

**GENETIC ANALYSIS FOR YIELD AND QUALITY
TRAITS IN AROMATIC GENOTYPES OF RICE (*Oryza
sativa* L.)**

M. Sc. (Ag.) Thesis

By

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RAIPUR (Chhattisgarh)**

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sativa* L.)**

THESIS

SUBMITTED TO THE

INDIRA GANDHI KRISHI VISHWAVIDYALAYA

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BY

Nidhi Paikra

**IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR
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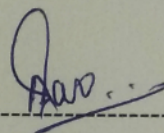
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CERTIFICATE-I

This is to certify that the thesis entitled “**Genetic analysis for yield and quality traits in aromatic genotypes of rice (*Oryza sativa* L.)**” submitted in partial fulfillment of requirements for 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 **Nidhi Paikra** 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 been fully acknowledged. All the assistance and help received during the course of the investigation have been duly acknowledged by her.

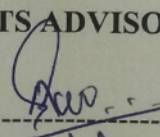
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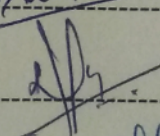
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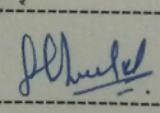
Chairman Dr. Abhinav Sao



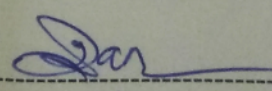
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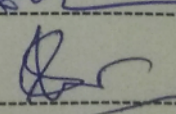
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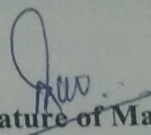
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CERTIFICATE

This is to certify that the thesis Viva-voce in respect of **Ms. Nidhi Paikra** student of **M.Sc. (Ag.) Department of Genetics and Plant Breeding** has been conducted under Chairmanship of Head of Department / Dean (in case of out campus) along with Advisory Committee on 20 - 09 - 2021. The necessary corrections have also been made as per comments / suggestions made by the Advisory Committee and Head of Department / Dean.

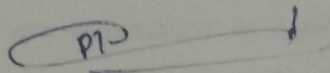
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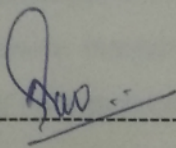
CERTIFICATE-II

This is to certify that the thesis entitled "**Genetic analysis for yield and quality traits in aromatic genotypes of rice (*Oryza sativa* L.)**" submitted by **Nidhi Paikra** to the Indira Gandhi Krishi Vishwavidyalaya, Raipur, in partial fulfilment of the requirements for the degree of **Master of Science in Agriculture** in the **Department of Genetics and Plant Breeding** has been approved by the external evaluator and Student's Advisory Committee after oral examination, under the chairmanship of Head of Department.


Signature of Head of the Department

Date: 20.9.21

Major Advisor



Faculty Dean

Approved / Not approved

Director of Instructions

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Date: 14.08.21


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TABLE OF CONTENTS

Chapters	Title	Page
	ACKNOWLEDGEMENT	i-ii
	TABLE OF CONTENTS	iii-iv
	LIST OF TABLES	v
	LIST OF FIGURES	vi
	LIST OF NOTATIONS	vii
	LIST OF ABBREVIATIONS	viii
	ABSTRACT	ix-xiv
I.	INTRODUCTION	01-04
II.	REVIEW OF LITERATURE	05-13
	2.1 Genetic variability and heritability	05
	2.2 Correlation analysis and Path-coefficient analysis	09
	2.3 Genetic diversity among the aromatic lines.	11
III.	MATERIALS AND METHODS	14-27
	3.1 Experimental site	14
	3.2 Geographical situation	14
	3.3 Experimental materials	14
	3.4 Observations	17
	3.5 Statistical analysis	24
IV.	RESULTS AND DISCUSSION	28-67
	4.1 Assessment of genetic variability	28
	4.2 Character association analysis among yield and yield determinants and Path coefficient analysis of	40

	yield and yield determinant traits	
	4.3 Cluster analysis among the genotypes	61
	4.4 Screening of rice of genotypes for aroma.	66
V.	SUMMARY AND CONCLUSION	68-70
VI.	REFERENCES	71-82
VII.	APPENDIX	83-88
VIII.	RESUME	89

LIST OF TABLES

Table	Title	Page
3.1	List of 51 rice genotypes used in experiment	15
3.2	List of characters undertaken for studies	17
3.3	Classification of Alkali spreading value	22
3.4	Value of Alkali spreading value (ASV)	22
3.5	Interpretation of results gel consistency	23
3.6	Classification of rice genotypes based on amylose content	24
3.7	Skeleton of ANOVA table	24
3.8	Scales for heritability	25
3.9	Classification of GAPM	26
3.10	Scales for path coefficient	27
4.1	Analysis of variance	29
4.2	Parameters of genetic variability of yield and yield component traits	37
4.3	Phenotypic and Genotypic correlation coefficient among different traits	49-50
4.4	Direct (diagonal bold) and indirect effect of various traits on grain yield	59-60
4.5	Cluster pattern of 53 rice genotypes	61
4.6	Inter cluster D ² values and distances among 6 clusters	62
4.7	Cluster mean values of different characters in 51 rice genotypes	65
4.8	Genotypes with their aroma reaction	66
4.9	List of top 10 high yielding genotypes alongwith aroma	67

LIST OF FIGURES

Figure	Title	Page
1	Graphical representation of Meteorological data recorded during crop growth season	16
2	Graphical representation of PCV, GCV, heritability and genetic advance as % mean of different characters	36
3	Direct and indirect effect of yield determinants on grain yield	58
4	Cluster diagram with inter cluster distance	62

LIST OF NOTATIONS / SYMBOLS

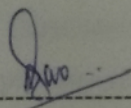
%	:	Percent
*	:	Significance level at 0.055
**	:	Significance level at 0.01
>	:	More than
<	:	Less than
Σ	:	Summation
°c	:	Degree Celsius
Cm	:	Centimetre
<i>et al.</i>	:	and others
G	:	Gram
Ha	:	Hectare
h^2	:	Heritability
i.e.,	:	That is
I ²	:	Iodine
KI	:	Potassium iodide
KOH	:	Potassium hydroxide
mm	:	Millimetre
viz.,	:	For example or such as
via	:	Through

LIST OF ABBREVIATIONS

AC	:	Amylose content
ASV	:	Alkali spreading value
DFP	:	Days to 50 % flowering
DM	:	Days to maturity
ET	:	Number of effective tillers per plant
FSP	:	Number of filled spikelets per panicle
GA	:	Genetic advance
GAM %	:	Genetic advance as percentage of mean
GB	:	Grain breadth
GC	:	Gel consistency
GCV	:	Genotypic coefficient of variation
GL	:	Grain length
GYP	:	Grain yield per plant
HI	:	Harvest index
KB	:	Kernel breadth
KL	:	Kernel length
KLB	:	Kernel length to breadth ratio
LB	:	Length to breadth ratio
PCV	:	Phenotypic coefficient of variation
PH	:	Plant height
PL	:	Panicle length
SPP	:	Number of spikelets per panicle
TT	:	Number of total tillers per plant
UPGMA	:	Un-Weighted Pair Group Method with Arithmetic Mean
USDA		US Department of Agriculture
1000 SW	:	Test weight/1000 seed weight

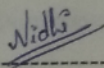
THESIS ABSTRACT

- a) Title of Thesis : Genetic analysis for yield and quality traits in aromatic genotypes of rice (*Oryza sativa* L.)
- b) Name of the Student : Nidhi Paikra
- c) Major Subject : Genetics and Plant Breeding
- d) Name and Address of the Major Advisor : Dr. Abhinav Sao
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- e) Degree to be awarded : M. Sc. (Agriculture) in Genetics and Plant Breeding
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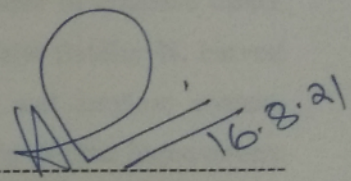


Signature of Major Advisor

Date:
17.08.2021



Signature of the Student



Signature of Head of the Department

Abstract

The present experiment on “Genetic analysis for yield and quality traits in aromatic genotypes of rice (*Oryza sativa* L.)” was conducted at “Research and Instructional Farm, Department of Genetics and Plant Breeding, College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur (Chhattisgarh), during Kharif 2020.” In this programme 51 aromatic rice lines (including 4 checks viz; Chhattishgarh Devbhog, Chhattishgarh Sugandhit Bhog, Dubraj Sel.1, Vishnubhog Sel.1) were used. The study was carried out using a randomised block design with two replications.

The analysis on qualitative and quantitative traits showed the presence of high level of variability except for number of total tillers and flag leaf width. High phenotypic coefficient of variation with genotypic coefficient of variation recorded for yield / plant, after that harvest index, number of filled spikelets / panicle, number of spikelets / panicle, 1000 seed weight, alkali spreading value and number of effective tillers.

Higher heritability with genetic advance as presentage of mean were found for number of filled spikelets / panicle, number of spikelets / panicle, harvest index, 1000 seed weight, alkali spreading value, spikelet fertility %, kernel L:B ratio, length / breadth ratio, kernel length, plant height, head rice recovery percentage, grain length, gel consistency, days to 50 percent flowering, days to maturity, amylose content, flag leaf length, and grain yield per plant these traits are influenced by additive gene action, so selection will be advantageous.

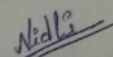
Correlation coefficient revealed yield / plant had a significant and positive genotypic correlation through number of total tillers, number of effective tillers, flag leaf width, number of filled spikelets / panicle, spikelet fertility %, harvest index, kernel breadth, hulling percent, milling percent and amylose content. Selection for these traits may be beneficial in achieving the desired improvement in yield and yield contributing traits. According to the path coefficient analysis, the kernel length / breadth ratio had the greatest direct impact on seed yield per plant, after that kernel breadth, grain length, milling percent, grain length breadth ratio, harvest index, days to 50 percent flowering, number of filled spikelets per panicle, flag leaf width, gel consistency, amylose content, plant height, grain breadth, number of effective tillers / plant and panicle length. Thus, these characters can be used for improvement of grain yield per plant in rice.

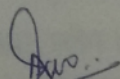
Genetic diversity analysis through cluster analysis was also performed for the 51 genotypes. The genotypes were distributed in 6 clusters on the basis of contribution of different traits. Cluster V comprised the most number of genotypes, i.e., 13. Cluster III and I (287.71) had the greatest inter-cluster distance, hence hybridization among the genotype of these clusters will give good heterotic recombination and transgressive segregants in later generation.

Out of 51 lines, 11 lines were found strongly scented, 13 were mild scented and 27 non- scented. Top yielding genotypes are R 2356-231-2-104-1, R 1771-600-1-308-1, 2356-232-3-105-1, R 2356-218-1-98-1, R 2400-337-1-158-1, R 1771-580-1-298-1, R 2400-340-1-160-1, Luchai, Jau phool, and R 2418-1018-4-454-1. These genotypes can be utilized in future breeding programmes and also they can be directly released as varieties after rigorous multilocation testing.

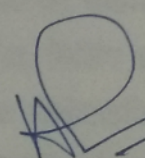
शोध सारांश

- अ. शोध का शीर्षक : चावल (ओराइजा सटाइवा एल.) की सुगंधित लाईनों में उपज और गुणवत्ता लक्षणों के लिए आनुवंशिक विश्लेषण।
- ब. छात्रा का पूरा नाम : निधि पैकरा
- स. प्रमुख विषय : आनुवंशिकी एवं पादप प्रजनन
- द. प्रमुख सलाहकार का नाम और पता : डॉ. अभिनव साव
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कृषि महाविद्यालय, इंदिरा गांधी कृषि विश्वविद्यालय
रायपुर (छ.ग.) 492012
- इ. उपाधि से सम्मानित किया गया : एम. एस. सी. (कृषि), आनुवंशिकी एवं पादप प्रजनन


छात्रा का हस्ताक्षर


प्रमुख सलाहकार के हस्ताक्षर

दिनांक: 17.08.2021


विभाग के प्रमुख का हस्ताक्षर

सारांश

वर्तमान प्रयोग "चावल (ओराइजा सटाइवा एल.) की सुगंधित लाईनों में उपज और गुणवत्ता लक्षणों के लिए आनुवंशिक विश्लेषण" अनुसंधान और निदेशात्मक प्रक्षेत्र, आनुवंशिकी और पादप प्रजनन विभाग, कृषि महाविद्यालय, इंदिरा गांधी कृषि विश्वविद्यालय, रायपुर (छ.ग.) में, खरीफ 2020 के दौरान आयोजित किया गया था। इस कार्यक्रम में 51 सुगंधित चावल की लाइनें (4 चेक किस्में) छत्तीसगढ़ देवभोग, छत्तीसगढ़ सुगंधभोग, दुबराज सेलेक्शन 1, विष्णुभोग सेलेक्शन 1 का उपयोग किया गया था। अध्ययन दो प्रतिकृति के साथ रेन्डमाइज़्ड ब्लॉक डिजाइन का उपयोग करके किया गया था।

गुणात्मक और मात्रात्मक लक्षणों के विश्लेषण ने कुल कंसों की संख्या और फ्लैग लीफ चौड़ाई को छोड़कर उच्चस्तर की परिवर्तन शीलता की उपस्थिति को दिखाया। उपज

प्रति पौधे के लिए दर्ज की गई भिन्नता के जीनोटाइपिक गुणांक के साथ भिन्नता के उच्च फेनोटाइपिक गुणांक, उसके बाद फसल सूचकांक, भरे हुए दाने प्रति पैनिकल की संख्या, दाने प्रति पैनिकल की संख्या, 1000 बीज वजन, क्षार प्रसार मूल्य और प्रभावी टिलर की संख्या के लिए प्राप्त हुआ।

आनुवंशिक प्रगति के साथ उच्च आनुवंशिकता भरे हुए स्पाइकलेट्स प्रति पैनिकल्स की संख्या, दाने प्रति पैनिकल्स की संख्या, हार्वेस्ट इंडेक्स, 1000 बीज वजन, क्षार प्रसार मूल्य, स्पाइकलेट उर्वरता प्रतिशत, कर्नेल लंबाई चौड़ाई अनुपात, लंबाई चौड़ाई अनुपात के लिए, कर्नेल की लंबाई, पौधे की ऊंचाई, हेड राइस रिकवरी (%), अनाज की लंबाई, जेल की स्थिरता, 50 प्रतिशत फूल आने के दिन, परिपक्वता के दिन, एमाइलोज सामग्री, पत्ती की लंबाई, और प्रति पौधे अनाज की उपज के लिए पाए गए, ये लक्षण योज्य जीन क्रिया से प्रभावित होते हैं, इसलिए चयन लाभ प्रद होगा।

सहसंबंध गुणांक से पता चला कि उपज प्रति पौधे का कुल कंसें की संख्या, प्रभावी टिलर की संख्या, फ्लैग लीफ चौड़ाई, भरे हुए दाने प्रति पैनिकल्स की संख्या, स्पाइकलेट उर्वरता प्रतिशत, हार्वेस्ट इंडेक्स, कर्नेल चौड़ाई, हलिंग प्रतिशत, मिलिंग प्रतिशत और एमाइलोज सामग्री के माध्यम से एक महत्वपूर्ण और सकारात्मक जीनोटाइपिक सहसंबंध था। इन लक्षणों के लिए चयन उपज और उपज योगदान लक्षणों में वांछित सुधार प्राप्त करने में फायदेमंद हो सकता है। पथ गुणांक विश्लेषण के अनुसार, कर्नेल की लंबाई चौड़ाई अनुपात का प्रति पौधे बीज उपज पर सबसे अधिक प्रत्यक्ष प्रभाव पड़ता है, उसके बाद कर्नेल की चौड़ाई, अनाज की लंबाई, मिलिंग प्रतिशत, अनाज की लंबाई चौड़ाई अनुपात, फसल सूचकांक, 50 प्रतिशत फूल आने के दिन, भरे हुए दाने प्रति पैनिकल, फ्लैग लीफ चौड़ाई, जेल स्थिरता, एमाइलोज सामग्री, पौधे की ऊंचाई, अनाज की चौड़ाई, प्रभावी टिलर/ पौधे की संख्या और पैनिकल लंबाई का प्रभाव देखा गया। इस प्रकार, इन लक्षणों का उपयोग चावल में प्रति पौधे अनाज की उपज में सुधार के लिए किया जा सकता है।

51 प्रभेदों के लिए क्लस्टर विश्लेषण के माध्यम से आनुवंशिक विविधता विश्लेषण भी किया गया था। विभिन्न लक्षणों के योगदान के आधार पर जीनोटाइप को 6 समूहों में वितरित किया गया था। क्लस्टर V में सबसे अधिक संख्या में जीनोटाइप, यानी 13 शामिल थे। क्लस्टर III और I (287.71) में सबसे बड़ी अंतर – क्लस्टर दूरी थी, इस लिए इन समूहों के

प्रभेदों के बीच संकरण बाद की पीढ़ी में अच्छा विषम पुनर्संयोजन और संक्रमणकारी अलगाव प्रदान करेगा।

51 लाईनों में से 11 अत्यधिक सुगंधित, 13 हल्की सुगंधित और 27 गैर-सुगंधित पाई गईं। शीर्ष उपज देने वाले जीनोटाइप, आर 2356-231-2-104-1, आर 1771-600-1-308-1, 2356-232-3-105-1, आर 2356-218-1-98-1, आर 2400- 337-1-158-1, आर 1771-580-1-298-1, आर 2400-340-1-160-1, लुचई, जौफूल और आर 2418-1018-4-454-1। इन जीनोटाइप का उपयोग भविष्य के प्रजनन कार्यक्रमों में किया जा सकता है और बारंबार बहुस्थानीय परीक्षण के बाद इन्हें सीधे किस्मों के रूप में विमोचित किया जा सकता है।

CHAPTER-I

INTRODUCTION

Rice (*Oryza sativa* L.) is the most important cereal crop in the developing world and the primary source of nutrition for half of the world's population. It is considered as a semi-aquatic annual grass plant. There are approximately 20 recognised *Oryza* species, but nearly all cultivated rice is *O. sativa* L. In Africa, *Oryza glaberrima* a perennial species is grown in small pockets. The most commonly cultivated rice grows to a height of half a metre or two metres, but some varieties grow much taller (6-9 metres).

Rice is a nutritional staple food due to its carbohydrate content, provides instant energy (starch). It is regarded as a complete food due to the presence of low nitrogenous substances, with an average composition of these substances of only 8% and fat content or lipids of only 1%.

The USDA estimates that approximately 500 million tonnes of milled rice were produced globally during the 2019-20 marketing year. This output remains consistent year after year (a 1% increase is predicted in 2020-21). China is the leading producer, accounting for 30% of total output, after that second is India with (24%), Bangladesh (7%), Indonesia (7%), Vietnam (5%), and Thailand (4%). Consumption rankings are similar; China is the largest consumer (29% of global consumption), followed by India (21%), Bangladesh (7%), Indonesia (7%), Vietnam (4%), and the Philippines (3%).

Rice production is an important part of the Indian economy. India is the world's second largest rice producer and the world's largest rice exporter. In the 2020-21 *kharif* season, India produced 102.36 million tonnes of rice. In the 2019-20 crop year, rice produce was 101.98 million tonnes. Rice can be grown in a diverse range of soil and climatic conditions, and it is said that there is almost no soil type that it cannot be grown, including alkaline and acidic soils. Rice crops are also highly adaptable in terms of physical adaptability.

As a result, it is grown below sea level to 2000 metres areas. Rice is grown in India under widely varying altitude and climatic conditions. Rice cultivation in India range from 8 to 35 degrees North latitude and from mean sea level to 3000 metres high. A hot and humid climate is required for rice cultivation. It succeeds in areas with high humidity, long periods of sunlight, and a consistent supply of water. Throughout the crop's life cycle, the average temperature required ranges from 21 to 37 °C. The crop can withstand temperatures ranging from 40 degree Celsius to 42 degree Celsius.

“Chhattisgarh” is famous as “Rice bowl of India” because rice is grown in the maximum land area. Chhattisgarh is one of the largest producers of rice in India, has ideal weather conditions and soil for growing rice. In financial year 2019, rice production across the state of Chhattisgarh in India amounted to over 6 million metric tons. The state has approximately 3.7 million ha of rice cultivation, which is primarily rainfed and covers both uplands and shallow lowlands. The average productivity in the state is around 2.5 tonnes/ha.

Rice is mentioned for the first time in the Yajur Veda (c. 1500-800 BC) and is then frequently mentioned in Sanskrit text. On a global scale, India is the leading producer and exporter of aromatic rice. Aromatic landraces and genotypes exhibit a wide range of genetic diversity. Grain quality (both before and after cooking), fragrance, and flavour are all important factors in consumer preference.

Aromatic rices constitute a small but distinct group of rices that are considered to be of the highest quality. These rices have gained great popularity in the Orient, and they are now gaining popularity in the Middle East, Europe, and the United States. The majority of aromatic rice trade comes from India, Pakistan, and Thailand.

Aroma is an important aspect of rice quality that raises the potential value of rice in international trade. Aromatic rice varieties are becoming increasingly important in global rice trade. Aromatic rice is distinguished from ordinary rice by its flavour, which is regarded as one of the most important factors in market business. Rice grain of aromatic cultivars is characterised by its

unique characteristics and graded as export quality rice with high nutritional value. Consumers are becoming more selective about the rice cultivars they eat. Farmers were motivated to produce higher-quality rice after becoming aware of their quality.

Grain quality is the second most important breeding goal (after yield potential) for the 11 countries that responded to a 1990 survey of national rice programmes (Juliano and Duff, 1991). Since human first cultivated rice, grain quality has most likely been used as a criterion for selection (Juliano and Villareal, 1993).

The existence of variability is important in any breeding programme for effective selection. Genetic parameter degree the quantity of variation found in populace viz., phenotypic coefficient of variation and genetic coefficient of variation. Estimates of heritability offer record approximately a specific genetic characteristic to be passed directly to the successive generations and the breeders select the parents to enhance their crops. Inheritance gives more information on a specific genetic characteristic to be passed directly to successive era and breeder selects the parent for crop. The information extracted from the coefficient by dividing into direct and indirect results through coefficient of path analysis (Kumar *et al.*, 2014).

