GENETIC BASIS OF YIELD VARIATIONS IN LOW LAND RICE

A
THESIS SUBMITTED TO
THE ORISSA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY
BHUBANESWAR
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE DEGREE OF

MASTER OF SCIENCE IN AGRICULTURE
(PLANT BREEDING AND GENETICS)

By

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BHUBANESWAR, ORISSA
2008

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Dedicated to my Parents

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Dated, the 25th August, 2008

CERTIFICATE- I

This is to certify that the thesis entitled **"GENETIC BASIS OF YIELD VARIATIONS IN LOW LAND RICE "** submitted by **NILESH KUMAR VERMA, Adm. No.21 PBG/06** to the Orissa University of Agriculture and Technology, Bhubaneswar in partial fulfilment of the requirements for the award of the degree of **MASTER OF SCIENCE IN AGRICULTURE (PLANT BREEDING AND GENETICS)** is a faithful record of *bona fide* research work carried out under my guidance and supervision. No part of this thesis has been submitted for any other degree or diploma or published in any other form. The assistance and help received during the course of investigation have been duly acknowledged.

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CERTIFICATE – II

This is to certify that the thesis entitled **"GENETIC BASIS OF YIELD VARIATIONS IN LOW LAND RICE"** submitted by **NILESH KUMAR VERMA, Adm. No.21 PBG/06** to the Orissa University of Agriculture and Technology, Bhubaneswar in partial fulfilment of the requirements for degree of **MASTER OF SCIENCE IN AGRICULTURE (PLANT BREEDING AND GENETICS),** has been approved by the Student's Advisory Committee after oral examination on the same in collaboration with an External Examiner.

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ACKNOWLEDGEMENT

I fall in short of words to acknowledge those who were with me for the successful completion of my dissertation.

First and foremost I would like to express deep gratitude and indebtedness to Dr. B. Pradhan, Associate Professor, Department of Plant Breeding and Genetics, College of Agriculture, OUAT, Bhubaneswar, the Chairman of my Advisory Committee, for his valuable guidance, constant supervision, steady encouragement, whole-hearted co-operation and painstaking efforts during the entire period of investigation and throughout the preparation of this manuscript.

I express my heartfelt gratitude to Dr. L. D. Mishra, Professor and Head, Department of Plant Breeding and Genetics, OUAT, Bhubaneswar for providing the necessary facilities for the present investigation.

I also wish to acknowledge from the core of my heart Dr. S.R. Das, Professor and Rice Breeder, Department of Plant Breeding and Genetics, OUAT, Bhubaneswar for providing me opportunity to work under his guidance during field evaluation of the material and providing necessary facilities for the present investigation in EB -1 section of the Department of Plant Breeding and Genetics, OUAT, Bhubaneswar.

I am very much grateful to Dr. M.C. Pattnaik, Dr. R.C. Mishra, , Dr. B. Nayak, Dr. P.K. Mishra, Dr. B. Baisakh, Dr. Ch. H. P. Mishra, Dr. P. N. Jagdev, Dr. D. N. Bastia, Dr. T. K. Mishra, Dr. S. K. Tripathy, Dr. P. K.Sahoo, Dr. P. K. Nayak and Dr. M. M. Mishra for their sustained interest, valuable suggestions, needful encouragement and wholehearted support throughout the period of my research work.

I express my courteous gratitude to Dr. M. Kar, Professor and Head, Department of Plant Physiology, College of Agriculture, OUAT, Bhubaneswar, for his proper guidance, needful encouragement and wholehearted support throughout the period of my research work.

I especially thank my friends Dillip, Jewel, Amit, Tsewang, Hemant and Nadim for their kind support and selfless help during the entire course and research.

I deeply acknowledge my beloved father and mother and my dear brother and sister for being there for me in all my good and bad times with constant support, encouragement and blessings to build my career.

Last but not the least, I thank "Almighty" for everything.

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Title of the thesis	:	**GENETIC BASIS OF YIELD VARIATIONS IN LOW LAND RICE**
Name of the student	:	**Nilesh Kumar Verma**
Admission number	:	**Adm.No. 21 PBG/ 06**
Name of the advisor	:	**Dr. B. Pradhan** **Associate Professor (PBG)**
Year of submission	:	**2008**

ABSTRACT

The present investigation aimed at evaluating thirty elite low land rice cultures along with ten different checks under both normal and sub-merged water situations to study the genetic basis of yield variations in low land rice. In addition, efforts were also made to evaluate 85 low land cultures including five varieties as checks in augmented design to identify the most promising entries for their future use. The experimental material possess a highly significant difference among the test genotypes for all the characters except fertility percentage and grain yield per plant under normal condition and except grain yield per plant under submerged condition. The magnitude of genetic variance was high for majority of traits except for panicle length, panicle number,100-grain weight and grain yield per plant. In general, under the submerged condition the days to flowering was longer with taller plant height, higher panicle number and the traits like fertility percentage, harvest index, grain yield per plant and plot yield were reduced considerably. The GCV and PCV in different traits maintained correspondence for most of the traits except for panicle number, grain number, fertility percentage, harvest index, and grain yield per plant indicating the greater influence of the environment in the expression of these traits. The majority of traits exhibited higher magnitude of both GCV and PCV under submerged conditions except for panicle length and plot yield and in general PCVwas higher than GCV suggesting the influence of environmental factors in the expression of these traits. As majority of traits except panicle number, grain number, fertility percentage, harvest index and grain yield per plant showed smaller difference between GCV and PCV indicating least influence of environment, therefore, selection on the basis of phenotypic values for majority of characters is expected to be effective. A moderate to low degree of heritability estimates were observed for most of the traits except for days to 50 % flowering, plant height, grain number and 100-grain weight indicating high degree of influence of environment in the expression of these traits. High heritability estimates associated with moderate to high genetic gain for days to 50 % flowering, plant height, grain number and 100-grain weight indicate the presence of additive gene effects and hence selection based on phenotypic performance would be effective. The characters like panicle length and plot yield exhibited moderately high heritability value and low genetic gain which suggested the influence of both additive and non-additive gene effects in the inheritance of these traits. Therefore, selection of genotypes on the basis of phenotypic performance for such traits may not be effective. Low heritability estimates with moderate to low genetic gain for panicle number, fertility percentage, harvest index and grain yield per plant suggested that dominance and epistatic gene effects may be operating in the inheritance of these traits. Plot yield exhibited positive association with panicle number, fertile grain number, fertility percentage and grain yield per plant under normal condition whereas, it was positively correlated with plant height, fertility percentage, grain yield per plant and negatively correlated with days to 50% flowering under submerged condition. Grain yield per plant was positively correlated with panicle number, fertile grain number, fertility percentage and harvest index under normal condition where as, it was only positively correlated with harvest index under submerged condition. Both plot yield and grain yield per plant appear to show positive association with panicle number, fertile grain number and fertility

percentage; where as grain yield per plant exhibited positive association with harvest index under both the cultural conditions indicating the importance of such traits for realization of high yield in rice. The association of different characters with plot yield and grain yield per plant exhibited more or less similar trend and the strong association between themselves revealed that selection on the basis of characters contributing grain yield per plant also bears relevance to plot yield. Panicle number was positively correlated with both grain yield per plant and plot yield but it exhibited negative or insignificant associations with majority of traits under study. Therefore, the utility of this trait for selection of high yield becomes doubtful. Although the association between grain yield per plant and grain number was positive but the grain number exhibited negative association with 100-grain weight. As expected, grain number was found to show negative association with 100-grain weight and which might have resulted due to compensating mechanism. The positive association of grain yield per plant with harvest index reflects that yield is a function of total dry matter and harvest index and yield can be increased by increasing either biomass or harvest index or both. The grain yield per plant exhibited maximum positive direct effect on plot yield followed by plant height, fertility percentage, panicle number, days to 50% flowering, harvest index, fertile grain number, panicle length and 100-grain weight under normal condition and plant height exhibited maximum positive direct effect on plot yield followed by fertility percentage, grain yield per plant, panicle number, panicle length, 100-grain weight, harvest index, fertile grain number and days to 50% flowering under submerged condition thus, indicating the importance of such traits as criteria for selection in that order for realization of higher productivity under two cultural conditions. Fertile grain number exerted greatest indirect effect on yield via other traits following panicle number, fertility percentage, harvest index, panicle length, grain yield per plant, plant height, days to 50 % flowering, and 100-grain weight under normal condition and fertile grain number exerted greatest indirect effect on yield via other traits following panicle length, harvest index, grain yield per plant, plant height, fertility percentage, 100-grain weight, panicle number and days to 50 % flowering under submerged condition. Out of thirty cultures evaluated under both the cultural conditions as many as ten cultures showing yield level of more than 45.0 q/ha under normal condition and yield level of more than 30.0 q/ha under submerged condition could be sorted out to be promising. The most promising cultures under normal condition were OR 2119-13, OR 2315-6, OR 1878-3, OR 2314-47, OR 1903-6-67, OR 2109-2, CN 1592-5-1, OR 2162-5 and Kanchan. Similarly the cultures like OR 1903-6-67, OR 2119-13, IR 70242-24-TTB-1-3, OR 2314-47, NDR 8024, OR 2315-6, OR 2109-2, NDR 8027, IR 53945-CN-35-8-2 and Kanchan were found promising under submerged condition. The cultures like OR 2119-13, OR 2315-6, OR 2314-47, OR 1903-6-67, OR 2109-2 and Kanchan were found promising under both the cultural conditions.Cultures like CN 1592-5-1, OR 1878-3, OR 2315-6, OR 1903-6-67, OR 2162-5 and CR 2025-1 found promising for combining three or more than three desirable component traits under normal condition and cultures like CN 1039-9, OR 2109-2, OR 1903-6-67, IR 70242-24-TTB-1-3, TTB 303-1-13, NDR 8024,Swarna Sub-1 and Kanchan found promising for combining two or more than two desirable component traits under submerged conditions,.During the present investigation selection indices were constructed with grain yield as the economic criterion and ten different characters namely plot yield, days to 50% flowering, plant height, panicle length, panicle number, number of fertile grains/panicle, fertility percentage, 100-grain weight, harvest index and grain yield per plant were chosen for the construction of ten selection indices. On the basis of the index score the promising genotypes namely Kanchan, OR 2314-47, OR 2315-6, IR 70242-24-TTB- 1-3, and OR 2109-2 under normal condition and promising genotypes namely OR 1903-6-67, IR 70242-24-TTB- 1-3, Kanchan, OR 2119-13, Jagabandhu and OR 2315-6 under submerged condition were selected for their future use. It is imperative to note that the cultures like Kanchan, OR 2314-47, OR 2315-6, IR 70242-24-TTB-1-3 and IR 53945-CN-35-8-2 were found promising under both the cultural conditions. In addition efforts were also made to evaluate 85 low land cultures including five varieties as checks in augmented design. The promising entries like CN 1233-47-30-4, OR 2150-2, CN 1205-5-1-2, CR 2543-83, IR 674601-17TTB-225, CR 2458-99, RAU 678-82-4, OR 2407-KK-29, LPR 07006 and RAU 1392-5-3-7-2 were identified and which could be successfully utilized in the future breeding programmes for genetic improvement of yield in low land rice.

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INTRODUCTION

Rice occupies a pivotal role in Indian agriculture. It is the staple food for more than 70 per cent Indians and a source of livelihood for 120-150 millions rural households. It provides more than fifty per cent of daily calorie intake and considered as the cheapest source of food, energy and protein in the developing countries. It contributes to 43 per cent of total food grain production and 53 per cent of cereal production, thus continues to hold the key to sustain food sufficiency in the country (Siddiq *et al*., 2004)

Rice is considered as a semi-aquatic annual plant and can grow under a wide range of soil-water regimes, from a prolonged period of flooding in deep water to dry land on hill slopes. The crop has remarkable diversity in adapting itself to varying conditions, *viz*., rainfall, temperature, soil, pest and disease incidences. Though it is grown in varied ecosystems, the rainfed upland and rainfed low land are the less favourable rice ecosystems where the yield is very poor.

The country has witnessed impressive production and productivity growth trends during eighties, although declined, sustained during nineties due to adoption of modern rice production technology. Rice production in India has been transformed from chronic stage with 30 million tonnes in 1965 to sustainable strong surplus level of 93.34 million tonnes and a productivity level of 2075 kg/ha in 2001-02. As a result of enhanced rice production the country made a mark in international trade by becoming the fourth largest exporter of rice in the world earning considerable foreign exchange of about Rs.3000 crores during 1999-2000.

During the past three decades due to extensive adoption and spread of plant type based high yielding varieties, extension of area under irrigation and adoption of modern production and protection technologies, rice production advanced in the country many fold, enabling to march from an era of chronic deficiency and excessive dependence on imported food, to a period of self sufficiency and surplus (Siddiq, 1997).

At the current rate of population growth of 1.8 per cent, rice requirement by 2020 would be around 140 million tonnes. However, at the present level of 93 million tonnes we would be requiring to add annually not less than 3.0-3.5 million tonnes of milled rice to sustain the present level of self-sufficiency in rice. It is therefore, a challenging task to achieve this targeted production levels in the next few decades as increase in productivity has to come from the declining and degrading resource base in terms of land, water and other inputs and demand for environmentally sound rice production practices. It is estimated to achieve production by 70 per cent from irrigated ecology, 5 per cent from uplands, 21 per cent from rainfed medium lands and shallow low lands and 3 per cent from flood prone systems.

In terms of area rice crop is grown in about 44.6 million hectares in India, which is about 36.58 per cent of net cropped area and 44.5 per cent of area under cereals, which is the largest acreage in the world. Of the 43.2 million hectares of harvested area in 2004-05, about 30.8 % were rainfed low lands, 44.9 per cent irrigated, 17.4 per cent rainfed uplands and 6.9 per cent flood prone, which profoundly influenced the overall productivity of the country and such vast areas under each ecosystem is not encountered in any other rice growing country and the traditional rice growing states of eastern India, where rice farming is exposed to several uncertainties imposed by drought, floods or both (Shobha Rani and Das, 2007).

The rainfed low land rice area in the state comprised of 2.3 million hectares which is more than 50 per cent of the total rice area; have shallow, semi-deep and deep water situations. Shallow low lands occupy a major area (1.3 m ha) followed by semi-deep water (0.8 m ha) and deep water with 0.2 million hectares. Erratic rainfall and uncontrolled water situations are the major constraints in these rainfed ecosystems. Some of the other adverse factors like impeded drainage and water logging, flash floods and early and terminal drought leading to poor crop stand and sub-optimal plant population and continued use of traditional low input responsive and low yielding varieties restrict rice production in the state.

With increase in area under high yielding varieties like Jagannath, Savitri, Gayatri, Mahsuri, Mahalaxmi and Kanchan the productivity of the shallow water low lands has been showing a significant upward trend. These varieties recommended for low lands are only found suitable for shallow low lands with water depth upto 30 cm and are not suitable for low lands where there is recurrent flood situations causing submergence. Besides flash flood submergence, there is poor seedling establishment, early drought suppressed tillering, post flood drought and premature lodging due to general wet condition and low light intensity which are the major field problems associated with poor crop growth.

Submergence tolerance is largely controlled by the Sub 1 gene. The identification of the precise gene underlying tolerance has enabled the tailed manipulation of this gene through marker assisted selection (MAS) schemes. Through a marker-assisted back crossing (MAB) approach, this gene can also be transferred rapidly into mega varieties.

The effects of Sub 1 gene on plant survival under submergence are dramatic and the Sub 1 varieties give an average of 1-2 tonnes higher yield than non-Sub 1 types under 12-17 days of complete submergence. In cases, Sub 1 varieties give a near normal yield whereas in tolerant varieties are completely destroyed. The advantages of Sub 1 varieties (Swarna-Sub 1) have already been verified in multilocation test centers of India and Bangladesh.

Although the Sub 1 technology is certainly ready for upscaling, it is clear that further gains in tolerance can also be made from the use of QTLs that complement the Sub 1 gene and enhance survival under a longer duration of submergence. That is why the highly tolerant variety FR 13A and Some breeding lines such as IR 49830-7 have more tolerance than Swarna-Sub 1. Some times moderately tolerant varieties that do not have the Sub 1 gene are potential sources of new genes for submergence tolerance.

However, the farmers continue to grow tall saturated varieties like CR 1014, BAM 6, T 1242 and common land races in semi-deep water lands and the high yielding varieties recommended for semi-deep water situations are yet to gain popularity among the low land farmers. Thus lack of suitable rice varieties with high yield and resistance to various biotic and abiotic stresses is the major constraint to high productivity in these ecologically handicapped low lands of the state. Therefore, there is a need for enhancement of genetic yield potential of rainfed low land rice with emphasis on flash flood submergence.

Mohanty *et al.* (1990-91) and Khush and Sarkarung (1998) suggested a suitable plant type for rainfed low lands by considering several morpho-physiological traits like semi-dwarf to intermediate stature, late maturity duration (150-155 days), lodging resistance, moderate tillering habit, desirable canopy structure with dark green erect leaves, larger panicles, high grain number (more than 200 grains per panicle) with improved fertility, photo-period sensitivity and thermo-insensitivity, improved harvest index of 0.5, tolerance to early drought and flash flood submergence, multiple disease and insect resistance and superior grain quality for genetic enhancement of yield in low land rice.

Realizing the importance of high yield and greater stability of production of low land rice and in the light of above discussions, the present investigation on genetic basis of yield variation in low land rice was undertaken with the following objectives.

- To evaluate a set of low land rice genotypes including Swarna-Sub 1 for their yield performance and other characters under two different cultural conditions and identify promising genotypes based on *per se* performance
- To study the availability and extent of genetic variability in yield and yield attributing characters present in the experimental material
- To examine the nature and magnitude of character association in relation to yield and various other traits
- To asses the direct and indirect effects of different component traits on yield through path coefficient analysis
- To find out useful criteria for selection of yield through construction of selection indices and identify promising cultures for their future use
- To identify different characters as important selection criteria for prediction of higher yield, greater stability and better adaptation in low land rice.

