

**GENETIC ANALYSIS OF QUANTITATIVE CHARACTERS IN
UPLAND RICE (*Oryza sativa* L)**

BY

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BREEDING**

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DECLARATION

I hereby declare that this thesis has been written by me and that it is a record of my own research work. It has not been presented before in any previous application for higher degree.

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Date

CERTIFICATION

‘This thesis entitled “**GENETIC ANALYSIS OF QUANTITATIVE CHARACTERS IN UPLAND RICE (*Oryza sativa L*)**” by Bebom Noudji Kouambai Tite registration number **M.Sc/Agric/37056/2002-2003**, meets the regulations governing the degree of Master of Science of Ahmadu Bello University, Zaria and is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

This thesis is dedicated to the memories of my late father Mr. BEBOM PAIJL, my mother Mrs. YOSKOM PAULINE, and my nuclear family.

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I wish to express my profound appreciation to my late major supervisor Dr. S.O. ALABI. His keen interest in this study and prompt reading of the proposal left me with a great lesson to learn in his supervisory role to graduate students. I wish to express my sincere and profound appreciation to my new major supervisor, Prof. C.A. ECHEKWU. His right guidance, his encouragement, and his keen attention to me, made me very happy and satisfied throughout his period of supervision and helping hand given previously. I am deeply indebted to the other members of the Supervisory Committee; Prof D.A.ABA, Dr U.S. ABDULLAHI, and the former member of my Supervisory Committee, Dr. I.S. USMAN.

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ABSTRACT

Four genotypes of upland rice with diverse background have been hybridized and evaluated in a Nested design with three replications in the wet seasons of 2004 and 2005. The experiment was carried out to estimate genetic analysis of quantitative traits and heritability of agronomic traits of yield and yield components. Results indicated significant difference between the four parents with respect to days to 50% flowering, plant height, 1000 grain-weight, number of tillers, grain width, ear weight and yield. High heterosis values were obtained with number of tillers (78%) and yield (40%). This indicated high degree of heterozygosity of parents. Significant scaling test was observed for number of tillers suggesting dominance x dominance of gene at interaction with non-allelic gene interaction effect. Strongest positive correlation coefficients were obtained between grain length and either number of tillers ($r = 0.54$), or panicle weight ($r = 0.53$), yield and either 100 grain-weight ($r = 0.64$) or number of tillers. Similar result was observed between flag leaf length and panicle weight. Yield and panicle weight, yield and 100-grain-weight exhibited strongest correlation. High heritability was observed for all the traits in *Yarumji x Wab 35-1-F₁F₂* generation. Yield exhibited high heritability in all F₂ generation. All the significant characters could lead to efficient selection of rice crop.

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CHAPTER ONE

INTRODUCTION

Rice belongs to the genus *Oryza* and to the family poaceae. The genus *Oryza* has several species but only two are cultivated, that is *Oryza sativa* and *Oryza glaberrima*. *Oryza glaberrima* originated from West Africa while *Oryza sativa* originated from Asia. Twenty two wild species of rice have been identified which show vast genetic diversity and geographical distribution in area with varying production potentials depending on soil and climatic conditions (Aggraval *et al* 1996a; Vaughan, 2003). Although, mainly grown in tropical regions, rice cultivation area ranges from latitude 40°N to 50°S and from longitude 70° to 140°E , but it produces its best yields between 30°S and 45°N around the equator. The global annual rice production in 1991 was 562,260 thousand metric tons (tmt), and was ranked third after wheat (584, 874tmt) and maize (576,821tmt) (FAO, 1991). In 1991, Asia was the first producer of rice grain (about 91% of world production). Africa comes in second position with 16,730tmt (Memento de l’Agronome, 2002). The world’s average yield was 4.5t/ha (Memento de l’Agronome, 2002). West Africa is important for genetic diversity of rice because uniquely, two species *Oryza glaberrima* and *Oryza sativa* L co-exist within the region. Since 1980, Nigeria has become the largest rice producing country in West Africa producing about 50% of the rice grown in the sub region (Ajayi *et al*, 2010) and third largest in Africa after Egypt and Madagascar (WARDA, 1990).

In Nigeria, rice is the sixth major crop in cultivable area after sorghum (*Sorghum bicolor*), millet (*Pennisetum spp*), cowpea (*Vigna unguiculata*), maize (*Zea mays*) and

cassava (*Manihor spp*) (Ukwungwu, 2000). Rice crop can tolerate soils of pH ranging from 4.5 to 8.0 and is grown either as a rain-fed or irrigated crop.

Rice is one of the most important cereal crops. It is the staple food for about three billion people and more than a third of the world's population has rice as a component of their diet. Rice is eaten by many households without any religious consideration. In 1991, it provided 80% of world food at the global level (USDA, 1991). Arrandean, (1988) reported that rice constitutes a source of income for about 2.4 billion populations.

In Africa, the economic importance of rice has steadily increased over the last two decades and the amount imported has more than doubled following the gradual evolution which has taken place in the nutritional habits of many Africans, especially those living in the urban - which has changed from eating only traditional foods such as cassava, millet and sorghum to rice and wheat (Dat Van Tran, 2010). In spite of these improvements, local rice production has not kept up with domestic consumption demands of the Nigerian populace, and consequently, rice is still imported (Singh *et al*, 1997). Nigeria, along with many countries across the world has ecologies that are suitable for different rice varieties and that can be harnessed to boost rice production to meet domestic demands and even to produce a surplus for export (Anonymous, 1997).

1.1 Threats to Rice Production

Despite the importance however, farmers have identified a number of constraints as limiting to rice production efforts. These include:

- Cultivation of local cultivars with low yield such as *Oryza glaberrima*, although well adapted in the environment, are disappearing gradually and

- need to benefit from improved varieties some desirable characters that could be incorporated through research.
- Low temperature (Abiotic stress): The effect of low temperature at flowering period causes high rate of abortion of flowers consequently leading to low grain yield and low volume of paddy production. This could in turn compromise food security in the country.
 - High temperature (abiotic): Temperature above 35°C generally causes sterility if they occur during anthesis. However, higher night temperatures in tropical regions during the ripening stage decreases rice yields appreciably (Peng *et al.*, 2004). Higher temperatures also cause deterioration in grain quality (Counce *et al.*, 2005; Zhong *et al.*, 2005; Tanaka *et al.*, 2009)
 - Drought (abiotic stress) is the most serious constraint to rice production in unfavourable rice growing areas and most of the popular farmers are susceptible to drought stress (Serraj *et al.*, 2009). Most of the popular varieties collapse under these drought conditions. Erratic rainfed fall during some wet seasons causes stunted growth rate which inhibits the rice plant from attaining its full life cycle leading to immature plants and high rate of unfilled grain. This negatively affects yield production.
 - Salinity: Soil salinity is responsible for appreciable yield reduction in a range of cultivated rice saline soils occupying more than 6% of the world's land area (Szabolcs, 1994; Ohassemi *et al.*, 1995). Substantial differences in spikelet and tiller number have been reported between rice genotypes exposed to salinity and

these characters are important contributors to variation in grain yield under saline environments (Zeng *et al.*, 2002)

- Effect of pest (biotic stress): Pest causes stunted growth of plant, damages plant leaves and reduces chlorophyll in plants. This leads to low organic matter accumulation consequently affecting negatively rice production.

