VARIABILITY ANALYSIS OF ALLOGAMOUS TRAITS IN RICE (*Oryza sativa* L.)

By

K. P. DEEPA

THESIS

Submitted in partial fulfilment of the requirement for the degree of

Master of Science in Agriculture

Faculty of Agriculture

Kerala Agricultural University

Department of Plant Breeding and Genetics

COLLEGE OF HORTICULTURE

VELLANIKKARA, THRISSUR - 680 656

KERALA, INDIA

2000

DECLARATION

I hereby declare that this thesis entitled **"Variability analysis of allogamous traits in rice"** is a bona fide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other University or Society.

Vellanikkara
14.2.2000

Deepa.k.p
K. P. DEEPA

Dr.V.V. Radhakrishnan
Associate Professor
College of Horticulture
Kerala Agricultural University
Vellanikkara

CERTIFICATE

Certified that this thesis, entitled **"Variability analysis of allogamous traits in rice"** is a record of research work done independently by Miss. Deepa, K.P. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

Dr. V. V. Radhakrishnan
Chairman, Advisory Committee

Vellanikkara
14.2.2000

CERTIFICATE

We, the undersigned members of the Advisory Committee of **Miss.Deepa, K.P.**, a candidate for the degree of **Master of Science in Agriculture**, agree that the thesis entitled **"Variability analysis of allogamous traits in rice (*Oryza sativa* L.)"** may be submitted by Miss.Deepa, K.P., in partial fulfilment of the requirement for the degree.

Dr.RADHAKRISHNAN, V.V.
(Chairperson, Advisory Committee)
Associate Professor
College of Horticulture, Vellanikkara

Dr.PUSHKARAN, K.
(Member, Advisory Committee)
Associate Professor and Head
Department of Plant Breeding & Genetics
College of Horticulture
Vellanikkara

Dr.UNNITHAN, V.K.G.
(Member, Advisory Committee)
Associate Professor
Department of Agricultural Statistics
College of Horticulture
Vellanikkara

Dr.ROSAMMA, C.A.
(Member, Advisory Committee)
Assistant Professor
Agricultural Research Station,
Mannuthy

5/2/2000
EXTERNAL EXAMINER

Dedicated to my parents

and

beloved sister

ACKNOWLEDGEMENT

Words cannot express my deep sense of gratitude and indebtedness to all those who have helped me for the successful completion of this endeavor. Even then, I wish to express my sincere thanks and heartfelt gratitude to Dr.Tessy Joseph, Assistant Professor, College of Horticulture, Vellanikkara and ex-chairperson of my advisory committee for her valuable guidance, constant encouragement and sustained interest during the course of this investigation and preparation of the manuscript.

I have immense pleasure to express my deep sense of gratitude and indebtedness to Dr.Radhakrishnan, V.V., Associate Professor, College of Horticulture, Vellanikkara and chairman of my advisory committee for his valuable guidance and unfailing patience. I am highly grateful to him for critically going through the manuscript and for his valuable suggestions for the improvement of the thesis.

I take this opportunity to express my heartfelt thanks to Dr.Unnithan, V.K.G., Associate Professor, Department of Agricultural Statistics and member of my advisory committee for his ever willing help and advice in the statistical analysis of the data and subsequent interpretations.

My thanks and gratitude are due to Dr.Pushkaran, K., Associate Professor and Head i/c, Department of Plant Breeding and Genetics and member of my advisory committee for his valuable help and suggestions through out study.

I gratefully acknowledge Dr.Rosamma, C.A., Assistant Professor, Agricultural Research Station, Mannuthy and member of my advisory committee for her valuable technical advice and ever willing help rendered during the course of my research and preparation of the thesis.

My sincere thanks are due to Dr.Jaikumaran, U., Associate Professor and Head, Agricultural Research Station, Mannuthy for his help and co-operation rendered at the research station.

I wish to express my gratitude and sincere thanks to all the teaching and non-teaching staff of the Department of Plant Breeding and Genetics and Agricultural Research Station, Mannuthy for their unbounded support at different stages of the study.

A note of thanks to Jayamani madam and library staff of TNAU, Coimbatore for providing all possible facilities for literature collection.

My soulful thanks and indebtedness are due to my loving friends Annie, Shanat, Anju and Sangeetha for their concern and ever willing help throughout the course programme. I express my sincere thanks to all my friends Sindhu, Maya, Sreedevi, Ambily, Kavitha, Sulaja, Divya, Sreeja, Renu, Sunil, K.M., Subha, Srinivas Reddy, Biju Chettan, Ajith, C.B., Sainudheen and Leju for their valuable help rendered at different stages of the study.

My thanks are due to Mrs.Soniya for assisting me in taking observations. I accord my sincere thanks to Smt.Joicy, Programmer, Department of Agricultural Statistics for her help in analysing the data. I would like to thank Mr.Joy, J.M.J. Computers, Thottappady for neat typing and excellent presentation of graphs and tables in the manuscript. I am thankful to Thushara Studio, Mannuthy for their excellent photography.

KAU Junior Research Fellowship is duly acknowledged.

Last but not least I express my heartfelt thanks and indebtedness to my father, mother and sister Miss.Divya without whose support and sacrifice the study would have never seen light. I accord my respectful thanks to all other family members for their encouragement and warm blessings.

Finally I bow my head before `God Almighty' who blessed me with health, strength and confidence for the successful completion of this endeavor.

DEEPA, K.P.

CONTENTS

LIST OF TABLES

LIST OF PLATES

LIST OF FIGURES

LIST OF APPENDICES

INTRODUCTION

Rice is the prime food crop of the world occupying an area of 146.5 million hectares with a total production of 534.7 million tonnes in 1997. Coming to the Indian scenario, sad irony lies in the fact that China outweighs us in rice production even though they are behind us in area coverage. One of the factors that pushed China to the forefront in productivity has been the hybrid rice cultivation. It has been undoubtedly proved that hybrid rice gave more than 30 per cent yield advantage over conventional varieties. India was too late in developing and adopting hybrid rice technology inspite of knowing its potential.

However with the release of as many as 14 hybrids developed by public and private sector institutions and with 1.2 lakh hectares under them, now India has earned the unique distinction of being the second country after China to make hybrid rice a commercial reality. Now even at the one tonne yield advantage, adoption of hybrid rice technology is expected to add 1-1.5 million tonnes of milled rice annually by 2001 and the additional volume is bound to steadily rise to over 5-6 million tonnes by 2006.

Identification of hybrid rice breeding as a thrust area for continued and enhanced support in the nineth plan by the Indian Council of Agricultural Research, generous support from MAHYCO Research Foundation, and the likelihood of UNDP extending its ongoing support, besides support from several state governments reflect how strong a conviction the various sources have on the potential of the hybrid rice technology.

The hybrid rice programme has already been launched in KAU and good combiners have been identified at RARS, Pattambi and ARS, Mannuthy. With this background present study was undertaken and as this study includes identified parents, the information generated in the study will provide basic data for choosing the parents, based on their synchronisation in anthesis and floral biology. The study will also help to identify wild or local genotypes, which can be utilized for restructuring the rice flower to suit hybrid seed production.

With due consideration to the above, the following objectives have been identified for.the study

1) to estimate the amount of variability for allogamous traits in selected high yielding, local and wild genotypes
2) to identify local or wild rice genotypes with good morphological traits favouring out-crossing
3) to find the association of these characters to out-crossing
4) to estimate the amount of out-crossing in high yielding and local varieties included in this study.

REVIEW OF LITERATURE

The successful exploitation of hybrids in an autogamous crop like rice depends upon the hybrid seed production, which in turn depends upon the out-crossing potential of the parents. This can be done by improving floral characteristics favouring cross-pollination and determining favourable conditions for natural out-crossing. The cytoplasmic male sterile lines should have longer and exserted stigma, longer stigmatic receptivity wider and longer opening of glumes and exserted panicle. Floral biological aspects like panicle emergence, sequence of blooming in a panicle, duration of blooming, opening and closing of spikelets, time of anther dehiscence, pollen viability etc. are associated with the rate of out-crossing.

The present investigation was initiated to evaluate the rice germplasm for various floral and morphological traits influencing open pollination and to explore their use in restructuring the floral morphology in rice so as to enable hybrid production. While choosing parents for a three line breeding system, the out-crossing potential of the parent is as important as their combining ability. Hence important literatures on different floral traits influencing out-crossing have been reviewed briefly.

2.1 Cytoplasmic male sterile lines and out-crossing

The most important floral trait influencing out-crossing is male sterility.

Hoff and Torre (1981) studied stigma exsertion in rice and its effect on the seed set of male sterile plants. They reported significant correlation between seed set and stigma exsertion.

In a study by Azzine and Rutger (1982) three male sterile lines were planted for two years in alternate rows with pollinators made up of mixture of five tall varieties. Seed set was poor in genetically male sterile lines. Higher seed set in cytoplasmically male sterile line was attributed to better synchronization of flowering of male and female plants.

Percentage grain set in cytoplasmically male-sterile V20 A, using V20 B as pollinator was reported as 29.3 per cent and 31.1 per cent in 1981 and 1982 respectively by Sarma *et al.* (1982). About one third of the basal florets did not set grain because of lack of exsertion and physical hindrance to pollination by the flag leaf.

BRRI initiated collaborative research on hybrid rice with IRRI in 1982. A study on field production of hybrid seed using cytoplasmically male sterile line V20 A and its maintainer V20 B revealed low seed set in V20 A which showed the less out-crossing rate. Study was undertaken by Sarkar (1983) and low seed set was attributed to small number of pollen parents, improper synchronization of flowering, poor panicle exsertion of V20 A and lack of supplementary pollination.

A similar study using V20 A and V20 B was done by Silitonga (1985). He attributed low seed set to poor panicle exsertion.

Genetic correlations study between natural out-crossing and floral characters of rice male sterile lines by Li *et al.* (1988) showed the genetic differences in stigma width, ovary length and stigma angle.

CMS lines flowered earlier than their respective maintainers and there was slight reduction in flag leaf length, spikelets/panicle and panicle exsertion compared to maintainers. Extent of natural out-crossing ranged from 14.9 to 26.5 per cent (Pradhan *et al.*, 1989).

A study with IR 54752 A revealed that pollinator distance did not significantly affect seed set per cent or filled grains per plant tended to decrease with distance. Pollination at 80 cm depended on wind velocity (Satato and Sutaryo, 1989).

Nishimak *et al.* (1992) studied flowering habits of cytoplasmic male sterile lines of rice with different male sterile cytoplasm and nuclei. Delayed flowering and reduced number of bloomed florets, compared to the maintainers were identified as the main draw backs for out-crossing and seed set in the male sterile lines. It was also observed that flowering habits of CMS line in rice are decided by the interaction of nuclear and cytoplasmic genes.

2.2 Out-crossing in wild species

The higher rate of natural out-crossing in wild rice than cultivated rices has been reported by Shinjyo and Omura (1966) and Stansel and Craigmiles (1966).

Oka and Morishma (1967) studied the allogamous nature of the species *Oryza longistaminata* (with large and feathery exserted stigmas and very large anthers) and *Oryza perennis* (with high pollen viability).

Virmani and Athwal (1973) were the pioneers to transfer the allogamous floral traits enhancing out-crossing, from wild rice to cultivated rice. The genotypic correlations from the study indicate that, it is possible to increase the proportion of exserted stigma by selecting an increased length of stigma and of anther. The increased length of anther will improve out-crossing not only through its influence on stigma exsertion but also presumably by directly increasing the number of pollen grains available in pollination.

Jayamani and Rangaswamy (1995) studied seven wild species in rice for their out-crossing traits and suggested that the available variability in wild species can be exploited to restructure the rice flower to increase out-crossing.

2.3 Variability

2.3.1 Variability in plant characters

Virmani and Athwal (1973) in a pioneer study recorded higher per cent out-crossing in wild rices like *Oryza spontanea* and *Oryza longistaminata*.

In rice, Unnikrishnan (1982) reported high phenotypic and genotypic coefficients of variation for panicle exsertion and grain yield.

Jebaraj and Palanisamy (1990) studied panicle exsertion in 40 genotypes and reported considerable variation for this character.

Jayamani and Rangaswamy (1995) studied seven wild species in rice for their out-crossing traits and suggested that the available variability in wild species can be exploited to restructure the rice flower to fit out-crossing.

2.3.2 Variability in spikelet characters

Namai *et al.* (1988) reported variation in spikelets flowering and found it as one of the most effective floral characteristics for enhancing seed set.

Rangaswamy and Vijayakumar (1995) recorded that out-crossing can be increased by selecting genotypes where there is synchronization in flowering period.

2.3.3 Variability in anther characters

Virmani *et al.* (1980) reported significant variation in characters for out-crossing like anther length, anther breadth and filament length in eleven out of eighty six elite breeding lines identified.

Significant variation in floral traits like anther length was found by Sarkar and Miah (1983) in ten total varieties out of the ninety eight field grown local varieties.

Variability in anther characteristics was found in allogamous species in a study for improving out-crossing rate in rice by Taillebois *et al.* (1988).

Genetic diversity in A and B lines based on traits influencing out-crossing in rice was reported by Rao (1996). Considerable variation was observed for all traits. B lines had bigger anthers, greater plant height and earlier flowering than A lines, while A lines where characterised by pronounced stigmatic traits, longer duration of anthesis and poor panicle exsertion.

2.3.4 Variability in stigma characters

Significant variation in floral traits like stigma length and stigma exsertion was found by Sarkar and Miah (1983) in ten local varieties out of the ninety eight field grown local varieties.

Exserted stigma showed the highest genetic variability in a study of variability of nine floral characters by Li and Yang (1986).

Taillebois *et al.* (1988) also reported variability in stigma characters in a study for `improving out-crossing'.