CHAPTER-II

Review of Literature

CHAPTER-II

REVIEW OF LITERATURE

Rice is the most important grain crop providing food for more than fifty per cent of the world population. It is considered as semi-aquatic plant and can be grown under a wide range of eco-geographic situations. The crop has also remarkable diversity in adapting itself to varying conditions. Significant achievements (genetic improvements) have already been achieved in irrigated rice through effective breeding programme in genetic background of semi-dwarf plant types, but very little has been done for semi-deep water condition where rice yield is generally low. Studies on estimation of naturally occurring genetic variability in different crop plants by estimating different genetic parameters helps in planning successful breeding programme. In this endeavour, the various elite breeding lines along with check varieties need to be adequately evaluated and properly utilized in the various crop improvement programme. The knowledge of genetic parameters of variation, provides an idea about the extend of genetic improvement possible for different characters. The knowledge of interrelationship of plant characters with seed yield and among themselves also help the breeders in improvement of a complex character like seed yield for which direct selection is not much effective.

The present investigation was therefore, undertaken to assess the genetic variability with the objective of drawing creation conclusions regarding genetic basis of yield variation, interrelationship among some quantitative traits and the efficacy of some selection criteria in a set of selected low land genotypes of rice thereby selecting a few high yielding genotypes for future use in breeding programme. Hence, the available literature on rice having direct bearing on the present investigation have been reviewed under different sections viz., genetic variability for yield and yield related traits, correlations and path analysis between yield and yield components and selection index for direct and multiple criteria of selection.

2.1 Genetic variability

The amount of genetic variability present among genotypes on the population determines the extent of success in the varietal improvement of any crop plant. The knowledge on the extent of genetic variability present in the population with respect to various agronomic traits and their nature of transmission to subsequent generation enables the plant breeder to initiate and bring out varietal improvement in any crop species. It is therefore, imperative to quantify the genetic variability of different characters in terms of various genetic parameters which would of great help in selection of superior individuals. It is therefore, essential to make a review of literature on genetic variability for yield and yield related traits.

2.1.1 Yield and yield attributing characters

There have been extensive reports on both qualitative and quantitative variation in rice germplasm and reviewed by Ramiah and Rao (1953), Ghose *et al.* (1956) and Chandraratna (1964). The present work contains recent work on genetic variability in quantitative traits in rice (Table 2.1 and 2.2).

2.1 Genotypic and phenotypic coefficients of variability

Author(s) and Year	Characters studied	Magnitude of genetic parameters	
		GCV	PCV
Yadav (2000)	GY	High	-
	GN	High	-
Shivani and Reddy (2000)	GY	High	High
	DH	Low	Low
	PH	Moderate	Moderate
	PL	Low	Low
	PN	High	High
	GN	High	High
	GY	Moderate	Moderate
	BY	Moderate	High
	HI	High	High
Bidhan Roy *et al.* (2001)	GY	High	High
	GN	High	High
	GW	High	High
	GB	High	High
Satyavathi *et al.* (2001)	GY	High	High
	PH	High	High
	PL	Moderate	Moderate
	PN	High	High
	GN	High	High
	GW	Moderate	Moderate
Bhandarkar *et al.* (2002)	GY	High	High
	DH	Low	Low
	PH	High	High
	PL	Low	Low
	PN	High	High
	GN	High	High
	SF	Low	Low
Panwar *et al.* (2002)	GY	High	High
	PL	Low	Moderate
	PN	Moderate	Moderate
	GN	High	High
	GW	Moderate	Moderate
Krishna Veni *et al.* (2002)	GY	High	High
	PH	Low	Low
	PN	Low	Low
	PL	Low	Low
	GN	High	High
	GW	Low	Low

Author(s) and Year	Characters studied	Magnitude of genetic parameters	
		GCV	PCV
Satish *et al*. (2003)	GY	High	High
	DH	Moderate	Moderate
	PH	Moderate	Moderate
	PN	High	High
	PL	Moderate	Moderate
	GN	High	High
	GW	High	High
Krishnappa (2003)	GY	High	High
	DH	High	High
	PH	Moderate	High
	PN	High	High
	PL	High	High
	GN	High	High
	GW	High	High
	SW	High	High
Choudhury and Motiramani (2003)	GY	High	High
	PH	Low	Low
	GN	High	High
	PN	High	High
	PL	Moderate	Moderate
	GW	High	High
	BY	High	High
	HI	Low	Low
Chand *et al.* (2004)	GY	High	High
	PH	High	High
	PN	Moderate	High
	PL	Moderate	High
	GN	High	High
	GW	Moderate	High
Hosib *et al*. (2004)	GY	Moderate to low	Moderate to low
	PH	Moderate to low	Moderate to low
	PL	Moderate to low	Moderate to low
	PN	Moderate to low	Moderate to low
	GN	Moderate to low	Moderate to low
	GW	Moderate to low	Moderate to low

Author(s) and Year	Characters studied	Magnitude of genetic parameters	
		GCV	PCV
Nayak *et al.* (2004)	GY	High	High
	DH	Low	Low
	PH	Moderate	Moderate
	PL	Low	Low
	PN	Low	Low
	GN	High	High
	GW	Moderate	Moderate
	HI	High	High
Shukla *et al.* (2004)	GH	High	High
	DH	Low	Low
	PH	Low	Low
	PN	High	High
	GN	High	High
	PL	Low	High
	GW	High	High
	BY	High	High
	HI	High	High
Singh *et al.* (2005)	GH	High	High
	DF	Low	Low
	PH	High	High
	PL	Moderate	Moderate
	PN	High	High
	GN	High	High
	GW	Moderate	Moderate
Satyanarayan *et al.* (2005)	GH	High	High
	DF	High	High
	PH	High	High
	PL	High	High
	PN	High	High
	GN	High	High
	GW	High	High
Nair and Rosamma (2007)	GY	High	High
	DF	High	High
	PH	High	High
	PL	Low	Low
	PN	High	High
	GN	High	High
	GW	High	High
	HI	High	High
	GB	Moderate	Moderate
	GT	High	High
Sarkar *et al.* (2007)	GW	High	High

DH:Days to heading, PH : Plant height, PL:Panicle length, PN:Panicle number FLA :Flag leaf area, GN:Grain number, SF:Spikelet fertility,GW:100-grain weight, GY:Grain yield, BY :Biological yield, HI: Harvest index

Table 2.2 Genetic advance and heritability

Sl. No.	Characters studied	Magnitudes of genetic parameters		References
		h^2	GA	
1	Days to 50 % flowering	High	High	Das *et al.* (2000) Shivani and Reddi (2000) Verma *et al.* (2000) Kumar *et al.* (2001) Kavitha and Reddi (2002) Krishnappa (2003) Mahato *et al.* (2003) Satish *et al.* (2003) Rajamani *et al.* (2004) Raju *et al.* (2004) Sinha *et al.* (2004) Shukla *et al.* (2004) Satyanarayan *et al.* (2005) Singh *et al.* (2005) Nair and Rosamma (2007)
		High	Low	Selvarani and Rangasamy (1998) Ganesan *et al.* (1998) Venkataramana and Hittalmani (1999)
		Low	Low	Mishra *et al.* (1996)
				Suresh and Reddy (2002)
2.	Plant height	High	High	Ali *et al.* (2000) Sadhukhan and Chattopadhyay (2000) Shivani and Reddy (2000) Verma *et al.* (2000) Bidhan Roy *et al.* (2001) Kumar *et al.* (2001) Kavitha and Reddy (2002) KrishnaVeni *et al.* (2002) Mishra and Verma (2002b) Suresh and Reddy (2002) Choudhury and Motiramani (2003) Krishnappa (2003) Mahato *et al.* (2003) Nassir and Akinsanya (2003) Chand *et al.* (2004) Hosib *et al.* (2004) Rajamani *et al.* (2004) Raju *et al.*(2004) Shukla *et al.* (2004) Sinha *et al.* (2004) Satyanarayan *et al.* (2005) Singh *et al.* (2005) Patra *et al.*(2006) Nair and Rosamma (2007)
		High	Low	Chauhan *et al.* (1993)

Sl. No.	Characters studied	Magnitudes of genetic parameters		References
		h^2	GA	
3.	Productive tillers per plant	High	High	Ali *et al.* (2000) Mishra and Verma (2002) Shivani and Reddy (2000) Bidhan Roy *et al.* (2001) Das *et al.* (2001) Kavitha and Reddi (2002) Choudhury and Motiramani (2003) Krishnappa (2003) Chand *et al.* (2004) Hosib *et al.* (2004) Nayak *et al.* (2004) Raju *et al.* (2004) Satish *et al.* (2004) Shukla *et al.* (2004) Singh (2005) Singh and Singh (2005) Patra *et al.* (2006) Nair and Rosamma (2007)
		High	Low	Shivani and Reddy (2000) Krishna Veni *et al.* (2002)
		Low	Low	Venkataraman and Hittalmani (1999) Bhandarkar *et al.* (2000) Nassir and Akinsanya (2003) Singh and Singh (2005)
4.	Panicle length	High	High	Shivani and Reddy (2000) Bidhan Roy *et al.* (2001) Bhandarkar *et al.* (2002) Kavitha and Reddi (2002) Mishra and Verma (2002) Panwar *et al.* (2002) Choudhury and Motiramani (2003) Krishnappa (2003) Mahato *et al.* (2003) Satish *et al.*(2003) Chand *et al.* (2004) Hosib *et al.* (2004) Nayak *et al.*(2004) Rajamani *et al.*(2004) Raju *et al.* (2004) Singh *et al.*(2005), Patra *et al.*(2006)
		High	Low	Kaw *et al.* (1999) Ali *et al.* (2000) Shivani and Reddy (2000) Das *et al* (2001) Krishna Veni *et al.* (2002) Shukla *et al.* (2004) Nair and Rosamma (2007)
		Low	Low	Thakur *et al.* (2000), Mahato *et al.* (2003) Nasir and Akinsanya (2003) Satyanarayan *et al.* (2005)

Sl. No.	Characters studied	Magnitudes of genetic parameters		References
		h^2	GA	
5.	Grain number	High	High	Sadhukhan and Chattopathyay (2000) Shivani and Reddy (2000) Yadav (2000) Bidhan Roy *et al.*(2001) Das *et al.* (2001) Bhandarkar *et al.* (2000) Kavitha and Reddi (2002) Krishna Veni *et al.*(2002) Mishra and Verma (2002) Panwar *et al.* (2002) Choudhury and Motiramani (2003) Krishnappa (2003) Mahato *et al.* (2003) Satish *et al.* (2003) Chand *et al.* (2004) Nayak *et al.* (2004) Rajamani *et al.* (2004) Raju *et al.* (2004) Satish *et al.* (2004) Shukla *et al.* (2004) Satyanarayan *et al.* (2005) Singh *et al.* (2005) Nair and Rosammma (2007)
		High	Low	Das *et al.* (2001) Hosib *et al.* (2004)
6.	Grain weight	High	High	Sadhukhan and Chattopadhyay (2000) Verma *et al.* (2000) Bidhan Roy *et al.*(2001) Das *et al.*(2001) Kavitha and Reddi (2002) Krishna Veni *et al.* (2002) Mishra and Verma (2002) Panwar *et al.* (2002) Choudhury and Motiramani (2003) Krishnappa (2003) Mahato *et al.* (2003), Satish *et al.* (2003) Chand *et al.*(2004) Hosib *et al.* (2004) Nayak *et al.*(2004) Rajamani *et al.* (2004) Satish *et al.* (2004) Shukla *et al.*(2004), Sinha *et al.* (2004) Satyanarayan *et al.* (2005) Singh and Singh (2005) Patra *et al.* (2006) Nair and Rosmma (2007) Sarkar *et al.* (2007)
		High	Low	Ali *et al.* (2000) Shivani and Reddy (2000) Kumar *et al.* (2001)

Sl. No.	Characters studied	Magnitudes of genetic parameters		References
		h^2	GA	
7.	Harvest index	High	High	Shivani and Reddy (2000) Das *et al*. (2001) Nayak *et al*. (2004) Satish *et al*. (2004) Shukla *et al*. (2004)
		High	Low	Verma *et al*. (2000) Mishra and Verma (2002) Nair and Rosamma (2007) Singh and Singh (2007)
		Low	Low	Kavitha and Reddy (2002) Choudhury and Motiramani (2003)
8.	Grain yield	High	High	Sadhukhan and Chattopadhyay (2000) Shivani and Reddi (2000) Yadav (2000) Bhandarkar *et al*.(2000) Bidhan Roy *et al*.(2001) Das *et al*. (2001) Kumar *et al*.(2001) Kavitha and Reddi (2002) Krishna Veni *et al*. (2002) Mishra and Verma (2002) Panwar *et al*. (2002) Choudhury and Motiramani (2003) Krishnappa (2003) Satish *et al*.(2003) Chand *et al*. (2004) Hosib *et al*. (2004) Nayak *et al*.(2004) Rajmani *et al*.(2004) Raju *et al* (2004) Satish *et al*.(2004) Shukla *et al*.(2004) Sinha *et al*.(2004) Singh *et al*.(2005) Patra *et al*.(2006) Nair and Rosamma (2007)
		Low	Low	Basavaraja *et al*. (1997) Chandra and Pradhan (2003) Singh and Singh (2005)
		High	Low	Reddy *et al*.(1993)

2.2 Association analysis

Correlation coefficient analysis measures the mutual relationship between various plant characters and determines the component characters on which selection can be based for genetic improvement in yield.

It helps in making selection in the field, particularly for grain yield. If a high correlation exists between a low heritable character like yield and high heritable character number of grains per plant, selection can be based on the latter for improvement in the former. Similarly, negative correlations among components and yield would require selection for intermediate level of expression of such components for improvement in yield

The phenotypic correlation between quantitative traits may be due to genotype, environment or both. The genetic correlation is due to association of genetic factors controlling the correlated characters and constitutes a more reliable guide in selection. The environment is a cause of correlation insofar as two characters are influenced by the same environmental difference in a particular manner. The utility of correlation is enhanced when the phenotypic correlation is further analysed into genetic and environmental correlations.

2.2.1 Yield and yield components

There have been extensive published reports on character association studies in rice. Several workers reported positive correlation of grain yield with various other characters. A brief review of recent works is summerised below (Table 2.3 and 2.4).

Table 2.3 Correlation of grain yield with component traits

Sl. No.	Characters	Directions of association	References
1.	Days to 50 % flowering	Positive	Ahmed *et al.* (2000) Shivani and Reddy (2000) Mahato *et al.* (2003) Raju *et al.* (2003) Sumit Chaturvedi *et al.* (2004) Tyagi *et al.* (2004) Vinothini and Anand Kumar (2005)
2.	Plant height	Positive	Das *et al.* (2000) Sarawagi *et al.* (2000) Shivani and Reddy (2000) Bala (2001) Chakraborty *et al.* (2001) Nayak, *et al.* (2001) Shanthi and Shing (2001) Rajmani *et al.* (2004) Raju *et al.* (2004) Shashidhar *et al.* (2005) Vinothini and Ananda Kumar (2005) Babu *et al.* (2005)
		Negative	Bala (2001) Latha *et al.*(2003) Mahato *et al.* (2003) Nayak *et al.* (2004) Babu *et al.* (2005)
3.	Productive tillers per plant	Positive	Ahmed *et al.* (2000) Goswami *et al.* (2000) Venkataramana and Hittalmani (2000) Chakraborty *et al.*(2001) Kavitha and Reddi (2001) Nayak *et al.* (2001) Mishra and Verma (2002) Chaudhury and Motiramani (2003) Mahato *et al.* (2003) Satish *et al.* (2003) Shriram and Muley (2003) Surek and Beser (2003) Rajamani *et al.* (2004) Sinha *et al.* (2004) Tyagi *et al.* (2004) Chitra *et al.* (2005) Satyanarayan *et al.* (2005) Shashidhar *et al.* (2005) Vinothini and Anand Kumar (2005) Babu *et al.* (2006) Tayeng and Singh (2006)

Sl. No.	Characters	Directions of association	References
4.	Panicle length	Positive	Bala (2001) Chakraborty *et al.* (2001) Janardhan *et al.* (2001) Nayak *et al.* (2001) Shanthi and Shing (2001) Choudhury and Motiramani (2003) Raju *et al.* (2003) Rajamani *et al.* (2004) Tyagi *et al.* (2004) Satyanarayan *et al.* (2005) Vinothini and Anand Kumar (2005) Tayeng and Singh (2006)
		Negative	Pradhan and Das (2001) Nassir and Akinsanya (2003) Babu *et al.* (2006)
5.	Grain number	Positive	Goswami *et al.* (2000), Rao (2000) Shivani and Reddy (2000) Chakraborty *et al.* (2001) Janardhan *et al.* (2001) Kavitha and Reddy (2001) Nayak *et al.*(2001) Satyavathi *et al.* (2001) Shanthi and Singh (2001) Panwar *et al.* (2002) Chaudhary and Motiraman (2003) Latha *et al.* (2003) Mahato *et al.* (2003), Satish *et al.* (2003) Shriram and Muley (2003) Surek and Beser (2003) Nayak *et al.* (2004), Rajamani *et al.* (2004) Sashidhar *et al.* (2005) Satyanarayan *et al.* (2005) Vinothini and Ananda Kumar (2005) Babu *et al* (2006) Tayeng and Singh (2006)
		Negative	Malik *et al.* (1990)

Sl. No.	Characters	Directions of association	References
6.	Grain weight (Test weight)	Positive	Sadhukhan and Chattopadhyay (2000) Kavitha and Reddy (2001) Latha *et al*. (2003), Rajamani *et al*. (2004) Sinha *et al*. (2004), Tyagi *et al*. (2004)
		Negative	Pradhan and Das (2001) Satyavathi *et al*.(2001) Mahato *et al*. (2003),Nayak *et al*.(2004) Babu *et al*.(2006) Tayeng and Singh (2006)
7.	Harvest index and Biological yield	Positive	Shivani and Reddy (2000) Chakrabarty *et al*. (2001) Durai (2001) Kavitha and Reddi (2001) Sarwagi *et al*. (2000) Mishra and Verma (2002) Chaudhury and Motiramani (2003) Mishra and Verma (2003) Raju *et al*. (2003) Satish *et al*. (2003) Surek and Beser (2003) Nayak *et al*. (2004) Chitra *et al*. (2005) Sashidhar *et al*. (2005) Vinothini and Ananda Kumar (2005)
8.	Spikelet fertility	Positive	Das *et al*. (2000) Goswami *et al*. (2000) Nasir and Akinsanya (2003) Satyanarayan *et al*. (2005)

