CHARACTERIZATION OF RICE (*Oryza sativa* L.) GERMPLASM FOR COLD TOLERANCE THROUGH FIELD EVALUATION AND PARTICIPATORY SELECTION IN THE SOUTHERN HIGHLANDS

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A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN CROP SCIENCE OF SOKOINE UNIVERSITY OF AGRICULTURE.

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ABSTRACT

A study was conducted at Igurusi in Mbarali district of Mbeya region, Tanzania to evaluate and identify rice genotypes that perform better in the field under cold stress conditions. Three experiments were conducted, two in the field and one in the laboratory. The first field experiment was conducted during the wet season from December, 2010 to May, 2011 and the second from June to December, 2011(cool/dry season). Fifty two (52) test genotypes and five checks were randomly allocated to four blocks each with a maximum of 20 plots at a spacing of 20 cm between and within rows in an augmented Randomized Complete Block Design. Agronomic and morphological data were collected for grain yield and yield attributes followed by grain quality variables for ten selected genotypes using participatory varietal selection. Analyses of variance revealed significant to very highly significant differences among the test genotypes for the characters studied in both experiments. This indicates that, the test genotypes exhibit a sufficient amount of genetic variability in which desired lines can be selected for further manipulation. Correlation studies revealed that, grain yield was significantly correlated with filled spikelets/ panicle, days to 50% flowering and 90% maturity in experiment one and with filled spikelets/panicle and panicle length in experiment two. Thus, selection for these traits would be effective in grain yield improvement. Estimates of genetic parameters showed high heritability coupled with high genetic coefficient of variation (GCV) and genetic advance as percentage of the mean for productive tillers per hill, grain yield, filled spikelets per panicle and percent sterility in experiments one and two except for filled spikelets in experiment two. This suggests that these traits are controlled by additive gene action and can therefore be improved through simple/progeny selection methods. Ten genotypes were selected as cold tolerant materials through Participatory Varietal Selection (PVS). Grain quality analysis showed that five genotypes have combined acceptable

quality and agronomic characteristics and are therefore ear marked for recommendation in Tanzania.

DECLARATION

I LOBULU JOHN, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work done within the period of registration and that it has neither been submitted nor being concurrently submitted in any other institution.

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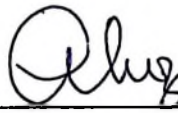

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LIST OF ABBREVIATIONS AND SYMBOLS

%	Percentage
<	Less than
>	Greater than
1st	First
2nd	Second
a.i	Active ingredient
a.s.l	Above sea level
AFRICARICE	Africa Rice Center
ANOVA	Analysis of variance
CAN	Calcium ammonium nitrate
CD	Critical difference
cm	Centimeter
CV	Coefficient of Variation
DAP	Di Ammonium Phosphate
DF	Degrees of freedom
ER	Elongation Ratio
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organization Statistics
Fig.	Figure
g	Gram
ha	Hectare
INGER	International Network for Genetic Evaluation of Rice
IRRI	International Rice Research Institute.
kg	Kilograms

KOH	Potassium hydroxide
LSD	Least significant difference
m	Meter
MC	Moisture content
Mls	Mills
MS	Mean squares
N	Nitrogen
OB	Observed Moisture
°C	degree Celsius
pH	Hydrogen ion concentration
PVS	Participatory Varietal Selection
RCBD	Randomized Complete Block Design
SES	Standard Evaluation System
SPSS	Statistical Package for Social Science Studies
SS	Sum of squares
ST	Storage Moisture
SUA	Sokoine University of Agriculture
SV	Source of variation
VER	Volume expansion ratio

CHAPTER ONE

1.0 INTRODUCTION

Rice (*Oryza sativa* L.) belongs to the genus *Oryza* under the family *Gramineae*. The genus has at least 20 species of which *O. sativa* L. and *O. glaberrima* Steud. are the only cultivated species (Matsuo *et al.*, 1997). Rice is an important staple food crop that feeds over 51% of the world's population (Nguyen and Tran, 1998). It is a food crop in many countries of Africa and constitutes a major part of the diet in many others (FAO, 1999). Tanzania is the second largest producer and consumer of rice after Madagascar in Eastern, Central, and Southern Africa (AfricaRice, 2007) with production level of 1 104 890 tons of paddy from an estimated area of 720 000 hectares in 2010 (FAOSTAT, 2010). Rice is the second widely cultivated and consumed cereal food crop in Tanzania after maize. It is the third most important source of calories in Tanzania contributing 8% of caloric intake after maize (33%) and cassava (15%) (Minot, 2010). It is estimated that, about 60% of the Tanzanian population consumes rice and its derivatives per day (Kanyeka *et al.*, 1994).The average per capita rice consumption in the country is about 25 - 30 kg/year (Kibanda, 2008).

In sub-Saharan Africa rice production was estimated at 14.2 million tons in 2006 which has been growing at a rate of 3.23% per annum from 1961 to 2005. This growth rate was higher than the yearly population growth rate of 2.90% during the same period (AfricaRice, 2007). Sub-Saharan Africa harvested an average of 7.86 million hectares of rice per year during 2001- 2005 with 3.29% per annum growth rate. Between 1961 and 2005 annual increase in rice consumption in SSA was 4.52% mostly faster than rice production growth during the same period (AfricaRice, 2007). The total quantity of milled rice consumed in SSA in 2006, was 14.7 million tons.

In East Africa the milled rice production estimates in 2006 was 3.1 million tons with Madagascar and Tanzania accounting for 2.3 million tons and 525 300 tons respectively (AfricaRice, 2007). It is estimated further that in 2008, Tanzania produced an average of 1.35 million tons of paddy or 875 000 tons of milled rice from an area of 664 667 hectares (FAOSTAT, 2010). About 99% of all rice in Tanzania is grown by smallholders, although some of them are part of large-scale rice irrigation schemes that were formerly state-managed farms (NBS, 2006).

In Tanzania, rice is grown in three agro-ecosystems namely rainfed lowland (74%), rainfed upland (20%) and irrigated lowland (6%) (Kanyeka *et al.*, 1994; Mghase *et al.*, 2010). On average, farmers in the upland rice agro-ecosystem produce about 1277 kg/ha (Mghase *et al.*, 2010). This falls in the national average of 0.5 to 1.5 tons/ha of upland rice (MAFSC, 1998). Drastic shift of consumers' preference both in urban and rural areas from conventional foods to rice coupled with rapid urbanization have led to an increased annual per capita consumption of rice in the country. These changes in consumption habits and low production per unit area have led to a growing gap between the demand and supply of rice which has to be filled by imports (Mghase *et al.*, 2010). According to Minot (2010), in 2005 to 2007, Tanzania imported an average of 71 000 tons of rice which accounts for 8% of apparent domestic consumption and exported only about 10 000 tons. This reveals that internal production is so low that it cannot meet the growing demand. Possible ways to increase rice production is through intensification (double cropping) and expansion, where production can be possible with some improvements and the right variety introduction. However, this could not be realized in the southern highlands where both double cropping and expansion of rice production is possible, due to the use of cold water from the mountains for irrigation during the cool season just after the end of long rains (Zenna *et al.*, 2010). Cold weather affects rice plant's developmental processes and impairs

photosynthesis, thus reducing growth and resulting in indirect yield loss because of less carbohydrate available for grain production (Smillie *et al.*, 1988). It is documented that, during the rice growing season (January to June) in the Southern highlands monthly temperatures can be as low as 6.6 °C in June and 21.9 °C in January (Mghase *et al.*, 2010). Farmers who plant the crop late during the season face high yield loss or total loss as a result of cold weather.

Despite the importance of rice in the country, its production is still low with fluctuations and occasional decline (Table 1). These yields are very low as compared to that of Mauritania (4.3 t/ha) (AfricaRice, 2007), Benin (4.18 t/ha), Japan (6.51 t/ha), Republic of Korea (6.88 t/ha) and Spain (7.56 t/ha) (FAOSTAT, 2010). The major constraints that limit rice production in the United Republic of Tanzania include; lack of improved varieties with acceptable grain quality, poor weed management, pests, inadequate fertilizer and soil amendments, inadequate soil and water management and unavailability of inputs (Luzi-Kihupi *et al.*, 2008). Apart from the availability of desirable varieties with acceptable grain qualities, some of the constraints like abiotic stresses greatly reduce the genotypic performance of cultivars in different ways (Kibanda, 2001). The common environmental stress affecting growth and development of rice is the irregular exposure to low temperature and drought. Thus, the ability of crop plants of tropical and subtropical origins to resist a period of low temperature during growth is an agriculturally important trait (Binh and Oono, 1992).

Table 1: Rice production statistics trends in Tanzania (2001- 2010)

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Area harvested (1000 ha)	405.8	565.6	620.8	613.1	701.9	633.8	557.9	664.7	904.5	720
Production (tons/ha)	2.138	1.741	1.767	1.726	1.663	1.903	2.405	2.026	1.475	1.535

Source: FAOSTAT 2010.

In the southern highlands, rice producers produce the crop under irrigation and rainfed conditions, in which low temperature stress affect the crop during the cool period. Rice is adversely affected by cold stress, unlike other crops such as wheat and barley. Low temperature causes growth retardation, spikelet sterility and consequently reductions in grain yield (Lee *et al.*, 2005). Cold stress is a common problem to farmers who sow rice during cool seasons, and among those who grow rice at high altitudes and in areas that have a cold irrigation-water supply. The damage depends on the prevalent air or water temperature, cropping pattern, growth stages of the crop and variety. Damage can be observed at any growth stage, and it often leads to crop failure (Zenna *et al.*, 2010). Cold tolerant varieties during the reproductive stage are important to guarantee high yield under low temperature environments (Cruz *et al.*, 2006). Low temperature at the young microspore stage disrupts the development of pollen grains, preventing fertilization and hence causing higher spikelet sterility and consequently lower yields (Farrell *et al.*, 2004). It has been reported that in Australia, annual yield reduction in rice production due to cold conditions was 5% to 10% which accounts for 44 million Australian dollars and unpredictable cold snaps occurring on average of 3 to 4 years can cause losses between 30 and 40% (CPICG, 2005). It is documented further that in 1980 and 1993, low temperatures seriously damaged the Korean rice crop thus reducing grain yield by 26% and 9.2% respectively as compared with the average yield of other years (Lee, 2001). In the double-crop rice growing regions in south China, a cold current outbreak in April often makes early season rice seedlings rot, causing a heavy seed loss and a delayed growth period (Qian *et al.*, 2000). In Tanzania, even though farmers suffer grain yield loss during the cool season, no information on the yield losses has been documented quantifying the loss. Availability of cold tolerant varieties would allow farmers to grow rice in mountainous areas and would facilitate double cropping in lowland areas so as to increase productivity. Studies done by Saito *et al.* (2004) revealed that Japonica rice are more cold

tolerant than Indica rice. Selection of cold tolerant genotypes under field conditions has been employed in countries such as Korea and United States (Cruz and Milach, 2004). Improved Indica and Japonica breeding lines that are known to possess cold tolerance, during both the seedling and reproductive stages are already available.

This research therefore aimed at characterizing different rice genotypes that are known to possess cold tolerance ability through field evaluation and participatory selection in the southern highlands of Tanzania. The overall objective of this study was to assess the response of different rice genotypes to cold stress in the southern highlands.

The specific objectives were:

i. To evaluate and identify rice genotypes that performs better in the field under cold stress in the southern highlands.

ii. To identify rice genotypes with good quality and cold tolerance ability through participatory varietal selection.

iii. To perform preliminary grain quality analysis of the selected cold tolerant rice genotypes.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Origin and Distribution of Rice

Rice is an ancient cultivated crop in the world. Through selections, it was later established under a variety of habitats before any organized sea borne expeditions (Carpenter, 1978). There are two cultivated species viz. *O. sativa* L. and *O. glaberrima* Steud. The origin of *O. glaberrima* Steud. is in West Africa where it is grown as an upland crop (Grist, 1986). It was first grown in the Central Niger with other centres of diversity in Gambia, Casamance and Sokoto basins (Grist, 1986). The earliest cultivation of *O. sativa* in Nigeria was around 1890 when upland varieties were introduced to the high forest zones in Western Nigeria (Grist, 1986). In East Africa, Carpenter (1978) identified *O.glaberrima* in Zanzibar. *O. sativa,* the common cultivated rice in the world has its origin in Asia, particularly in the South East Asia. He further hypothesized that Asian rice was introduced into West Africa along the routes viz., Zaire, Cameroon, Nigeria and Ghana. The crop is now cultivated in tropical and subtropical regions of Asia, Africa, Central and South America and Australia (Grist, 1986).

2.2 Ecology

Though rice possesses roots of a dry land plant it can flourish in all types of soils with differential moisture and fertility status. It may perform well under a wide range of climates extending from wet tropical to regions of semi-arid warm temperate climates (Grist, 1986). Earlier studies (IITA, 1984) indicated that rice performs well in almost any condition provided there is sufficient sunshine and water requirement for a particular variety. In addition to sunshine and water, soil fertility and temperature are also important for optimum performance of the rice crop (De Datta, 1981). Physical and chemical

characteristics of the soil can deny nutritional elements from being absorbed by the plant. The redox potential and pH are among the important soil chemical factors affecting soil elements availability for plant uptake and therefore they have direct bearing in determining and evaluating the fertility status and management of rice soils (Gupta and O'Toole, 1986). Most rice soils have a pH range of 6.5 – 7.5, but the most suitable for most nutrient availability and less toxicity is pH 6.5 (Patrick and Reddy, 1978).

2.3 Rice as a Source of Income in Tanzania

A part from being a staple food, rice is also a source of income for many smallholder's and large scale farmers in the country. Rice is more commercialized than other staple food crops. According to the 2002-03 national agricultural sample census, 42% of rice production is marketed, compared to only 28% of maize and just 18% of sorghum (NBS, 2006). It has been reported that Tanzania is both an importer and exporter of rice. From 2005 to 2007 rice exports were about 10 000 tons, mostly to Kenya, Zambia, and other countries in the region and imports averaged 71 000 tons of rice in the same period (Minot, 2010). Studies done by Mghase *et al.* (2010) showed that farming activities (crop and livestock) contribute up to about 83.6% of the total household revenue in the study area. Out of this, 52.5% is coming from rice, maize (16.3%), sesame (6.4%), livestock (4.9%) and other crops (4.0%). In addition, studies done by Ngailo *et al.* (2007) ranked rice as the major cash crop followed by cotton and maize in the study area. Rice occupies a superior position over other crops in terms of its contribution to the welfare of the household. In addition it serves as both cash and food crop.

2.4 Low Temperature Problems

Low temperature is one of the major environmental stresses that adversely affect rice productivity in temperate, subtropical zones and in high-elevation areas. It affects the crop

at all growth stages at a varying degree starting from germination, vegetative and reproductive phases. Various phenotypic symptoms in response to cold stress include reduced leaf expansion, wilting, chlorosis (yellowing of leaves) and may lead to necrosis. The vegetative phase-stress may be recoverable but make the crop extend the growth duration. While unrepairable losses could occur if the stress is imposed at the reproductive phase (Nahar *et al.*, 2009a).

2.4.1 Germination phase

Germination is divided into three phases viz., imbibition, activation and post-germination growth (Yoshida, 1981). The largest effects of cold temperature during germination seem to be associated to the imbibition phase and considered the most sensitive (Blum, 1988). Cruz and Milach (2004) documented that, the optimum temperature range for rice germination lies between 20 and 35 °C, and the temperature of 10 °C is cited as the minimum critical value below which rice does not germinate. Cold temperature during this phase leads to increasing escape of solutes from the seeds, such as amino acids and carbohydrates, which have been attributed to the incomplete plasma membrane of the dry seed and to the disturbance caused on its reconstruction during imbibition phase by cold temperature. When plasma membrane gets chilled or freezes due to severe cold the fatty acids tails of phospholipids become more rigid, thus affects the fluidity, the permeability of the membrane and cell's ability to live. The membrane must be fluid to remain biologically active (Uemura *et al.*, 2006). Therefore for plant cells to remain active at low temperatures require freezing tolerance. Thus it is necessary that, the plasma membrane increases its cryostability during freeze-thaw excursion.

2.4.2 Vegetative and reproductive phases

Lee *et al.* (2005) documented that, unlike other crops such as wheat and barley, rice is adversely affected by cold stress. Poor seedling vigor and fertility, and consequently reduction in yield have been major problems provoked by cold stress. Yoshida (1978) found that temperature range of 25-35 °C is optimum to most rice growth stages except at germination (18-40 °C). According to Yoshida (1981), the optimum temperature for rice tillering is 25-31 °C, anthesis 30-33 °C, and ripening 20-25 °C. Mandal and Chartterjee (1984) observed high reduction in the number of tillers per square meter at lower temperatures (13-20 °C). Low temperature in the range of 15-19 °C during the reproductive stage impairs microspore development and leads to the production of sterile pollen grains, resulting in poor grain filling and high spikelet sterility (Satake, 1976) and consequently yield reduction (Farrell *et al.*, 2004). It has been reported that, serious yield losses occur when night temperatures drop below 15 °C for two to three consecutive nights (Oliver *et al.*, 2005).This temperature reduces the number of engorged pollen grains and fertilized spikelets in rice (Farrell *et al.*, 2001).

Other studies have indicated that fertility percentage is determined from young panicle initiation to flowering stage, and that lower temperatures (17-19 °C) usually below 20 °C after fertilization and grain filling disrupt translocation of photo assimilates (Matsushima, 1980). Sterility percentage depends on the variety, growth stage at which the rice plant is exposed and period of exposure to low temperature extremes. Yoshida (1981) documented that temperature as low as 12 °C will not induce sterility if they last for 2 days, but will induce about 100% sterility if they last for 6 days at flowering. Studies conducted under controlled environment revealed that, temperature of 17 °C for only three days was capable of causing damage to the plants and this damage varied according to the genotype and reproductive stage (Cruz *et al.*, 2006).

Farrell *et al.* (2006) reported that rice plants are susceptible to low temperature during the young microspore stage, which occurs 10–12 days before heading. Low temperatures at this stage of pollen development result in an accumulation of sucrose in the anthers, accompanied by decreased activity of cell wall bound acid invertase and depletion of starch in mature pollen grains. The decreased cell wall invertase activity and sucrose accumulation in cold-stressed anthers indicate a reduction in the supply of sucrose from the anther wall apoplast to the tapetum and young microspores. As a result most of the pollen grains appear immature at the time of anthesis (Oliver *et al.*, 2005). The presence of sufficient levels of sucrose is of vital importance for the growth of the male reproductive cells in plants (Zhang *et al.*, 2010). Farrell *et al.* (2006) documented further that, the susceptibility of rice plants to low temperature increases with high nitrogen (N) levels.

2.5 Extent of Cold Stress Problem in Tanzania

Even though low temperatures have been causing yield losses in some parts of the country there is no documented information about the problem. Cool season starts in around April of the growing season and goes beyond August depending on the climatic conditions of the region. Farmers who plant the crop late in February and early March face the problem as the reproductive phase coincides with low temperature which reduces the number of engorged pollen grains (Farrell *et al.*, 2001). Hence yields are greatly reduced and sometimes total loss depending on the variety and period of exposure to low temperature. Farmers have been experiencing this problem in Tanga (Lushoto), Mbeya (Mbarali and Kyela), and Kilimanjaro (Moshi). Therefore farmers have been using avoidance mechanisms by planting rice before late February.

2.6 Mechanism for Cold Tolerance in Rice

2.6.1 Gene expression and signal transduction

Plants respond and adapt to cold stress at the molecular and cellular levels as well as induction of an array of biochemical and physiological alterations that enable them to survive (Bohnert *et al.*, 1995; Browse and Xin, 2001). Under cold stress, the expression of many genes is induced in various plant species (Hughes and Dunn, 1996; Thomashow, 1999). The products of these genes function not only in adaptations that promote stress tolerance, but also in the regulation of gene expression and signaling transduction in stress responses (Su *et al.*, 2010) such as transcription factors and proteins involved in RNA processing and nuclear export (Chinnusamy *et al.*, 2007). The sequential expression of dehydration responsive element binding factor 1(DREB1) and myeloblastosis 3 (MYBS3) provides two complementary mechanisms for conferring cold tolerance in rice, with the DREB1-mediated process mediating the immediate cold shock response and the MYBS3-mediated system adjusting the long-term cold adaptation in rice. The transient activation of the α-amylase gene (αAmy3) expression by DREB1 allows hydrolysis of reserved starch to answer the immediate need for a carbon source and energy to combat the cold shock, while the subsequent suppression of αAmy3 expression by MYBS3 allows rice to conserve carbohydrates until regrowth is allowed at elevated temperatures (Su *et al.*, 2010).