While some strategies for improving productivity can readily be implemented, others though effective, may be achieved at high cost which is unaffordable by farmers. Consequently, there is a constant search for superior and more effective options for confronting challenges to increase rice production as a strategy for addressing world food insecurity. From a plant breeding perspective, moderate to high yield could be achieved at relatively low cost through the development and cultivation of varieties which show high stability under diverse environmental conditions, resistance to various diseases and pest and with acceptable grain quality that meets the consumer preferences could be achieved. This is the least cost and most stable option for managing rice production constraints.

The development of improved crop varieties through plant breeding depends to a large extent on the amount and relative importance of genetic variability for these traits that determine the worth of an elite variety as envisaged by farmers and end-users. Elucidation of the genetic control of these important traits will help in planning effective and efficient breeding methodologies to effectively tackle production constraints and improve rice variety.

For rice, the production potential of available varieties vary so much depending on the agro ecology areas which they are produced.

- Upland rice generally has poor yield (800-1.5kg/ha), local upland rice response poorly in fertilizers and is exposed to drought depending on the plasm. It suffers from poor establishment and high grain sterility due to variable climate every year.
- Lowland rice necessities: Some costly investment for irrigation, skill techniques for water use efficiency. Water availability, water quality, poor drainage are the major factors connected to water problems including water logging, high cost of labour, salinity and water pollution which have negative effects in lowland rice production.

The scope for improvement is to increase sustainability, rice production per unit area at low cost, which can help to boost globally rice production. This could increase income of farmers, consequently reduce food insecurity and poverty.

The present study intends to study the pattern of recombination characters and efficient selection of traits in upland rice (low cost of production, easy cultivation, low fertilizer application, increase in number of cultivators annually) in order to have a baseline to improve rice varieties well adapted in the environment.

1.2 Objectives of the Study

The main objective of the study was to determine the genetic control of some selected quantitative traits in upland rice.

The specific objectives are:

- ❖ To estimate heritability for selected traits.
- ❖ To study correlation between agromorphological traits, yield and yield related components.

CHAPTER TWO

LITERATURE REVIEW

In the higher plants many phenotypic effects are not related to the gene in a simple way. Rather, they result from a chain of physico-chemical reactions and interactions initiated by specific genes but through complex chains of events modified by other gene and the external environment to produce the phenotype (Allard, 1960).

2.1 Genetic Control of Quantitative Characters

Fisher (1918) conceived that the genotypic variance can be partitioned into its three components namely: (i) additive portion arising due to difference between homozygote; (ii) dominant part arising due to intrallelic interactions and (iii) an epistatic component arising from interallelic interactions. Supriyo *et al.* (2010) worked on rice and reported that 100 grain weight was controlled by major gene and polygenes. Number of the spikelets of the main panicle and grain weight per plant were controlled by two pairs of major genes and polygene. Mahmood *et al.* (2004) carried out an experiment on rice and it indicated that in the early season, the developmental dynamics of grain weight of rice were mainly controlled by dominant effects. The dominance increased rapidly during the filling stage, and additive genes scarcely expressed in the early period and functional with low efficacy in the late period. In the late season, the entire courses of grain weight filling were affected by dominant and additive effects. They reported that additive and dominant genetic effects contributed significantly to the total heritable variation observed for plant height, panicle length. Additive genetic effect was important for the expression of productive tiller per plant, while dominance genetic effect was important for the expression of variation of the number of days to maturity.

Supriyo *et al.* (2010) carried out an experiment on rice and it indicated that the major genes were recessive - epistatic, complementary, additive effects of panicle length was controlled by two pairs of genes with additive-epistatic effects and polygenes, grain density was controlled by two pairs of major genes and polygene. Grain length, grain width were controlled by two major genes and polygenes. The major genes were additive and recessive-epistatic effect. Hosseini *et al.* (2005) worked on rice and reported that the presence of partial dominance in the genetic control of time of 50% heading and plant height was observed with 68 and 61% heritability, respectively.

Kumar *et al.* (2010) on their part reported that among the yield and yield component traits, 1000-grain weight was controlled by a major genes and polygenes. Number of the spikelets of main panicle, number of grains main panicles, grain weight were all controlled by two pairs of major genes and polygenes. As to panicle length, it was controlled by two pairs of genes with additive-epistatic effect and polygenes. Grain length was controlled by two major genes and polygenes. Three pairs of major genes with additive - epistatic and polygenes played their roles in grain width. As to stem characters, two pairs of major genes and polygenes with additive-epistatis, played their roles in plant height. Two pairs of major genes and polygenes worked in culm length.

2.2 Heterosis

Whalery (1944) made a comprehensive review of heterosis which has been established in literature as synonym for hybrid vigor. Heterosis refers to the developmental simulation resulting, by whatever mechanism, from the union of different gametes. According to Whalery, the manifesting effects of heterosis were those

of increase in size of plant parts or increase in physiological activity, and similar phenomena, resulting from the hybrid condition. Genetical explanations indicated that heterosis was the increased vigor of F1 over the mean of the parents or over the better parent-whichever definition is used is not due to any single genetic cause (Hayes, 1946). Powers (1944, 1945) prefers to use the term heterosis as Shull (1948) intended for cases where the hybrid showed hybrid vigor at least over the mean of the parents. Bruce (1910) explained heterosis on the combined action of favourable dominant or partially dominant factors. East and G.H Shull (1912) considered hybrid vigor to result from heterozygosis. A.F. Shull (1912) attributed hybrid vigor “to the effect of a changed nucleus and a (relatively) unaltered cytoplasm on each other”. Mean while the multiple factor phyphotesis of quantitative inheritance had been very largely adopted. Powers (1944, 1945) prefers to use the term heterosis as Shull (1948) intended for cases where the hybrid showed hybrid vigor at least over the mean of the parents. He considered also that heterosis and dominance are different degrees of expression of the some “physiological genetic phenomena”. He indicated that if the term “heterosis” is to be use in reference to definite characters of an organism where the character of the hybrid is superior to the better parent, or inferior to the weaker, then it seems that the definition of heterosis must be on the basis of “manifestation” by “of heterozygosity” rather than stimulus of heterozygosis.