2.4 Heritability, genetic advance and genetic gain

Of nine floral characters studied in thirty varieties to assess their importance for out-crossing, stigma length, stigma exsertion and spikelet length had high heritability values (Yang and Luang, 1986).

Taillebois *et al.* (1988) have reported high heritability for characters like anther length, anther diameter and stigma length.

Rangaswamy and Vijayakumar (1995) in a study on out-crossing revealed high heritability for panicle exsertion.

2.5 Correlated characters

Oka and Morishma (1967) in their study found out a significant positive correlation between lengths of stigma and style. They also reported that number of pollen grains per anther was found to be highly correlated with anther length.

Virmani and Athwal (1973) reported positive correlation between percentage of exserted stigma and stigma length. Both traits were also positively correlated with anther length, but their correlation coefficients were relatively smaller.

Hoffe and Torre (1981) reported a highly significant correlation between stigma length and stigma exsertion. He also reported in his study a significant positive correlation between stigma exsertion and seed set.

In a study on genetic variability and correlations of floral characters of big stigma rice, Li and Yang (1986) found out significant positive correlation between long stigma and out-crossing rate.

Of nine floral characters studied in thirty varieties to assess their importance for out-crossing, stigma length, percentage stigma exsertion, spikelet length/width ratio and spikelet length had high heritability values and genotypic and phenotypic correlations between these characters were close (Yang and Luang, 1986).

Namai *et al.* (1988) reported a significant positive correlation between glume angle and protruding stigma percentage and natural out-crossing rate.

Genetic correlations between natural out-crossing and floral characters of rice male sterile lines are reported by Li *et al.* (1988). The genetic correlations between out-crossing and floral structural traits were negative, while those between out-crossing and traits related to flowering behaviour were positive.

The most effective floral characteristics for enhancing seed set were frequent stigma exsertion for CMS line and residual pollen per exserted anther for the pollen parent and many spikelets flowering daily for both as revealed in a correlation study by Namai, Kato and Smith (1988).

2.6 Flowering behaviour and other factors in relation to out-crossing

The flowering process in rice has been described by Rodrigo (1921). Grist (1953) stated that duration of blooming depend much on the pace of pollination. Delay or failure of pollination had been reported to prolong blooming interval in rice and wheat.

A study by Kato and Namai (1987) revealed that in the seed parents, percentage of spikelets with protruding stigmas was positively associated with grain set, pistil size and stigma size and glume angle were positively associated with protruding stigma percentage and natural out-crossing rate. The pollen parent possessed a large amount of residual pollen at the stage of anther protrusion and is considered desirable. A wind velocity of 2-3 m/sec and >1.5 airborne pollen grains/litre of air were necessary to achieve 50 per cent grain set.

The influence of nine floral traits on out-crossing was evaluated for 15 CMS lines grown under dry and wet seasons. Genotypes performed differently in the two environments. Seetharamaiah *et al.* (1994) suggested that hybrid seed production is better during dry season because more floral traits are better expressed than during wet season.

Siddiq *et al.* (1994) reported wide variation for flowering behaviour and floral traits in rice. Accessions that could be utilised for improving the floral traits like panicle exsertion, prolonged anthesis and additional flush of flowering, prolonged glume opening, large anther, large stigma surface and good stigma protrusion were also identified.

MATERIALS AND METHODS

Plate 1. Source germplasm

MATERIALS AND METHODS

The present investigations were conducted in the Department of Plant Breeding and Genetics, College of Horticulture, Vellanikkara during the period 1997-1999. The field experiments were conducted at Agricultural Research Station, Mannuthy of Kerala Agricultural University during rabi 1998-99. It is located at an altitude of 1.5 m above mean sea level and falls between 10°32' N latitude and 76°10' E longitude. Soil is lateritic loam and geographically it falls in the warm humid tropical climatic zone. The weather parameters during the period of study are presented in Appendix I.

3.1 Materials

Thirty three rice genotypes including high yielding varieties (15 Nos.), local varieties (8 Nos.), wild rice (4 species), CMS lines (3 lines) and B lines (3 lines) formed the experimental materials for the study. The high yielding varieties were selected from among the good combiners identified at RARS, Pattambi and ARS, Mannuthy. The wild genotypes were selected from the germplasm maintained by NBPGR during kharif 1998 by observing specific morphological traits. Details of the genotypes are presented in Tables 1, 2, 3, and 4.

3.2 Methods

Methods involved in the study can be divided in to

3.2.1 Field experiments

3.2.2 Observations recorded

3.2.3 Statistical analysis, (which include analysis of variance and correlation studies).

Table 1. Details of CMS lines used in the study

Sl.No.	CMS lines	Cytoplasmic source	Origin
1	IR 62829A	WA	IRRI
2	V 20 A	WA	China
3	IR 58025 A	WA	IRRI

Table 2. Details of maintainers used in the study

Sl.No.	Maintainers	Origin
1	IR 62829 B	IRRI
2	V 20 B	China
3	IR 58025 B	IRRI

Table 3. Details of high yielding varieties evaluating for out-crossing traits

Sl.No.	Genotype	Pedigree	Source
1	Jaya	TN(1)/T14	India
2	Kanchana	IR 36/Pavizham	"
3	Kairali	IR 36/Jyothi	"
4	Aathira	BR51-46-1/KAU 23332-2	"
5	Aiswarya	Jyothi/BR51-46-1	"
6	Annapoorna	TN(1)/Ptb10	"
7	Bharathi	Ptb10/IR8	"
8	Neeraja	IR20/IR5	IRRI
9	Matta triveni	Re-selection from Triveni	India
10	MDU-4	AC 2836/Jaganath	"
11	Jyothi	Ptb10/IR8	"
12	Basmathi-217	Punjab local	"
13	ADT-37	BG28012/PTB 33	"
14	Swarnaprabha	Bhavani/Triveni	"
15	IR-42	IR 203/*O. nivara*/CR-94-13	IRRI

Table 4. List of local varieties and its source

Local varieties	Source
1. Pokkali	Paravoor, Kerala
2. Njavara	Paravoor, Kerala
3. Vadakkankaran	Pattambi, Kerala
4. Nandyar	Pattambi, Kerala
5. Chennellu	Pattambi, Kerala
6. Poochempan	Pattambi, Kerala
7. Veluthacheera	Pattambi, Kerala
8. Eruvakkali	Pattambi, Kerala

Wild varieties used in the study

1. *Oryza officinalis*
2. *Oryza spontanea*
3. *Oryza meridionalis*
4. *Oryza longistaminata*

3.2.1 Field experiments

The field study was conducted in rabi 1998-99. The experiment was laid out with thirty three genotypes in RBD with three replications adopting a spacing of 15 x 20 cm. Two rows of each genotype (ten plants in each row) were alternated with one row of pigmented rice (IR 1552) as a pollinator with marker. At flowering, observations on allogamous traits listed below were recorded. At maturity seeds from each replication were collected. A sample of 500 seeds was sown from each replication, to study the percentage of out-crossing. Package of practices recommendations of Kerala Agricultural University (KAU, 1996) were adopted for raising the crop. Need based plant protection measures were adopted to control pest and diseases.

3.2.2 Observations

The following observations were recorded during the study.

Plant characters

The observations were recorded from five plants in each replication.

1. Plant height

The height of the main culm or tallest tiller, from base to the tip of the panicle was recorded, excluding awn if any, and expressed in centimeters.

2. Flag leaf angle

A right angle constructed on a thick paper was used for plotting the flag leaf angle in the field. The culm was held along one perpendicular line and position of flag leaf was plotted. The angle was later measured by a protractor.

3. Panicle exsertion

Length of the exposed part of the panicle, from flag leaf junction to panicle tip was measured and expressed as percentage of exsertion over total panicle length.

Spikelet characters

These observations were noted in five panicles in each replication, at the rate of ten spikelets at random per panicle.

4. Time and duration of spikelet opening

Time interval between spikelet opening and closing was noted in individual spikelets and expressed in minutes.

5. Duration of anthesis in a panicle (flowering period)

Time interval between opening of first flower and closing of last flower in a panicle was calculated for five panicles and expressed as mean number of days.

6. Angle of glume opening

The observation was taken one hour after glume opening, in individual spikelets. Three points namely, the tips of lemma, palea and the point of attachment of pedicel were plotted on a thick paper from the field. The angle was later measured using protractor and expressed in degrees.

Staminal characters

7. Anther length

Anther length was measured under a projection microscope and expressed in millimeters. Hundred anthers were measured for each replication for each genotype.

8. Filament length

Filament length was measured in hundred anthers from each replication for each genotype under the projection microscope and expressed in millimeters.

9. Pollen fertility

Pollen fertility counts were taken from five randomly selected spikelets of each panicle. The pollen grains were squeezed out from well-matured anthers and stained with two percent Iodine-potassium iodide solutions and examined under microscope. Fully round well developed and deeply stained pollen grains were counted as fertile and unstained or poorly stained and shriveled pollen grains were counted as sterile. Five slides were prepared for each replication. Four microscopic fields were observed from each slide and pollen fertility was expressed in percentage.

10. Pollen viability

Spikelets were collected just before anthesis. The pollen immediately after dehiscence was dusted on to the media in cavity slides. The media composed of 0.5 M sucrose and 100 ppm boric acid. Five slides were prepared from random spikelets in each replication. After three hours of incubation, five microscopic fields were observed from each slide and pollen germinated was expressed in percentage.

11. Number of pollen grains/anther

The number of pollen grains per anther was estimated from the formula given by Suzuki (1981).

$y = -1172 + 1277x$, where y is the number of pollen grains per anther and x is the length of anther in mm.

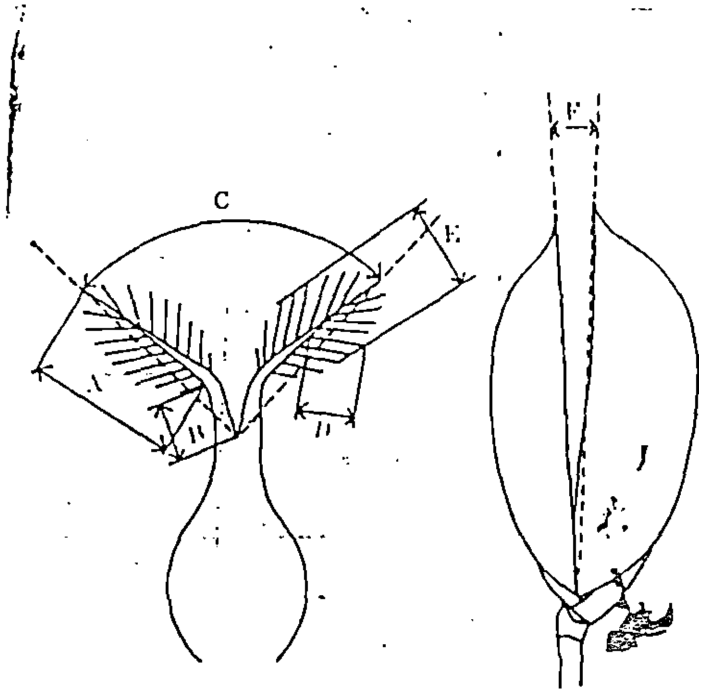


Fig. 1. Diagram showing the portions of the stigma measured.

A : Stigma length
A+B : Pistil length
C : Internal angle of the stigma lobes
D : Length of stigma-hair
E : Diameter of stigma
$2\pi(E/2)^2A$: Volume of the stigma lobes
F : Angle between lemma and palea at 1 hr. after flowering

12. Residual pollen

The residual pollen, i.e., pollen remaining just after dehiscence was counted using a haemocytometer. Hundred anthers were collected from each replication, in each genotype, immediately after dehiscence in the field. The dehisced anthers were collected in plastic vials containing 2.5 ml distilled water and teepol as dispersing agent. The anthers were crushed and vials were shaken well to allow dispersion of residual pollen. A drop of this suspension was transferred to each of the two counting chambers of the haemocytometer, using a fine pipette. The counting chambers were 0.1 mm in depth, so that the volume of solution over a millimetere square was 0.1 mm^3. Pollen grains in each of the four corner squares of each counting chamber were counted by using the projection microscope and the mean was recorded as N. Total number of pollen in one anther was estimated using the formula

$$x = \frac{2.5 \text{ x } N}{0.1\text{x}100} = 25\,N$$

where,

N - average number of pollen counted per corner square

x - total number of pollen per anther

Stigmatic characters

13. Stigma length

Stigma length was measured under the projection microscope. The same spikelets used for measuring angle between stigmatic lobes were used for measuring stigma length.

14. Stigma exsertion

The percentage of exserted stigma was determined from a sample of bloomed spikelets selected from five panicles per plant and from five plants in each replication. Percentage of spikelets with exserted stigma to the total number of bloomed spikelets was calculated.

15. Length of stigmatic hair and diameter of stigma

Length of stigmatic hair and stigma diameter was measured under the projection microscope as illustrated in the Fig.1 and expressed in millimeters.

16. Angle between stigmatic lobes

Angle between two lobes of stigma was measured from microscopic screen using a protractor and expressed in degrees. Hundred spikelets from each replication for each genotype were used for taking observation.

17. Volume of stigmatic lobes

Volume was found out using the following formula as proposed by Oka and Morishma (1967).

$$V = 2\pi(E/2)^2A$$

where,

E - Diameter of stigma

A - stigma length

18. Percentage of out-crossing

A random sample of five hundred seeds was sown from each replication and pigmented seedlings were counted and expressed as percentage of out-crossing for each genotype. For CMS lines, percentage of total set per panicle was considered as percentage of out-crossing.

19. Meteorological data relevant to the experiment was collected from Department of Agricultural Meteorology, College of Horticulture, Vellanikkara.