2.6.2 Membrane composition

Membrane fluidity refers to the viscosity of the lipid bilayer of a cell membrane. The cell membrane consists of lipids and proteins in variable proportions with very little carbohydrates (Uemura *et al.*, 2006). Membrane fluidity is largely dictated by the composition of lipid molecular species, the degree of membrane saturation and temperature of the environments (Sung *et al.*, 2003). Membrane lipids are primarily

composed of two kinds of fatty acids viz., saturated as well as unsaturated fatty acids. Lipids containing saturated fatty acids solidify at temperatures higher than those containing unsaturated fatty acids. Therefore, the relative proportion of unsaturated fatty acids in the membrane strongly influences the fluidity of the membrane (Steponkus *et al.*, 1993). The temperature at which a membrane changes from semi fluid state to a semi crystalline state is known as the transition temperature. Low temperature sensitive plants usually have a higher proportion of saturated fatty acids and hence a higher transition temperature. Low temperature resistant species on the other hand have higher proportion of unsaturated fatty acids and correspondingly a lower transition temperature (Mahajan and Tuteja, 2005). Differences in the composition of the lipid layer were pointed out as responsible for the greater tolerance to the phase transition under cold temperature. Therefore, the greater the degree of lipids instauration the larger the cold tolerance, because phase transition would occur at a lower temperature (Murata and Yamaya, 1984).

2.7 Participatory Varietal Selection (PVS)

Participatory variety selection is the selection of genotypes/ varieties done by farmers in target environment using their own selection criteria (Islam *et al.*, 2008). It is an approach to provide choices of varieties to the farmers for increasing production in their diversity of socioeconomic and agro-ecological condition. PVS includes research and extension methods to deploy genetic materials at on farm experiment (Yadaw *et al.*, 2006). Participatory plant selection has shown success in identifying more numbers of preferred varieties by farmers in shorter time than the conventional system, accelerating their dissemination and increasing cultivar diversity (Weltzien *et al.*, 2003).

Participatory breeding aims at eliminating the problems that come when a breeder develops varieties without reference to the needs of farmers and other stakeholders in the rice value chain. PVS helps to strengthen farmers' autonomy and to increase their freedom

to select varieties. It weighs selection criteria appropriately according to gender preferences and strengthens groups that are traditionally left out of development. Participatory variety selection occurs at the evaluation phase of participatory breeding and includes advanced fixed lines provided by breeders and farmers' local/traditional varieties (AfricaRice, 2010).

2.8 Rice Grain Quality

2.8.1 Consumer preference

Rice is the only cereal crop cooked and consumed mainly as whole grains thus quality considerations are much more important than for any other food crop (Hossain *et al.*, 2009). Grain quality is determined by a variety, production and harvesting conditions, postharvest handling, milling, and marketing techniques. The quality desired in rice varies from one country to another and from one geographical region to another. Quality demanded by one community may be completely unacceptable to another. A given quality that brings a premium price in one market may be sold only at a major discount in another. For instance, in japonica rice eating countries, low amylose and short grain rice is preferred since it becomes soft, moist and sticky after cooking. However, in indica rice consuming countries, long grain with intermediate amylose and gelatinization temperature is preferred since it becomes soft and fluffy after cooking (Hossain *et al.*, 2009). It is reported further that, consumer from Thailand prefers well-milled long-grain indica rice, arguing that it separates freely and tastes better. While an American consumer will pay only half as much for milled rice with a trace of red or striped grains, Some West African consumers will pay a premium for milled rice with most grains showing red color. On the other hand, consumers from Bangladesh insists on parboiled rice stating that it cooks and tastes better (Efferson, 1985).

2.8.2 Grain dimensions and appearance

Appearance is one the critical quality attribute of rice. Rice buyers, millers, and consumers judge the quality of the rice on the uniformity of its size and shape as well as the appearance of its overall size-shape relationship (Armstrong *et al.*, 2005). The appearance of milled rice is important to the consumer, which in turn makes it important to the producer and the miller. Grouping of varieties is made on the basis of sizes; long, medium and short (Belsnio, 1980).

Rice of different sizes adversely affect the milling quality and yield of head rice. Therefore, proper segregation of grain according to sizes is absolutely necessary to improve the milling quality of rice (Belsnio, 1980). Thus, grain size and shape are among the first criteria of rice quality that breeders consider in developing new varieties for release in commercial production. If a variety does not conform to recognized standards for grain size, shape, weight, and uniformity, it is simply not considered for release (Mutters, 1998).

In most regions, rice that has clear endosperm is preferred most than the one with opaque endosperm, even though all grains are equally translucent after cooking and clarity of endosperm does not affect the rice's taste or texture. Chalkiness occurs mainly at the center of the grain and can occupy more than 50% of the area of the grain. It is caused by loose packing of starch and protein particles. Grains with chalky endosperm have lower market value than clear grains (Mackill *et al.*, 1996). Waxy rices are devoid of or have only traces of amylose content and are opaque. Non-waxy rices have varying amylose level (2.1 to 32%) and are dull, hazy or translucent (Rani *et al.*, 2006). Consumers in Tanzania prefer long grained rice with clear endosperm.

2.8.3 Milling quality

Milling quality refers to the ability of rice grains to resist breaking while being mechanically hulled (Mackill *et al.*, 1996). It is one of the most important criteria of rice quality especially from the standpoint of marketing. The price of rice generally is based on the percentage of whole grains (Rani *et al.*, 2006). A variety should posses a high turnout of whole grain (head) rice and total milled rice (Webb, 1985). Milling recovery of rough rice is an estimation of the quantity of head rice and total milled rice that can be produced from a unit of rough rice. Milling recovery depends on grain shape and appearance, which has direct effect on the percentage of hulling, milling and head rice recovery. Normally the hull content is 20 to 22% of the rough rice although a variation of 18 to 26% has been recorded. Bran and embryo account for 8 to 10%.The head rice recovery may vary from as low as 25 per cent to as high as 65 per cent. Head rice recoverability is an inherited trait, although environmental factors such as temperature and humidity during ripening and post harvest stages are known to influence grain breakage during milling. In general, varieties with long grains and those having white centers give lower head rice yields. Varieties possessing medium slender, long slender and translucent grains give high head rice yields (Rani *et al.*, 2006).

2.8.4 Gelatinization temperature

Gelatinization temperature refers to the temperature at which the rice absorbs water and starch granules swell irreversibly, resulting in loss of crystallinity. It is the one that determines the time required for cooking rice (Corke, 2010). Gelatinization temperature is important in determining the physical cooking properties of rice. It is used in varietal development as an indicator of the cooking time of rice samples. Rices that gelatinize at high temperatures become excessively soft and disintegrate when overcooked. They generally require more water and time for cooking than do rices that have low or

intermediate gelatinization temperatures (Mackill *et al.*, 1996). Estimate of the gelatinization temperature is indexed by the alkali digestibility test (Little *et al.*, 1958). It is measured by the alkali spreading value. The degree of spreading value of individual milled rice kernels in a weak alkali solution (1.7% KOH) is very closely correlated with gelatinization temperature. Rice with low gelatinization temperature disintegrates completely, whereas rice with intermediate gelatinization temperature shows only partial disintegration. Rice with high gelatinization temperature remains largely unaffected in the alkali solution. In breeding programmes the alkali spreading value (ASV) technique is used extensively for estimating gelatinization temperature (Rani *et al.*, 2006). Most of the tropical indica rice varieties have intermediate or low gelatinization temperatures while most japonica varieties have low gelatinization temperatures. Both seem to be acceptable to respective consumers (Mackill *et al.*, 1996).

2.8.5 Gel consistency

The main factor that determines the texture of cooked rice is amylose content. However the cohesiveness, tenderness, colour and gloss differ greatly based on gel consistency when the amylose content is high. Gel consistency measures the tendency of cooked rice to harden when it cools down (Rani *et al.*, 2006). It is a measure of firmness of the rice after cooking and is performed to classify rice varieties of the same amylose content, particularly in the high amylose content class (> 25%) into hard, medium, or soft texture (Cagampang *et al.*, 1973, Mackill *et al.*, 1996). Gel consistency is commonly measured by determining the length of a cooled gel made from flour previously cooked in 0.2 M KOH. The test separates high amylose rices into three categories; (1) Very flaky rices with hard gel consistency (length of gel, 40 mm or less), (2) Flaky rices with medium gel consistency (length of gel, 41 to 60mm), and (3) Soft rices with soft gel consistency (length of gel more than 61 mm). Varieties with softer gel consistency are preferred as the

rice cooked would be tender. Gel consistency of rice is normally soft, when the amylose content is less than 25% (Cagampang *et al.*, 1973; Rani *et al.*, 2006).

2.8.6 Amylose content (AC)

Amylose content is considered the single most important character for predicting rice cooking and processing behavior (Juliano, 1979). Many of the cooking and eating characteristics of milled rice are influenced by the ratio of two kinds of starches; amylose and amylopectin in the rice grain. Amylose is the linear fraction of starch in the non-glutinous varieties, where as amylopectin, the branched fraction, makes up the reminder of the starch. Amylose content correlates negatively with taste panel scores for cohesiveness, tenderness, colour and gloss of rice (Jennings *et al.*, 1979). High amylose rices show high volume expansion and a high degree of flakiness. They cook dry, are less tender and become hard upon cooling. Intermediate amylose rices are the preferred types in most of the rice growing areas of the world except where low-amylose Japonicas are grown (Rani *et al.*, 2006). Amylose is almost absent from the waxy (glutinous) rices. Such rices do not expand in volume, are glossy, sticky and remain firm when cooked. They readily split and disintegrate when overcooked (Jennings *et al.*, 1979).

2.8.7 Aroma

The aroma of rice plays a role in its consumer acceptability and it draws a premium price in certain specialty markets. The Middle East consumers prefer rice with strong aroma, they feel that rice without a distinctive aroma is like food without salt. For consumers in Europe, a trace of aroma is an objectionable trait, because for them any scent signals spoilage and contamination. They will do without rice rather than buy the scented one, a similar situation occurs in China (Efferson, 1985). The scent of aromatic rice is a highly heritable trait and has been reported (Pinson, 1994) to be under the control of one to four

genes, depending on the population studied. More than 100 compounds that contribute to the aroma of rice have been identified (Tsugita, 1986; Widjaja *et al.*, 1996). Some of these volatile compounds contribute to consumer acceptance of certain type of rice whereas other compounds contribute to consumer rejection. The popcorn-like smell of aromatic rice stemming primarily from its 2-acetyl-1-pyrroline (2-AP) content is considered desirable by many rice consumers (Buttery *et al.*, 1988). Quantification of 2-AP in rice has been performed by Buttery *et al.* (1986) using a simultaneous stream distillation and solvent extraction methods. However, there is only limited evidence that there are genetic differences associated with the intensity of 2-AP (Pinson, 1994). Tanzania consumers prefer aromatic rice.

2.8.8 Volume expansion ratio and elongation ratio

Volume expansion of kernels on cooking is considered another important measure of consumer preference. Large volume expansion is a matter of great satisfaction to an average rice consumer irrespective of whether the increased volume is due to lengthwise or breadth wise expansion (Hossain *et al.*, 2009). Volume expansion is mostly determined by water uptake, but is also influenced by kernel texture.

Linear elongation of rice on cooking is one of the major characteristics of good rice. Some varieties expand more in size than others upon cooking. Length-wise expansion without increase in girth is considered a highly desirable trait of high quality rice (Rani *et al.*, 2006). Elongation ratio is a better index of quality than elongation index and proportionate change (Pilaiyar, 1988).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental Site

The study was conducted at Igurusi - Ruanda Majenje irrigation scheme (latitude. 8° 3'S, longitude 33° 3'E and 1239 m a.s.l) in Mbarali district of Mbeya region, Tanzania. Two experiments were conducted in two different seasons in the same year under field conditions. The first experiment was conducted during the wet season from 29 December, 2010 to 28 May, 2011 and the second was conducted in the same field during the cool/dry season from 4 June to 11 December, 2011. Experiment one was set as a control (wet conditions) while experiment two was a stressed one (cool conditions).

3.2 Germplasm Used in the Experiments

Genotypes from International Network for Genetic Evaluation of Rice (INGER)–IRRI, INGER-Africa and Sokoine University of Agriculture (SUA) were evaluated for cold tolerance. Fifty five (55) genotypes were collected from AfricaRice and five (5) from SUA. Check varieties used were; Supa, Saro 5, Mbawambili, Rangimbili mkia, and Cherehani for both seasons. The check varieties were collected from farmers at Igurusi with exception for Supa and Saro 5. The check varieties were considered cold susceptible. These materials differed widely for days to maturity, plant height, cold tolerance ability and grain characteristics. List of lines/genotypes used in the study is presented in Table 2.

3.3 Experimental Design and Layout

3.3.1 Experiment one (Wet season).

The experiment was set in an augmented (RCB) design according to Petersen (1985) and Sharma (1988). A total of sixty (60) test genotypes and five (5) checks were randomly

allocated to four (4) blocks each with a maximum of twenty (20) plots. Plot size for this experiment was 4 m x 1 m in which plants were 20 cm apart and 20 cm from row to row. There were five rows in each plot with 20 hills each and net plot area was 2.4 m^2. In this study only the check varieties were replicated so as to measure the variation within and across the blocks.

All the sixty five (65) genotypes were sown in the nursery using trays, two genotypes per tray for a period of 21 days. The seedlings were transplanted in well ploughed and pulverized blocks at two seedlings per hill. Phosphorus at the rate 50 kg/ha (DAP) was applied two days after transplanting. During the third week after transplanting nitrogen in the form of Urea (46% N) was applied at the rate of 200 kgN/ha in two splits. The first split was at vegetative stage and the second during booting stage. Hand weeding was done three times during the course of the experiment. The experiment was rainfed and supplemented with irrigation.

Bird scaring was done when the rice grains were at milky stage until harvesting time. Harvesting and threshing were done by hand when 90% of the materials attained maturity and the grains were showing a khaki colour. Harvesting was done in two phases, early maturing materials were harvested from 5 to 7 May, 2011 and the remaining on 27 May, 2011.

3.3.2 Experiment two (Cool/ Dry season).

The experiment was set out in augmented design as in experiment one. Materials used for this experiment were the same as those used in experiment one with a reduction of eight genotypes from 60 test varieties leaving a total of 52 genotypes. The 52 genotypes and five checks were randomly allocated in four blocks each with 18 plots of five rows and 25 hills per row at a spacing of 20 cm between and within rows. The plot size was 5 m x 1 m

to comply with participatory variety selection (PVS) requirements. Therefore the net plot area was 3 m^2. Like in experiment one, test genotypes were not replicated.

The materials were raised in the nursery as in experiment one for 21 dayas before it was transplanted in the field on 1 and 2 June, 2011. Operations for transplanting and fertilization were done as in experiment two. Hand weeding was done three times during the course of the experiment. Experiment two was totally irrigated as it was planted at the end of the rain season when the cool season starts.

Birds scaring started as soon as when some materials were at milky stage. Harvesting and threshing was done in two phases as in experiment one. Early maturing materials were harvested on 4 November, 2011 while the late maturing materials were harvested on 1 December, 2011.

Participatory variety selection was conducted in two phases viz., during vegetative and maturity stages. Farmers were invited to the field to evaluate the varieties at maximum tillering and at maturity one week before harvest. A total of eighteen farmers (18) were involved during vegetative stage and twenty one (21) at maturity stage. Genotypes were labeled with numbers and farmers were requested to select ten (10) varieties they would like to sow in their fields or ten good performing ones concurrently with ten (10) poorly performing ones using their own criteria. Additionally, they were requested to mention the criteria they used to judge the genotypes. A short open ended questionnaire was prepared and administered to the farmers while they were walking through the field using PVS procedures (AfricaRice, 2010). Number of times a variety had been selected was used to summarize the selection. The one with highest frequency ranked first due to the fact that the criteria used in selecting it, have been compromised by many farmers.

Table 2: List of lines/varieties used in the study

S/N	Designation	Source
1	Cherehani	Farmers-Mbeya
2	Mbawambili	Farmers-Mbeya
3	Rangimbili mkia	Farmers-Mbeya
4	Supa	AfricaRice
5	SARO 5	AfricaRice
6	WAB 450-12-2-BL1-DV1	AfricaRice
7	Geumobyeo	AfricaRice
8	X-Jigna	AfricaRice
9	Zhongeng	AfricaRice
10	ZHI 205	AfricaRice
11	M202	AfricaRice
12	Lanbayeque	AfricaRice
13	FOFIFA 4178	AfricaRice
14	Amaro	AfricaRice
15	Palung - 2	AfricaRice
16	87020-TR-968-1-1-1	AfricaRice
17	86011 - TR - 888 - 2 - 1 - 2 - 1	AfricaRice
18	WAB 515 – B – 16A1.1	AfricaRice
19	Somewake	AfricaRice
20	Stejarec	AfricaRice
21	PSB RC 92	AfricaRice
22	Chandannath - 1	AfricaRice
23	FAC 56	AfricaRice
24	Kunming	AfricaRice
25	Silewah	AfricaRice
26	Skau 23	AfricaRice
27	Olbyc-1	AfricaRice
28	Yunyin	AfricaRice
29	Dourado Agulaha	AfricaRice
30	Mwangaza	SUA -Morogoro
31	Supa M - 106	SUA -Morogoro
32	Supa M – 70 - 10	SUA -Morogoro
33	Supa M – 101 – 22	SUA -Morogoro
34	Salama M – 19	SUA -Morogoro
35	Mitak	AfricaRice
36	Yunkeng	AfricaRice
37	Koshihikari	AfricaRice
38	88076 - TR - 1101 - 9 - 2 - 1	AfricaRice
39	WAB 189 – B – B – B- B -HB	AfricaRice
40	HS379	AfricaRice
41	89010 - TR - 1130 - 8 - 1 - 1 -2	AfricaRice
42	88088 - TR - 1113-4-1-1	AfricaRice
43	Padi Labou Alumbra	AfricaRice
44	Padi Sashal	AfricaRice
45	FOFIFA 4355	AfricaRice
46	Polvidov 22	AfricaRice
47	Calaro	AfricaRice
48	Skau 105	AfricaRice
49	Rojofotsy 653	AfricaRice
50	Hexi 25	AfricaRice
51	Machhapuchre	AfricaRice
52	FOFIFA 3737	AfricaRice
53	Chandannath - 3	AfricaRice
54	Jumli Morshi	AfricaRice
55	China 1039	AfricaRice
56	Yoneshiro	AfricaRice
57	YR 1076 -B - 4 - 1 - 2 - 3 - 1 - 2	AfricaRice
58	Diamante	AfricaRice
59	Nippon Bare	AfricaRice
60	PSB RC 28	AfricaRice
61	88090 - TR - 1115 - 4 - 1 - 1	AfricaRice
62	Yunlen 15	AfricaRice
63	Chomrong	AfricaRice
64	Hexi-24	AfricaRice
65	Agulah	AfricaRice

3.4 Data Collection

3.4.1 Experiment one and two: Agronomic and morphological data

i. Days to 50% flowering: Number of days taken for half of the plants in a particular plot to flower. Days to 50% flowering were calculated from transplanting to recording date respectively for both experiments.

ii. Days to Maturity: Number of days taken from transplanting to when 90% of the plants in a particular plot had matured i.e. when spikelets/grains of a particular plot showed a khaki or yellow brown colour.

iii. Plant height: Measurements were done at maturity on five (5) randomly selected hills in any particular plot and the average was computed. It was measured as the distance from ground level to the tip of the tallest panicle.

iv. Tiller number and number of panicles per hill: These were recorded at maturity as number of tillers per hill. They were counted from five randomly selected hills and the average was computed. The number of panicles per hill is synonymous to the number of reproductive tillers per hill (tillers bearing the panicle). This was determined by discarding unproductive tillers from the total number of tillers.

v. Panicle length: This was measured on the tallest panicle from its base to the tip for each of the randomly chosen hills in each plot. Thus an average of five observations was taken from each plot.

vi. Number of filled grains per panicle: Is the average number of fully developed grains per panicle measured from five randomly selected hills, using five panicles from each hill. Number of unfilled grains per panicle was determined from the same five panicles used to determine number of filled grains per panicle. From each sample, all the panicles were threshed and bulked, then total spikelets (filled and unfilled grains) were counted using Elmor, Model C1, Version 1, seed counter machine. Filled and unfilled grains were separated manually. Filled grains

alone were counted and subtracted from the total spikelets and the difference was unfilled grains and averaging was done.

vii. 1000 grain weights: This is the weight recorded by weighing well fully developed 1000 grains. Which were counted by Elmor, Model C1, Version 1 seed counter and weighed by Scout Pro. Sp 6001 weighing balance.

viii. Percentage sterility: This was computed using the following equation

$$\text{Spikelet sterility \%} = \frac{\text{No. of unfilled spikelets/panicle}}{\text{Total number spikelets (filled and unfilled spikelets)/panicle}} \text{x100}$$

.....(1)

ix. Grain yield: Measured by harvesting the inner three rows in each plot. The harvested plants were threshed, winnowed, and sun dried. Moisture content was determined before weighing in grams/m^2. Grain yield was converted into kg/ha at constant moisture of 14%.

$$\text{Yield (kg/ha)} = \text{Sample wt (gm)} \frac{(100 - \text{OB\%})}{100} \text{X} \frac{(100 + \text{ST MC\%})}{100} \text{X} \frac{10\,m^2}{\text{Net plot area}}$$

.....(2)

Where, OB = Observed moisture,

ST = Storage Moisture i.e. 14%

x. Leaf discolouration: Leaf discolouration was done by using a scale of 1 to 9 according to standard evaluation system (SES) of rice (IRRI, 2002). Where 1 represented plants with normal colour, rate of growth and flowering normal while 9 represented plants that were severely stunted, with brown leaves, development much delayed and panicles not exerted.

xi. Participatory varietal selection was conducted in experiment two. Selection was aided with the use of absolute and pairwise ranking techniques. Grain quality analysis for the selected materials was done at the final stage.

