makeup of a population's members or the environment in which they are raised. Here is a review of the existing data on the variability among character traits and seed yield in chickpea.

Takkuri *et al*., 2017, studied at yield and yield-related parameters in chickpea. They reported that except for the number of secondary branches per plant, the analysis of variance indicated significant differences between the genotypes for all of the parameters tested. Against every characteristic, the phenotypic variance was greater than the genotypic variance. GCV and PCV levels were low in variables like seed length and days to 50% flowering, indicating that these traits have a limited chance of improvement by selection.

Johnson *et al.,* 2016, analysis of variance indicated mean sum of squares due genotypes were significant for the characteristics days to maturity, plant height, 100-seed weight, seed volume, and protein content in chickpea (*Cicer arietinum* L.). The results of the variability analysis revealed that in germplasm accessions, there was a wide range of variability for hydration index (51.67), followed by hydration capacity (43.75), 100 seed weight, pod plant^{-1}, and primary branches plant^{-1}, indicating that there was enough variability among genotypes for character.

Jha *et al*. (2015) studied for 8 distinct quantitative and morpho-physiological parameters; researchers looked at 62 chickpea accessions to capture existing genetic diversity and discovered very broad genetic variation among genotypes. The membrane stability trait had the greatest PCV (64.75%) and GCV (56.3%), while membrane stability had the highest broad sense heritability (75%) followed by pods per plant (53%) and days to maturity (45%).

Hagos *et al*., 2015, studied at the variability, heritability, among twelve genotypes the highest genotypic and phenotypic coefficients of variation was observed in number of pods per plant, number of seeds per plant, number of secondary branches per plant, and 100 seed weight all had.

Mishra *et al*. (2014) revealed selection procedures to evaluate the 12 promising chickpea lines under normal and heat stress conditions, and found that the characteristics seed yield per plant had high PCV and GCV. In both early and late sown conditions, the number of effective pods per plant, the number of total pods per plant, the seed size and the harvest index were measured. Days to flower starting and days to 50% flowering were shown to have strong heritability, as well as a high genetic progress as a percentage of the mean.

Puri *et al*. (2013) investigated the genetic variability of chickpea (*Cicer arietinum* L.) and found that the characters like, days to first flowering, days to 50% flowering, days to maturity,biological yield, 100 seed weight, harvest index and seed yield per plant showed sufficient variability. Days to first flowering, seeds per pod, pods per plant and days to maturity all had strong heritability and genetic advance as a percentage of the mean. Days to first flowering, days to maturity and 100 seed weight per plant were measured on the first date of sowing, whereas days to first flowering, 100 seed weight and days to maturity were measured on the second date of sowing.

Akhtar *et al*., (2011) studied the PCV was higher than the GCV for days to 50% flowering, plant height, days to maturity and seed yield. This suggests that environmental factors have a greater influence on the manifestation of certain features. As a result, it is advised that utilizing the 100-seed weight and number of pods per plant as a selection criterion in chickpea may improve seed yield.

Sharma and Saini (2010) measured the genetic variance between genotypes. Because of the effect of environment on the expression of these characters, the magnitude of the phenotypic coefficient of variance (PCV) was larger than the equivalent GCV for all of the characters. 100-seed weight had the greatest GCV and PCV, followed by branches per plant, pods per plant, seed yield per plant, days to flowering, and days to maturityand plant height.

Malik *et al*. (2009) conducted analysis of variance and genetic factors to find that genotypes for biological yield, secondary branches, 100-seed weight, number of pods per plant, seed yield per plant and harvest index had a high degree of GCV.

Joshi and Bapu (2008) investigated genetic variability and found that mean squares attributable to genotypes were very significant for all features, indicating substantial genotype variability. Modest GCV was found for seeds per plant, number of pods per plant, 100-seed weight, and biological yield per plant. Primary branches per plant, secondary branches per plant, days to 50% flowering, plant height and days to maturity all had low GCV values.

Singh and Kumar (2008) explored at the genetic diversity of branches per plant, days to flowering, number of pods per plant, plant height, 100-seed weight, days to maturity, and biological yield per plant, seed yield per plant and harvest index in different environments. As a result, it was discovered that there was a lot of genetic diversity among different chickpea genotypes. The existing variability has a significant influence on how an individual quantitative characteristic is expressed.

Khan *et al*. (2006) found days to flowering, plant height, days to maturity, number of pods per plant, 100-seed weight and seed yield (kg) per ha genetic diversity in 13 chickpea genotypes days to flowering, days to maturity and plant height all had high genotypic coefficients of variation (GCV). Days to flowering, days to maturity and seed yield kg per hectare had low GCV.

Patel and Babbar (2005) found that pod weight per plant in desi chickpea, seed yield per plant in kabuli Chickpea, and seeds per plant in gulabi Chickpea had strong phenotypic and genotypic coefficients of variation.

Kashyap *et al*. (2003) investigated 60 chickpea genotypes and found a wide range of PCV for features such as number of primary branches, pods per plant, number of secondary branches, biological yield and harvest index.

Subhash *et al*. (2001) investigated at a variety of variables in 33 Chickpea genotypes cultivated in five different conditions and found that data on days to 50% flowering, primary and secondary branches per plant, days to maturity and plant height were all consistent. In all of the characteristics, phenotypic coefficients of variation were greater than genotypic coefficients of variation values, indicating that the environment had an impact on these features.

Chandra (1968) studied 25 indigenous and alien lines in five habitats and found that the material varied widely for all features, and that variability was influenced by the environment, notably for plant height. In primary branches per plant and pods per plant, he discovered strong genetic improvements accompanied by high heritability.

2.1.2 Heritability and Genetics Advance

Heritability is implied by the heritable component of phenotypic variation; nevertheless, in the broad sense, heritability represents the ratio of genotypic variance to total variance. Total genetic variance consists of additive, dominance, and epistatic components, which are used to estimate heritability. It's an excellent indicator of how parents' characteristics are passed on to their daughters. Plant breeders can use estimates of broad sense heritability to select elite genotypes from homozygous populations. The amount of heritable genetic variation in relation to total variation is determined by the heritability estimate, which also influences genetic improvement and responsiveness to selection.Genetic advance is defined as an increase in the mean genotypic value of selected plants over the parental population. It's a measurement for how much genetic progress has been made as a result of selection. It help in perceive the kind of gene action involved in the manifestation of various polygenic characteristics and deciding on a breeding technique for the genetic improvement of various polygenic features. The combination of genetic progress and heritability assists in determining the genetic reason of any given characteristic.

Yadav *et al*. (2015) studied the number of primary branches, secondary branches, pod length, pods/plant and plant height had substantial heritability, indicating that these features are influenced by the environment. Days to maturity had a low heritability percentage, indicating that this feature was heavily impacted by the environment.

Mohammadi and Talebi (2015) studied the number of seeds per plant; 100-seed weight and plant biomass all have high heritability values.

Mallu *et al*. (2014) observed highest heritability was obtained for 100 seed weights, followed by the days to 50% flowering and plant height.

Mishra *et al*. (2014) used selection procedures to evaluate the 12 promising chickpea lines under normal and heat stress conditions and found that the characteristics seed yield per plant had high PCV and GCV. In both early and late seeded conditions, number of effective pods per plant, number of total pods per plant, harvest index and seed size were measured. Flower commencement (days) and 50% flowering (days) were shown to have strong heritability, as well as a high genetic advance as a percentage of the mean.

Monpara and Dhameliya (2013) studies in chickpea, flowering durations, plant eight, days to maturity and seed yield per plant all are highly heritable. Alike, Gul *et al*. (2013) observed strong heritability estimates and genetic advances for pods per plant, primary branches per plant, secondary branches per plant and seed yield.

Jain *et al*. (2013) showed strongly and significantly different genotypes in chickpea characteristics. Strong heritability was found in seed yield per plant, 100-seed weight and harvest index as well as high estimates of genetic advance as a percentage of mean.

Nizama (2013) recorded high heritability combined with high genetic advance as percentage mean estimates for 100-seed weight, days to 50% flowering, secondary branches per plant, pods per plant, harvest index, seed yield per plant and protein content whereas high heritability showed for harvest index, days to 50% flowering, secondary branches per plant and protein content.

Puri *et al*. (2013) found days to 50% flowering, pods per plant, seeds per pod, days to maturity, 100 seed weight and seed yield per plant had highest heritability and high genetic advance as a percentage of mean in chickpea.

Babbar *et al*. (2012) observed moderate genetic advance as a percentage of mean for characteristics such as days to 50% flowering, days to maturity, seed yields per plant, 100- seed weight and plant height in 44 promising lines of chickpea grown under late sowing conditions.

Singh *et al*. (2012) found in chickpea, number of pods per plant, 100-seed weight, number of branches per plant, plant height and seed yields where all are highly heritable.

Parameshwarappa *et al*. (2011) found strong heritability along with high genetic advance for the characteristics 100 seed weight and seed yield per plant for all climates.

Johnson *et al*. (2010) observed significant heritability and genetic advance for 100-seed weight and days to 50% flowering, suggesting that selection for these traits might lead to the accumulation of additive genes, resulting in additional improvement in chickpea.

Atta *et al*. (2008) studies for days to flowering, plant height, days to maturity, primary branches and secondary branchesin 32 chickpea genotypes were tested. They found substantial variations between genotypes for all of the parameters, including100 seed weight, pods per plant and grain production per plant. For various traits, broad sense heritability estimates ranged from 39 to 97 percent.

Sidramappa *et al*. (2008) found significant heritability for number of pods per plant, plant height, seed weight, days to 50% flowering, days to pod initiation and seed yields per plant in chickpea.

Jeena *et al*. (2005) explored genetic variability and correlation coefficients in eighty genetically distinct chickpea genotypes and found a lot of variation in number of pods per plant, 100-seed weight, seed yield per plant and biological yield per plant. These characteristics also have a high heritability and a high predicated genetic advance.

Saleem *et al*. (2005) studied at 18 elite genotypes and found that seeds per plant, pods per plant, 100-seed weight and total plant weight were all highly heritable.

Muhammad *et al*. (2004) estimated 24 advance lines of chickpea, the heritability and genetic advance for yield and yield components. Days to flowering, days to maturity and 100-seed weight all had great heritability with little genetic advance, indicating the impact of dominant and epistatic genes for these characteristics.

Pratap *et al*. (2004) evaluated thirty eight genetically different, early ripening chickpea genotypes in four separate environments and found that seed production, 100- seed weight and biological yield were all exhibited strong genetic advances.