It has been indicated that there is a much closer relation between the characters of parents and of their F1 crosses in self-pollinated plants than between the characters in inbred liens of cross-pollinated plants and their F1 crosses.

Heterosis can facilitate yield enhancement 30 to 40% and contributes to enrich many other desirable quantitative and other desirable quantitative and qualitative traits in crops (Verma, 2003). Verma et al (2002) evaluated seven diverse rice ecotypes in 1994-1995 for heterosis and inbreeding depression for important quantitative traits. Their results revealed significant heterosis for grain yield and number of productive tillers per plant and 100-grain weight. Heterosis has been exhibited for day to 50% flowering and spikelets per panicle. Kshirsaga et al (2005) developed 40 rice hybrids and indicated that the highest heterobeltiosis for grain yield per hill was recorded by the eras IR-68886A x IR-56381-139-2-2. The cross JR - 68388A x JET-16309 had the highest standard heterosis for grain yield.

Vahaja et al (2004) crossed eight genetically diverse rice cultivars. The results suggest that yield increase was largely due to significant and favourable heterosis in yield component, that is, number of spikelets panicle - 1, panicle length, leaf area plant - 1 (at maximum tillering stage) and number of panicles m⁻². Five top heterotic crosses over their mid and better parents for each traits were identified.

2.3 Correlation

Correlation coefficient is a statistical measure which determines the degree (strength) and direction of relationship. Correlation coefficient analysis measures the mutual relationship between plant characters on which selection can be based for genetic improvement. Correlations are always defined in relation to a population under a given environment. The environmental correlation has its basis always in the genes and it is due to the variation of the expression of gene according to the environments. Supriyo et al.

(2010) conducted an experiment on twenty-one genotypes of boro rice (*Oryza sativa*), the correlation analysis revealed significant positive genotypic correlation of yield per panicle with plant height (0.21), panicles per plant (0.53), panicle length (0.53), effective grains per panicle (0.57) and harvest index (0.86). Aghura Luzi-kihupi, 2010) evaluated thirty six lines of rice for yield and other components. Correlation coefficient analysis revealed grain per plant positively correlated with all the characters except per cent unfilled grains and days to 50% flowering.

Akinwale et al. (2011) reported significantly positive correlation between yield and number of tillers per plant ($r = 0.58^{**}$), panicle weight ($r=0.60^*$) and number of grains per panicle ($r=0.52^*$). These traits can be used for grain yield selection. Sharma and Chouhey (1985) and Dhanraj and Jagadish (1987) reported that yield per plant was positively correlated with the number of productive tillers per plant, number of panicles per plant, spikelets per plant, spikelets per plant and 1000 grain weight. Prasad *et al.* (1988) observed positive correlations between grain yield per plant and the number of spikelets per panicle, number of fertile grains per panicle and 1000 grain weight.

Honarnezhad (2002) carried out an experiment with seeds of six rice cultivars. The result indicated that the genotypic correlation coefficient of grain yield per plant was highly significant with 1000 grain weight ($r_g=0.31^{**}$), number of filled grain per panicle ($r_g=0.61^{**}$), and number of tillers per plant ($r_g=0.37^{**}$). However, genotypic correlation coefficients of grain yield per plant with number of dead seeds per panicle ($r_0=0.65^{**}$). Plant height ($r_g=0.26^{**}$) and day's 11am transplantation to full grain maturity ($r_g=0.52^{**}$) were significantly negative.

Yadav et al (2011) showed that sufficient amount of variability existed in the entire gene pool of rice for all traits and phenotypic coefficient of variation was significant for seed yield, harvest index, biological yield, number of spikelets per panicle, flag leaf length, plant height and number of tillers. The results indicated that these characters are least influenced by environment. Those characters are the most important that contribute directly to yield and may serve as selection criteria for improving the genetic potential of rice. Ullah et al. (2011) corroborated that grains per panicle, panicle length, leaf area index appeared to influence yield characters for local biroin rice. Sink and Quot (2002) revealed that the selection for grain yield is most efficient if it is based on panicle length, grain number per panicle, grain weight, number of primary branches, number of secondary branches and harvest index, since the characters fulfilled the requirements of genotype association with yield. Rice varieties show a strong positive correlation between ear length and plant height, and the assumption that the polygenes governing plant height exercise a pleiotropic effect on ear length appears justified (Longmans 16, 64).

2.4 Heritability

Heritability describes the relationship between the genotype and phenotype. heritability is a measure of the value of selection for particular characters in various types of progenies and as an index of transmissibility.

Robinson et al. (1949) defined heritability as the “additive genetic variance in per cent of the total variance”. Smith (1952) describes heritability as “the ratio expressed in per cent of the variance component due to additive fixable gene effects and its variance due to dominance.”

Akinwale et al. (2011) estimated broad sense heritability and indicated that low broad sense heritability observed for the number of tillers per plant and 1000-grain weight is indicative of the influence of the environment on these traits.

Syed et al. (2000) studied genetic variability and broad sense heritability in rice. The results indicated that heritability estimates was maximum for plant height, low-seed weight, number of tillers per plant, spikelet density and panicle length. Expected relative genetic advance was the function of heritability and coefficient of genotypic variability.

Ullah et al. (2011) indicated that for rice crop, high heritability with high genetic advance in percentage was recorded for the characters grains per panicle, grain yield per plant and 1000-grain weight.

Okelola et al. (2007) worked on rice and reported that high heritability of 78.64% and low genetic advance of 2.10% were observed for emergence index and 100 seed weight in the first season whereas low heritability (30.01%) and low genetic advance (4.63%) were recorded with speed of emergence.