3.4.2 Experiment three: Determination of grain quality

i. Physical appearance (length, width and shape) of milled rice.

The lengths and widths of milled rice kernels were measured by the aid of vernier callipers. The average of ten unbroken kernels were measured from the base of the grain to its tip for lengths, and for widths measured at the widest point. Then shape was obtained by dividing the length by width. Grain dimensions were grouped according to the standard evaluation system for rice (IRRI, 2002) (Table 3).

Table 3: Grain shape and dimensions as adapted from (IRRI, 2002)

Scale	Length (mm)	Scale/ Shape	Length-Width ratio
Extra long	More than 7.5	1. Slender	Over 3
Long	6.61 – 7.5	3. Medium	2.1 – 3.0
Medium	5.51 - 6.60	5. Bold	1.1 - 2.0
Short	5.5 or less	9. Round	Less than 1.1

ii. Chalkiness

The chalkiness of milled whole grains was determined using an S21 Rice Statistic Analyser (LKL Technologia; Sao Paulo, Brazil). 50g of grains were passed through the equipment at an average rate of 1.1g/s. Each grain was photographed several times and the in-built software proceeds to digitally calculate the percent (%) area chalkiness and the average grain dimensions of the sample. The results were grouped into three categories viz., small (less than 10%), Medium (11% to 20%) and large (more than 20%) according to SES by IRRI (2002). This parameter was computed in AfricaRice Laboratory in Cotonou-Benin.

iii. Gelatinization temperature (Alkali spreading value).

Gelatinization temperature was estimated through alkali digestibility test according to Little *et al.* (1958). Six milled rice kernels of each genotype were taken into a Petri dish in duplicate. Then 10mls of 1.7% Potassium hydroxide (KOH) solution was added to the sample and kept undisturbed for 23 hours in an incubator at 30 °C. Then the alkali spreading value was calculated as low, low - intermediate, intermediate or high. Gelatinization temperature was rated according to standard evaluation system for rice (IRRI, 2002) (Table 4).

Table 4: Alkali spreading value and gelatinization temperature classification

Score	Alkali spreading	Alkali digestion	Gelatinization Temperature
1.	Kernel not affected.	Low	High
2.	Kernel swollen.	Low	High
3.	Kernel swollen; Collar complete or narrow.	Low or Intermediate	High or Intermediate
4.	Kernel swollen; Collar complete and wide.	Intermediate	Intermediate
5.	Kernel split or segregated; Collar complete and wide.	Intermediate	Intermediate
6.	Kernel dispersed; Merging with collar.	High	Low
7.	Kernel completely dispersed and cleared	High	Low

iv. Gel consistency

Milled rice kernels were ground to a fine powder using mortar and pestle and sieved with 1mm sieve. Then 100 mg of rice flour was taken in duplicate into a long test tube (2x19.5 cm). Then 0.2 ml of 95% ethanol containing 0.25% thymol blue and 2 ml of 0.2 N of KOH was added into the sample. Then the mixture was mixed well with the aid of vortex mixer. Test tubes were covered well with a cotton wool to prevent steam and to reflux the sample. The samples were cooked vigorously in boiling water bath for 8minutes to make the content reach two thirds of the tube. Then the test tubes were removed from the water bath and kept at a room temperature for five minutes before placing in an ice water bath for 20 minutes.

After that, tubes were laid horizontally on a table lined with millimeter graphic paper for one hour and measurements were made. The gel length was classified according to standard evaluation system for rice (IRRI, 2002) (Table 5).

Table 5: Rice gel length classification

Scale	Length of gel (mm)	Gel classification
1	80 – 100	Soft
3	61 – 80	Soft
5	41 – 60	Medium
7	36 – 40	Hard
9	Less than 35	Hard

v. Aroma.

Determination of aroma followed the cooking method developed at IRRI (Graham, 2002). Twenty grams (20 g) of milled rice kernels from each of the tested genotypes was taken into a beaker; then 60 ml of water was added. The sample was soaked for 10 minutes and cooked for 15 minutes and transferred into a Petri dish and placed in refrigerator for 20 minutes. The cooked rice was divided into six portions for each sample then smelled by a random panel of twenty two (22) untrained judges at an interval of time. The panel scored the rice genotypes as; scented (SS), mild scented (MS), and non scented (NS). The scores of each genotype were averaged and differentiated into three groups viz., non scented (< 0.5), mild scented (0.51 to 1.5) and strongly scented (1.51 to 2) according to Lestari *et al.* (2011a) and standard evaluation system for rice (IRRI, 2002).

vi. Volume expansion ratio (VER) and elongation ratio (ER).

25 g of milled rice kernel for each genotype were taken into a 250 ml measuring cylinder filled with 100 ml of water. Initial volume increase was measured as (Y). Volume increase before cooking can be computed as Y-100. Rice samples were

soaked for 10 minutes and then cooked in a water bath for 20 minutes. Cooked rice samples were placed on a whateman filter paper (15 cm) to allow free water to drain out. Ten (10) cooked rice kernels (intact at both ends) were selected and the lengths of the kernels after cooking were measured using millimeter graphic paper. Then the cooked rice was placed in a 250 ml cylinder filled with 150 ml of water and the volume was recorded as (X). Then volume increase was computed as X-150. Volume expansion ratio and elongation ratio were computed according to Bhonsle and Krishnan (2010) as follows;

$$VER = \frac{\text{Volume of cooked rice}}{\text{Volume of raw rice}}$$

$$ER = \frac{\text{Length of cooked rice}}{\text{Length of raw rice}}$$

3.5 Data Analysis

All the agronomic and morphological data collected from each experiment were subjected to analysis of variance separately using the procedure outlined by Sharma (1988), Petersen (1985) for augmented Randomized Complete Block Design, using Windostat computer statistical software version 8.6.

The analysis took into account the variability among the blocks as measured by the check varieties. The values of test genotypes were adjusted for block effects as estimated by the check varieties. The statistical model used for each experiment was; $Y_{ij} = \mu + B_i + Cj + E_{ij}$ according to Petersen (1985).

Where;

Y_{ij} = Observation of the i^{th} check from the j^{th} block.

μ = Overall mean,

B_i = i^{th} block effect,

$C_j = j^{th}$ check effect

E_{ij} = Residual

i= 1, 2, 3,....., t and j = 1, 2, 3. .....,r

Adjusted model for the genotypes (test varieties) was: $\hat{Y}_i = Y_{ij} - R_j$

Where;

Y_{ij} = yield of the i^{th} check in the j^{th} block

$\hat{Y}_i$ = adjusted yield of the i^{th} genotype (adjusted for block effect).

R_j = adjustment factor.

Relationships between agronomic characters and grain yield were described using simple correlation analysis. Phenotypic and genotypic coefficients of variation, heritability in broad sense, genetic advance % of mean and simple correlation coefficients were computed using Windostat computer statistical software version 8.6.

Data from participatory variety selection (PVS) were analyzed using Statistical Package for Social Science studies (SPSS) Version 12. Grain quality data were analyzed using Genstat computer statistical software version 14.2 and means separated using Student-Newman Keuls test.

To compare test varieties, adjusted values were obtained using the block effects estimated from the check varieties. CD/LSD – Critical difference or least significance difference used to compare the performance of the checks. There were three standard errors to compare the differences of adjusted means for test genotypes viz., one to compare test varieties in the same block (CD/LSD 1), second to compare test varieties in different blocks (CD/LSD 2) and the last one is to compare test varieties and checks mean (CD/LSD 3). These allowed all possible comparisons to be made.

CHAPTER FOUR

4.0 RESULTS

4.1 Experiment One (Wet Season)

Analysis of variance revealed significant to very highly significant differences ($P<0.001$) among the checks (local genotypes) used in this experiment for the traits under consideration except for number of days to maturity, number of filled spikelets per panicle and percentage sterility (Table 6). Block effects were highly significant for all the agronomic traits studied among the checks and the test varieties except for filled spikelets per panicle. The single degrees of freedom comparison (checks vs varieties) were very highly significant for days to 50% flowering, days to maturity, plant height, reproductive tillers per hill, grain yield,1000 grain weight, filled spikelets per panicle except for panicle length and percentage sterility.

Mean performance for agronomic and morphological traits among the check varieties exhibited significant differences for days to 50% flowering, plant height, panicle length, reproductive tillers per hill, grain yield and 1000 grain weight (Table 7). Rangimbili exhibited higher days to 50% flowering (113 days) than the rest of the check varieties (106 days). Check varieties differed significantly among each other for plant height. Rangimbili was significantly longer (154.6 cm) than other check varieties and Saro 5 was the shortest (86.9 cm) genotype among the checks. The general mean among genotypes for plant height was 102.6 cm. Furthermore Rangimbili had significantly longer panicles (28.9 cm) than other checks while the shortest panicle (21.1 cm) was recorded from Saro. Additionally, highly significant differences were recorded for reproductive tillers per hill with Saro 5 having maximum number of tillers (15.8) and Mbawambili had the least (10.6) (Table 7). The average mean for number of tillers per hill was 15.5 tillers. It follows

that Saro 5 had higher grain yield (8084.9 kg/ha) among the checks while the least (4179.8 kg/ha) was recorded from Supa and the grand mean for grain yield was 4066.58kg/ha. Test varieties exhibited highly significant differences for days to 50% flowering, days to maturity, plant height, panicle length, grain yield, 1000 grain weight, filled spikelets per panicle and percent sterility (Table 6). These results were reported individually for each trait as shown below.

Table 6: Mean square values from ANOVA for selected variables (experiment one)

Character	Blocks	Checks	Checks vs Genotypes	Genotypes	Error
Days to 50% flowering	123.413 ***	39.200 ***	14060.7 ***	154.749 ***	0.0001
Days to 90% Maturity	51.613 ***	0.000 ns	13908.04 ***	184.557 ***	0.0003
Plant height	536.527 ***	2510.517 ***	5480.749 ***	523.036 ***	7.845
Panicle length	61.734 ***	34.862 ***	12.881 ns	30.579 ***	2.861
Reproductive tillers/hill	38.760 ***	16.612 *	75.152 ***	45.840 ***	3.149
Grain yield/plot	5651458 ***	9957852 ***	47315260 ***	2846119 ***	55547.51
1000 grain weight	16.796 ***	15.829 ***	360.861 ***	22.018 ***	0.829
Filled spikelets per panicle	1099.108 ns	3122.565 ns	393684.3 ***	8306.739 **	2073.546
Sterility (%)	25.666 **	5.644 ns	0.047 ns	19.066 **	3.554

Key: *** = significant at 0.001 probability level
** = significant at 0.01 probability level
* = significant at 0.05 probability level
ns = No significant difference

Table 7: Agronomic and growth characteristics of local genotypes (experiment one)

	Days to 50% flow	Maturity days	Plant height (cm)	Pan. length (cm)	No. of reprod. Tiller/hill	Yield kg/ha	1000 Grain wt. (g)	No. of filled grains/pan	Spikelet sterility (%)
Cherehani	106	148	119.9	24.9	14.5	5928.7	34.7	336.5	14.2
Mbawambili	106	148	113.4	23.8	10.6	6493.7	34.7	268.6	14.6
Supa	106	148	113.4	22.6	12.0	4179.8	31.2	320.8	11.8
Saro	106	148	86.9	21.1	15.8	8084.9	31.4	335.9	12.9
Rangimbili	113	148	154.6	28.9	13.4	4525.9	35.4	322.2	14.5
Mean	**76.78**	**117.55**	**102.64**	**25.17**	**15.47**	**4066.58**	**28.58**	**154.80**	**13.57**
SED	**0.01**	**0.01**	**2.99**	**1.19**	**1.26**	**166.66**	**0.64**	**0.64**	**1.33**
CD/LSD	**0.01**	**0.03**	**6.51**	**2.61**	**2.73**	**363.11**	**1.40**	**1.40**	**2.90**
Pr > F	***	**ns**	***	***	*	***	***	**ns**	**ns**

Key:

SED – Standard error of the mean difference

CD/LSD – Critical difference or least significance difference

*** = significant at 0.001 probability level. ** = significant at 0.01 probability level. *= significant at 0.05 probability level. ns = No Significant difference
50% flow = Days from transplanting to 50% heading. Pan. length = Panicle length. No. of Reprod. Tiller/hill = Number of reproductive tillers per hill.
1000 grain wt. = Thousands grain weight. No. of Filled spklts/pan = Number of filled spikelets per panicle.

4.1.1 Days to 50% flowering

The analysis of variance showed highly significant difference ($p \leq 0.001$) among the test varieties for days to 50 % flowering (Table 6) which ranged from 54 days to 106 days among the test varieties (Table 8) and from 106 days to 113 days among the check varieties (Table 7). Less number of days to 50 % flowering (54 days) was observed from the genotype Olbye-1 and the higher (106 days) was recorded from the Supa mutant lines. Generally test varieties behaved in six (6) groups for days to 50% flowering with exception of Olbye – 1 which stood alone. Group one had 27 test varieties with 67 days to 50% flowering, second group had eleven (11) test varieties with 74 days, third group had 4 genotypes with 82 days, fourth group had 11 genotypes with 90 days to 50% flowering, the fifth group had three genotypes with 98 days to 50% flowering and the last group had three genotypes with 106 days to 50 % flowering. The six groups do not include local genotypes (checks) which had two groups, first group had four genotypes with 106 days and the second group had only Rangimbili mkia with 113days to 50% flowering.

4.1.2 Days to 90% maturity

The analysis of variance exhibited highly significant differences ($p \leq 0.001$) among the test genotypes for number of days to 90% maturity (Table 6) which ranged from 99 to 148 days (Table 8). The genotype 88076-TR-1101-9-2 -1 took less days (99) to maturity compared to others. Checks and the mutant genotypes took maximum of 148 days to mature. Thus, genotype 88076-TR-1101-9-2 -1 was 49 days earlier in maturity than the checks and the Supa mutants (Tables 7 and 8). The latest maturing varieties viz., Supa mutants, Local checks, Hex 24, Hex 25 and Nippon bare took 106 days to 50% flowering. Generally the test genotypes can be put into three main categories on the basis of maturity viz., early maturing (99 to 106 days); medium maturing (119 days) and the late maturing

(148 days). The early maturing genotypes were attacked by birds but bird scaring was effective.

4.1.3 Plant height

Analysis of variance showed that plant height varied significantly ($p \leq 0.001$) among the test genotypes (Table 6) which ranged from 56.12 to 178.54 cm (Table 8). Minimum plant height (56.12 cm) was observed in Nippon bare while maximum height (178.54 cm) was observed in Silewah. Nippon bare genotype was significantly shorter (by 30.8 cm) than the shortest check variety Saro 5 (86.95 cm) and Silewah was 23.94 cm significantly longer than the longest check variety (Rangimbili 154.6 cm). Plant height is divided into three categories viz., short plants (<110 cm), medium tall (110-130 cm), and tall (>130 cm). Based on these categories and from the average data on plant height, 34 genotypes were short with plant height ranging from 56.12 to 109.94 cm recorded from Nippon bare and Chandannath-1 respectively, Saro 5 (86.95 cm) a check genotype falls in this category. Medium tall genotypes were 16 with plant height ranging from 110.72 to 123.68 cm observed in Yunlen 15 and Supa M-101-22 respectively. Supa (113.43 cm) and Cherehani (119.9 cm) checks also fall in this group. The last group was composed of 10 genotypes with plant height ranging from 130.88 to 178.54 cm recorded from Supa M-106 and Silewah respectively. In addition, Mbawambili (133.9 cm) and Rangimbili (154.60 cm) check genotypes fall in this category (Tables 7 and 8).

4.1.4 Panicle length

The test genotypes exhibited very highly significant differences ($p \leq 0.001$) for panicle length (Table 6). Panicle length ranged from 11.76 to 36.64 cm among test genotypes (Table 8). Minimum panicle length (11.76 cm) was recorded from 89010 – TR- 1130- 8-1-1 genotype and the maximum panicle length (36.64 cm) was recorded from Silewah

(Table 8). The genotype 89010 – TR-1130 -8-1-1 had a shorter panicle length than the checks shortest panicle (21.05 cm) observed from Saro.5. The genotype mean for panicle length was 25.17 cm.

4.1.5 Reproductive tillers per hill (Number of panicles per hill)

The results showed highly significant difference among test genotypes ($p \leq 0.001$) for number of productive tillers per hill (Table 6). Number of reproductive tillers per hill ranged from 6.4 to 36.6 (Table 8). Minimum number of productive tillers per hill of 6.4 was produced by WAB 189 and maximum (36.6) were produced by Nippon bare. The genotype mean for reproductive tillers per hill was 15.5. Nippon bare had significantly higher number of productive tillers per hill than the maximum tillering check Saro 5 (15.8) (LSD = 4.72).

4.1.6 Weight of one thousand (1000) grains

The tested genotypes exhibited very highly significant differences ($p \leq 0.001$) for 1000 grains weight (Table 6). Thousand grains weight ranged from 18.11 to 37.74 g (Table 8) and the genotype grand mean was 28.58 g. Minimum thousand grains weight (18.11 g) was recorded from the genotype PSB RC 92 and the maximum (37.74, 37.54 g) were recorded from 88090-TR-1115-4-1-1 and 88088-TR-1113-4-1-1. The genotype 88088-TR-1113-4-1-1 is among the ten (10) selected genotypes during PVS. Comparison of test varieties ($p \leq 0.05$) and a check mean for thousand grains weight revealed significant difference (13.12 g) for the minimum values and non significant (2.37 g) for maximum values (LSD= 2.4).

4.1.7 Number of filled spikelets per panicle

The analysis of variance showed highly significant differences ($P \leq 0.01$) among the tested genotypes for number of filled spikelets per panicle (Table 6). Means for number of spikelets per panicle ranged from 13.02 to 467.74 (Table 8) and the genotype mean for number of spikelets per panicle was 154.8. Least number of filled spikelets per panicle (13.02) was observed from Kunming and maximum (467.74) numbers were observed from Lanbayeque. Least value for number of filled spikelets per panicle (13.02) among genotypes was significantly lower ($p \leq 0.05$) than the lowest value (268.6) among checks (LSD=121.11). Significant difference was also observed for the comparison of maximum values between test varieties and check means at 5% level of probability. Minimum number of filled spikelets per panicle (268.6) among checks was recorded in Mbawambili and maximum (336.46) from Cherehani.

4.1.8 Percentage spikelet sterility

The tested genotypes exhibited highly significant differences ($p \leq 0.01$) for percent spikelet sterility (Table 6). The mean values ranged from 4.89 to 16.90%. The minimum spikelet sterility (4.89%) was recorded from WAB 189 and the maximum (16.90%) was observed in Nippon bare (Table 8). Genotype WAB 189 had significantly lower percentage sterility (4.89%) than the minimum spikelet sterility (11.84%) among checks recorded from Supa. Maximum spikelet sterility (14.59%) among checks which was recorded from Mbawambili did not differ significantly ($p \leq 0.05$) with that recorded from Nippon bare (Tables 7 and 8). The genotype grand mean for percentage spikelet sterility was 13.57%.