Arshad *et al*. (2004) found significant heritability for secondary branches and biological yield, as well as high genetic advances, showed that additive gene effects play a role in determining these traits.

Sharma *et al*. (2003) observed a strong heritability fordays to 50% flowering, 100-seed weight, days to maturity and plant height in chickpea, suggesting the possibility of increasing seed yields.

Malik *et al*. (1988) investigated the heritability, genetic variance and yield correlations for seven yield components in fifteen chickpea genotypes, founded that pods per plant, seeds per pod and 100-seed weight were all positively linked with seed yield.

Arora and Jeena (2001) assessed on 18 quantitative features in 40 chickpea genotypes. The 100 seed weight had the most genetic advance, followed by primary branches per plant and seeds per plant.

Gupta *et al*. (1992) revealed 100 seed weight and seed yield there was a strong genetic advance as a percentage of the mean, for number of pods per plant, number of seeds per pod and number of seeds per plant. On the other hand Days to 50% flowerings, number of branches per plant, plant height and days to maturity was showed low genetic advance.

Mishra *et al*. (1988) studied 117 genotypes of chickpea to estimated genetic parameters of variability for yield and its components. All of the characters have strong heritability estimates. Number of secondary branches per plant, number of pods per plant, seed yield per plant, biological yield per plant and harvest index all had strong heritability and genetic advance represented as a percentage of mean.

2.2 Correlation

Correlation is a statistical method for determining the degree and direction of a relationship between two or more variables. The phenotypic correlation coefficient assists in the determination of the selection index, but the genotypic correlation coefficient gives a close measure of relationship between traits that may be valuable for crop development. A positive correlation value indicates that two variables are moving in the same direction, whereas a negative correlation indicates that two variables are moving in opposite directions.It determines the component characters on which selection can be based for genetic yield improvement by measuring the interaction between various plant characters. There are three types of correlation: phenotypic, genotypic and environmental. Phenotypic correlation is observable and includes both genotypic and environmental impacts, whereas genotypic correlation measures intrinsic relationship.

Banik *et al*. (2017) conducted a two-replication study on 60 chickpea genotypes. They discovered a significant and negative relationship between 50% flowering, seed yield per plant and the number of seeds per plant, as well as a significant positive relationship between seed yield per plant and the number of pods per plant, 100 seed weight, plant spread, plant height, number of secondary branches per plant, and number of primary branches per plant.

Shafique *et al*. (2016) found harvest index and number of pods per plant exhibited a substantial and positive relationship with seed yield.

Jha *et al*. (2015) revealed the interrelationships between 8 quantitative and morpho-physiological features, finding a positive correlation between days to 50% flowering and plant height, pods per plant and plant height, and pods per plant and membrane stability. Days to maturity and membrane stability, on the other hand, exhibited a strong positive correlation.

Jadhav *et al*. (2014) observed both genotypic and phenotypic levels, seed yield per plant had a positive and significant correlation with number of branches per plant, 100-seed weight, pods per plant, number of seeds per plant, plant height and harvest index.

Mohamad *et al*. (2013) conducted a genetic study for seed yield and quality features in the kabuli chickpea (*Cicer arietinum* L.). According to the correlation analysis, seed yield per plant had a significant positive correlation with primary branches per plant, secondary branches per plant, biological yield per plant, harvest index and pods per plant at the genotypic level, whereas significant negative correlation with days to maturity. When the seed quality measures were associated, the 100-seed weight (seed size) showed a highly significant positive association with hydration capacity, swelling capacity, and seed volumes.

Padmavathi *et al*. (2013) observed in chickpea, primary branches per plant, secondary branches per plant, pods per plant, biological yield per plant, plant height, 100-seed weight, and harvest index were all shown to be positively correlated with seed yield.

Babbar *et al*. (2012) studied forty four promising chickpea lines under late sowed conditions and observed that seed yield per plant had a positive correlation with seed per plant, biological yield, pods per plant, plant height, and 100-seed weight. It has been shown that days to 50% flowering have a negative correlation.

Ahsan and Ali (2011) found the genotypic and phenotypic levels, the number of secondary branches per plant, biological yield per and number of pods per plant plant were all positively correlated with seed yield per plant.

Sidramappa *et al*. (2010) observed days to first flowering, days to 50% flowering, days to pod initiation and days to physiological maturity all showed a strong positive correlation. Except for the duration of the reproductive period, phenological parameters had a positive and substantial relationship with plant height and branching.

Sreelakshmi *et al*. (2010) found in chickpea a positive correlation between days to 50% flowering, number of pods per plant, seed yields and days to maturity.

Thakur and Sirohi (2009) observed seed yield per plant exhibited a positive association with biological yield per plant, major branches per plant, pods per plant, plant height and harvest index in chickpea.

Farshadfar *et al*. (2008) estimated correlation coefficients for growth type, number of leaflets per leaf, leaflet size, plant height, days to 50% flowering, flowering duration, flower colour, pod size, pods per plant, seed number per pod, days to maturity, seed colour, seed shape and seed weight. Seed yield per plant and pod quantity had the largest correlation value.

Talebi *et al*. (2007) found a positive and substantial relationship between 100-seed weight, secondary branches and plant height in chickpea. However, negative correlations were observed between pods per plant, 100-seed weight and secondary branches.

Obaidullah *et al*. (2006) investigated the phenotypic and genotypic correlation of seed yield and other important characters in twelve chickpea lines, finding that seed yield was positively allied with secondary branches per plant and pods per plant, and that seed yield was negatively correlated with days to maturity.

Bhaduoria and Chaturvedi (2003) evaluated at 46 genetically different chickpea genotypes from all over India and found a strong positive correlation between pods per plant and primary branches plant.

Yadav and Haquae (2001)revealed the number of seeds per pod and days to maturity were both positively correlated with seed yield, however days to 50% flowering were negatively correlated.

Vijaylakshmi *et al*. (2000) used desi, Kabuli, and intermediate type parents to examine two chickpea crosses, P 9623X T39-1 and RS 11X T39-1, and found that seed yield was directly correlated with number of pods, seeds, primary branches and secondary branches per plant in both crosses.

Dasgupta *et al*., (1992) estimated in chickpea, seed yield was found to be strongly connected with the number of pods per plant, number of branches per plant, harvest index, 100-seed weight and seeds per pod, whereas days to maturity was found to be negatively correlated with seed yield. Positive inter-correlation was found between pods per plant and seeds per plant.

Rao (2001) evaluated 21 vascular wilt resistant chickpea genotypes and found that biological yield and seed yield were positively correlated. Harvest index revealed a substantial positive relationship with biological yield and 100 seed weight.

Bhardwaj and Singh (1972) found a positivecorrelation between seed yield with height, number of branches, pods per plant, and 1000 seed weight in 60 chickpea (*C. arietinum*) lines.

2.3 Path analysis

The path coefficient analysis is a standardised partial regression coefficient that divides the correlation coefficient into direct and indirect influence measures. The reason of two variables' relationship is measured via path analysis. It is based on every potential simple correlation between different characteristics. It aids in the identification of yield-contributing traits as well as indirect selection. Path analysis is a regression model extension that is used to examine the fit of the correlation matrix against two or more causal models. The following is the literature on chickpea path analysis that is currently available:

Shafique *et al*. (2016) studies the number of pods per plant had the most positive direct influence on seed yields, with a 52.87 percent ratio.

Joshi and Yasin (2015) observed the biological yield per plant had the greatest direct impact on seed yield, followed by harvest index. Through, biological yield, days to 50% flowering, harvest index, and days to maturity had a negative indirect influence on seed yield.

Hagos *et al*., 2015, studied at the direct and indirect impacts of yield and yield components among twelve genotypes. They found Seed yield was positively influenced by seeds per plant, biomass yield, days to maturity, and 100 seed weight, according to path coefficient analysis.

Hasan and Deb (2014) observed at the genotypic level, found that number of seeds per plant had the greatest positive direct effect on seed yield, followed by days to first flower and plant height, while at the phenotypic level, plant height at maximum flowering, biological yield at harvest and number of pods per plant had the greatest positive direct effect on yield.

Jadhav *et al*. (2014) studies in chickpea,found the plant branches had the most positive direct influence on seed yields, followed by 100-seed weight, harvest index and number of pods per plant at both genotypic and phenotypic level.

Mohamad *et al.* (2013) studied genetic study for seed yield and quality attributes In the kabuli chickpea. Direct selection for biological yield per plant, harvest index, pods per plant, and secondary branches per plant would likely be successful in improving seed production in kabuli chickpea, according to path coefficient analysis.

Padmavathi *et al*. (2013) observed biological yield per plant, harvest index and number of pods per plant had a strong positive direct influence on seed yield per plant, indicating the significance of these factors in improving chickpea seed yields.

Shrivastava *et al*. (2012) studiedunder rice fallow conditions, days to maturity,pods per plant,biological yield and harvest index all had the most direct positive effect on seed yield per plant.

Shukla and Babbar (2011) investigated the relationship between several morpho-phenological features and yield in 30 heat-tolerant lines in 3 environments using association and path coefficient analysis. In yield and its component traits, there was a significant genotype x environment interaction.

Borate and Dalvi (2010) observed the number of pods per plant and number of primary branch had the greatest direct positive impact on seed yields, followed by biological yield per plant. Similarly, Yucel and Anlarsal (2010) reported harvest index had the highest direct influence on seed yield.

Yucel and Anlarsal (2010) revealed the direct and indirect impacts of 10 traits on seed yield. Harvest index was shown to be the most significant direct contributor to seed yield in a path analysis. The seeds per plant had the second biggest direct influence on seed yields.

Thakur and Sirohi (2009) discovered that biological yield per plant had the largest positive and direct influence on seed yield per plant, followed by harvest index and pods per plant, within the seasons. The number of pods per plant, number of primary branches per plant, and plant height all had an indirect effect on seed yield via biological yield. As a consequence, choosing for high biological yield and harvest index yields high seed production, whilst selecting for pods per plant, primary branches per plant, and plant height aids in biological yield selection.

Vaghela *et al*. (2009) observed every plant had the most direct positive impact on biological yield, followed by the harvest index for seed yield. The essential factors for constructing selection criterion to increase seed yield in chickpea were found to be biological yield per plant and harvest index.

Singh and Sandhu (2008) studied the seed yield was determined by five variables, including pods per plant, 100-seed weight, harvest index and biological yield because these factors had the most direct influence on seed yields in all of the environments studied.

Farshadfer and Farshadfer (2008) studies pod number had the greatest direct influence on seed yield, followed by seed number and seed weight.