Rice grain quality can be influenced by variety, environment, and processing. Demand for quality rice is growing rapidly and with the improvement of living standard, it is likely to rise further. Breeding for rice varieties with advanced grain qualities and aroma, is therefore, primary concern of the breeders in many countries.

It is important to understand existing genetic variability, association among yield contributing traits, direct and indirect effect on yield components. Keeping those factors in view, the existing research entitled **“Genetic analysis for yield and quality traits in aromatic genotypes of rice (*Oryza sativa* L.)”** was carried out with the objectives:

- ❖ To estimate genetic variability parameters for yield and quality traits.

- ❖ To estimate association of yield and yield contributing traits.
- ❖ To estimate genetic diversity among the aromatic lines.

CHAPTER II

REVIEW OF LITERATURE

The experimental findings of the current study entitled “**Genetic analysis for yield and quality traits in aromatic genotypes of rice (*Oryza sativa* L.)**” is reviewed for earlier similar reports are following heads:

- ❖ To estimate genetic variability parameters for yield and grain quality traits.
- ❖ To estimate association of yield and yield contributing traits.
- ❖ To estimate genetic diversity among the aromatic lines.

2.1 Genetic variability parameters for yield and quality traits.

The tendency of individual genetic traits in a population to differ from one another is called variability. Genetic enhancement of a trait is difficult without sufficient genetic variability. The prerequisite is the estimation of the genetic variability parameters for yield and quality characteristics.

Karim *et al.* (2007) studied variability and genetic parameter of forty-one genotypes of aromatic rice. There are significant differences; the variance of the phenotype of the trait is greater than the variance of the corresponding genotype. The least difference between phenotypic and genotypic variance was seen in 1000-grain weight and days to maturity, indicating additive gene action for expression of traits. Taking into account the genetic parameters, a high value of the GCV was observed for the 1000 grains weight followed by the spikelet sterility (%), grain yield / hill and no. of filled grains / panicle while very low GCV showed by days to maturity. High heritability was observed with a high G A as a percentage of the mean (GAPM) for 1000 grain weight, followed by the spikelets sterility (%), and the no. of filled grains / panicle indicated that these traits were under additive gene control and selection for improvement could be beneficial.

Mishu *et al.* (2015) carried an experiment and the analysis of the variability parameters showed that the PCV for all traits examined were higher than the GCV. Spikelete per panicle and a thousand seed -weight showed high heritability and effective tillers per hill showed low heritability.

Abebe *et al.* (2017) examined genetic variability, heritability and G A for grain yield and 13 yield related attributes. The presence of genetic variability among the 36 genotypes for every one of the attributes considered. Days to maturity, plant height, raceme length, stem length, flag leaf length, number of filled grain / panicle, number of total spike / panicle, days to heading, biomass yield, grain yield, and harvest index all showed significant genotype-location interactions. With the overall mean, significant variances in grain yield were discovered. Plant height, culm length, number of unfilled grain / panicle, biomass yield, and grain yield all had higher PCV and GCV values, indicating the possibility of improving this trait through selection. Culm length, followed by plant height, biomass yield, and panicle length, had the highest heritability. Plant height, biomass yield, grain yield, and the number of unfilled grains per panicle all showed high to medium heritability, high GCV, and high genetic progress as percent of means. Plant height, culm length, biomass yield, grain yield, and the number of unfilled grains / panicles all showed significant genetic progress as a percentage of the way.

Pragnya *et al.* (2018) assessed plant height, panicle length, percent filled grains per panicle, and test weight all showed moderate GCV and PCV values, whereas seed yield per plant, number of tillers per plant, and number of effective tillers per plant all exhibited high GCV and PCV values. The yield and its segmental features showed significant genotypic differences between genotypes, according to analysis of variance. Plant height, number of tillers per plant, number of productive tillers per plant, percent filled grains per panicle, seed yield per plant, and test weight all showed high heritability and genetic progress as a percentage of mean, demonstrating that plant height, number of tillers per plant, number of productive tillers per plant, percent filled grains per panicle, seed yield per plant, and test weight all showed high heritability and genetic progress as a percentage of mean, demonstrating that additive gene activity was regulating these parameters.

Adhikari *et al.* (2018) conducted study using 26 development genotypes of low land irrigated rice to investigate genotypic and phenotypic variability, heritability, GA and correlation on grain yield and yield associated parameters.

Analysis of variance was used to determine the presence of significant differences for days of blooming, days of maturity, plant height, panicle length, 1000 grain weight, and grain yield. Days to flowering, maturity, 1000-grain weight, and plant height all demonstrated high heritability, showing that they are not genetically manipulated. Grain yield, no. of grains per-panicle, and no. of panicles/m² all displayed high phenotypic variance, while straw yield was medium, and the last traits verified a low genotypic coefficient of variation. When compared to GCV, a high PCV confirmed a natural effect on the assertion of characteristics. Grain yield and days to flowering were both average, but the rest of the features were low genotypic advance as percentage of mean.

Singh *et al.* (2018) observed that GCV and PCV estimations for sterile spikelets / panicle were found to be the highest, followed by grains yield / plot and grain yield / plant. Low amounts of GCV and PCV were found in the canopy temperature depression, followed by chlorophyll content and amylose content, while medium levels of PCV were found in the other features. For the traits panicle weight, grain yield per plant, kernel breadth, kernel L/B ratio, proline content, days to 50 percent flowering, days to first flowering, panicle length, and 1000 grain weight, high GA with high expected GA as percent of mean was observed, followed by days to 50 percent flowering, days to first flowering, panicle length, and 1000 grain weight, kernel length.

Tiwari *et al.* (2019) investigated the variability and correlation coefficients, different quantitative features were calculated. For each attribute studied, there was significant variance among genotypes and locations. For all qualities studied, GCV was lower than PCV. For grain yield, 1000-grain weight, and days to heading, the GCV was somewhat higher. Days to maturity had the highest broad sense heritability, while plant height had the lowest heredity.

Hasan *et al.* (2020) assessed seven advanced lines created through hybridization breeding project and a popular cultivar were utilized to examine variability, heritability, character association, and path coefficient analysis in rice for grain yield and its related agronomic attributes.

Keerthiraj and Biju (2020) determined the PCV and GCV, as well as heritability (broad sense) and genetic gain in lodging and lodging-related variables among selected high-yielding rice varieties from Kerala. There were genotypic differences in yield, lodging, and lodging-related characteristics, as well as differences between PCV and GCV, among all genotypes studied. Seed yield per plant was the highest for each PCV and GCV, followed by panicle weight and tillers per plant. Potassium concentration to panicle weight yield had a high heritability. For each trait, the GA percent of mean assessments was high, especially for lodging percent.

Nath *et al.* (2021) examined 26 different genotypes in order to determine the genetic variation and the ratio-influence ratio of various quantitative traits on the rice seed yield. The genotypes showed a significant variation for each trait. The GCV and PCV were high for the area of the flag leaf, number of spikelets, grain count, specific gravity and grain yield and moderate for the height of the plant, the days to flowering, the no. of panicles and primary branches / panicle. Heredity was high during the days leading up to flowering, the height of the plant and the specific gravity. The G A in % of the mean was extremely high for the specific gravity and the grain yield, moderate for the plant height, the flag leaf area and the no. of grains and low for the fertility of the spikelets (%).

Nanda *et al.* (2021) examined the nature and magnitude of genetic variability for yield and grain quality character, 29 rice genotypes with three checks were studied. An analysis of variance examination revealed a high level of genetic variability among the genotypes. PCV and GCV were high for the number of filled grains per panicle and moderate for flag leaf area, grain yield, 100-grain weight, plant height, and effective tiller number per plant. For the number of filled grains per panicle, flag leaf area, grain yield, and 100-grain weight, there was a high heritability with a high GA percent over mean. The majority of the genotypes had a long-slender grain type with kernel length, L/B Ratio, and amylose concentration, gelatinization temperature, and medium to delicate gel consistency.

2.2 To estimate association of yield and yield contributing traits.

Correlation analysis plays a major role towards successful breeding initiative and has been used by breeders to find out a positive association between yield and other characters that enhance grain yield. Correlation coefficient gives an idea about direction and degree of association of other component traits with that grain yield. However, selection process is also affected by the extent of association among the traits. Galton (1988) had suggested the extent of association between independent and dependent variables and Pearson (1904) elaborated the theory. Correlation is simply the measure of the intensity of the association between any two variables.

Sarawgi *et al.* (1997) reported the number of fertile spikelets / panicles, 100-grain weight, grain breadth, and yield index are all positively connected with rice grain yield. The number of effective tillers per plant, the number of viable spikelets per panicle, the 100 grain weight, grain length, and grain breadth were all directly correlated to the harvest index. Direct selection for the number of fertile spikelets/panicle and harvest index, according to a path coefficient analysis, would probably be viable for enhancing grain yield. A greater harvest index may be influenced by the direct selection of effective tillers per plant, grain yield per plant, 100 grain weight, grain breadth, grain length, and grain thickness.

Reddy *et al.* (2008) determined the relationship between traits and their direct and indirect impacts on seed yield. Grain yield/plant was found to have a positive and large association with the characters panicle length, no. of spikelets / panicle, flag leaf length, flag leaf breadth, biological yield, and harvest index at the genotypic level. There was a highly positive and significant relationship between the number of tillers and the number of panicles / plant.

Bhadru *et al.* (2011) studied 93 rice genotypes, including hybrids and their progenitor lines, were studied. Plant height, productivity per day, full grains per panicle, days of 50% flowering, and panicle weight all had a favourable direct impact on yield, demonstrating a substantial positive correlation with yield at both the phenotypic and genotypic levels. When compared to other features, these traits

contributed the most to higher grain production; as a result, selecting for these traits aids in the identification of superior hybrid rice cross combinations.

Osman *et al.* (2012) reported grain yield was significantly and adversely associated to percent of unfilled grains/panicle in 13 genotypes of upland rice studied. However, it was extremely significant and positively related to panicle length, number of tillers plant-1, number of full grains panicle-1, and thousand grain weight during the course of the two seasons. According to path coefficient analysis, the attributes most directly connected to grain yield tha^{-1} were the number of tillers plant-1, 1000 grain weight, panicle length, and number of filled grains panicle-1.

Ranawake and Amarasinghe (2014) indicated by statistical analysis that grain yield was significantly and highly correlated with no. of fertile spikelets /panicle, panicle weight, no. of spikelets / panicle, filled grain %, no. of fertile tillers / plant, no. of tillers / plant. 100 grain weight and plant height were also correlated with at 1% significant level. None of the considered traits was negatively correlated with the yield.

Naseer *et al.* (2015) based on eight morphological parameters, a research of 24 Asian rice accessions revealed useful results on yield and its components (*Oryza sativa* L.). At the genotypic and phenotypic levels, plant production was significantly and positively linked with filled grains weight / panicle, number of grains / panicle, 1000-grain weight, and spikelet fertility percent. The number of grains per panicle, filled grains weight per panicle, plant height, and 1000-grain weight all exhibited a considerable positive direct effect on yield, according to path coefficient analysis.

Dhurai *et al.* (2016) examined 32 rice genotypes during the *kharif* period of 2009. Grain yield / plant has a positive significant relationship with harvest index, days to maturity, and number of grains / panicle, according to character association analysis. With kernel elongation, kernel length, harvest index, and days to maturity, path analysis demonstrated strong positive direct effects on grain yield.

Afrin *et al.* (2017) examined for the association among yield and its contributory traits, and to pick out traits which will increase yield of submerged conditions. Correlation analysis reveals a significant positive link between yield and total tiller no. plant⁻¹, effective tiller no. plant⁻¹, flag leaf breadth, fresh weight, dry weight, and harvest index. Tiller no. plant⁻¹, panicle length, Unfilled grain panicle⁻¹, fresh weight, dry weight, harvest index, and chlorophyll content were all found to have a direct positive relationship with yield.

Singh *et al.* (2020) conducted experiment and observations were recorded in randomly 5 selected plants for sixteen traits. For 112 rice genotypes, character association and path coefficients for sixteen different yield and yield-contributing parameters were evaluated. The study discovered a significant link between grain yield per plot and biomass yield per plot. Days to first flowering were found to have a substantial relationship with days to 50% flowering and days to maturity. Grain yield / plot was found to be highly influenced by biomass yield / plot, grain yield / plant, grain weight / panicle, grains / panicle, spikelets / panicle, harvest index, days to first flowering, days to 50% flowering, days to maturity, and panicle length, according to path coefficient analysis.

2.3 To estimate genetic diversity among the aromatic lines.

Diversity are often delineated because the degree of differentiation between or among species. Genetic diversity is that the basis for the survival of plants in nature and for the improvement of plants. The diversity of plant genetic resources offers plant breeders the chance to develop new and improved varieties with desirable traits that include farmers as well as farmers preferred traits.

Naik *et al.* (2006) studied 50 aromatic rice accessions, including 5 scented enhanced type, assess the nature and degree of the problem. The D² examination revealed that the sample contains a significant amount of genetic diversity. The fifty genotypes were divided into seven groups. Cluster VI has the highest average grain yield per plant and biological yield per plant. Cluster 3 and cluster 4 had the greatest inter-cluster distance. Cluster 1 and cluster 5 were found

to have the shortest distance. There is a lot of variation in genotypes of different qualities in different clusters.

Pandey *et al.* (2009) grouped genotypes into seven clusters using Mahalanobis D^2 statistics. Plant height, biological yield, and test weight all played a role in the absolute difference, accounting for 86.16 percent of the total.

Sohrabi *et al.* (2012) reported twelve growth characteristics, yield and yield components of fifty rice accessions from Malaysia were examined. As per UPGMA cluster analysis all accessions were clustered into six groups. Twelve morphological traits gave around 77% of total variation among them.

Ovung *et al.* (2012) analyzed Mahalanobis D^2 revealed diversity in materials. The genotypes were classified into 9 clusters. Clusters I and III had the greatest number of genotypes (each 12). Cluster VII genotypes exhibited the most divergence, followed by cluster V and cluster I. Cluster VI and VII had the greatest inter cluster distance, followed by Cluster III and IX, suggesting that the genotypes created in these groupings might be used as parents for future generations.

Kiani (2013) divided into three categories based on cluster analysis of genotypes using Ward's minimum approach and Euclidian distance criterion. In order to generate new high yielding rice lines, observed differences in mean values of agronomic variables suggest the need for conducting crosses between genotypes of clusters II and III and subsequent selection for grains per panicle, filled grains per panicle, and panicles per plant.

Anjali *et al.* (2014) studied divergence including Basmati and aromatic short grain varieties, and found significant differences in yield, yield components, and grain quality parameters among the genotypes. Because of the relative size of D^2 values, the genotypes were divided into eight groups for divergence analysis using both Tocher's and Euclidian approaches. Cluster IV was the largest, with 12 genotypes, whereas Cluster VIII had only one genotype.

Tuhina *et al.* (2015) conducted study with 43 genotypes in a RCBD, with 3 replications. All genotypes showed large and significant variation in 22 traits. Based on the cluster analysis of 22 traits, 43 rice genotypes were divided into five clusters. The larger one consists of 20 genotypes, most of which are from the Philippines. The first four components of 22 traits accounted for about 72% of the total variability, and showed large differences between genotypes.

Chopkar and Sarawgi (2017) reported the divergence analysis of 81 aromatic rice germplasms from different regions of Chhattisgarh was carried out. For 16 agromorphological and quality characters, observations were made on five randomly chosen plants. D^2 estimates 81 genotypes, which were split into nine clusters based on their relative magnitude. Cluster mean showed a wide range of variation for each character. Cluster II genotypes with desired mean values for quality characters such as hulling, processing, head rice recovery percent, and panicle length; cluster VII genotypes with high kernel length and length breadth ratio; and cluster V genotypes with high earliness and yield could be used in hybridization to create a high yielding, early developing aromatic rice variety.

Ranjith *et al.* (2018) reported that material had a lot of diversity, according to the Mahalanobis D^2 analysis. Six clusters were formed from the genotypes. Cluster I has the greatest number of genotypes (19). Cluster II genotypes exhibited the highest degree of divergence. Cluster II and V had the greatest inter cluster distance, followed by Cluster III and V, indicating that the genotypes in these clusters could be used as parents in a future hybridization experiment. Genetic divergence was influenced by traits such as plant height, viable grains, panicle length, and plot yield.

Shoba *et al.* (2019) conducted study with 43 genotypes in a RCBD, with 3 replications. All genotypes showed large and significant variation in 22 traits. Based on the cluster analysis of 22 traits, 43 rice genotypes were divided into 5 clusters. The larger one consists of 20 genotypes, most of which are from the Philippines. The first 4 components of 22 traits accounted for about 72% of the total variability, and showed large differences between genotypes.

CHAPTER- III

MATERIALS AND METHODS

The present study entitled “**Genetic analysis for yield and quality traits in aromatic genotypes of rice (*Oryza sativa* L.)**” was undertaken to study 51 entries, during *kharif* -2020. The procedure, material and method used in research are given below:-

3.1 Experimental site

The research work was carried out at Research cum Instructional Farm, Department of Genetics and Plant Breeding, College of Agriculture, Indira Gandhi Krishi Vishwavidalaya, Raipur, (C.G.), India. The quality parameters were estimated in Crop Quality Lab Dr. Richharia Rice Laboratory Research, IGKV, Raipur, Dept. of Genetics and Plant Breeding.

3.2 Geographical situation

Chhattisgarh is situated between 17°.14’ and 24°.45’ N latitude and 79.16 and 84°.15’ E latitude, at a height of 289.60 meters above mean sea level. Raipur is the capital of Chhattisgarh. It is located between the latitudes of 22° 33’ N and 21° 14’ N, and the longitudes of 82° 6’ to 81° 38’ E.

3.3 Material used in the experiment

Fifty one aromatic rice with four checks particularly Chhattisgarh Devbhog, Chhattisgarh Sugandhit Bhog, Dubraj Sel.1, Vishnubhog Sel.1 were taken. In *kharif*, 2020 all the fifty one aromatic rice genotype were raised as a seedling in nursery bed. The genotypes utilized in this study are listed below in Table 3.1:

Table 3.1: Experimental material used in the study

S. No.	Entry	S. No	Entry
1	R 2348-201-1-91-1	27	R 2417-927-1-404-1
2	R 2356-218-1-97-1	28	R 2417-935-1-406-1
3	R 2356-218-1-98-1	29	R 2417-936-1-407-1
4	R 2356-219-1-99-1	30	R 2418-1018-4-454-1
5	R 2356-231-2-104-1	31	R 2418-1034-1-480-1
6	2356-232-3-105-1	32	R 2418-1034-2-481-1
7	R 2356-236-1-106-1	33	R 2419-1066-1-506-1
8	2299-319-1-144-1	34	R 24151-1286-1-638-1
9	R 2306-329-1-152-1	35	CG Devbhog (check)
10	R 2397-335-1-157-1	36	CG Sugandhit Bhog (check)
11	R 2400-337-1-158-1	37	Dubraj Sel.1 (check)
12	R 2400-340-1-160-1	38	Vishnubhog (check)
13	R 1771-580-1-298-1	39	Improved Kankadiya
14	R 1771-583-2-300-1	40	Improved khuddi
15	R 1771-589-1-303-1	41	Improved Shrikamal
16	R 1771-593-1-304-1	42	R.K.M
17	R 1771-595-1-306-1	43	Luchai
18	R 1771-600-1-308-1	44	Umari
19	R 1771-602-1-309-1	45	Mokdo
20	R 1771-64-1-312-1	46	M 0: 8 (Aruna)
21	R 1771-635-1-313-1	47	M 0: 19 (Krishnajana)
22	R 2413-791-1-1-354-1	48	Jau phool
23	R 2413-802-1-358-1	49	Jaigundi
24	R 2413-803-360-1	50	Funderi
25	R 2413-808-1-361-1	51	R-FS-2019-3
26	R 2417-915-1-399-1		

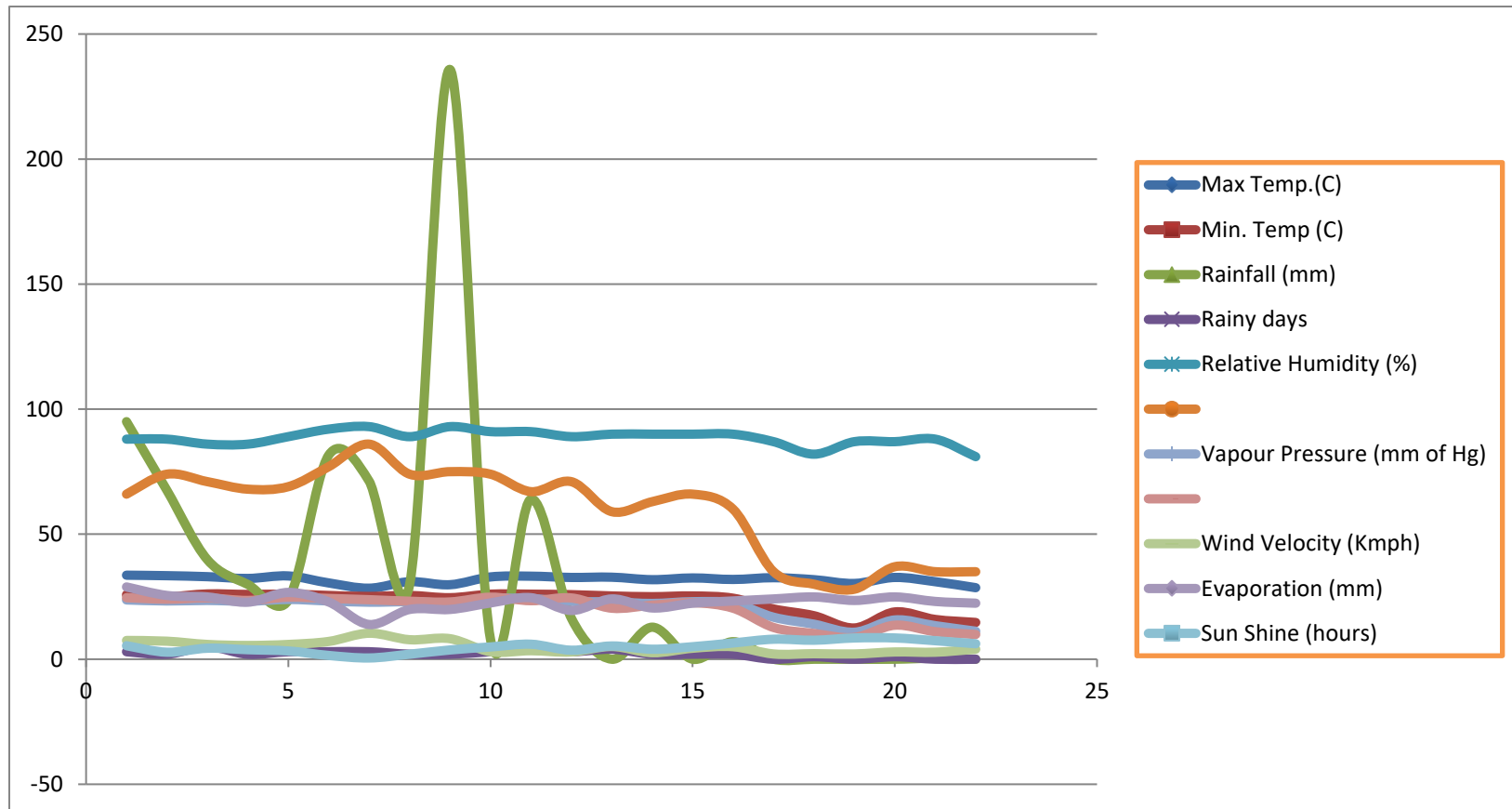


Fig-1 Meteorological data recorded during crop growth season

3.4 Observations recorded:

The observations were recorded in field conditions and in the laboratory and mean values were calculated for statistical data analysis. Five randomly selected plants were taken per replication per plot for recording data. The observation data were recorded during crop growth period for each character.