4.1.9 Grain yield

The analysis of variance showed very highly significant differences ($P \leq 0.001$) among the tested genotypes for grain yield (Table 6). Grain yield ranged from 820.6 to 7896.5 kg/ha

(Table 8) indicating the diverse nature of the genotypes studied. The genotype mean for grain yield was 4066.6 kg/ha. Minimum grain yield was recorded from Jumli morshi and the maximum from Rojofotsy 653. Local genotypes (checks) were superior over the test genotypes for both minimum and maximum grain yield (Tables 7 and 8). However, the difference for maximum yield was not significant at 5% as for the case for minimum grain yield (LSD =626.82).

4.1.10 Relationships among selected characters with grain yields (experiment one)

Results for correlation coefficients between growth variables and grain yield are presented on Table 9. Grain yield showed highly significant positive correlation with filled spikelets per panicle (r =0.608***), days to 50% flowering (r = 0.507***) and days to 90% maturity (r = 0.484***). Furthermore grain yield exhibited a positive non-significant correlation with plant height, 1000 grain weight, panicle length and non significant negative correlations with percent sterility and reproductive tillers per hill.

Days to 50% flowering showed highly significant positive correlation (r = 0.869***) with days to 90% maturity, plant height (0.552***), 1000 grain weight (0.321***), filled spikelets per panicle (r = 0.741***) and a significant negative correlation (r = -0.263*) with reproductive tillers per hill. It also had non significant correlations with panicle length and percent sterility. Days to 90% maturity also showed highly significant correlations with plant height (r = 0.303**), filled spikelets per panicle (r = 0.801***), 1000 grain weight (0.222*). It also had a non significant positive correlation with percent sterility. Days to 90% maturity showed weak negative correlations with panicle length and reproductive tillers per hill (Table 9).

Table 8: Agronomic and growth characteristics of the test genotypes (experiment one)

		Blocks number	Days to 50% flow	Maturity days	Plant height (cm)	Pan. length (cm)	No. of reprod. Tiller/hill	Yield kg/ha	1000 Grain wt. (g)	No. of filled grains/pan	Spikelet sterility (%)
1.	WAB450-12-2-BL1-DV1	1	74	106	100.48	26.56	9.74	2423.28	26.67	170.64	14.74
2.	Geumobyeo	1	67	106	69.68	22.36	21.94	3416.19	23.50	112.54	10.16
3.	X-jigna	1	67	106	118.48	32.56	12.94	4330.28	30.07	216.58	14.99
4.	Zhongeng	1	74	119	118.88	30.96	8.14	2797.28	30.81	186.46	14.61
5.	ZHI 205	1	98	148	86.08	19.76	14.94	6333.09	23.12	366.22	14.99
6.	M 202	1	67	119	74.88	21.96	17.94	3724.51	7.14	196.02	13.72
7.	Lanbayeque	1	82	119	132.88	25.16	27.94	6002.21	30.31	467.74	8.16
8.	FOFIFA 4178	1	67	106	103.08	28.36	11.54	4785.84	35.34	204.54	11.58
9.	Supa M-106	1	106	148	130.88	21.96	11.54	5759.02	34.42	279.30	14.22
10.	Amaro	1	82	119	114.68	25.96	12.14	5351.28	30.50	198.94	13.54
11.	Palung-2	1	74	119	122.88	32.16	18.14	7039.25	22.17	152.26	12.55
12.	87020-TR-968-1	1	67	119	79.68	21.56	25.54	5049.08	22.81	238.46	9.73
13.	Supa M-101-22	1	106	148	123.68	24.96	10.94	5341.83	35.04	278.58	15.04
14.	86011-TR-888-2-1-2-1	1	67	106	87.28	22.36	15.34	6632.79	34.29	205.90	14.17
15.	WAB 515-B-16A1.1	1	82	119	119.88	30.16	11.34	6424.42	35.39	252.70	11.74
16.	Somewake	2	67	106	102.34	27.44	15.99	4940.26	28.41	184.74	12.82
17.	Stejaree	2	67	106	86.74	20.84	16.39	4099.08	32.95	100.30	13.38
18.	PSB RC 92	2	82	119	121.34	30.84	13.99	2588.68	18.11	183.14	13.82
19.	Chandannath-1	2	67	106	109.34	34.04	13.19	4108.33	22.57	183.90	9.29
20.	FAC 56	2	90	119	111.34	28.44	18.79	6845.85	21.4	297.06	12.25
21.	Kunming	2	90	119	135.74	35.64	3.99	1470.83	27.49	13.02	40.09
22.	Silewah	2	90	119	178.54	36.64	10.99	3770.53	28.66	175.10	13.28

Table 8: Agronomic and growth characteristics of the test genotypes (experiment one) cont....

		Blocks number	Days to 50% flow	Maturity days	Plant height (cm)	Pan. length (cm)	No. of reprod. Tiller/hill	Yield kg/ha	1000 Grain wt. (g)	No. of filled grains/pan	Spikelet sterility (%
23	Skau 23	2	90	119	111.54	24.24	26.99	6142.38	26.47	158.98	13.31
24	Olbye-1	2	54	119	64.94	13.44	26.99	1698.04	23.31	123.06	11.26
25	Yunyin	2	74	119	108.34	29.44	13.79	5196.31	27.82	127.54	12.73
26	Dourado agulaha	2	90	119	133.14	25.44	10.19	3177.58	30.29	136.10	13.49
27	Mwangaza	2	74	106	118.74	22.44	9.79	6145.28	34.65	72.34	7.37
28	Mitak	2	90	106	137.34	31.24	7.19	4605.38	28.17	150.26	13.78
29	Supa M-70-10	2	106	148	130.94	22.64	12.59	5810.31	30.44	288.90	13.52
30	Yunkeng	2	74	119	114.34	31.04	12.59	6222.44	31.03	120.58	10.68
31	Koshihikari	3	67	119	70.88	18.96	36.04	1952.6	23.59	89.79	8.33
32	88076-TR-1101-9-2-1	3	67	99	72.08	12.76	23.64	2746.38	33.77	48.83	13.75
33	WAB 189-B-B-B-B-HB	3	67	106	98.88	24.96	6.44	4958.67	35.64	130.43	4.89
34	HS 379	3	67	106	87.88	21.16	8.24	2407.15	30.69	51.07	13.39
35	89010-TR-1130-8-1-1-2	3	67	106	72.48	11.76	14.04	3364.18	28.93	21.43	13.74
36	88088-TR-1113-4-1-1	3	67	106	90.08	20.96	18.64	4265.06	37.71	79.27	9.74
37	Padi Labou alumbra	3	90	119	138.28	33.56	13.64	3729.96	25.10	199.59	14.43
38	Padisashal	3	90	119	131.48	28.16	14.04	1808.71	32.67	72.79	14.25
39	FOFIFA 4355	3	67	106	100.28	29.76	9.04	5037.47	35.81	101.91	5.21
40	Polvidov 22	3	67	106	87.28	20.16	11.44	1576.42	33.70	29.55	14.69
41	Calaro	3	74	119	90.08	27.16	14.64	3586.6	30.20	61.99	15.09
42	Skau 105	3	74	119	101.68	25.36	16.64	3568.37	25.64	104.71	13.98
43	Rojofotsy 653	3	90	148	137.88	31.76	14.64	7896.52	27.97	421.43	13.97
44	Hexi 25	3	98	148	73.48	22.56	17.44	4141.93	22.65	289.95	15.98
45	Machhapuchre	3	74	106	99.88	27.36	16.04	2757.97	29.63	81.03	9.04
46	FOFIFA 3737	4	74	106	114.32	25.04	7.24	2090.92	30.02	45.84	16.98

Table 8: Agronomic and growth characteristics of the test genotypes (experiment one) cont....

		Blocks number	Days to 50% flow	Maturity days	Plant height (cm)	Pan. length (cm)	No. of reprod. Tiller/hill	Yield kg/ha	1000 Grain wt. (g)	No. of filled grains/pan	Spikelet sterility (%)
47	Chandannath-3	4	67	106	111.12	30.44	10.84	5367.59	24.47	52.60	16.42
48	Jumlimorshi	4	67	106	97.92	23.24	21.64	820.57	25.84	30.68	16.15
49	China 1039	4	67	106	115.12	25.84	22.64	5014.25	24.76	241.48	16.58
50	Yoneshiro	4	67	106	69.32	20.44	24.44	1286.37	26.26	83.48	15.28
51	YR 1076-B-4-1-2-3-1-2	4	67	119	80.32	20.84	9.04	4084.13	23.36	91.76	12.63
52	Diamante	4	67	119	78.72	19.44	17.04	3198.47	25.74	62.44	13.94
53	Nippon bare	4	67	148	56.12	20.64	36.64	1179.77	23.88	242.68	16.89
54	PSB RC 28	4	90	119	68.52	22.24	19.64	4755.93	20.69	121.72	14.94
55	88090-TR-1115-4-1-1	4	67	119	78.92	14.24	17.84	2813.41	37.74	73.56	15.09
56	Yunlen 15	4	74	119	110.72	28.04	15.84	3626.19	26.01	53.44	15.62
57	Chomrong	4	67	106	94.32	28.04	10.04	2441.56	31.21	25.36	12.6
58	Hexi-24	4	98	148	76.52	25.64	16.64	6544.26	23.04	359.48	16.57
59	Salama M-19	4	90	119	111.12	25.64	11.84	2392.97	29.79	127.36	14.83
60	Agulah	4	67	119	94.32	23.24	9.04	2348.79	34.56	50.48	14.28
	Mean		**76.78**	**117.55**	**102.64**	**25.17**	**15.47**	**4066.58**	**28.58**	**154.80**	**13.57**
	BiVi – BiVj (LSD 1)		**0.03**	**0.05**	**13.02**	**5.21**	**5.47**	**726.21**	**2.81**	**140.31**	**5.81**
	BiVi - BjVj (LSD 2)		**0.03**	**0.06**	**14.26**	**5.71**	**5.99**	**795.53**	**3.07**	**153.70**	**6.36**
	Ci - Vi (LSD 3)		**0.02**	**0.05**	**11.24**	**4.49**	**4.72**	**626.82**	**2.42**	**121.11**	**5.01**
	Pr > F		***	***	***	***	***	***	***	**	**

Key

*** = significant at 0.001 probability level. ** = significant at 0.01 probability level. *= significant at 0.05 probability level.

50% flow = Days from transplanting to 50% heading. Pan. length = Panicle length, No. of Reprod. Tiller/hill = Number of reproductive tillers per hill, 1000 grain wt. = Thousands grain weight, No. of Filled spklts/pan = Number of filled spikelets per panicle.

BiVi - Bivj (CD/LSD 1) – Standard error to compare the difference of test varieties in the same block.

BiVi-BjVj (CD/LSD 2) - Standard error to compare the difference of test varieties in different blocks.

Ci –Vi (CD/LSD 3) - Standard error to compare the difference of test varieties and a check mean.

Plant height showed very highly significant positive correlation with panicle length (r = 0.653***), 1000 grain weight (r = 0.357***), filled spikelets per panicle (r = 0.317***) and a very highly negative correlation with reproductive tillers per hill (r = -0.483***) (Table 9). The correlation between plant height and percentage sterility was not significant.

Panicle length exhibited very highly significant negative correlation with reproductive tillers per hill (r = -0.411***). It also showed a significant positive correlation with percent sterility (r = 0.234*) (Table 9). Reproductive tillers per hill showed significant negative correlation with 1000 grain weight (r = -0.384***), percent sterility (r = -0.221**). Correlations with the rest of the variables were not significant (Table 9).

4.1.11 Estimates of variance components and genetic parameters (experiment one)

Analyses of variance components and genetic parameters were computed and compared for all agronomic and morphological characters studied during experiment I (Table 10). Grain yield and filled spikelets per panicle exhibited high genotypic and phenotypic variances, followed by plant height, days to 90% maturity and days to 50% flowering.

The characters studied showed moderate to high genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV). The GCV and PCV estimates were classified as; low (0-10%), moderate (10-20%) and high (>20%). The highest values for GCV and PCV were recorded for filled spikelets per panicle (44.94%, 53.71%), productive tillers per hill (37.21%, 38.93%), grain yield (36.19%, 36.36%), and for sterility percentage (25.57%, 29.105%) respectively (Table 10). Moderate values for GCV and PCV were recorded for days to 90% maturity (10.18% for each), days to 50% flowering (14.28% for each), 1000 grain weight (14.19%, 14.55%), panicle length

(18.43%, 19.62%), plant height (19.29%, 19.73%) respectively. The estimates of phenotypic coefficient of variation (PCV) were slightly higher than those of genotypic coefficient of variation (GCV) for all the traits studied except for days to 50% flowering and days to 90% maturity.

Heritability in broad sense (h^2b) was higher (70 to 100%) for all the characters studied viz., days to 50% flowering (100%), days to 90% maturity (100%), grain yield (98%), plant height (96%), 1000 grain weight (95%), productive tillers per hill (91%), panicle length (88%), sterility (77%) and filled spikelets per panicle (70%) (Table 10). Heritability estimates were classified as; low (0-30%), moderate (30-60%) and high (>60%).

All the characters under study during the wet season exhibited high genetic advance (20.98 to 77.45%) as per cent of the mean (GAM). The lowest value (20.98 %) was recorded for number of days to 90% maturity and the highest (77.45%) for number of filled spikelets per panicle (Table 10). Genetic advance as percentage of the mean (GAM) were classified as; low (0-10%), medium (10-20%) and high (>20%).

Table 9: Simple correlation coefficients (d.f = 64) of some rice parameters (experiment one)

Character/Trait	50% Flow	Maturity	Pheight	Panlength	Rtillers/hill	1000gwt	Fspklts/pa	Sterility	Grain yield
50% flow	1.000	0.869***	0.552***	0.127	-0.263*	0.321**	0.741***	0.198	0.507***
Maturity		1.000	0.303**	-0.074	-0.039	0.222*	0.801***	0.123	0.484***
Pheight			1.000	0.653***	-0.483 ***	0.357 **	0.317**	0.200	0.207
Panlength				1.000	-0.411***	-0.070	0.046	0.234*	0.099
Rtillers/hill					1.000	-0.384***	0.093	-0.221**	-0.123
1000 gwt						1.000	0.146	-0.093	0.205
Filled spklts/pa							1.000	-0.077	0.608***
% Sterility								1.000	-0.177
Grain yield									1.000

Key:

*** = significant at 0.001
** = significant at 0.01
*= significant at 0.05.
NB: = Figures without asterisk are not – significant at 0.05

50% flow = Number of days to 50% flowering
Maturity = Number of days to 90% maturity
Pheight = Plant height
Panlength = Panicle length
Rtillers/hill = Number of reproductive tillers per hill
1000 gwt = Thousands grain weight
Fspklts/pa = Number of filled spikelets per panicle.

Table 10: Estimates of variance components and genetic parameters for selected traits (experiment one)

Trait	$G\delta^2$	$P\delta^2$	$E\ \delta^2$	ECV%	GCV %	PCV %	h^2_b	GA 5%	GAM 5%
Days to 50% flowering	120.134	120.134	0.0001	0.010	14. 275	14.275	1.00	22.5788	29.4058
Days to 90% Maturity	143.274	143.274	0.0003	0.015	10.183	10.183	1.00	24.6576	20.9763
Plant height	392.18	410.033	17.845	4.116	19.294	19.728	0.96	39.8981	38.8718
Panicle length	21.5183	24.3790	2.8607	6.721	18.432	19.619	0.88	8.9777	35.6731
Reproductive tillers/hill	33.1419	36.2906	3.1487	11.468	37.205	38.933	0.91	11.3331	73.2426
Grain yield	2166364.5	2221911.9	55547.5	5.796	36.194	36.655	0.98	2993.886	73.6217
1000 grain weight	16.4487	17.2782	0.8295	3.187	14. 192	14.546	0.95	8.1517	28.5258
Filled spikelets/ panicle	4838.927	6912.4726	2073.5456	29.416	44.936	53.708	0.70	119.895	77.4498
Percent sterility	12.0425	15.5965	3.5539	13.891	25.571	29.101	0.77	6.2816	46.2877

Source: Field data.

Key:

$G\delta^2$ = Genotypic variance.
Pδ2 = Phenotypic variance.
$E\ \delta^2$ = Environmental variance.
ECV = Environmental coefficient of variation (%).
GCV = Genotypic coefficient of variation (%).
PCV = Phenotypic coefficient of variation (%).
GA = Genetic Advancement (5%).
GAM = Genetic Advancement as a percentage of mean (5%).

4.2 Experiment Two (Dry/Cool Season)

Analysis of variance revealed significant and very highly significant differences among the checks used in this experiment for all the characters studied except for number of filled spikelets per panicle (Table 11). Block effects were very highly significant for all the agronomic traits studied among the check varieties except for number of filled spikelets per panicle and percentage sterility. The single degrees of freedom comparison (checks vs varieties) were significant to very highly significant for the studied variables except for panicle length and number of filled spikelets per panicle.

Mean performance for agronomic and morphological traits among the check genotypes revealed significant difference for all the characters studied except for filled spikelets/panicle (Table 12). Check varieties differed significantly for days to 50% flowering where Rangimbili and Cherehani flowered earlier (136 days) while Supa, Saro.5 and Mbawambili took 141 days. When comparing with the normal season, Rangimbili and Cherehani delayed flowering for 23 days (20.4%) while the other checks delayed flowering for 35 days (33%) (Tables 7 and 12). Additionally, check varieties differed significantly for the number of days to 90% maturity. Cherehani was the earliest maturing check (166 days) followed by Supa and Saro 5 (170 days) while the latest maturing checks were Mbawambili and Rangimbili (178 days) (Table 12). Comparison of the check varieties for normal and cold season showed a great variation for number of days to maturity. Cherehani delayed maturity for 18days, Supa and Saro delayed maturity for 22 days while Rangimbili and Mbawambili delayed for 30 days in relation to experiment one. This accounted for 12.2%, 14.9% and 20.3% delay for number of days to maturity compared to normal season respectively.

Furthermore, check varieties differed significantly among each other for plant height (Table 12). Maximum plant height (124.5 cm) was observed from Rangimbili and the minimum (71.2 cm) from Saro 5. Saro 5 and Rangimbili differed significantly for plant height with each other and among the rest of the check genotypes. The general mean among genotypes for plant height was 90.6 cm. Generally plant height was reduced during this season as compared to normal season. For Saro.5 and Rangimbili alone, height reduction in relation to experiment one accounted for 18.1 and 19.5% respectively (Table 7 and 12).

Additionally, Rangimbili had a significantly longer panicle (27.1 cm) than other check varieties while the shortest panicle length (17.7 cm) was recorded from Saro 5. As it was the case for the other traits, panicle length also was reduced during this season. The genotypes mean for panicle lengths was 21.4cm less than that observed (25.2 cm) during experiment one (Tables 7 and 12). There were also significant differences among the check genotypes for the number of productive tillers per hill. Saro 5 (11.7) and Rangimbili mkia (11.6) differed significantly from other check varieties for number of productive tillers per hill. Less number of productive tillers per hill (9.1) was recorded from Supa and higher (11.7) from Saro 5 while the general mean was 11.1. Results showed high reduction (28.4%) for number of productive tillers per hill in relation to experiment one with the general mean of 15.5 tillers.

Furthermore check varieties differed significantly among each other for grain yield. Maximum grain yield (2352.9 kg/ha) was recorded from Saro 5 while minimum (367.2 kg/ha) was observed in Rangimbili mkia. These two genotypes differed significantly with the rest of the check varieties viz., Supa (1735.8 kg/ha), Mbawambili (1711.2 kg/ha) and Cherehani (1445.6 kg/ha) for grain yield. However, there was no significant difference

between Supa and Mbawambili for grain yield. The general mean among varieties for grain yield was 1669.65 kg/ha which is very small compared to the one (4066.6 kg/ha) recorded in experiment one. This shows high yield reduction (58.9%) among check varieties in experiment two compared to experiment one. Significant differences were also recorded among check varieties for one 1000 grains weight. Maximum one 1000 grains weight was observed from Supa (31 g) and minimum (26.7 g) from Saro.5. The genotypes grand mean for one 1000 grains weight was 26.98 g. Generally this trait was also reduced in magnitude when compared with wet season results.

To compare test varieties, adjusted values were obtained using block effects estimated from the check genotypes as in experiment one. There were three standard errors to compare the differences of adjusted means viz., to compare test varieties in the same block (CD/LSD 1), to compare test varieties in different blocks (CD/LSD 2) and the last one was to compare test varieties and a check mean (CD/LSD 3). These allowed all possible comparisons to be made.

Test varieties were highly significant for days to 50% flowering, days to 90% maturity, plant height, panicle length, grain yield, 1000 grain weights, number of filled spikelets per panicle and for percentage sterility (Table 11). This indicates presence of high variability among the genotypes. Each trait was discussed independently as was the case in wet season experiment.

