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School of Agriculture and Food Sciences
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RICE RESPONSE ON NITROGEN APPLICATION METHOD UNDER HUYE ECOLOGICAL CONDITIONS

Thesis submitted to the School of Agriculture and food sciences, College of Agriculture and veterinary medicine, University of Rwanda in partial fulfilment of the requirements for the degree of Master of Science in Crop science

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5th October 2019

CERTIFICATION

I, Dr. Obedi I. Nyamangyoku certify that I have read and hereby recommend for acceptance by the University of Rwanda the dissertation entitled “**Rice response on nitrogen application method under Huye ecological conditions** in partial fulfilment of the requirements for Master’s Degree in crop science.

Date October 5th 2019

Signature

Dr. Obedi I. Nyamangyoku

DECLARATION

I, Aline MUKAKALINDA, declare that this dissertation is my original work and has not been presented to any other institution. No part of this work should be reproduced without the author's consent or that of the University of Rwanda.

Aline MUKAKALINDA
Date: 9th October
Signature:

It is with my deepest gratitude that I dedicate this thesis to:
The God Almighty for blessing my life with so much more than I deserve
My loving Mother, husband, Siblings and the friends for unwavering love, support and encouragement
Especially to my daughter; may this work inspire her to aim higher.

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ABSTRACT

As one of important food crop, rice (*Oryza sativa* L.) is cultivated across Rwanda, it plays a critical role in nation food security. The use of fertilizers is sensitized for increasing production, however there is a need of proper use of nitrogenous fertilizer as the most important nutrient which may limit the production or causes the pollution when are not used efficiently by plant. Therefore, this study investigated rice response using growth and yield parameters, correlation among parameters and nitrogen use efficiency (NUE), in four different treatments selected; T0 (Control), T1 (FFP; nitrogen was splited three times), T2 (Basal; all nitrogen applied as basal), T3 (SSNM; site specific nitrogen management) these treatments were replicated three times in randomized complete block design (RCBD) in Cyili wetland south province of Rwanda, analysis were performed using genstat statistical software.

The result showed no significant difference at $p<0.05$ observed in all treatment on plant height, number of tillers, panicle weight ,1000 grain weight and grain yield. Significant difference at $p<0,05$ was observed on dry matter and nitrogen uptake.

Adherence between parameters using (Pearson's correlation coefficient) were observed on following basis: Panicle initiation showed strong positive correlation with number of tillers (0.9983), negative correlation with plant height (-0.8716), strong positive correlation with grain yield (0.9182) and moderate positive correlation with 1000 grain weight (0.4486). Number of tillers have negative correlation with plant height (-0.8881), strong positive relationship with grain yield (0.9394) and moderate positive relationship with 1000 grain (0.4987). Plant height show negative relationship for all parameters; grain yield ,1000 grain weight, panicle weight, number of tillers; (-0,8904), (-0.7336), (-0.8881), (-08716) respectively. Grain yield have positive correlation with 100 grain yield weight of (0.7336).

Result of three different indicators of NUE revealed SSNM to be the best method which use N efficiently with Partial factor productivity of 100kg kg^{-1}, Agronomic efficiency of $21kgkg^{-1}$and Recovery efficiency of 78%. And enhanced yield and profit by saving form of reduced fertilizer use, without a reduction in yield, it reduces as well N_2O emission, by decreasing the total N application and timing to crop need.

Key word: Rice, Correlation, NUE, Nitrogen application method

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LIST OF ABBREVIATION

AE	Agronomic efficiency
ANOVA	Analysis of variance
EIC	Enquête Intégrale sur les Conditions de Vie des Ménages.
FAO	Food agriculture organisation
FFP	Farming farmer practice
Gy	Grain yield
KCL	Potassium chloride
M^2	Square meter
MINAGRI	Ministry of agriculture and animal resources
NPK	Nitrogen, phosphorus, potassium
NRDS	National Rice Development Strategies
NUE	Nitrogen use efficiency
PFP	Partial factor productivity
PH	Power of hydrogen
RAB	Rwanda Agriculture and Animal Board
RAB	Rwanda Agriculture and animal resources Board
RBD	Randomized block design
RE	Recovery efficiency
SPAD	Soil plant analysis Division
SSNM	Sites specific nitrogen management
TSP	Triple phosphate
WAP	Weeks after planting
N	Nitrogen

CHAPTER I: INTRODUCTION

1.1 Background

Rice (*Oryza sativa*) is ranking as the third cereal largely consumed Worldwide, the projection around the word anticipate to continue to grow steadily around 1.1 % by 2025. (Index box 2019), rice popularity is associated to its nutritional values and health benefit. Rice is vital to the food security over a half of the world population, 95% of total production is from developing countries (FAO,2016). In Africa, rice is cash crop for small to medium scale farmer and the demand exceeds production with the exception of a few countries that have attained self-sufficiency in rice production (FAO,1996).