In the second season, seed yield per plant showed high heritability combined with high genetic advance. However, 100 seed weight, emergence index, speed of emergence and plant height showed high heritability but had low genetic advance. Bhattacharyya (1978) reported that in rice crop plant height was highly heritable along with spikelet sterility and grain yield.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Experimental Materials

The experimental materials used were improved upland rice varieties with diverse genetic background: Faro49, Wab351<, Faro55, collected from the National Cereal Research Institute in Badegi, Niger State, Nigeria and a local variety from National Agricultural Seed Council. They were chosen based on their physical characteristics and distinguishing features from preliminary investigations. Some agronomic characteristics are recorded in the table 3.1 below.

Table 3.1: Characteristics and distinguishing features of the varieties used in the study

Name	Characteristics and distinguishing features
Yar rumji (local)	Brown glumes, thin culms and short narrow leaves, small panicles, poor response to fertilizer. Yield = 700 – 800kg/ha
FARO ₃₅	Brown glumes, red nodes (basal nodes), medium number of tillers, high plant height, vigorous stem, long leaves, reddish grain tip, good response to fertilizer application. Yield = 2000-2500kg/ha
FARO ₄₀	Brown glumes, large and long leaves, vigorous plant, a medium number of tillers, high plant, good response to fertilizer application. Yield = 3000-3500kg/ha
WAB _{35-1-FX}	Brown glumes, big and long panicles, big and large grains, vigorous plant, good response to application, medium number of tillers. Yield = 3000 – 3500kg/ha.

Crosses were made between the local variety and each of the improved varieties. Crossing consisted of emasculating the female parent (local variety) panicle and gentle friction of a ripe anther collected from male parent, dusted against the inner face of the glumes emasculated, and a cloud of pollen settles on the stigma. In each cross, there was enough seed to undertake evaluation. The materials consisted of parent seeds, F1 seed, F2 seed which were planted and evaluated in 2005 at the Institute for Agricultural Research field, Ahmadu Bello University, Zaria. The sample population used for observations and data recording for each population were twelve (12) plants.

3.2 Experimental Site

The experimental site was Institute for Agricultural Research field, Ahmadu Bello University, Samaru (Latitude 10°11'N, longitude 07°38'E and 686m above sea level) located in the derived guinea savannah ecological zone.

Samaru is characterized by sandy loam soils. The long term mean annual rainfall is 1050mm which falls between May and September while the mean annual minimum and maximum temperature are 17.8°C and 31.1°C respectively.

3.3 Experimental Field layout

The experimental design used in the conduct of this work was Nested design with three blocks. Each block consisted of three plots of 5m x 1.5m dimensions. Seeds were planted in 6 rows spaced 0.3m apart and 0.2m between seedlings. The interblock spacing was 1.5m and the plots were separated from each other by a 1m spacing. Three seeds were planted per hill 3.4cm deep. Three weeks after seedling, the plants were thinned to one plant per hill.

3.4 Cultural Practices

Land preparation: The experimental plots were cleared of weeds and other debris with a cutlass, dried and burnt. The field was later ploughed twice and harrowed. *Planting:* three seeds were manually sown. Replanting was done week after planting to replace missing hills.

Fertilizer application: NPK fertilizer (15:15:15) was applied at planting (100kg/ha). The plants received a complementary urea fertilizer (75kg/ha) at maximum tillering stage and eight weeks after planting (75/ha). 100kg of K₂O were applied at blooming stage.

Field sanitation: The plots were adequately kept weed-free by 2 manual hoe weeding operations carried out at three and six weeks after planting.

Harvesting: Harvesting was achieved manually by cutting the plant (at the ground level) with sickle when 2/3 of the principal axis of the panicle was yellow.

3.5 Observations and Measurements

Data were taken from 12 randomly selected plants at an interval of 2m within a row based on the following:

1. **Days to 50% flowering:** number of days from sowing to when the plant attains 50% flowering.
2. **Plant height (cm):** the perpendicular distance from the ground level to the top panicle of the plant.
3. **Grains-width (cm):** 20 grains of each selected plant were collected and measurements were made with a Vernier Caliper and their average recorded.
4. **Grain length (cm)** lengths of grains harvested from each selected plant were measured and their averages (mean) were recorded.

5. **Kernel weight (g):** this is the average weight of 1000 kernels collected from each plot block.
6. **Panicle weight(g):** 12 panicles for selected plant were collected and weighed and their average recorded.
7. **Panicle length(cm):** 12 panicles were collected randomly and measured with a ruler and their average recorded.
8. **Flag leaf length(cm):** lengths of flag leaf are measured from 12 plants per from the base of the leaf to the lip and their average was recorded.
9. **Number of tillers:** 12 were randomly selected at relative maturity period and their average was measured and recorded.
10. **Weight of tillers(g):** 12 tillers were harvested (1oin selected plants and weighed and their average recorded.
11. **Yield (t/ha):** grain harvested from each selected plants were weighed in grams to record data in grain yield per plant.

3.6 Statistical Analysis

Plot means were used in all analyses of the population studied.

The data collected were subjected to analysis of variance (ANOVA) to test the variability' of traits. Treatments that showed significant difference were further separated using least significant difference (LSD) at 5% level of probability.

The statistical model for the analysis was based on the general linear model (GLM) as follows:

$$Y_{ij} = \mu + v_i + t_j + \epsilon_{ij}$$

Where: Y_{ij} = is the observation made on i^{th} treatment in the j^{th} block

μ = the general mean

v_i = the effect of i^{th} treatment

t_j = the effect of j^{th} block (population)

ϵ_{ij} = the experiment error

The form of analysis of variance with expected mean squares (EMS) is presented in Table 3.2.

