ASSESSMENT OF RICE DISEASES AND YIELD UNDER SYSTEM OF RICE INTENSIFICATION (SRI) IN MOROGORO, TANZANIA

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A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN MANAGEMENT OF NATURAL RESOURCES FOR SUSTAINABLE AGRICULTURE OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA.

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ABSTRACT

The overall objective of the study was to assess the status of rice diseases under system of rice intensification (SRI) and farmer’s production system in Morogoro. A checklist survey in nine farmer fields was done and later experiments at Sokoine University of Agriculture, Crop Museum for two seasons. The experiment was laid down in a randomized complete block design with 4 replications. The treatments were three different types of spacing 25 cm x 25 cm for SRI, 20 cm x 20 cm for farmers practice one (FP1), random spacing for farmers practice two (FP2). Rice leaf samples were tested for presence of rice diseases pathogens using blotter method. Five rice diseases were observed in the survey. Rice brown spot diseases (RBSD) occurred most frequently in all locations while rice yellow mottle virus disease (RYMVD) was observed in seven locations. Rice sheath blight diseases (RSBD) and rice blast diseases (RBD) were recorded from four locations while rice bacterial leaf blight (RBLBD) in one location. On the other hand three diseases (RYMVD, RSBD and RBSD) were observed in on-station experiments, in all treatments for both seasons. The diseases incidence and severity were significantly different ($P<0.001$) between rice growing stages. System of rice intensification (SRI) plots appear to have high RYMVD incidence and severity than in FP1 and FP2 while the incidence and severity of RSBD and RBSD were higher in FP2 followed by FP1. The total yield were significantly higher for SRI than FP1 and FP2 ($P<0.01$). Diseases, water for irrigation and poor rice diseases knowledge were the main factors influencing yields in rice production. Adoption of SRI, farmer’s knowledge on SRI and field management, research on identification and characterization of disease pathogens and development of rice varieties which are resistant to diseases with preferable characteristics required by farmers and consumers is recommended.

DECLARATION

I, **LEAH D. MWAKASEGE,** 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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(**MSc. MNRSA**)

The above declaration is confirmed

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Prof. P. K. T. Munishi Date

(**Supervisor**)

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Dr. D. P. Mamiro Date

(**Supervisor**)

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I thank the Almighty God for His blessings and grace towards me in all aspects of my life. May His name be glorified.

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May God bless you all.

DEDICATION

I would like to draw my special dedication to my beloved parents Mr and Mrs David Mwakasege who laid the foundation for my education, to my husband Mr. Venance M. Buliga for his support in a number of ways, to my daughter Alivia Venance Buliga and all family members support in one way or another in my academic progress.

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LIST OF ABBREVIATIONS AND SYMBOLS

ANOVA	Analysis of variance
ASA	Agricultural Seed Agency
cm	Centimeter
CV	Coefficient of Variation
DAFW	Days after first weeding
DAS	Days after sowing
DAT	Days after transplanting
DF	Degrees of freedom
Fig	Figure
FAO	Food and Agriculture Organization
FP1	Farmers practice one
FP2	Farmers practice two
GIS	Geographical Information System
GPS	Global Positioning System
h	Hours
ha	Hectare
HSD	Honest Significant Difference
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IPM	Integrated Pest Management
IRRI	International Rice Research Institute
LSD	Least Significant Difference
m	Meter
mm	Millimeter

N	Number of respondents
NPK	Nitrogen, Phosphorus, Potassium
ns	Not significant
^{0}C	degree Celsius
RBD	Rice Blast Disease
RBLBD	Rice Bacteria Leaf Blight Disease
RBSD	Rice Brown Spot Disease
RCBD	Randomized Complete Block Design
RSBD	Rice Sheath Blight Disease
RYMD	Rice Yellow Mottle Disease
RYMV	Rice Yellow Mottle Virus
S1	Season one
S2	Season two
SES	Standard Evaluation System
SPSS	Statistical Package for Social Science
SRI	System of Rice Intensification
SUA	Sokoine University of Agriculture
t	Tonne
URT	United Republic of Tanzania
WWF	World Wide Fund

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Rice, *(Oryza sativa* L.) is an important food crop cultivated around the world (Mahadevappa, 2004). It is a staple food for over 2.7 billion people, more than half of the world population (Amna *et al.,* 2006). Rice was introduced in Tanzania in early 1890s and has become an important second staple food consumed by 60% of the population and grown in all regions of the country at varying levels of importance (FAO, 2009). It is a strategic component of food security and crucial element in the food economies of several African countries (IRRI, 2009). The existing rice ecosystem in Tanzania include: rain-fed upland, rain-fed lowlands and irrigated lowland (URT, 2009; Barreiro-Hurle, 2012). Rain-fed upland comprises 20%, 74% for rain-fed lowland and 6% for irrigated lowland (Kanyeka *et al*., 1994). Tables 1 show the characteristics of rice land ecosystem.

Table 1: Rice land ecosystem and its characteristics

Rainfed Upland	Rainfed Lowland	Irrigated
Level to steeply sloping fields, rarely flooded, aerobic soil; rice direct seeded on plowed dry soil or dibbled in wet, non puddled soil.	Level to slightly sloping, bundled fields, non-continuous flooding of variable depth and duration, submergence not exceeding 50 cm for more than 10 consecutive days; rice transplanted in puddle soil or direct seeded on puddle or plowed dry soil; alternating aerobic to anaerobic soil of variable frequency and duration.	Leveled, bundled fields with water control; rice transplanted or direct seeded in puddle soil; shallow flooded with anaerobic soil during crop growth.

Source: IRRI, (1993)

The system of rice intensification (SRI) is an agro-ecological method for increasing the productivity of irrigated rice by changing the management of plants, soil, water, and nutrients. The SRI was developed during the early 1980's in Madagascar as a low input system for resource poor farmers in rice production (Stoop *et al.*, 2002). System of rice intensification involves a set of six practices in paddy management that differ from common farmer's rice cultivation systems. These practices are: (i) transplanting younger seedlings (ii) using a single seedling per hill, (iii) using wider spacing between hills (30 cm x 30 cm when soil fertility is high and 25 cm x 25 cm when soil fertility level is low) (iv) Practicing dry and wetting (v) applying compost and (vi) mechanically managing weeds. It has been reported that transplanting early seedlings under optimal growth conditions like optimal spacing, humidity, biologically active and healthy aerobic soil conditions during vegetative phase leads to more tillers and grain (Bagayoko, 2012).

Diseases are considered major constraints in rice production and most rice diseases are caused by biotic agents which can be grouped as fungi, nematodes, bacteria or viruses. Many diseases infect rice but the most common and most severe are rice blast, rice yellow mottle virus, bacterial leaf blight and brown leaf spots. The importance of a disease is determined by its prevalence and the extent of loss in quantity or quality of produce (IRRI, 2009). Therefore, the current study was undertaken to assess the efficiency of System of Rice Intensification in diseases occurrence and rice yield under different farmer practices on-station and supplemented by observations from farmer practices.

1.2 Justification

In general, different reports and evaluations support the observation that the incidence and damage from pests are less with SRI practice. Chaboussou (2004) found that SRI crops are more resistant to damage from pests such as insect pests, weeds and diseases. In 2005-2006, in Vietnam the SRI plots were found to have less prevalence of rice diseases (sheath blight and leaf blight,) and insect pests (small leaf folder and brown plant hopper) when compared with farmer practice plots (Dung, 2007). In China, rice sheath blight disease was reduced by 70% in SRI fields in Tian-tai township of Zhejiang province (Jiaguo, 2004). Also in controlled trials, the index of rice sheath blight disease with SRI management was found to be 2.1% when compared with 14.9% in control plots (Lin, 2010). Field experiments conducted during 2004-2005 and 2005-2006 showed that sheath blight incidence was reduced significantly due to SRI when compared to standard method of cultivation (Kumar *et al*., 2009).

The studies on the effect of SRI on insect pests and diseases at present are scanty in Tanzania. Since diseases are the major constraint in rice production, the present study focused on the occurrence of rice diseases under SRI and the effects on yield versus farmers' practice in Morogoro. The result of this study aimed to increase the knowledge on the effect of SRI on disease incidences and severity which is useful to farmers so as to enhance rice production. Also by implementing SRI the detrimental effects of high external agriculture inputs on the environment and on the health of both producers and consumers will be reduced.

1.3 Objectives

1.3.1 Overall objective

The overall objective of the study was to assess the status of rice diseases under system of rice intensification (SRI) and farmer's production system.

1.3.2 Specific objectives

i. To determine the incidence and severity of diseases under system of rice intensification as compared to farmer production system

ii. To assess rice yield performance under system of rice intensification and farmers practices

iii. To assess farmer's perception on disease incidence and severity

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Criteria for Development of Disease

Diseases remain as a major factor for yield loss and low profit in rice production despite of using improved varieties and fungicides (Cartwright *et al.,* 2013). The effect of farming practices and rice varieties on diseases over time illustrates two sides of the well-known disease triangle (Fig. 1). For disease to occur; it all depends on the presence of the pathogen, the host, and favourable environmental conditions (Cartwright *et al.,* 2013). A combination of all three sides (factors) of the triangle results in the diseased plants.

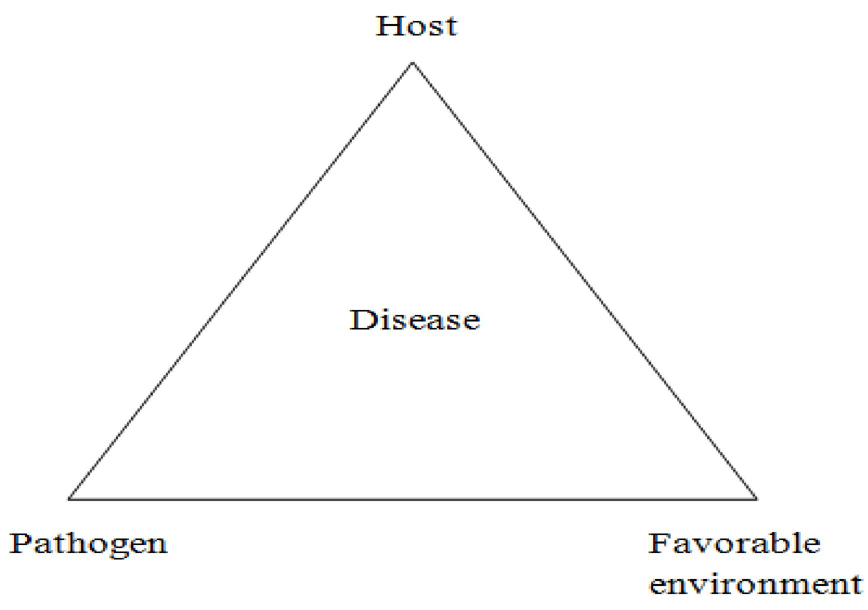


Figure 1: The Disease Triangle

Source: Cartwright *et al.,* (2013)

2.2 Disease Incidence in SRI and Conventional Practice

The incidence of pests and diseases in SRI crop appears to be lower than in conventional practice, it is influenced by the micro-environment created for plants, starting with younger seedlings, more widely spaced, with less water standing in the field, and later on, having profuse vegetative growth and doing inter-cultivation at regular intervals (Thiyagarajan and Gujja, 2013). According to Guideline on SRI practice for tropical countries (2012) it has been reported that the resulting rice plants appears to be stronger and more resistant against pests and diseases. The resistance of a rice crop grown under SRI management to insect pests and diseases has been frequently reported by farmers and has also been studied experimentally to some extent but the interaction of pathogens with SRI crops is yet to be studied in details (Thiyagarajan and Gujja, 2012).

A field experiment conducted in Chiba, Japan during the rice growing season (May-September, 2008) to assess SRI practice versus conventional practice showed incidence of insect pests and diseases were minimized in SRI when compared to the non SRI practice (Chapagain *et al*., 2011). Rice leaf folder reported as the major insect pest observed during 30-40 DAT, rice seedling blight as the primary disease observed and also insect pest damage was more severe in conventional plots planted with 21-day seedlings whereas no insect pests were observed in SRI plots with 14-day seedlings (Chapagain and Riseman, 2011).

2.3 Major Rice Diseases and Their Effect on Yield

There are various diseases that affect rice. However, the most common and most severe are rice blast, rice yellow mottle virus, bacterial leaf blight and brown spots (Wopereis, 2009). The importance of a disease is determined by its prevalence and the extent of loss in quantity or quality of produce (Mwalyego *et al*., 2011).