Rice has become the most consumed and preferable food in Rwanda, has radically replaced traditional food as it provides a viable choice for its long shelf life ease fuel and time use EICV (2010). National rice program (2005) estimated that in family of six, amount of rice daily consumption is 0.6kg and consumed three days per week. In addition, NRDS (2011-2018) projected that the per capita consumption of rice will be 15.6kg per Unum. This indicate the importance of rice in Rwandan lives, in order to meet the high demand of rice in Rwanda, the measures have been taken by increasing area under rice cultivation, usage of improved seed, reduction of post-harvest losses, development of marshland and the use of fertilizers (MINAGRI, October, 2011).

Optimum growth and production of rice are influenced by climate, soil physical condition, soil fertility, water management, sowing date, cultivar, weed control and fertilization (Angus *et al.*,1994). Regarding to rice ecosystem of submerged area the sustainable production relies on input and good N management (Nguyen *et al*., 2006). In addition, Nitrogen is mainly correlated to the rice yield (Bauman *et al*., 2008; Dorman 2003a). And yield is related to per unit of total N uptake (Peng *et al*., 2006; Jing *et al.*,2008).

It has approved (Ponnamperuma,1972) that Nitrogen is more dynamic than other crop nutrients. Soil microorganism activities are responsible of availability and loss of nitrogen favoured by rice soil ecosystem which characterized by depletion of oxygen on root zone, in that ecosystem N is present in dominant form of ammonium (NH_4^+) which is subjected to different transformation, these lead to the losses. the study shows that the high amount of nitrogen is lost through ammonium volatilisation up to >90% when applied as urea in submerged area. (Buresh and Datta,1990). An average recovery of applied nitrogen is only 30%, Regardless of the low nitrogen uptake efficiency, the research done on

Asian rice field, revealed that rice has potential to take up nitrogen when its application harmonized with crop demand (Doberman et al., 2003).

For exploring rice response on application of nitrogen at different growing stage three different application have been investigated in this study, to assess response of rice on yield, correlation between yield and its components and nitrogen use efficiency.

1.2 Problem statement

Soil does not usually supply enough nutrients to produce high, profitable yields; therefore, it is needed to add fertilizers in purpose of meeting nutrient requirements of crop for better growth. Rice crop requirements for supplemental nutrients can vary greatly among fields, seasons, and years as a result of differences in crop-growing conditions. It is known that the more nitrogen applied to the rice the more yield might be met, nevertheless, all nitrogen applied are not used by crop due to the different types of losses associated to nitrogen dynamics caused by microbial activities, method of application, temperature and timing (Doberman et al., 1999). These losses lead unnecessary cost and environmental pollution. In order to improve nitrogen use efficiency, split application of nitrogenous fertilizer is recommended to farmers however, split application must be adjusted to crop uptake to insure maximum assimilation.

Nitrogen use efficiency can reduce nitrogen emission such as ammonia that causes acidic rain and contributes to particulate matter formation; which are harmful to human beings as they are key contributing factors to global climate change and water pollution.

Research of (Ling *et al.*,2016) have shown that Nitrogen loss reduces 25% of total yield This loss affects mostly the small farmers to whom nitrogen fertilizer is the main cost of farming. In this study We have investigated different fertilizer application methods to identify the most efficient method that would allow high nitrogen efficiency use and maintain production.

1.3 OBJECTIVES

1.3.1 General objective

The main objective is to assess the rice response to nitrogen applications on different fertilizer application method under Huye ecological zone

1.3.2 Specific objectives

- To evaluate the rice vegetative growth response to nitrogen, supplied under different fertilizer application method
- To study correlation between yield and its components
- To assess nitrogen recovery and use efficiency from different application of nitrogen

1.4 Hypothesis

- The vegetative growth is influenced by nitrogen application at different stages
- All yield component is positively correlated to yields
- Nitrogen use efficiency of rice is influenced by nitrogen application

1.5 Significance of Study

Rice in Rwanda is cash crop for most of farmers, the increase of production with low cost will increase the income especial for small farmers, in additional the high demand of rice in country as well as in region need high productivity for sustaining the food security considering environmental quality and human wellbeing.

The high production relies on input such as fertilizer especial nitrogen. Fertilizer application on time and rate play key role in influencing plant growth and nutrient uptake (Sun *et al*,2012) hence identifying optimum fertilization time is so important to maximize nitrogen use efficiency at the same time avoiding losses and environmental problems, Therefore, this study attends to study rice response on nitrogen application method.