Table 11: Mean square values from ANOVA for selected variables (experiment two)

Character	Blocks	Checks	Checks vs Genotypes	Genotypes	Error
Days to 50% flowering	196.384 ***	30.000 ***	10877.83 ***	233.193 ***	0.0004
Days to 90% Maturity	165.199 ***	115.20 ***	10647.33 ***	125.25***	0.0003
Plant height	359.701 ***	1596.742 ***	2940.413 ***	334.215 ***	19.347
Panicle length	27.174 ***	57.437 ***	0.299 ns	28.899 ***	1.736
Reproductive tillers/hill	17.867 ***	6.045*	9.969 *	17.388***	1.372
Grain yield	1439450 ***	2111263 ***	312644.7 ***	1000808 ***	12065.3
1000 grain weight	13.698 ***	10.105 ***	76.092 ***	17.941 ***	0.060
Filled spikelets per panicle	128.108 ns	329.707 ns	201.736 ns	528.756 *	204.497
Percent sterility	153.363 ns	282.459 *	794.320 **	199.060 *	57.434

Key

* = Significant at $p \leq 0.05$
** = Significant at $p \leq 0.01$
*** = Significant at $p \leq 0.01$
ns = No significant difference at 0.05.

Table 12: Agronomic and growth characteristics of local genotypes (experiment two)

	Days to 50% flow	Maturity days	Plant height (cm)	Pan. length (cm)	No. of reprod. Tiller/hill	Yield kg/ha	1000 Grain wt. (g)	No. of filled grains/pan	Spikelet sterility (%)
Supa	141	170	110.7	21.9	9.1	1735.8	31.0	75.1	29.3
Mbawambili	141	178	110.9	22.6	9.7	1711.2	29.7	65.4	40.9
Cherehani	136	166	107.2	18.2	9.5	1445.6	29.1	68.3	40.1
Saro	141	170	71.2	17.7	11.7	2352.9	26.7	80.8	23.9
Rangimbili	136	178	124.5	27.1	11.6	367.2	29.9	57.2	43.2
Mean	**111.56**	**145.25**	**90.59**	**21.35**	**11.13**	**1669.65**	**26.98**	**65.63**	**28.09**
SED	**0.01**	**0.01**	**3.11**	**0.93**	**0.83**	**77.67**	**0.17**	**10.11**	**5.36**
CD/LSD	**0.03**	**0.03**	**6.78**	**2.03**	**1.80**	**169.23**	**0.38**	**22.03**	**11.68**
Pr > F value	***	***	***	***	*	***	***	ns	*

Key:

SED – Standard error of the mean difference

CD/LSD – Critical difference or least significance difference

*** = significant at 0.001 probability level
** = significant at 0.01 probability level
*= significant at 0.05 probability level
ns = No significant difference at 0.05

50% flow = Days from transplanting to 50% heading
Pan. length = Panicle length
No. of Reprod. Tiller/hill = Number of reproductive tillers per hill
1000 grain wt. = Thousands grain weight
No. of Filled spklts/pan = Number of filled spikelets per panicle.

4.2.1 Days to 50% flowering

Days to 50% flowering exhibited very highly significant differences ($P \leq 0.001$) among the tested genotypes (Table 11) which ranged from 86 to 141 days (Table 13). Fewer days to 50% flowering were observed on Olbye-1 (86 days) and higher days (141) were recorded from Supa mutant lines viz., Supa M-106, Supa M-101-22 and Supa M-70-10. All genotypes took more days to 50% flowering during experiment two in relation to experiment one. For minimum and maximum number of days to 50% flowering there was a delay of 32 and 35days which accounts to 59.3% and 33% respectively. The grand mean for number of days to 50% flowering was 111.56 days showing delayed heading by 45.3% compared to experiment one (Tables 7 and 12). Comparison with the local genotypes, Olbye-1 flowered earlier (86days) than the earliest checks viz., Cherehani and Rangimbili (136days) (Tables 12 and 13). However, many of the tested genotypes with exception of the mutant lines flowered earlier than the check varieties.

4.2.2 Days to 90% maturity

The analysis of variance showed highly significant differences ($P \leq 0.001$) among the test genotypes for number of days to 90% maturity (Table 11) which ranged from 126 to 170 days (Table 13). Fewer days to maturity (126 days) were observed on the genotype 88076-TR-1101-9-2-1 and more days (170) were observed on the genotypes Dourado agulaha and Supa mutants. Thus, genotype 88076-TR-1101-9-2 -1 was 40 days earlier in maturity than the earliest check (Cherehani) and 52 days earlier than the latest check (Mbawambili) . The genotypes grand mean for number of days to maturity was 145.3 days indicating delay of up 23.6% as compared to experiment one. Even though test varieties showed earliness in maturity than the check varieties, there was a delay in number of days to 90% maturity in relation to experiment one. The genotype 88076-TR-1101-9-2 -1 delayed maturity by 27 days (27.3%) and the mutants delayed by 22 days (14.9%) as

compared to experiment one. Generally test varieties occurred in seven categories viz., group one had two varieties with 126 days, group two had two varieties with 132 days, group three had 11 varieties with 136 days, group four had 17 varieties with 141days, group five had two varieties with 148 days, group six had 12 varieties with 153 days, group seven had two varieties with 166 days and the last four varieties with 170 days to maturity.

4.2.3 Plant height

Analysis of variance revealed very highly significant differences ($p \leq 0.001$) among the test varieties for plant height (Table 11) which ranged from 50.94 to 144.54 cm (Table 13). Minimum plant height (50.94 cm) was observed in Olbye-1 while the maximum height (144.54 cm) was recorded in Kunming. Generally plant height was reduced as compared to the plant height during wet season. Minimum and maximum plant height was reduced by 9.23% and 19.04% respectively. The genotype grand mean for plant height was 90.59 cm and was reduced by 12.05 cm which accounts for 11.74% reduction compared to that of wet season (Tables 8 and 13). Olbye-1 genotype was significantly shorter by 20.3 cm than the shortest check variety (Saro 5) while Kunming was significantly taller by 20.04 cm than the tallest check variety (Rangimbili) (Tables 12 and 13) (LSD = 11.7). Plant height is divided into three categories viz., short plants (<110 cm), medium tall (110-130 cm), and tall (>130 cm). Based on these categories and from the average data on plant height, 46 genotypes were short with plant height ranging from 50.94 to 109.12 cm observed from Olbye-1 and Chandannath-3 respectively while medium tall were 4 genotypes with plant height ranging from 111.3 to 121.78 cm observed from Supa M-106 and Padi labou alumbra respectively. The last group composed of only two test genotypes viz., Kunming and Silewah with plant height of

144.54 cm (Tables 12 and 13). Low temperature reduced varietal height making about 90% of the genotypes to fall in the short category.

4.2.4 Panicle length

The test genotypes showed very highly significant differences ($p \leq 0.001$) for panicle length (Table 11) which ranked from 11.69 to 35.69 cm among test genotypes (Table 13). Minimum panicle length (11.69 cm) was recorded from Olbye-1 and the maximum panicle length (35.69 cm) was recorded in Kunming. Minimum and maximum panicle lengths were recorded from the same genotypes with minimum and maximum plant height. Olbye-1 exhibited significantly shorter panicle than the shortest check's panicle observed in Saro 5 (17.7 cm) and Kunming had a longer panicle than the longest check's panicle (Rangimbili 27.1cm). The genotype grand mean for panicle length was 21.35 cm. Minimum and maximum panicle length revealed little reduction of 0.6% and 2.6% respectively while the general mean revealed panicle length reduction of up to 15.2% compared to the wet season.

4.2.5 Reproductive tillers per hill (number of panicles per hill)

Analysis of variance revealed very highly significant differences ($p \leq 0.001$) among the test varieties for number of productive tillers per hill (Table 11) which ranged from 6.18 to 30.14 (Table 13). Minimum numbers of productive tillers per hill (6.18) were recorded from FOFIFA 4355 while maximum (30.14) were observed in Olbye-1. Minimum and maximum number of productive tillers per hill was reduced by 4.03% and 17.74% respectively as compared to experiment one. Varietal mean for number of productive tillers per hill was 11.13 indicating reduction of 28.1% compared to the wet season. Minimum number of tillers (6.18) recorded from test varieties did not differ significantly at 5% level of probability with that (9.1) recorded among check varieties (LSD = 3.11)

(Tables 12 and 13). On the other hand Olbye-1 had significantly more number of productive tillers per hill than the maximum tillering check Saro 5 (11.7). However, it had high percentage spikelets sterility (74.5%) hence low yield.

4.2.6 Weight of one thousand (1000) grains

Analysis of variance revealed very highly significant differences ($p \leq 0.001$) among test genotypes for one thousand grains weight (Table 11) which ranged from 18.61 to 36.32g (Table 13). Least one thousand grain weight (18.61g) was recorded from Olbye-1 and the maximum (36.32, 36.19g) were recorded from 88088-TR-1113-4-1-1 and 88090-TR-1115-4-1-1 respectively. The genotypes grand mean for one thousand grains weight was 26.98g indicating sufficient amount of genetic variability among the genotypes. Comparison of test varieties ($p \leq 0.05$) and a check mean for one thousand grain weight revealed significant differences for both minimum and maximum values (LSD = 0.65). Comparison of one thousand grains weight for experiment one and two showed an increase of 2.76% for minimum one thousand grains weight and a reduction of 3.76% and 5.6% for maximum and grand mean respectively.

4.2.7 Number of filled spikelets per panicle

Filled spikelets per panicle exhibited significant differences ($p \leq 0.05$) among the test genotypes (Table 11). Means for number of spikelets per panicle varied from 10.96 to 140.17 (Table 13) and the grand mean for the genotypes was 65.63. The minimum number of filled spikelets per panicle (10.96) was recorded from Olbye-1 while maximum (140.17) was recorded from Yunlen 15. Minimum number of filled spikelets per panicle among test varieties was significantly lower ($p \leq 0.05$) than the minimum number of filled spikelets (57.2) among local varieties (LSD = 38.03). Also maximum number of filled spikelets per panicle among test varieties differed significantly at 5% with the maximum

number (80.8) of filled spikelets per panicle between checks (Tables 12 and 13). Number of filled spikelets per panicle was reduced to a large extent in relation to that of experiment one. Minimum and maximum numbers of filled spikelets per panicle were reduced by 15.82% and 70.05% respectively compared to experiment one. The grand mean for the number of filled spikelets had been reduced by 57.6%. The general mean indicated a reduction of more than 50% when compared with that of the wet season.

4.2.8 Percentage spikelet sterility

Analysis of variance revealed significant differences ($p \leq 0.05$) for percentage spikelet sterility among test varieties (Table 11). The means for percentage spikelet sterility ranged from 4.97 to 74.49%. Minimum spikelet sterility (4.97%) was recorded from Somewake and maximum spikelet sterility (74.49%) was observed in Olbye-1 (Table 13). The grand mean for percentage spikelet sterility was 28.09% indicating an increase of 14.52% compared to that of experiment one. Minimum spikelet sterility (4.97%) among test varieties does not differ significantly at 5% with the minimum sterility (23.9%) among check varieties. However, there was a significant difference between maximum sterility (74.49%) observed among test varieties with that observed among checks (43.20%) at 5% (Tables 12 and 13) (LSD = 20.16). Generally there was high percentage sterility among genotypes during experiment two compared to experiment one. Maximum percentage spikelets sterility indicated an increase of 57.59% sterility compared to experiment one. The selected genotypes from PVS had shown low spikelet sterility % in relation to the check varieties used. Somewake showed a minimum spikelet sterility of 4.97% and the maximum (29.98%) was recorded from 86011-TR-888-2-1-2-1. The check varieties indicated a maximum of 43.2% spikelet sterility and a minimum of 23.9% recorded from Rangimbili and Saro 5 respectively (Tables 12 and 13).

4.2.9 Grain yield

Grain yield exhibited very highly significant differences ($p \leq 0.001$) among the test varieties (Table 11). Grain yield ranged from 124.5 to 5284.03 kg/ha (Table 13). The minimum grain yield (124.5 kg/ha) was recorded from Olbye-1 while the maximum (5284.03 kg/ha) was observed from Kunming. The least grain yield observed among the test varieties do not differ significantly at 5% with the lowest grain yield (367.2 kg/ha) recorded from checks. However, test varieties differed significantly with check varieties for the maximum grain yield observed during this experiment (Tables 12 and 13) (LSD = 292.13). Therefore test varieties were superior over checks for grain yield during experiment two as opposed to experiment one although, there was high yield reduction among the genotypes caused by low temperature. Minimum and maximum grain yield were reduced by 84.84% and 33.1% respectively compared to the wet season (Tables 8 and 13). The genotypes grand mean for grain yield during experiment two was 1669.65 kg/ha indicating yield reduction of 58.94 % when compared with that of experiment I (4066.6 kg/ha). Plate 1, shows one of the low temperature symptoms (chlorosis) which was common at vegetative stage.

4.2.10 Relationships among selected characters with grain yields (experiment two)

The correlation coefficients between grain yield and the characters studied were computed and results are presented on Table 14. Grain yield showed very highly significant positive correlation with filled spikelets per panicle ($r = 0.366^{***}$) and panicle length ($r = 0.334^{***}$). It also had a significant negative correlation with percentage spikelets sterility ($r = -0.291^{*}$). Correlations with the rest of the variables were not significant (Table 14).

Days to 50% flowering showed very highly significant positive correlation (r = 0.932***) with days to 90% maturity and plant height (0.414***) and highly significant positive correlation with number of filled spikelets per panicle (0.311**). It also had significant positive correlation with 1000 grain weight (0.279*) and highly significant negative correlation (r = -0.307**) with productive tillers per hill. There was also a non significant correlation with panicle length (Table 14).

Days to 90% maturity showed very highly significant correlation with plant height (r = 0.402***) and non significant correlation with filled spikelets per panicle, 1000 grain weight and percent sterility. Days to 90% maturity showed a weak negative correlation with productive tillers (Table 14).

Plant height showed very highly significant positive correlation with panicle length (r = 0. 723***), significant positive correlation with 1000 grain weight (r = 0. 270*), a positive non significant correlation with filled spikelets per panicle and highly negative correlation with productive tillers per hill (r = -0.339**).

In addition panicle length exhibited very highly significant correlation with filled spikelets per panicle (r = 0.325***). The rest of the variables were not significant. Reproductive tillers per hill showed very highly significant negative correlation with 1000 grain weight (r = -0.541***), highly significant positive correlation with percent spikelet sterility (r = 0.361**) and a non significant correlation with filled spikelets per panicle. Filled spikelets per panicle also exhibited very highly significant negative correlation with percent spikelet sterility (r = -0.509***) (Table 14).

Table 13: Agronomic and growth characteristics of the test genotypes (experiment two)

		Blocks number	Days to 50% flow	Maturity days	Plant height (cm)	Pan. length (cm)	No. of reprod Tiller/hill	Yield kg/ha	1000 Grain wt. (g)	No. of filled grains/pan	Spikelet sterility (%)
1	WAB 450-12-2-BL1-DV1	1	118	141	85.3	20.85	8.06	1526.22	25.18	73.04	21.08
2	Geumobyeo	1	106	148	71.3	18.05	18.46	2263.43	21.88	58.92	31.98
3	X-jigna	1	106	141	101.5	27.25	14.66	1567.93	26.95	60.12	35.45
4	Zhongeng	1	122	153	116.1	32.05	9.66	1612.61	26.30	79.84	40.58
5	M 202	1	122	153	69.5	15.85	11.06	1582.85	26.79	58.44	31.67
6	Lanbayeque	1	110	141	96.1	15.65	13.86	1818.80	21.63	55.12	39.50
7	FOFIFA 4178	1	106	141	79.5	19.05	6.86	675.95	32.62	78.08	25.46
8	Supa M-106	1	141	170	111.3	22.05	9.66	2590.03	26.78	103.99	31.33
9	Amaro	1	126	153	84.1	17.65	9.86	1717.58	27.25	63.12	24.27
10	Palung-2	1	102	136	91.9	24.85	14.66	751.18	20.63	84.72	32.44
11	87020-TR-968-1	1	106	141	71.7	17.25	13.46	1109.36	19.83	70.92	23.42
12	Supa M-101-22	1	141	170	107.7	20.05	10.06	928.73	29.99	64.34	42.72
13	86011-TR-888-2-1-2-1	1	102	136	79.7	18.25	13.06	2939.94	31.33	5.39	29.98
14	WAB 515-B-16A1.1	2	96	132	96.7	29.09	8.74	1006.03	27.87	98.96	4.97
15	Somewake	2	96	141	80.3	17.69	11.94	2420.9	30.63	49.88	20.62
16	Stejaree	2	102	141	95.5	31.29	11.14	1503.66	21.99	112.19	8.98
17	Chandannath-1	2	122	153	77.7	21.49	15.34	2943.28	19.19	109.64	17.97
18	FAC 56	2	110	136	144.5	35.69	10.54	4222.76	28.07	49.39	23.69
19	Kunming	2	126	153	144.5	30.49	6.94	1654.80	26.24	76.84	19.12
20	Silewah	2	106	141	85.3	21.49	15.54	1621.57	22.49	82.92	15.86
21	Skau 23	2	86	141	50.9	11.69	30.14	124.54	18.61	10.96	74.49
22	Olbye-1	2	136	166	83.1	17.49	12.14	784.83	26.14	76.92	16.14
23	Yunyin	2	136	170	92.3	17.69	7.54	521.88	30.28	48.99	25.37
24	Dourado agulaha	2	110	141	81.3	15.69	7.34	1201.82	32.61	39.92	30.13
25	Mwangaza	2	141	170	102.9	20.89	10.54	3090.30	30.09	102.04	21.77
26	Supa M-70-10	2	126	153	90.9	26.49	7.74	4073.78	26.42	107.96	21.23
27	Yunkeng	3	102	136	77.8	19.13	16.18	968.58	20.83	44.28	36.05
28	Koshihikari	3	92	126	69.6	14.13	9.98	599.73	32.67	12.04	69.83
29	88076-TR-1101-9-2-1	3	96	136	77.4	16.93	9.18	1228.54	29.51	69.28	14.93
30	WAB 189-B-B-B-B-HB	3	96	136	78.4	13.93	9.18	1602.88	27.69	52.28	32.76

Table 13: Agronomic and growth characteristics of the test genotypes (experiment two) cont.....

		Blocks number	Days to 50% flow	Maturity days	Plant height (cm)	Pan. length (cm)	No. of reprod. Tiller/hill	Yield kg/ha	1000 Grain wt. (g)	No. of filled grains/pan	Spikelet sterility (%)
31	HS 379	3	102	136	67.2	14.53	10.58	1602.88	30.83	62.88	27.38
32	89010-TR-1130-8-1-1-2	3	102	136	87.6	14.93	9.58	1085.09	36.32	59.44	17.22
33	88088-TR-111-4-1-1	3	126	153	121.8	27.33	6.98	2289.74	25.58	68.84	10.26
34	Padi Labou alumbra	3	126	153	106.6	20.93	7.18	1947.31	29.59	38.19	29.63
35	Padisashal	3	110	141	79.2	18.33	6.18	1755.08	32.48	51.48	8.27
36	FOFIFA 4355	3	96	132	112.2	25.53	6.98	1414.84	27.86	71.19	33.87
37	Polvidov 22	3	136	166	90.6	23.53	13.38	2405.09	28.09	57.08	28.76
38	Calaro	3	106	141	81.4	23.13	12.98	1870.95	23.45	51.01	35.60
39	Skau 105	3	96	126	98.6	26.53	13.18	1994.27	26.22	48.39	25.96
40	Machhapuchre	4	126	153	105.4	27.73	7.62	1006.03	29.84	75.01	13.59
41	FOFIFA 3737	4	102	141	83.9	23.93	6.62	2569.26	28.52	44.32	24.22
42	Chandannath-3	4	96	141	109.2	27.53	8.82	2538.22	25.07	46.27	62.73
43	Jumlimorshi	4	96	141	89.8	20.53	8.62	295.57	22.13	39.81	19.23
44	China 1039	4	96	141	87.9	18.53	17.62	796.58	23.02	36.57	58.35
45	Yoneshiro	4	96	141	70.4	17.73	16.82	633.28	23.78	60.81	28.89
46	YR 1076-B-4-1-2-3-1-2	4	102	148	75.8	18.53	8.02	728.66	23.19	77.13	42.12
47	Diamante	4	102	136	80.8	18.93	12.02	1198.45	29.86	62.37	26.86
48	88090-TR-1115-4-1-1	4	102	136	88.6	19.13	9.62	1269.33	36.19	72.53	24.39
49	Yunlen 15	4	126	153	88.8	29.13	13.62	1274.75	23.07	140.17	25.11
50	Chomrong	4	102	136	108.2	24.73	12.02	1807.21	28.16	56.21	12.19
51	Salama M-19	4	136	153	82.9	19.73	8.02	587.63	28.02	54.97	20.05
52	Agulah	4	132	153	98.8	18.93	8.82	760.38	33.04	67.53	22.21
	Varietal Mean		**111.56**	**145.25**	**90.59**	**21.35**	**11.13**	**1669.65**	**26.98**	**65.63**	**28.09**
	BiVi – BiVj (LSD 1)		**0.06**	**0.06**	**13.55**	**4.06**	**3.61**	**338.45**	**0.75**	**44.06**	**23.35**
	BiVi - BjVj (LSD 2)		**0.07**	**0.06**	**14.85**	**4.45**	**3.95**	**370.76**	**0.83**	**48.27**	**25.58**
	Ci - Vi (LSD 3)		**0.05**	**0.05**	**11.70**	**3.50**	**3.12**	**292.13**	**0.65**	**38.03**	**20.16**
	Pr > F		***	***	***	***	*	***	***	ns	*

Key

*** = significant at 0.001 probability level, ** = significant at 0.01 probability level, *= significant at 0.05 probability level, ns = No significant difference at 0.05 50% flow = Days from transplanting to 50% heading. Pan. length = Panicle length. No. of Reprod. Tiller/hill = Number of reproductive tillers per hill. 1000 grain wt. = Thousands grain weight. No. of Filled spklts/pan = Number of filled spikelets per panicle.