Table -3.2 The observations were recorded

S. No.	Quantitative characters	S. No.	Qualitative characters
1	Days of 50% flowering	13	Grain length (mm)
2	Days of maturity	14	Grain breadth (mm)
3	Plant height (cm)	15	Kernel length (mm)
4	Effective tillers per plant	16	Kernel breadth (mm)
5	Panicle length (cm)	17	L: B ratio
6	No. of spikelets per panicle	18	Aroma test
7	No of filled spikelets per panicle	19	Hulling %
8	Spikelet fertility %	20	Milling %
9	Flag leaf length (cm)	21	Head rice recovery %
10	Grain yield per plant (g)	22	Alkali Spreading Value
11	1000 seed weight (g)		
12	Harvest index (%)		

3.4.1 Quantitative traits

3.4.1.1 Days to 50 % flowering:

The days up to 50% flowering time are recorded on which the seeds sown up to 50 % panicle emergence.

3.4.1.2 Days to maturity (days):

The maturity was determined in the maturity stage by visual assessment of the group of plants, i.e. when the terminal spikelets are matured.

3.4.1.3 Plant height (cm):

The height of the plant was measured in centimeters (cm) from the soil surface to the tip of the tallest panicle.

3.4.1.4 No. of effective tillers:

The no. of effective tillers / plant were counted for each 5 plants selected at random.

3.4.1.5 No. of total tillers:

The no. of total tillers/ plant were counted for each 5 plants selected at random.

3.4.1.6 Panicle length (cm):

The length of the terminal panicles formed on each tiller was measured from five randomly selected plants.

3.4.1.7 No. of spikelets / panicle:

Spikelet / panicle counted in 5 randomly selected plants.

3.4.1.8 No. of filled spikelets / panicle:

Filled spikelet / panicle was counted in 5 randomly selected plant.

3.4.1.9 Spikelet fertility %:

The ratio of total no. of filled spikelets produced in a single panicle to the total no. of spikelets in a single panicle has been worked out to calculate the spikelet fertility %. The formula used can be expressed as follows:

$$\text{Spikelet fertility \%} = \frac{\text{Total no. of filled spikelets/panicle}}{\text{Total no.of spikelets/panicle(filled+unfilled)}} \times 100$$

3.4.1.10 Flag leaf length (cm):

The length of the flag leaf was measured in centimeters (cm).

3.4.1.11 Flag leaf width (cm):

The width of the flag leaf was measured in centimeters (cm).

3.4.1.12 Grain yield per plant (GYP) (g):

Harvested crop were sun dried for 5 - 8 days and weight of each 5 plant except root was recorded in grams (gm).

3.4.1.13 1000 seed weight (gm):

Randomly 1000 seed are taken from each of the entry and weighed in gram (gm).

3.4.1.14 Harvest index (%):

Harvest index was determined as the ratio of grain yield (economic yield) to biological yield and the ratio of grain yield and biological yield are expressed in %.

3.4.2 Grain quality traits

Quality related traits which were observed is mentioned below:

3.4.2.1 Grain length (mm):

10 milled rice grain was aligned longitudinally lengthwise and the length was measured by measuring scale. The resulted value is then divided by 10 to determine the actual individual length.

3.4.2.2 Grain breadth (mm):

10 milled rice grain aligned breadth wise followed by measuring horizontal breadth. The resulted value is then divided by 10 to get the actual individual kernel breadth.

3.4.2.3 L/B ratio:

Grain length breadth ratio was calculated by simply dividing the average length of 10 grain to average breadth of the 10 rice grain.

3.4.2.4 Kernel length (mm):

After milling 10 whole kernels were randomly selected and average length was measured.

3.4.2.5 Kernel breadth (mm):

Breadth was measured in the same way by taking 10 whole milled kernels.

3.4.2.6 Kernel length breadth ratio:

The kernel length to breadth ratio of the rice kernel ratio was calculated by simply dividing the average length of kernel to average breadth of the rice kernel.

3.4.2.7 Aroma in leaf:

The fragrance of the leaf was measured at the pre-Tillage stage.

- 10 ml of 1.7 per cent KOH solution has been applied to a small Petri dish consisting of approximately 2 g finely minced green leaf or stem sample.
- After adding alkali sample immediately protected, and left for about 10 minutes at room temperature.
- Then the plates are opened and contents smelled.
- The samples that contain the aroma produce a strong and readily identifiable aroma i.e. marked as, SS = Strongly Scented; MS = Mild Scented; NS = Non Scented.

3.4.2.8 Hulling %:

- Measuring minimum 100 g of the sample after all foreign matter was separated from the sample.
- Dehusk sample with the Stake Sheller.
- The weight of the de-hulled grains of the sample was measured after hulling.

- Percentage is determined by following formula :-

$$\text{Hulling \%} = \frac{\text{Weight of dehusked kernel (g)}}{\text{Weight of paddy}} \times 100$$

3.4.2.9 Milling %:

- Dehusked Samples were milled.
- The weight of milled grains was estimated by using the formula :

$$\text{Milling \%} = \frac{\text{Weight of polished kernel (g)}}{\text{Weight of paddy}} \times 100$$

3.4.2.10 Head rice recovery (%):

- The polished kernels were passed through rice graders with specific (mm) grooves.
- Distinguish the whole grains from the broken ones, depending on the size of the grains.
- For the recovery of head rice the whole grains and 3/4th grains are considered and weighed.
- And determined by using the formula -

$$\text{Head rice recovery \%} = \frac{\text{Weight of total milled rice}}{\text{Weight of rough rice}} \times 100$$

3.4.2.11 Alkali spreading value (ASV):

The protocol given by Jennings *et al.* (1979) was followed to assess the alkali spreading values.

The method is comprised of:

1. Select 6 milled rice kernels without cracks and put them in petridishes.
2. Add 10 ml of 1.7 percent KOH to the sample.
3. Put uniformly in petridishes, allowing enough room to spread.
4. Keep petridish fully coated and undisturbed in an incubator at of 27- 30° C for 23 hours.
5. Visually endosperm disintegration was graded according to the following scale.

Table 3.3- Classification of Alkali spreading value

Score	Spreading
1	Kernel not affected
2	Kernel swollen
3	Kernel swollen, collar incomplete and narrow
4	Kernel swollen, collar complete and wide
5	Kernel split or segmented, collar complete and wide
6	Kernel dispersed, merging with collar
7	All kernel dispersed and inter mingled

Table-3.4 Value of Alkali spreading value (ASV)

Classification	Alkali spreading value (ASV)
1-2	Low
3	Low, intermediate
4-5	Intermediate
6-7	High

3.4.2.12 Gel consistency:

All samples are kept for at least 2 days in the same room so that the moisture content is equal.

- Place some milled grains in the wig 1-bug amalgamator, and grind to obtained flour.
- Add flour of 100 mg in culture tube.
- Add 0.25 percent blue thymol with 0.2 ml of ethanol.
- Add 2.0 ml of KOH of 0.2 N.
- Protect the mouth of test tubes using aluminum foil.
- Mix solution properly on cyclone mixer.
- Keep the test tubes in the water bath for 8 minutes at 90-100°C.
- Then cool down for 5 minutes after removing the culture tubes from the water bath.
- Mix the solution.

- Put the tubes in low temperature bath for 20 minutes at 0-20 C.
- The culture tubes are removed from the Ice bath and laid horizontally over graph paper for one hour.
- Length of the gel from the inside bottom of the test tube to the gel front was then measured as gel consistency of the sample.

Table 3.5 Interpretation of results

Range	Consistency
26-40 mm	Hard gel consistency
41-60 mm	Medium gel consistency
61-100 mm	Soft gel consistency

3.4.2.13 Amylose content:

- All samples to be used have been stored in the same room for at least 2 days for equal moisture content.
- Grind the samples to a fine powder in a Wig –L-Bug amalgamator or similar device.
- Take 100 mg rice flour in test tube add 1 ml of rectified spirit and add 9 ml of 1.0 N sodium hydroxide.
- Shake thoroughly and heat test tube on water bath for 15 min.
- Pour sample after digestion in a volumetric flask rinsed 2 with hot distilled water and latter make up to the sample to 100 ml.
- Draw 5 ml solution in 3 replications into three 100 ml volumetric flasks.
- For each 5 ml solutions add 1 ml of acetic acid and 2 ml of I₂-KI reagent and make it to 100 ml a volumetric flask.
- Cover the all flasks with black cloths as I₂-KI looses colour when exposed to light.
- Adjust the spectrophotometer for 620 nm and take the readings.

Table-3.6 Classification of rice based on amylose content %, (Kumar and Khush, 1986)

Amylose content %	Classes	Remarks
0-2	Waxy	Not desirable
3-9	Very low	Not desirable
10-19	Low	Not desirable
20-25	Intermediate	Desirable
> 25	High	Not desirable

3.5 Statistical analysis:

The data recorded on grain yield and their attributing characters were subjected to statistical analysis by using statistical software packages like Plant Breeding Tools.

3.5.1 Assessment of variability:

3.5.1.1 Analysis of Variance (ANOVA)

Table – 3.7 Skeleton of ANOVA table for Randomized Block Design

Source of variance	Degree of freedom	Mean sum of square	Expected mean sum of square	(F) calculated
Replication	$(r-1) = 1$	MSR	$T\sigma^2_r$	MSR/MSE
Treatment	$(t-1) = 50$	MST	$R\sigma^2_t$	MST/MSE
Error	$(r-1)(t-1) = 50$	MSE	σ^2_e	
Total	$(r \ t-1) = 101$			

3.5.1.2 Range

The range of distribution was expressed by the difference between largest and smallest value of observations.

Range = largest value – smallest value

3.5.1.3 Mean

It can be calculated as:

$$\bar{X} = \frac{\sum X_i}{N}$$

ΣX_i = Sum of all observation

N = Number of observation

3.5.1.4 Genotypic coefficient of variation (GCV %)

$$\text{GCV (\%)} = \sigma^2_g / \bar{X} \times 100$$

Where,

GCV (%) = Genotypic coefficient of variation

σ^2_g = Genotypic variance

$\bar{X}$ = Mean of the character

3.5.1.5 Phenotypic coefficient of variation (PCV %)

$$\text{PCV (\%)} = \sigma^2_p / \bar{X} \times 100$$

Where,

PCV (%) = Phenotypic coefficient of variation

σ^2_p = Phenotypic variance

$\bar{X}$ = Mean of the character

3.5.1.6 Heritability

Heritability is the ratio of variation due to difference between genotypic to the phenotypic variation for a character or a trait in a population.

$$H^2 = \sigma^2_g / \sigma^2_p \times 100$$

Where,

σ^2_g = Genotypic variance

σ^2_p = Phenotypic variance

Table 3.8 As suggested by Johnson *et al.* (1955) heritability values are categorized as-

State	Heritability
Low	(<30%)
Moderate	(30 - 60%)
High	(>60)

3.5.1.7 Genetic advance (GA)

Enhancement of mean phenotypic value of elected plants over the parental population is called as genetic advance.

The expected genetic advance was estimated by using formula:

$$GA = K \cdot \sigma_p \cdot h^2$$

Where,

GA = Genetic advance under selection

k = Selection differential (value of k at 5% selection intensity is 2.06)

σ_p = Phenotypic standard deviation

h^2 = Heritability value of the character

3.5.1.8 Genetic advance as % of mean

Expected genetic advance (GA) was estimated by method recommended by Johnson *et al.* (1955) given in table-3.9. It is the ratio of genetic advance to the grand mean and is expressed in percent.

Formula:

$$GA \text{ as percentage of mean} = \frac{\text{Genetic Advance}}{\text{General mean}} \times 100$$

Table-3.9 Classification of GAM % as suggested by Johnson *et al.* (1955)

Value for GAM (%)	Scale
> 20	High
10- 20	Moderate
< 10	Low

3.5.2 Correlation analysis

Comparison of measured value with r value was conducted at 5 per cent and 1 per cent meaning level with n-2 degree of freedom to carry out the study where 'n' refers to number of pairs of observations.

3.5.3 Path coefficient analysis

Dewey and Lu (1959) pioneered the analysis of plant selection pathways and developed Wright in 1921; they assessed the direct and indirect effects of independent variables on dependent variables. The analysis results of path coefficient are refined according to the following scale recommended by Lenka and Mishra (1973) below in table 3.10.

Table - 3.10 Interpretation of results

Rate	Effect of direct and indirect value
Negligible	0.00 to 0.09
Low	0.10 to 0.19
Moderate	0.20 to 0.29
High	0.30 to 0.99
Very high	>1.00

3.5.4 Genetic diversity analysis

PC Mahalanobis developed the D^2 statistics in 1936. Rao (1952) suggested using this method to assess genetic differences between populations. According to the standard procedure described by Spark (1973), genotypes are grouped into a series of clusters.

CHAPTER IV

RESULT AND DISCUSSION

The experimental results obtained from the study on "**Genetic analysis for yield and quality traits in aromatic genotypes of rice (*Oryza sativa* L.)**" are presented below:

- 4.1 Assessment of variability
- 4.2 Association analysis for yield and related traits
- 4.3 Study of genetic diversity for yield and grain quality traits
- 4.4 Screening of rice genotypes for aroma

4.1 Assessment of variability

4.1.1 Analysis of variance

The analysis of variance for yield and yield attributing traits of aromatic lines of rice presented in Table 4.1. The genotypes differed highly significantly, according to the analysis of variance at $p < 0.01$ for days to 50 % flowering, days to maturity, plant height, panicle length, no. of spikelets / panicle, no. of filled spikelets / panicle, spikelet fertility %, 1000 seed weight, grain length, grain breadth, length breadth ratio, kernel length, kernel breadth, kernel length / breadth ratio, hulling %, milling %, and alkali spreading value. No. of effective tillers, flag leaf length, harvest index, yield / plant, head rice recovery %, amylose content, and gel consistency at $p < 0.05$. In addition, no. of total tillers and flag leaf width were non-significant, suggesting that their variability is solely due to genetic architecture.

Table 4.1 Analysis of variance (ANOVA) for different yield and grain quality traits.

S. No.	Traits	Sources of Variance		
		Replication	Treatment	Error
		d.f. (1)	d.f. (50)	d.f. (50)
1	DFF	1.66	333.23 ^{**}	0.58
2	DM	2.21	430.81 ^{**}	0.85
3	PH	45.07	1051.64 ^{**}	52.12
4	PL	0.01	13.12 ^{**}	1.57
5	TT	17.29	5.74	1.95
6	ET	42.71	7.027 [*]	1.65
7	FLL	207.27	80.05 [*]	15.51
8	FLW	0.002	0.07	0.02
9	SPP	357.66	9864.58 ^{**}	532.56
10	FSP	830.21	5615.90 ^{**}	391.37
11	SF%	21.11	404.66 ^{**}	25.17
12	HI	582.73	115.74 [*]	23.87
13	1000 SW	1.23	42.06 ^{**}	2.29
14	GYP	85.53	55.38 [*]	10.67
15	GL	0.09	2.88 ^{**}	0.18
16	GB	0.40	0.11 ^{**}	0.01
17	L:B Ratio	0.79	0.97 ^{**}	0.10
18	KL	0.07	1.21 ^{**}	0.003
19	KB	0.03	0.06 ^{**}	0.004
20	K L:B	234.33	40.16 ^{**}	2.92
21	H%	129.21	96.87 ^{**}	0.27
22	M%	2.21	2.45 ^{**}	0.13
23	HRR	0.19	10.17 [*]	2.35
24	ASV	74.21	34.71 ^{**}	0.69
25	A C	85.53	55.37 [*]	10.67
26	G C	2.3	2.59 [*]	0.27

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

DFF = Days to 50 % flowering; DM = Days to maturity; PH = Plant height; PL= Panicle length; TT = Total tillers; ET= Effective tillers; FLL= Flag leaf length; FLW = Flag leaf width; FPP = Filled spikelets per panicle; SSP = Spikelets per panicle; SF% = Spikelet fertility %; HI = Harvest index; 1000 SW = 1000 seed weight; Y/P = Yield per plant; GL = Grain length; GB = Grain breadth; L:B ratio = Length breadth ratio; KL = Kernel length; KB = Kernel breadth; K L:B = Kernel length breadth ratio; H% = Hulling %; M% = Milling %; HRR= Head rice recovery %; ASV = Alkali spreading value; AC = Amylose content; GC = Gel consistency.

4.1.2 Mean performance of yield related traits

Reported and listed mean value of various genotypes of aromatic rice in Appendix- II.

4.1.2.1 Days to 50 % flowering

Days to 50 % flowering range varied from 76 to 128 days with mean performance of 102 days. Minimum days to 50 % flowering for R 2413-808-1-361-1 (76 days) and maximum was noted for R 1771-635-1-313-1 (128 days).

4.1.2.2 Plant height (cm)

Plant height range varied from 88 cm to 189.05 cm with mean performance of 146.81 cm. Minimum plant height recorded for R.K.M. (87.85 cm) and maximum for Funderi (189.05 cm).

4.1.2.3 Days to maturity

Days to maturity varied from 102 to 157 with mean performance of 131 days. The minimum days of maturity noted for R 2413-808-1-361-1 (102 days) and maximum day to maturity was noted for R 1771-635-1-313-1 (157 days).

4.1.2.4 No. of total tillers

No. of total tillers range varied from 5.5 to 12.5 with mean 9.04 tillers. Minimum no. of total tillers recorded in R 2413-803-360-1 (5.5) and maximum no. of total tillers were recorded in R 2400-337-1-158-1 (12.5).

4.1.2.5 No. of effective tillers

No. of effective tillers range varied from 3.5 to 11.5 with mean 7.77 tillers. Minimum effective tillers noted in R 2413-803-360-1 (3.5) and maximum effective tillers noted in R 2400-337-1-158-1 (11.5).

4.1.2.6 Panicle length (cm)

Panicle length range varied from 20.5 cm to 32 cm with mean 25.223 cm panicle length. Minimum panicle length noted in Dubraj Sel.1 (check) (20.5 cm) and maximum panicle length noted in R 1771-583-2-300-1 (32 cm).

4.1.2.7 No. of spikelets / panicle

No. of spikelets / panicle ranged from 83.5 to 540.5 with mean 201.60. Minimum no. of spikelets / panicle noted in R.K.M. (83.5) and maximum no. of spikelets / panicle was noted in R 1771-580-1-298-1 (540.5).

4.1.2.8 No. of filled spikelets / panicle

No. of filled spikelets / panicle range varied from 45.5 to 300.5 with mean 145.64. Minimum no. of filled spikelets / panicle noted in R 2413-791-1-1-354-1 (45.5) and maximum no. of filled spikelets / panicle noted in R 1771-580-1-298-1 (300.5).

4.1.2.9 Spikelet fertility %

The range for spikelet fertility varied from 24.95% to 89.75% with mean performance 72.57%. Minimum value is R 2417-935-1-406-1 (24.95%) and maximum value for spikelet fertility % noted in Dubraj Sel.1 (check) (89.75%).

4.1.2.10 Flag leaf length (cm)

Flag leaf length range varied from 21.75 cm to 49.25 cm with mean 34.789 cm. Minimum flag leaf length noted in R.K.M (21.75cm) and maximum flag leaf length noted in R 2417-935-1-406-1 (49.25cm).

4.1.2.11 Flag leaf width (cm)

The range for flag leaf width varied from 1.1 cm to 1.95 cm with mean 1.47 cm. Minimum flag leaf length noted in Jau phool (1.1 cm) and maximum flag leaf width noted in R 1771-580-1-298-1 (2.0 cm).

4.1.2.12 Grain length (mm)

Grain length range varied from 5.3 mm to 10 mm with mean 7.80 mm. Minimum grain length noted in R 1771-635-1-313-1 (5.3 mm) and maximum grain length noted in R 2417-935-1-406-1 (10 mm).

4.1.2.13 Grain breadth (mm)

Grain width range varied from 1.65 mm to 2.75 mm with mean 2.30 mm. Minimum grain breadth noted in R-FS-2019-3 (1.7 mm) and maximum grain breadth noted in R 2348-201-1-91-1 (2.75 mm).