CHAPTER II: LITTERATURE REVIEW

Introduction

This section presents relevant literature on nitrogen dynamics, application method of nitrogen, nitrogen use efficiency, nitrogen uptake, nitrogen recovery and site specific nitrogen management as theory upon which this study is based on.

2.1 Nitrogen dynamics and crop requirement

Nitrogen as an essential for plant growth is often most limiting nutrient for crop yield (Giller, 2004). Nitrogen promotes rapid growth (increased plant height and number of tillers) and increased leaf size spikelet, number per panicle, and grain protein content. Thus, N affects all parameters contributing to yield. leaf N concentration is closely related to the rate of leaf photosynthesis and crop biomass production. When sufficient N is applied to the crop, the demand for other micronutrients such as P and K is increased. As found pioneer work of Stanford 1975.

NO_3^- and $NH_4^+$are the major sources of N available for crop uptake, in paddy field ammonium ($NH_4{}^+$) is considered as main sources of nitrogen more than nitrate ($N0_3^-$) (Wang *et al.,* 1993). Most absorbed NH_4^- is incorporated into organic compound in the roots, where NO_3^- may also contribute to maintaining cation –anion balance and osmo -regulation. According to (Buresh,2008), the main N transformation processes in submerged soils as in aerated soils are mineralization, immobilization, nitrification, denitrification, ammonia volatilization, and biological N2 fixation, a unique feature of submerged soils is the simultaneous formation and loss of $NO3^−$, occurring within the adjoining aerobic and anaerobic soil zones. Submerged soils as compared with aerated soils are favourable environments for loss of N by nitrification denitrification, ammonia volatilization. (Buresh *et al.*,2008).

2.2 Method and Timing of Nitrogen Application

Nitrogen could be added in the soil from biological N fixation, atmospheric deposition, and residual (Janzen et al .2003; Smill 1999). However, the quantity supplied by these sources are not sufficient to support plant growth. Urea is generally the nitrogen fertilizer of choice, most of the nitrogen fertilizer should be applied pre flood. Nitrogen fertilizer should be placed either on dry soil and flooded immediately or shallow incorporated and flooded within 3-5 days. If several days elapse between the period of nitrogen application in ammonical form and flooding, much of the nitrogen will convert to nitrate. When the soil is flooded nitrate is broken down by bacteria and released to the atmosphere as a gas in denitrification process. Denitrification losses can be avoided by flooding the soils within 3-5 days after nitrogen application. These losses are greatest when nitrogen is applied into water on young rice. The field should be maintained in a saturated condition to protect the nitrogen. From internode elongation (green ring) through the beginning of head formation nitrogen must be available in sufficient quantity to promote the maximum number of grains. Nitrogen deficiency at this time reduces the number of potential grains and limits yield potential. Sufficient nitrogen should be applied preplant or pre flood to assure that the rice plant needs no additional nitrogen until the panicle initiation (green ring) or the panicle differentiation stage. When additional nitrogen is required, it should be top dressed at either of these plant stages. Early nitrogen deficiency may greatly reduce yields. (www.cibtech/jps.htm)

2.3 Nitrogen and yield

Nitrogen is an essential constituent of nucleic acid, nucleotide, amino acid and chlorophyll. Rapid growths, spikelet number per panicles, grain protein content are mainly promoted by Nitrogen. Nitrogen also provides a sink during late panicle formation stage (Artacho et al., 2009). Source of applied N Placement and timing is important as well as adjustment of the quantity of N in relation to variation in indigenous N supply. According to (Doberman and Fairhurst 2000), nitrogen affects all parameters contributing to yield when the sufficient quantity is supplied.

2.4 Nitrogen uptake

After application of Nitrogen fertilizer through broadcasting on flooded rice field, the concentration rate of Nitrogen in flood water and soil solution exceed the rate of root uptake, however with the time Nitrogen in flood water will be exhausted either by uptake or gaseous loss. The crop will rely on indigenous nitrogen in the soil, and then the concentration in solution is much smaller because of NH_4 cation. The main form of plant available N will be absorbed on soil clays and organic matter (Buresh*et al*., 2008).