Table 2.4 Inter-correlation among yield components

Sl. No.	Characters	Directions of association	References
I.	**Days to 50 % flowering with**		
1.	Plant height	Positive	Meenakshi *et al.*(1999) Raju *et al.*(2003)
2.	Panicle length	Positive	Raju *et al.* (2003) Tayeng and Singh (2006)
3.	Productive tillers per plant	Positive	Balan *et al.* (1999),Mahato *et al.* (2003) Raju *et al.* (2003)
4.	Fertile grain number	Positive	Shivani and Reddy (2000) Mahato *et al.* (2003)
5.	Grain weight	Postiive	Prasad *et al.* (1988) Tayeng and Singh (2006)
6.	Harvest Index	Positive	Selvarani and Rangasamy (1998) Shivani and Reddy (2000) Raju *et al.*(2003)
II.	**Plant height with**		
1.	Panicle length	Positive	Shivani and Reddy (2000) Janardnan *et al.* (2001) Raju *et al.* (2003), Rajamani *et al.* (2004)
2.	Productive tillers per plant	Positive	Rao and Shrivastav (1999) Janardnan *et al.* (2001)
		Negative	Shivani and Reddy (2002)
3.	Fertile grain number	Positive	Singh *et al.* (2000) Rajamani (2004)
4.	Harvest Index	Positive	Raju *et al.* (2003)
III.	**Panicle length with**		
1.	Productive tillers per plant	Positive	Rao and Shrivastav (1999) Janardan *et al.* (2001)
		Negative	Raju *et al.* (2004)
2.	Fertile grain number	Positive	Shivani and Reddy (2000) Rajamani *et al.* (2004)
3.	Grain weight	Positive	Ganesan *et al.* (1998) Yogameenakshi *et al.* (2004)
4.	Harvest index	Positive	Ganesan *et al.* (1998) Raju *et al.* (2003)
IV.	**Productive tillers/plant with**		
1.	Fertile grain number	Positive	Janardnan *et al.* (2001) Mahato *et al.*(2003), Satish *et al.* (2003)
		Negative	Shivani and Reddy (2000)
2.	Harvest index	Positive	Ganesan *et al.* (1998) Pradhan and Das (2001) Satish *et al.* (2003)
V.	**Fertile grain number with**		
1.	100 grain weight	Negative	Raju *et al.* (2004)
2.	Harvest index	Positive	Shivani and Reddy (2000) Satish *et al.* (2003)
VI	**Grain weight with**		
1.	Harvest index	Positive	Sarwgi *et al.* (1997) Ganesan *et al.* (1998)

2.3 Path analysis

Path analysis is an useful method, which specifies the causes and permits the separation of correlation into two measures of direct and indirect effects (absolute values with direction) and reveals the relative importance of the causal factors in producing the end product. Wigon and Mather (1942) stated the linkage of polygenes of different traits is presumable to be the most important cause of genetic correlation and reveals the importance of causal factors in producing the effect. The concept of path analysis developed by Wright (1921) with reference to genetic analysis was first used by Dewey and Lu (1959). In order to get reliable information selection of characters for computation of path analysis is crucial.

Wright (1921) gave the theory of "path analysis" on the basis of standardized partial regression analysis.Later, Nilesh (1922), Tukey (1954) and Kempthorne (1957) focused on its importance. It was first applied by Dewey and Lu (1959) for plant selection and it was observed that it permits a critical examination of specific forces acting to produce a particular correlation. Since then, several workers have used the method for analysis of character association in various crops. There have been extensive reports to determine the direct and indirect effects of component traits on grain yield by selecting quantitative traits in rice. The present effort is a brief review of recent reports on path analysis, which have been summarized below (Table 2.5 and 2.6).

Table 2.5 Direct effects of different characters on grain yield

Sl. No.	Characters	Directions of effects	References
1.	Days to 50 % flowering	Positive	Shivani and Reddy (2000) Mahato *et al.* (2003) Raju *et al.* (2003) Babu *et al.* (2006) Manonmani and Ranganathan (2006)
		Negative	Sarawgi *et al.* (2000) Vinothini and Anandkumar (2005)
2.	Plant height	Positive	Sarawgi *et al.*(2000) Bala (2001) Ganesan (2001) Janardnan *et al.* (2001) Mishra and Verma (2002) Mahato *et al.*(2003) Raju *et al.* (2003) Sashidhar *et al.*(2005) Babu *et al* (2006) Mononmani and Ranganathan (2006)
		Negative	Shivani and Reddy (2000) Chakraborty *et al.* (2001) Vinothini and Anandkumar (2005)
3.	Productive tillers per plant	Positive	Ganesan (2001) Singh *et al.* (2002) Chaudhury and Motiramani (2003) Mahato *et al.* (2003) Raju *et al.* (2003) Satish *et al.* (2003) Surek and Besar *et al.* (2003) Latha *et al.* (2003) Manonmani and Ranganathan (2006) Babu *et al.* (2006)
		Negative	Vanniarajan *et al.* (1996) Tayeng and Singh (2006)
4.	Panicle length	Positive	Bala (2001) Chakraborty *et al.* (2001) Ganesan (2001) Singh *et al.* (2002) Mishra and Verma (2002) Krishnappa (2003) Satyanarayan *et al.* (2005) Tayeng and Singh (2006)
		Negative	Ganesan *et al.* (1997)

Sl. No.	Characters	Directions of effects	References
5.	Grain number	Positive	Shivani and Reddy (2000) Ganesan (2001) Janardnan *et al.* (2001) Kavitha and Reddi (2001) Satyavathi *et al.* (2001) Biao *et al.* (2002) Singh *et al.* (2002) Latha *et al.*(2003) Mahato *et al.* (2003) Satish *et al.* (2003) Surek and Beser (2003) Nayak *et al.* (2004) Babu *et al.* (2006) Manonmani and Ranganathan (2006) Tayang and singh (2006)
6.	100 grain weight	Positive	Chakraborty *et al.* (2001) Nayak *et al.* (2001) Satyavathi *et al.* (2001) Biao *et al.* (2002) Mishra and Verma (2002) Singh *et al.*(2002) Krishnappa (2003) Latha *et al.* (2003) Mahato *et al.* (2003) Surek and Beser (2003) Nayak *et al.*(2004) Babu *et al.* (2006) Manonmani and Ranganathan (2006)
7.	Fertility percentage	Positive	Shivani and Reddy (2000) Nassir *et al.*(2003) Satyanarayan *et al.*(2005)
8	Harvest index	Positive	Chakraborty *et al.* (2001) Durai (2001) Kavitha and Reddi (2001) Mishra and Verma (2002) Raju *et al.* (2003) Surek and Beser (2003) Nayak *et al.* (2004) Chitra *et al.* (2005) Shashidhar *et al.*(2005) Babu *et al.*(2006) Tayeng and Singh (2006)

Table 2.6 Indirect effects of different characters through other characters

Sl. No.	Characters	Directions of effects	References
I.	**Days to 50 % flowering through**		
1.	Plant height	Negative	Sarawgi *et al.* (2000) Shivani and Reddy (2000) Vinothini and Anand Kumar (2005)
2.	Productive tillers/plant	Positive	Balan *et al.* (1999) Shivani and Reddy (2000)
3.	Fertile grain number	Positive	Shivani and Reddy (2000)
4.	Grain weight	Positive	Shivani and Reddy (2000)
II.	**Plant height through**		
1.	Days to 50 % flowering	Positive	Raju *et al.* (2003)
2.	Productive tillers/plant	Positive	Sundaram and Palanisamy (1994) Raju *et al.*(2003)
3.	Fertile grain number	Positive	Shivani and Reddy (2000) Janardnan *et al.* (2001)
4.	Grain weight	Negative	Shivani and Reddy (2000) Vinothini and Anand Kumar (2005)
5.	Harvest index (HI)	Positive	Shivani and Reddy (2000) Chakraborty *et al.* (2001) Raju *et al.* (2003)
		Negative	Shivani and Reddy (2000)
III.	**Productive tillers/ plant through**		
1.	Days to 50 % flowering	Positive	Selvarani and Rangasamy (1998) Raju *et al.*(2003)
2.	Plant height	Positive	Janardnan *et al.* (2001) Raju *et al.*(2003)
3.	Panicle length	Positive	Raju *et al.* (2003) Babu *et al.*(2006)
4.	Fertile grain number/ panicle	Positive	Janardnan *et al.*(2001) Babu *et al.*(2006)
5.	Spikelets/panicle	Positive	Janardnan *et al.* (2001)
7.	Grain weight	Positive	Babu *et al.* (2006)
8.	Harvest index	Positive	Meenakshi *et al.*(1999) Chakraborty *et al.*(2001) Raju *et al.*(2003)

Sl. No.	Characters	Directions of effects	References
IV.	**Panicle length through**		
1.	Days to 50 % flowering	Positive	Raju *et al.* (2003)
2.	Plant height	Positive	Janardnan *et al.*(2001) Raju *et al.*(2003)
3.	Grains/panicle	Positive	Yolanda and Das (1995) Janardan *et al.* (2001)
4.	Productive tillers	Positive	Raju *et al.* (2003)
5.	Spikelets/ panicle	Positive	Janardnan *et al.*(2001)
6.	Harvest index	Positive	Raju *et al.*(2003)
7.	Dry matter production	Positive	Gaenesan *et al.* (1998)
V.	**Grain weight through**		
1.	Plant height	Positive	Babu *et al.* (2006)
2.	Productive tillers/plant	Positive	Babu *et al.* (2006)
3.	Fertile grain number/ panicle	Positive	Babu *et al.* (2006)
4.	Spikelet fertility	Positive	Babu *et al.* (2006)
VI.	**Harvest index through**		
1.	Days to 50 % flowering	Positive	Selvarani and Rangasamy (1998) Raju *et al.*(2003)
2.	Plant height	Positive	Raju *et al.* (2003)
3.	Fertile grain numbers/panicle	Positive	Shivani and Reddy (2000)

2.4 Selection indices

Direct selection for grain yield *per se* is often not reliable and effective. Non-additive gene action, low heritability, inter-genotypic competition and experimental error associated with yield measurements often biases the outcome of selection for higher grain yield. Several workers, therefore, emphasized the important traits. Selection indices provide a useful method by making use of several correlated characters for greater efficiency in selection for yield. Therefore, efforts were made to review the recent reports on selection indices in rice which has been summerised below.

Swamy Rao and Goud (1971) analysed various selection indices in rice and observed that number of effective tillers, grain number per panicle along with grain yield was the most effective selection index for high yield in rice.

Talwar *et al.* (1974) opined that out of 40 selection indices constructed, one comprising of grain weight, yield and kernel volume and other of grain and kemel weight and yield, were most effective in rice.

Khaleque *et al.* (1977) used selection indices in different generations of the 10 x 10 and 6 x 6 diallel cross progenies. The use of discriminant function was found to be superior over straight selection. The inclusion of yield as an independent character is not essential. A combination of primary branch number, spikelet number and kernel number may be used as a selection index for high yield in rice.

Rao *et al.* (1979) analysed 13 varieties using path coefficient for an unspecified number of traits as relative weights for the construction of discriminant function which revealed that selection indices based on phenotypic correlation and path coefficients produced 3% and 9% superiority, respectively in genetic advance over an index based on economic weights.

Unnikrishnan (1980) observed that three characters combination index involving productive tillers, panicle weight and grain yield was the best for cross IR-20 x S-317. In Madhu x S-705 cross, combination of productive tillers, panicle weight and grain weight was superior, while in Mangala x S-317 cross four and five characters indices that included grain yield as one of the components were best.

Chaya (1986) studied grain yield and 11 yield related characters, in 6 F_2 populations under 3 fertilizer treatments and constructed 37 indices by discriminant function technique. Out of 37 indices all those involving spikelet number were superior to grain yield.

Rahangdale *et al.* (1987) studied 8 yield components in 25 lines and reported the importance of number of tillers/plant in influencing yield. Selection for 1000-grain weight, plant height or days to 50% flowering was predicted to be more efficient than direct selection for yield. Selection indices comprising yield and one or more yield components were most efficient.

Gravois and Mc New (1993) developed selection indices from the additive genetic and phenotypic variances and covariances. The selection indices indicated that selecting for increased yield via selection for either panicle weight or panicle number alone would be ineffective. A selection index that included selection for both panicle weight and panicle number increased yield to the extent of 91% as effective as selecting for yield directly.

Sundaram and Palaniswamy (1994) in a study to select parent for hybridization programme for early and medium duration groups reported that in early group, productive tiller had got more weightage followed by straw yield and dry matter and a high negative weightage was observed for grain weight. In medium group, productive tillers and days to flowering recorded more weightage towards the contribution of yield, while panicle weight had got more negative weightage followed by panicle length.

Chakraborty and Hazarika (1996) reported that selection would be ineffective, if based on grain yield alone as the heritability of grain yield was low. They suggested simultaneous selection for four other characters *viz.*, plant height, panicles/plant, spikelet density and 100-grain weight.

In a study of two segregating population for each generation used in F_3, F_4 and F_5, Surek and Beser (2005) reported that selection for grain weight and the number of grains per panicle were effective in early generation. The selection for grain weight was effective as much as direct grain yield selection and number of grains per panicle followed it. The results of selection conducted for low and high values of the yield components, correlation between grain yield and yield components and heritability values revealed that the number of grains per panicle could be used as selection criteria in early generations. Also selection for desired grain size may also be done in early generations.

CHAPTER-III

Materials & Methods

CHAPTER - III

MATERIALS AND METHODS

The experimental material used in the present investigation consisted of thirty elite low land rice cultures along with ten different checks (Table 3.1). The test genotypes were evaluated under both normal and semi-deep water situations at Rice Research Station, Orissa University of Agriculture and Technology, Bhubaneswar during *kharif,* 2007 in order to study the genetic basis of yield variations in low land rice. Besides such trials, efforts were also made to evaluate 85 low land rice cultures including five varieties as checks using augmented design in observational nursery trial to identify the most promising entries for their future use in the breeding programme. Month wise total rainy days, weekly rainfall in mm, and water depth during crop growth period were recorded (Table 3.2 and 3.3) to justify the suitability of experimental site for evaluation of the low land rice cultures. Geographically the field experimentation site is located on 20^0 52` N latitude, $82^0$ 52` E longitude and at an altitude of 25.9 m above the mean sea level and nearly 64 kms west of Bay of Bengal. It falls in the humid and sub-tropical climatic zone of the state.

3.1 Field plot technique

Both the trials were laid out in randomized block design with three replications. The experimental materials were sown on 10.07.2007 and were transplanted on 17.08.2007 as ten row plots of 2.55 m length and five row plots of 2.85 m length with row to row distance of 20cm and plant to plant spacing of 15cm under semi-deep water and normal planting situations respectively in rainfed lowlands. A fertilizer dose of 80kg N, 40kg P_2O_5 and 40kg K_2O/ha was applied as per the scheduled management practices. The recommended crop management practices were followed including need based plant protection to raise a normal crop.

Observations were recorded in respect of eight metric traits on five competitive plants selected randomly from the middle rows of each plot, whereas, characters like plot yield and days to 50% flowering were recorded on plot basis to study the genetic basis of yield variations in low land rice and to identify the best performing cultures for their future use.

Table 3.1 Details of genotypes used in the study

Sl. No.	Name / Designation	Parentage	Origin
1	IR 53945-CN-35-8-2	IR 68 / IR 32720-138-2-1-2 // IR 39334-1-3-1-1	Chinsura
2	IR 69973-CN-8-33-1	Sabita / CT 9897-50-3-M-1-M	Chinsura
3	CN 1039-9	Sabita / IR 57540-8	Chinsura
4	CN 1230-27-5-1	Banla Phadao / Mahsuri // Sabita	Chinsura
5	CN 1592-5-1	CN 1503 / CN 1366-7-2	Chinsura
6	OR 2314-47	Mahanadi / IR 74	OUAT
7	OR 2109-2	Indravati / IR 72 // Salivahan	OUAT
8	OR 1878-3	OR 909-4-89 / Pankaj	OUAT
9	OR 2162-5	OR 142-99 / Surendra	OUAT
10	OR 2315-6	Mahanadi /PSBRC 2	OUAT
11	OR 2119-13	Manika / Manosarovar	OUAT
12	OR 1903-6-67	IR 49517 / OR 1301-32	OUAT
13	IR 70242-24-TTB-1-3	Kong Phlouk / IR 52555-UBN-3-2-1 // Sabita	AAU
14	TTB 303-1-13	Kmj 1-17-2 / IET 10016	AAU
15	RAU 759-5-41	WAT 31-B-B-70-3-8 / IR 73-1-16	RAU
16	RAU 1338-33	Rajshree / RAU 617-59-14	RAU
17	CR 2025-1	IR 53479-B-45 / IR 53519-26- 4 // IR 57519-PMI	CRRI
18	NDR 8024	IR 49830-7 / Sabita // IR 69502-6-SR-3-UB-1-3	NDAUT
19	NDR 8027	IR 49830-7 / Sabita // IR 69502-6-SR-3-UB-1-3	NDAUT
20	NDR 8034	IR 49830-7 / Sabita // IR 69502-6-SR-3-UB-1-3	NDAUT
21	SAVITRI	Pankaj / Jagannath	CRRI
22	SABITA	Pure line selection from Boyen	Chinsura
23	SWARNA	Vasistha / Mahsuri	ANGRAU
24	SWARNA SUB-1	Sub-1 in Swarna	IRRI
25	KANCHAN	Jajati / Mahsuri	OUAT
26	MAHANADI	IR 19661-131-1-3-1 / Savitri	OUAT
27	JAGABANDHU	Savitri / IR 4819 Sel. // IR 27301Sel.	OUAT
28	SALIVAHAN	RP 5-32 / Pankaj	DRR
29	DHANRASI	B 32-Sel. 4 / *O. rufipogan* // B-127	DRR
30	UPAHAR	Mahalaxmi / IR 62	OUAT

Table 3.2 **Month wise total rainy days and total weekly rainfall during the crop growth period**

Month	Weekly Rainfall (mm)				Total Rainfall (mm)	Total Rainy days
	1st	2nd	3rd	4th		
Jun.	27.7	26.6	11.1	96.6	162.0	18
Jul.	68.1	6.6	42.6	66.0	183.3	15
Aug.	258.3	28.7	8.1	51.3	346.4	16
Sept.	109.5	101.9	209.8	114.1	535.3	26
Oct.	106.8	0.5	5.8	17.4	130.5	9
Nov.	15.9	0.0	0.0	0.0	15.9	3

Table 3.3 **Water depth during the crop growth period**

Date (DAT)	Water Depth (cm)	Date (DAT)	Water Depth (cm)	Date (DAT)	Water Depth (cm)
0-7	5-10	29-35	41-50	57-63	15-20
8-14	5-10	36-42	50.0	64-70	15-20
15-21	20-37	43-49	20-30	71-77	15-20
22-28	38-41	50-56	20-25	78-84	15-20

(DAT: Days after transplanting)

Note : The crop between 28-42 DAT was completely submerged for fifteen days and the crop was seriously damaged

3.2 Characters studied

Observations were recorded on the following characters during the course of investigation.