4.1.2.14 L : B ratio

L/B ratio range varied from 2.2 mm to 5.5 mm with mean 3.459 mm. Minimum L:B ratio noted in R 1771-635-1-313-1 (2.2 mm) and maximum L:B ratio noted in R 2397-335-1-157-1 (5.5 mm).

4.1.2.15 Harvest index (%)

The range for Harvest Index varied from 4.75 % to 34.35 % with mean 17.89 %. Minimum harvest index noted in R 1771-593-1-304-1 (4.75 %) and maximum harvesting index noted in R 1771-602-1-309-1 (34.35 %).

4.1.2.16 1000 seed weight (g)

The range for 1000 seed weight varied from 7.4 g to 28.3 g with mean 16.92 g. Minimum 1000 seed weight noted in Jau phool (7.4 g) and maximum 1000 seed weight noted (test weight) in M 0: 8 (Aruna) (28.3 g).

4.1.2.17 Grain yield / plant (g)

Grain yield / plant range varied from 2.1 g to 22.2 g with mean 9.94 g. Minimum grain yield / plant found in Improved Shrikamal (2.1 g) and maximum grain yield / plant found in R 2348-201-1-91-1 (22.2 g).

4.1.2.18 Hulling %

The range for hulling % varied from 60.1 % to 82.15 % with mean 73.40 %. Minimum hulling % recorded in R 2418-1034-2-481-1 (60.1 %) and maximum hulling % is noted in R 2306-329-1-152-1 (82.15 %).

4.1.2.19 Milling %

The range for milling % varied from 48.7 % to 76 % with mean 66.25 %. Minimum milling % noted in Kalikamod (48.7 %) and maximum milling % noted in Tilkasturi (76 %).

4.1.2.20 Head rice recovery %

The range for head rice recovery % varied from 37.2 % to 64.7 % with mean 49.21. Minimum head rice recovery % noted in R 1771-589-1-303-1 (37.2 %) and maximum head rice recovery % noted in R 2306-329-1-152-1 (64.7 %).

4.1.2.21 Kernel length (mm)

The range for kernel length varied from 3.4 mm to 6.75 mm with mean 5.343. Minimum value for kernel length noted in R 1771-635-1-313-1 (3.4 mm) and maximum value kernel length noted in R 2306-329-1-152-1 (6.75 mm).

4.1.2.22 Kernel breadth (mm)

The range for kernel breadth varied from 1.35 mm to 2.25 mm with mean 1.84. Minimum kernel breadth noted in R-FS-2019-3 (1.35 mm) and maximum kernel breadth noted in R 2417-936-1-407-1 (2.3 mm).

4.1.2.23 Kernel L:B ratio

The range for kernel L/B ratio varied from 1.75 to 3.9 with mean 2.94. Minimum kernel L/B ratio noted in R 1771-635-1-313-1 (1.75) and maximum kernel L/B ratio noted in R 2419-1066-1-506-1 (3.9).

4.1.2.24 Alkali spreading value (ASV)

The range for ASV varied from 3 to 6.5 with mean 4.42. Minimum ASV value noted in R 2348-201-1-91-1, R 2356-218-1-98-1, R 2356-219-1-99-1, R 1771-600-1-308-1, R 1771-64-1-312-1, R 2417-935-1-406-1, R 24151-1286-1-638-1, CG Devbhog (check), CG Sugandhit Bhog (check), Vishnubhog (check), Improved Shrikamal, M 0: 8 (Aruna), Funderi (3) and maximum ASV value noted in R 2397-335-1-157-1, R 2413-803-360-1, R 2413-808-1-361-1, R 2417-915-1-399-1 (6.5).

4.1.2.25 Amylose content

The range for amylose content varied from 17.25 to 27.75 with mean 22.44. Minimum value for amylose content noted in R 2417-915-1-399-1 (17.25) and maximum value for amylose content noted in R 2306-329-1-152-1 (27.75).

4.1.2.26 Gel consistency

The range for gel consistency varied from 24.5 to 46.5 with mean 28.91. Minimum gel consistency noted in R 1771-64-1-312-1 (24.5) and maximum gel consistency noted in R 2356-218-1-97-1 (46.5).

4.1.3 The phenotypic and genotypic coefficients of variation

The result of PCV and GCV analysis are presented in Table-4.2 and Fig-2. For all of the characters, the PCV value was higher than the GCV value, indicating a strong environmental impact on the expression of the characters. The PCV and GCV ranged from (6.32% and 5.88 %) for hulling % to (57.79 % and 47.55 %) for yield / plant respectively.

Observed high PCV and GCV for grain yield / plant (57.79 %) and (47.55 %), followed by harvest index (46.71 % and 37.89 %), no. of filled spikelets / panicle (37.63 % and 35.09 %), no. of spikelets / panicle (35.77 % and 33.88%), 1000 seed weight (27.83% and 26.36 %), ASV (25.65 %and 24.37 %) and number of effective tillers (26.82 % and 21.22 %). This suggested that the genotypes used in the research have a broad genetic base, indicating the likelihood of genetic

change by selection for these traits. Similar findings by Nath and Kole (2021) for yield / plant, 1000 seed weight, spikelets / panicle , for spikelets / panicle by Saha *et al.* (2019) and for yield / plant by Bhati *et al.* (2015), Mamata *et al.*(2018) and Keerthiraj *et al.* (2020).

High PCV with moderate GCV for no. of total tillers / plant (21.69 % and 15.22 %), L / B ratio (21.18 % and 19.05 %) , spikelet fertility % (20.20 % and 17.33 %).

Moderate values of PCV with GCV for flag leaf length (19.87 % and 16.33 %), kernel L/B ratio (17.81 % and 17.33 %), plant height (16.00 % and 15.23 %), grain length (15.85 % and 14.56 %), kernel length (14.59 % and 14.56 %), gel consistency (14.55 % and 14.27 %), flag leaf width (14.51 % and 11.11 %) , head rice recovery % (14.16 % and 14.12 %), days to 50% flowering (12.62 % and 12.60 %) , and days to maturity (11.19 % and 11.16 %). Similar findings for plant height, days to 50 % flowering by Nath and Kole (2021). For plant height by Sudeepthi *et al.* (2020) and Sharma *et al.* (2013), for kernel length by Singh *et al.* (2014), Nirmaladevi *et al.* (2015) and Singh *et al.* (2016), for kernel length breadth ratio by Dhanwani *et al.* (2013), Nirmaladevi *et al.* (2015), Mohanty *et al.* (2012) and for grain length by Akter *et al.* (2010); Singh *et al.* (2016).

Moderate PCV and low GCV exhibited by amylose content (11.15 % and 8.81 %). Lower estimates of PCV with GCV were exhibited by grain breadth (10.77 % and 9.45 %), panicle length (10.75 % and 9.53 %), kernel breadth (9.53 % and 8.89 %), and milling % (9.159 % and 8.969 %), hulling % (6.32 % and 5.88 %). Similar results for panicle length were reported by Mohanty *et al.* (2012), Sudeepthi *et al.* (2020), Rashid *et al.* (2017), for grain breadth by Singh *et al.* (2016), for milling and hulling % by Dhanwani *et al.* (2013) and Nirmaladevi *et al.* (2015).

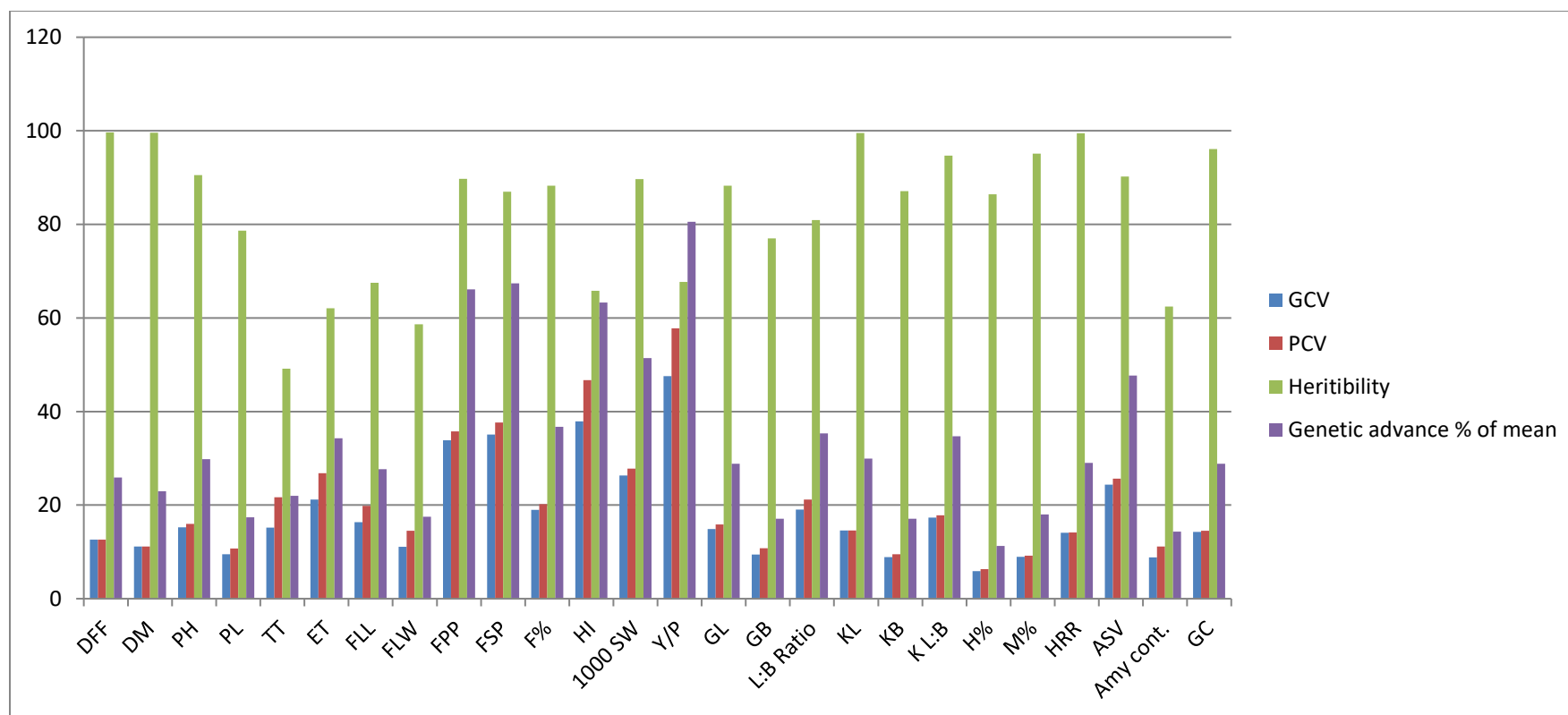


Fig. 2 Showing GCV, PCV, heritability and genetic advance percentage mean.

DFF = Days to 50 % flowering; DM = Days to maturity; PH = Plant height; PL= Panicle length; TT = Total tillers; ET= Effective tillers; FLL= Flag leaf length; FLW = Flag leaf width; FPP = Filled spikelets per panicle; SSP = Spikelets per panicle; SF% = Spikelet fertility %; HI = Harvest index; 1000 SW = 1000 seed weight; Y/P = Yield per plant; GL = Grain length; GB = Grain breadth; L:B ratio = Length breadth ratio; KL = Kernel length; KB = Kernel breadth; K L:B = Kernel length breadth ratio; H% = Hulling %; M% = Milling %; HRR= Head rice recovery; ASV = Alkali spreading value; AC = Amylose content; GC = Gel consistency.

Table 4.2 Variability parameters for yield and grain quality traits

S.No	Character	Mean	Range		Coefficient of variance (%)		Heritability (%)	Genetic advance	Genetic advance as % of mean
			Min	Max	GCV	PCV			
1	DFF	102.38	77.5	127.5	12.60	12.62	99.65	26.52	25.90
2	DM	131.34	101.5	157	11.16	11.19	99.6	30.15	22.95
3	PH	146.81	87.85	189.05	15.23	16.00	90.56	43.82	29.85
4	PL	25.22	20.5	31.95	9.53	10.75	78.67	4.39	17.41
5	TT	9.04	5.5	12.5	15.22	21.69	49.18	1.99	21.98
6	ET	7.77	3.5	11.5	21.22	26.82	62.05	2.66	34.28
7	FLL	34.79	21.75	49.25	16.33	19.87	67.54	9.62	27.65
8	FLW	1.47	1.1	1.95	11.11	14.51	58.64	0.26	17.52
9	SPP	201.60	83.5	540.5	33.88	35.77	89.76	133.31	66.13
10	FSP	145.64	45.5	300.5	35.09	37.63	86.97	98.19	67.42
11	F%	72.57	24.95	89.75	18.98	20.20	88.29	26.66	36.743
12	HI	17.89	4.75	34.35	37.89	46.71	65.81	11.33	63.32
13	1000 SW	16.92	7.4	28.3	26.36	27.83	89.69	8.7	51.42
14	Y/P	9.94	2.1	22.2	47.55	57.79	67.69	8.012	80.58
15	GL	7.80	5.3	10	14.90	15.85	88.29	2.25	28.83
16	GB	2.30	1.65	2.75	9.45	10.77	76.99	10.77	17.08
17	L:B Ratio	3.46	2.2	5.5	19.05	21.177	80.93	1.22	35.31
18	KL	5.34	3.4	6.75	14.56	14.59	99.53	1.60	29.92
19	KB	1.84	1.35	2.25	8.89	9.53	87.09	0.31	17.10
20	K L:B	2.94	1.75	3.85	17.33	17.81	94.67	1.02	34.73
21	H%	73.40	60.1	82.15	5.88	6.32	86.44	8.26	11.26
22	M%	66.25	48.7	76	8.97	9.20	95.13	11.94	18.02
23	HRR	49.21	37.2	64.7	14.12	14.16	99.45	14.28	29.01
24	ASV	4.42	3	6.5	24.37	25.65	90.22	2.11	47.68
25	AC	22.44	17.25	27.75	8.81	11.15	62.45	3.13	14.35
26	GC	28.91	24.5	46.5	14.27	14.55	96.13	8.33	28.82

DFF = Days to 50 % flowering; DM = Days to maturity; PH = Plant height; PL= Panicle length; TT = Total tillers; ET= Effective tillers; FLL= Flag leaf length; FLW = Flag leaf width; FPP = Filled spikelets per panicle; SSP = Spikelets per panicle; SF% = Spikelet fertility %; HI = Harvest index; 1000 SW = 1000 seed weight; Y/P = Yield per plant; GL = Grain length; GB = Grain breadth; L:B ratio = Length breadth ratio; KL = Kernel length; KB = Kernel breadth; K L:B = Kernel length breadth ratio; H% = Hulling %; M% = Milling %; HRR= Head rice recovery; ASV = Alkali spreading value; AC = Amylose content; GC = Gel consistency.

4.1.4 Heritability

Estimates of heritability provide information about the amount of genetic variation that can be transferred to total variation and are used to determine genetic improvement and response to selection. As a result, heritability is the hereditary component of phenotypic variance. It is a good indicator of character development from parents to offspring (Falconer, 1981).

High heritability showed by days to 50% flowering (99.654%), days to maturity (99.6%), kernel length (99.53%), head rice recovery % (99.45%), gel consistency (96.13 %), milling % (95.13%), kernel L/B ratio (94.67 %), plant height (90.56 %), ASV (90.22 %), no. of spikelets / panicle (89.76%), 1000 seed weight (89.69 %), fertility % (88.29 %), grain length (88.29 %), kernel breadth (87.09 %), no. of filled spikelets / panicle (86.97%), hulling % (86.44 %), L/B ratio (80.93%), panicle length (78.67 %), grain breadth (76.99 %), yield / plant (67.69 %), flag leaf length (67.54 %), harvest index (65.81 %), amylose content (62. 45 %), and no. of effective tillers (62.05 %) (Table-4.2 and Fig-2). Similar result seen for no. of spikelets panicle / panicle and 1000-grain weight showed high heritability by Mishu *et al.* (2015); Tuwar *et al.* (2013); Islam *et al.* (2015) for days of 50 % flowering, days of crop maturity, 1000 seed weight, plant height, no. of spikelets / panicle and no. of filled spikelets / panicle. The similar findings were reported for kernel breadth by Singh *et al.* (2014); Chouhan *et al.* (2014), for kernel length by Babu *et al.* (2012), for grain length and grain breadth by Islam *et al.* (2015), Akter *et al.* (2010), for days of 50% flowering, kernel length, gel consistency, plant height, ASV, no. of filled spikelets / panicle, yield / plant by Dhanwani *et al.* (2013) , for grain length breadth ratio by Karupaiyan *et al.* (2013), for panicle length by Tuwar *et al.* (2013, Akinwale *et al.* (2011) and for 1000 seed weight, yield / plant , filled spikelets / panicle, grain length by Singh *et al.* (2020).

All character showed high heritability except flag leaf width (58.64 %) and no. of total tillers (49.18 %) which showed moderate heritability.

4.1.5 Genetic advance

The range of genetic advance varied from 133.31 for no. of spikelets / panicle to 0.26 for flag leaf width. The high amount of genetic advance was measured for no. of spikelets / panicle (133.31), plant height (43.82), days to maturity (30.14), spikelet fertility % 26.66, days of 50 % flowering (26.52) head rice recovery% (14.28), milling % (11.93), harvest index (11.33), grain breadth (10.77), flag leaf length (9.62), 1000 seed weight (8.7), gel consistency (8.3), hulling % (8.27), yield / plant (8.01), panicle length (4.39), amylose content (3.12), number of effective tillers (2.67), grain length (2.25), ASV (2.11), number of total tillers (1.99), kernel length (1.60), L/B ratio (1.23), kernel length breadth ratio (1.02), kernel breadth (0.31), and flag leaf width (0.26).

4.1.6 Genetic advance as % of mean

High Genetic advance as % of mean was observed (Table - 4.2 and Fig-2) for yield / plant (80.581%), no. of filled spikelets / panicle (67.42 %), no. of spikelets / panicle (66.13 %), harvest index (63.32 %), 1000 seed weight (51.42 %), ASV (47.68 %), spikelet fertility % (36.74 %), L/B ratio (35.31 %), kernel L / B ratio (34.74 %), no. of effective tillers (34.28 %), kernel length (29.92 %), plant height (29.85 %), head rice recovery % (29.02 %), grain length (28.84 %), gel consistency (28.82 %), flag leaf length (27.66 %), days to 50% flowering (25.91 %), days to maturity (22.96 %), no. of total tillers (21.99 %). Indicated that the traits are governed by additive genes and selection will be beneficial for improving such traits. These findings are in agreement with report of Dhanwani *et al.* (2013) for yield / plant. Seyoum *et al.* (2012) for yield / plant, 1000 seed weight, spikelets / panicle, plant height. Nath and Kole (2021) for 1000 seed weight, yield / plant, Abebe *et al.* (2017), Adhikari *et al.* (2018) for grain yield and for test weight by Singh *et al.* (2018).

Moderate Genetic advance as % of mean was found in milling % (18.02%), flag leaf width (17.53%), panicle length (17.42%), kernel breadth (17.10%), grain breadth (17.08%), amylose content (14.35%) and hulling % (11.26%). Seyoum *et al.* (2012) for panicle length. High genetic gain is not always indicated by high

heritability, heritability with genetic advance should be used for selection of superior genotypes (Ali *et al.*, 2002).

4.1.7 Heritability with Genetic advance as % of Mean

Higher estimates of heritability with genetic advance as % of mean was for no. of filled spikelets / panicle, no. of spikelets / panicle, harvest index, 1000 seed weight, ASV, fertility %, kernel L/B ratio, L: B ratio, kernel length, plant height, head rice recovery %, grain length, gel consistency, days to 50% flowering, days to maturity, amylose content, flag leaf length and grain yield / plant. These character are governed by additive gene action and selection will be rewarding (Table 4.2.1). Present findings are in tune with the previous reports of Karim *et al.* (2007) for 1000 seed weight, Edukondalu *et al.* (2017); Karuppaiyan *et al.* (2013) for grain L:B ratio, Edukondalu *et al.* (2017) for kernel length, Tuwar *et al.* (2013); Edukondalu *et al.* (2017); Khare *et al.* (2014) for total grains / panicle and Edukondalu *et al.* (2017); Devi *et al.* (2016); Khare *et al.* (2014); Sudeepthi *et al.* (2020) for plant height, Gupta *et al.* (2020); Devi *et al.* (2016); Singh *et al.* (2014) for 1000 seed weight, Aditya *et al.* (2013); Khare *et al.* (2014); Babu *et al.* (2012) for filled spikelets / panicle, Ekka *et al.* (2015); Devi *et al.* (2016) for head rice recovery, Devi *et al.* (2016) for kernel L:B ratio. Singh *et al.* (2020) for no. of filled spikelets / panicle, and for plant height by Nath and Kole (2021). High heritability with moderate genetic advance as % mean for milling %, kernel breadth, hulling %, panicle length, grain breadth, and amylose content. The findings are also supported by Konate *et al.* (2016); Sudeepthi *et al.* (2020) for panicle length.

Moderate heritability and genetic advance as % mean for leaf width, and numbers of total tillers were also observed in the present study.

4.2 Association analysis for yield and related traits

Correlation analysis

Plant breeding necessitates the correlation of different traits. If two traits are positively correlated, then one trait can be improved indirectly by improving the other.

4.2.1 Character association of grain yield per plant with other characters

Correlation analysis are presented in Table 4.3.

Grain yield / plant showed significant and positive correlation with no. of total tillers ($r_p = 0.418, r_g = 0.639$), no. of effective tillers ($r_p = 0.548, r_g = 0.749$), flag leaf width ($r_p = 0.262, r_g = 0.473$), no. of filled spikelets / panicle ($r_p = 0.285, r_g = 0.386$), spikelet fertility % ($r_p = 0.336, r_g = 0.460$), harvest index ($r_p = 0.879, r_g = 0.926$), kernel breadth ($r_g = 0.249$), hulling % ($r_p = 0.236, r_g = 0.295$), milling % ($r_p = 0.235, r_g = 0.280$), amylose content ($r_g = 0.308$). According to the findings of the study, rice grain yield can be increased by selecting these characters. The study was supported by findings of Seyoum *et al.* (2012) for spikelet fertility, Hairmansis *et al.* (2010) for filled spikelets / panicle, spikelet fertility %. No. of effective tillers / plant, spikelets fertility % and harvest index by Thippani *et al.* (2017), and for no. of total tillers / plant by Kalyan *et al.* (2017).