Talebi *et al*. (2007) observed harvest index had the greatest direct effect on seed yield, whereas indirect effect on seed yield was positive through plant height, number of seeds per pod and biomass, but negative and low through days to maturity, 100 seed weight and number of primary branches.

Renukadevi and Subbalakshmi (2006) observed days to maturity, pods plant and seeds per pod all had a beneficial direct influence on plant yields in Chickpea genotypes.

Deb and Khaleque (2005) studied the path coefficient analysis of yield and yield components from six chickpea lines was presented. At the phenotypic level, the path coefficient revealed that the pod weight plant had the most positive direct influence on seed yield plant and days to 50% flowering. Days until first flowering and the number of pods on the plant had a direct negative impact on seed yield.

Rao and Rao (2005) observed days to 50% flowering, plant height, number of primary branches per plant, number of secondary branches per plant, pods per plant, 100-seed weight, biological yield per plant, seed yield per plant, days to maturity and harvest index were studied using path analysis, and it was discovered that biological yield per plant had the greatest direct effect on seed yield, followed by harvest index.

Narayana and Reddy (2002) investigated the direct and indirect impacts of several features on seed yields using path analysis. The direct impacts of pods perplant, 100-seed weight, seeds per pod and harvest index on seed yield were shown to be significant in path analysis. At both genotypic and phenotypic levels, there was a strong relationship between seed yield and harvest index, pods per plant and secondary branches per plant.

Dasgupta *et al*. (1992) observed number of pods per plant, number of seeds per plant, and 100-seed weight all had significant positive direct influence on yield whereas number of pods per plant, number of seeds per plant, and number of seeds per pod all had strong positive indirect effects.

Sontakey *et al*. (1991) reported the relevance of number of pods per plant, number of seeds per pod, and seed weight per 100 seeds in improving seed yield was highlighted since these variables had a strong direct influence on yield.

CHAPTER- III

METHODS AND MATERIALS

The present investigation entitled, **"Identification of chickpea (*Cicer arietinum* L.) genotypes under rice based cropping system for late sown condition"** was carried out during *Rabi*, 2021-22. The procedures followed & materials used during the course of analysis are as:

3.1 Experimental site:

The present research work was conducted at Research cum Instructional farm Department of Genetics and Plant Breeding, College of agriculture, Indira Gandhi Agricultural University, Raipur, Chhattisgarh, during the *Rabi* season of 2021-22.

3.2 Climate and weather:

Chhattisgarh is situated between 17°14'N and 24°45'N latitudes and 79°16' E and 84°15' E longitudes. Raipur (C.G.) is lies at 21°16'N latitude and 81°36' E longitude with an altitude of (289.60 m) above mean sea level. The maximum monthly mean temperature was 36.52°C during March, 2022 and minimum monthly mean temperature was 12.80°C during January, 2022. The total rainfall during crop growing period was (156.00 mm) (Table 3.1). The data pertaining to total rainfall, monthly lower and highest temperatures, RH, evaporation and shining sunshine hours of total crop growing time have been presented in Fig.3.1.

Table 3.1: Average monthly meteorological data of Raipur from November 2021 to March 2022

Month	MAXT (°C)	MINT (°C)	Total RF (mm)*	RH I (%)	RH II (%)	VP I (mm)	VP II (mm)	WS (kmph)	EP (mm)	SS (hr)
Nov-21	30.09	18.11	48.60	89.00	47.03	15.35	14.29	3.34	2.95	6.12
Dec-21	27.13	13.20	82.40	88.16	44.26	11.10	11.22	2.81	2.41	4.73
Jan-22	25.51	12.80	18.00	91.32	47.71	10.87	10.80	2.65	2.24	5.97
Feb-22	29.74	13.28	7.00	83.96	31.79	10.76	9.83	1.71	3.64	7.07
Mar-22	36.52	18.59	0.00	72.23	22.42	13.35	9.79	1.42	5.58	7.84

- Total rainfall (mm)

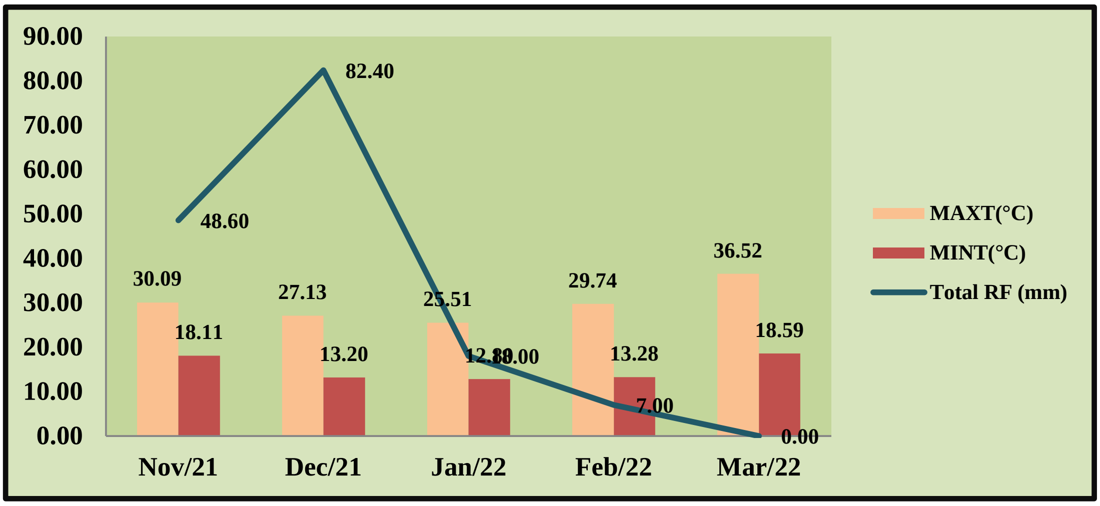

Fig 3.1: Average minimum and maximum temperature (°C) and total rainfall (mm) from November 2021 to March 2022

3.3 Experimental Materials and Methods:

Thirty-seven genotypes of chickpea were taken for this research (Table 3.2). The material was grown in the *Rabi* season of 2021-22. The chickpea seeds were sown in the field, in RBD with 3 replications on 14th December, 2021. Each plot comprised of 4 rows of 4m length in each replication. The row x row and plant x plant distance of 30 cm and 10 cm and net plot area was 4.8 m^2. The seeds were pre-treated with Bavistin, Trichoderma, Rhizobium and PSB cultures. Fertilizer dose @ of 20:40:20 kg per hectare (NPK) was applied. Two irrigations were given to the trial after one month of sowing and after 45 days of first irrigation. Random five plants are selected from each of the plot in each replication and were taken for collecting data on yield and yield attributing traits.

Table 3.2: List of chickpea genotypes

S. No	Accession No.	Entries	S. No	Accession	Entries
1	C-21226	NBeG 1634	21	C-21250	H 19-12
2	C-21227	PBC 626	22	C-21252	RSGD-1155
3	C-21228	JG 2021-68	23	C-21253	PBC 624
4	C-21230	RVG 203 (ch)	24	C-21254	GL18148
5	C-21232	BG 4032	25	C-21256	Phule G1216-10-17

S. No	Accession No.	Entries	S. No	Accession No.	Entries
6	C-21233	H 19-16	26	C-21257	PG 282
7	C-21234	IG 21-05	27	C-21258	NBeG 1423
8	C-21235	Phule G 1314-3-27	28	C-21260	GJG 1810
9	C-21236	IPC 2016-231	29	C-21261	BG 372 (ch)
10	C-21237	RKG 21-4	30	C-21263	RKG 21-3
11	C-21239	IPC 2006-77 (ch)	31	C-21264	GNG-2549
12	C-21240	GJG 1907	32	C-21265	IPC 2017-373
13	C-21241	RSGD-984	33	C-21266	IPCB 2014-88
14	C-21243	PG 281	34	C-21267	NDG 17-6-3
15	C-21244	IG 21-06	35	C-21268	GL16056
16	C-21245	RVSSG-109	36	C-21269	BG 4031
17	C-21246	JG 2021-71	37	C-21270	DC 2021-1664
18	C-21247	RVG 202 (ch)	38	C-21271	BRC-8
20	C-21249	GNG-2555			

Fig 3.2: Sowing of chickpea genotypes in the field C#2

Fig 3.3: Trial view of chickpea crop 31 days after sowing

Fig 3.4a: Trial view of chickpea genotypes in the field C#2

Fig 3.4b: Trial view of matured chickpea crop in the field C#2

3.4 Observations recorded:

Studied thirteen various yield and yield attributing traits were recorded to fulfil the objectives and purpose of the study. Random five plants are selected from each of the plot and replications for collecting data of different traits at optimal plant growth period. For statistical analysis, average data from the sampled plants with respect to various traits are used.

Days to 50 % flowering (DTF):

Days to 50 % flowering were recorded when the plants in the plot attained 50 percent flowering with at least one open flower.

Days to maturity (DTM):

Days to maturity was recorded when the plants attained physiological maturity.

Height of the first pod (cm) (HOFP):

The height was estimated in centimetres (cm) from the surface of the crop to the first pod emergence.

Plant height (cm) (PH):

The plant height was estimatedin centimetres (cm) from the surface of the crop to the last tip of theplant.

Primary branches (PB):

Total number of primary branches was recorded from randomly five plants and was averaged.

Secondary branches (SB):

Total number of secondary branches was recorded from randomly five plants and was averaged.

Number of seeds per pod (SPP):

Total number of seeds per pod was counted in randomly five plants and was averaged.

Number of pods per plant (PPP):

Total number of pods per plant was counted in randomly five plants and was averaged.

100 grain weight (g) (HSW):

Randomly 100 seed are taken from each of the entry and weighed in gram.

Biological yield per plant (g) (BY):

The crop was harvested and sun drying to 5 - 8 days and weight of each of the 5 plant except root was recorded in grams.

Harvest- index (%)(HI):

Harvest index was estimated as the ratio of seed yield to biological yield and the ratio of seed yield and biological yield are expressed in percentage.

Plot yield in grams (g) (PLYG):

The seed yield of each of the plot in each replication was recorded in grams after sun drying for five to eight days after harvesting.

3.5 Statistical analysis:

The data was notable in favour to divergent phenotypic and quantitative traits on the 13 yield and its related characters of chickpea accessions were subjected to the statistical analysis.

3.5.1 Analysis of variance:

Firstly, mean values were worked out for all traits for each genotype. These mean data were utilized to calculate variability parameters *viz.*, range, standard deviation, and coefficient of variation. ANOVA is calculated by using O.P.STAT software (Sheoran *et al.*, 1998).