BiVi - Bivj (CD/LSD 1) – Standard error to compare the difference of test varieties in the same block.
BiVi-BjVj (CD/LSD 2) - Standard error to compare the difference of test varieties in different blocks.
Ci –Vi (CD/LSD 3) - Standard error to compare the difference of test varieties and a check mean.

Plate 1: Symptoms of low temperature (chlorosis) which was common at vegetative stage in experiment two.

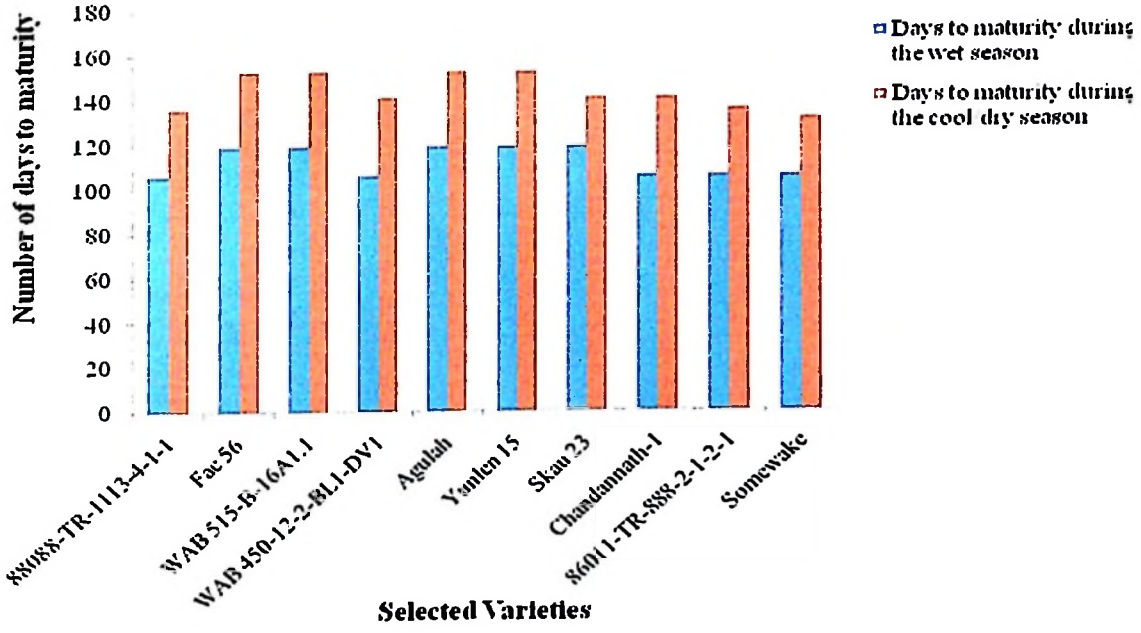

Figure 1: Comparison of days to maturity for the selected genotypes between wet and cool/dry seasons.

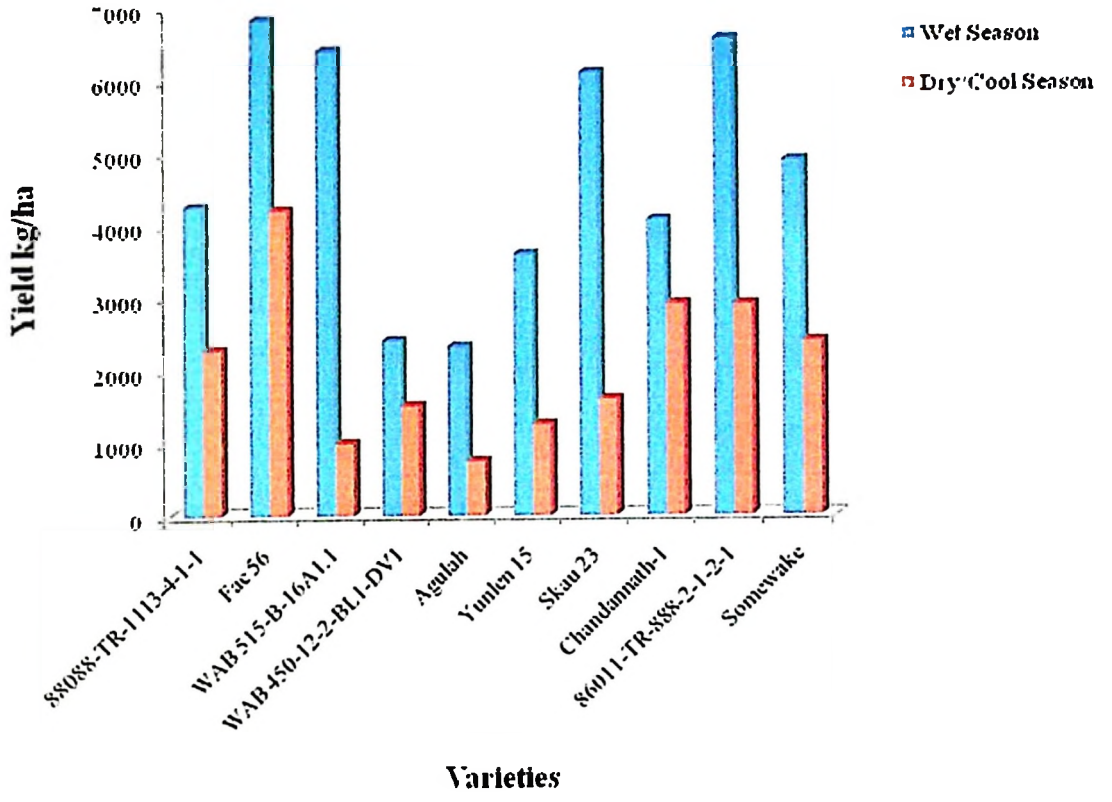

Figure 2: Yield comparison of the selected genotypes between wet and dry/cool seasons

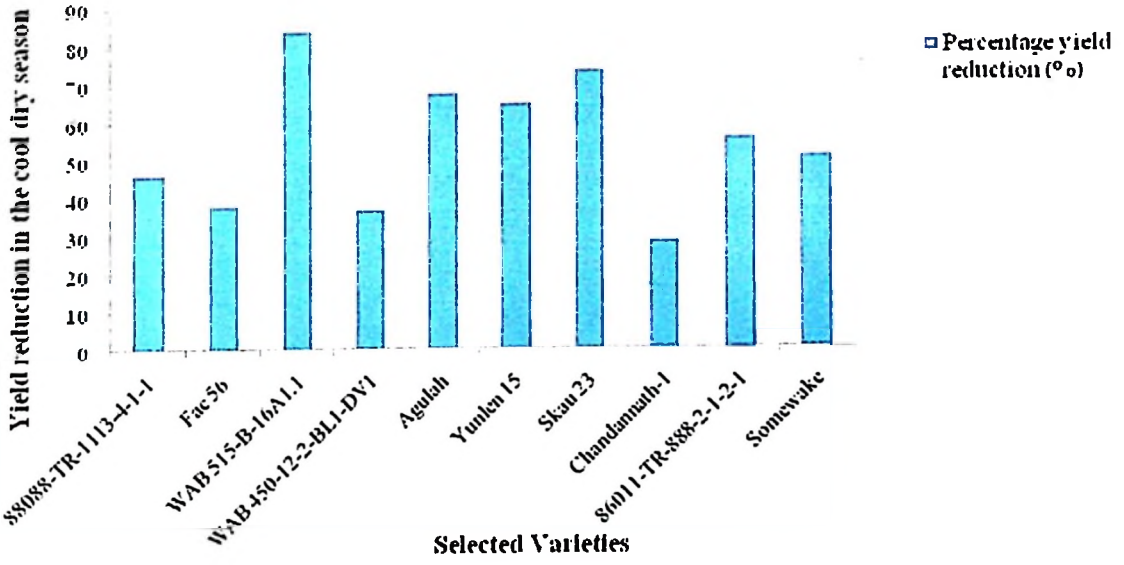

Figure 3: Percentage yield reduction due low temperature (dry season) in comparison to the wet season.

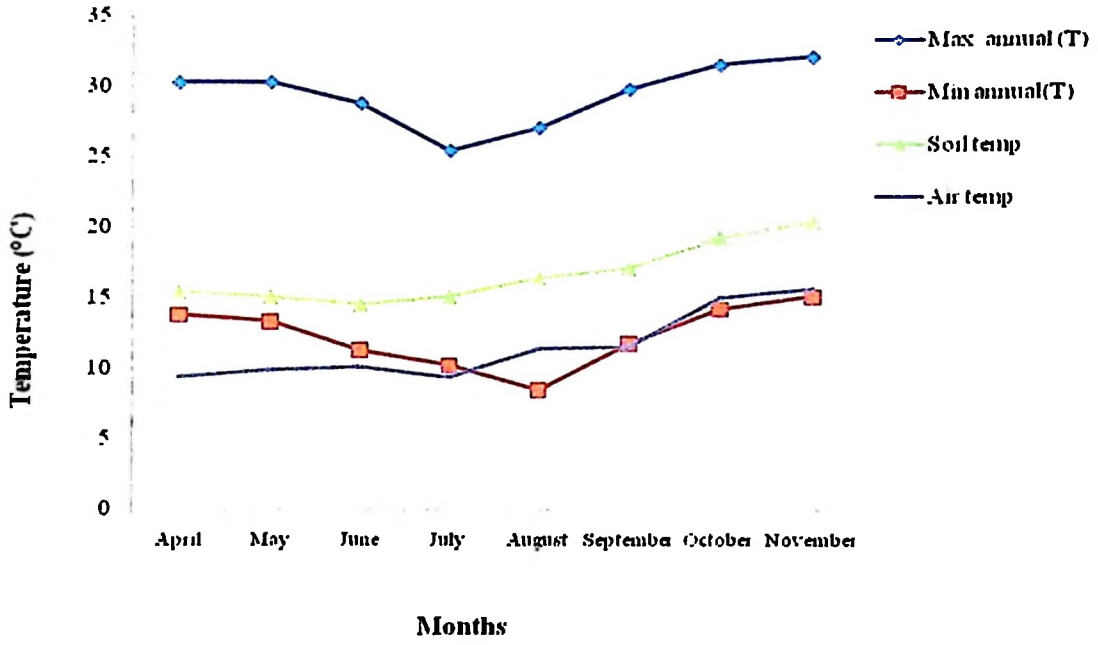

Figure 4: Maximum and minimum annual temperatures, soil and air temperature during the cool/dry season.

4.2.11 Estimates of variance components and genetic parameters (experiment two)

Analyses of variance components and genetic parameters were computed and compared for the variables studied during experiment two (Table 15). Grain yield, filled spikelets per panicle and plant height exhibited high genotypic and phenotypic variances, followed by days to 50% flowering, days to 90% maturity and percentage sterility.

The variables studied showed low to high genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) with slight reduction compared to experiment one. The highest values for GCV and PCV were recorded for grain yield (51.58%, 51.99%), percent sterility (36.69%, 45.54%), productive tillers per hill (31.14%, 32.87%), filled spikelets per panicle (23.76%, 32.24%), and for panicle length (21.15%, 22.03%) respectively.

Moderate values for GCV and PCV were recorded for 1000 grain weight (13.58%, 13.61%), plant height (16.96%, 17.64%) and for days to 50% flowering (11.86% for each) respectively. Low GCV and PCV were recorded for days to 50% flowering (6.67% for each) (Table 15). The comparison of GCV and PCV values for experiments one and two indicated reduction in magnitude for all traits studied except for grain yield. For example, GCV and PCV for 50% flowering were reduced by 16.95% for each, days to 90% maturity by 34.46% for each, plant height by 12.08% and 10.59%, number of filled spikelets per panicle by 47.13% and 39.97% and number of reproductive tillers/ hill by 16.31% and 15.57% respectively as compared to experiment one.

Heritability in broad sense (h^2b) was higher (65 to 100%) for all the traits studied except for filled spikelets per panicle which had a moderate value (54%). The heritability values do not differ largely in magnitude with those recorded in experiment one (Tables 10 and 15). However, as it was the case for GCV and PCV values, heritability showed slight reduction in magnitude in relation to the wet season for some characters viz., plant height (4.17%), productive tillers per hill (2.19%), filled spikelets per panicle (22.86%) and percent sterility (15.58%). However no magnitude reduction was observed in heritability for grain yield, days to 50% flowering and days to 90% flowering while there was an increase in magnitude for heritability for panicle length (4.55%) and 1000 grain weight.

The agronomic traits under study exhibited high genetic advance (24.42% to 105.39%) as per cent of mean (GAM) except for 90% maturity (13.75%) (Table 15). The lowest value (24.42%) in the range was recorded for days to 50% flowering and the highest (105.39%) for grain yield. The rest of the characters showed moderate magnitude of GCV coupled by high heritability and genetic advance.

Table 14: Simple correlation coefficients (d.f = 56) of some rice parameters (experiment two)

Character/Trait	50% Flow	Maturity	Pheight	Panlength	Rtillers/hill	1000gwt	Fspklts/pa	Sterility	Grain yield
50% flow	1.000	0.932***	0.414***	0.112	-0.307**	0.279*	0.311**	-0.049	0.059
Maturity		1.000	0.402***	0.085	-0.163	0.215	0.201	0.136	-0.064
Pheight			1.000	0.723 ***	-0.339**	0.270*	0.104	0.064	0.145
Panlength				1.000	-0.175	-0.081	0.325**	-0.144	0.334**
Rtillers/hill					1.000	-0.541 ***	0.183	0.361**	-0.078
1000 gwt						1.000	0.082	-0.045	-0.054
Filled spklts/pa							1.000	-0.509***	0.366**
% Sterility								1.000	-0.291*
Grain yield									1.000

Key:

*** = significant at $p \leq 0.001$
** = significant at $p \leq 0.01$
* = significant at $p \leq 0.05$
NB: Figures without asterisk are not significant at 0.05

50% flow = Number of days to 50% flowering.
Maturity = Number of days to 90% maturity.
Pheight = Plant height
Panlength Panicle length
Rtillers/hill = Number of reproductive tillers per hill
1000 gwt = Thousand grain weight
Fspklts/pa = Number of filled spikelets per panicle
Gyield = Grain yield.

Table 15: Estimates of variance components and genetic parameters for the selected traits (experiment two)

Trait	$G\delta^2$	$P\delta^2$	$E\ \delta^2$	ECV%	GCV%	PCV%	h^2_b	GA 5%	GAM 5%
Days to 50% flowering	174.894	174.895	0.0004	0.017	11.855	11.855	1.00	27.243	24.421
Days to 90% Maturity	93.937	93.938	0.0003	0.012	6.673	6.673	1.00	19.966	13.746
Plant height	236.151	255.498	19.347	4.855	16.963	17.644	0.92	30.434	33.595
Panicle length	20.373	22.108	1.736	6.172	21.145	22.027	0.92	8.926	41.813
Reproductive tillers/hill	12.012	13.384	1.372	10.522	31.138	32.868	0.89	6.764	60.768
Grain yield	741557.02	753622.31	12065.29	6.579	51.576	51.994	0.98	1759.68	105.393
1000 grain weight	13.411	13.471	0.059	0.907	13.575	13.605	0.99	7.527	27.902
Filled spikelets/ panicle	243.194	447.691	204.497	21.790	23.762	32.240	0.54	23.677	36.078
Percent sterility	106.219	163.654	57.434	26.977	36.687	45.537	0.65	17.105	60.886

Key:

$G\delta^2$ = Genotypic variance
$P\delta^2$ = Phenotypic variance
$E\ \delta^2$ = Environmental variance
ECV = Environmental coefficient of variation (%)
GCV = Genotypic coefficient of variation (%)
PCV = Phenotypic coefficient of variation (%)
GA = Genetic Advancement (5%)
GAM = Genetic Advancement as a percentage of mean (5%)

4.3 Participatory Varietal Selection (PVS)

Results from participatory varietal selection are presented in Tables 16 to 18. Each farmer selected ten (10) good and ten poorly performing genotypes. Results from the selection were subjected to Statistical Package for Social Science studies to obtain the frequency of selection. However, only the summaries for good performing varieties from the two selections were presented in Tables 16 and 17. The farmers who participated and evaluated the trial were representative to the area, most of them having long experience in rice farming. Comparison of the results from the two selections indicated that, three genotypes out of ten had a common selection. These genotypes and percent of selection in the parenthesis during vegetative stage were; 88088-TR-1113-4-1-1 (38.9%), Chandannath-1 (33.3%) and Fac 56 (27.8%). Selection at maturity indicated that, the genotype 88088-TR-1113-4-1-1 ranked the first with 90.5% of selection, followed by, Fac 56 (80.9%), WAB 515-B-16A1.1 (71.4%) and WAB 450-12-2-BL1-DV1 (52.4%) (Table 17). This indicates high chances of acceptance of these varieties after release. Farmers used about 16 and 21 different criteria to judge the genotypes during PVS at vegetative and maturity stages respectively. The most frequently cited ones were presented in Appendices one and two where good tillering ranked the first in each case.

The selected genotypes matured between 106 to 119 days during experiment one and between 132 to 153 days during experiment two. The maximum number of days to maturity recorded during experiment one was 148 and 178 days during experiment two (Fig. 1). Results show that the selected varieties were early to medium maturing ones. Furthermore, results from absolute and pairwise ranking indicated that the genotype 88088-TR-1113-4-1-1 was the most preferred variety, followed by WAB 515-B-16A1.1, Fac 56 and WAB 450-12-2-BL1-DV1 (Tables 17 and 18). Plates two and three show PVS activities at vegetative and maturity stages respectively.

Plate 2: Farmers participation du ring PVS at vegetative stage

Plate 3: Farmers participation during PVS at maturity stage

Absolute Ranking

Table 16: Varieties that performed well at vegetative phase (PVS) (n =18)

S/N	Variety	No. of farmers	Selection %age	Rank
1	HS 379	15	83.3	1
2	X-jigna	13	72.2	2
3	Geumobyeo	12	66.7	3
4	Olbye-1	9	50.0	4
5	Zhongeng	9	50.0	5
6	88088-TR-1113-4-1-1	7	38.9	6
7	Chandannath-1	6	33.3	7
8	Fac 56	5	27.8	8
9	China 1039	5	27.8	9
10	Skau 105	5	27.8	10

*Percentages do not add up to 100 because each farmer was required to select at most ten varieties

Absolute Ranking

Table 17: Varieties that performed well at maturity stage (PVS) (n = 21)

S/N	Variety	No. of farmers	Selection %age	Rank
1	88088-TR-1113-4-1-1	19	90.5	1
2	Fac 56	17	80.9	2
3	WAB 515-B-16A1.1	15	71.4	3
4	WAB 450-12-2-BL1- DV1	11	52.4	4
5	Agulah	10	47.6	5
6	Yunlen 15	9	42.9	6
7	Skau 23	8	38.9	7
8	Chandannath-1	8	38.9	8
9	86011-TR-888-2-1-2-1	7	33.3	9
10	Somewake	7	33.3	10

*Percentages do not add up to 100 because each farmer was required to select at most ten varieties

Table 18: Pairwise ranking of cold tolerant genotypes at Igurusi Ward in 2011 (experiment two)

	88088-TR-1113	Fac 56	WAB 515	WAB 450	Agulah	Yunlen 15	Skau 23	Chandannat-1	86011-TR	Somewake	Total	Rank
88088-TR-1113	——	A	A	A	A	A	A	A	A	A	9	1
Fac 56		——	C	B	B	B	B	B	B	B	7	3
WAB 515			——	C	C	C	C	C	C	C	8	2
WAB 450				——	D	D	D	D	D	D	6	4
Agulah					——	E	E	E	E	E	5	5
Yunlen 15						——	G	F	I	F	2	8
Skau 23							——	G	I	G	3	7
Chandannat-1								——	I	J	0	10
86011-TR-888-2-1-2-1									——	I	4	6
Somewake										——	1	9

Key: Each letter represents a variety on the table, variety with the lowest number was the highly preferred.