Negative significant correlation was reported for plant height ($r_p = -0.470, r_g = -0.627$), panicle length ($r_p = -0.216, r_g = -0.341$), flag leaf length ($r_p = -0.293, r_g = -0.354$), and ASV ($r_p = -0.301, r_g = -0.393$).

4.2.1.1 Days to 50 % flowering (DFF)

Showed significant positive correlation with days to maturity ($r_p = 0.995^{**}; r_g = 0.995^{**}$), plant height ($r_p = 0.374^{**}; r_g = 0.394^{**}$), no. of spikelets / panicle ($r_p = 0.322^{**}; r_g = 0.341^{**}$), no. of filled spikelets / panicle ($r_p = 0.537^{**}; r_g = 0.575^{**}$), spikelet fertility % ($r_p = 0.519^{**}; r_g = 0.549^{**}$), and negative significant correlation was found with 1000 seed weight ($r_p = -0.375^{**}; r_g = -0.398^{**}$). Showed non-significant positive correlation with yield / plant ($r_p = 0.153; r_g = 0.190$), effective tillers ($r_p = 0.109; r_g = 0.151$), no. of total tillers ($r_p = 0.080; r_g = 0.125$), flag leaf width ($r_p = 0.065; r_g = 0.086$), harvest index ($r_p = 0.016; r_g = 0.021$), 0.021) and non significant negative correlation with flag leaf length ($r_p = -0.112; r_g = -0.141$), panicle length ($r_p = -0.043; r_g = -0.043$). Findings are similar for days to maturity, spikelet fertility %, 1000 seed weight by Qamar *et al.* (2005). For no. of effective tillers, no. of total tillers by Sarker *et al.* (2014) and for yield / plant by Das *et al.* (1992) and Choudhury *et al.* (1998), for days to maturity by Akhi *et al.* (2016); for

plant height and effective tillers / plant by Bhadru *et al.* (2011); Lakshmi *et al.* (2014), Sudeepthi *et al.* (2020); for days to maturity Gupta *et al.* (2020); Lakshmi *et al.* (2014); Pandey *et al.* (2012).

4.2.1.2 Days to maturity

It showed significant positive correlation with no. of filled spikelets / panicle ($r_p = 0.528^{**}$; $r_g = 0.564^{**}$), fertility % ($r_p = 0.502^{**}$; $r_g = 0.531^{**}$), plant height ($r_p = 0.401^{**}$; $r_g = 0.424^{**}$), no. of spikelets / panicle ($r_p = -0.324^{**}$; $r_g = 0.341^{**}$) and significant negative correlation with 1000 seed weight ($r_p = 0.356^{**}$; $r_g = -0.377^{**}$). Also showed non significant positive correlation with yield / plant ($r_p = 0.150$; $r_g = 0.188$), no. of effective tillers ($r_p = 0.101$; $r_g = 0.141$), no. of total tillers ($r_p = 0.075$; $r_g = 0.115$), flag leaf width ($r_p = 0.078$; $r_g = 0.106$), panicle length (0.; $r_g = 0.006^{**}$), harvest index ($r_p = 0.014$; $r_g = 0.017$) and non significant negative correlation with flag leaf length ($r_p = -0.100$; $r_g = -0.127$), and panicle length ($r_p = -0.001$). Findings are similar for no. of effective tillers, no. of total tillers by Sarker *et al.* (2014), for yield / plant by Dilruba *et al.* (2014), for no. of total tillers by Qamar *et al.* (2005).

4.2.1.3 Plant height (cm)

Positive significant correlation with panicle length ($r_p = 0.479^{**}$; $r_g = 0.531^{**}$), flag leaf length ($r_p = 0.309^{**}$; $r_g = 0.383^{**}$) and negative significant correlation was found with harvest index ($r_p = -0.548^{**}$; $r_g = -0.738^{**}$), yield / plant ($r_p = 0.470^{**}$; $r_g = -0.627^{**}$), no. of effective tillers ($r_p = -0.458^{**}$; $r_g = -0.622^{**}$), no. of total tillers ($r_p = -0.375^{**}$; $r_g = -0.564^{**}$). Non significant positive correlation found with no. of spikelets / panicle ($r_p = 0.138$; $r_g = 0.148$), no. of filled spikelets / panicle ($r_p = 0.123$; $r_g = 0.148$), and non significant negative correlation found with 1000 seed weight ($r_p = -0.162$; $r_g = -0.169$), flag leaf width ($r_p = -0.033$; $r_g = -0.018$), spikelet fertility % ($r_p = 0.020$; $r_g = -0.003$). Similar findings were recorded by Ratna *et al.* (2015) for no. of effective tillers, for grain yield by Gholipoor *et al.* (1998), for panicle length by Sarker *et al.* (2014).

4.2.1.4 Panicle length (cm)

Panicle length showed positive significant correlation with flag leaf length ($r_p = 0.227^*$; $r_g = 0.260^{**}$) and significant negative correlation was found with spikelet fertility % ($r_p = -0.396^{**}$; $r_g = -0.476^{**}$), harvest index ($r_p = -0.258^{**}$; $r_g = -0.430^{**}$), no. of total tillers ($r_g = -0.358^{**}$), no. of effective tillers ($r_g = -0.353$), yield /plant ($r_p = -0.216^*$; $r_g = -0.341^{**}$).

4.2.1.5 No. of total tillers (TT)

Positive significant correlation with no. of effective tillers ($r_p = 0.915^{**}$; $r_g = 0.954^{**}$), yield / plant ($r_p = 0.418^{**}$; $r_g = 0.639^{**}$), harvest index ($r_p = 0.305^{**}$; $r_g = 0.502^{**}$), fertility % ($r_p = 0.198^{**}$; $r_g = 0.271^{**}$). Negative significant correlation was found with flag leaf length ($r_p = -0.413^{**}$; $r_g = -0.746^{**}$), 1000 seed weight ($r_p = -0.262^{**}$; $r_g = -0.469^{**}$), flag leaf width ($r_p = -0.006^{**}$; $r_g = -0.201^*$). Non significant positive correlation found with no. of filled spikelets / panicle ($r_p = 0.011$; $r_g = 0.047$) and non significant negative correlation with no. of spikelets / panicle ($r_p = -0.089$; $r_g = -0.112$), flag leaf width ($r_p = -0.006$). Similar results are also observed by Akhi *et al.* (2016) for no. of effective tillers and spikelet fertility %.

4.2.1.6 No. of effective tillers (ET)

It showed positive significant correlation with yield /plant ($r_p = 0.548^{**}$; $r_g = 0.749^{**}$), harvest index ($r_p = 0.440^{**}$; $r_g = 0.611^{**}$), fertility % ($r_p = 0.236^*$; $r_g = 0.303^{**}$) and negative significant correlation with flag leaf length ($r_p = -0.455^{**}$; $r_g = -0.699^{**}$), 1000 seed weight ($r_p = -0.203^*$; $r_g = -0.341^{**}$). Positive non significant correlation with filled spikelets / panicle ($r_p = 0.053$; $r_g = 0.085$), flag leaf width ($r_p = 0.016$) and negative non significant correlation with no. of spikelets / panicle ($r_p = -0.055$; $r_g = -0.079$), flag leaf width ($r_g = -0.071$). The results are supported by the findings of Akhi *et al.* (2016) for spikelet fertility %.

4.2.1.7 Flag leaf length (cm)

Positive significant correlation for flag leaf length with 1000 seed weight ($r_p = 0.241^*$; $r_g = 0.327^{**}$) and significant negative correlation with harvest index ($r_p = -0.334^{**}$; $r_g = -0.410^{**}$), yield /plant ($r_p = -0.293^{**}$; $r_g = -0.354^{**}$), spikelet

fertility % ($r_p = -0.259^{**}$; $r_g = -0.346^{**}$), and no. of filled spikelets / panicle ($r_g = -0.197^*$). Positive non significant correlation showed by flag leaf width ($r_p = 0.104$; $r_g = 0.081$) and negative non significant correlation showed by no. of filled spikelets / panicle ($r_p = -0.172$), no. of spikelets / panicle ($r_p = -0.058$; $r_g = -0.073$).

4.2.1.8 Flag leaf width

Flag leaf width has positive correlation with yield /plant ($r_p = 0.262^{**}$; $r_g = 0.473^{**}$), 1000 seed weight ($r_p = 0.288^{**}$; $r_g = 0.365^{**}$), no. of spikelets / panicle ($r_p = 0.196^*$; $r_g = 0.317^{**}$), no. of filled spikelets / panicle ($r_p = 0.207^*$; $r_g = 0.296^{**}$) and harvest index ($r_g = 0.247^*$). Positive non significant correlation showed by fertility % ($r_p = 0.143$; $r_g = 0.147$), harvest index ($r_p = 0.094$).

4.2.1.9 No. of spikelets / panicle

Showed positive significant correlation with no. of filled spikelets / panicle ($r_p = 0.840^{**}$; $r_g = 0.842^{**}$). Negative significant correlation with 1000 seed weight ($r_p = -0.403^{**}$; $r_g = -0.469^{**}$). Non significant positive correlation showed by yield / plant ($r_p = 0.125$; $r_g = 0.175$), harvest index ($r_p = 0.097$; $r_g = 0.157$). Non significant positive correlation showed by spikelet fertility % ($r_p = -0.023$; $r_g = -0.021$).

4.2.1.10 No. of filled spikelets / panicle

No. of filled spikelet / panicle have positive significant correlation with fertility % ($r_p = 0.493^{**}$; $r_g = 0.501^{**}$), yield /plant ($r_p = 0.285^{**}$; $r_g = 0.386^{**}$), harvest index ($r_p = 0.230^*$; $r_g = 0.322^{**}$). Negative significant correlation with 1000 seed weight ($r_p = -0.461^{**}$; $r_g = -0.549^{**}$). Findings are similar to the reports for yield / plant by Nath and Kole (2021), Chaudhury *et al.* (1998) and Debi *et al.* (1997). And for 1000 seed weight by Dilruba *et al.* (2014).

4.2.1.11 Spikelet fertility %

Positive significant correlation with yield / plant ($r_p = 0.336^{**}$; $r_g = 0.460^{**}$), harvest index ($r_p = 0.277^{**}$; $r_g = 0.367^{**}$) and negative significant correlation with 1000 seed weight ($r_p = -0.199^*$; $r_g = -0.254$).

4.2.1.12 Harvest index

Significant positive correlation with yield / plant ($r_p = 0.879^{**}$; $r_g = 0.926^{**}$). Non significant positive correlation coefficient with 1000 seed weight ($r_p = 0.168$; $r_g = 0.160$). Results are in accordance to Dilruba *et al.* (2014) for yield / plant.

4.2.1.13 1000 Seed weight (g)

1000 seed weight showed positive non significant correlation with yield / plant ($r_p = 0.143$; $r_g = 0.120$). Results are also in agreement with observation of Das *et al.* (1992) and Choudhury *et al.* (1998).

4.2.1.14 Grain length (mm)

Positive significant correlation with kernel length ($r_p = 0.898^{**}$; $r_g = 0.964^{**}$), kernel L:B ratio ($r_p = 0.823^{**}$; $r_g = 0.909^{**}$), L:B ratio ($r_p = 0.762^{**}$; $r_g = 0.819^{**}$) and significant negative correlation kernel breadth ($r_p = -0.242^*$; $r_g = -0.270^{**}$), milling % ($r_g = -0.208^*$), hulling% ($r_g = -0.205^*$). Positive non significant correlation with ASV ($r_p = 0.037$; $r_g = 0.039$), gel consistency ($r_p = 0.024$; $r_g = 0.025$), grain breadth ($r_p = 0.013$). Non significant negative correlation with head rice recovery % ($r_p = -0.156$; $r_g = -0.166$), yield /plant ($r_p = -0.053$; $r_g = -0.083$), amylose content ($r_p = -0.014$; $r_g = -0.039$), grain breadth ($r_g = -0.018$), milling % ($r_p = -0.172$), hulling % ($r_p = -0.148$).

4.2.1.15 Grain breadth

Significant positive correlation with kernel breadth ($r_p = 0.623^{**}$; $r_g = 0.792^{**}$) and negative significant correlation with L/B ratio ($r_p = -0.553^{**}$; $r_g = -0.585^{**}$), kernel L: B ratio ($r_p = -0.306^{**}$; $r_g = -0.368^{**}$). Non significant positive correlation with hulling % ($r_p = 0.122$; $r_g = 0.179$), milling % ($r_p = 0.125$; $r_g = 0.142$), amylose content ($r_p = 0.173$; $r_g = 0.139$), ASV ($r_p = 0.099$; $r_g = 0.123$), head rice recovery % ($r_p = 0.070$; $r_g = 0.075$), yield / plant ($r_p = 0.090$; $r_g = 0.064$), kernel length ($r_p = 0.050$; $r_g = 0.061$) and non significant negative correlation with gel consistency ($r_p = -0.090$; $r_g = -0.115$).

4.2.1.16 L / B ratio

Significant positive correlation with kernel L:B ratio ($r_p = 0.814^{**}$; $r_g = 0.931^{**}$), kernel length ($r_p = 0.650^{**}$; $r_g = 0.725^{**}$), and negative significant correlation with kernel breadth ($r_p = 0.560^{**}$; $r_g = -0.670^{**}$), milling % ($r_p = -0.255^{**}$; $r_g = -0.306^{**}$), hulling % ($r_p = -0.254^{*}$; $r_g = -0.286^{**}$). Non significant positive correlation with gel consistency ($r_p = 0.035$; $r_g = 0.046$), ASV ($r_p = 0.037$; $r_g = 0.022$), and non significant negative correlation with head rice recovery % ($r_p = -0.172$; $r_g = -0.185$), amylose content ($r_p = -0.136$; $r_g = -0.133$), and yield / plant ($r_p = -0.037$; $r_g = -0.068$).

4.2.1.17 Kernel length (mm)

Significant positive correlation with kernel L/B Ratio ($r_p = 0.843^{**}$; $r_g = 0.863^{**}$) and negative significant correlation with head rice recovery ($r_p = -0.236^{*}$; $r_g = -0.237^{*}$). Non significant positive correlation with yield /plant ($r_p = 0.027$; $r_g = 0.026$) and non significant negative correlation with milling % ($r_p = -0.134$; $r_g = -0.137$), kernel breadth ($r_p = -0.110$; $r_g = -0.113$), hulling % ($r_p = -0.082$; $r_g = -0.087$), ASV ($r_p = -0.023$; $r_g = -0.025$), gel consistency ($r_p = -0.007$; $r_g = -0.008$), amylose content ($r_p = -0.002$; $r_g = -0.004$).

4.2.1.18 Kernel breadth (mm)

Positive correlation with amylose content ($r_p = 0.257^{**}$; $r_g = 0.356^{**}$), hulling % ($r_p = 0.212^{**}$; $r_g = 0.271^{**}$) yield /plant ($r_g = 0.249^{*}$), hulling % ($r_p = 0.212^{*}$). Negative significant correlation with kernel L/B ratio ($r_p = -0.616^{**}$; $r_g = -0.596^{**}$). Non significant positive correlation with head rice recovery % ($r_p = 0.142$; $r_g = 0.149$), milling % ($r_p = 0.055$) yield /plant ($r_p = 0.156$) and non significant negative correlation with gel consistency ($r_p = -0.134$; $r_g = -0.154$), ASV ($r_p = -0.073$; $r_g = -0.064$).

4.2.1.19 Kernel L/B ratio

Significant negative correlation with head rice recovery % ($r_p = -0.256^{**}$; $r_g = -0.262^{**}$) and hulling % ($r_g = -0.202^{*}$), amylose content ($r_g = -0.200^{*}$). Non significant positive correlation with gel consistency ($r_p = 0.056$; $r_g = 0.064$), ASV

($r_p = 0.019$; $r_g = 0.009$). Non significant negative correlation with milling % ($r_p = -0.148$; $r_g = -0.163$), yield /plant ($r_p = -0.067$), hulling % ($r_p = -0.176$), amylose content ($r_p = -0.200$).

4.2.1.20 Hulling %

Significant positive correlation with milling % ($r_p = 0.766^{**}$; $r_g = 0.785^{**}$), head rice recovery % ($r_p = 0.419^{**}$; $r_g = 0.446^{**}$), yield / plant ($r_p = 0.236^{**}$; $r_g = 0.295^{**}$) and significant negative correlation with ASV ($r_p = -0.197^*$; $r_g = -0.229^*$). Non significant positive correlation with amylose content ($r_p = 0.070$; $r_g = 0.081$) and non significant negative correlation with gel consistency ($r_p = -0.060$; $r_g = -0.062$).

4.2.1.21 Milling %

Milling % showed significant positive correlation with head rice recovery% ($r_p = 0.502^{**}$; $r_g = 0.514^{**}$), yield / plant ($r_p = 0.235^{**}$; $r_g = 0.280^{**}$), amylose content ($r_g = 0.207^{**}$), yield / plant ($r_p = 0.235^*$) and significant negative correlation with ASV value ($r_g = -0.196^*$). Non significant positive correlation with amylose content ($r_p = 0.164$) and non significant negative correlation with gel consistency ($r_p = -0.137$; $r_g = -0.138$), ASV ($r_p = -0.183$).

4.2.1.22 Head rice recovery (%)

Significant positive correlation with amylose content ($r_p = 0.213^*$; $r_g = 0.270^{**}$). Non significant positive correlation with ASV ($r_p = 0.117$; $r_g = 0.125$), yield / plant ($r_p = 0.068$; $r_g = 0.074$) and non significant negative correlation with gel consistency ($r_p = -0.109$; $r_g = -0.111$).

4.3.1.23 Alkali spreading value

Significant negative correlation with yield / plant ($r_p = -0.301^{**}$; $r_g = -0.393^{**}$), amylose content ($r_p = -0.236^*$; $r_g = -0.276$).

4.2.1.24 Amylose content

Positive significant correlation with yield / plant ($r_g = 0.308^{**}$). Non significant positive correlation with gel consistency ($r_g = 0.008$), yield / plant ($r_p = 0.192$) and non significant negative correlation with gel consistency ($r_p = -0.018$).

4.2.1.25 Gel consistency

It showed non significant positive correlation with yield / plant ($r_p = 0.054$; $r_g = 0.049$).

Similar reports for grain quality traits were also published by Roy *et al.* (2021) i.e., kernel breadth had negative significant association with length breadth ratio; grain yield had negative significant association with alkali digestion value, hulling percent has significant positive correlation with milling % and head rice recovery. Results related to the current study were familiar with the reports of Singh *et al.* (2020), Nirmala Devi *et al.* (2015), Nayak *et al.* (2003) i.e., head rice recovery had negative but non-significant correlations with L/B ratio. Head rice recovery was positively non-significant correlated with ASV as reported by Divya Prasanna *et al.* (2020).