Table 3.3 Skeleton of analysis of variance

Source of Variation	DF	SS	MSS	F Cal.
Replication	(r-1)	SSR	MSR	MSR/MSE
Genotypes	(g-1)	SSG	MSG	MSG/MSE
Error	(r-1)(g-1)	SSE	MSE	
Total	(rg-1)	SStotal		

3.5.2 Assessment of variability:

3.5.2.1 Range:

The minimum and maximum value of a trait tells its range, which is expressed as follows:

Range = maximum value – minimum value.

3.5.2.2 Mean($\bar{X}$):

Mean can be evaluated by sum of no. of observation by total no. of observation and the formula are follows as:

$$\bar{X} = \frac{\Sigma \mathrm{Xi}}{\mathrm{N}}$$

Where,

ΣX_i = sum of all the observation

N = total number of observation

3.5.2.3 Estimation of coefficient of variation (CV %):

The coefficient of variation for different traits was calculated by formula which is given by Burton and De Vane (1953). The category of magnitude of coefficient of variation was given as higher (greater than 20%), moderate (between 20% - 10%) and low (lower than 10%).

a) Phenotypic coefficient of variation (PCV %)

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

b) Genotypic coefficient of variation (GCV %)

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

3.5.2.4 Heritability (broad sense) (h^2_{bs} %):

Heritability is the ratio of variation due to difference between genotypic to the phenotypic variation for a character or a trait in a population. For the present study broad sense heritability was estimated and adopting the formula as suggested by Hanson *et al*., 1956.

The estimates of heritability broad sense were classified as low, moderate and high according to Robinson (1949).

< 50 % – Low

50-70 % – Moderate

> 70 % – High

3.5.2.5 Genetic advance as percentage of mean (GA %):

Enhancement of mean phenotypic value of elected plants over the parental population is called as genetic advance. Expected genetic advance (GA) was estimated by method recommended by Johnson *et al.*, (1955). It is the ratio of genetic advance to the grand mean and is expressed in percent.

$$G\ A=K\ .h^2.\ p$$

Where,

GA = Genetic advance

K = Constant (Standardized selection differential) having the value of 2.06 at 5 percent level of selection intensity.

The genetic advance is interpreted as GA is greater than 20% = High; GA = 10 – 20 per cent = Moderate and GA less than 10 % Low.

3.5.3 Association analysis:

Estimate the correlative relationship between different traits through correlation coefficient analysis at phenotypic, genotypic and environment levels with the support of formula recommended by Miller *et al.* (1958).

3.5.4 Path analysis:

Path analysis was originally developed by Wright (1921) and first used for plant selection by Dewey and Lu (1959). It measures the direct and indirect contribution of independent variables on dependent variable. The results of path coefficient analysis are interpreted as per the following scale suggested by Lenka and Mishra (1973).

Chapter – IV

RESULT AND DISCUSSION

The current study, titled "Identification of chickpea (*Cicer arietinum* L.) genotypes under rice based cropping system for late sown condition" evaluated 37 chickpea genotypes for seed yield and component traits under late sown conditions in field during *rabi* 2021-22 for seed yield and its component traits by growing at Research Field of Pulses Section, Department of Genetics and Plant Breeding, IGKV, Raipur College of Agriculture, Raipur Chhattisgarh. The observations for thirteen morpho-physiological traits "days to 50 % flowering, days to maturity, plant height, height of first pod, primary branches per plant, secondary branches per plant, number of pods per plant, number of seeds per pod, 100 seed weight, biological yield, seed yield per plant, harvest index and plot yield" of the chickpea genotypes were recorded in field conditions. The following headers and subheads explain the results achieved for various traits:

4.1 Analysis of variance (ANOVA)

4.2 Genetic parameters of variability

4.3 Correlation coefficient analysis

4.4 Path coefficient analysis

4.1 Analysis of variance

Variability refers to the differences that exist among individuals in a plant population. To understand the extent of variation in the observed features across the thirty-seven genotypes of chickpea, an analysis of variance was performed and the results are provided in Table 4.1. The mean sum of squares owing to genotypes is important for all the examined features, indicating that seed yield and its component qualities appear to have significant genetic variability that may be used in selection, according to the results of an analysis of variance. The mean sum of squares owing to genotypes is important for all the studied traits, indicating that seed yield and its component qualities appear to have significant genetic variability that may be used in selection, according to the results of an analysis of variance. In chickpea, Johnson *et al.*,(2016), Takkuri *et al.*,(2017), Kashyap *et al*. (2003), Puri *et al*. (2013), Singh and Kumar (2008), Patel and Babbar (2005) discovered high variability in all yield-related variables. The mean sum of squares due to genotype was found to be significant for all of the yield traits except seeds per pod which showed non-significant results. This clearly illustrates that all genotypes have variability in all aspects. The fact that genotype x environment interaction accounts for such a large and reasonably significant portion of total variation indicates that genotypes react to the environment differently.

4.2 Genetic parameter of variability:

The genetic parameters of variability for all 13morpho-physiological features tested have been calculated and the analyzed data are provided in Tables 4.2a, 4.2b and 4.3.

4.2.1 Mean and range of traits:

Table 4.2 a, 4.2 b and 4.3 provide the mean values, genetic parameters, and descriptive statistics of 37 genotypes of chickpea for all thirteen characteristics for varied yield and its component qualities under late sown situations for all thirteen characters.

Days to 50% flowering (DTF):

The days to 50% flowering ranged from 37 to 64.33 days, with a mean value of 51.36 days (Table 4.3). The genotypes (RKG 21-4) and (PBC 626) recorded early flowering of 37.00 days and 39.33 days, respectively for days to 50 percent flowering, which is extra early flowering, whereas the genotype PG 281 took 64.33 days for 50 percent flowering under late sown condition (Table 4.4).

Table 4.1: Analysis of variance of thirteen yield and yield attributing traits in thirty seven chickpea genotypes

SV	DF	DTF	DTM	PH	HOFP	PB	SB	SPP	PPP	HSW	BY	HI	SYP	PLYG
Replication	2	22.77	1.77	34.64	11.59	20.01	4.17	0.04	272.09	3.80	368.04	608.60	228.43	122288.62
Treatment	36	147.32**	65.76**	106.47**	68.48**	1.63*	6.48**	0.17	70.18**	54.33**	389.96**	302.81**	61.87**	34369.13**
Error	72	17.48	2.15	8.45	10.29	1.15	2.88	0.05	39.18	16.02	229.70	106.72	44.34	13461.21

* and ** significant at 0.05 and 0.01 probability level

DTF = Days to flowering; DM = Days to maturity; PH = Plant height (cm); HOFP = Height of first pod (cm); PB = Primary branches; SB = Secondary branches; PPP = Pods per plant; SPP = Seeds per pod; HSW = Hundred seed weight (g); BY = Biological yield (g); HI = Harvest index (%); SYP = Seed yield per plant (g); PLYG = Plot yield (g)

Table 4.2a: Mean performance of thirty seven genotypes of chickpea

S. No.	Code No.	DTF	DM	PH	HOFP	PB	SB	NSP	NPP	BYP	SYP	HI	HSW	PLYG
1	C-21226	49.00	96.67	53.07	31.73	2.80	4.93	1.00	17.80	21.44	48.00	37.27	18.00	382.67
2	C-21227	39.33	90.67	36.07	19.67	4.33	3.27	1.47	16.07	16.22	29.33	41.51	12.00	211.67
3	C-21228	45.67	96.33	39.33	23.73	2.80	4.73	1.67	19.73	13.52	33.33	40.07	14.00	365.00
4	C-21230	41.67	91.00	33.33	16.33	3.73	5.73	1.47	23.47	21.35	44.67	59.42	26.67	292.67
5	C-21232	40.33	86.00	44.87	25.27	2.00	3.27	1.20	18.60	15.14	28.00	51.85	14.67	336.67
6	C-21233	54.33	100.00	37.80	23.53	4.80	5.60	1.13	14.40	27.40	36.00	31.27	10.00	243.33
7	C-21234	55.00	93.00	39.60	25.80	3.00	3.73	1.60	15.00	23.15	39.33	40.68	16.67	302.00
8	C-21235	55.00	99.00	49.73	27.40	4.13	2.87	1.27	20.07	19.83	50.67	37.89	20.00	230.33
9	C-21236	55.33	99.33	39.67	26.00	3.20	5.47	1.40	18.07	17.89	39.33	41.07	15.33	336.00
10	C-21237	37.00	89.00	49.33	23.33	2.27	4.73	1.27	17.73	19.61	35.33	54.43	19.33	395.67
11	C-21239	56.67	101.33	34.20	16.27	3.07	9.53	1.27	28.80	13.51	69.33	36.21	24.67	99.67
12	C-21240	54.00	99.00	37.80	24.80	3.73	5.87	1.07	14.33	24.21	45.33	34.27	16.67	209.00
13	C-21241	42.33	86.33	36.67	19.53	2.33	3.80	1.27	21.07	14.16	32.67	52.84	17.33	333.33
14	C-21243	64.33	100.67	30.67	23.53	4.07	3.60	1.27	3.60	14.35	20.00	31.25	6.00	14.67
15	C-21244	45.67	99.00	48.00	26.73	3.13	4.60	1.00	15.33	27.40	51.33	29.35	16.00	169.67
16	C-21245	63.00	97.00	36.33	25.33	3.67	4.87	1.07	10.00	22.46	48.00	22.06	10.67	110.67
17	C-21246	55.33	95.33	37.47	22.27	2.73	3.60	1.27	15.20	13.56	26.00	44.40	12.00	222.00
18	C-21247	50.33	96.00	35.60	23.33	2.87	3.67	1.40	16.33	21.27	37.33	48.17	18.00	346.33
19	C-21249	55.33	98.00	43.40	30.40	3.07	3.33	1.20	11.47	24.23	37.33	37.75	14.00	310.33

DTF = Days to flowering; DM = Days to maturity; PH = Plant height (cm); HOFP = Height of first pod (cm); PB = Primary branches; SB = Secondary branches; PPP = Pods per plant; SPP = Seeds per pod; HSW = Hundred seed weight (g); BY = Biological yield (g); SYP = Seed yield per plant (g); HI = Harvest index (%); PLYG = Plot yield (g)

Contd...