3.2.3 Statistical analysis

Measures like mean, variance and standard error were calculated as per Panse and Sukhatme (1978). Mean values of all characters from each plot were subjected to analysis of variance. Further, phenotypic coefficient of variation, genotypic coefficient of variation, heritability, genetic advance, genetic gain and phenotypic and genotypic correlation coefficients were worked out. The analysis techniques suggested by Fisher (1954) was employed for estimation of various genetic parameters.

3.2.3.1 Phenotypic, genotypic and environmental variance

The variance components were estimated using the formula suggested by Burton (1952).

Genotypic variance (V_g) = $(V_T - V_E)/N$

where

V_T = mean sum of squares due to treatments

V_E = mean sum of squares due to error

N = number of replications

Environmental variance (V_e) = V_E

Phenotypic variance (V_p) = $V_g + V_e$

Phenotypic and genotypic coefficient of variation

The phenotypic and genotypic coefficients of variation were calculated by the formula suggested by Burton and Devane (1953).

Phenotypic coefficient of variation (pcv) = $(\sqrt{V_P} / \bar{X}) \times 100$

$\bar{X}$ = Mean of character under study

Genotypic coefficient of variation (gcv) = $(\sqrt{V_g} / \bar{X}) \times 100$

3.2.3.2 Heritability

Heritability in the broad sense was estimated by the formula suggested by Burton and Devane (1953).

$$H^2 = (V_g/V_p) \times 100$$

The range of heritability was categorised as suggested by Robinson *et al.* (1949) as

0 - 30 per cent - low

31-60 per cent - moderate

61 per cent and above - high

3.2.3.3 Expected Genetic Advance

The genetic advance expected for the genotype at five percent selection pressure was calculated using the formula by Lush (1949) and Johnson *et al.* (1955) with the value of the constant K as 2.06 as given by Allard (1960).

Expected genetic advance GA = $\sqrt{V_g/V_p} \times 2.06$

3.2.3.4 Genetic gain

Genetic advance calculated by the above method was used for estimation of genetic gain.

Genetic gain (GG) = $(GA/ \bar{x}) \times 100$

where,

GA = Genetic advance

$\bar{X}$ = mean of characters under study

The genetic gain was classified according to Johnson *et al.* (1955) as follows

1-10 percent - low

11-20 percent - moderate

21 percent and above - high

3.2.3.5 Phenotypic and genotypic correlation coefficients

The phenotypic and genotypic correlation coefficients were worked out to study the extent of association between the characters. The phenotypic and genotypic covariances were worked out by the method suggested by Fisher (1954).

Phenotypic covariance between two characters 1 and 2

$$(COV_{p12}) = COV_{g12} + COV_{e12}$$

where,

COV_{g12} = genotypic covariance between characters 1 and 2

COV_{e12} = environmental covariance between characters 1 and 2

Genotypic covariance between characters 1 and 2

$$COV_{g12} = (M_{t12} - M_{e12})/N$$

where,

M_{t12} = Treatment mean sum of product of characters 1 and 2

M_{e12} = Error mean sum of product of characters 1 and 2

N = Number of replications

The phenotypic and genotypic correlation coefficients among the various characters were worked out in all possible combinations according to the formula suggested by Johnson *et al.* (1955). Phenotypic correlation coefficient between two characters 1 and 2.

where,

V_{p1} = phenotypic variance of character 1

V_{p2} = phenotypic variance of character 2

Genotypic correlation coefficient between two character 1 and 2 was calculated by the formula

$$(rg_{12}) = COV_{g12}/(V_{g1}.V_{g2})^{½}$$

where,

V_{g1} = Genotypic variance of character 1

V_{g2} = Genotypic variance of character 2

For all the above analysis computer facilities attached to College of Horticulture were utilised.

RESULTS

RESULTS

The results of statistical analysis of the data on eighteen traits influencing out-crossing in rice are presented in this chapter.

4.1 Variability analysis in allogamous traits in rice

4.1.1 Analysis of variance

The results of analysis of variance for eighteen characters in thirty genotypes of rice are summarised in Table 5, 6, 7 and 8. Variance due to genotypes for all the traits were significant at 1 per cent level.

4.1.2 Mean performance

The population mean, range, genotypic coefficient of variation (gcv) and phenotypic coefficient of variation (pcv) for various characters are given in Tables 9, 10, 11 and 12. Mean performance of various genotypes are summarised in Tables 13, 14, 15 and 16.

4.1.2.1 Plant characters

a) Plant height

Analysis of variance for plant height showed significant difference among different genotypes for this character. Plant height ranged from 47.80 cm (Kanchana) to 107.47 cm (Veluthacheera) with an average value of 77.71 cm. The pcv and gcv where 19.98 and 19.94 respectively.

b) Flag leaf angle

Flag leaf angle varied from 5.90° (Basmati-217) to 27.23° (Jaya) with an average of 13.5°. This character too, showed significant difference among the genotypes. The pcv and gcv values are 51.79 and 51.42 respectively.

Table 5. Analysis of variance for five plant characters associated with out-crossing potential in rice genotypes

Sources of variation	Mean sum of squares					
	df	Plant height (cm)	Flag leaf angle	Panicle exsertion at flowering (%)	Panicle exsertion at maturity (%)	% out crossing
Replication	2	0.94	0.101	214.43	268.3	0.109
Genotypes	32	721.1**	146.2**	1040.08**	1324.0**	101.1**
Error	64	0.99	0.70	126.92	127.1	0.137

** Significant at 1% level

Table 6. Analysis of variance for spikelet characters associated with out-crossing potential in rice genotypes

Source of variation	df	Glume angle	Duration of spikelet opening (minutes)	Duration of anthesis in a panicle (days)
Replication	2	9.38	54.87	2.131
Genotypes	32	102.51**	16375.5**	6.63**
Error	64	1.57	49.89	0.38

** Significant at 1% level

Table 7. Analysis of variance for staminal characters in rice

Source of variation	Mean sum of squares					
	df	Anther length (mm)	Filament length (mm)	Pollen fertility (%)	Pollen viability (%)	Residual pollen per anther
Replication	2	0.003	0.006	0.500	7.91	0.293
Treatment	32	1.24**	1.80**	2534.5**	1913.6**	2.08**
Error	64	0.010	0.012	0.7874	7.127	0.13

** Significant at 1% level

Table 8. Analysis of variance for stigma characters in rice

Source of variation	Mean sum of squares					
	df	Stigma length (mm)	Stigma diameter (mm)	Length of stigma hair (mm)	Stigma exsertion (%)	Angle between stigmatic lobes
Replication	2	0.002	0.003	0.00006	0.095	0.359
Treatment	32	0.442**	0.44**	0.0045**	2534.5**	552.2**
Error	64	0.004	0.0008	0.0003	0.7874	1.85

** Significant at 1% level

Table 9. Range, mean, phenotypic coefficients of variation and genotypic coefficient of variation of plant characters in 33 genotypes of rice

	Plant height (cm)	Flag leaf angle (degrees)	Panicle exsertion at flowering (%)	Panicle exsertion at maturity (%)	Percentage out-crossing (%)
Range	47.80-107.47	5.90-27.23	63.37-146.6	63.54-149.75	0.07-17.97
Mean ± SE	77.71±0.81	13.55±0.68	105.17±1.91	104.78±1.92	3.58±0.30
Phenotypic coefficient of variation	19.98	51.79	19.75	21.89	162.48
Genotypic coefficient of variation	19.94	51.42	16.59	19.06	162.15

Table 10. Range, mean, phenotypic coefficients of variation and genotypic coefficient of variation of staminal characters in 33 genotypes of rice

	Anther length (cm)	Filament length (mm)	Pollen fertility (%)	Pollen viability (%)	Residual pollen per anther
Range	1.42-3.91	3.05-6.03	0.00-100	0.00-73.13	0.17-3.75
Mean ± SE	2.50±0.083	4.62±0.09	90.51±0.72	32.36±1.22	0.953±0.29
Phenotypic coefficient of variation	25.96	16.87	32.11	78.32	92.58
Genotypic coefficient of variation	25.64	16.70	32.10	77.89	84.68

Table 11. Range, mean, phenotypic coefficient of variation and genotypic coefficient of variation of stigma characters in 33 genotypes of rice

	Stigma length mm)	Stigma diameter (mm)	Stigma hair length (mm)	Angle between stigmatic lobes	Stigma exsertion (%)
Range	1.04-3.20	0.29-0.96	0.17-0.29	29.33-72.00	0.00-100
Mean ± SE	1.57±0.06	0.45±0.24	0.22±0.014	50.16±1.11	14.01±0.39
Phenotypic coefficient of variation	24.91	27.11	18.81	27.14	188.80
Genotypic coefficient of variation	24.32	26.31	17.04	27.00	188.77

Table 12. Range, mean, phenotypic and genotypic coefficient of variation for spikelet characters in 33 genotypes of rice

	Glume angle (degrees)	Duration of anthesis in a panicle (days)	Duration of spikelets opening (mts)
Range	23.93-47.37	3.00-9.67	44.00-371.67
Mean ± SE	35.71±1.10	5.50±0.51	159.77±1.57
Phenotypic coefficient of variation	16.62	28.56	46.38
Genotypic coefficient of variation	16.24	26.26	46.17

Table 13. Mean performance of five plant characters of 33 genotypes of rice

Genotypes	Plant height (cm)	Flag leaf angle	Panicle exsertion (%)		% out-crossing
			at flowering	at maturity	
IR 62829A	72.07	22.63	78.22	79.04	12.50
IR 62829B	73.63	10.47	94.73	94.88	-
V20A	56.83	22.27	66.93	67.11	15.53
V20B	57.53	22.03	95.04	95.38	-
IR 58025A	78.50	19.83	63.37	63.54	15.10
IR 58025B	79.50	19.83	91.58	91.73	-
Jaya	80.53	27.23	133.62	134.87	2.15
Kanchana	47.80	8.50	95.04	95.54	1.33
Kairali	74.67	7.03	104.99	106.42	1.27
Aathira	47.87	5.97	106.25	106.73	0.87
Aiswarya	74.93	14.97	111.26	111.75	0.20
Annapoorna	67.23	11.73	95.22	96.06	1.07
Bharathi	66.60	5.97	105.66	106.38	1.27
Neeraja	84.87	6.93	129.56	130.56	2.53
Matta Triveni	72.20	25.20	108.99	110.57	0.53
MDU-4	75.17	9.07	114.44	114.55	0.87
Jyothi	72.58	7.77	111.63	112.31	1.07
Basmati-217	101.57	5.90	81.49	84.48	0.33
ADT-37	85.80	6.27	120.41	120.65	0.13
Swarnaprabha	62.33	5.93	124.90	126.30	0.73
IR 42	76.50	7.37	110.21	111.04	0.23
Pokkali	102.33	8.23	123.48	124.72	0.13
Njavara	73.83	7.20	118.15	117.88	0.07
Vadakkankaran	85.63	7.75	93.94	94.14	0.93
Nandyar	88.83	5.87	105.67	106.76	1.33
Chennellu	97.03	16.13	84.48	85.09	1.20
Poochempan	63.40	16.15	119.58	119.94	0.47
Veluthacheera	107.47	12.27	83.49	83.56	0.13
Eruvakkali	102.50	21.67	112.75	113.13	0.23
Oryza officinalis	68.50	16.37	118.78	119.14	0.43
Oryza spontanea	105.63	23.43	146.60	149.75	2.40
Oryza meridionalis	80.27	19.23	106.77	106.97	0.50
Oryza longistaminata	81.23	21.43	113.52	113.58	2.67
CD(0.05)	1.36	1.14	3.206	3.208	0.506
CD(0.01)	1.95	1.63	4.76	4.76	0.751

Table 14. Mean performance of three spikelet characters in 33 genotypes of rice

Genotypes	Glume angle	Duration of spikelet opening (mts.)	Flowering period (days)
IR 62829A	29.23	371.67	7.33
IR 62829B	29.27	301.67	5.67
V20A	37.03	260.00	9.67
V20B	35.63	240.67	5.33
IR 58025A	41.30	180.67	3.00
IR 58025B	28.07	249.67	3.67
Jaya	39.63	191.00	5.33
Kanchana	42.07	218.00	5.00
Kairali	41.63	141.67	4.33
Aathira	38.20	88.67	4.33
Aiswarya	24.70	168.00	4.00
Annapoorna	44.80	130.33	8.67
Bharathi	36.50	216.33	4.67
Neeraja	40.53	126.00	5.67
Matta Triveni	38.20	147.67	4.67
MDU-4	36.97	190.00	7.33
Jyothi	38.70	180.33	5.33
Basmati-217	34.37	155.33	4.67
ADT-37	33.37	109.00	6.67
Swarnaprabha	26.73	159.00	5.67
IR 42	36.17	189.00	6.00
Pokkali	26.00	82.00	4.00
Njavara	36.87	104.33	3.33
Vadakkankaran	30.53	158.67	5.67
Nandyar	47.37	185.33	5.67
Chennellu	41.83	167.00	5.67
Poochempan	35.70	145.67	6.33
Veluthacheera	40.07	73.33	5.67
Eruvakkali	33.70	117.00	5.33
Oryza officinalis	37.07	57.33	8.00
Oryza spontanea	40.00	67.67	5.00
Oryza meridionalis	23.93	44.00	6.00
Oryza longistaminata	32.37	53.33	3.67
CD(0.05)	1.71	2.63	0.842
CD(0.01)	2.54	3.90	1.25