Table 4.3 (a) Phenotypic and genotypic correlation coefficient for yield and grain quality traits

		DFE	DM	PH	PL	TT	ET	FLL	FLW	SPP	FSP	F%	HI	1000 SW
DFE	P	1.000												
	G	1.000												
DM	P	0.995**	1.000											
	G	0.995**	1.000											
PH	P	0.374**	0.401**	1.000										
	G	0.394**	0.424**	1.000										
PL	P	-0.043	-0.001	0.479**	1.000									
	G	-0.043	0.006	0.531**	1.000									
TT	P	0.080	0.075	-0.375**	-0.185	1.000								
	G	0.125	0.115	-0.564**	-0.358**	1.000								
ET	P	0.109	0.101	-0.458**	-0.187	0.915**	1.000							
	G	0.151	0.141	-0.622**	-0.353**	0.954**	1.000							
FLL	P	-0.112	-0.100	0.309**	0.227*	-0.413**	-0.455**	1.000						
	G	-0.141	-0.127	0.383**	0.260**	-0.746**	-0.699**	1.000						
FLW	P	0.065	0.078	-0.033	-0.039	-0.006	0.016	0.104	1.000					
	G	0.086	0.106	-0.018	-0.002	-0.201*	-0.071	0.081	1.000					
SPP	P	0.322**	0.324**	0.138	0.121	-0.089	-0.055	-0.058	0.196*	1.000				
	G	0.341**	0.341**	0.148	0.126	-0.112	-0.079	-0.073	0.317**	1.000				
FSP	P	0.537**	0.528**	0.123	-0.089	0.011	0.053	-0.172	0.207*	0.840**	1.000			
	G	0.575**	0.564**	0.149	-0.113	0.047	0.085	-0.197*	0.296**	0.842**	1.000			
F%	P	0.519**	0.502**	-0.020	-0.396**	0.198*	0.236*	-0.259**	0.143	-0.023	0.493**	1.000		
	G	0.549**	0.531**	-0.003	-0.476**	0.271**	0.303**	-0.346**	0.147	-0.021	0.501**	1.000		
HI	P	0.016	0.014	-0.548**	-0.258**	0.305**	0.440**	-0.334**	0.094	0.097	0.230*	0.277**	1.000	
	G	0.021	0.017	-0.738**	-0.430**	0.502**	0.611**	-0.410**	0.247*	0.157	0.322**	0.367**	1.000	
1000 SW	P	-0.375**	-0.356	-0.162	0.057	-0.262**	-0.203*	0.241*	0.288**	-0.403**	-0.461**	-0.199*	0.168	1.000
	G	-0.398**	-0.377	-0.169	0.040	-0.469**	-0.341**	0.327**	0.365**	-0.469**	-0.549**	-0.254**	0.160	1.000
GYP	P	0.153	0.150	-0.470**	-0.216*	0.418**	0.548**	-0.293**	0.262**	0.125	0.285**	0.336**	0.879**	0.143
	G	0.190	0.188	-0.627**	-0.341**	0.639**	0.749**	-0.354**	0.473**	0.175	0.386**	0.460**	0.926**	0.120

DFE = Days to 50 % flowering; DM = Days to maturity; PH = Plant height; PL= Panicle length; TT = Total tillers; ET= Effective tillers; FLL= Flag leaf length; FLW= Flag leaf width; FPP = Filled spikelets per panicle; SSP = Spikelets per panicle; SF% = Spikelet fertility %; HI = Harvest index; 1000 SW = 1000 seed weight; GYP = grain yield per plant

Table 4.3 (b) Phenotypic and genotypic correlation coefficient for yield and grain quality traits

		GL	GB	L : B ratio	K L	K B	K L : B ratio	H %	M %	HRR%	ASV	AC	GC
GL	P	1.000											
	G	1.000											
GB	P	0.013	1.000										
	G	-0.018	1.000										
L:B ratio	P	0.762**	-0.553**	1.000									
	G	0.819**	-0.585**	1.000									
K L	P	0.898**	0.050	0.650**	1.000								
	G	0.964**	0.061	0.725**	1.000								
K B	P	-0.242*	0.623**	-0.560**	-0.110	1.000							
	G	-0.270**	0.792**	-0.670**	-0.113	1.000							
K L : B ratio	P	0.823**	-0.306**	0.814**	0.843**	-0.616**	1.000						
	G	0.909**	-0.368**	0.931**	0.863**	-0.596**	1.000						
H%	P	-0.148	0.122	-0.254*	-0.082	0.212*	-0.176	1.000					
	G	-0.205*	0.179	-0.286**	-0.087	0.271**	-0.202*	1.000					
M%	P	-0.172	0.125	-0.255**	-0.134	0.055	-0.148	0.766**	1.000				
	G	-0.208*	0.142	-0.306**	-0.137	0.080	-0.163	0.785**	1.000				
HRR%	P	-0.156	0.070	-0.172	-0.236*	0.142	-0.256**	0.419**	0.502**	1.000			
	G	-0.166	0.075	-0.185	-0.237*	0.149	-0.262**	0.446**	0.514**	1.000			
ASV	P	0.037	0.099	0.037	-0.023	-0.073	0.019	-0.197*	-0.183	0.117	1.000		
	G	0.039	0.123	0.022	-0.025	-0.064	0.009	-0.229*	-0.196*	0.125	1.000		
A C	P	-0.014	0.173	-0.136	-0.002	0.257**	-0.150	0.070	0.164	0.213*	-0.236*	1.000	
	G	-0.039	0.139	-0.133	-0.004	0.356**	-0.200*	0.081	0.207*	0.270**	-0.276**	1.000	
GC	P	0.024	-0.090	0.035	-0.007	-0.134	0.056	-0.060	-0.137	-0.109	-0.017	-0.018	1.000
	G	0.025	-0.115	0.046	-0.008	-0.154	0.064	-0.062	-0.138	-0.111	-0.021	0.008	1.000
GYP	P	-0.053	0.090	-0.037	0.027	0.156	-0.043	0.236*	0.235*	0.068	-0.301**	0.192	0.054
	G	-0.083	0.064	-0.068	0.026	0.249*	-0.067	0.295**	0.280**	0.074	-0.393**	0.308	0.049

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

GL = Grain length; GB = Grain breadth; KL = Kernel length; KB = Kernel breadth; L:B ratio = Length breadth ratio; H% = Hulling %; M% = Milling %; ASV =

Alkali spreading value; GC = Gel consistency; GYP = Grain yield per plant; AC = Amylose content; K L:B ratio = Kernel length breadth ratio; HRR% = Head rice recovery.

4.2.2 Path coefficient analysis

4.2.2.1 Direct effect

The path coefficient analysis of the material presented in Table 4.4 and Fig. 3 displayed that very high positive direct effect on grain yield was showed by kernel length / breadth (20.187), kernel breadth (12.135), grain length (3.841) milling % (2.199), length breadth ratio (1.811), harvest index (1.440), days to 50% flowering (1.341). High positive direct effect on grain yield was displayed by no. of filled spikelets / panicle (0.809), flag leaf width (0.749), gel consistency (0.410). Similar results were seen by Alam *et al.* (2014), Hairmansis *et al.*, (2010) for no. of filled spikelets / panicle.

Moderate positive direct effect on grain yield was showed by amylose content (0.254), plant height (0.243), grain breadth (0.207). Negligible positive direct effect on grain yield was showed by no. of effective tillers (0.096), and panicle length (0.037). Similar findings were reported by Akhi *et al.* (2016) for plant height. Reported direct effect for days to 50% flowering, panicle length and milling % by Ekka *et al.* (2011). Ray *et al.* (1993) Choudhury and Das (1998) reported a positive direct effect of plant height on yield. Kumar *et al.* (1992), Ray *et al.* (1993), Marwat *et al.* (1994), Dash *et al.* (1996), and Kumar *et al.* (1998) reported the high and positive direct effect of panicle length on grain yield of rice.

Direct but very high negative effects on grain yield was exhibited by kernel length (-21.123) followed by no. of spikelets per panicle (-1.516), head rice recovery (-1.379), days of maturity (-1.095). High negative effects on grain yield was exhibited by fertility % (-0.920), 1000 seed weight (-0.810), hulling % (-0.592). Moderate negative effects on grain yield was exhibited by no. of total tillers (-0.262). Negligible negative effects on grain yield was showed by flag leaf length (-0.011), ASV (-0.0004). Similar findings were recorded for day to maturity, no. of total tillers, spikelet fertility % by Akhi *et al.* (2016).

4.2.2.1 Indirect effects

4.2.2.1 Days to 50 % flowering

It has positive indirect effect through no. of spikelets /panicle (0.466), 1000 seed weight (0.323), plant height (0.096), flag leaf width (0.064), harvest index (0.031), no. of effective tillers (0.014), flag leaf length (0.002) and negative value for days to maturity (-1.090), spikelets / panicle (-0.517), fertility % (-0.505) , no. of total tillers (-0.033) and panicle length (-0.001).

4.2.2.2 Days to maturity

It showed indirect effect on days to 50% flowering (1.335), plant height (0.103), panicle length (0.0002), no. of effective tillers (0.014), flag leaf length (0.001), flag leaf width (0.079), no. of filled spikelets / panicle (0.457), harvest index (0.025) , 1000 seed weight (0.305) and negative indirect effect through no. of total tillers (-0.030), no. of spikelets / panicle (-0.517), spikelet fertility % (-0.488) .

4.2.2.3 Plant height (cm)

It has positive indirect effect via days to 50% flowering (0.529), panicle length (0.019), no. of total tillers (0.148), no. of filled spikelets / panicle (0.121), spikelet fertility % (0.003), 1000 seed weight (0.137) and negative indirect effect through days of maturity (-0.464), no. of effective tillers (-0.060), flag leaf length (-0.0042), flag leaf width (-0.013), no. of spikelets / panicle (-0.223) harvest index (-1.062).

4.2.2.4 Panicle length (cm)

It has positive indirect effect through plant height (0.129), no. of total tillers (0.094), spikelet fertility % (0.437) and negative indirect effect through days to 50% flowering (-0.057), days to maturity (-0.007), no. of effective tillers (-0.034), flag leaf length (-0.003), flag leaf width (-0.002), no. of spikelets / panicle (-0.191), no. of filled spikelet / panicle (-0.092), harvest index (-0.620), 1000 seed weight (-0.032).

4.2.2.5 No. of total tillers

It has high positive indirect effect through days to 50% flowering (0.168), no. of effective tillers (0.0913), flag leaf length (0.008), no. of spikelets / panicle (0.169), no. of filled spikelets / panicle (0.038), harvest index (0.723), 1000 seed weight (0.380) and negative indirect effect was found for days to maturity (-0.126), plant height (-0.137), panicle length (-0.013), flag leaf width (-0.151), spikelet fertility % (-0.249) .

4.2.2.6 No. of effective tillers

It has positive indirect effect through days to 50% flowering (0.202), flag leaf length (0.008), no. of spikelets / panicle (0.119), no. of filled spikelets / panicle (0.069), harvest index (0.879), 1000 seed weight (0.276) and negative indirect effect for days to maturity (-0.154), plant height (-0.151), panicle length (-0.013), no. of total tillers (-0.250), flag leaf width (-0.053), spikelet fertility % (-0.279).

4.2.2.7 Flag leaf length (cm)

It has positive indirect effect through days to maturity (0.140), plant height (0.093), panicle length (0.010), no. of total tillers (0.196), flag leaf width (0.061) , no. of spikelets / panicle (0.111), spikelet fertility % (0.318) and negative indirect effect for days to 50% flowering (-0.188), no. of effective tillers (-0.067), no. of filled spikelets / panicle (-0.159) , harvest index (-0.591), 1000 seed weight (-0.265).

4.2.2.8 Flag leaf width (cm)

It has positive indirect effect through days to 50% flowering (0.115), no. of total tillers (0.053), no. of filled spikelets / panicle (0.239) , harvest index (0.356) and negative indirect effect through days to maturity (-0.116), plant height (-0.004), panicle length (-0.00009), no. of effective tillers (-0.007), flag leaf length (-0.0009), no. of spikelets / panicle (-0.481), spikelet fertility % (-0.135), 1000 seed weight (-0.296).

4.2.2.9 No. of spikelets / panicle

It has positive indirect effect through days to 50% flowering (0.457), plant height (0.036), panicle length (0.005), no. of total tillers (0.029), flag leaf length (0.0008), flag leaf width (0.238), no. of filled spikelets / panicle (0.682), spikelet fertility % (0.019), harvest index (0.227), 1000 seed weight (0.380) and negative indirect effect for days to maturity (-0.374), no. of effective tillers (-0.008).

4.2.2.10 No. of filled spikelets / panicle

It has positive indirect effect through days to 50% flowering (0.771), plant height (0.036), no. of effective tillers (0.008), flag leaf length (0.002), flag leaf width (0.222), harvest index (0.463), 1000 seed weight (0.445) and negative indirect effect for days to maturity (-0.618), panicle length (-0.004), no. of total tillers (-0.012), no. of spikelet / panicle (-1.277), spikelet fertility % (-0.460).

4.2.2.11 Spikelet fertility %

It has positive indirect effect through days to 50% flowering (0.736), no. of effective tillers (0.029), flag leaf length (0.004), flag leaf width (0.110), no. of spikelets / panicle (0.032), no. of filled spikelets / panicle (0.406), harvest index (0.528), 1000 seed weight (0.206) and negative indirect effect for days to maturity (-0.581), plant height (-0.0007), panicle length (-0.018), no. of total tillers (-0.071).

4.2.2.12 Harvest index

It has positive indirect effect for days to 50% flowering (0.028), no. of effective tillers (0.058), flag leaf length (0.005), flag leaf width (0.185), no. of filled spikelets / panicle (0.261) and negative indirect effect for days to maturity (-0.019), plant height (-0.179), panicle length (-0.016), no. of total tillers (-0.132), no. of spikelets / panicle (-0.238), spikelet fertility % (-0.337), 1000 seed weight (-0.130).

4.2.2.13 1000 SW

It has positive indirect effect through days of maturity (0.412), panicle length (0.001), no. of total tillers (0.123), flag leaf width (0.274), no. of spikelet /

panicle (0.712), spikelet fertility % (0.234), harvest index (0.230) and negative indirect effect through days to 50% flowering (-0.534), plant height (-0.041), no. of effective tillers (-0.032), flag leaf length (-0.004), no. of filled spikelets / panicle (-0.445).

4.2.2.14 Grain length (mm)

It has positive indirect effect through L:B ratio (1.483), kernel L/B ratio (18.34), hulling % (0.121), head rice recovery % (0.228), gel consistency (0.010) and negative indirect effect for grain breadth (-0.004), kernel length (-20.365), kernel breadth (-3.27), milling % (-0.458), ASV (-0.00001), amylose content (-0.0097).

4.2.2.15 Grain breadth (mm)

It has positive indirect effect through kernel breadth (9.61) milling % (0.312), amylose content (0.035) and negative indirect effect for L:B ratio (-1.060), kernel length (-1.30), kernel L/B ratio (-7.42), hulling % -0.106 , head rice recovery % -0.103, ASV -0.00005, gel consistency (-0.047).

4.2.2.16 L:B ratio

It has positive indirect effect through grain length (-0.069), kernel L/B ratio (18.80), hulling % (0.169), head rice recovery % (0.256), gel consistency (0.019) and negative indirect effect through grain breadth (-0.121), kernel length (-15.31), kernel breadth (-8.125), milling % (-0.672), ASV (-0.00001), amylose content (-0.034).

4.2.2.17 Kernel length (mm)

It has positive indirect effect through grain length (3.704), grain breadth (0.013), L:B ratio (1.314), kernel L/B ratio (17.418), hulling % (0.0516), head rice recovery % (0.326), ASV (0.00001) and negative indirect effect through kernel breadth (-1.37), milling % (-0.302), amylose content (-0.002), gel consistency (-0.003).

4.2.2.18 Kernel breadth (mm)

It has positive indirect effect through grain breadth (0.164), kernel length (2.386), milling % (0.176), ASV (0.00002), amylose content (0.090) and negative indirect effect through grain length (-1.036), L:B ratio (-1.213), kernel L/B ratio (-12.023), hulling % -0.160, head rice recovery % (-0.205), gel consistency (-0.063).

4.2.2.19 Kernel L : B ratio

It has positive indirect effect through grain length (3.490), L:B ratio (1.687), hulling % (0.120), head rice recovery % (0.360), ASV (0.00001), gel consistency (0.026) and negative indirect effect with grain breadth (-0.076), kernel length (-18.225), kernel breadth (-7.227), milling % (-0.358), amylose content (-0.051).

4.2.2.20 Hulling %

It has positive indirect effect through grain breadth (0.037), kernel length (1.842), kernel breadth (3.285), milling % (1.726), ASV (0.00008), amylose content (0.020) and negative effect through grain length (-0.789), L/B ratio (-0.518), kernel L: B ratio (-4.076), head rice recovery % (-0.615), gel consistency (-0.025).

4.2.2.21 Milling %

It has positive indirect effect through grain breadth (0.029), kernel length (2.901), kernel breadth (0.971), ASV (0.00007), amylose content (0.0523) and negative indirect effect grain length (-0.800), L:B ratio (-0.554), kernel L/B ratio (-3.287), hulling % (-0.464), head rice recovery% (-0.709), gel consistency (-0.056).

4.2.2.22 Head rice recovery %

It has positive indirect effect through grain breadth (0.015), kernel length (4.997), kernel breadth (1.805), milling % (1.130), amylose content (0.069) and negative indirect effect through grain length (-0.637), L/B ratio (-0.336), kernel L:B ratio (-5.279), hulling % (-0.264), ASV (-0.00005), gel consistency (-0.046).

4.2.2.23 Alkali spreading value

It has positive indirect effect grain length (0.151), grain breadth (0.025), L/B ratio (0.041), kernel length (0.522), kernel L:B ratio (0.187), hulling % (0.136) and negative indirect effect with amylose content (-0.070), gel consistency (-0.009), kernel breadth (-0.772), milling % (-0.431), head rice recovery % (-0.172).

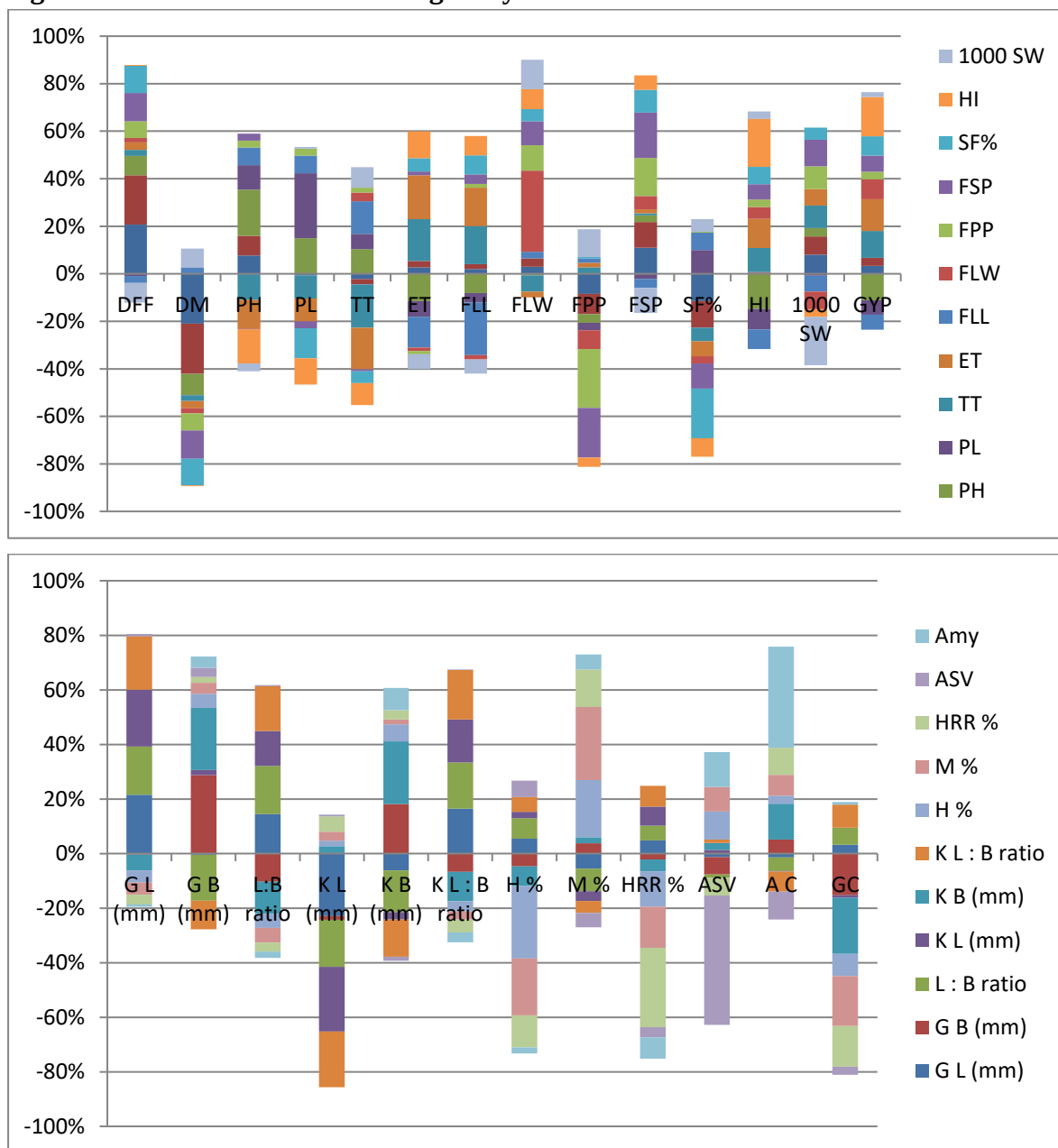
4.2.2.24 Amylose content

It has positive indirect effect through gel consistency (0.003) grain breadth (0.029), kernel length (0.089), kernel breadth (4.324), milling % (0.454), ASV (0.0001) and negative indirect effect through grain length (-0.148), L/B ratio (-0.241), kernel L: B ratio (-4.036), hulling % (-0.048), head rice recovery (-0.373) .

4.2.2.25 Gel consistency

It has positive indirect effect through grain length (0.098), L/B ratio (0.084), kernel length (0.171), kernel L:B ratio (1.293), hulling %(0.037), head rice recovery (0.153), ASV(0.00001), amylose content (0.002) and negative indirect effect for grain breadth (-0.024), kernel breadth (-1.873), milling % (-0.302).

The results of the path analysis are in accordance with the findings of Parimala *et al.* (2020) for indirect positive effect of productive tillers / plant through 1000 SW and Ekka *et al.* (2011) seen indirect positive effect of head rice recovery through kernel breadth, milling %. Akhi *et al.* (2016) for indirect effects through days of 50% flowering through plant height, days to maturity, spikelet fertility, no. of total tillers.

Fig-3 Direct and indirect effect on grain yield.

DFF = Days to 50 % flowering; DM = Days to maturity; PH = Plant height; PL= Panicle length; TT = Total tillers; ET= Effective tillers; FLL= Flag leaf length; FLW = Flag leaf width; FPP = Filled spikelets per panicle; SSP = Spikelets per panicle; SF% = Spikelet fertility %; HI = Harvest index; 1000 SW = 1000 seed weight; GL = Grain length; GB = Grain breadth; L:B ratio = Length breadth ratio; KL = Kernel length; KB = Kernel breadth; K L:B ratio = Kernel length breadth ratio; H% = Hulling %; M% = Milling %; HRR= Head rice recovery; ASV = Alkali spreading value; AC = Amylose content; GC = Gel consistency.

Table 4.4(a) Path matrix of direct and indirect effects (Direct effects on main diagonal) for yield and grain quality traits.