Rice blast disease (RBD) is caused by an Ascomycota fungus *Magnaporthe oryzae* (Couch and Kohn, 2002). It infects any organ of the rice plant such as leaf, neck, panicle rachis, stem node, and grain. The disease causal agent multiplies rapidly by spores while mycelia penetrate into tissues. Then few days later the lesions appear. The tips of leaf lesion are typically spindle shaped, wide in the centre and pointed at the ends. Large lesion develops grey centres bordered by brown to dark red spots (IRRI, 2011). Chlorophyll disappears in the parts attacked hence impaired photosynthesis and yields are reduced (Wopereis, 2009). Yield loss due to rice blast disease can be as high as 50% (Babujee and Gnanamanickam, 2000) when the pathogen found the favourable environmental conditions, i.e. relatively high humidity (up to 85% and above), high or excessive nitrogen fertilizer application and presence of dew (Piotti *et al*., 2005).

Rice brown spot disease (RBSD) caused by the fungus *Bipolaris oryzae*, attacks leaves, leaf sheaths, panicle, branches, glumes, and grain (Hollier and Whitney, 2014). The disease is first seen as brownish spots on the leaves and glumes of the plant The spots enlarge and become grey at the centre and brown at the edge. Fully developed lesions are brown, with grey or whitish centres. Most spots have a light-yellow halo around their margins. Spots on the glumes are black or dark brown. The disease attacks the crop from the seedling stage in the nursery to the milk stage in the field (Balamurugan, 2013). Brown leaf spot can cause 10-58% seedling mortality. It also affects the quality and the number of grains per panicle. The reduction in yield can be as high as 45% in severe infection and 12% in moderate infection (IRRI, 2009).

Rice yellow mottle disease (RYMD) caused by *Rice Yellow Mottle Virus* (RYMV) is the main virus affecting the rice crop in Africa where it causes major yield losses in farmers' fields (Abo *et al*., 1998). The most important symptom on a rice plant is that leaves turn yellow, with alternate yellow and green stripes that give its typical mottled appearance to the plant (Nwilene *et al*., 2008). The other symptoms are stunting, reduced tillering, leaf mottle with yellow stripes, incomplete panicle exertion, the panicle sometimes being poorly formed and spikelet sterility (Wopereis, 2009).

Bacteria leaf blight disease (RBLBD) caused by *Xanthomonas oryzea* pv. *oryza,* causes water-soaked to yellowish stripes on leaf blades or starting at leaf tips then later increase in length and width with a wavy margin (Akhtar *et al*., 2008). Lesions turn yellow to white as the disease advances later become greyish from growth of various saprophytic fungi. Severely infected leaves tend to dry quickly (IRRI, 2009). In highly susceptible rice varieties, a yield loss of up to 80% was reported to be common (Lee and Khush, 2003).

Rice sheath blight disease (RSBD) is a fungal disease caused by *Rhizoctonia solani* (Groth and Bond, 2007). Symptoms are usually observed from tillering to milk stage in a rice crop. Sheath blight is characterized by large oval spots on the leaf sheaths and irregular spots on leaf blades. It occurs throughout the rice-growing areas in temperate, subtropical, and tropical countries. This disease causes 10–30% loss in yield and degrades rice quality (Xie *et al*., 2008).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Rice Disease Survey in Farmers' Fields

The study was conducted in farmer's rice fields (Fig. 2) in Morogoro Region. Farmers' fields and their GPS reading for each location are presented in Table 1. Nine farmers' fields in Morogoro Region were selected randomly and a total of 27 farmer's fields (3 field/site) were assessed using quadrats of 1 m x 1 m. Three quadrats were established diagonally in each field. At each quadrat the total number of plants and number of infected plants were counted and diseases severity scored according to standard evaluation system for rice (IRRI, 2002). Disease incidence was calculated using the formula described by Nwilene *et al*. (2008). At each quadrat, 10 rice plants were randomly selected along two diagonals and hills numbers, tillers per hill, number of leaves per tiller and number of infected leaves was counted (Appendix 1).

Table 2: Farmers' fields location in different districts of Morogoro region

Location number	Location name	District	Eastings	Northing
1.1	Lumemo F1	Kilombero	84902	3665511
1.2	Lumemo F2	Kilombero	616223	3731200
1.3	Lumemo F3	Kilombero	814675	3666448
2.1	Chisano F1	Kilombero	814756	3666013
2.2	Chisano F2	Kilombero	840048	3552249
2.3	Chisano F3	Kilombero	840081	3552353
3.1	Mang'ula F1	Kilombero	752956	3552363
3.2	Mang'ula F2	Kilombero	752795	3654837
3.3	Mang'ula F3	Kilombero	752795	3654288
4.1	Ilonga F1	Kilosa	752573	3654303
4.2	Ilonga F2	Kilosa	646398	3703843
4.3	Ilonga F3	Kilosa	646375	3703904
5.1	Mvumi F1	Kilosa	646406	3703804
5.2	Mvumi F2	Kilosa	636295	3713439
5.3	Mvumi F3	Kilosa	635999	3713651
6.1	Kilangali F1	Kilosa	635988	3713600
6.2	Kilangali F2	Kilosa	657971	3705825
6.3	Kilangali F3	Kilosa	658004	3705853
7.1	Sangasanga F1	Morogoro	657862	3705952
7.2	Sangasanga F2	Morogoro	653564	3733885
7.3	Sangasanga F3	Morogoro	653542	3733927
8.1	Hembeti F1	Mvomero	65321	3733854
8.2	Hembeti F2	Mvomero	616278	3731209
8.3	Hembeti F3	Mvomero	616324	3731256
9.1	Wami F1	Mvomero	627181	3732116
9.2	Wami F2	Mvomero	627014	3732074
9.3	Wami F3	Mvomero	626989	3732028

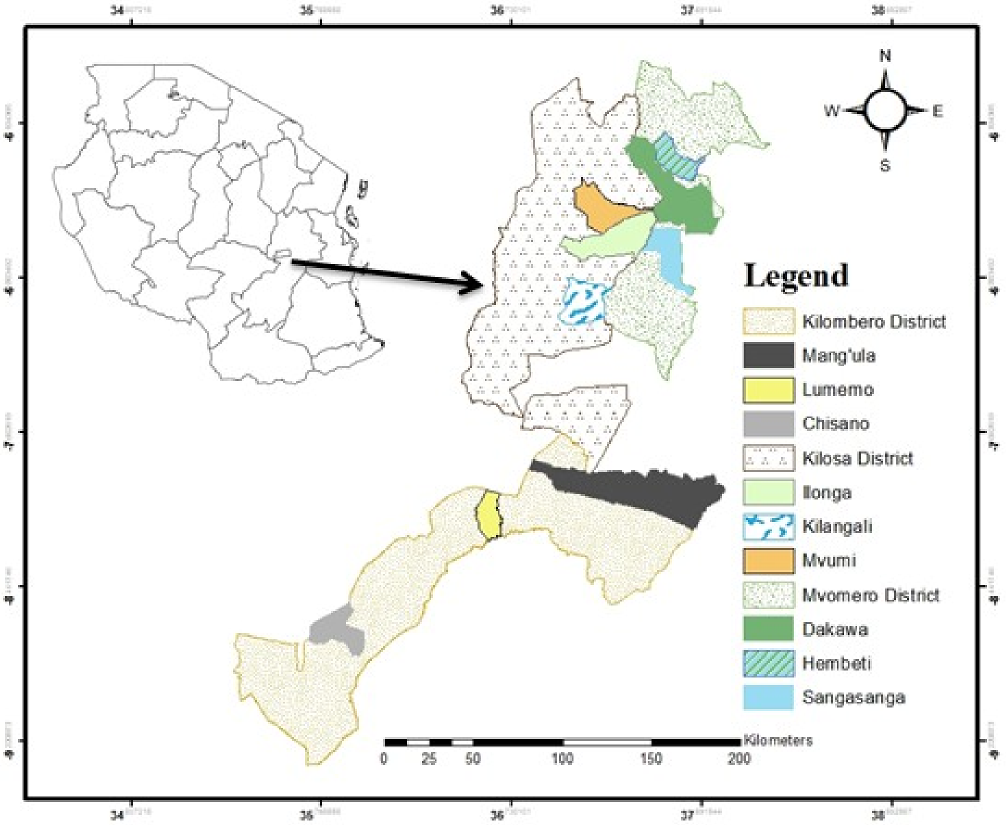
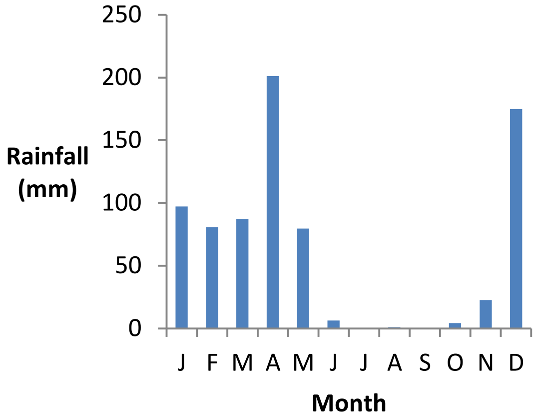


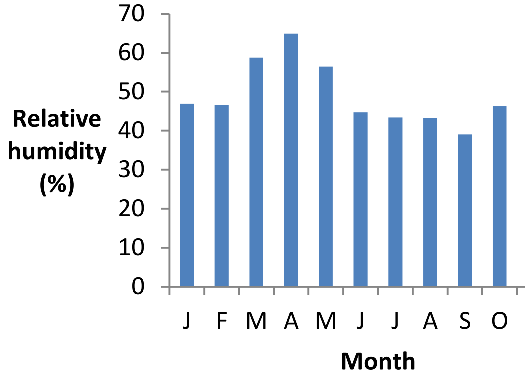
Figure 2: Map indicating data collection sites in Morogoro Region

3.2 On-station Experiments

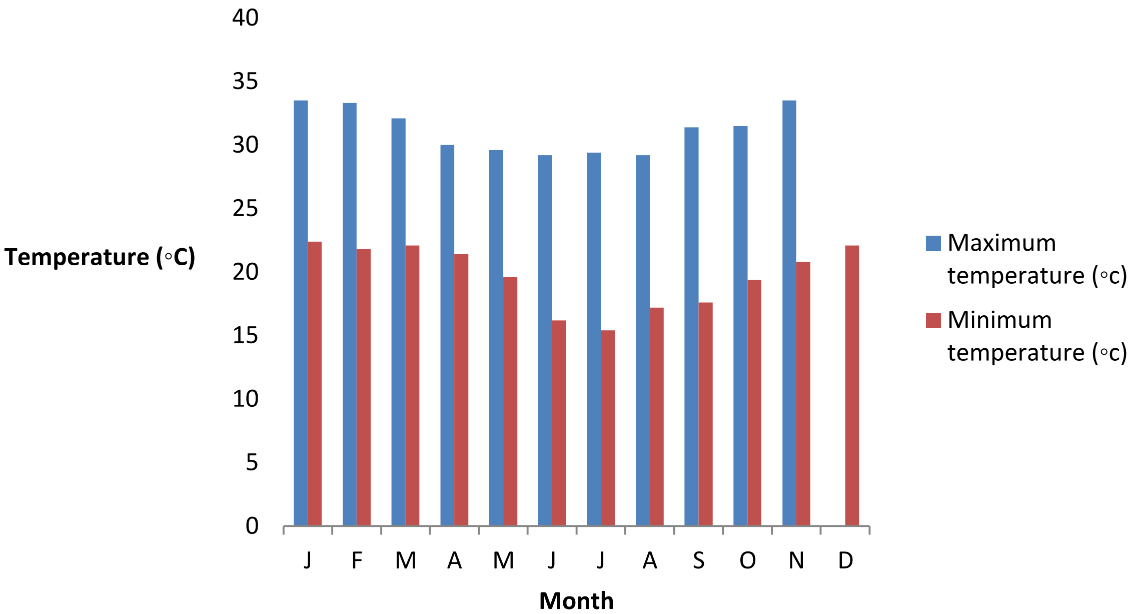
Experiments were conducted at SUA Crop Museum (6° 50'S, 37^0 39' E, altitude 526 m. a. s. l.) Morogoro, Tanzania and the weather data during study period have been shown in Figures 3 and 4. Rice variety (SARO 5 (TXD 306) bought from the Agricultural Seed Agency (ASA), Morogoro was selected based on farmers' preference in Morogoro such as strong aroma, good milling quality and translucent kernels. The variety officially released in 2002 (URT, 2009) and appears in Tanzania National Variety List (Kanyeka *et al*., 2005) has emerged as the best choice for farmers and fetches competitive prices in many local markets.