The research done on two rice variety by Basuchaudhuri and Dasgupta (1983) shows that the concentration of nutrient is differ in organs of the rice cultivars at various stages of growth this implies that Nitrogen concentrations decreases with ageing. According to Ishizuka (1965), reduction in concentration in plant parts could be attributing to slow rate associated to the effect caused by gradient movement of nitrogen to the developing grains. The minimum nitrogen concentration needed for maximum growth rate at any time is known as critical nitrogen concentration. It has been suggested the critical nitrogen concentration varied with stages of growth. (Sheehy et al.,1998)

2.5 Nitrogen use efficiency (NUE)

Nitrogen use efficiency (NUE) is the fraction of applied nitrogen that is absorbed and used by the plant**.** Crop productivity relies heavily on nitrogen (N) fertilization. Production and application of N fertilizers consume huge amounts of energy, and excess is detrimental to the environment. Therefore, increasing plant N use efficiency (NUE) is essential for the development of sustainable agriculture and environmental. (Xu *et al*.,2012) generally, plant NUE comprises two key mechanism: uptake efficiency (NUpE), which is the efficiency of absorption/uptake of supplied N, and N utilization efficiency (NUtE), which is the efficiency of assimilation and remobilization of plant N to ultimately produce grain (Han *et al*.,2015; Xu *et al*.,2012). Studies done by Yavad et al., (1997) and Hori et al., (2006) confirmed that the method applying Nitrogen fertilizer eg; right sources, right rate, right time and right placement associated with type of soil, tillage, cropping system and microorganism increasing nitrogen use efficiency and reduce N losses. (Cassman *et al.,* 2002).

2.5.1 Objective of nutrient use and nutrient use efficiency

The objective of nutrient use is to increase the overall performance of cropping systems by providing economically optimum nourishment to the crop while minimizing nutrient losses from the field and supporting agricultural system sustainability through contributions to soil fertility or other soil quality components. NUE addresses some but not all aspects of that performance (Mikkelsen *et al.,* 2012). The most valuable NUE improvements are those contributing most to overall cropping system performance.

Therefore, management practices that improve NUE without reducing productivity or the potential for future productivity increases are likely to be most valuable. If the pursuit of improved NUE impairs current or future productivity, the need for cropping fragile lands will likely increase. Fragile lands usually support systems with lower NUE that also use water less efficiently. At the same time, as nutrient rates increase towards an optimum, productivity continues to increase but at a decreasing rate, and NUE typically declines (Barbieri *et al.,* 2008). The extent of the decline will be determined by source, time, and place factors, other cultural practices, as well as soil and climatic conditions

2.5.2 Common Measures of NUE and their Application

Dobermann in (2007) in his review suggest the measurement and calculation of NUE as follow

Partial factor productivity (PFP) is a simple production efficiency expression, calculated in units of crop yield per unit of nutrient applied. to address question of how productive is this cropping system in comparison to its nutrient input However, partial factor productivity values vary among crops in different cropping systems, because crops differ in their nutrient and water needs

Agronomic efficiency (AE) is calculated in units of yield increase per unit of nutrient applied.is used to evaluate how much productivity improvement was gained by use of nutrient input The calculation of AE requires knowledge of yield without nutrient input, so is only known when research plots with zero nutrient input have been implemented

Apparent recovery efficiency (RE) is one of the more complex forms of NUE expressions and is most commonly defined as the difference in nutrient uptake in above-ground parts of the plant between the fertilized and unfertilized crop relative to the quantity of nutrient applied. It is often the preferred NUE expression by scientists studying the nutrient response of the crop. Like AE, it can only be measured when a plot without nutrient has been implemented on the site it used to assess how much the nutrient applied

2.6 Fertilizer Application Method in Irrigated Rice Production

Different method is being used to maximize production Today, the N-fertilizer applied in Soil, by chemical fertilizer, in conventional (Current Farmer practice); 40% is lost, 30% fixed in the soil, only 30% can be uptaken by the plant.

(a) Basal (Incorporation)

To minimize losses due to runoff, volatilization, leaching, and denitrification, it is desirable to incorporate the ammonia-containing or ammonia-forming fertilizers into the reduced surbsurface zone at land preparation. Once incorporated into the soil at puddling, the mobility of ammonia-containing fertilizers is relatively low whereas urea, being highly soluble and nonpolar, runs the risks of being lost in flowing waters. Patnaik (1996) and Patnaik and Nanda (1967), who studied the kinetics of hydrolysis of urea to ammonium carbonate in different soil types, suggest that urea be mixed with soil 2-5 times its weight and incubated for about 48 hours for hydrolysis to ammonium carbonate, before being applied and incorporated into the fields. This procedure minimizes mobility losses of urea in runoff waters. A better return was obtained from a given amount of N when it was applied in suitable fractions to synchronize with the stages of vigorous absorption and efficient N assimilation by the plant for grain production, than when it was entirely applied at puddling.