Table 4.2b: Mean performance of thirty seven genotypes of chickpea

S. No.	Code No.	DTF	DM	PH	HOFP	PB	SB	NSP	NPP	BYP	SYP	HI	HSW	PLYG
20	C-21250	49.00	96.00	34.87	21.60	3.07	3.40	1.20	16.93	14.69	27.33	57.22	14.67	288.00
21	C-21252	41.33	91.00	40.67	22.20	2.33	4.27	1.07	21.20	14.94	28.67	36.94	11.33	267.67
22	C-21253	57.33	100.00	45.07	34.53	2.93	3.87	1.27	7.60	21.45	34.00	21.62	7.33	90.33
23	C-21254	45.67	96.00	42.13	22.87	2.47	3.67	1.20	14.87	23.51	36.00	41.65	15.33	152.33
24	C-21256	56.33	101.67	38.67	27.07	4.20	5.80	1.33	9.40	15.58	47.33	23.25	9.33	42.33
25	C-21257	51.67	100.33	45.53	28.93	2.80	5.47	1.07	13.40	20.67	53.33	25.51	13.33	37.00
26	C-21258	44.33	98.33	40.40	23.27	2.47	2.87	1.33	8.47	25.48	24.67	35.49	8.67	154.33
27	C-21260	55.33	87.67	35.60	25.07	3.33	4.80	1.73	13.27	11.51	22.00	35.18	8.00	142.67
28	C-21261	41.00	88.33	39.13	20.07	3.47	3.07	1.00	20.33	17.06	28.67	44.32	12.67	183.00
39	C-21263	57.67	99.00	41.67	28.33	2.47	3.93	2.07	11.53	14.77	23.33	42.36	10.00	117.33
30	C-21264	60.00	101.67	55.80	40.13	4.47	3.73	1.00	11.60	20.56	37.33	28.21	10.67	174.00
31	C-21265	49.67	99.33	43.53	25.73	3.60	4.87	1.33	16.40	22.02	50.67	37.78	19.33	265.33
32	C-21266	50.67	101.67	42.93	25.00	4.33	5.53	1.13	19.40	20.53	53.33	38.03	20.00	201.67
33	C-21267	60.33	102.00	35.60	19.47	4.27	9.13	1.00	18.67	15.37	51.33	30.92	16.00	43.67
34	C-21268	54.00	97.67	41.20	27.93	4.07	4.33	1.07	13.80	20.74	33.33	44.58	14.67	219.33
35	C-21269	55.33	99.00	54.20	29.60	4.13	6.27	0.93	12.27	19.07	57.33	15.86	11.67	82.67
36	C-21270	55.33	100.33	45.53	30.47	3.47	4.33	1.20	20.60	15.82	39.33	38.57	15.33	175.33
37	C-21271	49.00	96.00	34.87	21.60	3.07	3.40	1.20	16.93	14.69	27.33	57.22	14.67	288.00
Grand Mean		51.36	96.56	41.33	25.31	3.31	4.62	1.25	15.79	18.91	38.56	38.31	14.41	213.35

DTF = Days to flowering; DM = Days to maturity; PH = Plant height (cm); HOFP = Height of first pod (cm); PB = Primary branches; SB = Secondary branches; PPP = Pods per plant; SPP = Seeds per pod; HSW = Hundred seed weight (g); BY = Biological yield (g); SYP = Seed yield per plant (g); HI = Harvest index (%); PLYG = Plot yield (g)

Table 4.3: Genetic variability parameters for thirteen yield attributing traits

Parameters	DTF	DTM	PH	HOFP	PB	SB	SPP	PPP	HSW	BY	HI	SYP	PLYG
GM	51.36	96.56	41.33	25.31	3.31	4.62	1.25	15.79	18.91	38.56	38.31	14.41	213.35
Min.	37.00	86.00	30.67	16.27	2.00	2.87	0.93	3.60	11.51	20.00	15.86	6.00	14.67
Max.	64.33	102.00	55.80	40.13	4.80	9.53	2.07	28.80	27.40	69.33	59.42	26.67	395.67
PCV (%)	15.18	5.00	15.52	21.53	34.64	**43.69**	23.60	**44.57**	28.38	43.64	**34.24**	49.18	**67.00**
GCV (%)	12.81	4.77	13.83	17.40	12.02	**23.70**	16.34	**20.36**	18.90	18.96	**21.11**	16.78	**39.13**
h^2 ($_{bs}$) (%)	71.23	90.81	79.45	65.33	12.04	29.42	47.96	20.87	44.36	18.87	37.99	11.65	34.11
GA as % of mean	22.27	9.36	25.40	28.97	8.59	26.48	23.32	19.16	25.93	16.96	26.80	11.80	47.08

DTF = Days to flowering; DM = Days to maturity; PH = Plant height (cm); HOFP = Height of first pod (cm); PB = Primary branches; SB = Secondary branches; PPP = Pods per plant; SPP = Seeds per pod; HSW = Hundred seed weight (g); BY = Biological yield (g); SYP = Seed yield per plant (g); HI = Harvest index (%); PLYG = Plot yield (g)

Table 4.4: Classification of chickpea genotypes based on days to flowering (DTF) and days to maturity (DM)

Classification	Entry no.	Classification	Entry no.
DTF		DTM	
Extra early (<40 Days)	RKG 21-4 (37.00) ; PBC 626 (39.33)	Early (<90 days)	BG 4032 (86.00); RSGD-984 (86.33); BG 372 (ch) (87.67); RKG 21-3 (88.33); RKG 21-4 (89.00)
Early (40-60 Days)	BG 4032 (40.33); RKG 21-3 (41.00); PBC 624 (41.33); RVG 203 (ch) (41.67); RSGD-984 (42.33); IPCB 2014-88 (43.00); GJG 1810 (44.33); JG 2021-68 (45.67); IG21-06 (45.67); Phule G1216-10-17 (45.67); NBeG 1634 (49.00); RSGD-1155 (49.00); RVG 202 (ch) (50.33); NBeG 1423 (51.67); GJG 1907 (54.00); NDG 17-6-3 (54.00); BG 4031 (54.00); H 19-16 (54.33); IG21-05 (55.00); Phule G 1314-3-27 (55.00); IPC 2016-231 (55.33); JG 2021-71 (55.33); GNG-2555 (55.33); BG 372 (ch) (55.33); DC 2021-1664 (55.33); BRC-8 (55.33); H 19-12 (55.67); PG 282 (56.33); IPC 2006-77 (ch) (56.67); GL18148 (57.33); GNG-2549 (57.67); IPC 2017-373 (60.00)	Medium (90-100 days)	PBC 626 (90.67); RVG 203 (ch) (91.00); PBC 624 (91.00); IG21-05 (93.00); JG 2021-71 (95.33); RVG 202 (ch) (96.00); RSGD-1155 (96.00); Phule G1216-10-17 (96.00); JG 2021-68 (96.33); NBeG 1634 (96.67); RVSSG-109 (97.00); BG 4031 (97.67); GNG-2555 (98.00); GJG 1810 (98.33); Phule G 1314-3-27 (99.00); GJG 1907 (99.00); IG21-06 (99.00); H 19-12 (99.00); GNG-2549 (99.00); DC 2021-1664 (99.00); IPC 2016-231 (99.33); IPCB 2014-88 (99.33); H 19-16 (100.00); GL18148 (100.00); NBeG 1423 (100.33); BRC-8 (100.33)
Medium (60 – 80 Says)	GL16056 (60.33); RVSSG-109 (63.00); PG 281 (64.33)	Late (>100days)	PG 281 (100.67); IPC 2006-77 (ch) (101.33); PG 282 (101.67); IPC 2017-373 (101.67); NDG 17-6-3 (101.67); GL16056 (102.00)

Days to maturity (DM):

Crop maturity was reported to be 86 days minimum and 102 days maximum, with an average of 96.56 days. The earliest physiological maturing genotype was BG 4032 (86 days), whereas GL16056 reported (102 days) late maturing than the other genotypes (Table 4.4) in his investigation.

Plant height (PH) (cm):

The height of the plants ranged from 30.67 cm to 55.80 cm, with an average of 41.33 cm. The genotype, IPC 2017-373 was the tallest entry whereas, the genotype PG 281, recorded shortest plant height.

Height of first pod (HOFP) (cm):

The genotype IPC 2017-373 recoded maximum height of first pod (Table 4.5). The height of first pod varied from 16.27 cm and 40.13 cm, with a mean of 25.31 cm (Table 4.3). Five genotypes had tallest height (>30cm) of first pod, namely, GNG-2555 (30.40); BRC-8 (30.47); NBeG 1634 (31.73); GL18148 (34.53) and IPC 2017-373 (40.13).

Primary branches plant^{-1} (PB):

The range of this character was 2.00 to 4.80, with a mean value of 3.31. The genotype BG 4032 (2.00) had the fewest main branches per plant, whereas H 19-16 (4.80) had more primary branches per plant.

Secondary branches plant^{-1} (SB):

The number of secondary branches per plant ranged from 2.87 to 9.53, with a mean value of 4.62. The genotype IPC 2006-77 had the highest number of secondary branches per plant, whereas genotype Phule G 1314-3-27 had the lowest number of secondary branches per plant.

Seeds per pod (SPP):

The average value of seeds per pod was 1.25 ranging from 0.93 to 2.07. Seeds were found in the more in pods of GNG-2549 and the least in pods of DC 2021-1664

Table 4.5: Classification of chickpea genotypes based on height of first pod (HOFP)

Classification	Entry no.
Short < 20cm	IPC 2006-77 (ch) (16.27); RVG 203 (ch) (16.33); GL16056 (19.47) RSGD-984 (19.53); PBC 626 (19.67)
Medium 20 – 30cm	RKG 21-3 (20.07); RSGD-1155 (21.60); PBC 624 (22.20); JG 2021-71 (22.27); Phule G1216-10-17 (22.87); GJG 1810 (23.27); RKG 21-4 (23.33); RVG 202 (ch) (23.33); H 19-16 (23.53); PG 281 (23.53; JG 2021-68 (23.73); GJG 1907 (24.80); NDG 17-6-3 (25.00); BG 372 (ch) (25.07); BG 4032 (25.27); RVSSG-109 (25.33); IPCB 2014-88 (25.73); IG21-05 (25.80); IPC 2016-231 (26.00); IG21-06 (26.73); PG 282 (27.07); Phule G 1314-3-27 (27.40); BG 4031 (27.93); GNG-2549 (28.33); NBeG 1423 (28.93); C-21250 (29.33); H 19-12 (29.60)
Tall > 30cm	GNG-2555 (30.40); BRC-8 (30.47); NBeG 1634 (31.73); GL18148 (34.53); IPC 2017-373 (40.13)

Pods per plant (PPP):

This feature showed a large range of variation ranging from 3.60 to 28.80 with an overall mean of 15.79 pods plant^{-1}. The genotype IPC 2006-77 (ch) had the highest number of pods per plant, whereas genotype PG 281 had the lowest number of pods per plant.