1. **Days to 50% flowering (DF):** Period in number of days from the date of sowing to the date on which 50% plants are in panicle emergence stage.

2. **Plant height (PH):** Height from the base of the plant to the tip of the topmost panicle in the main culm, recorded after the culms ceased elongating, measured in centimeter.

3. **Panicle length (PL):** Length from the ciliate base to the tip of the panicle of the main culm measured in centimeter at the time of recording plant height.

4. **Panicle number (PN):** Number of ear bearing tillers recorded at the time of maturity.

5. **Fertile grain number (FGN):** Average number of fertile grains was counted from the panicles of the main culm of the five sampled plants.

6. **Fertility percentage (F %):** The average ratio of fertile spikelets to the total number of spikelets per panicle expressed in percentage.

7. **100-grain weight (100-GW):** Weight of 100 well filled grains taken at random from the panicles of each plant and weighed in grams.

8. **Harvest index (HI):** The ratio of grain yield to the total biological yield of the above ground plant parts including stem and leaves expressed in percentage

9. **Grain yield per plant (GYP):** Weight of the threshed, cleaned and dried seeds of each plant measured in grams.

10. **Plot yield (PY):** Weight of the threshed, cleaned and dried seeds of each plot measured in grams and converted to plot yield in quintals per hectare.

3.3 Estimation of parameters of variability

The data recorded were subjected to statistical analysis based on the sample mean of the various characters under observation. The different parameters of variability like mean, range, standard error of mean (Sem)standard error of difference (SEd), critical difference (CD), phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability (h^2_{bs}) and genetic advance (GA) were estimated:

3.3.1 Analysis of variance and test of significance

The analysis of variance was carried out separately for each trait following the procedures of randomized block design analysis (Panse and Shukhatme, 1954). The analysis of variance was done on the basis of the following model.

$Y_{ij} = M + g_i + r_j + e_{ij}$

Where,

Y_{ij} = phenotypic observation of the i^{th} genotype in j^{th} replication

M = general mean

g_i = effect of the i^{th} genotype

r_j = effect of the j^{th} replication

e_{ij} = random error associated with i^{th} genotype and j^{th} replication

The structure of analysis of variance is as follows:

Table 3.4 ANOVA with expectations of mean sum of squares

Sources of variation	Degrees of freedom (df)	Sum of squares (SS)	Mean sum of squares (MSS)	Expectations of mean sum of squares (EMS)	F-values
Replication	(r-1)	$(1/g_j)\ \Sigma y_j^2$-CF	MS_r	$\sigma^2_e+g\sigma^2_r$	MS_r/MS_e
Genotype	(g-1)	$(1/r_j)\ \Sigma y_i^2$-CF	MS_g	$\sigma^2_e+r\sigma^2_g$	MS_g/MS_e
Error	(r-1) (g-1)	By subtraction	MS_e	σ^2_e	
Total	(rg-1)	$\Sigma y_i{}^2{}_j$-CF			

Where,

r = number of replications

g = number of genotypes

MS_r = mean square due to replications

MS_g = mean square due to genotypes

MS_e = mean square due to error

σ^2_e = environmental variance

σ^2_g = genotypic variance

σ^2_p = phenotypic variance

$$\sigma^2_e = MS_e$$

$$\sigma^2_g = \frac{MS_g - MS_e}{r}$$

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

3.3.2 Estimation of mean, range, standard error and critical differences

The different parameters of variability like mean, range, standard error of mean(SEm), standard error of difference (SEd) and critical difference (CD)were estimated as follows:

Mean values of each character was averaged out over replications. The lowest and the highest values for each character were taken as range.

Standard error of mean (Sem) = $\sqrt{\frac{\sigma^2_e}{r}}$

The significance of difference between means of any two genotypes was ascertained by using critical difference (CD), calculated as follows:

Standard error of difference (SEd) = $\sqrt{\frac{2\sigma^2_e}{r}}$

Critical difference (CD) = $\sqrt{\frac{2\sigma^2_e}{r}}$ x 't' at error df (5% level of significance)

Where,

r = number of replications

σ^2_e = error mean sum of squares

3.3.3 Estimation of genotypic and phenotypic coefficients of variance and coefficients of variation

The phenotypic, genotypic and environmental variance components for different characters were estimated from ANOVA using the expectations of mean square following Al-Jibouri *et al.* (1958).

Variability for different characters was estimated by the formula suggested by Burton (1952). The phenotypic, genotypic and environmental coefficients of variation for different characters were estimated as follows :

PCV (Phenotypic coefficient of variation in per cent) = $\frac{\sigma_p}{\bar{x}} \times 100$

GCV (Genotypic coefficient of variation in per cent) = $\frac{\sigma_g}{\bar{x}} \times 100$

ECV (Environmental coefficient of variation in per cent) = $\frac{\sigma_e}{\bar{x}} \times 100$

3.3.4 Heritability (broad sense)

Heritability (in broad sense) coefficients of different characters were estimated by the formula suggested by Hanson *et al.* (1956), Lush (1949) and Burton and de Vane (1953).

Heritability in broad sense was calculated as follows :

$$h^2_{bs} = \frac{\sigma^2_g}{\sigma^2_p}$$

Where,

σ^2_g = genotypic variance

σ^2_p = phenotypic variance

3.3.5 Estimation of genetic advance

The expected genetic advance (GA) from selection among varieties for different characters was calculated following Johnson *et al.* (1955).

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

Where,

K = standardized selection differential, which is 2.06 at 5% selection intensity

h^2 = heritability coefficient in broad sense

σ_p = phenotypic standard deviation

Genetic advance expressed as percentage= $\frac{GA}{Mean} \times 100$

3.4 Correlation studies

The phenotypic, genotypic and environmental correlations were estimated to examine the pattern of association between the component characters.

3.4.1 Estimation of covariance components

The analysis of covariance (ANCOVA) between all possible pairs of ten characters were carried out on mean values. Phenotypic, genotypic and environmental components of covariance were estimated from the ANCOVA using the expectations of mean products (which are analogous to those of the mean squares in ANOVA) in the same way as the variance components.

Table 3.5 Analysis of covariance (ANCOVA) with expectations of mean sum of products (msp)

Source	df	MSP	Expectations of MSP
Replication	(r-1)	MP_r	σ_e (xy) + g σ_r (xy)
Genotype	(g-1)	MP_g	σ_e (xy) + r σ_g (xy)
Error	(r-1) (g-1)	MP_e	σ_e (xy)

The components of covariance between two characters x and y were estimated according to Al-Jibouri *et al.* (1958) as follows :

Phenotypic covariance between x and y = σ_p (xy) = σ_g (xy) + σ_e(xy)

Environmental covariance between x and y = σ_e (xy) = MP_e

Genotypic covariance = $\sigma_g(xy)$ = $$\frac{MP_g(xy) - MP_e(xy)}{r}$$

Where,

MP_g and MP_e are mean sum of products of genotype and error respectively and r is the number of replications

3.4.2 Estimation of genotypic, phenotypic and environmental correlations

Using the various covariance components as described in the previous section, the genotypic, phenotypic and environmental correlations between character pairs were computed according to Robinson *et al.* (1951), Johnson *et al.* (1955) and Al-Jibouri *et al.* (1958) as follows :

Phenotypic correlation (r_p) = $$\frac{\sigma_p(xy)}{\sigma_p(x)\sigma_p(y)}$$

Genotypic correlation (r_g) = $$\frac{\sigma_g(xy)}{\sigma_g(x)\sigma_g(y)}$$

Environmental correlation (r_e) = $$\frac{\sigma_e(xy)}{\sigma_e(x)\sigma_e(y)}$$

Where,

σ_p (xy) = phenotypic covariance between x and y

σ_p (x) and σ_p (y) = phenotypic standard deviations of the characters x and y respectively

σ_g(xy) = genotypic covariance between x and y

σ_g (x) and σ_g (y) = genotypic standard deviations of the characters x and y respectively

σ_e (xy) = environmental covariance between x and y

σ_e (x) and σ_e(y) = environmental standard deviations of the characters x and y respectively

Standard errors of the correlation coefficients were calculated using the following formula.

$$SE\ (r_p) = \sqrt{\frac{1-r_p^2}{(g-2)}}$$

$$SE\ (r_g) = \sqrt{\frac{1-r_g^2}{(g-2)}}$$

$$SE\ (r_e) = \sqrt{\frac{1-r_e^2}{(r-1)(g-1)-1}}$$

Significance of the correlation coefficients was tested by't' test at (g-2) degrees of freedom for r_g and r_p, and at {(r-1) (g-1)-1} degrees of freedom for r_e.

Where,

g is the number of genotypes and r is the number of replications

$$t = \frac{r}{\sqrt{[(1-r^2)/(n-2)]}}$$

Where,

r is the correlation coefficient and n is the number of genotypes

3.5 Path coefficient analysis

The method of analysis by path coefficients requires a cause-and-effect relationship among correlated variables. Path coefficients are standardized partial regression coefficients which individually provide a measure of the direct effect of a causal factor on the effect variable. They permit partitioning of the correlations between a causal factor and the effect variable into components of direct and indirect effects and thus, give a better picture of the associations of the causal factors with the effect variable.

In the present study, yield was taken as the "effect" with nine other characters related to yield as the causal factors. The path coefficients were obtained by solving the following simultaneous equations which give the basic relationship between correlations and path coefficients in a system of correlated causes (Wright, 1921 and Dewey and Lu, 1959).

$r_{1.10} = p_{1.10} + r_{1.2}\, p_{2.10} + r_{1.3}\, p_{3.10} + \ldots\ldots\ldots\ldots + r_{1.9}\, p_{9.10}$

$r_{2.10} = r_{2.1}\, p_{1.10} + p_{2.10} + r_{2.3}\, p_{3.10} + \ldots\ldots\ldots\ldots + r_{2.9}\, p_{9.10}$

$r_{3.10} = r_{3.1}\, p_{1.10} + r_{3.2}\, p_{2.10} + p_{3.10} + \ldots\ldots\ldots\ldots + r_{3.9}\, p_{9.10}$

....

....

....

$r_{9.10} = r_{9.1}\, p_{1.10} + r_{9.2}\, p_{2.10} + r_{9.3}\, p_{3.10} + \ldots\ldots\ldots + p_{9.10}$

Where,

r_{ij} = the coefficient of correlation between i^{th} and j^{th} characters

p_{qi} = the path coefficient (direct effect of i^{th} character on yield (character10))

The solutions for path coefficients, direct and indirect effects of the causal factors were estimated as the values of the individual terms of the above equation in RHS.

The residual effect (P_R) was calculated as follows:

$1 = P^2_{RPY} + P_{ipy} \cdot r_{IPY}$

3.6 Construction of selection indices

Application of discriminate function as a basis for making selection on several characters simultaneously is aimed at discriminating the desirable genotypes from undesirable ones on the basis of their phenotypic performance. The selection index for different character combinations were constructed considering grain yield per plant as the ultimate economic criterion. The indices were of the following form.

$$I_x = b_1x_1+b_2 x_2+b_3x_3 \ldots\ldots\ldots\ldots\ldots\ldots + b_n x_n$$

Where,

x's = character means of a particular genotype included in the index

b's = relative weights to be assigned to the characters in computing the single index value I_x for each genotype on which the selection is based

The b values which would maximize the expected genetic advance in yield from index selection were obtained by solving the following simultaneous equations as suggested by Smith (1936) and Hazel (1943).

$$b_1 p_{1.1} + b_2p_{1.2} + b_3p_{1.3} + \ldots\ldots\ldots\ldots + b_np_{1.n} = G_{1}.y$$

$$b_1 p_{2.1} + b_2p_{2.2} + b_3p_{2.3} + \ldots\ldots\ldots\ldots + b_np_{2.n} = G_{2}.y$$

$$b_1 p_{3.1} + b_2p_{3.2} + b_3p_{3.3} + \ldots\ldots\ldots\ldots + b_np_{3.n} = G_{3}.y$$

$$b_1 p_{n.1} + b_2p_{n.2} + b_3p_{n.3} + \ldots\ldots\ldots\ldots + b_np_{n.n} = G_{n}.y$$

Where,

P = phenotypic variance/covariance

G = genotypic covariance between a particular character and grain yield

3.6.1 Character combination and groups of indices

Since grain yield is a complex trait, controlled by non-additive gene action and is believed to have low heritability, hence direct selection for grain yield *per se* is often not reliable and effective. Further inter-genotypic competition and a large experimental error associated with yield measurements often bias the outcome of selection for higher yield. Therefore, several workers in different crop plants have emphasized the importance of indirect selection for yield through the use of component traits governed by genes with additive effect and with strong correlation on grain yield. As no single trait can be taken as adequate criterion of selection for yield, therefore selection indices provide a useful method by making use of several correlated characters for greater efficiency of selection in yield.

During the present investigation selection indices were constructed with grain yield as the economic criterion and ten different characters namely plot yield, days to 50% flowering, plant height, panicle length, panicle number, fertile grain number, fertility percentage, 100-grain weight, harvest index and grain yield per plant were chosen for the construction of ten selection indices. The ten character index including all the ten traits was used for the selection of genotypes. Those genotypes which occupied better rankings in the above selection indices were selected for their future use.

The following ten characters namely plot yield (x_1), days to 50% flowering (x_2), plant height (x_3), panicle length (x_4), panicle number (x_5), fertile grain number (x_6), fertility percentage (x_7), 100-grain weight (x_8), grain yield per plant (x_9) and harvest index (x_{10}) were chosen on the basis of heritability and phenotypic correlation for the construction of nine selection indices. The number of characters in the combination was increased each time by the inclusion of characters one after the other such that the indices varies from single character to a complete nine character index.

3.6.2 Genetic advance and relative efficiency of indices

The expected genetic advance from selection indices was computed on the basis of model suggested by Smith (1936) in the following manner.

$$GA = K \sqrt{\Sigma b.G_i y} \quad \text{(in general)}$$

$$= K\sqrt{b_1G_{1y} + b_2G_{2y} + b_3G_{3y} + ... + b_nG_{ny}} \quad \text{(in particular)}$$

Where,

K = standardized selection differential which takes the values of 2.06 at 5% selection intensity

G_{iy} = genotypic covariance between i[th] character and yield

b_i = index value of the i[th] character

The relative efficiency of an index was estimated as the ratio of the expected genetic advance from index selection to that from direct selection on the basis of yield and was expressed in percentage.

3.6.3 Criteria of selection

On the basis of genetic advance values two selection indices including grain yield per plant as single character and combination of all the nine characters were used for the selection of genotypes from the present set of material. Those cultures which occupy better rankings in all the above selection indices were selected during the course of the present investigation for their future use.

3.7 Observational nursery trial

The experimental material used in the present investigation consisted of 85 test entries including five varieties as checks. The materials were evaluated in augmented design representing sixteen entries and five checks in each block. The trial was sown on 10.07.2007 and transplanted on 17.08.2007 as 5 row plots of 6.6m length with row to row distance of 20cm and plant to plant spacing of 15cm in low land situation. The experiment was conducted as per the scheduled management practices including need based plant protection to raise a normal crop. Observations were recorded on yield and different yield contributing traits like days to 50% flowering and plant height to identify the most promising entries for their future use.

The replicated sub design is analysed and used to adjust yields of un-replicated varieties for location effects and to estimate common error variance which is used to compare all the varieties statistically as per the standard procedure adopted in augmented design.

Where,

c = number of check varieties

v = number of test varieties

b = number of blocks

$n = v/b$ = number of test varieties per block

$p = c+n$ = number of plots per block

$N = b(c+n)$ = total number of plots

Block effect r_j for each block is estimated as follows :

r_j = $B_j - M$

B_j = mean of all checks in the j^{th} block

M = grand mean of all checks

Σr_j = 0

Adjusted yield = Actual yield - Block effect

Table3.6 Analysis of variance (ANOVA) with expectations of mean squares (for Augmented Design)

Source	df	MSS	F
Block	(b-1)	M_b	M_b / M_e
Checks	(c-1)	M_c	M_c / M_e
Error	(b-1) (c-1)	M_e	

Where,

b = number of blocks

c = number of check varieties

M_b, M_c and M_e stand for mean sum of squares due to blocks, check varieties and error respectively

Other parameters were calculated as follows :

Difference between two check means = $\sqrt{\frac{2MSE}{b}}$

Difference between adjusted yields of two varieties in the same block = $\sqrt{2MSE}$

Difference between adjusted yields of two varieties in different blocks = $\sqrt{2MSE\left(1+\frac{1}{c}\right)}$

Difference between an adjusted variety yield and check mean = $\sqrt{MSE\left(\frac{(b+1)(c+1)}{bc}\right)}$

CHAPTER-IV

Results & Discussion

CHAPTER- IV

RESULTS AND DISCUSSION

The present investigation aimed at evaluating thirty elite low land rice cultures along with ten different checks. The test genotypes were evaluated under both normal and sub-merged water situations to study the genetic basis of yield variations in low land rice. Different yield attributing traits were examined to study the availability and extent of genetic variability, nature and magnitude of character association in relation to yield and other traits, path analysis and multiple criteria for selection of genotypes using discriminant function to sort out the most useful and promising genotypes for their possible use in future breeding programmes.