CHARACTERS	DDF	DM	PH	PL	TT	ET	FLL	FLW	SPP	FSP	F%	HI	1000 SW	GYP
DDF	1.341	-1.090	0.096	-0.002	-0.033	0.014	0.002	0.064	-0.517	0.466	-0.505	0.031	0.323	0.19
DM	1.335	-1.095	0.103	0.0002	-0.030	0.0134	0.001	0.079	-0.518	0.457	-0.488	0.025	0.305	0.188
PH	0.529	-0.464	0.243	0.020	0.148	-0.060	-0.004	-0.013	-0.224	0.121	0.003	-1.062	0.137	-0.627
PL	-0.057	-0.007	0.129	0.037	0.094	-0.034	-0.003	-0.002	-0.191	-0.092	0.437	-0.620	-0.032	-0.341
TT	0.168	-0.126	-0.137	-0.013	-0.262	0.091	0.008	-0.151	0.169	0.038	-0.249	0.723	0.380	0.639
ET	0.202	-0.154	-0.151	-0.013	-0.250	0.096	0.008	-0.053	0.119	0.069	-0.279	0.879	0.276	0.749
FLL	-0.188	0.140	0.093	0.010	0.196	-0.067	-0.011	0.061	0.111	-0.159	0.318	-0.591	-0.265	-0.354
FLW	0.115	-0.116	-0.004	-0.00009	0.053	-0.007	-0.0009	0.749	-0.481	0.240	-0.135	0.356	-0.296	0.473
SPP	0.457	-0.374	0.036	0.005	0.029	-0.008	0.0008	0.237	-1.517	0.682	0.019	0.227	0.380	0.175
FSP	0.771	-0.618	0.036	-0.004	-0.012	0.008	0.002	0.222	-1.277	0.810	-0.460	0.463	0.445	0.386
F%	0.736	-0.581	-0.0007	-0.018	-0.071	0.029	0.004	0.110	0.032	0.406	-0.920	0.528	0.206	0.46
HI	0.028	-0.019	-0.179	-0.016	-0.132	0.058	0.005	0.185	-0.239	0.261	-0.337	1.440	-0.130	0.926
1000 SW	-0.534	0.412	-0.041	0.001	0.123	-0.033	-0.004	0.274	0.712	-0.445	0.234	0.230	-0.810	0.12

DDF = Days to 50 % flowering; DM = Days to maturity; PH = Plant height; PL= Panicle length; TT = Total tillers; ET= Effective tillers; FLL= Flag leaf length; FLW = Flag leaf width; FPP = Filled spikelets per panicle; SSP = Spikelets per panicle; SF% = Spikelet fertility %; HI = Harvest index; 1000 SW = 1000 seed weight; GYP = Grain yield per plant.

Table 4.4 (b) Path matrix of direct and indirect effects (Direct effects on main diagonal) for yield and grain quality traits.

CHARACTERS	G L	G B	L:B ratio	K L	K B	K L : B ratio	H %	M %	HRR %	ASV	A C	GC	GYP
G L	3.841	-0.003	1.483	-20.365	-3.272	18.341	0.12	-0.458	0.229	-0.00001	-0.010	0.010	-0.083
G B	-0.069	0.207	-1.059	-1.297	9.615	-7.423	-0.106	0.312	-0.103	-0.00005	0.035	-0.047	0.064
L : B ratio	3.145	-0.121	1.811	-15.319	-8.125	18.802	0.169	-0.673	0.256	-0.00001	-0.034	0.019	-0.068
K L	3.704	0.013	1.314	-21.123	-1.370	17.418	0.052	-0.302	0.326	0.00001	-0.001	-0.003	0.026
K B	-1.036	0.164	-1.213	2.386	12.135	-12.023	-0.160	0.176	-0.205	0.00002	0.090	-0.063	0.249
K L : B ratio	3.490	-0.076	1.687	-18.225	-7.227	20.187	0.120	-0.358	0.361	0.00001	-0.051	0.026	-0.067
H %	-0.789	0.037	-0.518	1.842	3.285	-4.076	-0.592	1.726	-0.615	0.00008	0.020	-0.025	0.295
M %	-0.800	0.029	-0.554	2.901	0.971	-3.287	-0.465	2.199	-0.709	0.00007	0.052	-0.056	0.28
HRR %	-0.637	0.015	-0.336	4.997	1.805	-5.279	-0.264	1.130	-1.379	-0.00005	0.069	-0.046	0.074
ASV	0.151	0.025	0.041	0.522	-0.772	0.187	0.136	-0.431	-0.172	-0.00037	-0.070	-0.009	-0.393
Amy	-0.148	0.029	-0.241	0.089	4.324	-4.036	-0.048	0.454	-0.373	0.0001	0.254	0.003	0.308
GC	0.098	-0.024	0.084	0.171	-1.873	1.293	0.037	-0.302	0.153	0.00001	0.002	0.410	0.049

GYP = Grain yield per plant; GL = Grain length; GB = Grain breadth; L:B ratio = Length breadth ratio; KL = Kernel length; KB = Kernel breadth; K L:B = Kernel length breadth ratio; H% = Hulling %; M% = Milling %; HRR= Head rice recovery; ASV = Alkali spreading value; AC = Amylose content; GC = Gel consistency.

4.3 Cluster analysis

All 51 genotypes were divided into six clusters (Table 4.5) gives an idea about the significant amount of genetic diversity in the material.

The maximum no. of genotypes were found in cluster V containing 13 genotypes, after that cluster VI contains 11 genotypes, cluster II contains 10 genotypes, cluster III contains 9 genotypes, cluster I contains 5 genotypes, cluster IV contains 3 genotypes.

Table 4.5 Grouping of the genotypes in different clusters

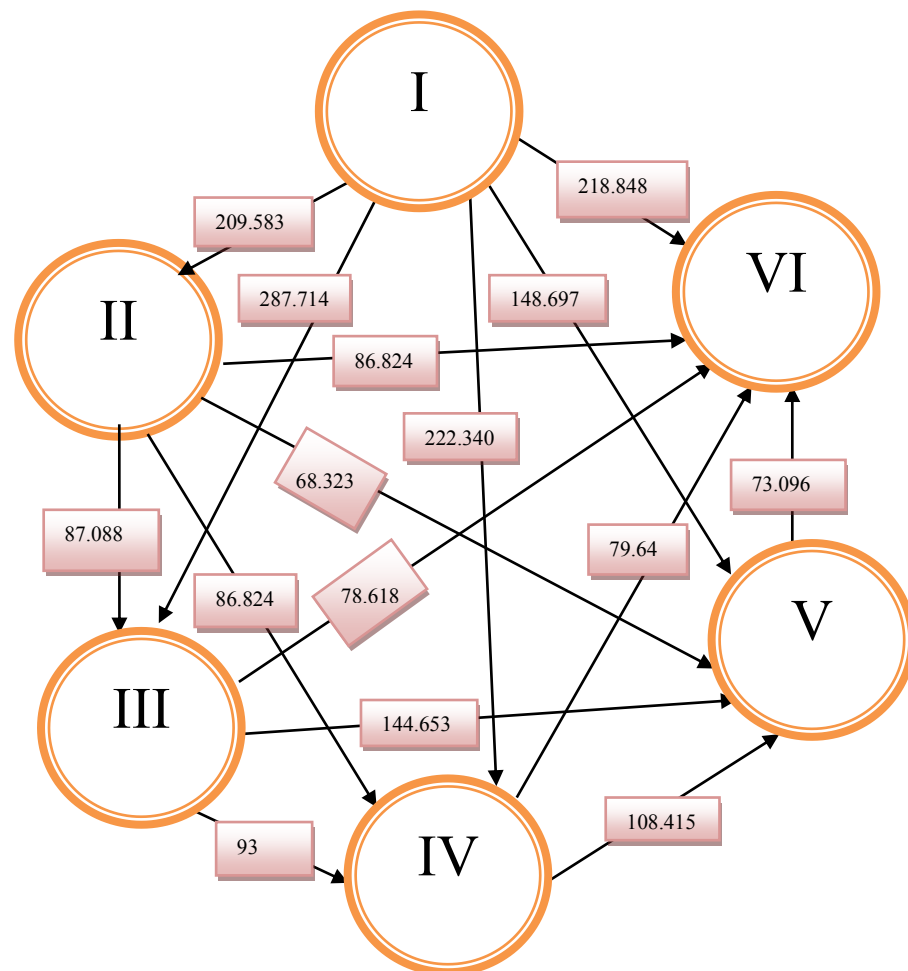
Cluster No.	No. of genotypes	Name of genotypes
I	5	R 2356-236-1-106-1, R 1771-580-1-298-1, R 1771-600-1-308-1, R 1771-635-1-313-1, Jau phool.
II	10	R 2356-218-1-97-1, R 2356-218-1-98-1, R 2356-219-1-99-1, R 2356-231-2-104-1, 2356-232-3-105-1, R 2397-335-1-157-1, R 2400-340-1-160-1, R 2418-1018-4-454-1, CG Devbhog (check) , CG Sugandhit Bhog (check).
III	9	R 2400-337-1-158-1, R 1771-593-1-304-1, R 2413-791-1-1-354-1, R 2413-802-1-358-1, R 2418-1034-2-481-1, Improved Kankadiya, Improved Shrikamal, R.K.M, M 0: 19 (Krishnajana).
IV	3	R 2417-927-1-404-1, R 2417-935-1-406-1, R 2419-1066-1-506-1.
V	13	R 2348-201-1-91-1, R 1771-583-2-300-1, R 1771-602-1-309-1, R 1771-64-1-312-1, R 2413-808-1-361-1, R 2417-936-1-407-1, R 24151-1286-1-638-1, Dubraj Sel.1(check), Vishnubhog (check), Luchai, Umari, Jaigundi, R-FS-2019-3.
VI	11	2299-319-1-144-1, R 2306-329-1-152-1, R 1771-589-1-303-1, R 1771-595-1-306-1, R 2413-803-360-1, R 2417-915-1-399-1, R 2418-1034-1-480-1, Improved khuddi, Mokdo, M 0: 8 (Aruna), Funderi.

4.3.1 Inter cluster distance

The highest inter cluster distance (Table No 4.3.2 and fig. 4) was recorded between cluster III and I (287.71), after that cluster IV and I (222.34), cluster VI and I (218.848), cluster II and I (209.58), cluster V and I (148.69) and cluster V and III (144.65) while lowest was noticed among cluster VI and II.

Table 4.6 Inter cluster distance

Cluster No	1	2	3	4	5	6
1	0.000	209.583	287.714	222.340	148.697	218.848
2		0.000	87.088	86.824	68.323	48.159
3			0.000	93.506	144.653	78.618
4				0.000	108.415	79.647
5					0.000	73.096
6						0.000

Fig -4 Cluster diagram with inter cluster distance

4.3.3 Cluster mean

Cluster I containing 5 genotypes exhibited highest mean values (Table 4.7 and in Fig 4.) for days to 50% flowering, days of maturity, no. of spikelets / panicle, no. of filled spikelets / panicle, milling %, head rice recovery %, alkali sreading value and amylose content.

Cluster II with 10 genotypes had highest mean values for total tillers, effective tillers, flag leaf width, harvest index, yield / plant and gel consistency.

Cluster III containing 9 genotypes had highest cluster mean values for 1000 seed weight, kernel length and kernel L : B ratio.

Cluster IV containing 11 genotypes exhibited highest mean values for panicle length, flag leaf length, grain length and L : B ratio.

The 13 genotypes present in cluster V exhibited highest values for fertility %, kernel breadth and hulling %.

Cluster VI containing 3 genotypes exhibited highest mean values for plant height and grain breadth.

The character days to 50% flowering gave highest mean value from cluster I and lowest mean value from cluster IV. The high yielding genotypes were present in cluster II i.e. R 2356-231-2-104-1, 2356-232-3-105-1, R 2356-218-1-98-1, R 2400-340-1-160-1, R 2418-1018-4-454-1.

The cluster analysis helps to see the genetic distance among the genotypes. This can be the pre-requisite for deciding any plant breeding programme. Once there's high cluster distance between 2 cluster show additional diversity and crossing of those genotypes provide higher heterotic combination. When high intra cluster of two completely different cluster show low diversity and choice are going to be rewarding. To appreciate bigger variability and powerful heterotic cause, parents ought to be choosen from two different clusters having broader inter cluster distance.

The similar findings are also reported by Reddy *et al.* (2021) i.e, Cluster II had maximum mean for effective tillers. Cluster VI include superior cultivars for plant height by Rashid *et al.* (2013); Cluster IV had maximum mean for panicle length by Anjali *et al.* (2014).

Table 4.7 Cluster means of yield and grain quality traits

	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V	Cluster VI
DFF	114	100.5	93	87.33	107.31	107
DM	144	129	120	116.33	136.54	136.82
PH	149.44	123.88	138.89	145.3	153.73	165.3
PL	25.36	24.18	25.12	27.4	25.32	25.61
TT	9.2	10.55	9.17	8.67	8.42	8.32
ET	8	9.4	7.67	7.5	7.31	6.86
FLL	30.56	31.15	32.733	41.9	36.63	37.69
LW	1.46	1.6	1.37	1.48	1.52	1.5
SPP	355.7	180.25	129.61	218.83	226.42	175.82
FSP	252	143.25	78.5	86	180.38	129.59
F%	73.46	79.63	62.01	38.8	80.41	74.44
HI	22.18	22.86	14.48	14.47	18.4	14.66
1000 SW	10.7	16.89	19.27	18.87	16.23	18.24
Y/p	12	14.09	6.72	6.13	10.75	7.96
G L	6	8.1	8.39	8.87	7.34	8.24
G B	2.3	2.25	2.32	2.2	2.38	2.39
L:B ratio	2.68	3.84	3.69	4.13	3.19	3.51
K L	4.1	5.5	5.79	6	5.16	5.63
K B	1.92	1.82	1.88	1.77	1.95	1.89
K L:B ratio	2.22	3.13	3.18	3.5	2.78	3.05
H%	75.04	71.93	71.16	70.63	75.38	74.34
M%	69.52	64.08	63.39	61	68.38	68.12
HRR	54.14	44.3	45.76	47.3	51.42	52.24
ASV	4.8	3.9	4.72	3.83	4.31	4.77
AC	23.82	22.08	22.66	22.27	22.21	22.34
GC	27.4	31.85	28.44	27.33	29.04	27.59

DFF = Days to 50 % flowering; DM = Days to maturity; PH = Plant height; PL= Panicle length; TT = Total tillers; ET= Effective tillers; FLL= Flag leaf length; FLW = Flag leaf width; FPP = Filled spikelets per panicle; SSP = Spikelets per panicle; SF% = Spikelet fertility %; HI = Harvest index; 1000 SW = 1000 seed weight; Y/P = Yield per plant; GL = Grain length; GB = Grain breadth; L:B ratio = Length breadth ratio; KL = Kernel length; KB = Kernel breadth; K L:B = Kernel length breadth ratio; H% = Hulling %; M% = Milling %; HRR= Head rice recovery; ASV = Alkali spreading value; AC = Amylose content; GC = Gel consistency.

4.4 Screening of rice of genotypes for aroma

Fifty one rice lines were taken along with 4 check varieties and were screened to estimate the presence of aroma in leaves using KOH test. Out of 51 lines, 11 lines were found strongly – scented, 13 were mild – scented and 27 were found non- scented were the table related to aroma test along with aroma score are described below (Table 4.8) :-

Table 4.8 Genotypes with their aroma reaction

S.No.	Entry	Aroma	S.No.	Entry	Aroma
1	R 2348-201-1-91-1	NS	27	R 2417-927-1-404-1	MS
2	R 2356-218-1-97-1	NS	28	R 2417-935-1-406-1	MS
3	R 2356-218-1-98-1	SS	29	R 2417-936-1-407-1	MS
4	R 2356-219-1-99-1	NS	30	R 2418-1018-4-454-1	MS
5	R 2356-231-2-104-1	MS	31	R 2418-1034-1-480-1	NS
6	2356-232-3-105-1	MS	32	R 2418-1034-2-481-1	NS
7	R 2356-236-1-106-1	NS	33	R 2419-1066-1-506-1	NS
8	2299-319-1-144-1	NS	34	R 24151-1286-1-638-1	NS
9	R 2306-329-1-152-1	NS	35	CG Devbhog (check)	SS
10	R 2397-335-1-157-1	NS	36	CG Sugandhit Bhog (check)	NS
11	R 2400-337-1-158-1	SS	37	Dubraj Sel.1 (check)	SS
12	R 2400-340-1-160-1	SS	38	Vishnubhog (check)	MS
13	R 1771-580-1-298-1	MS	39	Improved Kankadiya	NS
14	R 1771-583-2-300-1	NS	40	Improved khuddi	NS
15	R 1771-589-1-303-1	NS	41	Improved Shrikamal	NS
16	R 1771-593-1-304-1	NS	42	R.K.M	MS
17	R 1771-595-1-306-1	NS	43	Luchai	MS
18	R 1771-600-1-308-1	SS	44	Umari	MS
19	R 1771-602-1-309-1	NS	45	Mokdo	SS
20	R 1771-64-1-312-1	NS	46	M 0: 8(Aruna)	MS
21	R 1771-635-1-313-1	NS	47	M 0: 19 (Krishnajana)	NS
22	R 2413-791-1-1-354-1	SS	48	Jau phool	MS
23	R 2413-802-1-358-1	NS	49	Jaigundi	SS
24	R 2413-803-360-1	SS	50	Funderi	SS
25	R 2413-808-1-361-1	NS	51	R-FS-2019-3	NS
26	R 2417-915-1-399-1	NS			

NS = Non scented MS = Mild scented SS = Strongly scented

Table 4.9 List of top 10 high yielding genotypes alongwith aroma

The table 4.9 represents the list of top 10 genotypes on the basis of their

S.No.	Entry	Y/P	Aroma
1	R 2356-231-2-104-1	16.4	P
2	R 1771-600-1-308-1	16.4	P
3	2356-232-3-105-1	14.9	P
4	R 2356-218-1-98-1	13.5	P
5	R 2400-337-1-158-1	13.2	P
6	R 1771-580-1-298-1	11.5	P
7	R 2400-340-1-160-1	10.7	P
8	Luchai	10.4	P
9	Jau phool	9.5	P
10	R 2418-1018-4-454-1	8.2	P

yield / plant and also presence of aroma in leaf estimated through KOH test. These high yielding with aroma can be released as a new aromatic variety or they can be further utilized in rice breeding programme for development of good quality aromatic lines /genotypes.

CHAPTER-V

SUMMARY AND CONCLUSIONS

Present experiment entitled “**Genetic analysis for yield and quality traits in aromatic genotypes of rice (*Oryza sativa* L.)**” was conducted at “Research and Instructional Farm, Department of Genetics and Plant Breeding, College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur (Chhattisgarh) during *Kharif* 2020.” In this programme 51 aromatic rice lines (including 4 checks *via*; CG Devbhog, CG Sugandhit Bhog, Dubraj Sel.1, Vishnubhog Sel.1 were used. The study was carried out using a randomised block design with two replications.

Analysis of variance revealed that all the characters have shown highly significant variability for days to 50 % flowering, days to maturity, plant height, panicle length, no. of spikelets / panicle, no. of filled spikelets / panicle, spikelet fertility %, 1000 seed weight, grain length, grain breadth, length breadth ratio, kernel length, kernel breadth, kernel length / breadth ratio, hulling %, milling %, and alkali spreading value, number of effective tillers, flag leaf length, harvest index, yield / plant, head rice recovery %, amylose content, and gel consistency except for number of total tillers and flag leaf width which indicates the genotypes differ among them. The characters that showed considerable variance have the potential to be exploited for crop improvement. The non-significant traits suggested that variation is due to genetic inheritance.

The highest phenotypic coefficient of variation combined with genotypic coefficient of variation for grain yield per plant, after that harvest index, number of filled spikelets per panicle, no. of spikelets per panicle, 1000 seed weight, alkali spreading value and number of effective tillers.

Higher heritability with genetic advance as percentage mean estimates were found for no. of filled spikelets per panicle, number of spikelets per panicle, harvest index, 1000 seed weight, alkali spreading value, spikelet fertility %, kernel L:B ratio, grain length breadth ratio, kernel length, plant height, head rice recovery percentage, grain length, gel consistency, days to 50 % flowering, days to maturity,

amylose content, flag leaf length, and grain yield per plant these traits are influenced by additive gene action, so selection will be advantageous.

Grain yield / plant had positive significant genotypic correlations with number of total tillers, number of effective tillers, flag leaf width, number of filled spikelets per panicle, spikelet fertility percent, harvest index, kernel breadth, hulling percent, milling percent and amylose content. Selection for these grain quality traits may be beneficial in achieving the desired improvement in yield and yield related attributes. The most beneficial direct effects on grain yield was through kernel length / breadth ratio, kernel breadth, grain length, milling percent, L: B ratio, harvest index, days to 50 % flowering, number of filled spikelets per panicle, flag leaf width, gel consistency, amylose content, plant height, grain breadth, number of effective tillers, and panicle length.

Cluster V has the most number of genotypes, i.e. 13 whereas Cluster VI comprised of 11, Cluster II comprised of 10 genotypes, Cluster III comprised 9 genotypes, Cluster I had 5 genotypes, and Cluster IV having 3 genotypes. Cluster III and I (287.71) had the greatest inter-cluster distance, cluster IV and I (222.34), cluster VI and I (218.848), cluster II and I (209.58), cluster V and I (148.69), and cluster V and III (144.65), while lowest was noticed between cluster VI and II. The cluster analysis helps to understand genetic distance among the genotypes. To observe more variability and powerful heterotic cause, parents ought to be chosen from two different clusters having broader inter cluster distance.

Out of 51 lines, 11 lines were strongly scented i.e., R 2356-218-1-98-1, R 2400-337-1-158-1, R 2400-340-1-160-1, R 1771-600-1-308-1, R 2413-791-1-1-354-1, R 2413-803-360-1, Mokdo, Jaigundi, and Funderi including check Chhattishgarh Devbhog, Dubraj Sel.1, 13 were mild scented and 27 were recorded non scented. Top yielding genotypes identified are, R 2356-231-2-104-1, R 1771-600-1-308-1, 2356-232-3-105-1, R 2356-218-1-98-1, R 2400-337-1-158-1, R 1771-580-1-298-1, R 2400-340-1-160-1, Luchai, Jau phool and R 2418-1018-4-454-1.

Conclusion

The experimental results showed presence of significant variability in the existing materials for most of the characters. Traits association studies revealed that number of total tillers, number of effective tillers, flag leaf width, number of filled spikelets / panicle, spikelet fertility percent, harvest index, kernel breadth, hulling percent, milling percent, and amylose content are correlated positively and significantly with grain yield / plant. The most beneficial direct effects on grain yield were through kernel length / breadth ratio, kernel breadth, grain length, milling percent, L: B ratio, harvest index, days to 50 % flowering, number of filled spikelets / panicle, flag leaf width, gel consistency, amylose content, plant height, grain breadth, number of effective tillers, and panicle length.

Hence, improvement for grain yield / plant can be done through these traits and further indirect selection can be operated via these traits like kernel length / breadth ratio, kernel breadth, grain length, milling percent, L: B ratio, harvest index, days to 50 % flowering, number of filled spikelets / panicle, flag leaf width, gel consistency, amylose content, plant height, grain breadth, number of effective tillers, and panicle length.