Hundred seed weight (HSW) (g):

The average hundred seed weight was 18.91 g ranging from 11.51 g to 27.40 g. The genotype, BG 372 (ch) had the lowest 100-seed weight, whereas the genotype IG21-06 had the highest 100-seed weight. 20 genotypes had very small seed weight (<25g), 15 genotypes had small seed weight (20-25 g), 02 genotypes had medium seed weight (26-35 g), and none of the genotype had large and very large seed weight (36-45 and >45 g) out of 37 genotypes investigated (Table 4.6).

Table 4.6: Classification of chickpea genotypes based on seed index

Classification	Entry no	Classification	Entry no.
Very small (<20g)	BG 372 (ch) (11.51); IPC 2006-77 (ch) (13.51); JG 2021-68 (13.52); JG 2021-71 (13.56); RSGD-984 (14.16); PG 281 (14.35); RSGD-1155 (14.69); GNG-2549 (14.77); PBC 624 (14.94); H 19-12 (15.12); BG 4032 (15.14); GL16056 (15.37); PG 282 (15.58); BRC-8 (15.82); PBC 626 (16.22); RKG 21-3 (17.06); IPC 2016-231 (17.89); DC 2021-1664 (19.07); RKG 21-4 (19.61); Phule G 1314-3-27 (19.83)	Small (20 – 25g)	NDG 17-6-3 (20.53); IPC 2017-373 (20.56); NBeG 1423 (20.67); BG 4031 (20.74); RVG 202 (ch) (21.27); RVG 203 (ch) (21.35); NBeG 1634 (21.44); GL18148 (21.45); IPCB 2014-88 (22.02); RVSSG-109 (22.46); IG21-05 (23.15); Phule G1216-10-17 (23.51); GJG 1907 (24.21); GNG-2555 (24.23); GJG 1810 (25.48)
		Medium (26 – 35g)	H 19-16 (27.40); IG21-06 (27.40)
		Large (36 – 45g)	None
		Very large (>45g)	None

Biological yield per plant (BYP) (g):

Biological yield per plant ranged from 20.00 g to 69.33 g with a mean of 38.56 g. The genotype, IPC 2006-77 (ch) had the highest biological yield per plant, whereas genotype PG 281 had the lowest biological yield per plant.

Harvest index (HI) (%):

The harvest index had a mean of 38.31 percent, ranging from 15.68 percent to 59.42 percent. The genotype DC 2021-1664 had the lowest harvest index (15.86 percent), whereas RVG 203 (ch) (59.42 percent) had the highest harvest index.

Seed yield per plant (SYP) (g):

The seed yield per plant ranged from 6.00 to 26.67 g with an average of 14.41 g. The genotype RVG 203 (ch) had the highest seed yields per plant (26.67 g), whereas genotype PG 281 had the lowest seed yield per plan (6.00 g). 20 genotypes had High seed yield (>20g), 26 genotypes had Medium seed yield (10-20g), 07 genotypes had Low seed yield (<10g) out of 37 genotypes investigated (Table 4.7).

Plot yield (g)

Plot yield showed an average of 213.35 g with lowest and highest values of 14.67 g and 394.67 g, respectively. The genotype RKG 21-4 reported the highest plot yield value, whereas the genotype PG 281recorded the lowest plot yield. This character's coefficient of variation was found to be 28.49 percent, suggesting that there is a lot of variance.

Jha *et al*. (2015) reported broad genetic variation among genotypes. Puri *et al*. (2013) found that most of the characters studied, such as days to first flowering, days to 50% flowering, days to maturity, biological yield, 100 seed weight, harvest index and seed yield per plant, had sufficient variability, this relates to our study also.

Table 4.7: Classification of chickpea genotypes based on high seed yield (g)

Classification	Entry no
SYP	
High seed yield (>20g)	RVG 203 (ch) (26.67); IPC 2006-77 (ch) (24.67); Phule G 1314-3-27 (20.00); NDG 17-6-3 (20.00)
Medium seed yield (10-20g)	RKG 21-4 (19.33); IPCB 2014-88 (19.33); NBeG 1634 (18.00); RVG 202 (ch) (18.00); RSGD-984 (17.33); IG21-05 (16.67); GJG 1907 (16.67); IG21-06 (16.00); GL16056 (16.00); IPC 2016-231 (15.33); Phule G1216-10-17 (15.33); BRC-8 (15.33); BG 4032 (14.67); RSGD-1155 (14.67); BG 4031 (14.67); JG 2021-68 (14.00); GNG-2555 (14.00); NBeG 1423 (13.33); H 19-12 (12.67); RKG 21-3 (12.67) PBC 626 (12.00); JG 2021-71 (12.00); DC 2021-1664 (11.67); PBC 624 (11.33); RVSSG-109 (10.67); IPC 2017-373 (10.67)
Low seed yield (<10g)	H 19-16 (10.00); GNG-2549 (10.00); PG 282 (9.33); GJG 1810 (8.67); BG 372 (ch) (8.00); GL18148 (7.33); PG 281 (6.00)

4.2.2 Phenotypic and genotypic coefficient of variation (%):

Simple measures of variability, such as phenotypic and genotypic coefficients of variation, are often used to assess variability. The level of variability present in a genetic population is determined by the relative value of various sorts of coefficients. Thus, during the experiment, the components of variation such as genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were evaluated and are shown in table 4.3.

The fact that the phenotypic coefficients of variation were somewhat greater than the genotypic coefficients of variation suggested that the environment had an impact on the expression of the traits under evaluation. Coefficients of variation were calculated at the phenotypic and genotypic levels, classified them as low (10%), moderate (10-20%), and high (>20%) (Burton, 1952). For all of the examined traits, the phenotypic coefficients of variation were larger in magnitude than the genotypic coefficients. PCV values are somewhat greater than GCV, indicating that the apparent variance is attributable to environmental influences as well as genotypes; these results are in conformity with the findings of Takkuri *et al.,* 2017; Sharma and Saini 2010; Jha *et al.,* 2015 and Mishra *et al.,* 2014.

High magnitude of PCV coupled with GCV was exhibited by secondary branches, pods per plant, harvest index and plot yield in grams. For the trait, pods per plant, Sharma and Saini 2010; Jha *et al*., 2015 and Mishra *et al*., 2014 reported similar findings. Likewise for secondary branches, Sharma and Saini 2010 found same results.

Moderate values of PCV coupled with GCV were recorded by traits namely, days to 50 per cent flowering and plant height.

High PCV coupled with moderate GCV were shown by height of first pod, primary branches, and seeds per pod, hundred seed weight, biological yield and seed yield per plant.

PCV values are higher than GCV values; it means that apparent variation is not only due to genotype but also due to the influence of environment. Sometimes the selection based on such traits which have high PCV than GCV may be misleading. However, the relative values of these types of coefficients give an idea about the magnitude of variability present in the genetic population.

4.2.3 Heritability and genetic advance:

Selection criteria like as heritability and genetic advance are essential. Heritability estimates combined with genetic advance are usually more useful than heritability estimates alone in estimating the gain under selection. Genetic advance is defined as an increase in the mean genotypic value of chosen plants over the parental population. It's a measurement for how much genetic progress has been made as a result of selection. Genetic advance under selection is determined by genetic diversity, heritability, and selection intensity. Heritability is the heritable portion of the phenotypic variance. It is a good index of the transmission of characters from parents to their off-springs (Falconer, 1981). According to Robinson (1966), heritability estimates in the broad sense were estimated and classed as low (50%), moderate (50-70%) and high (>70%). Heritability in the broad sense and genetic advance was calculated for each character among all the characters and the results are reported in table 4.3.

High estimates of heritability (h^2_{bs}) were observed in days to maturity followed by plant height and days to 50 per cent flowering. This indicate that though these characters are least influenced by the environmental effects, the selection for the improvement of such traits may not be useful, because broad sense heritability is based on total genetic variance which includes both fixable (additive) and non-fixable (dominance and epistatic) variances. For plant height, Mallu *et al*., 2014; for days to flowering, Mallu *et al.*, 2014, Nizama 2013, Puri *et al.*, 2013 and Babbar *et al*., 2012 found same results. Similarly, for days to maturity, Monpara and Dhaneliya, 2013 and Babbar *et al*., 2012 reported the same findings.

However, the moderate values of heritability were recorded by height of first pod and rest of the traits had low values of heritability. This indicates that the trait is highly influenced by the environmental effects and genetic improvement through selection will be difficult due to masking effects of the environment over the genotypic effects. High heritability indicates that all of the traits under investigation have a good index of transmission.

Genetic advance is a method of selection based on genetic gain. The success of the selection is determined by the character's heritability in this study. Heritability is based on total genetic variance, which includes fixable (additive) and non-fixable (dominance and epistatic) so variance, even though the characteristics are less impacted by environmental factors, selection for improvement of such traits may not be effective.

High values of genetic advance as percent of means were recorded by days to 50 % flowering, plant height, height of first pod, secondary branches, seeds per pod, hundred seed weight, harvest index and plot yield in grams. This shows that the characters are governed by additive genes and selection will be rewarding for improvement of such traits.

Three characters namely, pods per plant, biological yield and seed yield per plant exhibited moderate values of genetic advance.

Days to flowering and plant height were the two traits which showed high heritability with high genetic advance. However, height of first pod showed moderate heritability with high genetic advance.

4.3 Correlation coefficient analysis:

The term correlation was first used by Karl Pearson in 1902. It measures the degree and direction of association between two or more variables and is denoted by ‘r’. The correlation analysis at phenotypic (P) and genotypic (G) level is presented in table 4.8. The results indicated that the magnitude of genotypic correlation was found high as compared to phenotypic correlations. This indicated the significant role of environment. The results of the correlation coefficient are presented in Table 4.8.

Plot yield in grams showed significant and positive association with seed yield per plant, harvest index and pods per plant. Days to flowering, days to maturity and secondary branches showed negative significant association with plot yield both at phenotypic and genotypic level.

Seed yield had positive and significant correlation with harvest index, biological yield and pods per plant, where as the trait exhibited negative association with days to flowering both at phenotypic and genotypic level.

Seeds per pod and pods per plant were the two characters which showed positive association with harvest index and negative association was achieved by days to flowering, days to maturity, plant height, and height of first pod, primary branches and biological yield.