For optimizing the supply and demand of nutrients according to their variation in time and space. It was found that indigenous N supply was quite variable among fields and not related to soil organic matter content (Cassman et al 1966 a,b) so that plant-based strategies for real-time N management were needed to increase yields and N-use efficiency (Peng et al. 1996 a, b). It became obvious that blanket fertilizer recommendations given for large areas have serious limitations and that a new approach was required.

b) Site specific nutrient management

The Site Specific Nutrient Management (SSNM) was developed in 1996 (Dobermann et al.,1996 a, Dobermann and White 1999).is an approach that helps to dynamically apply fertilizer at critical period when needed.

Site Specific Nutrient Management (SSNM) developed in Asia rice producing countries provides an approach for ‘feeding’ rice with nutrients as when needed (IRRI 2006)

SSNM utilizes two crucial tools, SPAD and leaf colour chart, The SPAD meter is a simple portable diagnostic tool used for monitoring crop N status. To achieve the maximum yield target, the N concentration of the upper most fully expanded leaf must be maintained at or above 1.4 g Nm^{-2} (leaf area basis). Leaf N status at this critical level gives a SPAD value of 35 regardless of genotypes (Dobermann and Fairhurst, 2000). The Leaf chlorophyll meter sensing was assessed in previous work by Blackmer and Schepers (1994), Blackmer et al. (1993) and Blackmer and Schepers (1995), using the Minolta SPAD 502 chlorophyll meter (CM) to monitor crop N status and applying fertilizer N, showed that crop-based approaches to manage N would be an improvement over current soil-based approaches. Several researches have shown the good performance of SPAD in Nitrogen fertilizer use. Threshold value is currently adapted (Balasubramanian et al. 1999). The SPAD meter based N management appeared to be more efficient and could save N fertilizer use than conventional N management to produce similar grain yield (Miah and Abmed, 2002).

CHAPTER III: METHODOLOGY

This chapter presents information about the study area, data and describes variables that captured for experimental work. It also contains the experimental Design

3.1 Description of the Study Area

The Field experiment was carried out at Cyili rice research farm of Rwanda Agriculture and Animal Resources Board (RAB), Rubona Station, Huye District, Southern Province, Republic of Rwanda, during the cropping season B 2019, located at 29° 53’26’’ East longitude and 2° 28’18’’ South latitude. The Cyili inland valley is situated in the medium plateau region at an altitude of 1380 m above sea level. The major characteristics for this site are captured in the table 1 below.

Table 1: Major Physico-chemical properties of Cyili wetland soil

[2]Soil type	Inceptisol
[2]Soil texture	Sandy clay loam (57% sand, 33% clay, 9% silt)
[1]pH (H_2O)	5.1
Total Nitrogen (g kg^{-1})	2
Available Phosphorus (ppm)	10.97
Cation Exchange Capacity (meq/100g)	23.86
Organic Carbon (g kg^{-1})	36.8
Calcium (Ca) meq/100g	1.84
Electrical conductivity (mS/Cm)	0.15

[1] Measured in 1:2.5 Soil: water

[2] Soil type: The soil order at this location has been mapped as an Inceptisol (RSSP, 2011, Gasore, 2016)

[2] Soil texture (hydrometer method: Gee &Bauder, 1986, Gasore, 2016)