Table 3 2: ANOVA table showing expected means square

Source of variation	Df	M_s	Expected MS
Genotype	$g-1$	M_{sg}	$\sigma^2_e + b\sigma^2_g$
Block	$b-1$	M_{sb}	$\sigma^2_e + g\sigma^2_b$
residue	$(b-1)(g-1)$	M_{sc}	σ^2_e

b = number of block

g = number of genotype

σ^2_e = environment variance

σ^2_b = effect of block

σ^2_g = genetic variance

3.7 Genetic Analysis a

3.7.1 Scalling Test

Data collected were subjected to scaling test based on the procedure outlined by Singh and Chaudhary (1985) .Mather (1949) and Ilayman and Mather (1955) proposed A,B,C and D of scaling test,

The significance of any one of these A,B,C and C taken to indicated the presence of noallelic interaction. In this study, backcrosses were not available; F3 was not available, so only C test was applied.

$$C = 4\bar{F}_2 - 2\bar{F}_1 - \bar{P}_1 - \bar{P}_2$$

The variance was computed thus:

$$V_c = 16V(\bar{F}_2) + 4V(\bar{F}_1) + V(\bar{P}_1) + V(\bar{P}_2)$$

V_c = variance of C,

\bar{P}_1 = mean of parent 1,

\bar{F}_1 = mean of hybrid 1,

\bar{P}_2 = mean of parent 2,

F_2 = mean of F2 generation,

$V(F_1)$ = mean variance of F hybrid,

$V(P_2)$ = mean variance of parent 2,

$V(F_2)$ = mean variance of F2 population,

Standard error (S.E) was estimated as the square root of the respective variance as follows:

$$S.E(c) = (V_c)^{1/2}$$

And t value was calculated as follows:

$$t_{(c)} = C/S.E_{(c)}$$

3.8 Heterosis

Heterosis was estimated based on the mid-parent values as the difference between F1 and the mid-parent.

$$\text{Mid parent (MP) heterosis} = \frac{f_1 - MP}{MP} \times 100$$

Where F1 = hybrid mean value

MP = mid-parent value

3.9 Heritability

Broad sense heritability was estimated following the procedures suggested by Mahmud and Kramer (1951) using the following relation:

$$h^2 = \frac{\sigma^2 F_2 - 2\sqrt{(\sigma^2 P_1 \times \sigma^2 P_2)}}{\sigma^2 F_2} \times 100$$

Where: $\sigma^2 F_2$ = variance of F2 population

$\sigma^2 P_1$ = variance of parent 1

$\sigma^2 P_2$ = variance of parent 2

3.10 Correlation in F₂

Simple linear correlation between pair of traits in F₂ generation was calculated using product moment correlation.

CHAPTER FOUR

RESULTS

4.1 Mean performance for populations

4.1.1 Evaluation of mean parent lines

The mean performance for agronomic traits of parents and hybrids of rice evaluated in 2004 and 2005 are in Table 4.1 and Table 4.2. In 2004 evaluation (Table 4.1), significant differences were obtained between the four parent lines with respect to days to 50% flowering, plant height, 100 grain-weight, number of tillers, grain width, ear weight and yield. The observed ranges were 60 to 85 days for days to 50% flowering, 60.2 to 102.0 cm for plant height, 3.0 to 7.0g for 100 grain-weight, 6.0 to 8.0 for number of tillers, 0.2 to 0.4 cm for grain width, 3.8 to 8.0g for ear weight and 1.0 to 4.0t/ha for yield. For the parents 51.0 to 61.0, days to 50% flowering 67.07 to 84.0 cm, for plant height 3.0 to 4.0g, for 100 grain-weight 18.0 to 22.0, for number of tillers, 5.0 to 6.0g, for ear weight and 3.5 to 4.0t/ha for yield for the hybrids. There were no significant differences observed between the parents and the hybrids for flag leaf length and tillers weight. No significant difference between parent Faro55 and hybrid (Yar rumji x Wab 35-1-FxF1) for grain width. Significant differences were observed between parents and hybrids for days to 50% flowering, plant height, 100 grain-weight, number of tillers, ear weight, ear length and yield. Hybrid (Yar rumji x Far₄₉F₁) was earlier than the earliest parent Faro₅₅ while two hybrids (Yar rumji x Far₄₉F₁), Yar rumji x Wab35-1-FxF1) had heavier panicle than the harvest parent panicles. Hybrid (Yar rumji x Faro₅₅) was lighter in 100 grain-weight than the lightest parent (Faro₅₅) for 100 grain-weight.

Table 4.1 reveals a low coefficient of variation (CV) for days to 50% flowering, plant height of all the populations studied. High variability was observed for 100 grain weight, ear width, flag leaf length, and yield for all the parent lines. Highest variability was observed for number of tillers and medium variability observed between grain width, ear length for the population studied.

Days to 50% flowering, ear weight and yield observed were highly difference significant due to the genotypes effects (GCV=72.3, GCV=72.7) and GCV73.0 respectively) and this could indicated that the selection of rice population based on those characters could be efficient. The result presented in Table 4. 1 indicated medium contribution of genotype in the expression of phenotypes for ear length, flag leaf length, 100 grains/weight. Low genetic coefficient of variation were observed fore plant height, grain width, tillers number, tillers weight, and grain length, and this indicated that, the phenotypes observed for those traits were mostly due to the environment effects.

Table 4.1: Agronomic characters of parent lines

Parents	Day to 50% flowering	Plant height (cm)	100 grains weight (g)	Grain width (cm)	Number of Tillers	Ear weight (g)	Ear length (cm)	Flag leaf length (cm)	Tillering weight (g)
Far0₄₉	64.0*	69.7*	7.0*	0.4*	18.9*	8.0*	23.8	36.0	4.0
Far0₅₅	60.0*	60.2	4.0*	0.3*	10.0*	5.0*	14.0	19.7	3.0
Wab_{35-1-FX}	66.0*	102.0*	6.7*	0.3*	14.9*	6.9*	26.0	31.5	3.0
Yar rumji	85.0*	61*	3.0*	0.2*	6.9*	3.8*	18.8*	25.8*	1.0
GM	68.8	73.2	5.2	0.3	12.9	5.7	20.7	28.0	2.0
LSD5%	8.0	1.4	0.1	0.009	0.7	0.3	9.8	14.9	1.0
CV(%)	6.9	1.9	29.4	20.5	62.5	33.5	23.4	20.0	31.0
GCV (%)	7.3	20.9	45.7	24.2	22.0	72.7	40.4	36.2	14.0

***Indicate significant difference between traits LSD = Least significant difference, GM + grand mean, GCV = genotypic coefficient of variation, CV (%) = coefficient of variation**

4.1.2 Evaluation of non segregated and segregated population in 2005.

The mean performance information for the parents and crosses are presented in Table 4.2. In the 2005 evaluation the results indicated significant differences between the parental lines for days to 50% flowering, plant height, 100 grain—weight, number of tillers, ear weight, ear length, grain length and yield. The observed ranges were 58.0 to 62.0 days. For days to 50% flowering, 62.0 to 89.6 cm, for plant height, 3.6 to 5.0g, for 100 grain-weight, 12.0 to 19.0, for number of tillers, 5.0 to 8.0g, for ear weight, 18.0 to 27.7 cm, for ear length, 0.7 to 0.8 cm, for grain length, and 3.0 to 4.0 t/ha for yield. There were no significant differences between the parents and F₂ generation for grain width, flag leaf length, tillers weight and grain length. F₂ generation (Yarumji x Faro₅₅F₂) was earlier than the earliest parent Faro₅₅.