3a. Rainfall



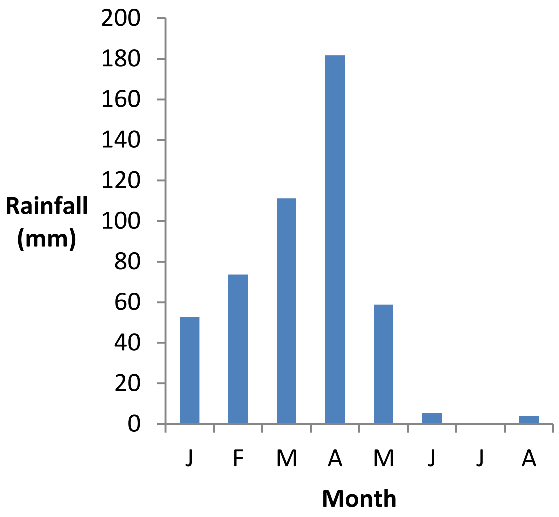
3b. Relative humidity



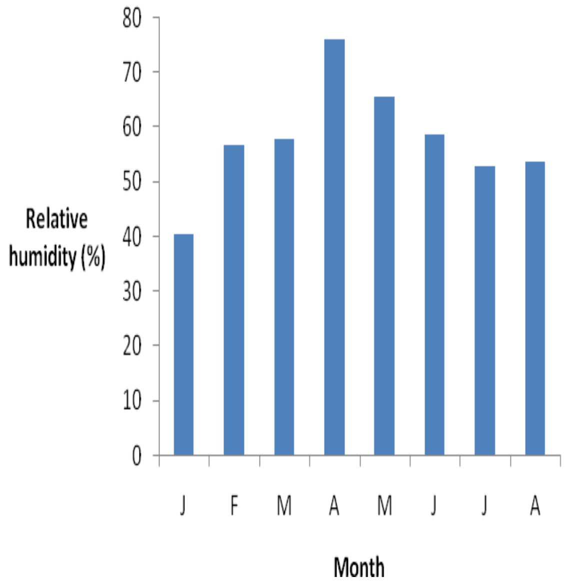
3c. Maximum and Minimum temperature

Figure 3: SUA weather parameters for 2013 in Morogoro region

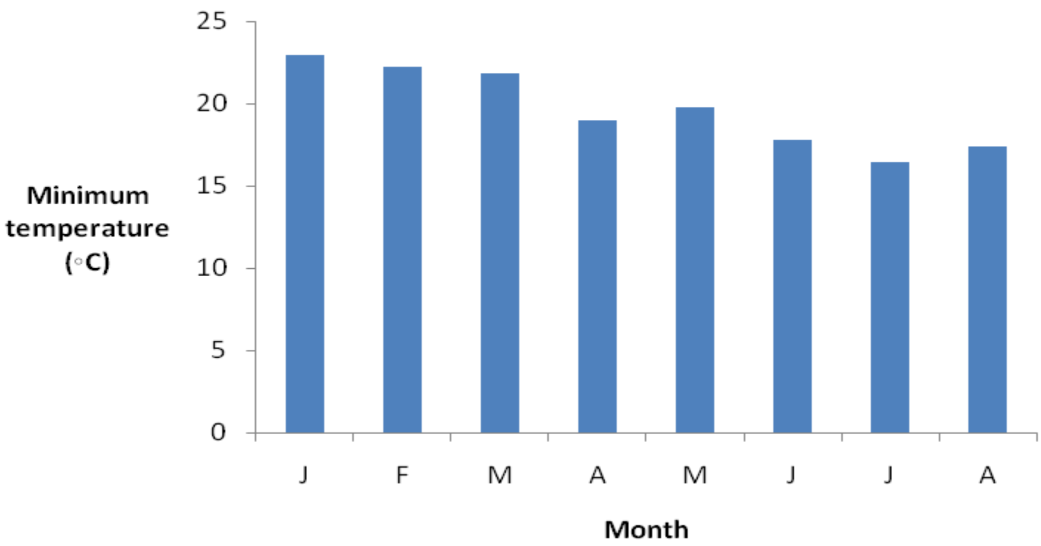
Source: Tanzania Meteorological Agency, SUA weather station, (2013)



4a.Rainfall



4b.Relative humidity



4c. Minimum temperature

Figure 4: SUA weather parameters for 2014

Source: Tanzania Meteorological Agency, SUA weather station, (2014)

3.2.1 Nursery establishment

The seedbed was prepared before sowing; hand hoe was used for plowing then followed by manual harrowing and leveling. Seedlings were raised in a nursery of 2.5 m^2. The seedbed was kept moist for two days then seeds were soaked for 48 h before planting in the nursery. The nursery was kept moist until full germination then regularly irrigated as needed without flooding.

3.2.2 Experimental layout

The experiment was laid down in a randomized complete block design with 4 replications. The blocks consisted of treatments which were three different types of spacing (25 cm x 25 cm, 20 cm x 20 cm, random spacing). The spacing of 25 cm x 25 cm was selected as recommended for SRI (Guidelines on SRI Practice for Tropical Countries, 2012), while 20 cm x 20 cm and random spacing was under farmer's practice. The plot size consisted of 5 m x 3 m and the experiment was done in two seasons (Dry or season one and Wet or season two).

3.2.3 Transplanting the seedlings

Seedlings were transplanted (one seedling per hill) 10 days after sowing (DAS) for SRI plots and 30 DAS for farmers practice. Line spacing between hills were 25 cm × 25 cm for SRI , 20 cm × 20 cm for FPI and random spacing for FP2 (Plate 1).

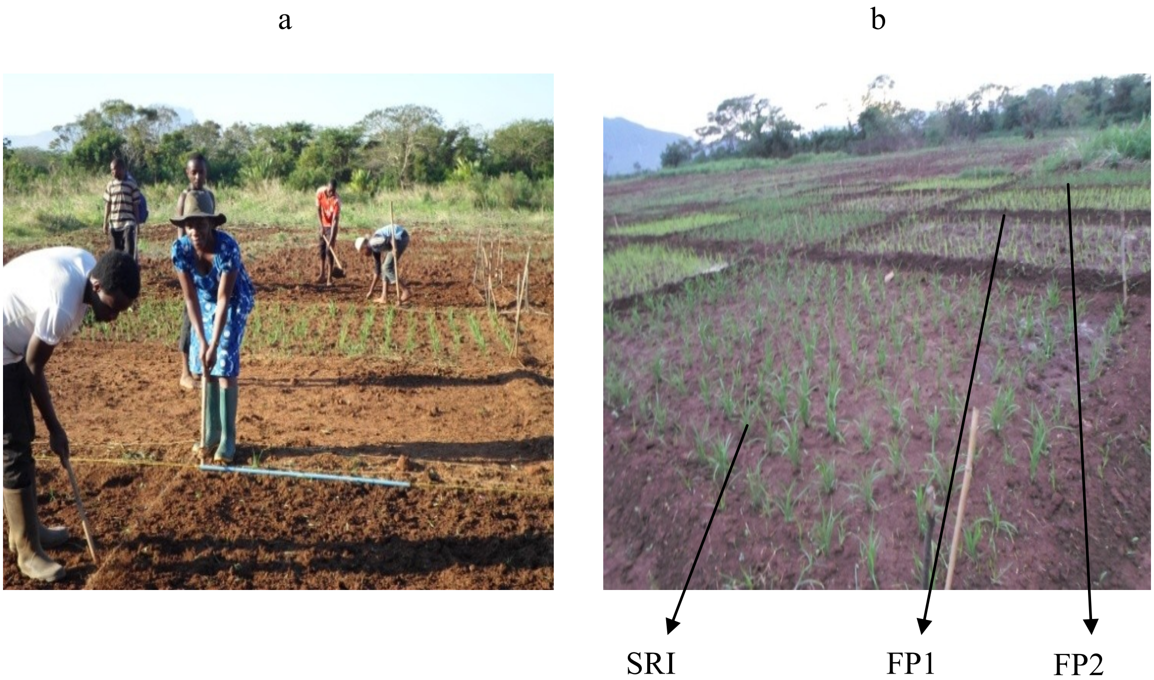


Plate 1: a) Transplanting of Rice b) Seedlings at one month of age, seedlings in each plot are the same age but SRI seedlings have already undergone transplant shock and begun to tiller.

Source: "Photograph from on-station experiment" 2013. JPEG file.

3.2.4 Rice agronomic practices

After transplanting, SRI plots were irrigated 3 days consecutively after which irrigation was done once at an interval of 5 days until harvesting while farmer's practice plots were irrigated every day until harvesting. Each plot was applied with NPK fertilizer (75 g) at transplanting and Urea fertilizer (165 g) at 14 days after transplanting (DAT) only in SRI plots. In SRI plots' weeding was done 10 DAT then 20 DAT, followed by hand pulling of grasses 40 DAT, but for FP1 and FP2 plots weeding was done 30 DAT only.

3.3 Data Collection

Disease severity and incidence were recorded according to Standard Evaluation System for rice (IRRI, 2009) while checklist (Appendices 1 and 2) was used in assessing farmer perception on rice diseases.

3.3.1 Evaluation of disease severity and incidence

3.3.1.1 On-farmer's fields

In the farmer's fields disease incidence and severity were recorded at booting stage because rice crop is severely affected from booting stage (Devasahayam, 2009). Diseases assessments were conducted based on observed symptoms. Rice plants were evaluated and scored using Standard Evaluation System for Rice, SES, (IRRI, 2002). The severities of diseases were assessed by using the disease rating scale of 0-9. Also other parameters like number of hills, tillers/hill and leaves/tiller were counted. Disease incidences was calculated using the formula described by Nwilene *et al.* (2008) as follows:

$$\text{Disease incidence (\%)} = \frac{\text{Number of hills with sick plants}}{\text{Total number of hills}} \times 100$$

3.3.1.2 On-station experiment

Disease incidence and severity were recorded four times at seedling, tillering, booting and maturity stages. All plants within the 6.8 m^2 plot were assessed. Disease severity was assessed using 0-9 rating scale while incidence per unit area was determined by using the following formula:

$$\text{Disease incidence (\%)} = \frac{\text{Number of hills with sick plants}}{\text{Total number of hills}} \times 100$$

Disease severity was determined using the IRRI Standard Evaluation System (SES) 0-9 scale as described by IRRI (2002). More over the calculation of severity (S) was based on scoring diseases according to scale 1 to 9 (Fininsa, 2003) where

$S = \{(n1*1 + n3*3 + n5*5 + n7*7 + n9*9)*100\} / \{(n1 + n3 + n5 + n7 + n9)*9\}$ where n1 n3, n5, n7 and n9 represented the number of plants scored 1, 3, 5, 7 and 9 respectively.

3.5 Testing Rice Leaf Samples for the Presence of Diseases Causing Pathogens Using Blotter Method

Infected leaves of suspected fungal disease symptoms were selected from the experimental trial. Testing Rice Leaf Samples done in the laboratory at African Seed Health Centre, Morogoro Tanzania where the infected leaves were cut into small pieces and placed on three well water-soaked blotters. The leaves were incubated in the Petri dishes with the infected leaves at 25°C for 7 days in alternating cycles of 12 h darkness and 12 h light to induce sporulation (Thakur *et al*., 2006). After 7days, each leaf was examined in a compound microscope under different magnifications. The spore observed on rice leaves (Plates 2a and 2c) were picked with inoculation needle and placed on sterilized microscope slide containing a sterile drop of water covered with a glass slip and placed on the compound microscope. The fungi that developed in each leaf were identified based on the morphological characters of the fruiting bodies and spores/conidia in the compound microscope under 10X, 40X, and 100X (Mathur and Kongsdal, 2003). The fungi observed in each leaf were differentiated and recorded based on the morphological characters (Plates 2b and 2d) and the incidences of these pathogens were recorded.