Table 15. Mean performance of five stigmatic characters in 33 genotypes of rice

Genotypes	Stigma length (mm)	Stigma diameter (mm)	Stigma exsertion (%)	Stigma hair length (mm)	Stigma angle
IR 62829A	1.81	0.40	38.87	0.19	65.60
IR 62829B	1.71	0.34	8.77	0.19	51.27
V20A	1.67	0.57	34.87	0.25	65.00
V20B	1.41	0.44	2.37	0.22	70.00
IR 58025A	1.80	0.48	43.11	0.23	44.17
IR 58025B	1.13	0.41	1.90	0.23	29.33
Jaya	1.42	0.43	0.47	0.21	32.23
Kanchana	1.93	0.39	0.00	0.21	81.63
Kairali	1.44	0.42	0.00	0.20	51.60
Aathira	1.52	0.51	0.00	0.22	30.10
Aiswarya	1.38	0.29	1.59	0.15	50.03
Annapoorna	1.35	0.55	0.00	0.28	58.20
Bharathi	1.43	0.38	5.13	0.18	45.97
Neeraja	1.68	0.44	4.72	0.21	29.73
Matta Triveni	1.39	0.35	0.00	0.18	59.67
MDU-4	1.53	0.41	0.00	0.20	38.80
Jyothi	1.78	0.42	0.00	0.22	47.87
Basmati-217	1.34	0.38	0.00	0.27	41.70
ADT-37	1.80	0.42	0.00	0.22	59.87
Swarnaprabha	1.72	0.42	0.79	0.22	51.17
IR 42	1.38	0.51	18.85	0.31	49.53
Pokkali	1.55	0.32	0.00	0.17	30.47
Njavara	1.53	0.59	12.00	0.28	32.83
Vadakkankaran	1.53	0.54	0.00	0.26	40.93
Nandyar	1.82	0.52	1.97	0.26	40.13
Chennellu	1.11	0.40	0.00	0.20	62.73
Poochempan	1.31	0.41	2.45	0.21	45.10
Veluthacheera	1.43	0.44	0.00	0.22	55.87
Eruvakkali	1.31	0.37	0.00	0.21	45.67
Oryza officinalis	3.20	0.96	100.00	0.20	61.43
Oryza spontanea	1.20	0.62	80.90	0.12	72.00
Oryza meridionalis	1.04	0.36	22.43	0.23	56.20
Oryza longistaminata	2.14	0.47	81.07	0.21	62.63
CD(0.05)	0.094	0.404	0.647	0.023	1.85
CD(0.01)	0.139	0.599	0.960	0.034	2.74

Table 16. Mean performance of five stamen characters of 33 genotypes of rice

Genotypes	Anther length (mm)	Filament length (mm)	Pollen viability (%)	Pollen fertility (%)	Residual pollen
IR 62829A	2.18	6.03	0.00	0.41	0.58
IR 62829B	2.27	5.01	53.90	99.69	0.17
V20A	2.20	5.46	0.00	0.00	0.67
V20B	2.43	4.18	62.50	100.00	0.08
IR 58025A	2.14	4.37	0.00	0.00	0.92
IR 58025B	3.35	3.98	73.13	99.87	0.58
Jaya	2.34	5.47	66.50	100.00	0.50
Kanchana	2.38	4.83	42.17	100.00	0.42
Kairali	2.76	5.41	60.43	100.00	0.67
Aathira	2.80	5.99	70.10	100.00	0.83
Aiswarya	3.08	5.43	47.43	100.00	0.83
Annapoorna	2.30	4.57	68.90	100.00	1.08
Bharathi	2.88	5.78	50.97	100.00	0.50
Neeraja	3.62	3.49	21.13	100.00	2.25
Matta Triveni	2.44	4.30	39.67	100.00	0.25
MDU-4	1.95	3.99	57.73	100.00	2.25
Jyothi	2.41	5.12	23.17	100.00	0.50
Basmati-217	2.01	4.35	37.67	100.00	0.92
ADT-37	1.98	5.82	6.79	97.67	1.08
Swarnaprabha	3.91	3.36	53.63	100.00	0.50
IR 42	3.45	4.60	25.63	100.00	1.17
Pokkali	2.08	3.57	0.00	99.73	0.50
Njavara	1.91	4.49	15.13	100.00	0.58
Vadakkankaran	1.95	3.91	56.67	100.00	0.25
Nandyar	2.32	4.13	44.20	100.00	0.50
Chennellu	2.89	4.31	25.93	100.00	0.42
Poochempan	2.19	4.20	0.00	98.30	0.50
Veluthacheera	1.69	3.05	34.53	100.00	0.83
Eruvakkali	1.42	4.51	16.00	100.00	1.08
Oryza officinalis	3.58	5.01	2.53	100.00	3.75
Oryza spontanea	3.75	4.28	1.90	92.37	3.08
Oryza meridionalis	1.60	5.19	4.57	100.00	2.13
Oryza longistaminata	2.33	4.32	5.17	100.00	1.08
CD(0.05)	0.139	0.148	1.21	3.62	0.486
CD(0.01)	0.206	0.219	1.79	5.37	0.721

c) Panicle exsertion

This character showed significant difference among the genotypes and it ranged from 63.37 per cent to 146.6 per cent at flowering with an average of 105.17 per cent. Panicle exsertion at maturity ranged from 68.54 per cent to 149.75 per cent with an average of 104.78 per cent. The least panicle exsertion or more specifically no exsertion was seen in IR 58025A and highest panicle exsertion was seen in wild rice species *Oryza spontanea*.

d) Per cent out-crossing

Analysis of variance revealed significant difference in per cent out-crossing among the genotypes. The value ranged from 0.07 per cent (Njavara) to 15.53% (V20A). The pcv and gcv values were 162.48 and 162.15 respectively.

4.1.2.2 Spikelet characters

a) Time and duration of spikelet opening and closing

Peak time of spikelet opening in all the genotypes are summarised in Table 17. Duration of spikelet opening to closing showed significant difference among the genotypes and it ranged from 44 mts (*Oryza meridionalis*) to 371.67 mts (IR 62829A) with a mean value of159.77 mts. The pcv and gcv values were 46.38 and 46.17 respectively (Table 12).

b) Flowering period in a panicle (Duration of anthesis in a panicle)

Analysis of variance showed significant difference among the genotypes for this character. Duration of anthesis ranged from 3 days (IR 58025A) to 9.67 days (V20A). The pcv and gcv values were 28.56 and 26.26 respectively. The characters showed a mean value of 5.5 days (Table 12).

Table 17. Peak time of spikelet opening in 33 genotypes of rice

Genotype	Peak time of spikelet opening
IR 62829A	9.40 am to 10.20 am
IR 62829B	9.40 am to 10.20 am
V20A	9.20 am to 9.45 am
V20B	9.20 am to 9.45 am
IR 58025A	9.40 am to 10.00 am
IR 58025B	9.40 am to 10.00 am
Jaya	10.25 am to 10.35 am
Kanchana	9.40 am to 10.05 am
Kairali	9.35 am to 9.50 am
Aathira	9.50 am to 10.25 am
Aiswarya	10.00 am to 10.30 am
Annapoorna	9.50 am to 10.15 am
Bharathi	10.55 am to 11.20 am
Neeraja	10.45 am to 11.10 am
Matta Triveni	9.30 am to 9.50 am
MDU-4	10.30 am to 10.50 am
Jyothi	9.55 am to 10.25 am
Basmati-217	9.35 am to 10.00 am
ADT-37	10.15 am to 10.40 am
Swarnaprabha	10.05 am to 10.30 am
IR 42	10.30 am to 10.45 am
Pokkali	10.15 am to 10.50 am
Njavara	10.45 am to 10.55 am
Vadakkankaran	9.55 am to 10.15 am
Nandyar	10.05 am to 10.20 am
Chennellu	10.35 am to 11.00 am
Poochempan	10.25 am to 10.55 am
Veluthacheera	10.15 am to 10.40 am
Eruvakkali	10.45 am to 11.15 am
Oryza officinalis	10.30 am to 11.05 am
Oryza spontanea	9.45 am to 10.05 am
Oryza meridionalis	10.10 to 10.20 am
Oryza longistaminata	9.55 am to 10.40 am

c) Angle of glume opening

Glume angle varied significantly among the genotypes and it ranged from 23.93° (*Oryza meridionalis*) to 47.37° (Nandyar) with an average of 35.71°. The pcv and gcv values were 16.62 and 16.24 respectively (Table 12).

4.1.2.3 Staminal characters

a) Anther length

Analysis of variance showed significant difference among genotypes in this character. Anther length varied from 1.42 mm (Eruvakkali) to 3.91 mm (Swarnaprabha) with an average of 2.50 mm. The pcv and gcv values were 25.96 and 25.64 respectively (Table 10).

b) Filament length

Filament length varied from 3.05 mm (Veluthacheera) to 6.03 mm (IR 62829B) with an average of 4.62 mm. Analysis of variance showed significant difference among the genotypes for this character and pcv and gcv values were estimated to be 16.87 and 16.76 respectively (Table 10).

c) Pollen fertility

Pollen fertility varied significantly among the genotypes. It ranged from 0 per cent (V20A, IR 58025A) to 100 per cent in most of the genotypes with an average of 90.51 per cent. The pcv and gcv values were 32.11 and 32.10 respectively (Table 10).

d) Pollen viability

Pollen viability varied significantly among genotypes and it ranged from 0 per cent (CMS lines) to 73.13 per cent (IR 58025 B) with a mean value of 32.36 per cent. The pcv and gcv values were 78.32 and 77.89 respectively (Table 10).

Table 18. Estimated number of pollen grains per anther in 33 genotypes of rice

Genotype	Number of pollen grains/anther
IR 62829A	1607.60
IR 62829B	1726.80
V20A	1935.40
V20B	1641.60
IR 58025A	3101.69
IR 58025B	1560.80
Jaya	1811.90
Kanchana	1867.30
Kairali	2352.50
Aathira	2403.60
Aiswarya	2765.40
Annapoorna	1769.40
Bharathi	2505.80
Neeraja	3454.90
Matta Triveni	1948.10
MDU-4	1313.89
Jyothi	1909.80
Basmati-217	1394.70
ADT-37	1356.50
Swarnaprabha	3816.80
IR 42	3237.90
Pokkali	1479.90
Njavara	1271.30
Vadakkankaran	1313.90
Nandyar	1786.38
Chennellu	2522.80
Poochempan	1620.40
Veluthacheera	990.40
Eruvakkali	645.50
Oryza officinalis	3403.90
Oryza spontanea	3612.50
Oryza meridionalis	866.90
Oryza longistaminata	1807.70

e) Number of pollen grains/anther

Number of pollen grains/anther, calculated using the formula given by Suzuki is given in Table 18. Pollen load ranged from 645.5 pollen/anther (Eruvakkali) to 3816.8 pollen/anther (Swarnaprabha).

f) Residual pollen

Analysis of variance showed significant difference among the genotypes in this character. It ranged from 0.17 (IR 62829B) to 3.75 (*Oryza officinalis*) with an average value of 0.95. The pcv and gcv values were 92.58 and 84.68 respectively (Table 10).

4.1.2.4 Stigmatic characters

a) Stigma length

Stigma length varied from 1.04 mm (*Oryza meridionalis*) to 3.20 mm (*Oryza officinalis*) with a mean value of 1.57 mm. This character showed significant difference between the genotypes. The pcv and gcv values were 24.71 and 24.32 respectively (Table 11).

b) Stigma diameter

Analysis of variance showed significant difference among the genotypes in stigma diameter. It varied from 0.29 mm (Aiswarya) to 0.96 mm (*Oryza officinalis*), with a mean value of 0.45 mm. The pcv and gcv values were 27.11 and 26.31 respectively (Table 11).

c) Stigma hair length

This character showed significant difference among the genotypes. The pcv and gcv values were 18.81 and 17.04. Stigma hair length ranged from 0.17 mm (Pokkali) to 0.29 mm (Kairali), with an average of 0.22 mm (Table 11).

Table 19. Estimated volume of stigma lobes in different genotypes included in the study

Genotype	Volume of stigma lobes (mm^3)
IR 62829A	0.310
IR 62829B	0.455
V20A	0.719
V20B	0.508
IR 58025A	0.409
IR 58025B	0.475
Jaya	0.412
Kanchana	0.461
Kairali	0.399
Aathira	0.621
Aiswarya	0.182
Annapoorna	0.641
Bharathi	0.324
Neeraja	0.511
Matta Triveni	0.267
MDU-4	0.404
Jyothi	0.493
Basmati-217	0.304
ADT-37	0.499
Swarnaprabha	0.476
IR 42	0.564
Pokkali	0.249
Njavara	0.836
Vadakkankaran	0.700
Nandyar	0.773
Chennellu	0.279
Poochempan	0.346
Veluthacheera	0.435
Eruvakkali	0.282
Oryza officinalis	4.630
Oryza spontanea	0.724
Oryza meridionalis	0.212
Oryza longistaminata	0.742

d) Angle between stigmatic lobes

The angle varied significantly among the genotypes from 29.33° (IR 58025B) to 72° (*Oryza spontanea*), with a mean value of 50.16°. The pcv and gcv values were 27.14 and 27.0 (Table 11).

e) Stigma exsertion

Stigma exsertion per cent varied significantly among the genotypes from 0 per cent in some of the genotypes to 100 per cent (*Oryza officinalis*), with an average value of 14.01 per cent. The pcv and gcv values were 188.80 and 188.77 respectively Table 11).

f) Volume of stigma lobes

Volume of stigma lobes estimated is presented in Table 19. It ranged from 0.182 mm^3 (Aiswarya) to 4.63 mm^3 (*Oryza officinalis*).

4.1.3 Heritability, genetic advance and genetic gain

4.1.3.1 Plant characters

Heritability, genetic advance and genetic gain of plant characters are presented in Table 20.