High variability ($cv \geq 30\%$) was exhibited in 100 grain weight, number of, ear weight, and yield traits while low variability ($cv < 10\%$) was observed in days to 50% flowering. However, medium variability ($10 < cv < 30\%$) was observed in plant height, grain width, panicle length, and grain length. Days to 50% flowering, 100 grain weight, grain length in this study were high due to the effect of genotype, and those characters could be efficient criteria for rice selection. Plant height and grain width are mostly due to environment effect.

Table 4.2: Mean performance of growth and yield parameters for non-segregated and segregated populations (2005)

Sources	Day to 50% flowerin g	Plant height (cm)	100 grains weight (g)	Grain width (cm)	Numb er of Tillers	Ear weight (g)	Ear length (cm)	Flag length (cm)
Faro₄₉	61*	74.0*	5.0*	0.3*	19.0*	8.0*	22.8*	27.0*
Faro₅₅	58*	62.9*	3.6*	0.2	12.0*	5.0*	18.0*	23.0
Wab_{35-1-FX}	62*	89.6*	5.0*	0.3*	13.0*	7.0*	27.7*	25.0
Yar rumji x Faro₄₉F₁	57*	67.0*	4.0*	0.3*	21.0*	6.0*	18.0*	22.5
Yar rumji x Faro₅₅F₁	61*	68.0*	3.0*	0.3*	-22.0*	9.0*	16.0*	18.5
Yar rumji x Wab_{35-1-fx}	61*	84.0*	4.0*	0.2	18.0*	9.0*	16.5*	24.5
Yar rumji x faro₄₉F₁	63*	76.0*	2.6*	0.3*	16.0*	5.0*	18.0*	26.0*
Yar rumji x faro₅₅F₂	56*	66.0*	4.0*	0.2	17.0*	3.5*	17.0*	19.0
Yar rumji x Wab_{35-1-fx}F₂	64*	67.0*	3.0*	0.3*	18.0*	4.5*	21.0*	23.0
Yar rumji	81*	60.5*	2.0*	0.2*	7.0*	2.5*	10.0*	18.0*
GM	6	70.0	4.0	0.2	14.0	5.0	18.0	22.5
LSD 0.05	7.0	2.0	0.1	0.1	1.0	0.3	5.0	8.0
CV (%)	5.2	13.0	31.0	1.0	40.0	35.5	22.0	27.0
GCV (%)	64.0	2406	59.7	25.6	61.7	75.5	40.0	72.0

4.2 Heterosis

The means and ranges of performance and heterosis from the values of F1 hybrids over the values of their mid- parents are given in Table 4.3. The degree of heterosis showed variation from trait to trait for mid-parent heterosis, Number of tillers showed the highest value (71% in Yar rumji x Faro₄₉, 78% in Yar rumji x Faro₃₅, 40% in Yar rumji x Wah_{35-1-fx}) followed by yield (27.3% in Yar rumji x Faro₄₉, 41.0% in Yar rumji x Faro₅₅, 39.6% in Yar rumji x Wab_{35-1-fx} heterosis). Ear length heterosis value (1, 2% in Yar rumji x Faro₄₉), 100 grain weight heterosis value (5% in Yar rumji x Wab_{35-1-fx}), flag leaf length heterosis value (2.2% in Yar rumji x Wab_{35-1-fx}, grain length heterosis value (2.8% in Yar rumji x Wab_{35-1-fx} heterosis) exhibited low heterosis. High heterosis was obtained from H1 heterosis for 100 grain weight. These results indicated high heterozygosity of parents and good combining ability for number of tillers and yield parameters.

Table 4.3: Heterosis Analysis

Type of Heterosis	Traits								
	Day to 50% flowering	100 grains weight (g)	Ear weight (g)	Ear length (cm)	Grain Width (cm)	Tillers number	Flag leaf length (cm)	Grain length (cm)	Yield (ton/ha)
Yar rumji x Faro ₄₉ - MP	16.8	35.0	5.0	1.2	3.0	71.0	12.2	8.4	27.2
Yar rumji x Faro ₅₅ - MP	10.3	10.0	20.3	27.7	13.3	78.0	20.0	19.2	41.0
Yar rumji Wab _{35-1-FX} -MP	12.5	5.0	1.0	7.3	16.1	40.0	2.2	2.8	38.7

MP = Mid-parent

4.3 From ANOVA Data

The mean square from the analysis of variance (ANOVA) for the growth and related characters estimated for the population in 2004 and 2005 arc presented in Table 4.4. The populations used in this study were Faro₄₉, Faro₅₅, Wab_{35-1-fx}, Yar rumji x Faro₄₉F₁., Yar rumji x Wab_{35-1-fx}F₁, Yar rumji x Faro₄₉F₂, Yar rumji x Faro₅₅F₂, Yar rumji x Wab_{35-1-fx}F₂ generations. The population studied had significant difference for days to 50% flowering, 100 grains length, plant height, grain length, and tillers weight and yield parameters in all years except that of ear long, grain width in 2004 (not significant). The effect of block was significant in year 2004. The result presented in Table 4.4 indicated that there was significant variability within the populations in 2004 and 2005 for most of the characters; block had no effect on the phenotypes expressed in 2005 for all the traits.

Table 4.4: Mean square from analysis of variance for some characters

Year	Source of variation	df	Traits										
			Days to 50% flowering	100 grains weight (g)	Ear weight (g)	Ear length (cm)	Number of tillers	Flag leaf length (cm)	Grains width (cm)	Plant height (cm)	Grains height (cm)	Tillers weight (g)	Yield (t/ha)
2004	Block	2	44.125*	0.64	1.08	816.83	12.1	19.09	-0.04	19.56	0.00125	0.135	9.25
	Population	3	14.39*	9.35*	9.92*	360.9	230*	271.46*	0.016	193.41*	0.025*	4.033*	145.48*
	Error	6	7.51	4.46	4.6	452.7	7.4	146.04	0.021	90.175	0.012	1.87	69.63
2005	Block	2	2.64	0.410	33	16.65	12.3	4.54	0.006	6.11	0.001	2.34	1.16*
	Population	6	0.05*	15.8*	52.1*	16.6*	234*	64*	0.021*	753.6*	0.108*	17.8*	14.5*
	Error	12	4.08	0.32	1.34	5.51	8.04	5.87	0.003	55.3	0.003	0.07	0.26

4.4 Simple linear correlations between traits in F₂ Generation

The results of correlations analysis of all possible linear correlations among the traits considered were presented in Table 4.5. Significant positive correlations ($r = 0.5$) were recorded between grain length and number of tillers ($r = 0.546$), panicle weight ($r = 0.530$), 100 grain weight ($r = 0.642$) and number of tillers per plant ($r = 0.5$).