In addition, efforts were also made to evaluate 85 low land cultures including five varieties as checks in augmented design representing sixteen entries and five checks in each block. The replicated sub design was analysed and used to adjust yields of un-replicated varieties for location effects and to estimate common error variance which is used to compare all the varieties statistically as per the standard procedure adopted in augmented design. Different yield attributing traits like days to 50% flowering, plant height and plot yield were examined to identify the most promising entries for their future use. The results obtained in the present investigation has been presented and in the light of findings of similar experiments reported by other workers discussed below topic wise for ease of better comprehension.

4.1 Study of variability

The genetic variability in respect of a trait is the direct measure as to how far the character could be manipulated in a desired norm and direction.

Therefore, it is essential to estimate analysis of variance for various traits to study the genetic variability in the present set of material.

4.1.1 Analysis of variance

The analysis of variance in respect of ten different traits under both normal and sub-merged water situations are presented in Table 4.1 and 4.2 respectively. From the analysis of variance it was revealed that there existed a highly significant difference among the test genotypes for all the characters except fertility percentage and grain yield per plant under normal condition and except grain yield per plant under semi deep water condition. The magnitude of genetic variance was high for majority of traits except for panicle length, panicle number,100-grain weight and grain yield per plant. However, the higher magnitude of genetic variance for grain number, fertility percentage, harvest index and plot yield which have direct bearing on yield may be sorted out as important selection criteria for realization of higher productivity in rice.

Table 4.1 Analysis of variance for 10 characters of 30 low land rice genotypes under normal condition

Sl. No.	Characters	Source of variation (df)		
		Replication (2)	Genotype (29)	Error (58)
1.	Days to 50% flowering	5.05	88.96**	2.94
2.	Plant height (cm)	130.68	624.22**	48.81
3.	Panicle length (cm)	1.07	8.10**	1.15
4.	Panicle number	3.38	4.35**	1.76
5.	No. of fertile grains/panicle	2303.47	2385.38**	768.78
6.	Fertility percentage	139.21	78.18	49.29
7.	100-grain weight (g)	0.007	0.23**	0.03
8.	Harvest index.	188.19	53.01*	31.65
9.	Grain yield / plant (g)	50.21	21.78	20.60
10.	Plot yield (g/ha)	308.99	132.63**	66.65

* and ** Significant at 5% and 1% level of probability respectively
Figures in parentheses indicates degrees of freedom (df) for corresponding sources of variation

Table 4.2 Analysis of variance for 10 characters of 30 low land rice genotypes under submerged condition

Sl. No.	Characters	Source of variation (df)		
		Replication (2)	Genotype (29)	Error (58)
1.	Days to 50% flowering	20.23	144.58**	1.29
2.	Plant height (cm)	220.21	1128.93**	35.80
3.	Panicle length (cm)	6.78	8.30**	1.31
4.	Panicle number	14.93	4.77**	1.61
5.	No. of fertile grains/panicle	4477.49	2766.84**	519.98
6.	Fertility percentage	113.56	194.66**	84.33
7.	100-grain weight (g)	0.001	0.260**	0.010
8.	Harvest index.	167.35	50.04**	21.60
9.	Grain yield / plant (g)	134.35	14.96	12.64
10.	Plot yield (g/ha)	92.85	70.07**	9.31

** Significant at 1% level of probability respectively
Figures in parentheses indicates degrees of freedom (df) for corresponding sources of variation

4.1.2 Variability of characters

The magnitude of variability in respect of mean, range and genotypic and phenotypic coefficients of variation for all the ten different traits under two cultural conditions are presented in Table 4.3. A perusal of data on mean and range indicated considerable amount of variability for majority of characters under study.

Days to 50% flowering

The overall mean was 115.0 days and 123.0 days with range of variation 107.0-129.00 days and 111.0-135.0 days under normal and submerged conditions respectively. It was indicated that the test genotypes could be placed into mid-late to late maturity duration groups and show considerable amount of variability for this trait.

Plant height

The overall mean plant height was 105.7 cm and 109.6 cm with range of 75.4-143.6 cm and 73.4-147.9 cm under normal and submerged conditions respectively. Thus from the range of variability in plant height, the genotypes in the present set of material could be classified as semi-dwarf to intermediate tall types.

Panicle length

The observed range of variability among the test genotypes was 20.9-27.1 cm and 21.2-27.5 cm with overall mean 23.9 and 24.7 cm under normal and submerged conditions respectively. On the basis of range and mean values, the test entries could be grouped into medium to long panicle types. This trait is a stable character and is least influenced by the environment. It has been observed that the longer panicle types are dominant over short panicle types and therefore, selection of genotypes with long panicle types might prove beneficial for realization of high yield.

Panicle number

The range of variability for panicle number among the test genotypes was observed between 6.0-10.7 and 6.0-11.0 with overall mean 8.11and 8.40 under normal and submerged situations respectively. Accordingly the test genotypes could be classified into profuse and moderate tillering types from the present set of material. Profuse tillering types usually reflect high biomass production. Higher biomass production cannot be efficiently used unless accompanied by large sink size to accumulate a greater portion of dry matter during grain filling process for higher productivity. Therefore, it is emphasized the importance of low to moderate panicle number types with large panicle and high grain number for realization of high yield in rice.

Number of fertile grains/panicle and 100-grain weight

The variation for fertile grain number per panicle ranged from 80-199 and 76-197 with an overall mean of 134.2 and 135.4 under normal and submerged situations respectively, whereas the variability in 100-grain weight ranged from 1.52-2.73 gm and 1.53-2.85 gm with an overall mean of 2.18 gm and 2.08 gm under normal and submerged situations respectively. As it has been emphasized by many workers that increased number of grains per panicle (panicle weight types) is an essential component for higher productivity and therefore, from the range of variability, the genotypes with higher grain number could be sorted out for future breeding programmes. On the contrary, it is an established fact that when selection for higher grain number is made, there is always a compensating decrease for grain size. It is therefore, suggested that in order to maintain higher productivity, a balance between grain number and grain weight should be made. The 100-grain weight of about 2.0-2.5 gm is considered ideal for maintaining productivity in rice.) and therefore, from the range of variability in the present set of material, the genotypes with desirable grain size could be selected for increasing yield potentiality in rice.

Fertility percentage

Fertility percentage varied from 73.0-89.9 % and 60.5-90.5 % with over all mean of 81.4 % and 76.4 % under normal and submerged situations respectively, indicating that the character being highly variable and might fluctuate due to change in the environmental conditions. One of the major environmental conditions is the low light intensity at reproductive and ripening phase which is more detrimental for inducing spikelet sterility. It is indicated that low light stress affects the total dry matter production, production of spikelets per unit area and grain size considerably. As dry matter production is reduced more after flowering, the grain filling is largely affected due to poor mobilization of pre-flowering photosynthates from shoot to panicle causing spikelet sterility. The genotypes on the basis of this trait could be grouped into low, medium and highly fertile types providing an effective method for selection of genotypes with improved fertility for realization of high yield in rice.

Harvest index

Yield is a function of total dry matter and harvest index. Therefore, yield can be increased by increasing biomass or harvest index or both. At present more attention has been paid to aspects like dry matter production and its partitioning into grains during grain filling. In other words, the physiological efficiency broadly includes higher biomass production and efficient translocation of dry matter for realization of higher yield. Therefore, the study of genetic variability for such traits not only helps to understand the basis of higher productivity but also useful to manipulate the characters in future breeding programme for realization of high and stable yields.

The magnitude of variability for harvest index ranged from 0.36-0.52 and 0.27-0.43 with an overall mean of 0.45 and 0.35 under normal and submerged situations respectively. The study of variability in this trait has shown the presence of enormous variability among the test genotypes under study.

Grain yield per plant

The overall mean grain yield per plant was 15.1g and 13.6 g with range of 9.2-20.1g and 8.9-18.2 g under normal and submerged situations respectively. Grain yield per plant exhibited a wide range of variability under both the cultural conditions. Based on the grain yield per plant, the genotypes could be classified into low, medium and high yielding types. This classification on the basis of mean values may not be always reliable and effective, due to variation in the micro-environment of single plants within a plot and competitive interactions between themselves resulting under or over estimation of genotypes for single plant measurements to yield and often bias the outcome of selection.

Plot yield

The observed range of variability among the test genotypes was 26.90-53.80 q/ha and 20.39-37.38 q/ha and the overall mean for plot yield was 42.30 q/ha and 29.25 q/ha. The yield level of the test entries in the present set of material was found to be moderate to low in magnitude. As during the present investigation efforts were taken to evaluate a number of low land types, under both normal as well as submerged (stress) conditions, it is therefore, not surprising to note that in general majority of these low land cultures exhibited moderate to low yield.

In general, under the submerged condition the days to flowering was longer with taller plant height, higher panicle number and the traits like fertility percentage, harvest index, grain yield per plant and plot yield were reduced considerably. However, the characters like panicle length, fertile grain number and 100-grain weight were least affected under submerged situation.

In the context of the above discussion and a perusal of the relative magnitude of variation from the analysis of variance and range of variations in respect of all the characters under study, revealed the presence of ample genetic variability in the material, thus providing enormous scope for selection of genotype, which could be used in the future breeding programme for realization of high and stable yields in rice.

4.1.3 Genotypic and phenotypic coefficients of variation

The study of the results on genotypic and phenotypic coefficients of variation maintained correspondence for majority of traits except for panicle number, grain number, fertility percentage, harvest index, and grain yield per plant indicating the greater influence of the environment in the expression of these traits. It was interesting to note that the majority of traits exhibited higher magnitude of both GCV and PCV under submerged conditions except for panicle length and plot yield and in general phenotypic coefficients of variation was higher than genotypic coefficients of variation suggesting the influence of environmental factors in the expression of these traits

Among the characters studied the GCV ranged from 3.81% for fertility percentage to 17.30% for grain number and for PCV, it ranged from 4.88% for days to flowering to 30.39% for grain yield per plant under normal condition. GCV varied from 5.63% for days to flowering to 20.22% for grain number and for PCV it ranged from 5.70% for days to flowering to 26.88% for grain yield per plant under semi-deep condition. As majority of traits except panicle number, grain number, fertility percentage, harvest index and grain yield per plant showed smaller difference between GCV and PCV indicating least influence of environment, therefore, selection on the basis of phenotypic values for majority of characters is expected to be effective.

A review of literature from published reports on genetic variability indicates very inconsistent and contrasting results by Yadav (2000), Bidhan Roy *et al* (2001), Satyavati *et al.* (2001), Bhandarkar *et al.* (2002), Panwar *et al.* (2002), Krishnappa (2003), Choudhury and Motiramani (2003), Chand *et al.* (2004), Nayak *et al.* (2004), Satyanarayan *et al*. (2005) and Sarkar *et al.* (2007). However, in majority of the cases, these estimates were found to be moderate to high for plant height, panicle number, grain number, 100-grain weight, grain yield per plant and plot yield. The contrasting and conflicting reports available for these two parameters for studying variability, is primarily ascribed to the type of experimental materials used in various experiments.

Table 4.3 Estimates of genetic parameters of yield and component traits in 30 rice genotypes under two cultural conditions

Sl. No.	Characters	Cultural condition	Mean	Range	GCV (%)	PCV (%)	h^2 (%)	GA (%)
1.	Days to flowering	Normal	**115.0**	**107.0-129.0**	**4.65**	**4.88**	**90.7**	**9.1**
		Submerged	123.0	111.0-135.0	5.63	5.70	97.4	11.4
2.	Plant height (cm)	Normal	**105.7**	**75.4-143.6**	**13.11**	**14.68**	**79.7**	**24.1**
		Submerged	109.6	73.4-147.9	17.42	18.25	91.1	34.2
3.	Panicle length(cm)	Normal	**23.9**	**20.9-27.1**	**6.34**	**7.76**	**66.9**	**10.7**
		Submerged	24.7	21.2-27.5	6.19	7.73	64.1	10.2
4.	Panicle number	Normal	**8.11**	**6.0-10.7**	**11.47**	**19.96**	**32.9**	**13.6**
		Submerged	8.40	6.0-11.0	12.21	19.43	39.5	15.8
5.	No. of fertile grains/panicle	Normal	**134.2**	**80.0-199.0**	**17.30**	**26.95**	**41.2**	**22.9**
		Submerged	135.4	76.0-197.0	20.22	26.32	59.0	32.0
6.	Fertility percentage	Normal	**81.4**	**73.0-89.9**	**3.81**	**9.43**	**16.4**	**3.2**
		Submerged	76.4	60.5-90.5	7.94	14.40	30.4	9.0
7.	100-grain weight (g)	Normal	**2.18**	**1.52-2.73**	**11.86**	**14.11**	**70.6**	**20.5**
		Submerged	2.08	1.53-2.85	13.90	14.74	88.9	27.0
8.	Harvest index	Normal	**0.45**	**0.36-0.52**	**5.95**	**13.89**	**18.4**	**5.3**
		Submerged	0.35	0.27-0.43	8.76	15.86	30.5	9.9
9.	Grain yield/ plant (g)	Normal	**15.1**	**9.2-20.1**	**4.16**	**30.39**	**1.9**	**1.2**
		Submerged	13.6	8.9-18.2	6.46	26.88	5.8	3.2
10.	Plot yield (q/ha)	Normal	**42.30**	**26.90-53.80**	**11.09**	**22.26**	**24.8**	**11.4**
		Submerged	29.25	20.39-37.38	15.38	18.59	68.5	26.2

4.1.4 Heritability and genetic advance

The heritability in broad sense and genetic advance as percentage of mean estimated for all the traits are presented in Table 4.3. As genotypic variance for a trait alone may not reflect the heritable proportion of variation, hence such studies assume special significance for consideration of the magnitude of different components related to the total genetic variations. Though heritability is the genetic property of a character, it is much influenced by the genotypic architecture, background history of the plant population and genotype-environment interaction. It is also subjected to certain experimental error (Falconer, 1960; Kaul and Bhan, 1974; Mather & Jinks, 1977). As genetic advance in conjunction with heritability gives a more reliable selection index value than heritability alone, therefore, efforts were made to indicate both heritability and genetic advance values for various traits estimated during the present investigation.

The heritability values estimated for different traits varied from 1.9% and 5.8% for grain yield per plant to 90.7% and 97.4% for days to flowering and the genetic advance expressed as percentage of mean ranged from 1.2% and 3.2% for grain yield per plant to 24.1% and 34.2% for plant height for normal and submerged conditions respectively. A moderate to low degree of heritability estimates were observed for most of the traits except for days to 50 % flowering, plant height, grain number and 100-grain weight indicating high degree of influence of environment in the expression of these traits.

High heritability estimates associated with moderate to high genetic gain for days to 50 % flowering, plant height, grain number and 100-grain weight indicate the presence of additive gene effects and hence selection based on phenotypic performance would be effective.(Das *et al.,* 2000; Kumar *et al.,*2001; Krishnaveni *et al.*, 2002; Mishra and Verma, 2002; Choudhury and Motiramani, 2003; Krishnappa, 2003; Sinha *et al.*, 2004; Singh *et al.* , 2005; Nair and Rosamma, 2007)

The characters like panicle length and plot yield exhibited moderately high heritability value and low genetic gain which suggested the influence of both additive and non-additive gene effects in the inheritance of these traits. (Reddy *et al.*,1993; Kaw *et al.*,1999; Shivani and Reddy, 2000; Das *et al.*, 2001; Krishnaveni *et al.*, 2002; Shukla *et al.*, 2004; Nair and Rosamma, 2007). Therefore, selection of genotypes on the basis of phenotypic performance for such traits may not be effective.

Low heritability estimates with moderate to low genetic gain for panicle number, fertility percentage, harvest index and grain yield per plant suggested that dominance and epistatic gene effects may be operating in the inheritance of these traits. (Basavaraja *et al.,* 1997; Vekataraman and Hittalmani, 1999; Bhandarkar *et al.*, 2000; Kavitha and Reddy, 2002; Choudhury and Motiramani, 2003).

A review of literature from the published reports on heritability and genetic advance indicated very inconsistent results by Ganesan *et al.* (1998), Vekataraman and Hittalmani (1999), Das *et al.* (2000), Verma *et al.* (2000), Bidhan Roy *et al.* (2001), Das *et al.* (2001), Kavitha and Reddy (2002), Krishna Veni *et al.* (2002), Mahato *et al.* (2003), Shukla *et al.* (2004),Singh *et al.* (2005), Patra *et al.* (2006) Nair and Rosamma (2007), and Singh and Singh (2007). However, the anomalies observed in the estimates of heritability and genetic advance in various morpho-physiological and metric traits from large volume of research publications are possibly due to difference in the composition of the test materials. Further more, the inter-genotypic competition resulted from single plant measurements might have reduced or inflated the apparent additive-dominance variance and consequently affected heritability estimates for various characters under study.

4.2 Nature of character association

Either linkage or pleiotropy is considered to be the genetic basis of character association. Associations arising from coupling phase linkage resist selection pressure more than that arising from repulsion phase of linkage. In addition to this pleiotropic effects also contribute to strong association of characters. Such associations are of practical use if characters associated are both desirable and complementary. In case of autogamous crops like rice long years of selection pressure have led to the fixation of both desirable and antagonistic association between grain yield and its component traits.

Very often selection for yield *per se* is not reliable and therefore, indirect selection through component traits becomes important for the ultimate output. Hence studies on character associations not only help to understand physical linkages but also provide information on nature and direction of selection. Therefore, during the present investigation an attempt has been made to estimate the nature and magnitude of correlation of character pairs, which would facilitate selection of genotypes where a balance combination of characters is associated with increased productivity.

The results of the nature and magnitude of association of characters at phenotypic levels under both the cultural conditions are presented in Table 4.4. and thus the results of such associations are discussed below trait wise for ease better comprehension.