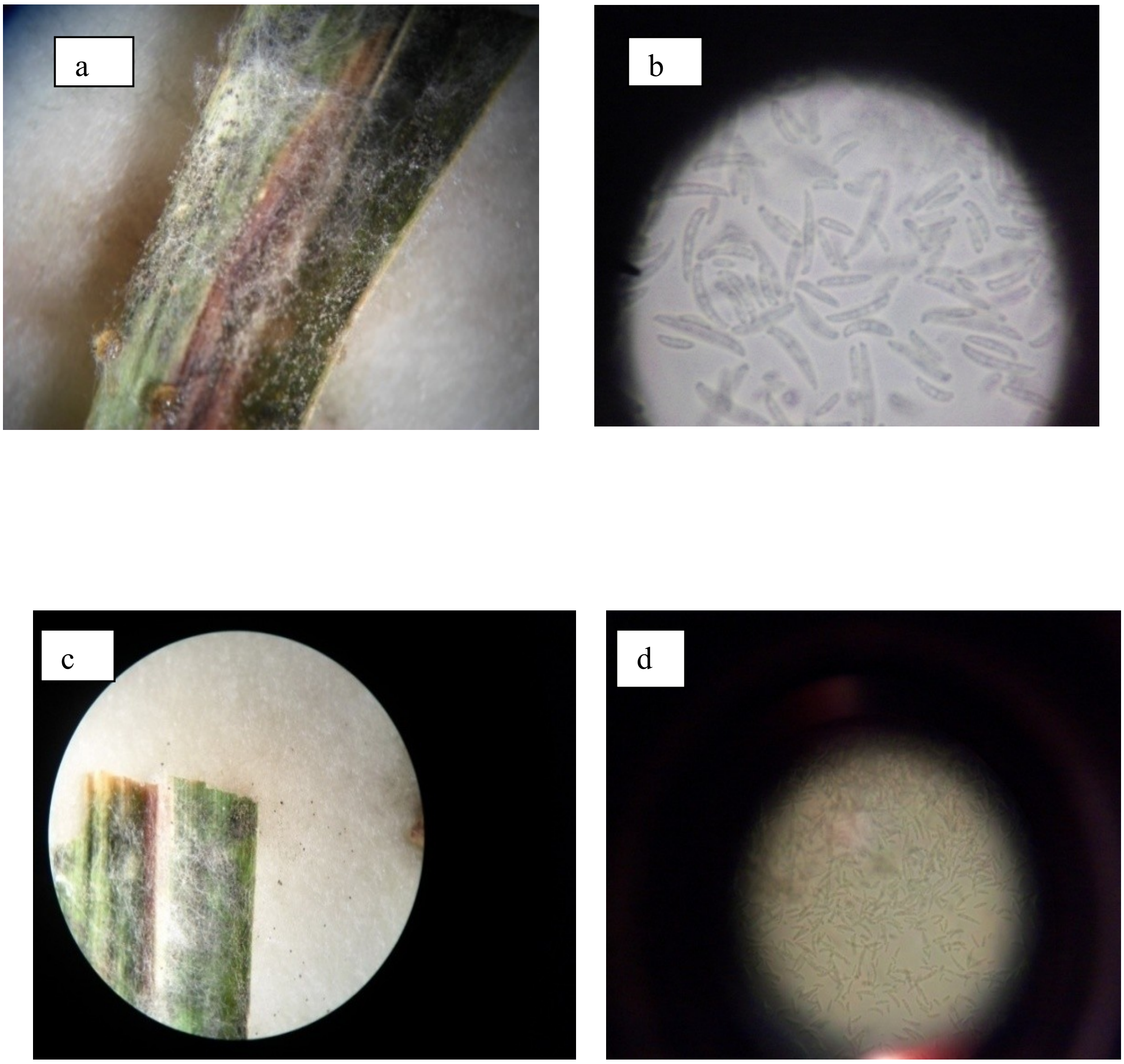


Plate 2: Fungi developed in leaf: (a) Conidia of rice brown spot disease causing pathogen (40X), (b) Conidia of rice brown spot disease causing pathogen (*Bipolaris oryzae*) (100X), (c) Conidia of rice sheath blight disease causing pathogen (40X), (d) Conidia of rice sheath blight disease causing pathogen (*Rhizoctonia solani*) (100X).

Source: "Photograph from on-station experiment" 2014. JPEG file

3.6 Evaluation of Yield

Twelve plants were selected from each plot within 6.8 m^2. Plant height, tiller number and panicle count were made on all 12 hills sampling units per plot followed by measuring the panicle weight. From each sample hill, the grains were hand threshed and bulked followed by weighing filled grains under 14% moisture content after separating them from unfilled grains. The total grains were measured using weighing balance.

3.7 Data Analysis

Diseases incidence and severity data collected were analyzed based on the RCBD experimental design analysis of variance (ANOVA) using Genstart statistical software. The data were subjected to square root transformation to normalize the data before analysis (McDonald, 2014). A constant value (0.5) was added to each observation, before taking square root transformation (Amadioha, 2000). ANOVA was followed by multiple comparisons of means using the Turkey Honest Significant Difference (HSD) at $P< 0.05$ confidence interval. Data on farmer's perception were analyzed using Statistical Package for Social Science (SPSS).

CHAPTER FOUR

4.0 RESULTS

4.1 Incidence and Severity of Diseases

4.1.1 Diseases status and incidence in farmer's fields

Five rice diseases were observed in the nine sites (Table 2) and averages values of diseases occurrence in 9 locations presented in Table 3. Rice brown spot disease was observed in all locations while Rice yellow mottle disease was observed in Lumemo (Plate 3), Ilonga, Wami, Mvumi, Kilangali, Chisano and Mang'ula. Rice blast disease was recorded in five locations (Ilonga, Wami, Mvumi, Kilangali and Hembeti). Rice bacterial leaf blight was recorded only in Sangasanga and Rice sheath blight was observed in four locations (Ilonga, Mvumi, Kilangali and Hembeti).

Plate 3: The field attacked by RYMD and RBSD at Lumemo, Kilombero district in Morogoro. Plants show typical mottled appearance and brownish spots on the leaves

Table 3: Diseases observed in farmer's fields

Location	Disease Observed					
	Rice Brown Spot (RBSD)	Rice Blast (RBD)	Bacterial Leaf Blight (BLBD)	Rice Yellow Mottle (RYMD)	Rice Sheath Blight (RSBD)	Total number of disease observed
Lumemo	√	-	-	√	-	2
Chisano	√	-	-	√	-	2
Mang'ula	√	-	-	√	-	2
Ilonga	√	√	-	√	√	4
Mvumi	√	√	-	√	√	4
Kilangali	√	√	-	√	√	4
Sangasanga	√	-	√	-	-	2
Hembeti	√	√	-	-	√	3
Wami	√	√	-	√	-	3

√ = presence of disease and
- = no disease observed

Among five diseases observed, RBSD occurred with higher incidence of 99% in Lumemo followed by Ilonga (98%), Mangula (96%) Kilangali (77%), Chisano (71%), Sangasanga (69%), Wami (51%) and Mvumi (35%). Rice yellow mottle disease occurred in seven locations with highest incidence in Lumemo (46%) followed by Mang'ula (40%), Ilonga (15%), Mvumi (5%), Wami (5%), Chisano (5%) and Kilangali (5%). Rice sheath blight disease was observed only in four locations: Ilonga (10%), followed by Hembeti (4%), Mvumi (3%) and Kilangali (3%). Rice blast disease was observed in five locations with 11% incidence in Ilonga followed by Hembeti (5%), Wami (5%), Mvumi (5%) and Kilangali (3%). Rice bacterial leaf blight disease was observed only in Sangasanga with incidence of 2% as shown in Fig. 5.

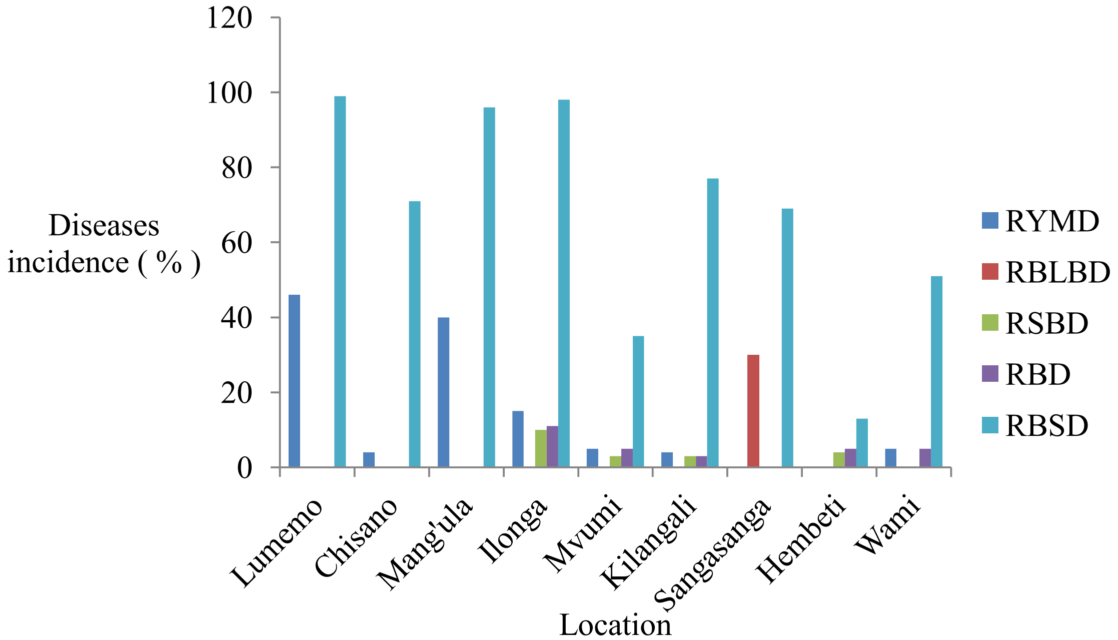


Figure 5: Disease incidence in farmers' fields

Table 4: Differential occurrences of diseases observed in farmers' fields

Villages	RYMD		RBSD		RBLBD		RBD		RSBD	
Lumemo	3.322	a	4.026	bc	0.7071	b	0.8939	b	0.7071	b
Chisano	0.822	b	3.224	cd	0.7071	b	0.7071	b	0.7071	b
Mang'ula	3.279	a	3.889	bc	0.7071	b	0.7071	b	0.7071	b
Ilonga	1.052	b	4.209	ab	0.7071	b	0.7071	b	1.1061	a
Mvumi	0.804	b	3.445	bcd	0.7071	b	0.7071	b	0.7646	b
Kilangali	0.822	b	4.982	a	0.7071	b	0.7071	b	0.9013	ab
Sangasanga	0.765	b	2.905	d	1.28	a	0.7071	b	0.7071	b
Hembeti	0.707	b	1.074	e	0.7071	b	0.7071	b	0.7071	b
Wami	1.149	b	3.818	bcd	0.7071	b	1.1493	a	0.7071	b
F test	***		***		***		***		***	
Mean	1.414		3.508		0.771		0.777		0.779	
CV (%)	36.2		17.4		29.6		21		25.8	

Number followed by the same letter within the columns are not significantly different at $P<0.05$, using Turkey (HSD) test. *** = Highly significantly different ($P<0.001$). RYMD = Rice yellow mottle diseases, RBSD = Rice brown spot disease, RBLB = Rice bacteria leaf blight disease, RBD = Rice blast disease, RSB = Rice sheath blight disease.

4.1.2 Disease severity

Rice brown spot disease was particularly severe in all fields while RYMD was severe in seven locations Lumemo (25%), Chisano (5%), Mang'ula (25%), Ilonga (15%), Mvumi (5%), Kilangali (5%) and Wami (5%). Rice sheath blight disease was more severe in four locations (Ilonga (30%), Mvumi (20%), Kilangali (20%) and Hembeti (20%) while RBD was severe in five locations Ilonga (3%), Mvumi (2%), Kilangali (1%), Hembeti (1%) and Wami (2%) as shown in Fig. 6.