Yield and panicle weight, yield and 100 grain-weight exhibited significant positive correlations. Grain width was significantly correlated with plant height ($r = 0.4$), and yield ($r = 0.443$). Similar result was obtained for number of tillers and 100 grain weight ($r = 0.488$), number of tiller and panicle weight ($r = 0.477$).

The result (Table 4.5) showed also significant correlations between panicle weight and plant height ($r = 0.412$), panicle weight and number of tillers ($r = 0.477$). Significantly correlations were observed between ear length and 100 grain weight ($r = 0.437$), ear length and plant height ($r = 0.415$), yield and ear length ($r = 0.443$), yield and grain length ($r = 0.424$). Strongest correlation was observed between flag leaf length and panicle weight ($r = 0.98$).

Table 4.5: Correlation analysis of traits of upland rice

Variables	Plant height (cm)	100 grains weight (g)	Grain width (cm)	Number of tillers	Ear panicle weight (g)	Ear panicle length (cm)	Grain length (cm)	Yield (ton/ha)
Plant height (cm)	1							
100 grains weight (g)	0.262**	1						
Grain width (cm)	0.400**	0.406**	1					
Number of tillers	0.273**	0.488**	0.248*	1				
Ear panicle weight (g)	0.412**	0.561**	0.332**	0.477**	1			
Ear panicle length (cm)	0.437**	0.415**	0.315**	0.387**	0.617**	1		
Grain length (cm)	0.234**	0.408**	0.329**	0.546**	0.530**	0.239**	1	
Yield (ton/ha)	0.387**	0.642**	0.468**	0.501**	0.557*	0.443**	0.424**	1

4.5 Scaling Test

The values of scaling tests and their standard error for the various traits are presented in Table 4.6. The results showed non adequacy of C scaling test for plant height, number of tillers, ear weight trait. Table 4.8 showed non adequacy of C scaling test for ear weight, grain length, and 100 grains weight parameters. In this table, significant Scaling test was observed for number of tillers suggesting dominance x dominance of gene interaction with non-allelic gene interaction effect.

Table 4.6 showed adequacy of C scaling test for 100 grain weight, grain width, and grain length with in Yar rumji x Faro₄₉F₂ generation, but no significant test indicating the absence of non allelic gene interaction in the expression of the phenotype of those traits. Similar results were observed in Table 4.7 for 100 grain weight, grain width, ear weight

and grain length in Yar rumji x Faro₅₅F₂ generation. Meanwhile Table 4.8 showed adequacy of C scaling test for grain width in Yar rumji x Wab_{35-1-fx} F₂generation.

Table 4.6: Scaling test for Yar rumji x Faro₄₉F₂

Component of scaling test	Plant height (cm)	100 grains weight (g)	Grain width (cm)	Number of tillers	Ear panicle weight (g)	Ear panicle length (cm)	Grain length (cm)	Yield (ton/ha)
C	24.09	0.03	0.11	2.94	2.71	5.31	0.2	3
VC	1626.96	7.32	0.037	123.21	37.34	296.89	0.10	10.84
S.E(c)	±40.33	±2.70	±0.19	±11.1	±6.11	±17.23	±0.31	±3.29
t(c)	0.59	0.011	0.57	0.26	0.4	0.3	0.64	0.91
t_{observed}	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1

Table 4.7: Scaling test for Yar rumji x Faro₅₅F₂ generation

Component of scaling test	Plant height (cm)	100 grains weight (g)	Grain width (cm)	Number of tillers	Ear panicle weight (g)	Ear panicle length (cm)	Grain length (cm)	Yield (ton/ha)
C	7.76	0.4	0.0	2.97	0.29	8.75	0.11	1.92
VC	998.92	3.53	0.036	104.52	11.16	54.38	0.097	8.54
S.E(c)	±31.6	±1.8	±0.18	±10.22	±3.34	±7.37	±0.3	±2.92
t(c)	0.24	0.22	0.0	0.29	0.086	1.18	0.36	0.65
t _{observed}	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1

Table 4.8: Scaling test for Yar rumji x Wab_{35-1-fx}F₂ generation

Component of scaling test	Plant height (cm)	100 grains weight (g)	Grain width (cm)	Number of tillers	Ear panicle weight (g)	Ear panicle length (cm)	Grain length (cm)	Yield (ton/ha)
C	14.23	1.28	0.38	43.02	3.08	8.89	0.29	1.98
VC	41.99	12.41	0.054	296.64	33.19	165.07	0.072	12.39
S.E(c)	±46.28	±3.52	±0.23	±17.22	±5.76	±12.84	±0.26	±3.51
t(c)	0.3	0.36	1.34	2.49	0.53	0.69	1.11	0.56
t _{observed}	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1

4.6 Heritability

The estimates of broad sense heritability of some agronomic traits and yield are presented in Table 4.9. The results indicated high heritability of 100 grain-weight, ear weight, number of tillers and yield in Yar rumji x Wab_{35-1-fx}F generation while low heritability exhibited in number of tillers, ear weight in Yar rumji x Faro₅₅F₂ generation, number of tillers and ear weight in Yar rumji x Faro₄₉F₂ generation. Yield exhibited a strongest heritability for all F₂ generations and this is mostly due to the genetic effect.