Soil sample were taken at a depth of 0-30 cm

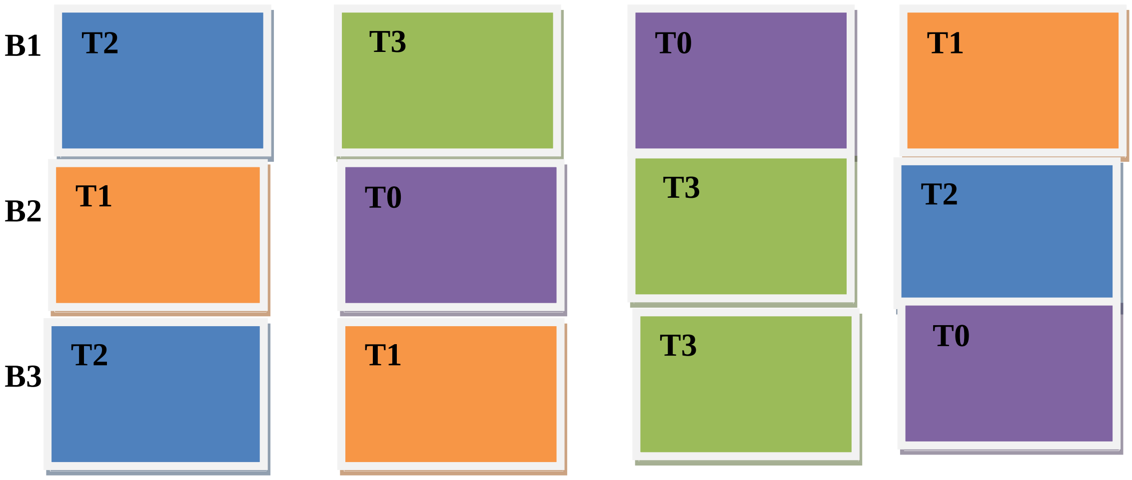
3.2 Material and Method

3.2.1 Field preparation

WAT Variety was sown on 30th January 2019, on nursery bed of 6 m of length and 1 m of width using density of 70 gm/m^2. 28 days aged seedling have been transplanted on distance of 20 cm x 20 cm. According to Agenda agricole 2019, the recommended quantity of nutrients on rice in Rwanda is 80 kg of Nitrogen, 34 kg of potassium and 34 kg of phosphorus per hectare. During the study, Kcl was used as source of Potassium and TSP (triple phosphate) as sources of phosphorus all applied as basal in recommended quantity to ensure that they do not limit plant growth. Urea was applied as source of nitrogen.

3.3 Experimental Design

The experiment was laid out in Randomized Block Design (RBD) with four Treatments and three replications The all experimental field cover 182m^2 with total of twelve replications of 9m^2 for each.



B1	**T2**	**T3**	**T0**	**T1**
B2	**T1**	**T0**	**T3**	**T2**
B3	**T2**	**T1**	**T3**	**T0**

Figure 1 The experiment layout

T0: Control, without fertilizer application

T1: Fertilizer containing phosphorus and potassium were applied at transplanting time while nitrogen splited three times first application at transplanted, the second at Mid- tillering, the third at panicle initiation

T2: All single fertilizer Treatment containing (NPK) at required amount have been applied at transplanting time.

T3: Fertilizers containing phosphorus and potassium all are applied at transplanting time while for nitrogen splited two times referring to the SPAD result, first application at early tillering the second at panicle initiation. (SSNM)

3.5 Data Collection

Data have been collected in purpose of evaluating rice response on nitrogen application. Different parameters have been taken according to the crop stages.

3.5.1 Growth parameters

Rice have transplanted on 26th February and harvest on 25th July 2019. As Nitrogen is mainly needed at vegetative growth to help plant to build biomass for food synthesis and tiller promotion, the following parameters were taken

- **Plant height**

  Ten plant were selected randomly from individual plant; their heights were measured in centimeter from ground level using ruler, observations were taken at early tillering and harvesting time
- **Number of tillers**

  Tillers were counted from ten plant selected randomly at mid tillering
- **Chlorophyll content**

  Leaf chlorophyll was measured using Soil-Plant Analyses Development (SPAD) at mid- tillering

3.5.2 Yield parameters

Production stage of rice starts with panicle initiation. At this stage the following parameters have been analysed to evaluate the yield under different method of nitrogen application

- Panicle weight have been recorded by using the balance
- The weight of each grain. (1000 grain weight)
- Grain Yield
- Grain weight
- Dry mater

3.5.3 Nitrogen use efficiency (NUE)

For assessing nitrogen use efficiency (NUE) three components have been evaluated.

Nitrogen use efficiency component:

- Partial Factor Productivity (PFP)
- Nitrogen Recovery Efficiency (NRE)
- Agronomical efficiency (AE)

3.6 Data analysis

Collected date have been subjected to analysis of variance (ANOVA). Statistical analysis was performed using LSD at $p > 0.05$ procedures by the Gen stat software 15 and figured with Microsoft excel 2016.

CHAPTER IV. RESULTS AND DISCUSSION

This chapter presents a detailed account of results from the study, this section also describes results interpretation for each parameter and discussion for each objective investigated.

I. RESULT INTERPRETATION

4.1 Soil Parameters

pH of the Soil

As shown in the table 1, the pH of Cyili field trial has a pH of 5.1, Therefore, we can conclude that this is an acidic soil.

Available phosphorus

The cyili soil show a quantity of available phosphorus (10.97 ppm) with that amount it can be concluded that the field site has a low available phosphorus.

Cation Exchange Capacity

The cation exchange capacity (CEC) shows how well a soil can hold onto and store cations, so a soil with a high CEC would be able to hold more nutrients. A soil with low CEC for example would not only be missing some important nutrients but would also not be able to hold onto nutrients as well as a soil with a higher CEC. Soils with a lot of cations can also hold onto water better since water is a polar molecule and is therefore attracted to the positively charged cations. (Donahue, 1958; Dr Mutwewingabo, D et Rutunga V, 1987).

In Cyli, the CEC show a rate of 10.97 ppm.