Highest heritability was observed for the character plant height (99.6%) and per cent out-crossing (99.6%). It was followed by the character flag leaf angle (98.6%). Panicle exsertion at flowering (70.6%) and maturity (75.8%) too showed high heritability.

Genetic advance was highest for panicle exsertion at maturity (35.83) and lowest for per cent out-crossing (11.92). Plant height gave a genetic advance value of 31.85 and flag leaf angle gave a value of 14.25.

Table 20. Heritability, genetic advance and genetic gain of plant characteristics

	Plant height	Flag leaf angle	Panicle exsertion at flowering	Panicle exsertion at maturity	% out-crossing
Heritability (%) (Broad sense)	99.60	98.60	70.60	75.80	99.60
Genetic advance	31.85	14.25	30.19	35.83	11.92
Genetic gain (%)	40.90	105.20	28.70	34.19	333.80

Table 21. Heritability, genetic advance and genetic gain of spikelets characteristics in rice

	Glume angle	Duration of antheis in a panicle	Duration of spikelet opening
Heritability (%) (Broad sense)	95.50	84.50	99.10
Genetic advance	11.68	2.73	151.27
Genetic gain (%)	32.70	49.70	94.60

All the plant characters showed high genetic gain. Per cent out-crossing showed the highest genetic gain (333.8%) followed by flag leaf angle (105.2%). Panicle exsertion and plant height too gave high genetic gain.

4.1.3.2 Spikelet characters

Heritability, genetic advance and genetic gain for spikelet characters are summarised in Table 21.

Duration of spikelet opening showed high heritability (99.1%), followed by glume angle (95.5%).

Genetic advance value for spikelet opening duration was high (151.27). Glume angle and flowering period gave a genetic advance value of 11.68 and 2.73 respectively.

Glume angle, flowering period and duration of spikelet opening showed high genetic gain of 32.7, 49.7 and 94.6 per cent respectively.

4.1.3.3 Anther characters

High heritability values were observed for all the anther characters. Heritability, genetic advance and genetic gain of anther characters are summarised in Table 22.

Highest heritability was observed for pollen fertility (99.9%) followed by pollen viability (98.9%). Residual pollen showed heritability of 83.7 per cent. Genetic advance value was high for pollen fertility (59.84) and least for anther length (1.31).

High genetic gain was observed for all characters except residual pollen. Highest genetic gain was observed for pollen viability (159.5%) and lowest genetic gain for residual pollen (1.59%).

Table 22. Heritability, genetic advance and genetic gain of staminal characteristics

	Anther length (mm)	Filament length (mm)	Pollen fertility	Pollen viability (%)	Residual pollen
Heritability (%) (Broad sense)	97.60	98.00	99.90	98.90	83.70
Genetic advance	1.31	1.57	59.84	51.64	1.52
Genetic gain (%)	52.3	33.90	66.09	159.50	1.59

Table 23. Heritability, genetic advance and genetic gain of stigmatic characteristics in rice

	Stigma length	Stigma diameter	Stigma hair length	Angle between stimatic lobes	Stigma exsertion (%)
Heritability (%) (Broad sense)	96.90	94.20	82.10	99.00	100.00
Genetic advance	0.77	0.24	0.07	27.76	54.46
Genetic gain (%)	49.04	53.33	31.80	55.30	388.80

Table 24. Genotypic correlation coefficients of allogamous traits in rice

Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	X_{18}
Anther Length (X_1)	1																	
Filament Length (X_2)	.066	1																
Glume Angle (X_3)	.176	-0.013	1															
Stigma Angle (X_4)	.114	.182	.121	1														
Stigma hair length (X_5)	-.159	.124	.226	-.236	1													
Pollen Viability (%) (X_6)	-.040	.052	.151	-.262	.206	1												
Plant height (X_7)	-.197	-0.462**	.014	-.145	-.132	-.307	1											
Flag leaf angle (X_8)	-.102	.099	-.123	0.331*	-0.459**	-.173	.112	1										
Stigma length (X_9)	.188	.045	.008	.149	-.036	-.054	-.289	-.113	1									
Stigma Diameter (X_{10})	0.434**	.081	0.346*	.173	.088	-.219	-.082	.033	0.587	1								
Stigma Exsertion (X_{11})	0.401**	.080	-.038	0.391**	-.252	-0.547**	.040	0.391*	0.461**	0.713**	1							
Pollen Fertility (X_{12})	-.116	-.224	-.064	-.146	-.060	0.369**	.156	-.282	.166	-.098	-.281	1						
Flowering duration (X_{13})	-.026	.280	.115	.305	.075	-.228	-.203	.017	.227	0.395*	.155	.264	1					
Duration of spikelet opening (X_{14})	-.059	.187	.070	.074	.197	.328	-0.401**	.105	.077	-.254	-.307	-0.460**	.263	1				
Panicle exsertion at flowering (X_{15})	.268	-.089	-.154	-.170	-.0442*	-.038	.108	-.033	.195	.106	.123	0.651**	.060	-0.510**	1			
Panicle exsertion at maturity (X_{16})	.287	-.066	-.108	-.110	-0.466**	-.043	.021	.038	.194	.133	.139	0.550**	-.033	-0.448**	0.906**	1		
Residual pollen (X_{17})	0.361*	-.056	-.007	.093	-.288	-.313	.193	.061	0.371*	0.610**	0.651**	.189	.217	-.525	0.511**	0.445**	1	
% out-crossing (X_{18})	-.009	.049	-.074	.117	.032	.050	.173	0.448**	-.008	.018	.143	-0.674**	.049	0.645**	-0.589**	-0.489**	-.218	1

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

Table 25. Phenotypic correlation coefficients of allogamous traits in rice.

Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	X_{18}
Anther Length (X_1)	1																	
Filament Length (X_2)	-.054	1																
Glume Angle (X_3)	.156	-.029	1															
Stigma Angle (X_4)	.101	.165	.006	1														
Stigma hair length (X_5)	-.157	.052	.250	-.176	1													
Pollen Viability (%) (X_6)	-.036	-.004	.132	-.250	.208	1												
Plant height (X_7)	-.190	-0.451*	.007	-.137	-.113	-.227	1											
Flag leaf angle (X_8)	-.111	.101	-.111	.301	-.366	-.189	.109	1										
Stigma length (X_9)	.189	.046	.003	.134	-.031	-.004	-.283	-.117	1									
Stigma Diameter (X_{10})	.399	.052	.344	.165	.107	-.204	-.083	+.042	0.587*	1								
Stigma Exsertion (X_{11})	.390	.098	-.004	.388	-.231	-0.550*	.036	.395	0.447*	0.667*	1							
Pollen Fertility (X_{12})	-.101	-.249	-.044	-.175	-.003	+0.426	-.150	-.319	.164	-.046	-.307	1						
Flowering duration (X_{13})	-.050	.174	.132	.309	.154	-.148	-.161	.059	.168	.352	.123	-.2324	1					
Duration of spikelet opening (X_{14})	-.047	.209	.034	.081	.125	.281	-0.435*	.114	-.072	-.267	-.281	-0.467*	.194	1				
Panicle exsertion at flowering (X_{15})	.230	-.068	-.097	-.163	-.298	.085	-.047	.178	.095	.094	.091	0.545*	-.083	-0.429	1			
Panicle exsertion at maturity (X_{16})	.260	-.082	-.067	-.111	-.323	-.038	.009	.013	.183	.112	.115	0.472*	-0.356	-.380	0.898*	1		
Residual pollen (X_{17})	.317	.058	-.022	.090	-.255	-.277	.172	.053	.327	0.521*	0.591*	.150	.194	-0.462*	.342	.329	1	
% out-crossing (X_{18})	-.011	.043	-.072	.113	.027	.055	-.171	.429	--.006	.017	.138	-0.619*	.038	0.626*	-0.488*	-0.419*	-0.201*	1

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

4.1.3.4 Stigmatic characters

Heritability, genetic advance and genetic gain are presented in Table 23.

Highest heritability was observed for stigma exsertion. Stigma angle showed a heritability value of 99 per cent and all the other stigmatic characters showed high heritability.

High genetic advance value was observed for stigma exsertion (54.46) and stigma hair length showed low genetic advance (0.07).

High genetic gain was seen for all stigmatic characters, with stigma exsertion being the highest (388.8%) and stigma angle (55.3%) follows. The least genetic gain was observed for stigma hairlength (31.8%).

4.2 Correlation studies

The estimates of genotypic and phenotypic correlations between different pairs of characters are presented in Tables 24 and 25.

Per cent out-crossing was found significantly and positively correlated with duration of spikelet opening phenotypically and genotypically (rp = 0.626, rg = 0.645) and with flag leaf angle genotypically (rg = 0.448). Significant negative correlation was found between per cent out-crossing and pollen fertility (rp = -0.619, rg = -0.674) and panicle exsertion at maturity and flowering. Per cent out-crossing also showed a significant negative correlation with residual pollen phenotypically (rp = -0.201).

Plant height showed significant negative correlation with filament length both genotypically and phenotypically (rp = -0.451, rg = -0.462). Flag leaf angle was found significantly positively correlated with stigma angle genotypically (rg = 0.331) and negatively correlated with stigma hair length (rg = -0.459).

Stigma diameter showed significant positive correlation with anther length (rg = 0.434) and glume angle (rg = 0.346) genotypically. It also showed a significant positive correlation with stigma length phenotypically (rp = 0.587).

Stigma exsertion per cent was found significantly and positively correlated with anther length (rg = 0.401), stigmatic angle (rg = 0.391) and flag leaf angle (rg = 0.391) genotypically. It showed significant positive correlation with stigma length (rp = 0.677, rg = 0.713) genotypically and phenotypically. A significant positive correlation between stigma exsertion per cent and pollen viability (rp = 0.550) was also seen. Genotypically it showed a significant negative correlation with pollen viability (rp = -0.547).

Pollen fertility was significantly and positively correlated with pollen viability phenotypically and genotypically (rp = 0.426, rg = 0.369). A significant negative genotypic correlation between pollen fertility and stigma exsertion per cent (rg = -0.322) was observed.

Flowering duration was significantly positively correlated with stigma diameter (rg = 0.395) genotypically. Duration of spikelet opening showed significant negative correlation with plant height phenotypically (rp = -0.435) and genotypically (rg = -0.401). Correlation studies also revealed a significant negative correlation with pollen fertility, genotypically and phenotypically (rp = -0.467), rg = -0.460).

Panicle exsertion at flowering showed significant positive correlation with pollen fertility, genotypically and phenotypically (rp = 0.545, rg = 0.651). It also showed a significant negative correlation with duration of spikelet opening genotypically and phenotypically. Panicle exsertion at flowering was found negatively correlated with stigma hair length genotypically (rg = -0.442).

Panicle exsertion at maturity was found significantly positively correlated with pollen fertility phenotypically and genotypically (rp = 0.472, rg = 0.550). It was found positively correlated with panicle exsertion at flowering phenotypically and genotypically (rp = 0.898, rg = 0.906). Panicle exsertion at maturity was also found to be negatively correlated with duration of spikelet opening genotypically (rg = -0.448).

Residual pollen was found significantly positively correlated with anther length (rg = 0.361), stigma length (rg = 0.371) and panicle exsertion at flowering and maturity (rg = 0.511, rg = 0.445 respectively) genotypically. Correlation studies revealed a significant positive correlation between residual pollen and stigma diameter (rp = 0.521, rg = 0.610) and residual pollen and stigma exsertion per cent (rp = 0.591, rg = 0.651) both phenotypically and genotypically. This character also showed a significant phenotypic negative correlation with duration of spikelet opening (rp = -0.462).

DISCUSSION

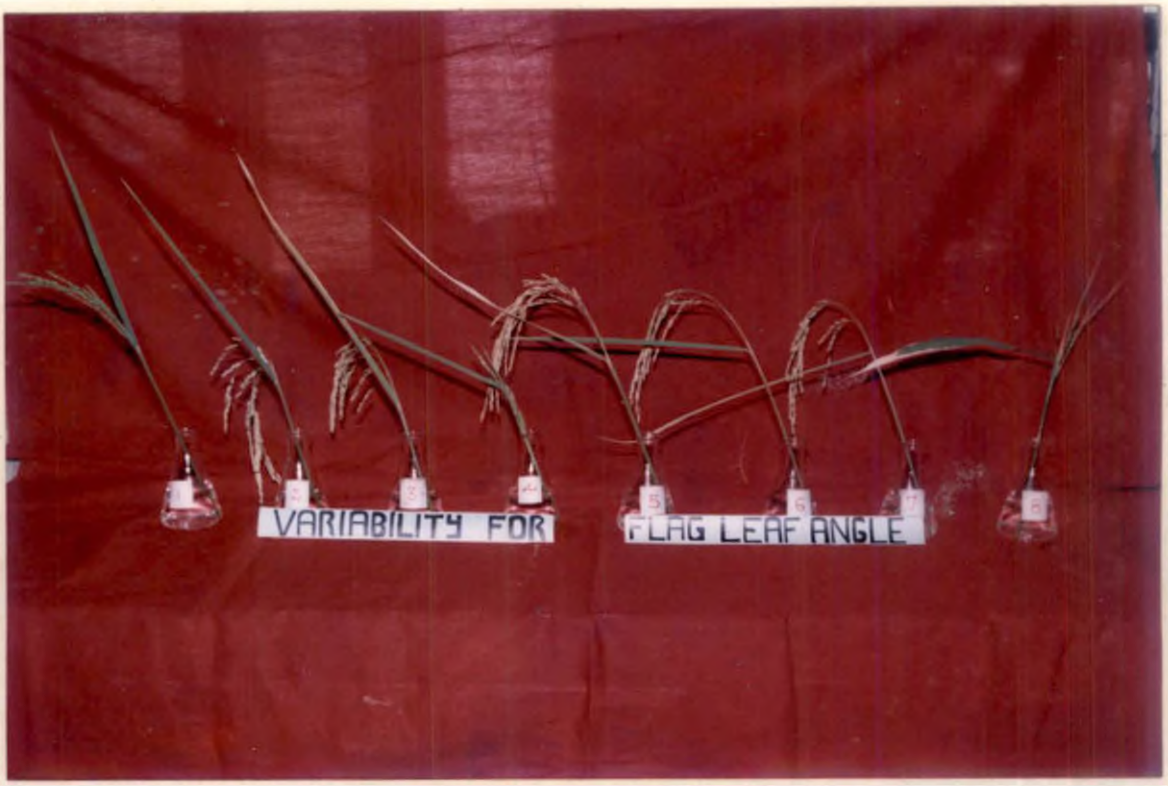


Plate 2. Variability in flag leaf angle

Plate 3. Variability in panicle exsertion

DISCUSSION

In recent years rice breeders have shown interest in developing hybrids for commercial production in using composite methods of breeding to upgrade populations for complex traits such as protein content and drought resistance. These breeding approaches have limited chances of success, however, because the rate of natural out-crossing in rice cultivars is extremely low. Even male sterile lines do not show satisfactory out-crossing under natural conditions (Carnahan and Rutger, 1972). Any genetic mechanism that could increase the out-crossing potential of rice would facilitate the use of additional breeding procedures for improving this crop. However, Oka and Morishma (1967) reported 20 to 100 per cent out-crossing in the wild rice *Oryza perennis*. So this study was undertaken with the objective of identifying germplasm, which will contribute genes for the improvement of out-crossing. The present investigation studied the extent of variability for floral characters favouring out-crossing, their heritability and genetic advance and correlations among them. The results are discussed here in this chapter.