4.2.1 Correlation of yield with other component traits

Plot yield exhibited positive association with panicle number, fertile grain number, fertility percentage and grain yield per plant under normal condition whereas, it was positively correlated with plant height, fertility percentage, grain yield per plant and negatively correlated with days to 50% flowering under submerged condition. Grain yield per plant was positively correlated with panicle number, fertile grain number, fertility percentage and harvest index under normal condition where as, it was only positively correlated with harvest index under submerged condition. However, it was interesting to observe that both plot yield and grain yield per plant appear to show positive association with panicle number, fertile grain number and fertility percentage; where as grain yield per plant exhibited positive association with harvest index under both the cultural conditions indicating the importance of such traits for realization of high yield in rice.

It was interesting to observe that the association of different characters with plot yield and grain yield per plant exhibited more or less similar trend and the strong association between themselves revealed that selection on the basis of characters contributing grain yield per plant also bears relevance to plot yield.

4.2.2 Correlation among other component characters

The correlation of days to 50% flowering with plant height was negative under submerged condition. Plant height was positively correlated with panicle length and fertile grain number under both the cultural conditions.

Panicle number was positively correlated with both grain yield per plant and plot yield but it exhibited negative or insignificant associations with majority of traits under study.

Fertile grain number was found to be positively associated with fertility percentage but was negatively correlated with 100-grain weight where as fertility percentage was found to exhibit positive association with harvest index under both the cultural conditions.

It is interesting to note that the association of panicle number and grain yield was found to be positive. This is in agreement with the results obtained by Goswami *et al.* (2000), Venkataramana and Hittalmani (2000), Chakraborty *et al.* (2001), Mishra and Verma (2002), Shriram and Muley (2003), Rajamani *et al.* (2004) and Chitra *et al.* (2005). But the association of panicle number was observed to be low, negative and insignificant with majority of characters under study. Therefore, the utility of this trait for selection of high yield becomes doubtful.

A perusal of correlation values indicate that although the association between grain yield per plant and grain number was positive but the grain number exhibited negative association with 100-grain weight. Most of the published reports by Rao (2000), Santhi and Singh (2001),Panwar *et al.* (2002), Shriram and Muley (2003), Nayak *et al.* (2004), Sashidhar *et al.* (2005) and Babu *et al.* (2006) revealed that grain number exhibited a positive association with grain yield which is in agreement with results obtained during the present investigation. As expected, grain number was found to show negative association with 100-grain weight and which might have resulted due to compensating mechanism. It is a foregone conclusion that where genetic selection has been made for large seeds, there has usually been compensating decrease in grain number, therefore, the best means to increase grain yield may be to select for more number of grains per panicle and allow the seed size to move as more or less a random variable (Grafius *et al.,* 1976).

The positive association of grain yield per plant with harvest index during the present investigation reflects that yield is a function of total dry matter and harvest index and yield can be increased by increasing either biomass or harvest index or both (Khush and Virk, 2000; Virk *et al.* 2004). In other words the physiological efficiency of crop plants broadly includes higher biomass production and efficient translocation of dry matter for realization of higher yield. Increasing the biomass production is determined by higher photosynthetic rate, high photosynthetic area, slow leaf senescence, high nitrate assimilation and high nitrate reductase activity, low respiration and photorespiration, high uptake and accumulation of nitrogen and minerals during early phases of growth. Efficient translocation of dry matter includes total dry matter production and partitioning of dry matter between grains and other plant parts. This is determined by large and active sink (high grain number per unit area and stability in grain number, high grain weight and lower spikelet sterility), thus reflecting high harvest index and increased yield (Siddiq *et al.*, 2004).

Several workers have studied the nature of association largely between yield and yield components and various morpho-physiological traits using varietal collections or segregating material derived through cross breeding or mutagen treatment extensively at phenotypic, genotypic and environmental levels. Numerous published reports on character association by Ahmed *et al.* (2000), Shivani and Reddy (2000), Santhi and Singh (2001), Mishra and Verma (2002), Raju *et al.* (2003), Mahto *et al.* (2003), Sinha *et al.* (2004), Satyanarayan *et al.* (2005), Tayeng and Singh (2006) and Patra *et al.* (2006) revealed that all the direct and indirect components are correlated with grain yield and some of the components were found to show positive or negative associations among themselves. In fact most of the literatures on correlation study indicate almost similar type of associations in pure line varieties as well as segregating materials. Although, a definite trend of relationship is suggested, yet there are several instances to show that correlation coefficients for any given character pairs varied from report to report possibly due to differences in the composition of test material.

4.3 Path coefficient analysis

Path analysis has been used to organize the relationship between predicted variables and responsible variables. To understand the direct and indirect effects of each character on grain yield and the application of selection pressure in a better way for yield improvement, partitioning of correlation coefficient into direct and indirect effects through path coefficient analysis is very important. It has been observed that the path coefficients worked out in different sets of characters as well as different cultural conditions show remarkable difference in direct and indirect effects of the component characters on grain yield. Therefore, selection of characters for computation of path analysis becomes essential to obtain reliable information. As there seems to be no definite method for selection of traits, hence the component traits like days to 50% flowering, plant height, panicle length, panicle number, fertile grain number, fertility percentage, 100-grain weight, harvest index and grain yield per plant which have direct bearing on yield were considered for computation of path analysis. During the present investigation the path analysis was carried out at phenotypic level under two cultural conditions, which is presented in Table 4.5 and the results obtained there from are discussed below.

It was observed from the path coefficient analysis that the grain yield per plant exhibited maximum positive direct effect on plot yield followed by plant height, fertility percentage, panicle number, days to 50% flowering, harvest index, fertile grain number, panicle length and 100-grain weight under normal condition and plant height exhibited maximum positive direct effect on plot yield followed by fertility percentage, grain yield per plant, panicle number, panicle length, 100-grain weight, harvest index, fertile grain number and days to 50% flowering under submerged condition thus, indicating the importance of such traits as criteria for selection in that order for realization of higher productivity under two cultural conditions.

Table 4.4 Estimates of phenotypic correlation coefficients (rp) among 10 characters in rice under two cultural conditions

Sl. No.	Characters		Plant height (cm)	Panicle length (cm)	Panicle number	No. of fertile grains/ plant (g)	Fertility percentage	100-grain weight (g)	Harvest index	Grain yield per plant (g)	Plot yield (q/ha)
1	Days to 50% flowering	Normal	**.043**	**-.049**	**.098**	**.189**	**.049**	**-.147**	**-.108**	**.206**	**.179**
		Submerged	-.550**	-.350	.231	-.354	-.213	-.141	-.189	-.199	-.374*
2.	Plant height (cm)	Normal		**.409***	**.006**	**.492****	**.253**	**-.103**	**-.178**	**.317**	**.344**
		Submerged		.562**	-.438*	.431*	.412*	-.089	-.084	.269	.574**
3.	Panicle length (cm)	Normal			**.117**	**.259**	**.029**	**.067**	**-.104**	**.322**	**.162**
		Submerged			-.206	.301	.047	.126	-.084	.205	.375*
4	Panicle number	Normal				**.003**	**.134**	**-.125**	**.221**	**.577****	**.389***
		Submerged				-.300	-.173	-.075	.176	.220	.013
5	No. of fertile grains/plant	Normal					**.438***	**-.512****	**.079**	**.453***	**.367***
		Submerged					.496**	-.378*	.164	.264	.293
6	Fertility percentage	Normal						**-.315**	**.367***	**.395***	**.391***
		Submerged						.073	.296	.301	.472**
7	100-grain weight (g)	Normal							**.127**	**-.115**	**-.189**
		Submerged							.029	.060	.135
8	Harvest index	Normal								**.500****	**.286**
		Submerged								.612**	.203
9	Grain yield/plant (g)	Normal									**.617****
		Submerged									.493**

* and ** significant at 5 % and 1 % level of probability respectively

Table 4.5 Path coefficient analysis of direct and indirect effects of various characters on plot yield under two cultural conditions

Sl. No.	Particulars	Normal	Submerged
1.	**Days to 50 % flowering**		
	Direct effect	0.066	-0.083
	Indirect effect via plant height	0.009	-0.214
	Panicle length	0.003	-0.042
	Panicle number	0.011	0.048
	Number of fertile grains/panicle	-0.006	0.027
	Fertility percentage	0.006	-0.063
	100-grain weight	0.011	-0.004
	Harvest index	-0.007	0.007
	Grain yield per plant	0.085	-0.051
	Total correlation	0.179	-0.374
2.	**Plant height**		
	Direct effect	0.218	0.390
	Indirect effect via days to 50 % flowering	0.003	0.046
	Panicle length	-0.022	0.068
	Panicle number	0.001	-0.091
	Number of fertile grains/panicle	-0.014	-0.033
	Fertility percentage	0.031	0.121
	100-grain weight	0.008	0.002
	Harvest index	-0.011	0.003
	Grain yield per plant	0.131	0.068
	Total correlation	0.344	0.574
3.	**Panicle length**		
	Direct effect	-0.054	0.121
	Indirect effect via days to 50 % flowering	-0.003	0.029
	Plant height	0.089	0.219
	Panicle number	0.013	-0.043
	Number of fertile grains/panicle	-0.008	-0.023
	Fertility percentage	0.004	0.014
	100-grain weight	-0.005	0.003
	Harvest index	-0.006	0.003
	Grain yield per plant	0.133	0.052
	Total correlation	0.162	0.375

Sl. No.	Particulars	Normal	Submerged
4.	**Panicle number**		
	Direct effect	0.109	0.209
	Indirect effect via days to 50 % flowering	0.007	-0.019
	Plant height	0.001	-0.171
	Panicle length	-0.006	-0.025
	Number of fertile grains/panicle	0.0001	0.023
	Fertility percentage	0.017	-0.051
	100-grain weight	0.010	-0.002
	Harvest index	0.014	-0.007
	Grain yield per plant	0.239	0.056
	Total correlation	0.389	0.013
5.	**Number of fertile grains/panicle**		
	Direct effect	-0.029	-0.076
	Indirect effect via days to 50 % flowering	0.013	0.029
	Plant height	0.107	0.168
	Panicle length	-0.014	0.036
	Panicle number	-0.0003	-0.063
	Fertility percentage	0.060	0.146
	100-grain weight	0.039	-0.009
	Harvest index	0.005	-0.006
	Grain yield per plant	0.187	0.067
	Total correlation	0.367	0.293
6.	**Fertility percentage**		
	Direct effect	0.124	0.295
	Indirect effect via days to 50 % flowering	0.003	0.018
	Plant height	0.055	0.161
	Panicle length	-0.002	0.006
	Panicle number	0.015	-0.036
	Number of fertile grains/panicle	0.014	-0.037
	100-grain weight	0.024	0.002
	Harvest index	0.023	-0.011
	Grain yield per plant	0.163	0.076
	Total correlation	0.391	0.472

Sl. No.	Particulars	Normal	Submerged
7.	**100-grain grain weight**		
	Direct effect	-0.076	0.025
	Indirect effect via days to 50 % flowering	-0.010	0.012
	Plant height	-0.022	0.035
	Panicle length	-0.004	0.015
	Panicle number	-0.014	-0.016
	Number of fertile grains/panicle	0.015	0.029
	Fertility percentage	-0.039	0.022
	Harvest index	0.008	-0.001
	Grain yield per plant	-0.048	0.015
	Total correlation	-0.189	0.135
8.	**Harvest index**		
	Direct effect	0.062	-0.037
	Indirect effect via days to 50 % flowering	-0.007	0.016
	Plant height	-0.039	-0.033
	Panicle length	0.006	-0.010
	Panicle number	0.024	0.037
	Number of fertile grains/panicle	-0.002	-0.012
	Fertility percentage	0.045	0.087
	100-grain weight	-0.010	0.001
	Grain yield per plant	0.207	0.155
	Total correlation	0.286	0.203
9.	**Grain yield per plant**		
	Direct effect	0.413	0.254
	Indirect effect via days to 50 % flowering	0.014	0.016
	Plant height	0.069	0.105
	Panicle length	-0.018	0.025
	Panicle number	0.063	0.046
	Number of fertile grains/panicle	-0.013	-0.019
	Fertility percentage	0.049	0.089
	100-grain weight	0.009	0.002
	Harvest index	0.031	-0.023
	Total correlation	0.617	0.493
	Residual	**44.53**	**54.03**

Out of the different characters under study fertile grain number exerted greatest indirect effect on yield via other traits following panicle number, fertility percentage, harvest index, panicle length, grain yield per plant, plant height, days to 50 % flowering, and 100-grain weight under normal condition and fertile grain number exerted greatest indirect effect on yield via other traits following panicle length, harvest index, grain yield per plant, plant height, fertility percentage, 100-grain weight, panicle number and days to 50 % flowering under submerged condition.

Thus from the foregoing observations on direct and indirect effects, the traits like grain yield per plant, number of fertile grains/panicle, fertility percentage, harvest index, panicle number, panicle length and plant height may be considered as important selection criteria for realization of high and stable yields in rice.

These findings in relation to different component traits are in agreement with published reports on path analysis by Shivani and Reddy (2000), Sarawgi *et al.*(2000), Ganesan (2001), Bala (2001),Singh *et al.* (2002), Mishra and Verma (2002), Mahto *et al.* (2003), Chaudhury and Motiramani (2003), Nayak *et al.* (2004), Sashidhar *et al.* (2005), Satyanarayan *et al.*(2005), Babu *et al.* (2006) and Tayeng and Singh (2006).

The observations on direct and indirect effects, as well as the published reports on path analysis indicate that number of fertile grain/panicle, fertility percentage and panicle number exert maximum for the ultimate output. Out of these two major yield components a major emphasis should also be given to grain number which is found to be a decisive character for higher productivity.

The correlation coefficients between characters like plant height, panicle number, fertility percentage, 100-grain weight and grain yield per plant with plot yield exhibited more or less similar direct effect under normal condition, and the correlation coefficients between characters like days to 50 % flowering, plant height, panicle length, fertility percentage, 100-grain weight and grain yield per plant with plot yield exhibited more or less similar direct effect under submerged condition, indicated that correlation explains the true relationship and therefore, direct selection through these traits would be effective under specific cultural condition.

The correlation coefficient was observed to be positive and the direct effect was negative or negligible for traits like days to 50 % flowering, panicle length, number of fertile grain/panicle and harvest index under normal condition, and for traits like fertile grain number and harvest index under submerged situation indicating that under such situations, a restricted simultaneous selection model to be followed to nullify the undesirable indirect effects in order to use of direct effects.

The results of residual effects was found to be 44.53 and 54.03 per cent under normal and submerged conditions respectively, indicating that more than fifty five percent and forty five percent of total variability was contributed by the variables under normal and submerged situations respectively. Although a moderate level of variability is included for analysis, still some of the traits which have least direct and indirect effects should be eliminated and some other factors need to be included in this analysis to give still higher amount of variation in yield.

4.4 Mean performance of different genotypes for various traits

The mean performance of different genotypes with respect to various characters including plot yield under normal and submerged conditions has been presented in Table 4.6 and Table 4.7 respectively. It was interesting to note that the increase or decrease in plot yield was not associated with the corresponding increase or decrease of related traits under study. This discrepancy might have resulted due to undetected sampling errors during recording of observations. Although maximum care has been taken for recording data from a large number of samples for estimating the mean, yet the experimental bias in favour of single plants cannot be ruled out. As during the present investigation, the *per se* performance of the varieties is more meaningful, therefore, major emphasis was given to plot yield than other yield components estimated on per plant basis to identify the most promising cultures for their future use. Out of thirty cultures evaluated under both the cultural conditions separately during the present investigation, as many as ten cultures showing yield level of more than 45.0 q/ha under normal condition and yield level of more than 30.0 q/ha under submerged condition could be sorted out to be promising. The yield performance of these promising entries along with other metric traits is presented in Table 4.8 and Table 4.9 for ease of better comprehension. The most promising cultures under normal condition were OR 2119-13, OR 2315-6, OR 1878-3, OR 2314-47, OR 1903-6-67, OR 2109-2, CN 1592-5-1, OR 2162-5 and Kanchan. Similarly the cultures like OR 1903-6-67, OR 2119-13, IR 70242-24-TTB-1-3, OR 2314-47, NDR 8024, OR 2315-6, OR 2109-2, NDR 8027, IR 53945-CN-35-8-2 and Kanchan were found promising under submerged condition. It was interesting to note that out of the thirty cultures evaluated, the cultures like OR 2119-13, OR 2315-6, OR 2314-47, OR 1903-6-67, OR 2109-2 and Kanchan were found promising under both the cultural conditions.

Besides, identification of promising entries on the basis of *per se* performance it is also imperative to note the promising cultures in relation to specific traits for their future use in a breeding programme for genetic enhancement of yield. The promising cultures in relation to specific traits under both the cultural conditions have been presented in Table 4.10 and Table 4.11 for ease of better comprehension

Cultures like CN 1592-5-1, OR 1878-3, OR 2315-6, OR 1903-6-67, OR 2162-5 and CR 2025-1 found promising for combining three or more than three desirable component traits under normal condition and cultures like CN 1039-9, OR 2109-2, OR 1903-6-67, IR 70242-24-TTB-1-3, TTB 303-1-13, NDR 8024, Swarna Sub-1 and Kanchan found promising for combining two or more than two desirable component traits under submerged conditions. It is therefore, interesting to mention that the above mentioned cultures should be successfully utilized in the future breeding programmes for genetic improvement of yield in low land rice.