Biological yield expressed positive correlation with hundred seed weight, secondary branches, and plant height and days to maturity, however it also showed negative correlation with seeds per pod.

Plant height and days to maturity showed positive and seeds per pod showed negative correlation with hundred seed weight.

Days to flowering and days to maturity showed negative association with pods per plant; plant height had negative correlation with seeds per pod; days to maturity had positive correlation with secondary branches.

Days to flowering and days to maturity showed positive correlation with primary branches. Apart from this, days to flowering, days to maturity and plant height exhibited positive correlation with height of first pod and days to maturity had positive association with days to flowering.

The traits possessing correlation coefficients more than 0.65 are showing very strong relationship or association (Searle, 1965). In our case harvest index is the trait that showed very strong association with plot yield in grams both at phenotypic and genotypic level.

In the study the magnitude of genotypic correlation (r_g) was high as compared to phenotypic correlation (r_p), it means there is strong association between the traits genetically, but the phenotypic value is lessened by the significant interaction of environment.

Table 4.8: Association analysis (phenotypic and genotypic) of thirteen yield attributing traits

Traits		DTF	DTM	PH	HOFP	PB	SB	SPP	PPP	HSW	BY	HI	SYP	PLYG
DTF	**P**	**1.000**												
	G	**1.000**												
DTM	**P**	0.662**	**1.000**											
	G	0.718**	**1.000**											
PH	**P**	-0.057^{NS}	0.135^{NS}	**1.000**										
	G	-0.051^{NS}	0.198*	**1.000**										
HOFP	**P**	0.321**	0.333**	0.695**	**1.000**									
	G	0.497**	0.466**	0.776**	**1.000**									
PB	**P**	0.255**	0.283**	0.006^{NS}	0.094^{NS}	**1.000**								
	G	0.849**	0.846**	-0.147^{NS}	0.119^{NS}	**1.000**								
SB	**P**	0.170^{NS}	0.257**	-0.018^{NS}	-0.136^{NS}	0.039^{NS}	**1.000**							
	G	0.431**	0.532**	-0.299**	-0.410**	0.959**	**1.000**							
SPP	**P**	-0.052^{NS}	-0.174^{NS}	-0.209*	-0.053^{NS}	-0.054^{NS}	-0.115^{NS}	**1.000**						
	G	-0.006^{NS}	-0.256**	-0.476**	-0.294**	-0.630**	-0.259**	**1.000**						
PPP	**P**	-0.342**	-0.240*	0.120^{NS}	-0.175^{NS}	-0.094^{NS}	0.487**	0.051^{NS}	**1.000**					
	G	-0.630**	-0.406**	-0.297**	-0.962**	-0.400**	0.078^{NS}	-0.205*	**1.000**					
HSW	**P**	-0.095^{NS}	0.218*	0.187*	0.090^{NS}	0.053^{NS}	-0.004^{NS}	-0.223*	-0.142^{NS}	**1.000**				
	G	0.009^{NS}	0.321**	0.412**	0.404**	0.463**	-0.250**	-0.381**	-0.493**	**1.000**				
BY	**P**	0.083^{NS}	0.271**	0.299**	0.084^{NS}	0.105^{NS}	0.624**	-0.188*	0.567**	0.900**	**1.000**			
	G	0.346**	0.760**	0.253**	-0.096^{NS}	1.056**	0.831**	-0.657**	-0.223*	0.453**	**1.000**			
HI	**P**	-0.455**	-0.467**	-0.201*	-0.274**	-0.291**	-0.148^{NS}	0.209*	0.433**	-0.175^{NS}	-0.231*	**1.000**		
	G	-0.694**	-0.710**	-0.350**	-0.659**	-0.791**	-0.513**	0.347**	0.688**	-0.327**	-0.725**	**1.000**		
SYP	**P**	-0.247**	-0.103^{NS}	0.160^{NS}	-0.106^{NS}	-0.085^{NS}	0.452**	0.029^{NS}	0.858**	0.080^{NS}	0.688**	0.478**	**1.000**	
	G	-0.555**	-0.106^{NS}	-0.213*	-0.971**	0.052^{NS}	0.132^{NS}	-0.224*	0.537**	0.243**	0.224*	0.573**	**1.000**	
PLYG	**P**	-0.370**	-0.375**	0.165^{NS}	0.053^{NS}	-0.198*	-0.193*	0.126^{NS}	0.412**	-0.041^{NS}	-0.018^{NS}	0.604**	0.437**	**1.000**
	G	-0.699**	-0.591**	0.086^{NS}	-0.217*	-0.937**	-0.497**	0.055^{NS}	0.518**	0.190*	-0.608**	0.840**	0.445**	**1.000**

* and ** significant at 0.05 and 0.01 probability level, DTF = Days to flowering; DM = Days to maturity; PH = Plant height (cm); HOFP = Height of first pod (cm); PB = Primary branches; SB = Secondary branches; PPP = Pods per plant; SPP = Seeds per pod; HSW = Hundred seed weight (g); BY = Biological yield (g); SYP = Seed yield per plant (g); HI = Harvest index (%); PLYG = Plot yield (g)

These results are in conformity with the findings of Shafique *et al*. (2016), Jadhav *et al*. (2014), Padmavathi *et al*. (2013), Sreelakshmi *et al*. (2010), Thakur and Sirohi (2009), Dasgupta *et al*., (1992) and Babbar *et al*. (2012).

4.4 Path coefficient analysis

Path coefficient analysis is useful for separating the connection into direct and indirect influence measurements. It calculates the direct and indirect impact of independent factors on the dependent variable. The partitioning of total correlation into direct and indirect effects gives actual information on character contribution and hence serves as the foundation for character selection to increase yield. The concept of path analysis was originally developed by Wright in 1921 but it was first used for plant selection by Dewey and Lu (1959). The results of the phenotypic path are presented in Table 4.9.

Biological yield, harvest index and pods per plant exhibited positive high direct effect on seed yield per plant. The correlation values of these three traits also confirm the results as they possess the positive and highly significant association with seed yield per plant.

Plot yield in grams recorded positive indirect effect on seed yield per plant through harvest index and pods per plant. Apart from this, the negative indirect effect was shown by days to flowering and days to maturity.

Secondary branches and pods per plant exhibited positive indirect effect on seed yield per plant through biological yield.

The residual effects of 0.06 indicate that all the traits under experiment are duly covered.

Biological yield, harvest index and pods per plant are the traits which also possessed positive association and direct effect, it reveals that there is true relationship between them and direct selection for these traits will be rewarding.

Plot yield in grams recorded positive indirect effect on seed yield per plant through harvest index and pods per plant, it shows that the correlation being positive but due to indirect effects, indirect selection through such trait will lead to yield improvement.

Table 4.9: Phenotypic direct and indirect effects of thirteen yield traits with seed yield per plant (SYP) as dependent variable

Traits	DTF	DTM	PH	HOFP	PB	SB	SPP	PPP	HSW	BY	HI	PLYG	P Corr
DTF	**0.084**	-0.004	-0.004	-0.016	0.005	0.000	-0.003	-0.105	-0.009	0.050	-0.232	-0.012	-0.247**
DTM	0.055	**-0.006**	0.010	-0.016	0.005	0.000	-0.009	-0.074	0.020	0.161	-0.238	-0.012	-0.103^{NS}
PH	-0.005	-0.001	**0.075**	-0.034	0.000	0.000	-0.011	0.037	0.017	0.178	-0.103	0.005	0.160^{NS}
HOFP	0.027	-0.002	0.052	**-0.048**	0.002	0.000	-0.003	-0.054	0.008	0.050	-0.140	0.002	-0.106^{NS}
PB	0.021	-0.002	0.000	-0.005	**0.018**	0.000	-0.003	-0.029	0.005	0.062	-0.148	-0.006	-0.085^{NS}
SB	0.014	-0.001	-0.001	0.007	0.001	**-0.001**	-0.006	0.150	0.000	0.372	-0.076	-0.006	0.452**
SPP	-0.004	0.001	-0.016	0.003	-0.001	0.000	**0.053**	0.016	-0.021	-0.112	0.107	0.004	0.029^{NS}
PPP	-0.029	0.001	0.009	0.008	-0.002	-0.001	0.003	**0.309**	-0.013	0.338	0.221	0.013	0.858**
HSW	-0.008	-0.001	0.014	-0.004	0.001	0.000	-0.012	-0.044	**0.093**	0.132	-0.089	-0.001	0.080^{NS}
BY	0.007	-0.002	0.022	-0.004	0.002	-0.001	-0.010	0.175	0.021	**0.596**	-0.118	-0.001	0.688**
HI	-0.038	0.003	-0.015	0.013	-0.005	0.000	0.011	0.134	-0.016	-0.138	**0.510**	0.019	0.478**
PLYG	-0.031	0.002	0.012	-0.003	-0.004	0.000	0.007	0.127	-0.004	-0.011	0.308	**0.032**	0.437**

RESIDUAL EFFECT = 0.06; Bold values shows direct and normal values shows indirect effects

DTF = Days to flowering; DM = Days to maturity; PH = Plant height (cm); HOFP = Height of first pod (cm); PB = Primary branches; SB = Secondary branches; PPP = Pods per plant; SPP = Seeds per pod; HSW = Hundred seed weight (g); BY = Biological yield (g); SYP = Seed yield per plant (g); HI = Harvest index (%); PLYG = Plot yield (g)

CHAPTER – V

SUMMARY AND CONCLUSION

The research entitled, **“Identification of chickpea (*Cicer arietinum* L.) genotypes under rice based cropping system for late sown condition"** was carried out during Rabi seasons of 2021-2022 at Research cum Instructional Farm of the “Department of Genetics and Plant Breeding” College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh. The experiment was conducted in Randomized Block Design with 37 genotypes in three replications to calculate genetic variability parameters, correlation, and path analysis. For metric observations, five competing plants were chosen at random from each plot and replication at different growth stage on 13 quantitative traits measured for genetic variability.

The mean sum of squares due to genotypes is substantial for all of the investigated variables, indicating that seed yield and its components appear to have significant genetic variability that may be utilized in selection. The mean sum of squares owing to genotype/treatment was found to be significant for all yield parameters except seeds per pod, which was determined to be non-significant. This clearly demonstrates that all genotypes vary in all dimensions.

The phenotypic coefficients of variation were greater in magnitude than the genotypic coefficients for all of the attributes studied. PCV levels are somewhat higher than GCV values, indicating that the apparent variation is due to environmental factors as well as genotypes. Secondary branches, pods per plant, harvest index, and plot yield in gram all showed a high magnitude of PCV combined with GCV. PCV and GCV levels were somewhat high in features such as days to 50% flowering and plant height. Height of first pod, primary branches, and seeds per pod, hundred seed weight, biological yield, and seed production per plant all demonstrated high PCV in association with modest GCV.