5.1 Variability

Information on variability helps the plant breeder for effective selection of characters for crop improvement.

5.1.1 Variability in plant characters

In the present study significant differences among the genotypes for the characters such as plant height, flag leaf angle (Plate 2), panicle exsertion at flowering and maturity (Plate 3) and percentage out-crossing was noted (Fig.2). Existence of variability for panicle exsertion was reported by Unnikrishnan (1982); Jebaraj and Palanisamy (1990); Jayamani and Rangaswamy (1995).

X_1 – Plant height
X_2 – Flag leaf angle
X_3 – Panicle exsertion at flowering
X_4 - Panicle exsertion at maturity
X_5 – Percentage of out-crossing
X_6 – Anther length
X_7 – Filament length
X_8 – Pollen fertility
X_9 - Pollen viability
X_{10} – Residual pollen
X_{11} – Stigma length
X_{12} – Stigma diameter
X_{13} – Stigma hair length
X_{14} – Angle between stigmatic lobes
X_{15} – Stigma exsertion
X_{16} – Glume angle
X_{17} – Duration of anthesis in a panicle
X_{18} – Duration of spikelets opening

Fig.2. RANGE EXPRESSED AS PERCENTAGE OF MEAN OF 18 CHARACTERS IN RICE

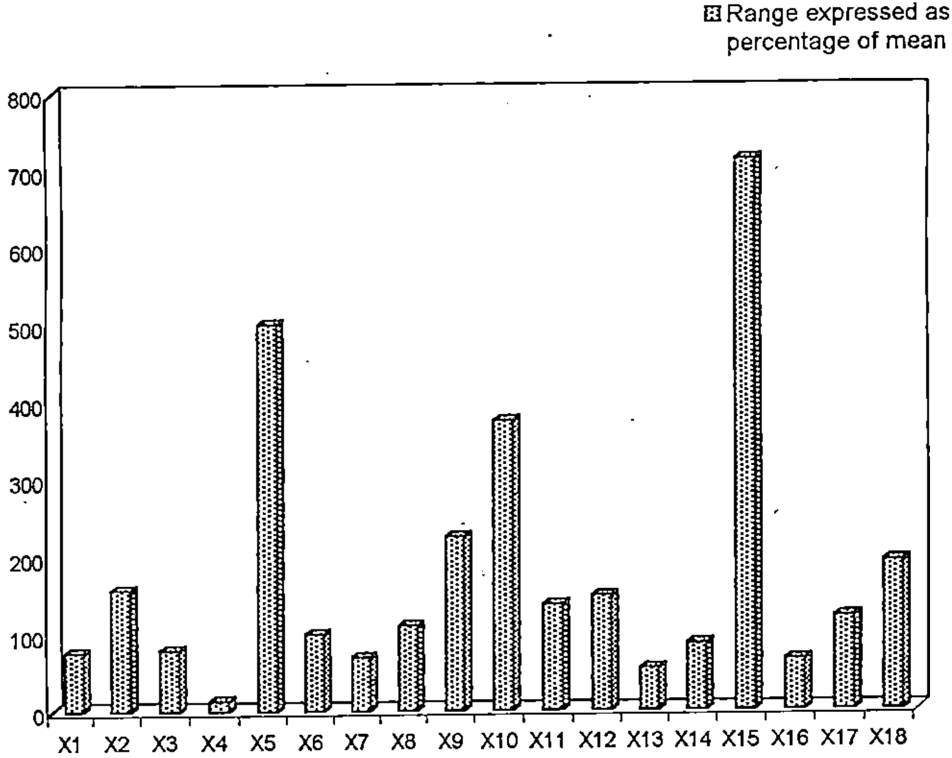
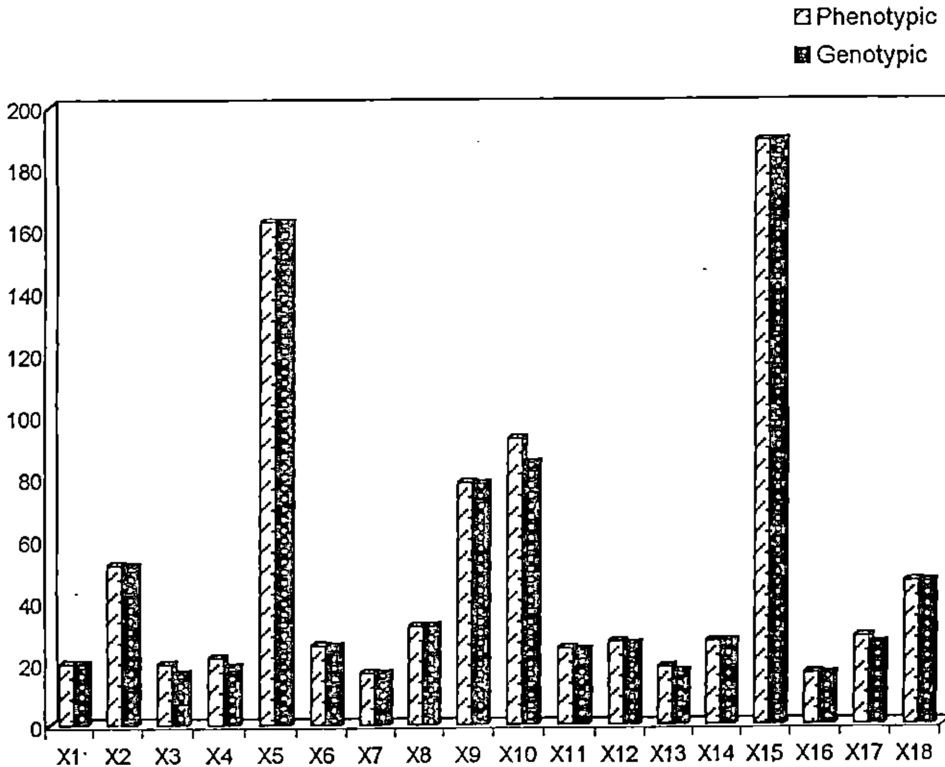


Fig. 3. PHENOTYPIC AND GENOTYPIC COEFFICIENT OF VARIATION OF 18 CHARACTERS IN RICE



All the above mentioned characters except plant height and percentage out-crossing had comparatively higher pcv than gcv suggesting the influence of environment on these characters. But it was noted that the gcv values of all these characters are nearer to pcv values indicating that effect of genotype on phenotypic expression is also high (Fig.3). So there is scope for selection.

Other than the CMS lines, some wild rices like *Oryza spontanea* and *Oryza longistaminata* showed higher percent out-crossing which is in agreement with the results of Virmani and Athwal (1973).

5.1.2 Variability in spikelet characters

Glume angle, duration and time of spikelet opening and flowering period showed significant variation among the genotypes, which is in agreement with the study of Kato and Namai (1987).

Glume angle and duration and time of spikelet opening showed very near pcv and gcv values even though pcv value is greater. It shows that genotype has strong effect on phenotype even though environmental effects exist. Flowering period too showed comparable pcv and gcv values even though pcv value is greater. So genotypes with similar flowering period and time and duration of spikelet opening may be selected for improving out-crossing. This result agrees with the report of Rangaswamy and Vijayakumar (1995).

5.1.3 Variability in anther characters

Anther length (Plate 6), filament length, pollen fertility (Plate 4) and viability and residual pollen showed significant variation among the genotypes. Gcv values were very near to pcv values, eventhough pcv values were greater. Pollen viability per cent showed highest pcv and gcv values. The results prove that phenotype is strongly influenced by genotype and selection will be effective for