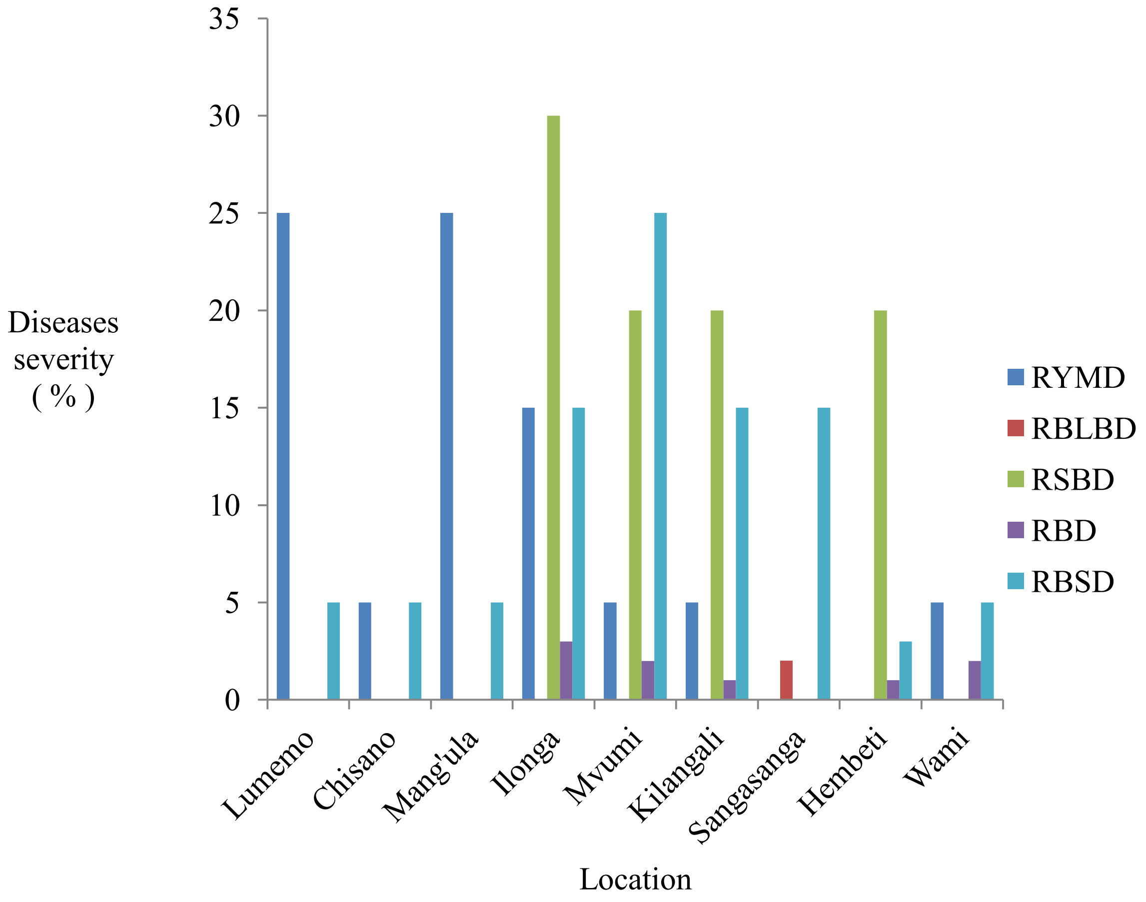


Figure 6: Diseases severity in farmers' fields

4.1.3 Diseases Incidence and Severity in Experiment (SRI, FP1 and FP2)

Two pathogens (*Bipolaris oryzae* and *Rhizoctonia solani*) were identified (Plate 2). The incidences of these pathogens were recorded and were observed to increase with the age of the crop. The incidence and severity of RYMD, RBSD and RSBD were therefore observed to be higher from booting to maturity stages than at the seedling and vegetative stages in all treatments.

Rice yellow mottle virus disease incidence and severity was significantly different between rice growing stages and treatments in dry seasons and rain seasons ($P< 0.01$). The incidence and severity of RYMD was higher in SRI practice than in FP1 and FP2 from tillering stage to maturity. But for RBSD and RSBD the incidence and severity from booting stage to maturity was higher in FP2 followed by FP1 (Table 5 and 6). The incidence and severity of RSBD was low during early plant growth stages. There were high RSBD intensity in each plot from booting stage to maturity but the incidence in FP2 was greater than FP1 and also was higher than in SRI plots.

Table 5: Diseases severity in SRI, FP1 and FP2 for the dry (S1) and wet (S2) seasons in the experiment at SUA crop museum

Rice growth stage	Rice production method	RYMD-S1		RYMD-S2		RBSD-S1		RBD-S2		RSBD-S1		RSBD-S2	
Seedling	SR	11.12	c	11.14	a	11.12	a	11.15	a	80	a	55.56	a
Seedling	FP1	11.11	c	11.12	a	11.11	a	11.11	a	80	a	55.56	a
Seedling	FP2	11.11	c	11.11	a	11.11	a	11.12	a	80	a	55.56	a
Tillering	SRI	11.22	bc	12.92	a	11.13	a	11.11	a	80	a	55.56	a
Tillering	FP1	11.13	c	11.17	a	11.14	a	11.14	a	80	a	55.56	a
Tillering	FP2	11.13	c	11.13	a	11.16	a	12.64	a	80	a	55.56	a
Booting	SRI	11.18	bc	13.14	a	11.15	a	12.68	a	89.83	a	45.16	ab
Booting	FP1	11.13	c	11.22	a	11.15	a	11.73	a	97.46	a	41.29	ab
Booting	FP2	11.13	c	11.14	a	11.2	a	11.18	a	99.95	a	34.16	b
Flowering	SRI	11.34	ab	13.24	a	11.15	a	12.78	a	94.89	a	39.36	ab
Flowering	FP1	11.16	bc	11.27	a	11.82	a	12.03	a	99.72	a	34.52	b
Flowering	FP2	11.16	bc	11.15	a	11.28	a	11.22	a	81.72	a	29.41	b
Maturity	SRI	11.47	a	13.49	a	11.14	a	12.99	a	94.9	a	39.35	ab
Maturity	FP1	11.17	bc	11.28	a	11.96	a	12.11	a	99.74	a	34.64	b
Maturity	FP2	11.19	bc	11.15	a	11.23	a	11.23	a	100	a	33.51	b
Means		11.2		11.71		11.3		11.75		44.3		0.0232	
F test		***		ns		ns		ns		ns		ns	
CV (%)		0.7		11.6		3.8		13.9		15.5		172.3	

Number followed by the same letter within the columns are not significantly different at P<0.05, using Turkey (HSD) test., ns = not significantly different, *** = highly significantly different (P<0.01). Comparisons are within each treatment in all rice growing stage. RYMD = Rice yellow mottle diseases, RBSD = Rice brown spot disease, RBLBD = Rice bacteria leaf blight disease, RBD = Rice blast disease, RSBD = Rice sheath blight disease, SRI = System of rice intensification, FP1 = Farmer's practice one, FP2 = Farmer's practice two

Table 6: Diseases incidence in SRI, FP1 and FP2 for dry (S1) and wet (S2) seasons in the experimental at SUA crop museum

Rice growth stage	Rice production method	RYMD-S1		RYMD-S2		RBD-S1		RBSD-S2		RSBD-S1		RSBD-S2	
Seedling	SRI	0.0077	c	11.14	a	0.0077	a	11.15	a	80	a	0.00474	b
Seedling	FP1	0.0017	c	11.12	a	0.0017	a	11.11	a	80	a	0.00212	b
Seedling	FP2	0.0014	c	11.11	a	0.0014	a	11.12	a	80	a	0.00055	b
Tillering	SRI	0.2595	bc	12.92	a	0.0884	a	11.11	a	80	a	0.00854	b
Tillering	FP1	0.0301	c	11.17	a	0.1074	a	11.14	a	80	a	0.00249	b
Tillering	FP2	0.0326	c	11.13	a	0.2205	a	12.64	a	80	a	0.00047	b
Booting	SRI	0.2589	bc	13.14	a	0.1721	a	12.68	a	89.83	a	0.00889	b
Booting	FP1	0.0406	c	11.22	a	0.135	a	11.73	a	97.46	a	0.00307	b
Booting	FP2	0.0539	c	11.14	a	0.3564	a	11.18	a	99.95	a	0.00049	b
Flowering	SRI	0.9252	ab	13.24	a	0.1239	a	12.78	a	94.89	a	0.0276	ab
Flowering	FP1	0.1028	c	11.27	a	3.1611	a	12.03	a	99.72	a	0.0654	ab
Flowering	FP2	0.1257	c	11.15	a	0.725	a	11.22	a	81.72	a	0.00393	b
Maturity	SRI	1.483	a	13.49	a	0.1002	a	12.99	a	94.9	a	0.09272	ab
Maturity	FP1	0.1374	bc	11.28	a	3.7975	a	12.11	a	99.74	a	0.11505	a
Maturity	FP2	0.2074	bc	11.15	a	0.6325	a	11.23	a	100	a	0.01208	b
Means		0.2		11.71		0.6		11.75		89.2		0.0232	
F test		***		ns		ns		ns		ns		ns	
CV (%)		128.7		11.6		299		13.9		11.8		172.3	

Number followed by the same letter within the columns are not significantly different at P<0.05, using Turkey HSD test. *** = highly significantly different (P<0.001). RYMD = Rice yellow mottle diseases, RBSD = Brown spot disease, RBLBD = Bacteria leaf blight, RBD = Rice blast disease, RSBD = Sheath blight, SRI= System of rice intensification, FP1 = Farmer’s practice one, FP2 = Farmer’s practice two.

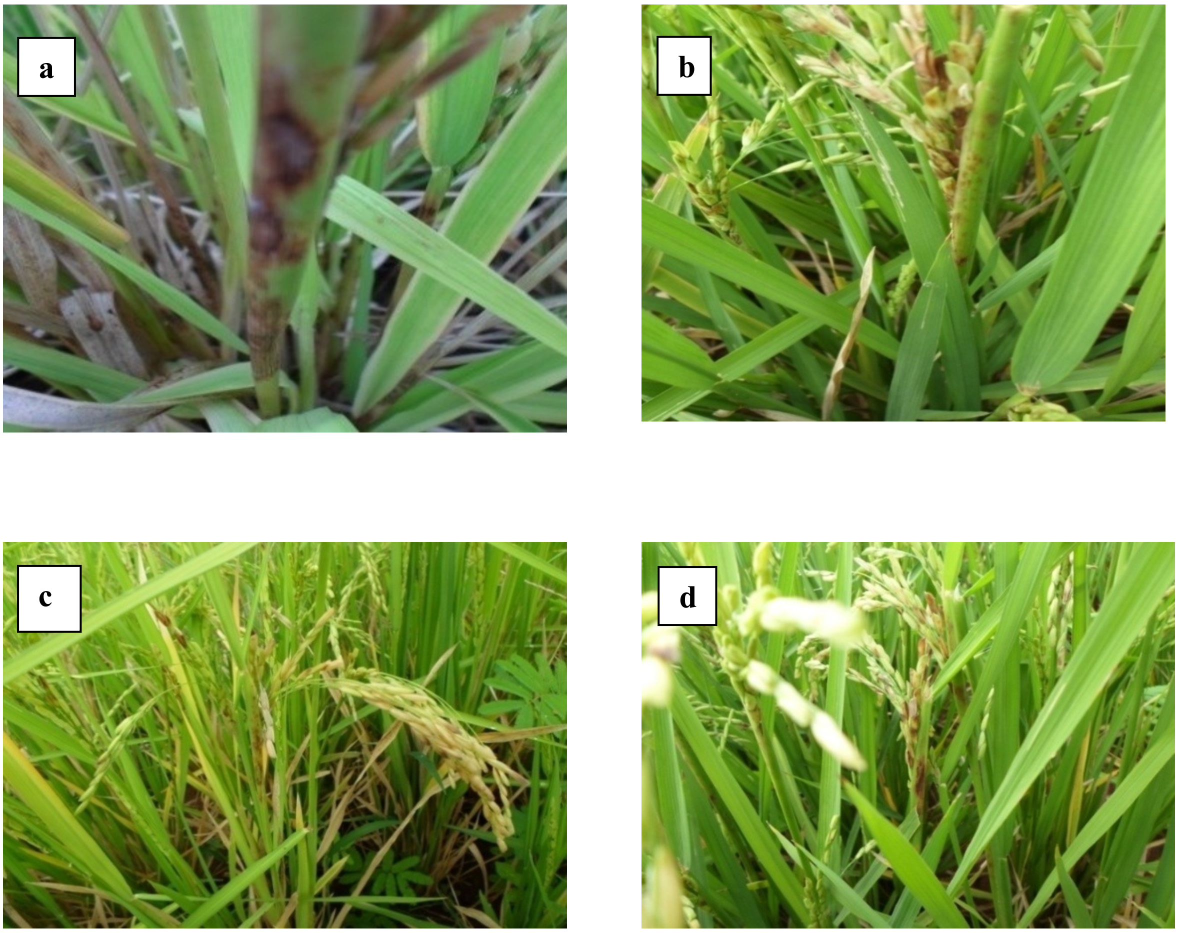


Plate 4: Rice sheath blight disease effect on panicle initiation and grain filling on station experiment at SUA crop Museum, (a) Leaf blight symptoms, oval spots on the leaf surrounded with black margin, (b and d) Poor panicle initiation and spikelet formation, (c) Sheath blight infected grain

Source: “Photograph from on-station experiment” 2014. JPEG file

Plate 5: RYMV effect on panicle and seed formation in the experiment at SUA crop museum. Rice plant leaves turn yellow, showing incomplete panicle exertion and spikelet sterility

Source: “Photograph from on-station experiment” 2014. JPEG file

4.2 Yield Performance under System of Rice Intensification and Farmers Practice

The statistical analysis of the three treatments using ANOVA revealed that among the three treatments, there was significantly higher yield performance in SRI for both seasons ($P<0.01$). A comparison between mean yields of the three treatments using LSD test further supported that yields were significantly higher in SRI.