Total Nitrogen

Nitrogen is represented as being the factor that is most limiting. Even though the other elements are present in adequate amounts, crop production can be no higher than allowed by the nitrogen. When nitrogen is sufficient in the soil, the level of crop production is raised until it is controlled by next limiting factor, in this case we may mention Potassium and Phosphorus. The nitrogen in cyili inland (2 gkg^{-1} of soil)

Organic Carbon

The organic matter influences physical and chemical properties of soils. It is commonly a factor for the stability of soil aggregates. Furthermore, it supplies energy and body building constituents for the microorganisms. Literatures indicate that as soil organic carbon increases, so does CEC, soil total N content, and other soil properties such as water-holding capacity and microbiological activity (Horneck et al.,2011).

4.2 Application of rate of nitrogen

Different method of nitrogen application has been used on the following basis as table 2 displays

Table 2 Rate of nitrogen

Treatment	Type of Fertilizer	Application Method	N (kg/ha)				
			Basal	**ET**	**MT**	**PI**	**Total**
T_0		**Control**	0	0	0	0	0
T_1	**Urea**	**FFP**	34	0	23	23	80
T_2		**Basal**	80	0	0	0	80
T_3		**SSNM**	0	34	-	23	57

ET; early tillering, MT; Mid - tillering, PI; Panicle initiation

N application at Mid-tillering was skipped for SSNM because of SPAD value was above the thresholder (> 35)

4.2 Plant height parameter

Plant height as growth parameter have been taken two times during experiment at Mid tillering and harvesting time as presented on table 3 below.

Table 3 Mean of plant height

		Plant height (cm)	
Treatment	**Application Method**	**Mid tillering**	**Harvesting time**
T_0	**Basal**	**54.73**	**100.43**
T_1	**Control**	**54.93**	**99.77**
T_2	**FFP**	**55.57**	**99.27**
T_3	**SSNM**	**57.5**	**98.73**
		ns	**ns**

Plant height was not significantly affected by nitrogen either on Mid - tillering or on harvesting time, nevertheless treatment four T4 (SSNM) showed high height with average 57.5 cm compare to treatment T2 (FFP) of 55.57cm, T1 (Control) of 54.93 cm and T3 (basal) of 54.73 Respectively at mid – tillering. Then again at harvesting time T0 had tallest plants of 100.43 cm followed by T1 of 99.77 cm, T2 of 99.27 cm, T3 of 98.73 cm. at all stages there were not significant difference at probability level of 5%.

4.3 Number of tillers Parameters

Tillers are important traits in rice production. Thiry et al., 2002 reported that moisture and Nitrogen fertilizer increases grain yield by stimulating development and survival of tiller. The table 4 below present the results of number of tillers obtained after treatments application.

Table 4 Mean of tillers

Treatments	**Type of Fertilizer**	**Application Method**	**Number of tillers**
kg/kg			
T_0	**Urea**	**Control**	**14.98**
T_1		**FFP**	**16.45**
T_2		**Basal**	**16.62**
T_3		**SSNM**	**16.75**
significance at $p < 0.005$			**ns**

Nitrogen did not show significant differences at $P < 0,05$ on number of tillers. The lowest number of tillers have been recorded on T1 (control) with mean of 14.98 followed by T2 (FFP treatment) with mean of 16,45 cm, T3 (Basal treatment) with mean of 16.62, T4 (SSNM treatment) with mean of 16.75 cm respectively. Poor tillering capacity of rice plant contribute to for poor stand, and there are main factors contributing to reduction of tillers including Nitrogen deficiency. (Luis 2014).

4.4 SPAD Value parameter

SPAD is a hand-held device for measuring the SPAD value correlated to Nitrogen concentration of the upper most fully expanded leaf, critical SPAD value must be maintained at or above 35 regardless of genotypes (Dobermann and Fairshust, 2000). In each treatment SPAD were measured as table 5 shows

Table 5 Mean of SPAD

Treatments	Type of Fertilizer	Application Method	SPAD at MT
T_0	**Urea**	**Control**	**44.36**
T_1		**FFP**	**44.30**
T_2		**Basal**	**44.54**
T_3		**SSNM**	**44.54**

SPAD values provides the relative chlorophyll content of the rice plant leaf. SPAD value in all treatment were above >35 the critical SPAD values. T0 (Control Treatment) had 44.36, T1 (Treatment FFP) had 44.3, T2 (Basal) had 44.54, T3(treatment of SSNM) had the highest 44,54 in that order.