Genetic diversity analysis through cluster analysis was also performed for the 51 genotypes. The genotypes were distributed in 6 clusters on the basis of different traits. Cluster V comprised the most genotypes, i.e. 13. Cluster III and I (287.71) had the greatest inter-cluster distance; hence hybridization among the genotypes of these clusters will give good heterotic recombination and better transgressive segregants in later generation.

Out of 51 lines, 11 lines were found strongly scented, 13 were mild scented and 27 non scented. Top yielding genotypes were observed are R 2356-231-2-104-1, R 1771-600-1-308-1, 2356-232-3-105-1, R 2356-218-1-98-1, R 2400-337-1-158-1, R 1771-580-1-298-1, R 2400-340-1-160-1, Luchai, Jau phool and R 2418-1018-4-454-1. These lines can be directly released as a new aromatic variety and utilized in future crop improvement programme.

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Appendix I: Weekly Meteorological Data during Crop Growth Period of *Kharif* -2020

Date	Max . Tem p. (°C)	Min. Temp. (°C)	Rain- fall (mm)	Rainy days	Relative Humidity (%)		Vapour Pressure (mm of Hg)		Wind Velocity (Kmph)	Evapo- ration (mm)	Sun Shine (hours)
					I	II	I	II			
Jun 04-10	37.1	25.5	44.2	3	80	38	22.8	19.7	5.3	46.0	8.7
11-17	34.3	25.9	62.0	2	87	69	23.5	24.1	6.6	26.9	2.3
18-24	30.9	24.5	156.8	5	89	72	22.1	22.9	9.8	20.5	0.4
25-01	33.9	26.0	20.6	2	85	68	23.7	24.9	5.7	27.3	4.2
Jul 02-08	33.6	25.8	95.0	3	88	66	23.7	24.6	7.5	28.9	5.4
09-15	33.4	25.0	67.5	3	88	74	23.3	24.0	7.2	25.5	2.8
16-22	33.0	26.1	39.8	3	86	71	23.5	24.5	5.9	24.9	4.4
23-29	32.3	25.9	29.9	2	86	68	23.2	23.5	5.5	22.8	3.8
30-05	33.3	26.0	23.6	2	89	69	23.9	24.8	5.9	26.7	3.3
Aug 06-12	30.5	25.5	81.6	3	92	77	23.3	24.3	7.1	22.9	1.5
13-19	28.4	25.1	71.2	4	93	86	22.8	23.8	10.4	13.9	0.5
20-26	31.0	25.5	29.8	3	89	74	23.0	23.2	7.8	19.9	2.0
27-02	29.8	24.6	235.8	4	93	75	22.6	22.9	8.2	19.9	3.7
Sep 03-09	32.9	26.0	8.0	2	91	74	24.3	24.8	3.0	22.5	4.9
10-16	33.2	26.0	64.0	2	91	67	24.2	23.4	3.4	24.6	6.0
17-23	32.7	25.8	16.4	2	89	71	23.1	24.5	2.9	19.5	3.6
24-30	32.8	25.3	0.0	0	90	59	22.9	20.4	5.1	24.1	5.3
Oct 01-07	31.8	25.0	12.8	1	90	63	22.3	21.6	2.6	20.5	4.0
08-14	32.5	25.3	0.0	0	90	66	23.0	22.6	4.4	22.4	5.0
15-21	31.9	24.4	7.0	1	90	60	22.4	20.4	5.0	23.3	6.5
22-28	32.6	20.1	0.0	0	87	35	16.8	12.7	2.1	24.1	8.0

29-04	31.8	17.4	0.0	0	82	30	14.0	10.3	2.2	24.9	7.6
Nov 05-11	30.3	12.5	0.0	0	87	28	10.8	8.7	2.1	23.5	8.5
12-18	32.7	18.9	0.0	0	87	37	15.7	13.6	2.9	24.9	8.5
19-25	31.0	15.9	0.4	0	88	35	13.4	11.0	2.8	23.1	7.4
26-02	28.6	14.7	0.0	0	81	35	11.2	9.9	4.0	22.4	6.2
Dec 03-09	30.7	11.9	0.0	0	89	33	9.9	9.6	1.3	22.2	7.3
10-16	30.2	15.8	0.0	0	86	37	12.5	11.4	2.4	20.1	3.7
17-23	27.7	10.3	0.0	0	87	27	9.4	7.1	2.5	22.7	5.0
24-31	28.4	10.3	0.0	0	87	28	8.8	7.8	1.8	24.6	4.8

Appendix II : Mean performance of rice genotypes for yield and grain quality traits.

S.No	Entry	DFE	DM	PH	PL	TT	ET	FLL	FLW	SPP	FSP	SF%	HI	1000 SW
1	R 2348-201-1-91-1	102.5	132.5	132.5	26.5	8.0	7.5	45.4	1.8	246.5	183.5	74.7	31.7	27.0
2	R 2356-218-1-97-1	93.5	120.5	120.1	24.3	10.5	9.0	29.9	1.8	190.5	159.0	83.2	21.1	15.7
3	R 2356-218-1-98-1	93.5	122.5	121.7	23.8	11.5	11.0	27.3	1.9	170.0	144.0	84.7	19.3	15.3
4	R 2356-219-1-99-1	96.5	123.5	124.9	25.3	12.0	11.0	30.6	1.8	192.5	139.0	72.6	25.2	20.7
5	R 2356-231-2-104-1	111.5	143.5	135.2	23.0	11.5	9.5	30.1	1.6	187.0	158.5	84.6	26.7	13.9
6	2356-232-3-105-1	111.5	143.0	142.2	22.6	9.5	9.0	30.5	1.4	179.5	148.0	82.7	23.3	15.1
7	R 2356-236-1-106-1	101.5	132.5	136.4	23.4	9.5	8.5	32.5	1.5	297.5	242.0	81.1	33.2	14.8
8	2299-319-1-144-1	100.5	130.0	149.7	25.7	9.5	8.0	34.6	1.6	168.5	139.5	82.4	27.5	21.5
9	R 2306-329-1-152-1	113.0	144.0	158.0	26.9	10.0	9.0	44.8	1.6	168.0	131.5	78.1	18.3	21.3
10	R 2397-335-1-157-1	94.5	123.0	125.5	27.7	11.0	9.5	33.4	1.5	166.0	136.0	81.5	23.1	17.7
11	R 2400-337-1-158-1	106.5	135.5	120.8	22.9	12.5	11.5	32.5	1.3	139.0	101.5	72.7	17.8	17.8
12	R 2400-340-1-160-1	99.5	126.5	117.4	23.5	9.5	8.5	32.7	1.3	168.0	117.0	70.4	22.1	18.5
13	R 1771-580-1-298-1	120.5	152.5	153.1	27.5	8.0	7.0	27.3	2.0	540.5	300.5	55.8	19.3	11.2
14	R 1771-583-2-300-1	108.5	140.5	169.4	32.0	8.5	8.5	34.7	1.5	212.5	159.0	74.4	16.2	15.7
15	R 1771-589-1-303-1	117.5	148.5	181.0	25.2	9.5	8.0	30.2	1.4	199.5	153.0	76.7	6.0	9.3
16	R 1771-593-1-304-1	98.5	126.5	157.8	27.7	9.5	9.0	32.2	1.3	131.5	91.5	70.3	4.8	12.7
17	R 1771-595-1-306-1	95.5	123.5	150.8	25.8	9.0	8.0	34.1	1.4	177.0	132.0	75.2	16.2	17.7
18	R 1771-600-1-308-1	101.5	128.5	128.8	24.4	11.0	10.0	28.2	1.2	317.0	219.0	69.7	27.8	10.5
19	R 1771-602-1-309-1	104.5	131.5	122.8	22.7	10.0	9.5	27.9	1.5	209.5	172.5	82.9	34.4	18.3
20	R 1771-64-1-312-1	104.5	132.5	127.4	23.6	9.5	9.5	27.0	1.6	212.5	180.0	84.6	34.1	18.5
21	R 1771-635-1-313-1	127.5	157.0	155.7	22.4	9.0	7.5	32.7	1.5	326.0	252.5	78.1	9.0	9.6
22	R 2413-791-1-1-354-1	77.5	102.5	152.3	28.6	8.5	7.0	37.9	1.4	117.0	45.5	37.2	12.2	24.1
23	R 2413-802-1-358-1	84.5	111.5	154.4	27.5	9.0	5.5	37.0	1.5	127.0	75.5	60.3	8.6	21.1
24	R 2413-803-360-1	87.5	114.0	164.0	27.3	5.5	3.5	43.2	1.6	192.0	119.5	62.0	11.2	19.0

25	R 2413-808-1-361-1	75.5	101.5	171.7	24.4	7.0	5.5	40.7	1.6	225.5	175.0	77.4	8.5	16.6
26	R 2417-915-1-399-1	105.5	135.5	163.6	24.0	7.5	6.5	34.0	1.5	188.5	135.0	72.5	17.4	19.9
27	R 2417-927-1-404-1	78.5	105.5	148.6	24.8	10.5	9.5	41.9	1.6	239.5	109.5	46.2	13.7	15.2
28	R 2417-935-1-406-1	91.5	121.5	146.6	29.4	7.0	6.0	49.1	1.4	186.5	47.0	25.0	12.9	19.9
29	R 2417-936-1-407-1	115.5	147.5	170.6	24.8	10.5	7.5	38.5	1.5	242.0	194.0	80.5	9.6	14.1
30	R 2418-1018-4-454-1	86.5	114.5	131.5	24.8	7.5	5.5	39.5	1.5	183.5	129.5	71.0	18.9	20.1
31	R 2418-1034-1-480-1	99.5	127.5	163.3	26.8	7.0	6.0	44.9	1.4	193.5	126.0	64.7	17.1	20.5
32	R 2418-1034-2-481-1	82.5	106.5	129.2	25.0	8.0	6.0	36.5	1.5	163.0	59.5	36.5	10.3	17.1
33	R 2419-1066-1-506-1	90.5	120.5	140.7	28.0	8.5	7.0	34.7	1.4	230.5	101.5	45.2	16.8	21.5
34	R 24151-1286-1-638-1	82.5	107.0	137.1	24.5	6.5	4.5	40.5	1.3	281.0	186.0	66.2	11.4	14.5
35	CG Devbhog (check)	105.5	133.5	111.5	23.1	12.0	11.5	29.9	1.6	194.0	151.0	78.0	28.2	17.4
36	CG Sugandhit Bhog (check)	107.5	135.5	108.8	23.7	10.5	9.5	27.6	1.6	171.5	150.5	87.6	20.7	14.5
37	Dubraj Sel.1 (check)	113.5	141.5	148.7	20.5	7.0	5.5	49.3	1.6	196.0	175.5	89.8	15.9	14.5
38	Vishnubhog (check)	113.5	142.0	159.7	23.9	9.0	7.0	35.6	1.3	249.0	211.5	86.0	17.8	10.7
39	Improved Kankadiya	107.5	136.5	165.4	23.2	9.0	7.0	29.8	1.4	110.0	91.0	83.5	19.4	19.1
40	Improved khuddi	111.5	141.5	158.0	21.2	9.5	8.0	36.4	1.5	139.0	112.0	80.2	18.8	14.8
41	Improved Shrikamal	101.5	128.5	168.1	25.6	8.5	7.0	35.3	1.4	142.0	90.0	63.2	6.5	17.2
42	R.K.M	79.5	104.5	87.9	20.6	8.5	8.0	21.8	1.2	83.5	64.5	77.9	24.0	21.8
43	Luchai	115.0	147.0	170.7	28.0	5.5	5.0	41.7	1.9	204.0	176.5	86.0	14.8	21.0
44	Umari	124.5	156.5	181.6	27.9	7.0	6.0	36.5	1.7	233.5	182.5	79.6	12.5	20.5
45	Mokdo	116.5	147.0	158.7	24.8	7.5	6.5	49.1	1.4	151.5	116.0	79.5	9.2	17.9
46	M 0: 8(Aruna)	112.5	144.5	182.1	23.8	6.0	4.5	30.9	1.7	179.5	146.0	81.3	11.2	28.3
47	M 0: 19 (Krishnajana)	94.5	123.5	114.1	25.0	9.0	8.0	31.6	1.3	153.5	87.5	56.5	26.7	22.5
48	Jau phool	116.5	147.5	173.2	29.1	8.5	7.0	32.1	1.1	297.5	246.0	82.6	21.6	7.4
49	Jaigundi	114.5	145.5	183.1	29.4	9.5	8.5	28.2	1.2	219.0	164.5	76.4	12.6	9.4
50	Funderi	112.5	145.5	189.1	30.2	10.5	7.5	32.4	1.4	177.0	115.0	66.3	8.4	10.5
51	R-FS-2019-3	114.5	144.5	123.2	21.0	11.5	10.5	30.2	1.3	212.5	184.5	86.9	19.7	10.2

Mean performance of rice genotypes for yield and grain quality traits.

S.No	Entry	Y/P	GL	GB	L:B ratio	KL	KB	K L:B ratio	H%	M%	HRR	ASV	AC	GC
1	R 2348-201-1-91-1	22.2	8.7	2.8	3.2	6.1	2.2	2.8	75.3	70.7	48.0	3.0	23.5	28.5
2	R 2356-218-1-97-1	13.9	8.7	2.1	4.3	5.5	1.7	3.3	64.9	55.3	41.9	4.0	23.6	46.5
3	R 2356-218-1-98-1	13.5	8.6	2.0	4.4	6.0	1.7	3.7	74.9	65.3	37.5	3.0	19.4	27.5
4	R 2356-219-1-99-1	19.8	8.8	2.4	3.8	6.2	1.8	3.5	67.9	64.8	37.8	3.0	24.8	27.0
5	R 2356-231-2-104-1	16.4	6.5	2.4	2.8	4.8	2.0	2.5	71.8	65.4	46.9	4.0	24.0	31.0
6	2356-232-3-105-1	14.9	6.9	2.5	2.8	5.1	2.0	2.7	79.6	73.5	54.4	4.0	22.0	40.5
7	R 2356-236-1-106-1	15.7	6.6	2.4	2.8	4.8	2.0	2.5	72.8	67.0	49.6	3.5	23.5	27.5
8	2299-319-1-144-1	15.6	8.7	2.4	3.7	6.4	2.0	3.3	78.5	69.9	48.4	4.5	21.8	25.5
9	R 2306-329-1-152-1	14.9	9.7	2.3	4.2	6.8	1.9	3.7	82.2	76.0	64.7	4.5	27.8	26.5
10	R 2397-335-1-157-1	12.1	8.7	2.0	5.5	5.6	1.6	3.5	66.8	54.7	43.4	6.5	20.6	25.5
11	R 2400-337-1-158-1	13.2	8.6	2.0	4.3	5.9	1.8	3.4	78.2	73.6	56.9	5.0	24.3	29.0
12	R 2400-340-1-160-1	10.7	8.5	2.3	3.7	5.6	1.7	3.3	74.0	70.8	39.3	4.0	23.2	28.0
13	R 1771-580-1-298-1	11.5	6.0	2.4	2.6	3.7	2.0	1.9	75.2	70.4	55.0	6.0	23.5	25.5
14	R 1771-583-2-300-1	10.6	7.9	2.3	3.6	5.1	1.7	3.1	77.2	72.2	48.6	5.0	18.0	29.0
15	R 1771-589-1-303-1	2.5	6.0	2.2	2.8	4.8	1.9	2.6	72.7	66.6	37.2	5.0	17.4	28.5
16	R 1771-593-1-304-1	2.8	7.6	2.2	3.4	5.0	1.7	3.0	75.8	66.0	46.8	4.0	18.9	27.5
17	R 1771-595-1-306-1	9.3	6.9	2.4	2.9	4.7	1.8	2.6	72.5	65.5	44.5	5.0	24.5	28.5
18	R 1771-600-1-308-1	16.4	6.1	2.3	2.8	4.5	1.9	2.4	77.7	70.5	42.7	3.0	23.9	25.5
19	R 1771-602-1-309-1	19.7	6.4	2.5	2.6	4.9	2.2	2.3	76.8	71.8	56.5	4.0	25.6	25.0
20	R 1771-64-1-312-1	20.6	6.7	2.7	2.5	4.9	2.1	2.4	80.9	73.4	54.8	3.0	22.7	24.5
21	R 1771-635-1-313-1	6.9	5.3	2.4	2.2	3.4	2.0	1.8	69.9	66.2	61.5	6.0	24.5	29.0
22	R 2413-791-1-1-354-1	5.4	9.0	2.3	4.0	6.2	1.8	3.5	67.4	57.9	43.6	5.5	17.8	28.0
23	R 2413-802-1-358-1	4.0	8.1	2.6	3.1	5.7	2.0	2.9	67.2	60.7	41.8	5.5	22.5	32.5
24	R 2413-803-360-1	4.7	8.5	2.6	3.3	5.6	1.8	3.2	66.3	60.1	47.5	6.5	23.0	27.0

25	R 2413-808-1-361-1	4.8	8.0	2.7	3.0	5.5	1.9	3.0	73.4	69.0	51.3	6.5	19.6	28.5
26	R 2417-915-1-399-1	9.4	8.9	2.5	3.6	6.2	1.9	3.4	70.8	65.6	49.5	6.5	17.3	28.5
27	R 2417-927-1-404-1	5.2	7.8	2.2	3.6	5.4	1.8	3.1	69.1	63.1	47.2	4.0	24.0	28.0
28	R 2417-935-1-406-1	5.7	10.0	2.1	4.9	6.2	1.8	3.5	67.6	57.0	50.2	3.0	22.5	26.0
29	R 2417-936-1-407-1	5.7	6.2	2.5	2.5	4.6	2.3	2.0	74.3	48.7	44.5	5.5	21.0	28.5
30	R 2418-1018-4-454-1	8.2	9.2	2.1	4.4	6.3	1.9	3.4	71.6	62.6	44.4	4.5	20.5	28.0
31	R 2418-1034-1-480-1	7.4	8.7	2.2	4.0	6.1	1.9	3.3	69.7	63.5	52.9	5.0	23.6	27.0
32	R 2418-1034-2-481-1	4.0	8.3	2.4	3.6	5.3	1.9	2.9	60.1	52.4	42.4	5.0	25.4	27.0
33	R 2419-1066-1-506-1	7.5	8.8	2.3	3.9	6.4	1.7	3.9	75.2	62.9	44.5	4.5	20.3	28.0
34	R 24151-1286-1-638-1	4.1	8.1	2.3	3.6	5.5	1.7	3.3	72.8	66.0	43.9	3.0	22.9	28.5
35	CG Devbhog (check)	18.6	8.5	2.1	4.1	5.6	1.8	3.2	74.4	57.8	47.7	3.0	21.0	36.5
36	CG Sugandhit Bhog (check)	12.8	6.6	2.6	2.6	4.3	2.0	2.2	73.4	70.6	49.7	3.0	21.7	28.0
37	Dubraj Sel.1 (check)	7.7	7.8	2.3	3.5	5.3	1.8	3.0	77.6	69.0	45.3	5.0	23.5	43.5
38	Vishnubhog (check)	7.2	5.9	2.3	2.6	4.5	1.9	2.4	73.6	68.1	49.8	3.0	22.7	28.5
39	Improved Kankadiya	10.9	8.3	2.2	3.8	5.8	1.9	3.1	71.5	64.8	43.7	5.0	23.5	28.0
40	Improved khuddi	8.7	8.1	2.1	3.9	5.0	1.7	3.0	78.0	73.4	54.1	4.0	21.5	27.0
41	Improved Shrikamal	2.1	8.3	2.1	4.0	6.0	1.8	3.4	75.2	70.0	39.9	3.0	25.5	27.5
42	R.K.M	5.6	9.5	2.4	4.0	6.3	1.8	3.6	72.6	64.2	53.5	5.5	21.5	29.0
43	Luchai	10.4	8.5	2.7	3.2	5.8	2.1	2.8	78.2	72.5	58.0	5.0	24.4	28.0
44	Umari	5.4	8.2	2.2	3.8	5.9	2.0	3.1	76.8	70.6	51.1	4.5	23.5	28.5
45	Mokdo	4.8	9.0	2.7	3.5	5.6	1.9	3.0	77.6	71.7	56.9	5.5	21.5	27.5
46	M 0: 8(Aruna)	6.0	9.6	2.6	3.8	6.5	2.1	3.2	75.6	69.6	59.3	3.0	24.5	29.0
47	M 0: 19 (Krishnajana)	12.5	7.8	2.7	3.0	5.9	2.2	2.8	72.4	60.9	43.2	4.0	24.5	27.5
48	Jau phool	9.5	6.0	2.0	3.0	4.1	1.7	2.5	79.6	73.5	61.9	5.5	23.7	29.5
49	Jaigundi	6.6	5.6	2.0	2.9	3.9	2.0	2.1	75.3	69.6	57.8	4.0	20.8	27.5
50	Funderi	4.3	6.5	2.3	2.9	4.2	1.9	2.3	73.8	67.4	59.7	3.0	22.9	28.5
51	R-FS-2019-3	14.7	7.4	1.7	4.5	5.1	1.4	3.8	67.8	67.3	58.9	4.5	20.5	29.0

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Development Yojana (READY) / RAWE
Membership of Professional Societies : Nil
Award/ Recognition : Nil
Publications : Nil

Signature

Nidhi

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Acceptance Letter

Manuscript Number: 2021/IJECC/74879

Article title: "Assessment of genetic variability, heritability and genetic advance in aromatic breeding lines based on yield and grain quality traits in Rice (*Oryza sativa* L.)"

Dear Sir/ Madam,

I am pleased to inform you that your "*Assessment of genetic variability, heritability and genetic advance in aromatic breeding lines based on yield and grain quality traits in Rice (*Oryza sativa* L.)*" authors Nidhi Paikra, Abhinav Sao, Deepak Gauraha, S.K. Nair and Ajay Tiwari has been accepted for publication. The date of acceptance and published date will vary once the gallery proof and response by authors after corrections in Volume XX, Issue XX.

Your paper was referred to an expert for suitability of publication. The comments of the expert and paper are enclosed herewith for revision.

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