Table 4.6 Mean performance of 30 rice genotypes with respect to 10 quantitative traits (NORMAL)

Sl. No.	Variety	DF	PH (cm)	PL (cm)	PN	GN	F (%)	100-GW (g)	HI	GYP (g)	PY (q/ha)
1	IR 53945-CN-35-8-2	119	143.6	23.1	6.0	176.0	79.1	2.25	0.41	13.9	43.74
2	IR 69973-CN-8-33-1	113	85.4	20.9	6.7	86.0	73.9	2.62	0.44	9.2	26.90
3	CN 1039-9	108	95.7	23.5	6.0	132.0	80.7	2.07	0.49	11.1	30.64
4	CN 1230-27-5-1	123	100.1	26.1	9.0	128.0	75.4	2.19	0.43	15.6	42.10
5	CN 1592-5-1	118	113.8	25.0	8.0	190.0	84.9	2.09	0.46	17.8	46.08 (9)
6	OR 2314-47	116	114.9	24.9	10.7	142.0	80.5	2.01	0.42	20.1	48.42 (4)
7	OR 2109-2	110	102.8	24.5	10	116.0	81.1	2.20	0.44	15.2	46.55 (8)
8	OR 1878-3	113	103.8	25.5	8.3	170.0	86.6	1.88	0.48	18.2	48.42 (4)
9	OR 2162-5	118	111.6	21.9	7.3	151.0	87.7	2.23	0.48	17.9	45.15 (10)
10	OR 2315-6	114	124.8	25.6	9.7	128.0	88.2	2.03	0.41	17.9	49.12 (3)
11	OR 2119-13	116	91.7	24.6	8.7	80.0	75.6	2.73	0.48	15.7	50.06 (2)
12	OR 1903-6-67	107	109.7	27.1	9.3	135.0	86.1	2.34	0.50	20.1	48.18 (5)
13	IR 70242-24-TTB-1-3	119	121.6	24.4	8.0	169.0	89.6	1.52	0.42	15.1	43.98
14	TTB 303-1-13	118	112.8	25.4	8.0	140.0	85.6	1.90	0.38	12.9	36.49
15	RAU 759-5-41	112	93.9	23.9	8.7	100.0	73.5	2.36	0.42	12.8	32.28
16	RAU 1338-33	108	124.6	25.2	6.7	124.0	86.2	2.55	0.47	12.4	44.44
17	CR 2025-1	116	84.6	19.5	9.7	107.0	85.2	2.12	0.52	14.7	41.87
18	NDR 8024	109	109..0	23.6	6.3	136.0	77.2	2.37	0.36	11.7	38.83
19	NDR 8027	111	115.2	23.8	8.7	100.0	84.1	2.30	0.42	12.9	37.43
20	NDR 8034	106	113.6	25.0	7.0	144.0	75.6	2.07	0.46	12.4	35.09
21	**SAVITRI**	129	90.9	23.4	8.0	126.0	84.5	2.16	0.47	16.7	42.57
22	**SABITA**	123	95.6	25.6	7.0	112.0	75.6	2.46	0.42	14.6	29.71
23	**SWARNA**	108	75.4	21.4	8.0	124.0	84.1	1.82	0.51	13.4	38.36
24	**SWARNA SUB-1**	115	86.3	21.9	8.7	140.0	83.9	1.98	0.51	14.8	43.04
25	**KANCHAN**	122	116.4	22.7	10.0	199.0	83.6	1.58	0.39	17.5	53.80 (1)
26	**MAHANADI**	114	101.2	23.3	8.0	120.0	73.1	2.25	0.43	16.4	50.06 (2)
27	**JAGABANDHU**	116	111.1	24.9	8.0	123.0	78.2	2.52	0.52	18.2	41.63
28	**SALIVAHAN**	117	98.7	23.6	7.7	122.0	73.0	2.32	0.44	13.2	39.77
29	**DHANRASI**	117	109.4	24.5	7.7	140.0	82.7	2.27	0.40	13.1	47.25 (6)
30	**UPAHAR**	119	111.7	24.7	7.7	163.0	85.8	2.17	0.46	16.9	47.01 (7)
	SED (+/-)	**1.4**	**5.7**	**0.9**	**1.1**	**22.6**	**5.7**	**0.14**	**0.05**	**3.7**	**6.7**

Table 4.7 Mean performance of genotypes with respect to 10 quantitative traits (Submerged)

Sl. No.	Variety	DF	PH (cm)	PL (cm)	PN	GN	F (%)	100-GW (g)	HI	GYP (g)	PY (q/ha)
1	IR 53945-CN-35-8-2	120	147.9	24.4	6.0	143.0	82.0	2.52	0.30	12.4	30.85
2	IR 69973-CN-8-33-1	115	95.3	23.3	8.7	142.0	83.1	2.62	0.43	15.2	27.19
3	CN 1039-9	111	104.9	23.6	6.7	175.0	84.6	1.92	0.39	13.7	30.59
4	CN 1230-27-5-1	129	91.1	25.6	7.6	87.0	60.5	2.20	0.27	8.9	21.57
5	CN 1592-5-1	127	109.0	23.1	6.3	121.0	79.0	2.21	0.41	14.1	23.53
6	OR 2314-47	131	107.9	25.1	8.7	139.0	76.6	1.83	0.35	16.9	33.72 (6)
7	OR 2109-2	124	104.0	24.8	10.0	129.0	75.9	2.01	0.43	18.2	32.42 (9)
8	OR 1878-3	118	113.6	25.3	7.3	182.0	76.6	1.85	0.35	12.9	26.53
9	OR 2162-5	128	106.9	22.6	7.6	129.0	83.4	2.16	0.38	15.7	29.93
10	OR 2315-6	123	130.8	26.5	8.3	107.0	84.3	2.19	0.32	14.1	33.07 (8)
11	OR 2119-13	132	88.6	24.4	11.0	76.0	75.9	2.85	0.36	14.5	36.60 (2)
12	OR 1903-6-67	111	118.6	27.1	9.3	134.0	82.4	2.30	0.36	13.8	37.38 (1)
13	IR 70242-24-TTB-1-3	120	137.1	26.6	7.7	187.0	90.5	1.56	0.32	13.7	34.90 (4)
14	TTB 303-1-13	126	124.2	26.2	8.0	156.0	74.3	1.78	0.30	12.9	29.80
15	RAU 759-5-41	117	107.9	25.4	9.0	105.0	65.5	2.29	0.33	18.0	26.41
16	RAU 1338-33	119	142.2	27.1	8.0	147.0	86.9	2.24	0.38	14.5	30.33
17	CR 2025-1	132	73.4	22.3	10.3	136.0	77.6	1.81	0.36	9.6	20.39
18	NDR 8024	115	128.9	27.5	7.0	196.0	70.5	2.16	0.37	17.2	33.20 (7)
19	NDR 8027	116	129.8	26.1	8.0	144.0	80.1	1.99	0.38	14.8	30.98 (10)
20	NDR 8034	108	123.9	25.6	8.3	135.0	61.9	1.96	0.38	12.7	30.33
21	SAVITRI	135	80.9	21.9	9.0	98.0	60.8	1.86	0.33	10.9	20.39
22	SABITA	133	88.2	26.5	8.0	126.0	63.8	2.09	0.31	11.1	21.18
23	SWARNA	126	78.5	21.2	11.0	98.0	70.7	1.75	0.37	12.7	23.01
24	SWARNA SUB-1	129	76.7	23.3	10.0	130.0	70.6	1.74	0.42	12.3	25.49
25	KANCHAN	126	118.9	23.2	8.3	197.0	85.6	1.53	0.34	15.3	35.42 (3)
26	MAHANADI	120	105.9	23.9	9.3	136.0	74.3	2.00	0.30	12.7	29.41
27	JAGABANDHU	121	116.1	24.5	8.0	120.0	84.0	2.26	0.37	14.4	34.38 (5)
28	SALIVAHAN	122	108.6	23.3	7.7	128.0	80.8	2.23	0.32	11.3	28.63
29	DHANRASI	123	113.7	24.4	9.3	106.0	73.9	2.22	0.33	12.0	29.02
30	UPAHAR	125	114.2	25.5	7.3	150.0	76.5	2.10	0.31	12.2	30.98 (10)
	SED (+/-)	**0.9**	**4.9**	**0.9**	**1.0**	**19.0**	**7.5**	**0.08**	**0.04**	**2.9**	**2.49**

PERFORMANCE OF SWARNA SUB-1 UNDER SUBMERGED SITUATION

Plate 1. The crop between 28-42 DAT was completely submerged for fifteen days at 50cm water depth

Plate 2. Fate of Swarna Sub-1 after water receded from the main field

Plate 3. Five days after receding of water (Regeneration of tillering)

Plate 4. Three weeks after receding of water (Normal tillering was restored)

Table 4.8 Promising low land cultures in rice (Normal)

Sl. No.	Designation	Days to 50% flowering	Plant height (cm)	PN	Grain yield (q/ha)
1.	OR 2119-13	116	91.7	8.7	50.06
2.	OR 2315-6	114	124.8	9.7	49.12
3.	OR 1878-3	113	103.8	8.3	48.42
4.	OR 2314-47	116	114.9	10.7	48.42
5.	OR 1903-6-67	107	109.7	9.3	48.18
6.	OR 2109-2	110	102.8	10.0	46.55
7.	CN 1592-5-1	118	113.8	8.0	46.08
8.	OR 2162-5	118	111.6	7.3	45.15
9.	SAVITRI	129	90.9	8.0	42.57
10.	SABITA	123	95.6	7.0	29.71
11.	SWARNA	108	75.4	8.0	38.36
12.	SWARNA SUB-1	115	86.3	8.7	43.04
13.	KANCHAN	122	116.4	10.0	53.80

Table 4.9 Promising low land cultures in rice (Submerged)

Sl. No.	Designation	Days to 50 % flowering	Plant height (cm)	PN	Grain yield (q/ha)
1.	OR 1903-6-67	111	118.6	9.3	37.38
2.	OR 2119-13	132	88.6	11.0	36.60
3.	IR 70242-24-TTB-1-3	120	137.1	7.7	34.90
4.	OR 2314-47	131	107.9	8.7	33.72
5.	NDR 8024	115	128.9	7.0	33.20
6.	OR 2315-6	123	130.8	8.3	33.07
7.	OR 2109-2	124	104.0	10.0	32.42
8.	NDR 8027	116	129.8	8.0	30.98
9.	IR 53945-CN-35-8-2	120	147.9	6.0	30.85
10.	SAVITRI	135	80.9	9.0	20.39
11.	SABITA	133	88.2	8.0	21.18
12.	SWARNA	126	78.5	11.0	23.01
13.	SWARNA SUB-1	129	76.7	10.0	25.49
14.	KANCHAN	126	118.9	8.3	35.42

Table 4.10 Promising cultures in relation to specific traits (Normal)

Name of the characters	Range	Promising cultures
1. Panicle length (cm)	25.5-27.0	CN 1230-27-5-1, CN 1592-5-1, OR 1878-3, OR 2315-6, OR 1903-6-67, Sabita
2. Panicle number	9.0-11.0	CN 1230-27-5-1, OR 2314-47, OR 2109-2, OR2315-6, OR1903-6-67,CR2025-1, Kanchan
3. Number of fertile grains/ panicle	150-199	IR 53945-CN-35-8-2, CN 1592-5-1, OR 1878-3, OR 2162-5, IR 70242-24-TTB-1-3, Kanchan
4. Fertility percentage	85.0-90.0	OR 1878-3, OR 2162-5, OR 2315-6, OR 1903-6-67, IR 70242-24-TTB-1-3,TTB 303-1-13,RAU 1338-33, CR 2025-1
5. Harvest index	0.45-0.52	CN 1039-9, CN 1592-5-1, OR 1878-3, OR 1903-6-67, OR 2162-5,OR 2119-13, RAU 1338-33, CR 2025-1,NDR 8034, SAVITRI, Swarna, Swarna Sub-1

Table 4.11. Promising cultures in relation to specific traits (Submerged)

Name of the characters	Range	Promising cultures
1. Panicle length (cm)	25.5-28.0	CN 1230-27-5-1,OR 1903-6-67, OR 2315-6 IR IR 70242-24-TTB-1-3, TTB 303-1-13, RAU1338-33,NDR 8024,NDR 8027,NDR 8034,Sabita
2. Panicle number	9.0-11.0	OR 2109-2, OR 2119-13, OR1903-6-67, RAU 759-5-41,CR 2025-1,Savitri, Swarna, Swarna Sub-1
3. Number of fertile grains/ panicle	150-199	CN 1039-9, OR 1878-3, IR 70242-24-TTB-1-3, TTB 303-1-13, NDR 8024,Kanchan
4. Fertility percentage	84.0-90.0	CN 1039-9,OR 2315-6, IR 70242-24-TTB-1-3, RAU 1338-33,Kanchan
5. Harvest index	0.41-0.43	CN 1592-5-1, OR 2109-2, Swarna Sub-1,IR 69973-CN-8-33-1,Kanchan

4.5 Direct and multiple criteria of selection for improvement of yield

4.5.1 Selection indices

Since grain yield is a complex trait, controlled by non-additive gene action and is believed to have low heritability, hence direct selection for grain yield *per se* is often not reliable and effective. Further intergenotypic competition and a large experimental error associated with yield measurements often bias the outcome of selection for higher yield. Therefore, several workers in different crop plants have emphasized the importance of indirect selection for yield through the use of component traits governed by genes with additive effect and with strong correlation on grain yield. Therefore, it would be rewarding and the efficiency of single plant selection for yield could be improved via selection for panicle number, number of fertile grains per panicle and 100-grain weight (Mohapatra and Mohanty, 1986). As no single trait could be taken as an adequate criterion of selection for yield, therefore, selection indices provide an useful method by making use of several correlated traits for greater efficiency of selection in yield (Das *et al.,* 2000).

During the present investigation selection indices were constructed with grain yield as the economic criterion and ten different characters namely plot yield, days to 50% flowering, plant height, panicle length, panicle number, number of fertile grains/panicle, fertility percentage, 100-grain weight, harvest index and grain yield per plant were chosen for the construction of ten selection indices. The ten character index including all the ten traits was used for the selection of genotypes. Those genotypes which occupied better rankings in the above selection indices were selected for their future use.

The expected genetic advance in yield from selection and different selection indices over direct selection on yield under both normal and submerged situations are presented in Table 4.12 and Table 4.13 respectively. The predicted genetic advance from different indices at 5%

selection intensity ranged from 2.258 q/ha in index 1 to 7.499 q/ha in index 10 under normal condition whereas it varied from 4.171 q/ha in index 1 to 8.149 q/ha in index 10 under submerged condition. Thus in terms of predicted genetic advance, the results of the present study brought out superiority of ten character index over direct selection on yield *per se.* This is in general agreement with those of Swamy Rao and Goud (1971), Talwar *et al.* (1974), Khaleque *et al.* (1977), Rao *et al.* (1979), Unnikrishnan (1980), Chaya (1986), Rahangadale *et al.* (1987), Gravois and McNew (1993), Sundaram and Palaniswamy (1994), Chakravarty and Hazarika (1996) and Surek and Beser (2005).

Table 4.12 Expected genetic advance selection index over direct selection on grain yield (Normal)

Index No. and No. of characters	Character	Expected GS
1 (One character index)	DF	2.258
2 (Two character index)	DF+PH	4.259
3 (Three character index)	DF+PH+PL	4.364
4 (Four character index)	DF+PH+PL+PN	5.947
5 (Five character index)	DF+PH+PL+PN+GN	6.191
6 (Six character index)	DF+PH+PL+PN+GN+F%	6.212
7 (Seven character index)	DF+PH+PL+PN+GN+F%+GW	6.339
8 (Eight character index)	DF+PH+PL+PN+GN+F%+GW+GYP	6.667
9 (Nine character index)	DF+PH+PL+PN+GN+F%+GW+GYP+HI	6.950
10(Ten character index)	PY+DF+PH+PL+PN+GN+F%+GW+ GYP+HI	7.499
Plot Yield	PY	4.812

Table 4.13 Expected genetic advance selection index over direct selection on grain yield (Submerged)

Index No. and No. of characters	Character	Expected GS
1 (One character index)	DF	4.171
2 (Two character index)	DF+PH	5.891
3 (Three character index)	DF+PH+PL	5.910
4 (Four character index)	DF+PH+PL+PN	6.177
5 (Five character index)	DF+PH+PL+PN+GN	6.183
6 (Six character index)	DF+PH+PL+PN+GN+F%	6.413
7(Seven character index)	DF+PH+PL+PN+GN+F%+GW	6.438
8 (Eight character index)	DF+PH+PL+PN+GN+F%+GW+GYP	6.446
9 (Nine character index)	DF+PH+PL+PN+GN+F%+GW+GYP+HI	6.589
10(Ten character index)	PY+DF+PH+PL+PN+GN+F%+GW+ GYP+HI	8.149
Plot Yield	PY	7.672

The promising genotypes occupying better ranking in the ten character index were selected for their future use. The plot yield and the index score of promising genotypes namely Kanchan, OR 2314-47, OR 2315-6, IR 70242-24-TTB- 1-3, and OR 2109-2 under normal condition is presented in Table 4.14 and similarly the plot yield and the index score of promising genotypes namely OR 1903-6-67, IR 70242-24-TTB- 1-3, Kanchan, OR 2119-13, Jagabandhu and OR 2315-6 under submerged condition is presented in Table 4.15. It is imperative to note that the cultures like Kanchan, OR 2314-47, OR 2315-6, IR 70242-24-TTB-1-3 and IR 53945-CN-35-8-2 were found promising under both the cultural conditions. It was interesting to note that the relative rankings of varieties selected on the basis of *per se* performance and index score differed indicating the importance of selection index over direct selection on grain yield

Most of the published works on selection indices based on index scores reflect the genotypic worth of a particular culture and the relative efficiency has been assessed in terms of genetic advance. However, the validity of such expectations in selecting different genotypes on the basis of different selection indices is often questioned as it varies due to difference in the composition of material, selection of characters for the construction of indices and the experimental precision associated with yield measurement. Therefore, it becomes imperative to study the relative efficiency of different selection criteria and to test the validity of expected superiority of selection indices over direct selection by testing the promising genotypes through appropriate field trials.