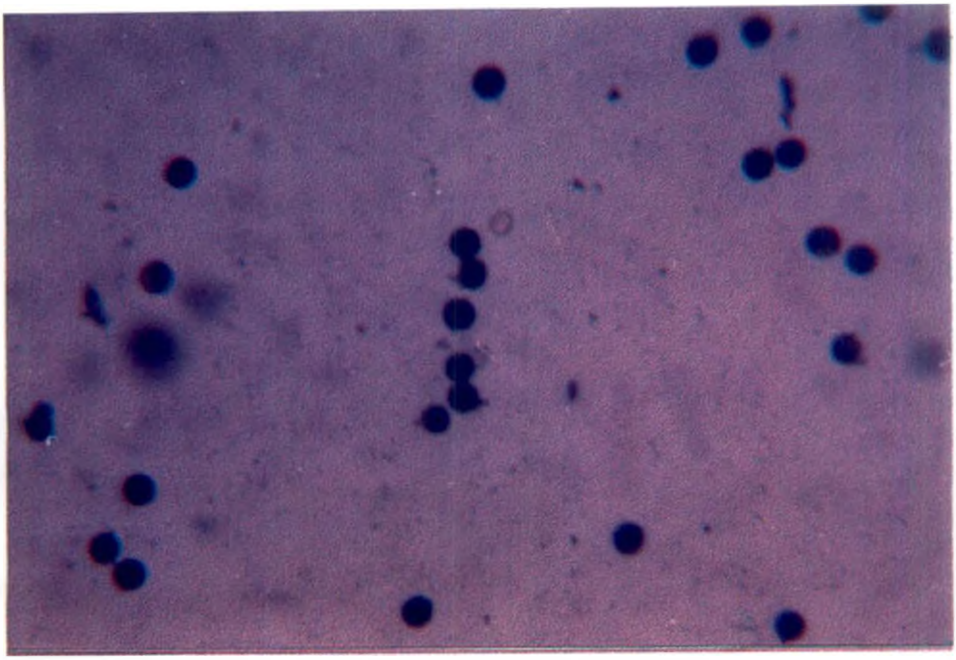


Plate. 4. Fertile pollen

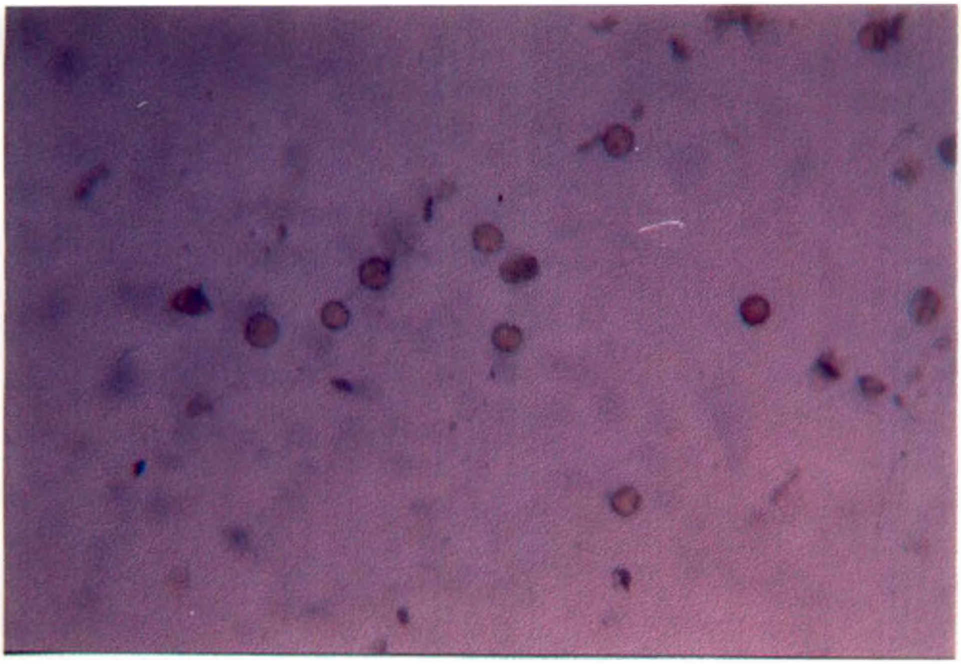


Plate. 5. Sterile pollen

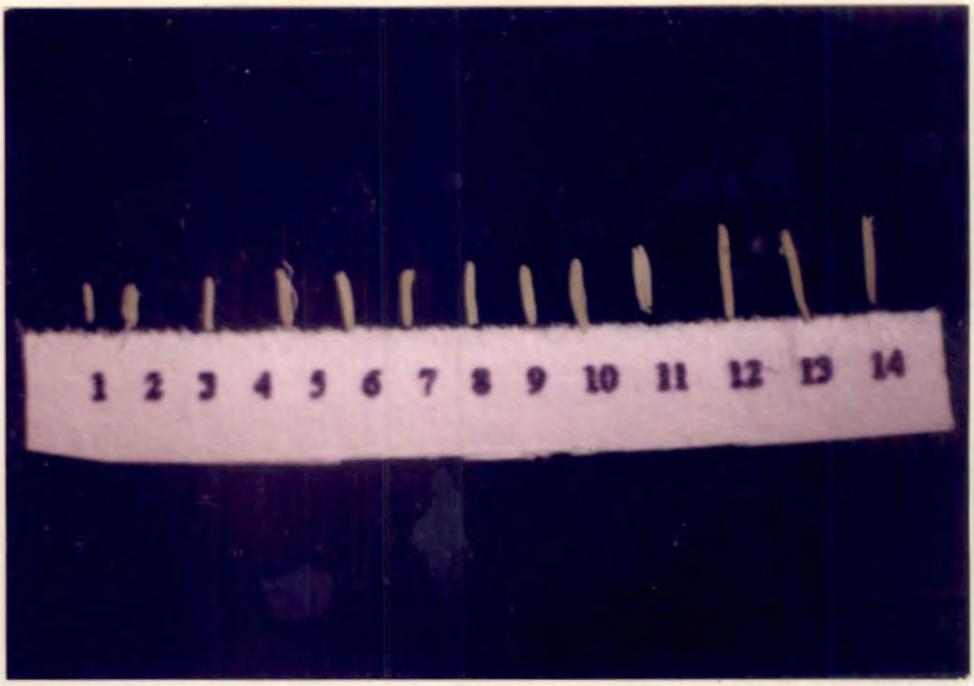


Plate 6. Variability in anther length

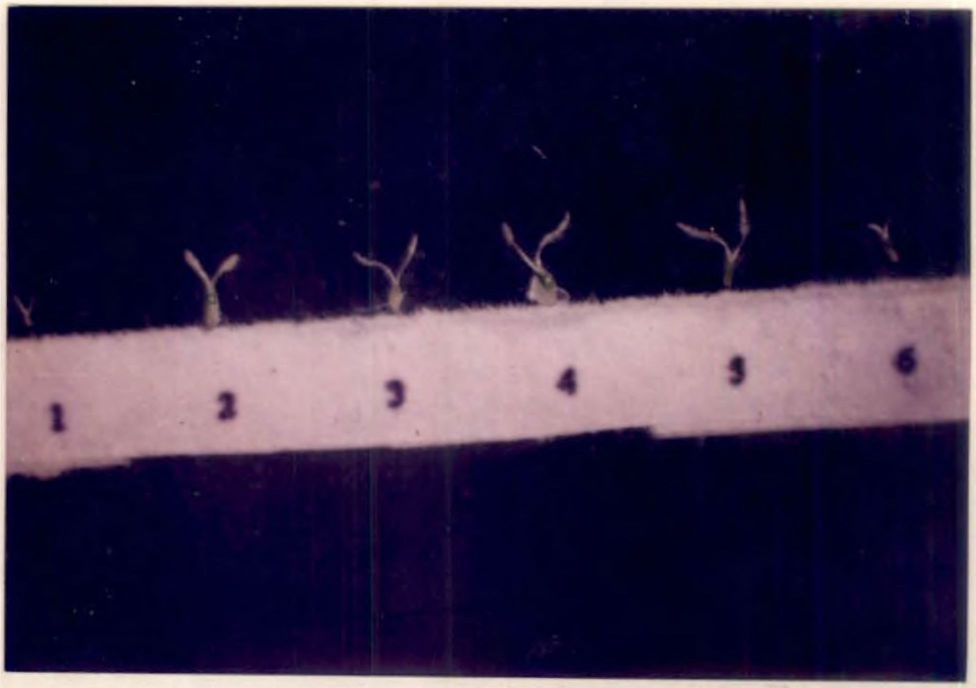


Plate 7. Variability in stigma length

these characters. The same result had been reported by Taillebois and Guimaereas (1988)

5.1.4 Variability in stigmatic characters

Stigma length (Plate 7) and diameter, stigma hair length, stigma exsertion and angle between stigmatic lobes showed significant variation among the genotypes. Significant variation in floral traits like stigma length and exsertion was reported by Sarkar and Miah (1983).

In the present study all the above mentioned characters had higher pcv than gcv suggesting the influence of environment on these characters. But it also showed that the gcv values of all these characters are nearer to pcv values, which indicates high effect of genotype on phenotypic expression is also high.

Stigma exsertion showed the highest pcv and gcv values in this study. Exserted stigma showed the highest genetic variability in a study of variability of nine floral characters by Li and Yang (1986).

5.2 Heritability, genetic advance and genetic gain

If heritability in broad sense is high it indicates that the environmental effects least influence the character. Low heritability is due to high influence of environmental effects. High genetic advance value shows that the character is governed by additive genes and low genetic advance value indicates that the character is governed by non-additive genes. High heritability with high genetic advance indicates that the heritability is due to additive gene effects and selection may be effective. High heritability accompanied with low genetic advance is an indicative of non additive gene action. The high heritability is being exhibited due to favourable influence of environment rather than genotype and selection for such traits may not be rewarding.

5.2.1 Plant characters

Results of the present study revealed high heritability, genetic advance and genetic gain for flag leaf angle, panicle exsertion at flowering and maturity, plant height and per cent out-crossing. So selection for these characters may be rewarding as heritability is due to additive gene action. High heritability for panicle exsertion is reported by Rangaswami and Vijayakumar (1995).

5.2.2 Spikelet characters

In this study glume angle, duration of spikelet opening to closing and flowering period showed high heritability, genetic advance and genetic gain. Duration of spikelet opening and closing had the highest heritability and genetic gain indicating that selection for this character is effective.

5.2.3 Anther characters

High heritability, genetic advance and genetic gain for anther length, filament length, pollen fertility and viability indicated that these characters are least influenced by environment and are determined by additive genes. So there is ample scope for selection in these characters. High heritability and genetic gain for anther characters are reported by Taillebois and Guimaraes (1988).

Residual pollen showed high heritability and low genetic gain. It means the character is governed by non additive gene action. So selection for this character may not be useful.

5.2.4 Stigmatic characters

All the stigmatic characters showed high heritability coupled with high genetic gain. Stigma exsertion showed 100 per cent heritability indicating that environment is not at all influencing the character. Genetic advance value is also high suggesting additive gene action and scope for selection for this character.

Plate 8. Variability in panicle

Of nine floral characters studied in thirty varieties to assess their importance for out-crossing, stigma length and percentage stigma exsertion had high heritability values (Yang and Luang, 1986).

This report coincides with the results of this study, which reveals that selection for stigmatic characters may be useful in increasing out-crossing.

5.3 Correlation studies

A significant correlation is an indicative of high association between two characters. If the value of genotypic correlation coefficient is higher than the phenotypic correlation coefficient, it means that there is strong association between these two characters genetically, but the phenotypic value is lessened by significant interaction of environment. Significant correlations are discussed below.

Per cent out-crossing was found significantly and positively correlated with duration of spikelet opening phenotypically and genotypically. Genotypic correlation coefficient was greater than phenotypic correlation coefficient indicating that environment had little effect on this character. Per cent out-crossing showed significant positive correlation with flag leaf angle genotypically and higher genotypic correlation coefficient indicates that there is strong association between these characters genetically. A positive correlation between natural out-crossing and flowering behaviour was earlier reported by Li *et al.* (1988).

Per cent out-crossing was also found to be positively correlated with filament length, stigma angle, pollen viability, stigma length, stigma exsertion and flowering duration and negatively correlated with glume angle, stigma hair length, plant height, stigma diameter and residual pollen. However, these correlations were found to be insignificant indicating the independent nature of these characters in relation to percent out-crossing.

Significant negative correlation was found for per cent out-crossing and both panicle exsertion and pollen fertility. It indicates smaller environmental effects and a negative association between these characters genetically. Per cent out-crossing showed a significant negative phenotypic correlation with residual pollen. Hence to increase out-crossing there should be a reduction in residual pollen.

Plant height showed significant negative correlation with filament length. Hence there may be a tendency of appearance of longer filament in dwarf plants.

Flag leaf angle showed a high genotypic correlation coefficient, which is significantly and positively related to stigma angle and negatively correlated to stigma hair length. Both the cases revealed association between the characters genetically.

Positive significant correlation of stigma diameter with anther length and glume angle indicated that when stigma diameter is more glume angle also would be high and so is the case with anther length. Hence a well opened flower may have thick and elongated stigma followed by elongated anthers. Stigma diameter is significantly and positively related to stigma length. But since the phenotypic correlation coefficient is greater, association may be influenced by environment.

A significant positive correlation of stigma exsertion per cent with anther length, stigmatic angle, stigma length, stigma diameter and flag leaf angle was noted. In all these cases genotypic correlation coefficient was great. Hence with a greater or higher stigma exsertion per cent we can expect a higher values for the above said correlated characters. Stigma exsertion per cent showed a significant negative correlation with pollen viability genotypically. Hence with a higher stigma exsertion per cent, pollen viability per cent may be less according to the result. Highly significant positive correlation between stigma length and stigma exsertion was earlier reported by Hoffe and Torre (1981). The same correlation was also reported by Virmani and Athwal (1973).

Pollen fertility was significantly and positively correlated to pollen viability and negatively correlated with flag leaf angle and stigma exsertion. Genotypic correlation coefficients were greater in all these cases. Hence with high pollen fertility, pollen viability should increase and flag leaf should be nearer to the panicle and stigma exsertion should decrease.

Flowering duration was found significantly and positively correlated with stigma angle and stigma diameter genotypically. Hence association between these characters is in such a way that with more flowering duration, there may be thick stigma with diverted stigmatic lobes.

Duration of spikelet opening showed significant negative correlation with pollen fertility and plant height. But since the phenotypic correlation coefficients are greater the association between the above said characters is not purely genetic but environmental influence is higher.

Panicle exsertion is found negatively correlated to duration of spikelet opening. Hence with more panicle exsertion duration of spikelet opening may be reduced. Panicle exsertion was found to increase with pollen fertility as revealed in a significant positive correlation.

Residual pollen was found significantly positively correlated with anther length, stigma length, panicle exsertion, stigma diameter and stigma exsertion per cent. Genotypic correlation coefficients were greater in all these cases. Hence with a greater residual pollen value all the above said correlated character values may increase. However, residual pollen showed a negative significant correlation with duration of spikelet opening. So with greater duration of spikelet opening residual pollen may decrease. The most effective floral characteristic for enhancing seed set was residual pollen per exserted anther for the pollen parent (Namai and Kato, 1988). However, this is in contrast to the findings of this study.

5.4 Evaluation of floral traits increasing out-crossing

From the statistical analysis and subsequent interpretation of the data higher duration of spikelet opening and flag leaf angle is directly related to out-crossing. All the other floral traits observed are indirectly influencing out-crossing, either positively or negatively. Higher correlated values for some of the characters like filament length, angle between stigmatic lobes, pollen viability and fertility, stigma exsertion per cent, stigma length and flowering duration tend to favour out-crossing in rice. Considering all these factors it can be said that anther characters, stigmatic characters and spikelet characters has a more pronounced effect on out-crossing as compared to plant characters.

5.5 Evaluation of source materials used in the study that favours out-crossing

V20A showed superior floral traits as compared to the other two male sterile lines. Wild species showed higher natural out-crossing. *Oryza spontanea* and *Oryza longistaminata* seemed better among the wild species. *Oryza officinalis* also have good floral traits influencing out-crossing. But *Oryza meridionalis* was not a good performer.

Among the local varieties two of the varieties gave more than 1 per cent natural out-crossing. Better performers among the local varieties were Nandyar and Chennellu.

Among the high yielding varieties with Kerala parentage Jaya and Neeraja showed good floral traits influencing out-crossing. Kanchana, Kairali, and Bharathi also have good floral traits favouring out-crossing as compared to the

Table 26. Donors of specific allogamous traits recorded on thirty three genotypes based on their per se performance.

Donors	Characters
1) IR 62829 A	Stigma length, flag leaf angle, filament length Duration of spikelet opening, stigmatic lobe angle.
2) IR 58025 A	Stigma length, stigma diameter, stigma exsertion, glume angle
3) V 20 A	Stigma diameter, flag leaf angle filament length, duration of spikelet opening, stigmatic lobe angle
4) Neeraja	Anther length, Stigma diameter, stigma exsertion, glume angle
5) Aiswarya	Anther length
6) IR-42	Anther length, Stigma diameter, stigma exsertion
7) Swarnaprabha	Anther length, Stigma length
8) Jaya	Pollen viability, stigma diameter, flag leaf angle, filament length, duration of spikelet opening
9) Aathira	Pollen viability, stigma diameter, filament length
10) Annapoorna	Pollen viability, stigma diameter, glume angle, stigmatic lobe angle
11) Kairali	Pollen viability, glume angle
12) Kanchana	Stigma length, glume angle, duration of spikelet opening, stigmatic lobe angle.
13) Jyothi	Stigma length, duration of spike let opening
14) Bharathi	Stigma exsertion, filament length, duration of spikelet opening.
15) ADT-37	Filament length, stigmatic lobe angle
16) Chennellu	Anther length, flag leaf angle, stigmatic lobe angle.
17) Nandyar	Stigma length, stigma diameter, stigma exsertion, glume angle, duration of spikelet opening.
18) Vadakkan karan	Stigma diameter, duration of spikelet opening.
19) *Oryza officinalis*	Anther length, stigma length, stigma diameter, stigma exsertion, stigmatic lobe angle.
20) *Oryza spontanea*	Anther length, stigma diameter, stigma exsertion, flagleaf angle
21) *Oryza longistaminata*	Stigma exsertion, flag leaf angle, stigmatic lobe angle.

others. Genotypes that can be used as donors of different floral traits favouring out-crossing are given in Table 26.