A = 88088-TR-1113-4-1-1
B = Fac 56
C = WAB 515-B-16A1.1
D = WAB 450-12-2-BL1-DV1
E = Agulah
F = Yunlen 15
G = Skau 23
H = Chandannath-1
I = 86011-TR-888-2-1-2-1
J = Somewake

4.4 Grain Quality of the Selected Genotypes and two Local Checks (experiment three)

4.4.1 Physical characteristics

Analysis of variance showed very highly significant differences ($p \leq 0.001$) among the studied genotypes for kernel length, kernel width and length to width ratio (L/W) (Table 19). Kernels length ranged from 4.99 to 7.44 mm with grand mean of 6.44 mm (Table 22). The minimum kernel length (4.99 mm) was observed in Somewake while the maximum (7.44mm) was recorded from Agulah and 88088-TR-1113-4-1-1. Among the studied genotypes, seven had long size kernels ranging from 6.63 to 7.44 mm, two medium (5.9 mm) and three short (4.99 to 5.21mm) (Table 22). Kernel length to width ratio (L/W) ranged from 1.55 to 3.07 mm (Table 19). The lowest length to width ratio (1.55mm) was recorded on Somewake while the highest (3.07 mm) was observed from Mbawambili. Genotypes with long and medium kernel lengths viz., 88088-TR-1113-4-1-1, WAB 515-B-16A1.1, Agulah, WAB 450-12-2-BL-DV1, 86011-TR-888-2-1-2-1, Cherehani, Fac 56 and Skau 23 had a medium shape except Mbawambili which had a long slender shape (Table 22). Those with short kernel length viz., Yunlen 15, Chandannath-1 and Somewake had bold shapes (Table 22).

Chalkiness was recorded among all the selected genotypes studied. The highest chalkiness was recorded in genotype Yunlen 15 (29.16%) and WAB 515 – B- 16A1.1 (28.90%). The lowest chalkiness was recorded in Chandannath-1 (3.13%) followed by Somewake (4.10) (Table 22). The percentage of chalkiness in all the genotypes studied ranged from 3.13% to 29.16% which in turn falls in two categories of chalkiness viz., small (kernel area less than 10%) and large (kernel area more than 20%).

4.4.2 Chemical characteristics

Gelatinization temperature of the grains for the tested genotypes ranged from low (55 °C) to high (79 °C) with most of the genotypes belonging to the intermediate class (70-74 °C) (Table 22). High gelatinization temperature (>74 °C) was recorded in two genotypes viz., WAB 450-12-2-BL1-DV1 and Skau 23 while low gelatinization temperature (55 - 69 °C) was recorded from Yunlen 15 and Somewake. Intermediate gelatinization temperature (70-74 °C) was recorded from six (6) genotypes viz., 88088-TR-1113-4-1-1, Fac 56, WAB %15-B-16A1.1, Agulah, Chandannath-1 and 86011-TR-888-2-1-2-1 (Table 22). Intermediate gelatinization temperature is highly desirable for quality grains. However, amylose content was not determined because of lack of proper equipments.

Analysis of variance revealed very highly significant differences ($p \leq 0.001$) among the studied genotypes for gel consistencies (Table 20). Gel consistencies ranged from 47.5 to 74 mm with the grand mean of 62.38 mm (Table 22). The minimum gel length (47.5mm) was recorded from Fac 56 and the highest (74 mm) was observed in Mbawambili. The studied genotypes fall in two categories viz., medium (47.5 to 55.5 mm) and soft (63 to 74 mm) gel consistency. Medium gel consistency was observed in Cherehani, Fac 56, Skau 23 and WAB 515-B-16A1.1 while soft gel was recorded from the remaining genotypes (Table 22).

Aroma exhibited very highly significant differences ($p \leq 0.001$) among the studied genotypes (Table 21). Among the selected genotypes, two were non scented with aroma mean score <0.5 viz., Skau 23 (0.36) and 86011-TR-888-2-1-2-1(0.41). The rest of the genotypes were mild scented with mean score ranging from 0.59 to 1.32. The coefficient of variation for aroma scores was 60% and the grand mean was 0.88. Local varieties tested simultaneously with the selected test genotypes were mild scented (Mbawambili) and strongly scented (Cherehani) with mean scores of 1.27 and 1.91 respectively (Table 22).

4.4.3 Cooking characteristics

Analysis of variance showed very highly significant differences ($p \leq 0.001$) for kernel elongation ratio among the tested genotypes (Table 19). Kernel elongation ratio (ER) ranged from 1.36 to 1.76. Highest kernel elongation ratio was observed in Chandannath-1 and lowest in WAB 515 –B- 16A1.1. The grand mean and coefficient of variation (CV) for kernel elongation ratio were 1.46 and 8.2% respectively (Table 22).

Volume expansion ratio (VER) exhibited highly significant differences ($p \leq 0.001$) among the test genotypes (Table 20). The volume expansion ratio ranged from 3.76 to 4.59. The lowest volume expansion ratio was observed in 88088-TR-1113-4-1-1 and the highest in Somewake. The two local varieties tested with the selected varieties showed medium (4.09) and high (4.66) volume expansion ratio and recorded from Cherehani and Mbawambili respectively. The genotypes grand mean and coefficient of variation for volume expansion ratio were 4.13 and 0.3% respectively.

Table 19: Mean squares of selected rice genotypes for grain quality appearance traits

Source of variation	Df	Kernel length	Kernel width	Length/ Width	Length after cooking	Elongation ratio
Replication	9	0.156	0.019	0.014	0.682	0.022
Genotype	11	9.677***	0.873***	2.489 ***	12.361****	0.122***
Error	99	0.066	0.011	0.016	0.423	0.014

Table 20: Mean squares of selected rice genotypes for gel length and volume expansion ratio

Source of Variation	Df	Gel length	Volume expansion ratio
Replication	2	13.021	0.145
Genotype	11	284.608***	0.314****
Error	22	8.566	0.0001

Table 21: Mean squares of selected rice genotypes for aroma trait

Source of Variation	Df	Aroma scores
Replication	21	0.704
Genotype	11	4.3426***
Error	231	0.281

Key
*** = Significant at 0.001

Table 22: Grain quality characteristics of selected rice genotypes

Genotype	L	Size	W	LC	L/W	Shape	ER	VER	Gel L	Scale	Gel type
1. 88088-TR-1113-4-1-1	7.435	Long	2.86	10.2	2.60	Medium	1.379	3.758	67.0	3	Soft
2. Fac 56	5.900	Medium	2.23	8.4	2.65	Medium	1.424	3.810	47.5	5	Medium
3. WAB 515 -B-16A1.1	7.260	Long	2.70	9.8	2.69	Medium	1.356	4.385	49.0	5	Medium
4. WAB 450-12-2-BL-DV1	6.630	Long	2.34	9.9	2.84	Medium	1.496	4.326	63.0	5	Soft
5. Agulah	7.440	Long	2.82	10.4	2.64	Medium	1.397	4.237	69.5	5	Soft
6. Yunlen 15	5.210	Short	2.99	7.9	1.75	Bold	1.518	3.841	73.5	5	Soft
7. Skau 23	5.890	Medium	2.57	9.0	2.29	Medium	1.530	3.796	48.5	5	Medium
8. Chandannath-1	5.055	Short	2.79	8.9	1.81	Bold	1.761	4.259	67.0	5	Soft
9. 86011-TR-888-2-1-2-1	6.765	Long	2.90	9.4	2.33	Medium	1.390	3.830	69.0	5	Soft
10. Somewake	4.990	Short	3.22	7.0	1.55	Bold	1.409	4.593	65.0	5	Soft
11. Cherehani	7.335	Long	2.45	10.5	2.99	Medium	1.432	4.659	55.5	5	Medium
12. Mbawambili	7.395	Long	2.41	10.4	3.07	Slender	1.407	4.096	74.0	3	Soft
Mean	**6.442**	**Medium**	**2.69**	**9.32**	**2.44**	**Medium**	**1.458**	**4.133**	**62.38**	**3**	**Soft**
CV%	**4.0**	**-**	**3.9**	**7.0**	**5.20**	**-**	**8.2**	**0.3**	**4.7**	**-**	
Se	**0.257**	**-**	**0.106**	**0.650**	**0.126**	**-**	**0.119**	**0.013**	**2.927**	**-**	
LSD 5%	**0.228**	**-**	**0.094**	**0.577**	**0.111**	**-**	**0.106**	**0.022**	**4.956**	**-**	
Pr > F	***		***	***	***	-	***	***	***	-	

Key:
*** = significant at 0.001
L = Kernel length, LC = Length of cooked rice, W = kernel width, L/W = Length width ratio, ER = Elongation ratio, VER = Volume expansion ratio, Gel L = Gel legth (mm), GT classfcn = Gelatinization temperature classification.

Table 22: Grain quality characteristics of selected rice genotypes cont....

Genotype	Chalkiness %	Kernel area	Scores for aroma	Aroma	GT	GT Classfctn
1. 88088-TR-1113-4-1-1	5.23	Small (<10 %)	0.82	Mild scented	70-74 °C	Intermediate
2. Fac 56	5.49	Small (<10 %)	1.32	Mild scented	70-74 °C	Intermediate
3. WAB 515 -B-16A1.1	28.90	Large (>20 %)	0.68	Mild scented	70-74 °C	Intermediate
4. WAB 450-12-2-BL1-DV1	9.56	Small (<10 %)	0.91	Mild scented	> 74 °C	High
5. Agulah	6.55	Small (<10 %)	0.59	Mild scented	70-74 °C	Intermediate
6. Yunlen 15	29.16	Large (>20 %)	1.05	Mild scented	55-69 °C	Low
7. Skau 23	10.47	Medium (11- 20%)	0.36	Non scented	> 74 °C	High
8. Chandannath-1	3.13	Small (<10 %)	0.68	Mild scented	70-74 °C	Intermediate
9. 86011-TR-888-2-1-2-1	6.09	Small (<10 %)	0.41	Non scented	70-74 °C	Intermediate
10. Somewake	4.10	Small (<10 %)	0.59	Mild scented	55-69 °C	Low
11. Cherehani	5.10	Small (<10 %)	1.91	Strongly scented	70-74 °C	Intermediate
12 Mbawambili			1.27	Mild scented	70-74 °C	Intermediate
Mean			**0.883**	**Mild scented**		
CV%			**60.0**			
Se			**0.529**			
LSD 5%			**0.315**			
Pr > F			***			

Key:
*** = Significant at 0.001, GT = Gelatinization temperature, GT classfctn = Gelatinization temperature classification. < 0.5 = Non scented, 0.51- 1.5 = Mild scented, >1.51-2.0 = Scented

CHAPTER FIVE

5.0 DISCUSSION

5.1 Cold Tolerance Evaluation Parameters

The results from analysis of variance for the check varieties revealed variation among blocks within the same experimental field. There were significant to very highly significant differences ($p< 0.001$) among the check varieties for the characters under consideration in both experiments except for number of days to maturity, number of filled spikelets per panicle and percentage spikelets sterility in experiment one while in experiment two, exception was made only on number of filled spikelet per panicle. This revealed that, field condition was not uniform in the study area. Thus performance of the test varieties in each block was adjusted according to the block effects measured by the checks according to Petersen (1985) and Sharma (1988).

Results from the analyses of variance for both experiments showed that the differences among the varietal means were significant to very highly significant. This indicated that, the test genotypes exhibit a sufficient amount of genetic variability in which desired lines can be selected for further manipulation.

The results showed that, the genotypes tested flowered later in experiment two as compared to experiment one. The wide range for number of days to 50% flowering among the test genotypes in experiments one and two indicates adequate genetic variability for the character. The observed variability might be the effects of low temperature damage. Low temperature causes slow vegetative growth and delayed heading (Lee, 2001). Delay in number of days to 50 % flowering due to low temperature was also reported by Oh *et al.* (2004) when mapping quantitative trait loci (QTL) for cold tolerance in rice. Zenna and

Berhe (2009) also reported the same in a cold tolerance rice trial. Jena *et al.* (2010) also reported delayed flowering due to low temperature during the development of cold tolerant breeding lines using QTL analysis in rice. However, many of the test genotypes with exception of the mutant lines flowered earlier than the check varieties in experiments one and two. The better performance of the test genotypes over the checks might be the genotypic novelty and adaptability to the test environment. Heading date is one of the most important traits for the adaptation of rice to different cultivation areas and cropping seasons (Wei *et al.*, 2009).

The test genotypes faced very low temperature (<16 °C) during vegetative stage than at reproductive stage (Fig. 4). The early flowering genotype (Olbye-1) attained fifty percent (50%) flowering in late August when temperature was below 17 °C. Thus it had faced low temperature arrest at microsporogenesis stage hence high spikelet sterility compared to other test genotypes that flowered in late August and early September when the temperature was at an average of 17 °C. As a result, late maturing varieties were able to escape low temperature stress during panicle initiation. The vegetative phase-stress may be recoverable but make the crop extend the growth duration. Normally there is unrepairable loss if the stress is imposed at the reproductive phase (Nahar *et al.*, 2009a).

The study revealed that, the test genotypes took longer to attain maturity during experiment two compared to experiment one. Minimum and maximum number of days to maturity in experiment two were prolonged by 27% and 14.9% respectively in relation to experiment one. Delayed flowering and consequently maturity is not the genetic makeup of the variety rather might be an effect of low temperature damage (Jennings *et al.*, 1979). Flowering occurs when a certain critical level of carbon to nitrogen (C/N) ratio is reached. Now under higher temperatures photosynthesis enhances carbohydrates production hence,

C/N ratio is raised faster for flowering. The reverse is true under low temperatures. Days to maturity plays a vital role in the cropping system. Early maturing varieties evacuate the land early for the next crop and escape from pest attack (Jamal *et al.*, 2009). Thus, allowing double cropping thereby increasing food security and improve rural livelihood. However, close examination of the test genotypes revealed that, the grain filling period was higher in experiment one compared to experiment two. This was assessed by comparing the number of days from 50% flowering to maturity for the two experiments. This might be one of the reasons for relatively low grain yields observed in experiment two in relation to experiment one. It is documented that, higher grain yields is associated with higher grain filling periods (Jennings *et al.*, 1979).

While number of days to heading and that of maturity were prolonged in experiment two as compared to experiment one, other traits like plant height and panicle length were reduced. Minimum and maximum plant height was reduced by 9.23% and 19.04% respectively while grand mean was reduced by 11.7% in relation to experiment one. This might be the effects of low temperature damage. Low temperatures can affect the rice plant's developmental processes and impair photosynthesis, thus reducing growth and resulting in indirect yield loss due to less carbohydrate available for grain production (Lee, 2001; Smillie *et al.*, 1988). Studies done by Zenna and Berhe (2009) on a cold tolerance rice trial, reported height reduction of up to 60% due to low temperatures. Plant height is mostly under genetic control of the cultivar, but environmental factors can also influence it (Ashrafuzzman *et al.*, 2009). It is stated that, taller genotypes have a higher leaf area index and a faster crop growth rate, thus they are more likely to produce more dry matter and filled grains per panicle as a result of longer panicles rather than dwarf cultivars (Lack, 2011).

Mean performance for agronomic and morphological traits between experiment one and two indicated a reduction of 15.8% and 70.1% for minimum and maximum number of filled spikelets per panicle respectively. Furthermore, the grand mean indicated a reduction of more than 50%, meaning that grain yield was also reduced by more than 50% depending on the extent of damage on the other yield components. Filled spikelets reduction in experiment two might be a result of low temperature damage (Jennings *et al.*, 1979). Nahar *et al.* (2009) reported filled spikelets reduction of up 38.52 % due to low temperature in the late transplanted rice. Studies done by Zenna and Berhe (2009) in a cold tolerance rice trial, reported spikelets fertility of up 60% due low temperature. Fertile spikelets are an obvious prerequisite for high grain yield. Thus, the fewer the number of filled spikelets per panicle the lower the grain yield and vice versa provided that other factors remain constant.

In addition test genotypes exhibited significant to highly significant differences ($p \leq 0.01$) for percentage spikelet sterility. Percentage sterility recorded in experiment one might have been caused by low temperature. However, the effects of low temperature during experiment one was very low due to short exposure period of the test genotypes. During the onset of low temperature in experiment one some of the genotypes were at flowering and others at milking stage hence low temperature damage was not significant compared to that of experiment two. The observed sterility falls in the range of normal spikelet sterility of 10 to 15%. According to Jennings *et al.* (1979), 10% to 15% percent sterility is a normal and allowable sterility. Percentage spikelets sterility should be estimated for breeding materials as a measurement of cold tolerance (Cruz et al., 2006; Mackill et al., 1996). Therefore percentage spikelets sterility was considered in this study as an indicator of cold tolerance by comparing experiments one and two.

Generally there was high percentage spikelets sterility among genotypes in the dry season compared to the wet season. Maximum spikelets sterility in experiment two indicated an increase of 57.59% sterility compared to experiment one. Studies done by Nahar *et al.* (2009) on late transplanted rice, reported increase in spikelets sterility of up 24.4% due to low temperature damage. Zenna and Berhe (2009), reported spikelets sterility of up to 40% in a cold tolerant rice trial. Spikelets sterility results from low temperature damage during pollen grain formation and germination (Cruz *et al.*, 2006). Low temperature disrupts the development of pollen grains, preventing fertilization and hence spikelet sterility. High spikelets sterility due to low temperature was also reported by Ortega *et al.* (2009) when studying the spatial variability of spikelets sterility in temperate rice. Test genotypes had shown high percentage spikelets sterility due to low temperature during experiment two in relation to experiment one.

The selected genotypes from participatory varietal selection had shown lower percentage spikelets sterility compared to the check varieties used. This indicates better performance of the selected test varieties. The better performance of the test genotypes over the checks might be the genotypic novelty and adaptability to the test environment. Therefore, this increases the chances of acceptance of these genotypes when they are released.

Furthermore, test genotypes performed better for one thousand grains weight in both experiments. It is documented that, values between 20 and 30 g for one thousand grains weight are considered good while those less than 20 g could be indicative of the presence of immature, damaged and unfilled grains (Diako *et al.*, 2011). Grand mean from the test genotypes for one thousand grains weight was above 26 g in both experiments indicating the suitability of the test genotypes. On the bases of one 1000 grains weight, the studied genotypes performed well as only four genotypes viz., PSB RC 92 (18.11) experiment

one, Olbye-1 (18.61 g), Fac 56 (19.18) and 87020-TR- 968-1 (19.83) for experiment two had values below 20 g. One thousand grains weight can be influenced by the environment and thus direct selection for this trait will be ineffective (Akinwale *et al.*, 2011). This is in contrast with the findings by Karim *et al.* (2007) who reported that, there was no environmental influence on the phenotypic expression of 1000 grain weight and thus phenotypic expression of one thousand grains weight was a true representation of the genetic makeup. The possible reasons for contrasting findings might be on the different set of genotypes used and environmental differences, thus gene effects may differ with populations and environments. According to Yoshida (1981), one 1000 grains weight is usually a stable varietal character because the grain size is rigidly controlled by the size of the hull. However, results from experiment two indicated a reduction of 3.76% and 5.6% for maximum one 1000 grains weight and genotype grand mean respectively compared to experiment one. This reduction might be a result of low temperature damage. Reduction of one thousand grains weight due to low temperature was also reported by Nahar *et al.* (2009) when studying the effects of low temperature on the transplanted rice.

Yield comparison among the test genotypes from experiment one and two indicated significant yield reduction as a result of low temperatures. Results from experiment two indicated that, minimum and maximum grain yields were reduced by 84.84% and 33.1% respectively compared to experiment one. Grand mean indicated grain yield reduction of up to 58.94% in relation to experiment one. Yield losses due to low temperatures are a result of incomplete pollen formation and subsequent floret sterility (Nahar *et al.*, 2009). Furthermore, the same authors reported yield reduction of up 36.73% for the late transplanted rice. It is documented that, grain yield is primarily under genetic control and its selection can be achieved through its phenotypic performance (Akinwale *et al.*, 2011). The better performance of the test genotypes during experiment one was mainly due to

favourable climatic conditions during the whole growing period as opposed to cool weather during experiment two.