Table 4.14 Selection of genotypes on the basis of ten character index (Normal)

Sl. No	Genotypes	Index score	Plot yield (q/ha)
1	Kanchan	34.53 (1)	53.80 (1)
2	OR 2314-47	30.64 (2)	48.42 (6)
3	OR 2315-6	30.07 (3)	49.12 (4)
4	IR 70242-24-TTB-1-3	28.73 (4)	43.98 (14)
5	OR 2109-2	28.42 (5)	46.55 (10)
6	Dhanrasi	28.27 (6)	47.25 (8)
7	CN 1592-5-1	27.96 (7)	46.08 (11)
8	CN 1230-27-5-1	27.51 (8)	42.10 (18)
9	TTB 303-1-13	27.48 (9)	36.49 (25)
10	IR 53945-CN-35-8-2	27.096 (10)	43.74 (15)

Figure in the parentheses indicate relative ranking of genotypes

Table 4.15 **Selection of genotypes on the basis of ten character index (Submerged)**

Sl. No	Genotypes	Index score	Plot yield (q/ha)
1	OR 1903-6-67	13.37 (1)	37.38 (1)
2	IR 70242-24-TTB-1-3	11.57 (2)	34.90 (4)
3	Kanchan	10.57 (3)	35.42 (3)
4	OR 2119-13	10.38 (4)	36.60 (2)
5	Jagabandhu	9.98 (5)	34.38 (5)
6	OR 2315-6	9.97 (6)	33.07 (8)
7	IR 53945-CN-35-8-2	9.89 (7)	30.85 (12)
8	NDR 8024	9.72 (8)	33.20 (7)
9	Upahar	8.35 (9)	30.98 (11)
10	OR 2314-47	8.29 (10)	33.72 (6)

- Figure in the parentheses indicate relative ranking of genotypes

4.6 Observational nursery trial

The experimental material used in the present investigation consisted of 85 test entries including five varieties as checks. The materials were evaluated in augmented design representing sixteen entries and five checks in each block. The replicated sub design was analysed and used to adjust yields of unreplicated varieties for location effects and to estimate common error variance which was used to compare all the varieties statistically as per the standard procedure adopted in augmented design.

Where,

C = number of check varieties	:	5
V = number of test varieties	:	80
b = number of blocks	:	5
n = v/b = number of test varieties per block	:	16
p = c+n = number of plots per block	:	21
N = b(c+n) = total number of plots	:	105

Block effect r_j for each block

r_j = $B_j - M$

B_j = Mean of all checks in the j^{th} block

M = Grand mean of all checks

Adjusted yield = Actual yield - Block effect

Block	r_j	
1	-0.39	
2	0.83	$\Sigma r_j = 0$
3	0.64	
4	-0.93	
5	-0.15	

As during the present investigation major emphasis was laid on identification of superior genotypes on the basis of the *per se* performance, therefore, out of 80 cultures evaluated fifteen cultures could be sorted out to be promising,yielding more than 34.00 q/ha have been presented in Table 4.16 along with other metric traits for ease of better comprehension.

ANOVA

Source	df	MSS	F
Block	4	2.675	0.093ns
Checks	4	223.191	7.797**
Error	16	28.626	

* Difference between two check means = 3.384
* Difference between adjusted yields of two varieties in the same block = 7.566
* Difference between adjusted yields of two varieties in different blocks = 8.289
* Difference between an adjusted variety yield and check mean = 6.420

Table 4.16 Promising cultures identified from observational nursery trial

Sl. No.	Designation	DF days)	PH (cm)	Block	Grain yield (kg/ha)	
					Actual yield	Adjusted yield
1.	CN 1233-47-30-4	106	142.8	2	42.73	41.90
2.	OR 2150-2	112	116.2	3	42.42	41.78
3.	CN 1205-5-1-2	124	104.3	1	40.91	41.30
4.	CR 2543-83	108	114.3	5	39.39	39.54
5.	IR 674601-17TTB-225	122	120.2	2	37.88	37.05
6.	CR 2458-99	116	108.7	1	36.36	36.75
7.	RAU 678-82-4	119	108.9	1	35.76	36.15
8.	OR 2407-KK-29	112	118.2	1	35.45	35.84
9.	LPR 07006	125	116.1	1	35.45	35.84
10.	RAU 1392-5-3-7-2	110	135.6	5	35.45	35.60
11.	CR 662-2211-1-1	117	110.1	5	35.15	35.30
12	IR 70242-CN36-12-3	106	131.3	3	34.85	34.21
13	OR 2164-1	122	116.2	2	34.54	33.71
14	OR 2343-2	112	120.6	3	34.54	33.90
15	LPR 07001	110	114.1	4	34.54	35.47
	CHECK MEANS					
1.	SAVITRI	133	90.4		22.84	
2.	SABITA	110	136.4		35.32	
3.	SWARNA	115	85.2		22.30	
4.	SWARNA SUB-1	120	91.0		19.88	
5.	KANCHAN	125	111.8		31.58	

CHAPTER-V

Summary & Conclusion

CHAPTER –V

SUMMARY AND CONCLUSION

Rice occupies a pivotal role in Indian agriculture. It is the staple food for more than 70 per cent Indians and a source of livelihood for 120-150 millions rural households. It contributes to 43 per cent of total food grain production and 53 per cent of cereal production, thus continues to hold the key to sustain food sufficiency in the country. The country has witnessed impressive production and productivity growth trends during eighties, although declined, sustained during nineties due to adoption of modern rice production technology. Rice production in India has been transformed from chronic stage with 30 million tonnes in 1965 to sustainable strong surplus level of 93.34 million tonnes and a productivity level of 2075 kg/ha in 2001-02.During the past three decades due to extensive adoption and spread of plant type based high yielding varieties, extension of area under irrigation and adoption of modern production and protection technologies, rice production advanced in the country many fold, enabling to march from an era of chronic deficiency and excessive dependence on imported food, to a period of self sufficiency and surplus. At the current rate of population growth of 1.8 per cent, rice requirement by 2020 would be around 140 million tonnes. However, at the present level of 93 million tonnes we would be requiring to add annually not less than 3.0-3.5 million tonnes of milled rice to sustain the present level of self-sufficiency in rice. It is therefore, a challenging task to achieve this targeted production levels in the next few decades as increase in productivity has to come from the declining and degrading resource base in terms of land, water and other inputs and demand for environmentally sound rice production practices. It is estimated to achieve production by 70 per cent from irrigated ecology, 5 per cent from uplands, 21 per cent from rainfed medium lands and shallow low lands and 3 per cent from flood prone systems.

In terms of area rice crop is grown in about 44.6 million hectares in India, which is about 36.58 per cent of net cropped area and 44.5 per cent of area under cereals, which is the largest acreage in the world. Of the 43.2 million hectares of harvested area in 2004-05, about 30.8 % were rainfed low lands, 44.9 per cent irrigated, 17.4 per cent rainfed uplands and 6.9 per cent flood prone, which profoundly influenced the overall productivity of the country and such vast areas under each ecosystem is not encountered in any other rice growing country and the traditional rice growing states of eastern India, where rice farming is exposed to several uncertainties imposed by drought, floods or both. The rainfed low land rice area in the state comprised of 2.3 million hectares which is more than 50 per cent of the total rice area; have shallow, semi-deep and deep water situations. Shallow low lands occupy a major area (1.3 m ha) followed by semi-deep water (0.8 m ha) and deep water with 0.2 million hectares. Erratic rainfall and uncontrolled water situations are the major constraints in these rainfed ecosystems. Some of the other adverse factors like impeded drainage and water logging, flash floods and early and terminal drought leading to poor crop stand and sub-optimal plant population and continued use of traditional low input responsive and low yielding varieties restrict rice production in the state. However, the farmers continue to grow tall saturated varieties like CR 1014, BAM 6, T 1242 and common land races in semi-deep water lands and the high yielding varieties recommended for semi-deep water situations are yet to gain popularity among the low land farmers. Thus lack of suitable rice varieties with high yield and resistance to various biotic and abiotic stresses is the major constraint to high productivity in these ecologically handicapped low lands of the state. Therefore, there is a need for enhancement of genetic yield potential of rainfed low land rice with emphasis on flash flood submergence.

Realizing the importance of high yield and greater stability of production of low land rice efforts were made to evaluate a set of low land rice genotypes including Swarna-Sub 1 for their yield performance and other characters under two different cultural conditions to study the genetic basis of yield variation in low land rice. Different yield attributing traits were examined to assess the availability and extent of genetic variability in yield and yield attributing characters, nature and magnitude of character association in relation to yield and various other traits, the direct and indirect effects of different component traits on yield through path coefficient analysis and multiple criteria for selection of genotypes using discriminant function to sort out the most useful and promising genotypes for their possible use in future breeding programmes. In addition efforts were also made to evaluate 85 low land cultures including five varieties as checks in augmented design. The major findings emerging from these studies have been outlined below.

The materials under the present piece of investigation possess a highly significant difference among the test genotypes for all the characters except fertility percentage and grain yield per plant under normal condition and except grain yield per plant under semi deep water condition. The magnitude of genetic variance was high for majority of traits except for panicle length, panicle number,100-grain weight and grain yield per plant. However, the higher magnitude of genetic variance for grain number, fertility percentage, harvest index and plot yield which have direct bearing on yield may be sorted out as important selection criteria for realization of higher productivity in rice. In general, under the submerged condition the days to flowering was longer with taller plant height, higher panicle number and the traits like fertility percentage, harvest index, grain yield per plant and plot yield were reduced considerably. However, the characters like panicle length, fertile grain number and 100-grain weight were least affected under submerged situation.

The genotypic and phenotypic co-efficient of variation maintained correspondence for most of the traits except for panicle number, grain number, fertility percentage, harvest index, and grain yield per plant indicating the greater influence of the environment in the expression of these traits. It was interesting to note that the majority of traits exhibited higher magnitude of both GCV and PCV under submerged conditions except for panicle length and plot yield and in general phenotypic coefficients of variation was higher than genotypic coefficients of variation suggesting the influence of environmental factors in the expression of these traits

Among the characters studied the GCV ranged from 3.81% for fertility percentage to 17.30% for grain number and for PCV, it ranged from 4.88% for days to flowering to 30.39% for grain yield per plant under normal condition. GCV varied from 5.63% for days to flowering to 20.22% for grain number and for PCV it ranged from 5.70% for days to flowering to 26.88% for grain yield per plant under submerged condition. As majority of traits except panicle number, grain number, fertility percentage, harvest index and grain yield per plant showed smaller difference between GCV and PCV indicating least influence of environment, therefore, selection on the basis of phenotypic values for majority of characters is expected to be effective.

The heritability values estimated for different traits varied from 1.9% and 5.8% for grain yield per plant to 90.7% and 97.4% for days to flowering and the genetic advance expressed as percentage of mean ranged from 1.2% and 3.2% for grain yield per plant to 24.1% and 34.2% for plant height for normal and submerged conditions respectively. A moderate to low degree of heritability estimates were observed for most of the traits except for days to 50 % flowering, plant height, grain number and 100-grain weight indicating high degree of influence of environment in the expression of these traits.

High heritability estimates associated with moderate to high genetic gain for days to 50 % flowering, plant height, grain number and 100-grain weight indicate the presence of additive gene effects and hence selection based on phenotypic performance would be effective. The characters like panicle length and plot yield exhibited moderately high heritability value and low genetic gain which suggested the influence of both additive and non-additive gene effects in the inheritance of these traits. Therefore, selection of genotypes on the basis of phenotypic performance for such traits may not be effective. Low heritability estimates with moderate to low genetic gain for panicle number, fertility percentage, harvest index and grain yield per plant suggested that dominance and epistatic gene effects may be operating in the inheritance of these traits.

Plot yield exhibited positive association with panicle number, fertile grain number, fertility percentage and grain yield per plant under normal condition whereas, it was positively correlated with plant height, fertility percentage, grain yield per plant and negatively correlated with days to 50% flowering under submerged condition. Grain yield per plant was positively correlated with panicle number, fertile grain number, fertility percentage and harvest index under normal condition where as, it was only positively correlated with harvest index under submerged condition. However, it was interesting to observe that both plot yield and grain yield per plant appear to show positive association with panicle number, fertile grain number and fertility percentage; where as grain yield per plant exhibited positive association with harvest index under both the cultural conditions indicating the importance of such traits for realization of high yield in rice. The association of different characters with plot yield and grain yield per plant exhibited more or less similar trend and the strong association between themselves revealed that selection on the basis of characters contributing grain yield per plant also bears relevance to plot yield.

The correlation of days to 50% flowering with plant height was negative under submerged condition. Plant height was positively correlated with panicle length and fertile grain number under both the cultural conditions. Panicle number was positively correlated with both grain yield per plant and plot yield but it exhibited negative or insignificant associations with majority of traits under study. Fertile grain number was found to be positively associated with fertility percentage but was negatively correlated with 100-grain weight where as fertility percentage was found to exhibit positive association with harvest index under both the cultural conditions.

It is interesting to note that the association of panicle number and grain yield was found to be positive. But the association of panicle number was observed to be low, negative and insignificant with majority of characters under study. Therefore, the utility of this trait for selection of high yield becomes doubtful. Although the association between grain yield per plant and grain number was positive but the grain number exhibited negative association with 100-grain weight. As expected, grain number was found to show negative association with 100-grain weight and which might have resulted due to compensating mechanism. The positive association of grain yield per plant with harvest index during the present investigation reflects that yield is a function of total dry matter and harvest index and yield can be increased by increasing either biomass or harvest index or both.

It was observed from the path coefficient analysis that the grain yield per plant exhibited maximum positive direct effect on plot yield followed by plant height, fertility percentage, panicle number, days to 50% flowering, harvest index, fertile grain number, panicle length and 100-grain weight under normal condition and plant height exhibited maximum positive direct effect on plot yield followed by fertility percentage, grain yield per plant, panicle number, panicle length, 100-grain weight, harvest index, fertile grain number and days to 50% flowering under submerged condition thus, indicating the importance of such traits as criteria for selection in that order for realization of higher productivity under two cultural conditions.

Out of the different characters under study fertile grain number exerted greatest indirect effect on yield via other traits following panicle number, fertility percentage, harvest index, panicle length, grain yield per plant, plant height, days to 50 % flowering, and 100-grain weight under normal condition and fertile grain number exerted greatest indirect effect on yield via other traits following panicle length, harvest index, grain yield per plant, plant height, fertility percentage, 100-grain weight, panicle number and days to 50 % flowering under submerged condition.

Thus from the foregoing observations on direct and indirect effects, the traits like grain yield per plant, number of fertile grains/panicle, fertility percentage, harvest index, panicle number, panicle length and plant height may be considered as important selection criteria for realization of high and stable yields in rice.

The correlation coefficients between characters like plant height, panicle number, fertility percentage, 100-grain weight and grain yield per plant with plot yield exhibited more or less similar direct effect under normal condition, and the correlation coefficients between characters like days to 50 % flowering, plant height, panicle length, fertility percentage, 100-grain weight and grain yield per plant with plot yield exhibited more or less similar direct effect under submerged condition, indicated that correlation explains the true relationship and therefore, direct selection through these traits would be effective under specific cultural condition.

The correlation coefficient was observed to be positive and the direct effect was negative or negligible for traits like days to 50 % flowering, panicle length, number of fertile grain/panicle and harvest index under normal condition, and for traits like fertile grain number and harvest index under submerged situation indicating that under such situations, a restricted simultaneous selection model to be followed to nullify the undesirable indirect effects in order to use of direct effects.

The results of residual effects was found to be 44.53 and 54.03 per cent under normal and submerged conditions respectively, indicating that more than fifty five percent and forty five percent of total variability was contributed by the variables under normal and submerged situations respectively. Although a moderate level of variability is included for analysis, still some of the traits which have least direct and indirect effects should be eliminated and some other factors need to be included in this analysis to give still higher amount of variation in yield.

Out of thirty cultures evaluated under both the cultural conditions separately during the present investigation, as many as ten cultures showing yield level of more than 45.0 q/ha under normal condition and yield level of more than 30.0 q/ha under submerged condition could be sorted out to be promising. The most promising cultures under normal condition were OR 2119-13, OR 2315-6, OR 1878-3, OR 2314-47, OR 1903-6-67, OR 2109-2, CN 1592-5-1, OR 2162-5 and Kanchan. Similarly the cultures like OR 1903-6-67, OR 2119-13, IR 70242-24-TTB-1-3, OR 2314-47, NDR 8024, OR 2315-6, OR 2109-2, NDR 8027, IR 53945-CN-35-8-2 and Kanchan were found promising under submerged condition. It was interesting to note that out of the thirty cultures evaluated, the cultures like OR 2119-13, OR 2315-6, OR 2314-47, OR 1903-6-67, OR 2109-2 and Kanchan were found promising under both the cultural conditions.

Cultures like CN 1592-5-1, OR 1878-3, OR 2315-6, OR 1903-6-67, OR 2162-5 and CR 2025-1 found promising for combining three or more than three desirable component traits under normal condition and cultures like CN 1039-9, OR 2109-2, OR 1903-6-67, IR 70242-24-TTB-1-3, TTB 303-1-13, NDR 8024,Swarna Sub-1 and Kanchan found promising for combining two or more than two desirable component traits under submerged conditions. It is therefore, interesting to mention that the above mentioned cultures should be successfully utilized in the future breeding programmes for genetic improvement of yield in low land rice.

During the present investigation selection indices were constructed with grain yield as the economic criterion and ten different characters namely plot yield, days to 50% flowering, plant height, panicle length, panicle number, number of fertile grains/panicle, fertility percentage, 100-grain weight, harvest index and grain yield per plant were chosen for the construction of ten selection indices. The ten character index including all the ten traits was used for the selection of genotypes. Those genotypes which occupied better rankings in the above selection indices were selected for their future use.

On the basis of the index score the promising genotypes namely Kanchan, OR 2314-47, OR 2315-6, IR 70242-24-TTB- 1-3, and OR 2109-2 under normal condition and promising genotypes namely OR 1903-6-67, IR 70242-24-TTB- 1-3, Kanchan, OR 2119-13, Jagabandhu and OR 2315-6 under submerged condition were selected for their future use. It is imperative to note that the cultures like Kanchan, OR 2314-47, OR 2315-6, IR 70242-24-TTB-1-3 and IR 53945-CN-35-8-2 were found promising under both the cultural conditions. It was interesting to note that the relative rankings of varieties selected on the basis of *per se* performance and index score differed indicating the importance of selection index over direct selection on grain yield. Further it is required to study the relative efficiency of different selection criteria and to test the validity of expected superiority of selection indices over direct selection by testing the promising genotypes through appropriate field trials.

In addition efforts were also made to evaluate 85 low land cultures including five varieties as checks in augmented design representing sixteen entries and five checks in each block. The promising entries like CN 1233-47-30-4, OR 2150-2, CN 1205-5-1-2, CR 2543-83, IR 674601-17TTB-225, CR 2458-99, RAU 678-82-4, OR 2407-KK-29, LPR 07006 and RAU 1392-5-3-7-2 were identified and which could be successfully utilized in the future breeding programmes for genetic improvement of yield in low land rice.

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