The results depicted in Table 6 showed that total number of tiller per hill and panicle per hill were significantly different among SRI, FP1 and FP2 ($P<0.005$). The total yield for dry (Season one) and wet (Season two) seasons were significantly higher in SRI followed by FP1 and FP2 ($P<0.01$). More fertile tillers (22.62 tillers/hill) was observed in SRI plots in both seasons while in FP1 and FP2 the average was 16 and 10.96 tillers/hill for both seasons respectively. Maximum number of panicles (22.58 panicles/hill) was noted in SRI plants followed by 15.9 panicles/hill for FP1 and 10.92 panicles/hill for FP2 plants in both seasons.

Plots under SRI were found to have higher yield than those under FP1 and FP2 and the total yield for wet (S2) season was higher in all treatments compared to dry (S2) season. The maximum yield for SRI was 1.0707 t/ha and 1.0981 t/ha for dry (S1) and wet (S2) respectively while for FP1 it was 0.6406 t/ha and 0.6906 t/ha, for FP2 was 0.4710 t/ha for the dry (S1) season and 0.4831 t/ha for wet (S2) season.

Table 7: Rice yield (t/ha) and yield parameters

Rice production method	Tiller/hill		Panicle/hill		Plant height (cm)		Rice yield (t/ha)	
	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2
SRI	22.62a	22.62a	22.58a	22.58a	84.85a	84.85a	0.7976a	0.8181a
FP1	16ab	16ab	15.9ab	15.9ab	82.94a	82.94a	0.6023ab	0.6177ab
FP2	10.96b	10.96b	10.92b	10.92b	82.62a	82.62a	0.3951b	0.4052b
Ftest	**	**	**	**	ns	ns	***	****
Mean	16.5	16.5	16.5	16.5	83.47	83.47	0.598	0.614
CV (%)	22.3	22.3	22.3	22.3	4	4	24	24

Means with the same superscripts along the same column are not significantly differently at P<0.05; using Turkey HSD test. **** = Highly significantly different (P<0.01); ** = significantly differently (P<0.005); *** = highly significantly different (P<0.001) ns = not significantly different, SRI = system of rice intensification, FP1 = Farmer's practice one, FP2 = farmer's practice two.

4.3 Farmers' Practices and Perceptions on Rice Diseases

4.3.1 Farmer practices

About 66.7% of the respondents practiced transplanting while 3.7% practiced direct sowing and only 8% practiced broadcasting. Among those who were transplanting 63% used one seedling per hill and 7.4% were planted two seedlings per hill. About 66.7% of farmers applied fertilizers in their fields but 40.7% of respondents applied fertilizer 30 DAT, 18.5% at transplanting and 3.7% applied two splits one at transplanting and 30 DAT. The other farmers, 3.7% applied fertilizers at transplanting and 21 days after first weeding. Line spacing used by farmers during transplanting was 20 cm (44.4%), 15 cm (3.7%), 25 cm (7.4%), 6 cm (3.7%) and about 40.7% applied random spacing. Majority do weeding once per crop season and about 96.3% used hand hoe, while 3.7 used herbicides (Fig. 7, 8, 9 and 10).

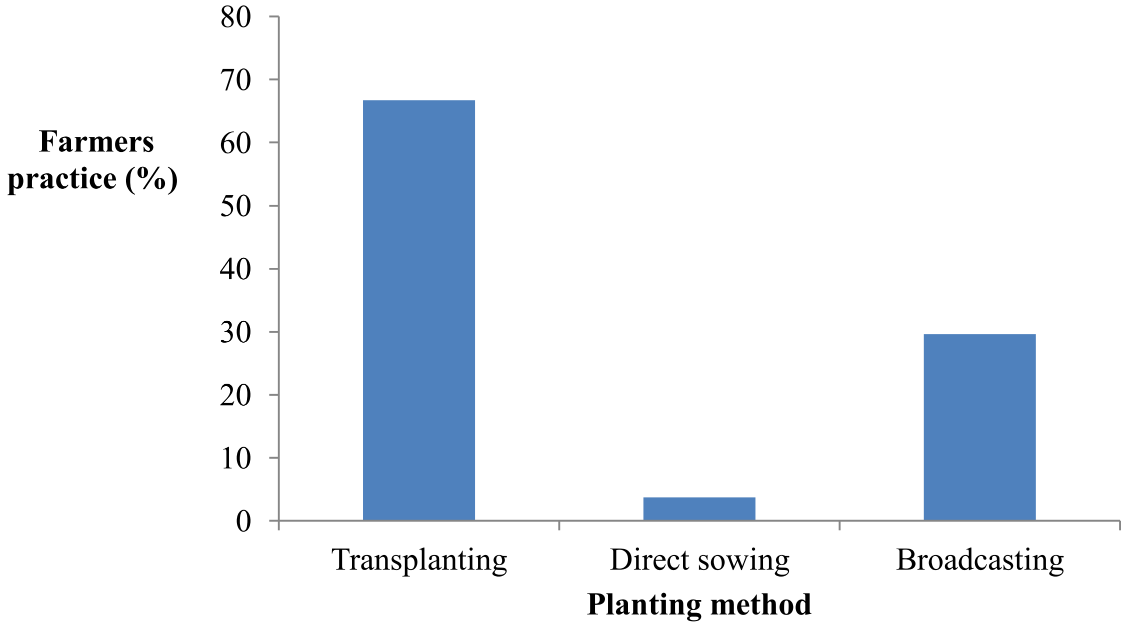


Figure 7: Planting method in farmer's fields (N=27)

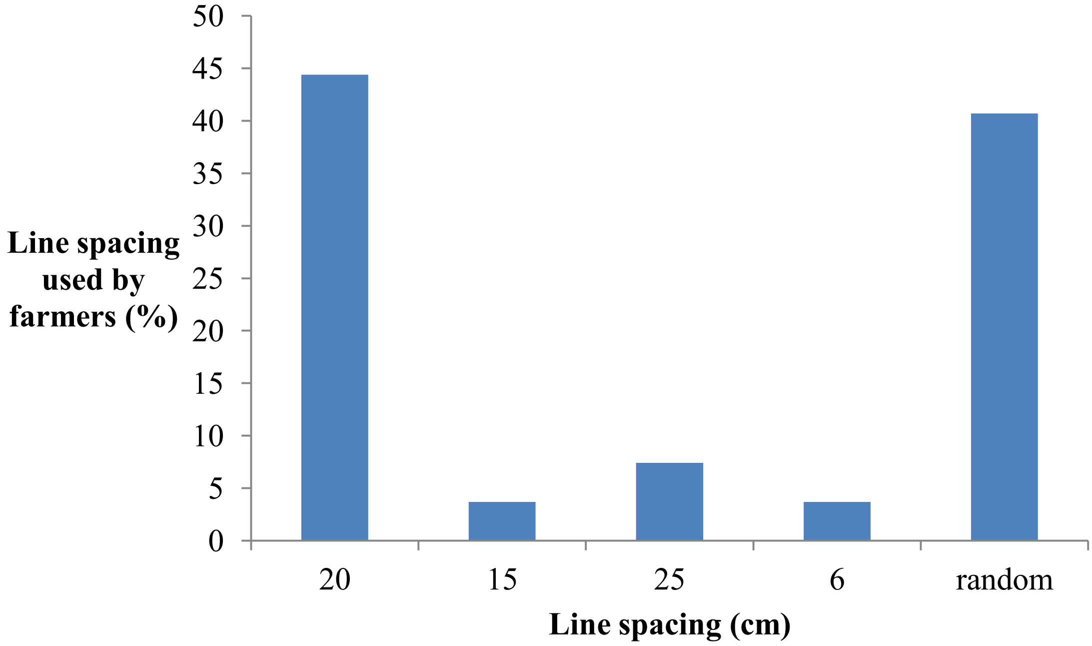


Figure 8: Line spacing used by farmers (N=27)

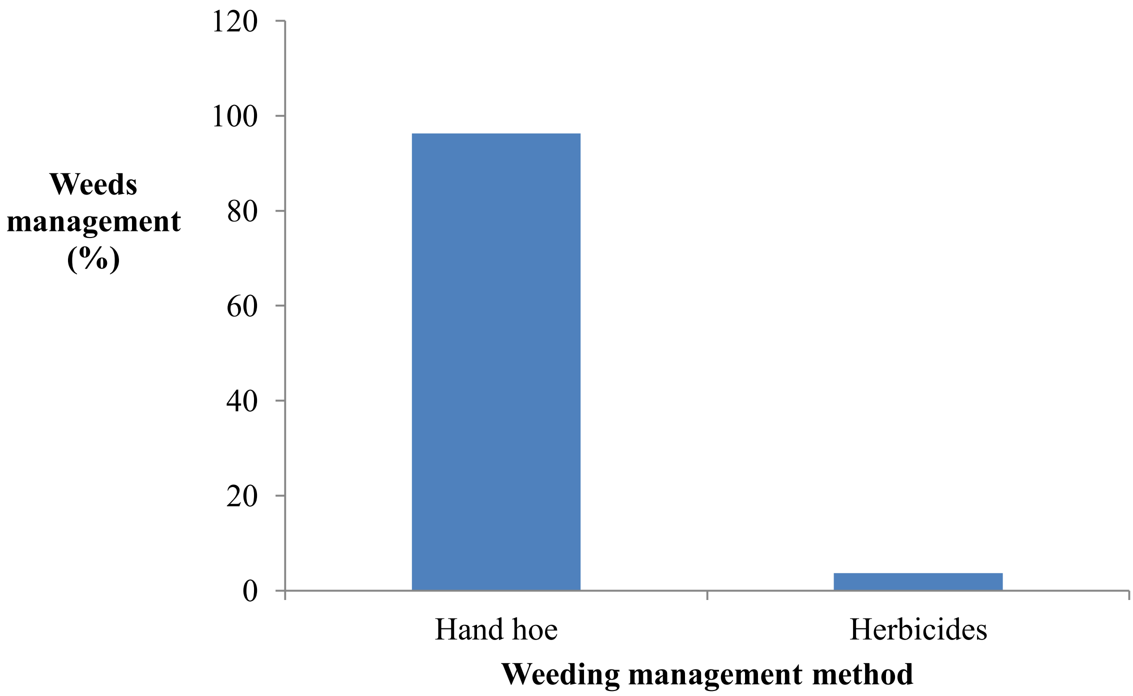


Figure 9: Weeding method used by farmers (N=27)

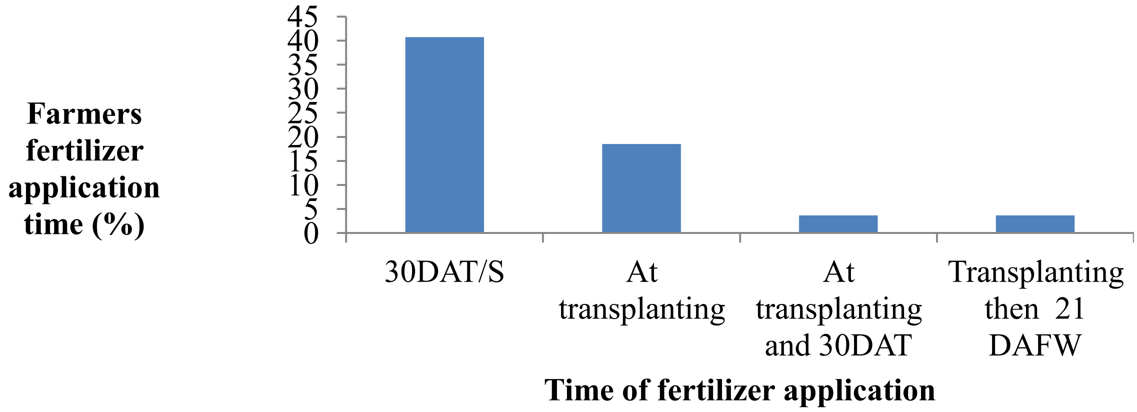


Figure 10: Time for fertilizer application in farmer's field (N= 27), DAT/S = days after transplanting or sowing, DAFW = days after first weeding and DAT = days after transplanting

4.3.2 Farmer perceptions on rice diseases

The results in Fig. 11 indicates that among 27 respondents interviewed in nine (9) locations 51.9% suggest that diseases is a major problem in rice production while 5% said that both diseases and scarcity of water for irrigation affected rice production in their locality. Five percent also perceived SRI as a better method to control diseases, while about 2% knew nothing about rice diseases. Farmer education on rice diseases and SRI were perceived by 1% of the respondents to be among the solutions to control rice diseases and improve yields.