Table 4.9: Heritability of some traits in F₂ generation

Component of scaling test	Yar rumji x Faro ₄₉ F ₂	Yar rumji x Faro ₄₅ F ₂	Yar rumji x Wab _{35-1-fx} F ₂
h ² (tiller numbers)	3.56	18.12	68.29
h ² (100 grains weight)	55.55	25	77.61
h ² (ear weight)	17.32	1.78	50.33
h ² (yield)	94.15	93.87	96.57

CHAPTER FIVE

DISCUSSION

5.1 Mean performance, coefficient of variation and genotypic coefficient of variation

Means performances indicated significant differences and high variability for day to 50% flowering, number of tillers, 100 grain weight, ear weight, and yield and for most of the characters linked to yield. High genetic coefficient of variation recorded for yield, tillers and 100 grain weight. Similar results have been reported by Dorosis et al (2004) indicating the greatest genetic variations. Singh et al (2005) reported that high estimates of genotypic coefficient of variance (GCV) and phenotypic coefficient (PCV) were recorded for grain yield (t/ha), panicle density. VIVEK *et al* (2004) indicated that grain yield per panicle, biological yield per plant, number of tillers and panicle per plant had high values of genetic coefficient of variation and phenotypic coefficient of variation, hence it is suggested that these characters can be of great importance for selecting better genotypes in rice improvement programme.

The coefficient of variability (CV) was higher than the genotypic coefficient of variability (GCV) for number of tillers and tillers weight (Table 4.1). The same trend was reported by Berry et al (1970) for *V. anthelmintia*; Gupta and Godwat (1981), Satapath et al (1987) for linseed and Bayed (2002) for *V. galarnens*. This suggests that environmental effects constitute a major portion of the total phenotypic variation in these traits. Thus, the selection of superior genotypes based on such traits would not be effective.

5.2 Heterosis

Based on the heterosis analysis indicated in Table 4.3, the estimation of heterosis for yield and number of tillers over mid parents values were highest for all the F1 hybrids.

Jones (296) observed heterosis, vigor, in plant height, tillers, and grain yield, hut not in car length. Idsumi (1936) after studying 79 hybrids in F1 generation discover that heterotic phenomenon was observed in plant height, stem weight, ear length and tillers per plant. He examined also six characters: plant height, length of panicle, ear weight, number of tillering, yield and 100 grain weight, found that for the first two characters, which is dominant, heterosis was considered to be present.

5.3 Correlations

The result of the correlation coefficient is given in Table (4.3). The revealed that panicle length exhibited significantly positive correlation with panicle weight ($r = 0.617$), strongest con-elation was observed between yield and panicle weight ($r = 0.557$), this is in conformity with Mohammed et al (2007) for the number of panicles per plant and Ramavirishman et al (2006) for number of grain per panicle. Shina-S-I et al (2004) studied the genetic variability and correlation co-efficient in midland landraces of rice, reported that significant positive genetic correlation were observed for panicles per plant, test weight and grain yield.

5.4. Scaling test

The results of individual scaling test are as presented in Tables 4.4, 4.5, 4.6. These results revealed adequacy of scale for 100 grain weight, grain width, grain length in Yar rumji x Faro₅₅F₂, generations.. Adequacy of scale was also observed for grain width and grain length in Rum rumji x generation but their respective t-test results were non-significant indicating the absence of non-allelic interaction. Whereas Mohamed et al (2004) reported that both additive and dominance genetic effects had significant contributions in the majority of crosses for the expression of plant height, days to flowering, panicle number, per plant, grain length, grain length and grain yield per plant. Similar results were obtained by Perera et al (1986) and Panwar (1993) for plant height, days to flowering, panicle length, kernel length and grain yield per plant. Meanwhile in cotton, Godoy and Paloma (1999), and Neelima et al (2004) reported that days to 1st flower, days to 1st ball opening and node for 1st fruiting branches were additively controlled and in contrast the studies by Rauf et al (2005) showed the days to flowering and days to ball were controlled by non-additive gene effects.

The significant additive effects were observed earlier by Buu and Hanh (1991) for panicle number and Majumbar (1995) for plant height, panicle number per plant, panicle length and grain yield per plant. The result presented in Table 4.6 showed non adequacy of scale for number of tillers but significant test indicating the effect of non-allelic interaction in the expression of the phenotype of the trait. Perera et al (1936) observed duplicated type of epistasis for days to flowering and panicle number Buu and Tao (1992) had observed similar phenomena for panicle number and grain yield per plant.

5.5 Heritability

The present studies have showed that heritability of 100 grain weight was high in Yar rumji x Faro₄₉F₂ and Yar rumji x Wab_{35-1-fx}F₂ generations; while that of ear weight was low in Yar rumji x Faro₄₉F₂ and Yar rumji x Wab_{35-1-fx}F₂ generation. Similar result was obtained with number of tiller in Yar rumji x Faro₄₉F₂ generation. Cao et al (2001) investigating on the influence of epistasis and QTL X environment on rice plant development, found a high to moderate genotypic coefficients of variation with high heritability and genetic advance for plant height, kernel length, kernel breath, and 100 grain weight in parental lines and their F₁, F₂ and F₃ generations. Similar result of high heritability and high genetic advance for yield traits were reported by Singh (1986), Varshmey et al (1986), using Brassica species, Baye (2002) using *V. galamensis*. Reddy et al (1971), Sethi and Singh (1972) also reported high heritability and genetic grain, number of tillers per plant. Whereas Tikka et al (1973), Rashinski (1971), Massod and Chaudhry (1987) recorded high heritability and genetic advance for plant height in wheat. The results have clearly indicated that significant variability and heritability resulted in high relative expected genetic advance indicating the possibility of genetic improvement of these traits.

CHAPTER SIX

SUMMARY AND CONCLUSIONS

The results (Tables 4.1, 4.2) indicated that, there is adequate genetic divergence and variability present in the material studied showing vast genetic diversity in the studied traits. The broad sense heritability, genetic coefficient of variation (GCV) and correlation revealed that 100 grain weight, panicle length, panicle weight, were the most important yield components. Therefore, the result suggest that, number of tillers, particle weight, panicle length, 100 grain weight are important yield contributing traits and selection based on these traits would be most effective.

Hybridization between Yar rumji and Faro₅₅ provided favourable heterosis in all the characters studied. Whereas, high GCV for days to 50% flowering, 100 grain weight, number of tillers, ear weight, ear long, yield indicating significant contributions of genotype effects in the phenotype expression of those traits and this could also be serious criteria for good selection in rice. Number of tillers, 100 grain weight, and yield had high heritability estimates and expected genetic advance and could be used as selection criteria for early Yar rumji x Wab_{35-1-fx}F₂ generation.

Significant positive correlations were observed with panicle weight and grain length ($r = 0.53$), 100 grain weight ($r = 0.56$) and number of tillers ($r = 0.5$) per plant. These traits could be used as efficient criteria for selection of panicle weight.

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APPENDIX I

A FIELD PLOT