Days to maturity had the highest heritability estimates (h^2_{bs}), followed by plant height and days to 50% flowering. The height of the first pod, on the other hand, exhibited moderate heredity values, while the others of the attributes had low heritability values. High values of genetic advance as percent of means were recorded by days to 50 % flowering, plant height, height of first pod, secondary branches, seeds per pod, 100 seed weight, harvest index and plot yield in grams.

Plot yield (g) was shown to be significantly and positively related to seed yield per plant, harvest index, and pods per plant. Days to flowering, days to maturity, and secondary branches all had a negative phenotypic and genotypic correlation with plot yield. Seed yield correlated positively and significantly with harvest index, biological yield, and pods per plant, however the attribute correlated negatively with days to flowering at both the phenotypic and genotypic levels.

The biological yield, harvest index, and pods per plant all had a direct positive effect on seed yield per plant. The correlation values of these three attributes also support the results, because they have a positive and highly significant relationship with seed yield per plant.

Conclusion

- Seed yield and its components appeared to contain a lot of genetic variability which can be used in selection.
- High mean values indicate that there is enough variability in the population, implying that there is more chance for genotype selection and improvement on these characteristics.
- PCV values are higher than GCV values show that there is variability among genotypes. High magnitude of PCV coupled with GCV was exhibited by secondary branches, pods per plant, harvest index and plot yield in grams.
- Days to flowering and plant height were the two traits which showed high heritability with high genetic advance.

- Plot yield in grams showed significant and positive association with seed yield per plant, harvest index and pods per plant both at phenotypic and genotypic level.
- Two genotypes namely "RKG 21-4 (37.00) and PBC 626 (39.33)" showed extra early flowering (<40 Days), whereas, five genotypes *viz*., "BG 4032 (86.00); RSGD-984 (86.33); BG 372 (ch) (87.67); RKG 21-3 (88.33); RKG 21-4 (89.00)" recorded early maturity (<90 days) under late sown condition in rice based cropping system.
- Genotypes, "GNG-2555 (30.40); BRC-8 (30.47); NBeG 1634 (31.73); GL18148 (34.53); IPC 2017-373 (40.13)" possessed height of first pod i.e., more than 30 cm.
- Twenty genotypes had very small 100 seed weight (< 25g), 15 genotypes had small 100 seed weight (20-25 g), and two genotypes had medium 100 seed weight (26-35 g) namely "H 19-16 (27.40) and IG21-06 (27.40).
- For high seed yield per plant, entries "RVG 203 (ch) (26.67g); IPC 2006-77 (ch) (24.67g); Phule G 1314-3-27 (20.00g); NDG 17-6-3 (20.00g)" possessed high yield.

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Table Average monthly meteorological data of Raipur from November 2021 to March 2022

Month	MAXT (°C)	MINT (°C)	Total RF (mm)*	RH I (%)	RH II (%)	VP I (mm)	VP II (mm)	WS (kmph)	EP (mm)	SS (hr)
Nov-21	30.09	18.11	48.60	89.00	47.03	15.35	14.29	3.34	2.95	6.12
Dec-21	27.13	13.20	82.40	88.16	44.26	11.10	11.22	2.81	2.41	4.73
Jan-22	25.51	12.80	18.00	91.32	47.71	10.87	10.80	2.65	2.24	5.97
Feb-22	29.74	13.28	7.00	83.96	31.79	10.76	9.83	1.71	3.64	7.07
Mar-22	36.52	18.59	0.00	72.23	22.42	13.35	9.79	1.42	5.58	7.84

APPENDIX - B

Mean performance of thirty seven genotypes for thirteen yield and yield attributing traits during Rabi 2021-22

S. No.	Code No.	DTF	DM	PH	HOFP	PB	SB	NSP	NPP	BYP	SYP	HI	HSW	PLYG
1	C-21226	49.00	96.67	53.07	31.73	2.80	4.93	1.00	17.80	21.44	48.00	37.27	18.00	382.67
2	C-21227	39.33	90.67	36.07	19.67	4.33	3.27	1.47	16.07	16.22	29.33	41.51	12.00	211.67
3	C-21228	45.67	96.33	39.33	23.73	2.80	4.73	1.67	19.73	13.52	33.33	40.07	14.00	365.00
4	C-21230	41.67	91.00	33.33	16.33	3.73	5.73	1.47	23.47	21.35	44.67	59.42	26.67	292.67
5	C-21232	40.33	86.00	44.87	25.27	2.00	3.27	1.20	18.60	15.14	28.00	51.85	14.67	336.67
6	C-21233	54.33	100.00	37.80	23.53	4.80	5.60	1.13	14.40	27.40	36.00	31.27	10.00	243.33
7	C-21234	55.00	93.00	39.60	25.80	3.00	3.73	1.60	15.00	23.15	39.33	40.68	16.67	302.00
8	C-21235	55.00	99.00	49.73	27.40	4.13	2.87	1.27	20.07	19.83	50.67	37.89	20.00	230.33
9	C-21236	55.33	99.33	39.67	26.00	3.20	5.47	1.40	18.07	17.89	39.33	41.07	15.33	336.00
10	C-21237	37.00	89.00	49.33	23.33	2.27	4.73	1.27	17.73	19.61	35.33	54.43	19.33	395.67
11	C-21239	56.67	101.33	34.20	16.27	3.07	9.53	1.27	28.80	13.51	69.33	36.21	24.67	99.67
12	C-21240	54.00	99.00	37.80	24.80	3.73	5.87	1.07	14.33	24.21	45.33	34.27	16.67	209.00
13	C-21241	42.33	86.33	36.67	19.53	2.33	3.80	1.27	21.07	14.16	32.67	52.84	17.33	333.33
14	C-21243	64.33	100.67	30.67	23.53	4.07	3.60	1.27	3.60	14.35	20.00	31.25	6.00	14.67
15	C-21244	45.67	99.00	48.00	26.73	3.13	4.60	1.00	15.33	27.40	51.33	29.35	16.00	169.67
16	C-21245	63.00	97.00	36.33	25.33	3.67	4.87	1.07	10.00	22.46	48.00	22.06	10.67	110.67
17	C-21246	55.33	95.33	37.47	22.27	2.73	3.60	1.27	15.20	13.56	26.00	44.40	12.00	222.00
18	C-21247	50.33	96.00	35.60	23.33	2.87	3.67	1.40	16.33	21.27	37.33	48.17	18.00	346.33
20	C-21249	55.33	98.00	43.40	30.40	3.07	3.33	1.20	11.47	24.23	37.33	37.75	14.00	310.33

DTF = Days to flowering; DM = Days to maturity; PH = Plant height (cm); HOFP = Height of first pod (cm); PB = Primary branches; SB = Secondary branches; PPP = Pods per plant; SPP = Seeds per pod; HSW = Hundred seed weight (g); BY = Biological yield (g); SYP = Seed yield per plant (g); HI = Harvest index (%); PLYG = Plot yield (g)

Contd...

Mean performance of thirty seven genotypes for thirteen yield and yield attributing traits during Rabi 2021-22

S. No.	Code No.	DTF	DM	PH	HOFP	PB	SB	NSP	NPP	BYP	SYP	HI	HSW	PLYG
21	C-21250	49.00	96.00	34.87	21.60	3.07	3.40	1.20	16.93	14.69	27.33	57.22	14.67	288.00
22	C-21252	41.33	91.00	40.67	22.20	2.33	4.27	1.07	21.20	14.94	28.67	36.94	11.33	267.67
23	C-21253	57.33	100.00	45.07	34.53	2.93	3.87	1.27	7.60	21.45	34.00	21.62	7.33	90.33
24	C-21254	45.67	96.00	42.13	22.87	2.47	3.67	1.20	14.87	23.51	36.00	41.65	15.33	152.33
25	C-21256	56.33	101.67	38.67	27.07	4.20	5.80	1.33	9.40	15.58	47.33	23.25	9.33	42.33
26	C-21257	51.67	100.33	45.53	28.93	2.80	5.47	1.07	13.40	20.67	53.33	25.51	13.33	37.00
27	C-21258	44.33	98.33	40.40	23.27	2.47	2.87	1.33	8.47	25.48	24.67	35.49	8.67	154.33
28	C-21260	55.33	87.67	35.60	25.07	3.33	4.80	1.73	13.27	11.51	22.00	35.18	8.00	142.67
29	C-21261	41.00	88.33	39.13	20.07	3.47	3.07	1.00	20.33	17.06	28.67	44.32	12.67	183.00
30	C-21263	57.67	99.00	41.67	28.33	2.47	3.93	2.07	11.53	14.77	23.33	42.36	10.00	117.33
31	C-21264	60.00	101.67	55.80	40.13	4.47	3.73	1.00	11.60	20.56	37.33	28.21	10.67	174.00
32	C-21265	49.67	99.33	43.53	25.73	3.60	4.87	1.33	16.40	22.02	50.67	37.78	19.33	265.33
33	C-21266	50.67	101.67	42.93	25.00	4.33	5.53	1.13	19.40	20.53	53.33	38.03	20.00	201.67
34	C-21267	60.33	102.00	35.60	19.47	4.27	9.13	1.00	18.67	15.37	51.33	30.92	16.00	43.67
35	C-21268	54.00	97.67	41.20	27.93	4.07	4.33	1.07	13.80	20.74	33.33	44.58	14.67	219.33
36	C-21269	55.33	99.00	54.20	29.60	4.13	6.27	0.93	12.27	19.07	57.33	15.86	11.67	82.67
37	C-21270	55.33	100.33	45.53	30.47	3.47	4.33	1.20	20.60	15.82	39.33	38.57	15.33	175.33
38	C-21271	49.00	96.00	34.87	21.60	3.07	3.40	1.20	16.93	14.69	27.33	57.22	14.67	288.00
Grand Mean		51.36	96.56	41.33	25.31	3.31	4.62	1.25	15.79	18.91	38.56	38.31	14.41	213.35

DTF = Days to flowering; DM = Days to maturity; PH = Plant height (cm); HOFP = Height of first pod (cm); PB = Primary branches; SB = Secondary branches; PPP = Pods per plant; SPP = Seeds per pod; HSW = Hundred seed weight (g); BY = Biological yield (g); SYP = Seed yield per plant (g); HI = Harvest index (%); PLYG = Plot yield (g)

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