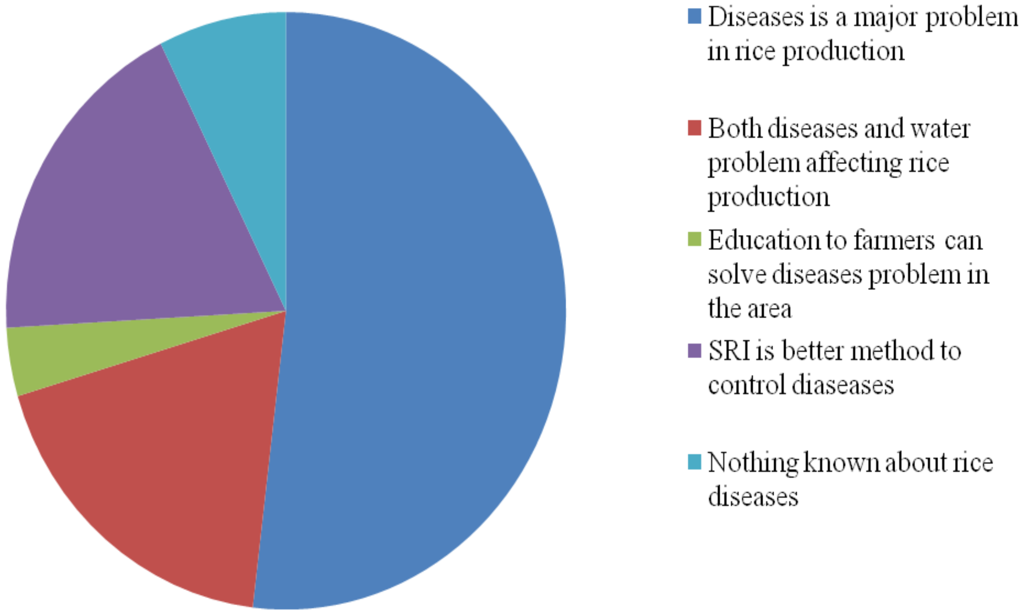


Figure 11: Farmers response on rice diseases (N= 27), data collected from farmers in different nine locations in Morogoro, Tanzania

CHAPTER FIVE

5.0 DISCUSSION

The findings indicate that diseases remain a major problem in rice production. Increase in incidence and severity of the diseases in farmers' fields can be attributed by source of water used for irrigation. Water may introduce initial disease inocula to be maintained in the rice straws and then continue to spread to newly established crop hence increases diseases incidence. Variation of disease incidences and severity in different locations may be due to differences in inocula amount, environmental conditions and cultural practices. This suggestion is supported by Groth and Bond, (2007) who reported that disease incidence and severity is dependent on inoculums amount, crop growth stage at infection, environmental conditions, varietal resistance, and cultural management.

Higher incidence of RBSD in all locations can be due to the fact that this disease is air borne so it can be spread easily, also poor field management and water stress may be the reason for high incidence. This corresponds to the findings of Roul and Mishra, (2014) who reported that rice brown spot disease is air borne disease and it is favoured by high humidity and warm temperatures. Use of resistant varieties, destruction of crop residues and using recommended rates of nitrogenous fertilizers it was also reported. Most of the field observed were poorly managed. Majority of farmers practiced weeding once per season, while others didn't consider line spacing during sowing or transplanting. Some farmers did not consider recommended rates in fertilizer application as well.

The whole field at Lumemo being attacked by RYMD may be due to the fact that RYMV tends to spread fast from plant to plant via vectors eventually covering all neighbouring plants. Thus, apart from that it can also be transmitted mechanically by touching diseased plant then healthier plant for example during weeding (Wopereis *et al.,* 2009). These results are consistent with those of Sarra (2005) who reported that in irrigated rice RYMV can be distributed randomly across the same region and across the same field.

It is evident that, rice diseases, scarcity of water and poor farmer's knowledge on rice disease and SRI are the major problem constraining rice production. This may be due to the fact that rice production depends greatly on factors such as water/rainfall, relative humidity and temperature. Water stress may lead to an increase in pest and diseases. This corresponds to the study of Edeh *et al.* (2011) that rice production depends on combination of optimum production inputs including environmental factors (rainfall, temperature and relative humidity) and the same factors may influence pest and diseases incidence positively or negatively. Suggestion of farmers on SRI being a good method to control rice diseases and improve yields may be due to the fact that SRI plants are known to be more resistant to damage from pests and apart from the possibility of being attacked by diseases, SRI plants can still yield more. These findings agree with observation of Roul and Mishra, (2014) who reported that SRI has low insect pest and disease incidence although under changing environmental conditions there is a possibility of disease pest attack to SRI crop. However, farmers suggestion on the need of education on rice diseases and SRI practice may imply that most farmers seems to have inadequate knowledge on good farming practices which require improvement and knowledge enhancement.

On –station experiment RYMD, RBSD and RSBD incidence and severity increased from booting to maturity stages. This may be due to the fact that rice crop is severely affected from booting stage (Devasahayam, 2009) and leads to incomplete panicle exertions and poor panicle formation, this affects seed formation, results into empty spikiletes and consequently reduces crop yield.

Rice sheath blight disease affected panicle initiation and grain filling in the on-station experiments. This may be the reason for reduction of the grain weight and the number of filled grain which resulted into low yield. The incidence and severity of RSBD was low during early plant growth stages because *Rhizoctonia solani* infect the rice plant early in the season without showing any symptoms and the pathogens are present on the rice plant during the whole rice-growing season. Lanoiselet *et al*. (2007) reported that *R. solani* survive as sclerotia or mycelium in the soil or in the crop debris in which the spore produced can initiate secondary infection. The inoculum that present early in the season play important role in final disease incidence. High RSBD incidence and severity in FPI and FP2 may be attributed to environmental conditions (Groth and Bond, 2007) and high plant populations which raise the canopy humidity. This suggestion is further demonstrated by Laha *et al*. (2014) that close planting increase the humidity, when high humidity tends to be maintained in the field rice sheath blight disease is usually observed.

The current results indicate that there is low incidence of brown spot disease and Shealth blight disease in SRI plots, which corresponds to the findings of Uphoff (2011) who reported that SRI reduced the incidence of sheath blight, leaf blight, small leaf-folder and brown plant hopper up to 70% compared with farmers practices. This suggestion is further reinforced by Chapagain and Riseman, (2011) observations that in SRI plots there were no significant pest or diseases infestation throughout the experimental period. During this study it has been observed that even in SRI plots diseases were present. The incidence and severity of RYMD was higher in SRI plots, this can be due to conditions favorable for disease development, also because the virus is transmitted mechanically between rice plants (Abo *et al*., 1998). Following infection, virus end to multiply and translocate slowly and gradually from site of infection to uninfected cells to cover the whole plant (Sasty and Zitter, 2014). Apart from SRI plants being resistant to insect pests and diseases, still the same diseases could appear in both SRI and farmers practice (Guideline on SRI Practice for Tropical Countries, 2012).

Beside SRI plants being attacked by diseases still it yielded higher when compared to FP1 and FP2. A comparison between mean yields of the three treatments supported that wider spacing gives better yield. This agrees with the findings of WWF-ICRISAT (2010) who reported that adoption of SRI practices such as wider spacing and others increase the yield significantly. These findings are in line with the evaluation conducted by Lhendup (2006) in Bhutan that SRI method has better yield performance compared with conventional methods.

Highest number of tiller in SRI plots may be attributed to transplanting young seedlings, using wider spacing and shallow irrigation (Uphoff, 2002). According to Surya Prabha *et al.* (2011), high yield in SRI is associated with transplanting young seedlings which leads into higher root growth for nutrients absorption which is important for plant growth and leads to higher tillering and grain filling. And also transplanting younger seedlings increases number of days for tillering and minimize transplanting shock hence help to add up to the total number of tillers (Thiyagarajan and Gujja, 2013).

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

It is revealed that RBSD and RYMD were the most prevalent diseases with highest incidences in farmers' fields followed by RSBD, RBD and, RBLBD. With the on-station experiments, RYMD, RBSD and RSBD incidence and severity were different between rice growing stages and treatments. At seedling stage the incidence and severity was low for all treatments but from booting stage to maturity was high with little differences between treatments.

The effect of treatments on yield was significant. The maximum total yield was noted in SRI plots followed by FP1 and FP2. The results clearly indicate that SRI can influence rice production positively.

Apart from diseases being a major constraint in rice production the knowledge on rice diseases seems poor among farmers. Majority never practiced SRI and knows nothing on how they can improve rice production regardless of diseases situation in their field.

6.2 Recommendations

i. It is necessary to improve farmer adoption of SRI for increasing rice production
ii. Farmer's knowledge and awareness on SRI can be a major contribution to improving rice production
iii. Knowledge on the field management of rice fields to farmers can help to reduce disease pressure in their field

iv. Research on identification and characterization of disease pathogens is recommended

v. Development of rice varieties which are resistant to diseases with preferable characteristics required by farmers and consumers is recommended.

REFERENCES

Abo, M. E., Sy, A. A. and Alegbejo, M. D. (1998). Rice yellow mottle virus in Africa. evolution, distribution, economic significance on sustainable rice production and management strategies. *Journal of Sustainable Agriculture* 11: 2 – 12.

Akhtar, M. A., Rafi, A. and Hameed, A. (2008). Comparison of methods of inoculation of Xanthomonas oryzae pv. oryzae in rice cultivars. *Pakistan Journal Botanic* 40(5): 2171 – 2175.

Amadioha, A. C. (2000). Controlling rice blast in-vitro and in-vivo with extracts of *Azadirachta indica*. *Journal of Crop protection* 19: 287 – 290.

Amna, N., Chaudhry, Z., Rashid, H. and Mirza, B. (2006). Evaluation of resistance of rice varieties against bacterial blight caused by Xanthomonas Oryzae Pv.Oryzae. *Pakistan Journal Botanic* 38(1): 193 – 203.

Babujee, L. and Gnanamanickam, S. S. (2000). Molecular tools for characterization of rice (*Magnaporthe grisea*). *Population and Molecular Marker Assisted Breeding for Disease Resistance* 78: 248 – 254.

Bagayoko, M. (2012). Effects of plant density, organic matter and nitrogen rates on rice yields in the system of rice intensification in the Office du Niger in Mali. *ARPN Journal of Agricultural and Biological Science* 7(8): 620 – 630.

Balamurugan, A. (2013). *Department of Plant Pathology*: Madurai Agricultural College and Research Institute, Tamil Nadu, India.1pp.

Barreiro-Hurle, J. (2012). *Analysis of Incentives and Disincentives for Rice in The United Republic of Tanzania.* Food and Agriculture Organization, Rome. 3pp.

Catwright, R., Lee, F. and Wamishe. Y. (2013). Management of rice diseases. [https://www.uaex.edu/publications/pdf/mp192/chapter-11.pdf] site visited on 15/6/2013.

Chaboussou, F. (2004). *Healthy Crops: A New Agricultural Revolution*. *Santé des Cultures: Une Révolution Agronomique*. Flammarion La Maison Rustique, Paris. 1985pp.

Chapagain, T. and Riseman, A. and Yamaji, E. (2011). Assessment of system of rice intensification and conventional practices under organic and inorganic management in Japan. *Journal of Rice Science* 18(4): 311 – 320.

Chapagain, T. and Riseman, A. (2011). Achieving More with Less Water: Alternate wet and dry irrigation as an alternative to the conventional water management practices in rice farming. *Journal of Agricultural Science* 3(3): 5 – 7.

Couch, B. C. and Kohn, L. M. (2002). A multilocus gene genealogy concordant with host preference indicates segregation of a new species, *Magnaporthe oryzae from M. grisea*. *Mycologia* 94: 683 – 693.

Devasahayam, H. (2009). *Illustrated Plant Pathology Basic Concept.* Publishing Agency, New Delhi, India. 199pp.

Dung, N. (2007). SRI application in Vietnam. SRI-Rice, CIIFAD, Cornell University. Plant Protection Department [http://www.slides hare.net /SRI.CORNELL/sri-application-in-vietnam] site visited on 2/7/2013.

Edeh, H. O., Eboh, E. C. and Mbam, B. N. (2011). Analysis of Environmental Risk Factors Affecting Rice Farming in Ebonyi State, Southeastern Nigeria. *World Journal of Agricultural Sciences* 7(1): 100 – 103.

Food and Agriculture Organization (2009). Rice information the secretariate of the international rice commission crop and grassland service plant. Production and Protection Division Agriculture Department, Rome, Italy.[www.fao.org]site visited on 12/7/2014.

Fininsa, C. (2003). Relationship between common bacterial blight severity and bean yield loss in pure stand and bean maize intercropping systems. *International Journal of Pest Management*.

Groth, D. E. and Bond, J. A. (2007). Effects of cultivars and fungicides on rice sheath blight, yield, and quality. *Plant Disease* 91: 1647 – 1650.