5.2 Relationships of Selected Characters with Grain Yields

Results revealed that, grain yield had highly significant positive correlation with filled spikelets per panicle, days to 50% flowering and days to 90% maturity for experiment one. These results are in conformity with those reported by Pal *et al.* (2011) and Prasad *et al*, (2001) for number of days to 50% flowering and number of days to 90% maturity but contrary with those reported by Golam *et al.* (2011) for the same traits. These results agree with reports by Seyoum *et al.* (2012), Golam *et al.* (2011), Wattoo *et al.* (2010) and Hairmansis *et al.* (2010), for filled spikelets per panicle. This implies that as filled spikelets per panicle increases, grain yield tends to increase under respective conditions. Correlation between two or more positive characters will facilitate the selection because it will be followed by an increase in other properties (Lestari *et al.*, 2011). Therefore using these traits to select high yielding breeding lines in early generations will be effective. Furthermore grain yield showed highly significant positive correlation with panicle length, filled spikelets per panicle and a significant negative correlation with percent spikelet sterility in experiment two. These results agree with those of Ortega *et al.* (2009) for percent spikelet sterility. Negative correlation was expected between grain yield and percent spikelet sterility because the two are inversely related. Thus as sterility percentage increases, grain yield tends to decrease. Therefore in order to increase grain yield for rice crop, percent spikelet sterility should be minimized.

In this study, number of days to 50% flowering showed significant positive correlation with number of days to 90% maturity, plant height, 1000 grain weight, number of filled spikelets per panicle and a significant negative correlation with number of reproductive

tillers per hill during experiment one and two. Similar results were reported by Lestari *et al.* (2011) though their findings were not significant for 1000 grain weight and number of reproductive tillers per hill. Similar results were also reported by Seyoum *et al.* (2012) and Wattoo *et al.* (2010) for the number of days to 90% maturity and plant height. Therefore, plant height, number of filled spikelets per panicle, 1000 grain weights, days to 50% flowering and 90% maturity can be selected simultaneously in the breeding programmes.

In addition, plant height showed a significant positive correlation with panicle length, 1000 grain weight, filled spikelets per panicle and a negative correlation with reproductive tillers per hill during wet and dry seasons. However, filled spikelets per panicle were not significant. These results are in conformity with those reported by Lestari *et al.* (2011) for panicle length, 1000 grain weight, number of filled spikelets per panicle and reproductive tillers per hill. Pal *et al.* (2011) reported similar results for panicle length, Akinwale *et al.* (2011) for reproductive tillers per hill. This revealed that under similar set of conditions, tall plants have long panicles which in turn have more grains per panicle. Tall plants provide minimum leaf shading resulting into larger surface area for photosynthesis and consequently improved photosynthate production (Kessy, 2009). This photosynthate is translocated to various parts of the plant including the panicles and hence high grain yield provided that other factors remain constant. Positive and significant correlation between plant height and number of filled spikelets per panicle suggests that conditions that favoured increase in plant height also favoured increase in the number of filled spikelets per panicle. Therefore, these traits can be selected or improved simultaneously in breeding programmes. It is documented that selection for one trait results in progress for all characters that are positively correlated and retrogress for traits that are negatively correlated (Akinwale *et al.*, 2011).

Panicle length exhibited significant negative correlation with reproductive tillers per hill followed by a significant positive correlation with percent sterility during experiment one. It also had a significant positive correlation with filled spikelets/panicle during experiment one. Similar results were reported by Lestari *et al.* (2011) for reproductive tillers per hill and for filled spikelets per hill. Furthermore, number of reproductive tillers per hill showed significant negative correlation with 1000 grain weight and percentage spikelets sterility for experiments one and two. However, its correlation with percentage sterility for experiment two was positive. Similar results were reported by Lestari *et al.* (2011) and Hairmansis *et al.* (2010) for 1000 grain weight. Filled spikelet per panicle also showed highly significant negative correlation with percentage spikelet sterility in experiment two. Lestari *et al.* (2011) reported similar results for filled spikelet per panicle. This means that, selection with these negatively correlated characters will not be effective. It was stated earlier that positive correlation between two or more characters will facilitate the selection because it is will be followed by an increase in other properties (Akinwale *et al.*, 2011).

Comparisons of the correlations results from experiments one and two showed very little variation among the genotypes for the characters studied. The observed differences were on the signs and magnitude of the correlations. For example, number of days to 50% flowering and 90% maturity showed significant positive correlations with grain yield during experiment one. However, during experiment two these characters showed very weak non significant correlations with change of sign for 90% maturity. Days to 50% flowering showed positive correlation with percentage sterility in the wet season and very weak negative correlation during the dry season. On the other hand, number of reproductive tillers per hill showed negative correlation with almost all the characters in both seasons with the exception of number of filled spikelets per panicle and percentage sterility in both seasons and for grain yield in the wet season. Consistent associations

mean that number of reproductive tillers per hill is a stable varietal character which is not affected by environmental changes due to genetic factors. Negative correlations between variables might have been caused by genetic linkages and unfavourable environments leading to intraplant competition hence, negative correlation. Possible ways to break these relations include; intercrossings, mutations and favourable environments.

5.3 Estimates of Variance Components and Genetic Parameters

High phenotypic and genotypic variances were exhibited by grain yield, number of filled spikelets per panicle, plant height, days to 50% flowering and days to 90% maturity for both experiments and only percentage spikelets sterility for experiment two. However, phenotypic variances were slightly higher than genotypic variances for all the characters studied except for number of days to 50% flowering and number of days to 90% maturity indicating little influence of the environment on the expression of these traits. Similar results of higher phenotypic variance than genotypic variance for rice characters were reported by Singh *et al.* (2011) and Idris *et al.* (2012). The classification of GCV and PCV estimates were according to Johnson *et al.* (1955).

The characters studied showed moderate to high genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV). The estimates of phenotypic coefficient of variation (PCV) were slightly higher than those of genotypic coefficient of variation (GCV) for all the traits studied except for days to 50% flowering and days to 90% maturity revealing little influence of environment for the expression of these characters. These results are in conformity with those reported by Idris *et al.* (2012), Singh *et al.* (2011) and Padmaja *et al.* (2008). The extent of environmental influence on these characters is explained by the magnitude of the difference between PCV and GCV values. Large difference reflects high environmental influence and small difference reflects high

genetic influence (Karim *et al.*, 2007). Comparison of GCV and PCV estimates for experiments one and two showed a slight reduction in magnitude for experiment two. This might have been caused by low temperature damage. This was expected because all the agronomic traits during experiment two were reduced in relation to experiment one. Test varieties performed well during experiment one due to favourable climatic conditions. However, during experiment two, low temperature caused slow vegetative growth, high percentage spikelet sterility, delayed heading and maturity.

Results from this study, showed high heritability in broad sense (h^2_b) (65 to 100%) for all the characters studied in experiments one and two except for number of filled spikelets per panicles (54%) in experiment two. Classification for heritability values was according to Robinson *et al.* (1949). High heritability values indicate the effectiveness of selection on the basis of phenotypic performance for a particular character. Results revealed that, days to 50% flowering, 90% maturity, grain yield, 1000 grain weight, panicle length and plant height are highly heritable traits. This suggests that these traits would respond to selection due to their high genetic variability and transmissibility. Similar results have been reported by Singh *et al.* (2011) and Akinwale *et al.* (2011). Comparison of heritability results for experiments one and two showed a slight reduction in magnitude for traits like plant height (4.17%), productive tillers per hill (2.19%), filled spikelets per panicle (22.86%) and percentage spikelets sterility (15.58). This might be the effects of low temperature which had also reduced the performance of all agronomic traits during experiment two.

Additionally, high heritability coupled with high GCV and genetic advance as percent of the mean (GAM) were exhibited by productive tillers per hill, grain yield, filled spikelets per panicle and percent sterility in experiments one and two with exception of filled spikelets in experiment two. Traits that show high heritability and high genetic advance as

percent of the mean are controlled by additive gene action (Rita *et al.*, 2009). Therefore these traits can be improved through simple or progeny selection methods. Selection for these traits is likely to accumulate more additive genes leading to further improvement of their performance (Padmaja *et al.*, 2008).

5.4 Participatory Varietal Selection (PVS)

Participatory variety selection was conducted during experiment two. A maximum of two visits was conducted viz., at vegetative and maturity stages. Farmers used different criteria to judge the test genotypes during selections. Higher tillering and earliness characteristics of the test varieties were the preferred traits. Farmers in the study area argued that, a variety with high tillering ability also had higher yields. Thus they equate high yield with high tillering capacity. High tillering ability is considered as a desirable trait in rice production, since number of tillers per plant is closely related to some extent to number of panicles per plant and thus yields (Feng *et al.*, 2007). Studies done by Baloch *et al.* (2006), reported higher yield due to higher number of productive tillers/m^2, number of spikelets per panicle and thousand grains weight when studying growth and yield of rice as affected by transplanting dates and seedlings per hill. However, it has been well documented that either excessive or insufficient tillering is unfavorable for high yield (Feng *et al.*, 2007). Excessive tillering leads to high tiller abortion, poor grain setting, small panicle size and further reduced grain yield (Shahidullah *et al.*, 2009a) due to intraplant competition.

Earliness was another most important criterion for the farmers in the study area. They argue that, early maturing varieties bridge the hunger gap. Additionally, early maturing varieties are available when prices are still higher in the market. Earliness was followed by intermediate height. Farmers said that, tall plants compete better against weeds than short plants and are easier to harvest. Furthermore, tall plants provide minimum leaf shading

resulting into larger surface area for photosynthesis and consequently improved photosynthate production which is translocated to various parts of the plant (Kessy, 2009).

The results from absolute and pairwise ranking indicated that the genotype 88088-TR-1113-4-1-1 was the most preferred variety, followed by WAB 515-B-16A1.1, Fac 56 and 450-12-2-BL1-DV1. This was evident as the first two genotypes also got attention in the first PVS at vegetative stage. However, WAB 515-B-16A1.1 showed lower grain yield in experiment two compared to that of experiment one and that of the rest of the genotypes in experiment two except for Agulah (Fig. 2). Results also show that, the genotype WAB 515-B-16A1.1 had higher percentage yield reduction than the rest of the genotypes (Fig. 3). This might be due to the damage caused by birds and rats to the genotype in experiment two. However, some varieties were not attacked by birds due to the presence of awns structures which naturally put off the birds.

5.5 Grain Quality for the Selected Genotypes

The ten (10) selected genotypes with two check varieties were analyzed for their grain quality. Among the studied genotypes, seven had long size kernels ranging from 6.63 to 7.44 mm, two medium (5.9 mm) and three short (4.99 to 5.21 mm) according to the standard evaluation system for rice (IRRI, 2002). Lestari *et al.* (2011a) also reported long and medium kernel length when studying the grain quality of new plant type (NPT) promising rice lines. Length to width ratio determines the shape of the kernel. Among the studied genotypes, eight (8) had a medium shape while three had a bold shape and one had long slender shape recorded from Mbawambili. These results are in conformity with those reported by Lestari *et al.* (2011a), Bhonsle and Krishnan (2010). Five (5) test varieties among the selected genotypes had long size and medium shape like that of the local check Cherehani. Thus acceptance of these genotypes after release will pose no problem due to

the fact that consumers in Tanzania prefer long grained rice. Size and shape are among the grain characteristics that dictate the marketability and commercial viability of rice in Ghana (Diako *et al.*, 2011).

Chalkiness was recorded for all the selected genotypes that were studied. The test genotypes with kernel area like that of Cherehani (small< 10%) will be acceptable. The test genotypes with acceptable chalkiness are; 88088-TR-1113-4-1-1, Fac 56, WAB 450-12-2-BL1-DV1, Agullah, Chandannath-1, 86011-TR-888-2-1-2-1 and Somewake. Varieties with unacceptable chalkiness (kernel area> 10%) with reference to Cherehani include WAB 515-B-16A1.1, Yunlen 15 and Skau 23. Chalkiness lower the market value of the grains compared to clear grains (Mackill *et al.*, 1996). It is an undesirable characteristic as it contributes indirectly to rice breakage through easier cracking. Tanzanian consumers prefer rice with a clear endosperm.

In this study high gelatinization temperature was recorded from two genotypes viz., WAB 450-12-2-BL1-DV1 and Skau 23 while low gelatinization temperature was recorded in Yunlen 15 and Somewake. Intermediate gelatinization temperature was recorded from; 88088-TR-1113-4-1-1, Fac 56, WAB 515-B-16A1.1, Agulah, Chandannath-1 and 86011-TR-888-2-1-2-1. The genotypes with high gelatinization temperature are likely to be rejected because they become excessively soft after cooking and tends to disintegrate when overcooked. High gelatinization temperature correlates with low amylose content (Jennings *et al.*, 1979). Low amylose varieties cook sticky which are not preferred by Tanzanian consumers. For the low gelatinizing genotypes, acceptance will depend on the amylose class they belong. The genotypes with intermediate gelatinization temperature are likely to be accepted due to their desirable grain quality. It is documented that, accessions with intermediate gelatinization temperature are preferred in the country (Kibanda and

Luzi-Kihupi, 2007). Gelatinization temperature determines the length of time required for cooking rice (Corke, 2010). Rice with low gelatinization temperature takes shorter cooking time and water compared with that having high gelatinization temperature (Lestari, 2011a).

The studied genotypes fall in two categories viz., medium (47.5 to 55.5 mm) and soft (63 to 74 mm) gel consistency. Since the selected genotypes had medium and soft gel consistency like that of Mbawambili and Cherehani, they will pose no problem of acceptance after release. This is because medium to soft gel consistency is acceptable in the study area with reference to local varieties Cherehani and Mbawambili. Gel consistency measures the tendency of cooked rice to harden when it cools down (Rani *et al.*, 2006). Genotypes with soft gel consistency are preferred in the country as the rice cooked would become soft on cooling.

Among the selected genotypes, two were non scented with aroma mean score <0.5 viz., Skau 23 (0.36) and 86011-TR-888-2-1-2-1(0.41). The rest of the genotypes were mild scented with mean score ranging from 0.59 to 1.32. The local varieties tested with the selected genotypes were mild scented (Mbawambili) and strongly scented (Cherehani) with scores of 1.27 and 1.91 respectively. This might be one of the reasons why farmers in the study area prefer these varieties. Since the selected genotypes had a mild aroma like that of Mbawambili their acceptances after release will pose no problem. Aroma is an important trait and aromatic rice has high demand in the global market (Bhonsle and Krishnan, 2010). However, Chinese and Europeans consumers do not prefer scented rice, for them a trace of aroma signals spoilage (Efferson, 1985).

Kernel elongation ratio (ER) ranged from 1.36 to 1.76. Highest kernel elongation ratio was observed in Chandannath-1, Skau 23, Yunlen 15 and lowest in WAB 515 –B- 16A1.1. Higher elongation ratio (ER) of the cooked rice is preferred to lower ER (Shahidullah *et al.*, 2009). It has been stated that, elongation ratio is a better index of quality than elongation index and proportionate change (Pilaiyar, 1988). The studied accessions had good elongation ratio (> 1). It is documented that, cooked kernel elongation and volume expansion ratio are important quality traits, which differentiate the highly valued aromatic rice from the other rice types (Golam *et al.*, 2010).

The lowest volume expansion ratio (VER) was observed in 88088-TR-1113-4-1-1 and the highest in Somewake. One of the local varieties among the two tested with the test varieties showed high volume expansion ratio (4.66) than the test varieties. Similar results for both ER and VER were reported by Shahidullah *et al.* (2009); Bhonsle and Krishnan (2010). It was reported that lower VER is preferred by the consumers than higher VER (Shahidullah *et al.*, 2009).

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMENTATIONS

6.1 Conclusions

Low temperature stress has been posing a big challenge to rice farmers especially those dwelling in cooler, high altitude and mountainous areas and those using cold irrigation water to produce the rice crop which is very susceptible to low temperature. This study was conducted in the southern highlands during the rainy and dry seasons in 2010/2011 to identify rice genotypes that are tolerant to low temperature stress. The genetic variations were evaluated on agronomic and morphological traits viz., number of days to 50% flowering, number of days to 90% maturity, plant height, panicle length, number of reproductive tillers per hill, grain yield, one 1000 grains weight, number of filled spikelets per panicle and percentage sterility. Based on this study, the following conclusion can be made:-

Results from the analyses of variance revealed that highly significant variation exists among the tested genotypes for all the agronomic traits studied in both seasons viz., wet and cool/dry. This indicates the presence of considerable genetic variation among the germplasm studied. These results provide important information about the diversity of genetic materials to rice breeders and thus widening the genetic base of existing rice cultivars.

The results on genetic studies revealed that, number of reproductive tillers per hill, grain yield, number of filled spikelets per panicle and percent spikelet sterility exhibited high genotypic coefficient of variation (GCV), high heritability in broad sense (h^2_b) and high genetic advance across the two seasons. Therefore, these traits can be improved through

simple or progeny selection methods. Traits that show high heritability with high genetic advance are controlled by additive gene action. Thus, their selection is likely to accumulate more additive genes leading to further improvement of their performance.

Results from correlation studies showed that under wet conditions, number of days to 50% flowering, number of days to 90% maturity and number of filled spikelets per panicle were very highly significant and positively correlated among themselves and with grain yield. Thus simultaneous selection of these traits will improve yield without compensation effects. Under stressed (cool) conditions, grain yield was significantly correlated with number of filled spikelet per panicle, panicle length and negatively correlated with percentage sterility. Therefore, improvement of any of these characters with positive association to grain yield under respective conditions from selection in the test genotypes would be effective in increasing grain yield. For the negative correlation, selection for low levels of this trait will improve yield.

Among the ten (10) genotypes selected by farmers, three viz., 88088-TR-1113-4-1-1, FAC 56 and Chandannath-1 had a common selection i.e. they have appeared in both PVS viz., at vegetative and at maturity stages. Therefore the farmers were able to judge these accessions at vegetative and maturity stages, thus increasing the chances of adoption of these genotypes when they are released in the country. These selected genotypes are also cold tolerant materials.

The results from grain quality analysis showed that, among the ten (10) selected genotypes, seven (7) had a medium shape while three had a bold shape. Most of these materials also had intermediate gelatinization temperatures which are highly desirable for quality grains and medium to soft gel consistency. In addition all of them had mild aroma

with exception of Skau 23 and 86011-TR-888-2-1-2-1 which are non aromatic and high length elongation ratio (>1.36) which is a better index of quality. These characteristics increase the chances of acceptance of these genotypes after release.

6.2 Recommendations

Results and observations were based on a single season's data. It is suggested that the experiment should be repeated in more than one season and location experiencing the problem.

Some of the genotypes like Kunming, Yunkeng, Chandannath-3, Calaro, and FOFIFA 4355 performed well during the stress period at all stages. Even though they were not selected during PVS, phenotypic data shows that these accessions are tolerant to low temperature stress and would therefore be used in breeding programmes to transfer the cold tolerance traits into farmers preferred varieties which are susceptible to low temperatures.

It is suggested that, advanced participatory varietal selection (PVS) in other cold environments be done for the ten (10) selected genotypes in order to further identify the preferred genotypes which can be ear marked for release as new varieties. This will aid easy adoption and diffusion of the genotypes after release.

The accessions which combined acceptable grain quality and agronomic characteristics viz., 88088-TR-1113-4-1-1, Fac 56, WAB 515-B-16A1.1, Agulah and Chandannath-1 can be ear marked for release following the normal release procedures in Tanzania

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APPENDICES

CRITERIA USED FOR SELECTION

Appendix 1: Traits considered of high priority during tillering PVS (n = 18)

S/N	Trait	No. of farmers	Selection %age	Rank
1	Good Tillering	16	88.9	1
2	Intermediate height	10	55.6	2
3	Green colour	10	55.6	3
4	Yield	5	27.8	6
5	Early maturing	7	38.9	4
6	Good Market	6	33.3	5
7	Large grains	4	22.2	7
8	Good taste	3	16.7	8

*Percentages do not add up to 100 because each farmer mentioned more than one criterion

Appendix 2: Traits considered of high priority during PVS at maturity (n = 21)

S/N	Trait	No. of farmers	Selection %age	Rank
1	Good Tillering	19	90.5	1
2	Early maturity	15	71.4	2
3	Long panicles	12	61.9	3
4	Good market	10	47.6	4
5	Intermediate height	9	42.9	5
6	High yield	7	33.3	6
7	Well filled panicles	6	28.6	7
8	Large grains	4	19.0	8
9	Good taste	3	14.3	9

*Percentages do not add up to 100 because each farmer mentioned more than one criterion