The present study reveals that for improving the hybrid seed production better combiners with Jaya, Neeraja, Kanchana, Kairali and Bharathi has to be evolved. Hybrids that are already developed in India that lacks seed production efficiency can be improved by utilising the above rice varieties through combination breeding.

This study has also revealed the variability for traits favouring out-crossing in selected high yielding, local and wild genotypes of rice. It has also estimated the amount of out-crossing, association of these characters to out-crossing and identified local, high yielding and wild rice genotypes with good morphological traits favouring out-crossing.

SUMMARY

SUMMARY

The investigation on "Variability analysis of allogamous traits in rice" was carried out in the College of Horticulture, Vellanikkara and the Agricultural Research Station, Mannuthy during 1998-99. The programme envisaged estimation of amount of variability for floral traits influencing out-crossing in selected high yielding local and wild genotypes and CMS lines. It also evaluated the association of these characters to out-crossing and identified wild, local and high yielding genotypes with good morphological traits favouring out-crossing, which can be utilized for restructuring rice flower to suit hybrid seed production.

The experimental material consisted of 33 rice genotypes including high yielding varieties (15 Nos.), local varieties (8 Nos.) wild rice (4 spp.), CMS lines (3 lines) and B lines (3 lines). Field experiment was laid out in RBD with three replications and the spacing adopted was 15 cm x 20 cm. Observations on plant, anther, spikelet and stigmatic characteristics were taken from five plants per genotype in each replication. The data were subjected to statistical analysis. The salient findings of the study are summarised below.

1) Analysis of variance showed significant variation in all the eighteen characters studied viz. plant height, flag leaf angle, panicle exsertion at flowering and maturity, per cent out-crossing, anther length, filament length, pollen fertility, pollen viability, residual pollen, stigma length, stigma diameter, stigma hair length, angle between stigmatic lobes, stigma exsertion per cent, glume angle, duration of spikelet opening and flowering period in thirty three genotypes of rice.
2) Highest per cent out-crossing was shown by V20A (15.53%). Wild genotypes *Oryza longistaminata* and *Oryza spontanea* showed higher natural out-crossing of 2.67 per cent and 2.40 per cent respectively. Among the high yielding varieties higher out-crossing was noted in Jaya (2.15%)

and Neeraja (2.53%). In local varieties Nandyar (1.33%) and Chennellu (1.20%) showed comparatively higher out-crossing.

3) Highest gcv and pcv were observed for stigma exsertion followed by per cent out-crossing and residual pollen.

4) High heritability and genetic gain were noted for all characters except residual pollen. Residual pollen showed high heritability but low genetic gain. Highest heritability and genetic gain was observed for stigma exsertion, followed by pollen viability, spikelet opening-closing duration and flag leaf angle.

5) Correlation studies revealed, significant positive correlation between per cent out-crossing and the traits flag leaf angle and spikelet opening-closing duration. Significant negative correlation between per cent out-crossing and the traits, panicle exsertion and residual pollen was also noted.

6) Based on the positive correlations of characters with out-crossing independently, certain floral traits viz. filament length angle between stigmatic lobes, pollen viability (%), flag leaf angle, stigma length, stigma exsertion, flowering period and spikelet opening-closing duration tend to favour natural out-crossing in rice.

7) Comparison of results proved that V20A and V20B showed good floral traits favouring out-crossing. Jaya, Kanchana, Bharathi, Kairali and Neeraja showed good floral traits favouring out-crossing among the high yielding varieties. Nandyar and Chennellu had better floral traits enhancing out-crossing among the local varieties. Wild species *Oryza longistaminata, Oryza spontanea* and *Oryza officinalis* showed good floral traits favouring out-crossing.

REFERENCES

REFERENCE

Allard, R.W. 1960. *Principles of Plant Breeding*. John Wiley and Sons, Inc., New York, p.89-98

Azzini, L.E. and Rutger, J.N. 1982. Amount of out-crossing on different male steriles of Rice. *Crop Sci.* **22**:905-907

Burton, G.W. and Devane, E.H. 1953. Estimating heritability in tall fescue from replicated clonal material. *Agron. J.* **45**:478-481

Carnahan, H.L. and Rutger, J.N. 1972. Outlook for hybrid rice in the U.S.A. *Rice breed.* p.603-607

Fisher, R.A. 1954. A fuller theory of junctions in breeding. *Heredity.* **8**:187-197

Grist, D.H. 1953. Floral biology and flowering behaviour in rice. *Rice*. Longman Green, London, p.53-148

Hoff, B.J and Torre, M. 1981. Stigma exsertion in rice and its effect on the seed set of male sterile plants. *Annual Progress Report,* Rice Experiment Station, Crowleg, Louisiana. p.240-243

Jayamani, P. and Rangaswamy, M. 1995. Floral characters influencing out-crossing in rice. *Oryza* **32**:9-12

Jebaraj, S. and Palanisamy, S. 1990. Screening rices for good panicle exsertion. *Int. Rice Res. Newsl.* **15**:3-8

Johnson, H.W., Robinson, H.I. and Constock, R.E. 1955. Estimates of genetic and environmental variability in soyabean. *Agron. J.* **47**:314-318

KAU. 1996. *Package of Practice Recommendations.* Directorate of Extension, Kerala Agricultural University, Mannuthy, p.11-21

Li, W.M., Cai, J.M. and Zhou, Y.C. 1988. Genetic correlations between natural out-crossing and floral characters of rice male sterile lines. *J. Fujian Agric. Coll.* 17(2):85-92

Li, W.M. and Yang, R.C. 1986. Genetic variability and correlations of floral characters of big-stigma rice. *J. Fujian. Agric. Coll.* 15(4):288-292

Lush, J.L. 1949. *Animal Breeding Plans.* Lown State University Press, Annes, p.473

Namai, H., Kato, H. and Smith, W.H. 1988. Hybrid rice. *Proc. Int. Symp.* Changsha, China. p.165-173

Nishimak, K., Mauryama, K. and Araki, H. 1992. Flowering habits of cytoplasmic male sterile lines of rice (*Oryza sativa* L.) with different male sterile cytoplasm and nuclei. *Oryza* 29:85-88

Oka, H.I. and Morishma, H. 1967. Variations in the breeding system of wild rice (*Oryza perennis*). *Evolution* 21:249-258

Panse, V.G. and Sukhatme, P.V. 1978. *Statistical Methods for Agricultural Workers.* Indian Council of Agricultural Research, New Delhi, p.381

Pradhan, S.B., Ratho, S.N. and Jachuck, P.J. 1989. Analysis of genetic divergence among maintainers and restorers for use in hybrid rice breeding. *Oryza* 32:12-17

Rangaswamy, M. and Vijayakumar, C.N.M. 1995. Growth development and floral biology of rice in relation to heterosis breeding. In: *Hybrid Rice Seed Production Technology.* DRR, Hyderabad, p.43-49

Rao, M.G. 1996. Genetic diversity in A and B lines based on traits influencing out-crossing in rice. *Indian J. Genet.* 56(4):510-519

Robinson, H.F., Comstock, R.E. and Harvey, P.H. 1949. Estimates of heritability and the degree of dominance in corn. *Agron. J.* 41:353-359

Rodrigo, P.A. 1921. Pollination and the flower of rice. *Philippa. Agric.* **14**:155-171

Sarkar, H.C. 1983. Local indica rice varieties with desirable floral traits influencing out-crossing. *Int. Rice Res. Newsl.* **8**(5):3

Sarkar, H.C. and Miah, N.M. 1983. Evaluation of cytoplasmic male sterile (CMS), maintainer and restorer lines in Bangladesh. *Int. Rice Res. Newsl.* 8(6):7

Sarma, N.P., Mohanty, P.K. and Jachuck, P.J. 1982. Out-crossing potential of a cytosterile stock of rice. *Int. Rice Res. Newsl.* 7(5):3

Satato, M. and Sutaryo, B. 1989. Natural out-crossing of cytoplasmic male sterile line IR54752A in Indonesia. *Int. Rice Res. Newsl.* **14**(1):7

Seetharamaiah, K.V., Kulkarni, R.S., Mahadevappa, M. and Prasad, T.G. 1994. Evaluation of rice cytoplasmic male sterile lines for floral traits influencing out-crossing. *Int. Rice Res. Notes* **19**(2):5-6

Shinjyo, C. and Omura, T. 1966. Cytoplasmic genetic male sterility in cultivated rice (*Oryza sativa*). *Jap. J. Beed.* **16**:179-180

Siddiq, E.A., Jachuck, P.J., Mahadevappa, M., Zaman, F.U., Kumar, V. and Rangaswamy, M. 1994. Hybrid Rice Research in India. *Hybrid Rice Technology - New Developments and Future Prospects* (Ed. Virmani, S.S.), IRRI, Philippines. p.157-171

Silitonga, T.S. 1985. Natural out-crossing of cytoplasmic male sterile V20A. *Int. Rice. Res. Newsl.* **10**(6):8-9

Stansel, J.W. an Craigmiles, D.S. 1966. Hybrid rice problems and potentials. *Rice. J.* **69**:14-15

Suzuki, S. 1981. Breeding in perennial rice. *Japan J. Breed* 31:57-64

Taillebois, J., Guimaraes, E.P. and Smith, W.H. 1988. Hybrid rice. *Proc. Int. Symp.* Changsha, China. p.175-180

Unnikrishnan, A. 1982. Studies on genetic variability and selection indices for grain yield in three F2 populations of the M.Sc.(Agri.) thesis. University of Agriculturel Science Bangalore, India.

Virmani, S. S. and Athwal, D.S. 1973. Genetic variability in floral characteristics influencing out-crossing in *Oryza sativa. Crop Rice.* **13**:66-67

Virmani, S.S., Khush, G.S. and Yang, R.C. 1980. Rice cultivars possessing some desirable floral traits influencing out-crossing. *Int. Rice Res. Newsl.* 5(4):4-5

Yang, R.C. and Luang, K.J. 1986. Study on the heritability of and correlations between major floral characters in early indica rice varieties in China. *Scientia-Agricultura Sinica.* 7:49-53

Appendix-I. Mean monthly weather parameters for the crop growth period (July 1998-June 1999)

Months	Maximum °C	Minimum °C	Relative humidity morning (%)	Relative humidity afternoon (%)	Rainfall (mm)	Rainy days	Evapo-ratopm (mm0	Sunshine hours	Wind speed (km/ha)
Jul	29.2	23.6	96	80	752.9	28	81.1	3.3	2.8
Aug	29.8	23.9	95	77	433.6	18	88.3	3.6	2.4
Sep	30.2	23.3	96	78	571.3	24	86.0	4.1	2.1
Oct	28.0	22.8	94	76	452.8	18	88.9	4.8	1.9
Nov	31.5	23.1	92	64	109.4	9	91.8	7.2	1.7
Dec	30.1	22.9	79	58	33.0	4	127.3	6.6	5.4
Jan	32.4	21.5	76	40	0	0	174.3	9.3	6.6
Feb	34.5	23.3	77	35	22.8	1	175.5	9.1	5.3
Mar	35.5	24.5	88	48	0	0	167.1	8.8	3.0
Apr	25.6	33.4	88	58	39.0	4	133.9	10.3	3.2
May	30.7	24.7	72	82	430.5	18	88.5	4.9	3.0
Jun	29.4	23.0	94	75	500.2	23	90.0	5.0	2.6

VARIABILITY ANALYSIS OF ALLOGAMOUS TRAITS IN RICE (*Oryza sativa* L.)

By

K. P. DEEPA

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the requirement for the degree of

Master of Science in Agriculture

Faculty of Agriculture

Kerala Agricultural University

Department of Plant Breeding and Genetics

COLLEGE OF HORTICULTURE

VELLANIKKARA, THRISSUR - 680 656

KERALA, INDIA

ABSTRACT

The research project entitled "Variability analysis of allogamous traits in rice (*Oryza sativa* L.)" was carried out in the College of Horticulture, Vellanikkara, Thrissur and the Agricultural Research Station, Mannuthy, Thrissur during the period 1998-99. The major objective of the study was to estimate the amount of variability for floral traits influencing out-crossing in high yielding, local and wild genotypes and CMS lines. It also evaluated the association of these floral traits to out-crossing and identified the genotypes with good morphological traits favouring out-crossing, which can be utilized for restructuring rice flower to suit hybrid seed production.

Statistical analysis revealed significant variation in all the 18 characters studied viz. plant height, flag leaf angle, panicle exsertion at flowering and maturity, per cent out-crossing, anther length, filament length, pollen fertility, pollen viability, residual pollen, stigma length, stigma diameter, stigma hair length, angle between stigmatic lobes, stigma exsertion per cent, glume angle, duration of spikelet opening and flowering period in thirty three genotypes of rice.

Highest genotypic coefficient and phenotypic coefficients of variations were observed for stigma exsertion followed by per cent out-crossing and residual pollen. Correlation studies revealed significant positive correlation between out-crossing and the floral traits flag leaf angle and spikelet opening-closing duration. All the traits except residual pollen showed high heritability coupled with genetic gain.

Statistical studies showed V20A and V20B, Jaya, Kanchana, Bharathi, Neeraja, Kairali, Nandyar, Chennellu, *Oryza longistamina, Oryza officinalis* and *Oryza spontanea* with good floral traits favouring out-crossing.