Guidelines on SRI Practice for Tropical Countries (2012). *Pest and Disease Management*. Association of the System of Rice Intensification, Japan. 14pp.

Hollier, C. and Whitney, G. (2014). Rice Diseases in Mississippi: A Guide to Identification, Mississippi.[http://msucares.com/experts.html]site visited on 11/9/2014.

IRRI (2002). *Standard Evaluation System for Rice*. International Rice Research Institute, Philippine. 27pp.

IRRI (2009). Crop infected with brown spot. [http://cropgenebank.sgrp.cgiar.org]site visited on 10/3/2013.

IRRI (2011). Disease and pest resistant rice. [http://www.irri.org] site visited on 10/3/2013.

IRRI (1993). The Rice Field Ecosystem. [http://pubs.iclarm.net/Pubs/ CultureOfFish/ section1.pdf] site visited on 10/06/2015.

Jiaguo, Z. (2004). *Incidence of Sheath Blight. Crop and Soil Management Institute.* Sichuan Academy of Agricultural Sciences, Chengdu, China.8pp.

Kanyeka, Z. L., Kibanda, J. M., Msomba, S. C. and Tusekelege, H. (2005). SARO 5 an emerging high yielding and profitable rice cultivar in Tanzania*: Research and Training Newsletter* 19: 1 – 4.

Kanyeka, Z. L., Msomba, S. W., Kihupi, A. N. and Penza, M. S. F. (1994). Rice ecosystem in Tanzania: Characterization and classification. *Research and Training Newsletter* 9(2): 13 – 15.

Kumar, J. W., Vijay, K., Kloepper, K. S., Lawrence, D. E., Groth and Mille, M. E. (2009). Sheath blight disease of rice (*Oryza sativa* L.). *An Overview* 6(2): 465 – 480.

Laha, G. S., Lakshmi, D. L. and Prasad, S. M. (2014). Rice knowledge management portal. [http://www.rkmp.co.in]site visited on 27/3/2014.

Lanoiselet, V. M., Cother, E. J. and Ash, G. J. (2007). Aggregate sheath spot and sheath spot of rice (review). *Crop Protection* 26(6): 799 – 808.

Lee, K. S. and Khush, G. S. (2003). Genetic analysis of resistance to bacterial blight in rice. In: *Advances in Rice Genetics.* (Editors by Khush, G. S., Brar, D. S. and Hardy, B.), International Rice Research Institute, Philippine. pp. 46 – 49.

Lhendup, L. (2006). *A Feasibility Study of a New Rice Farming System with Special Reference to Location Specific Trials and Yield Performance of Different Varieties*. The System of Rice Intensification, Bhutan. 8pp.

Lin, X. Q. (2010). Evaluation of key factors in SRI methods. China. [http://www. slideshare.net/SRI.CORNELL/1001-evaluation-of-key-factors-of-srimethod] site visited 0n 17/02/2013.

McDonald, J. H. (2014). Biological statistics. Data transformation. [http:// www. biostathandbook.com/transformation.html] site visited on 28/9/2014.

Mahadevappa, M. (2004). Rice production in India-Relevance of hybrid and transgenic technologies. *The Indian Journal of Genetics and Plant Breeding* 64(1): 1 – 4.

Mathur, S. B. and Kongsdal, O. (2003). *Common Laboratory Seed Healthy Testing Methods for Detecting Fungi*: 1st Edition. International Seed Testing Association, Switzerland. 293pp.

Mwalyego, F, S., Kayeke, J. M. and Mghogho, R. M. (2011). Important diseases in rice production, ASARECA rice project Tanzania.

Nwilene, F. E., Séré Y., Ndjiondjop, M. N., Abo, M. E., Traore, A. K., Asidi, A. N., Onasanya, A., Togola, A. and Agunbiade, T. A. (2008). *Rice Yellow Mottle Virus and its Insect Vectors: Ecology and Control.* Field Guide and Technical Manual. Blackwell Science Ltd., Oxford. 550pp.

Piotti, E., Rigano, M. M., Rodino, D., Rodolfi, M., Castiglione, S., Picco, A. M. and Sala, F. (2005). Genetic structure of *Pyricularia grisea* (Cooke) Sacc.isolates from Italian paddy fields. *Journal of Phytopathology* 153: 80 – 86.

Roul, P. K. and Mishra, H. P. (2014). Integrated disease pest management in SRI paddy. SRI Secretariat. College of Agriculture OUAT, Bhubaneswar Orissa. [http://www.sri-india.net/documents/ipm_idm_sri_paddy.pdf] site visited 27/9/2014.

Sarra, S. (2005). Novel insights in the transmission of RYMV in irrigated rice. Thesis for Award of PhD Degree at Wageningen University, Wageningen, The Netherlands, 87pp.

Sastry, K. S. and Zitter, A. (2014). Management of virus and viroid diseases of crops in the tropics. *Epidemiology and Management* 2: 150 – 153.

Stoop, A. W., Uphoff, N. and Kassam, A. (2002). A review of agricultural research issues raised by the system of rice intensification from Madagascar: Opportunities for improving farming systems for *resource-poor farmers. Agriculture Systems* 71: 249 – 274.

Surya Prabha, A. C., Thiyagarajan, T. M. and Senthivel, M. (2011). System of rice intensification principles on growth parameters, yield attributes and yield of rice (*Oryza sativa*. *L*.). *Journal of Agronomy* 10(1): 27 – 33.

Thakur, R. P., Sharmar, R., Rai, K. N., Gupta, S. K. and Rao, V. P. (2006). Screening techniques and resistance sources for foliar blast in pearl millet. *Journal of SAT Agricultural Research* 7: 1 – 5.

Thiyagarajan, T. M. and Gujja, B. (2013). *Transforming Rice Production with System of Rice Intensification Knowledge and Practice.* National Consortium on Sri, India. 123pp.

Thiyagarajan, T. M. and Gujja, B. (2012). *Transforming Rice Production with SRI: Knowledge and Practice.* India. 181pp.

Uphofff, N. (2002). System of Rice Intensification (SRI) for enhancing productivity of land, labour and water. *Journal of Agricultural Resource Management* 1: 43 – 49.

Uphoff, N. (2011). Agro ecological approaches to 'climate-proofing' agriculture while raising productivity. [http://www.slideshare.net/SRI] site visited on 21/3/2014.

URT (2009). *Tanzania Report on The State of Plant Genetic Resources for Food and Agriculture*. Regional Rice Centre of Excellence, Morogoro, Tanzania. 63pp.

Wopereis, M. C. S., Defoer, T., Idinoba, P., Diack, S. and Dugué, M. J. (2009). Participatory learning and action research for integrated rice management in Inland Valleys of Sub-Saharan Africa: *Technical Manual* 24: 105 – 107.

Wopereis, E.R. (2009). Major diseases in rice. *Journal of plant Disease* 24: 105.

WWF-ICRISAT (2010). *More Rice for People, More Water for the Planet.* WWF-ICRISAT, Hyderabad, India. 8pp.

Xie, X., Xu, M., Zang, J., Sun, Y., Zhu, L., Xu, J., Zhou. Y. and LI, Z. (2008). Genetic Background and Environmental Effects on QTLs for Sheath Blight. *Resistance Revealed by Reciprocal Introgression Lines in Rice* 34(11): 1885–1893.

APPENDICES

Appendix 1: Disease incidence and severity scoring sheet

Field number…………………………………

Location…………………………..Latitude……………….Longitude……………

Rice ecology…………………Planting method …………….

Crop establishment date…………………………Data collection date……

Name of Disease		Rice Blast Blast Disease		Bacteria Leaf Blight Disease		RYMVD		Brown Sport Disease		Shealth Blight Disease		Bacteria Leaf Streak Disease		Others
		I	S(1-9)	I	S(1-9)	I	S(1-9)	I	S(1-9)	I	S(1-9)	I	S(1-9)	
	n/N													
Q1														
Q2														
Q3														

Where,

N=Total number of hills per quadrant

n=Number of affected hills per quadrant

I=Incidence

S=Severity

Q= Quadrat

Quadrat 1

Hill Number.	1	2	3	4	5	6	7	8	9	10
No. of tillers per hill										
No. of leaves per tiller										
RYMV										
BLAST										
Brown spot										
BLB										
Shealth blight										
BLS										

Quadrat 2

Hill Number.	1	2	3	4	5	6	7	8	9	10
No. of tillers per hill										
No. of leaves per tiller										
RYMV										
BLAST										
Brown spot										
BLB										
Sheath blight										
BLS										

Quadrat 3

Hill Number.	1	2	3	4	5	6	7	8	9	10
No. of tillers per hill										
No. of leaves per tiller										
RYMV										
BLAST										
Brown spot										
BLB										
Sheath blight										
BLS										

Appendix 2: Checklist

FARMER NO……………………..

LOCATION……………………Latitude……………………….longitude………

DATE………………..

1. Type of variety used…………………………..
2. Seed source……………………………………….
3. Name of rice ecology…………………………………..
4. Planting method used………………………………………………
5. Crop establishment date……………………………………………..
6. Spacing used …………………………………..
7. Number of seedling per hill…………………………
8. Weeding method used…………………………at what stage…………………
9. Expected date of harvesting……………………………………
10. Type of fertilizer used……………………………………………………

    Dose……………………………………...Date of application………...
11. Yield estimates (kg/ha)……………………………………….
12. Type of diseases observed in the field

    ....……………………………………………
13. Disease control method used……………...
14. Perception on rice diseases.

Appendix 3: SHB S1 ANOVA table

	Incidence					Severity			
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr	s.s.	m.s.	v.r.	F pr.
Stage	4	1.20251	0.30063	7.59	<.001	0.045116	0.011279	7.05	<.001
Treatment	2	0.22264	0.11132	2.81	0.071	0.012492	0.006246	3.9	0.027
Stage. Treatments	8	0.45698	0.05712	1.44	0.206	0.019018	0.002377	1.49	0.189
Residual	45	1.78279	0.03962			0.072029	0.001601		
Total	59	3.66491				0.148654			

Appendix 4: RYMV S1 ANOVA table

		Incidence				Severity			
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.	s.s.	m.s.	v.r.	F pr.
Stage	4	29.27	7.32	0.61	0.655	5.521	1.38	0.74	0.567
Treatment	2	183.1	91.55	7.67	0.001	34.797	17.399	9.37	<.001
Stage. Treatment	8	45.9	5.74	0.48	0.863	8.756	1.094	0.59	0.781
Residual	45	536.8	11.93			83.537	1.856		
Total	59	795.08				132.611			

Appendix 5: Brown Spot S1 ANOVA table

		Incidence				Severity			
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.	s.s.	m.s.	v.r.	F pr.
Stage	4	38.7	9.67	0.73	0.579	7.321	1.83	0.69	0.602
Treatment	2	76.36	38.18	2.87	0.067	16.584	8.292	3.13	0.053
Stage Treatment	8	26.22	3.28	0.25	0.979	5.149	0.644	0.24	0.98
Residual	45	599.23	13.32			119.195	2.649		
Total	59	740.51				148.249			

Appendix 6: RYMD S2 ANOVA table

	Incidence					Severity			
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.	s.s.	m.s.	v.r.	F pr.
Stage	4	2.94644	0.73661	7.44	<.001	0.207951	0.051988	8.78	<.001
Treatment	2	3.5205	1.76025	17.77	<.001	0.203903	0.101952	17.21	<.001
Stage. Treatment	8	3.08337	0.38542	3.89	0.001	0.137866	0.017233	2.91	0.011
Residual	45	4.45757	0.09906			0.266535	0.005923		
Total	59	14.00788				0.816255			

Appendix 7: SHB S2 ANOVA Table

		Incidence				Severity			
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.	s.s.	m.s.	v.r.	F pr.
Stage	4	3621.8	905.4	8.11	<.001	5270.45	1317.61	27.78	<.001
TEATMENT	2	143	71.5	0.64	0.532	286.95	143.48	3.03	0.059
Stage. Treatment	8	840	105	0.94	0.493	236.62	29.58	0.62	0.753
Residual	45	5022.5	111.6			2134.07	47.42		
Total	59	9627.3				7928.09			

Appendix 8: Brown Spot S2 ANOVA Table

		Incidence				Severity			
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.	s.s.	m.s.	v.r.	F pr.
Stage	4	24.888	6.222	1.69	0.17	1.2471	0.3118	1.72	0.163
Teatment	2	19.96	9.98	2.71	0.078	0.974	0.487	2.68	0.079
Stage. Treatments	8	32.847	4.106	1.11	0.373	1.6125	0.2016	1.11	0.374
Residual	45	166.016	3.689			8.1656	0.1815		
Total	59	243.711				11.9992			