4.5 Panicles weight parameter

After harvesting the weight of panicle have been recorded as result indicated on table 6

Table 6 Mean Panicle weight

		Panicle weight (gr)	
Treatment	**Type of Fertilizer**	**Application Method**	**Mean**
T0		Control	103.7
T1	Urea	FFP	173.3
T2		Basal	175.7
T3		SSNM	183.7
significant at p <0.05			**ns**

The research has shown that T0 (control treatment) treatment had the lowest panicle weight of 103,7 gr, T1 (FFP treatments) had 173.3 gr, T2 (Basal treatment) had 175.7gr, T3 (SSNM treatment) had 183.7 gr respectively. This means that numerically, the SSNM (Site Specific Nitrogen Management) has performed well than others. However, the statistical difference between these treatments were not significant at $p < 0.05$

4.6 1000-Grain weight parameter

After drying the samples, grain was counted and measured using balance the results are presented on table 7

Table 7 Mean grain weight

		1000 Grain weight (gr)	
Treatment	**Type of Fertilizer**	**Application Method**	**Mean**
T1		FFP	27.83
T0	Urea	CONTROL	28.13
T3		Basal	28.87
T2		SSNM	29.03
significant at p>0.05		**ns**	

1000 grain weight were numerical different among treatments, however no statistical significant difference at $p < 0.05$ observed, T2 (basal treatment) showed high grain weight of 29,8 gr, T3 (SSNM treatment) had the 28.78 gr, T0 (control treatment) had 28.13, lowest are observed on T1 (FFP treatment) with 29,83 gr

4.7 Grain yield parameter

As displayed on figure 2, Grain from harvested sample have been measure and converted into hectare

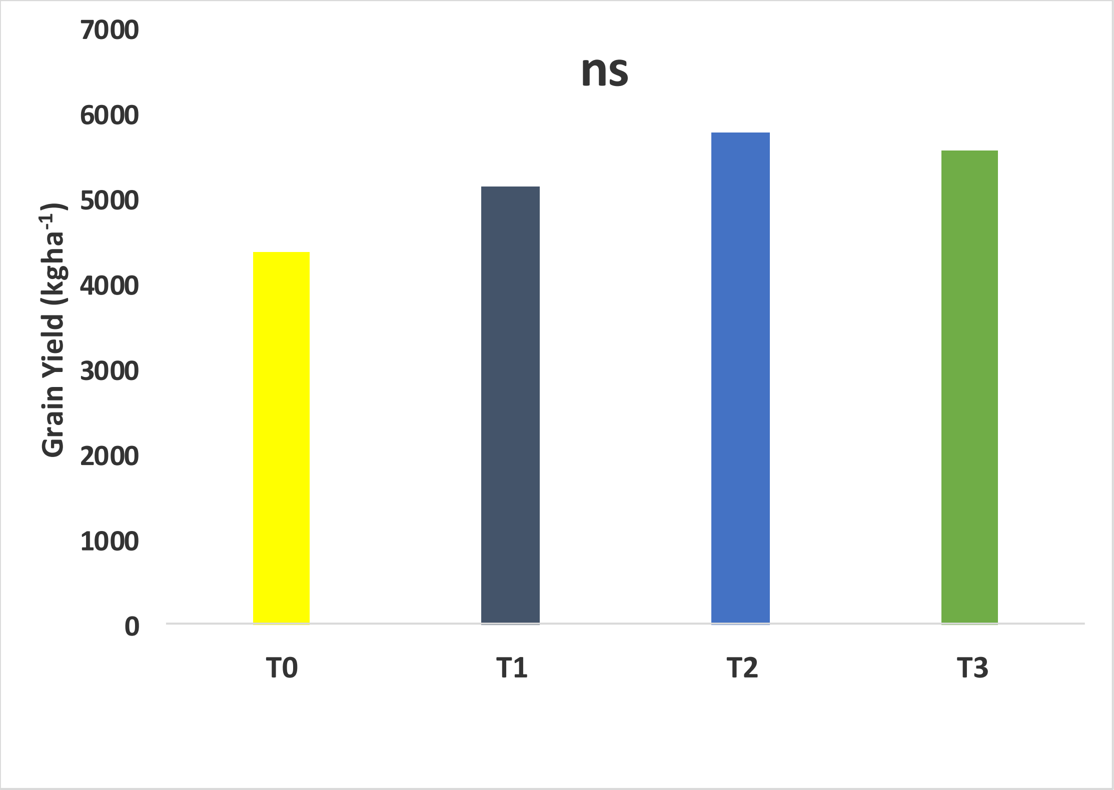


Figure 2: Grain yield Parameter

Grain yield did not show the significant difference t $p<0.05$; the highest grain yield was obtained on T 2 (basal Treatment) of 5801 kg/ha^{-1} followed by T3 (SSNM treatment) of 5581kg/ha^{-1}, T1(FFP treatment) 5157kg/ha^{-1} while the lowest grain yield was observed on T0 (control treatment) of 4378kg/$^{ha-1}$. No statistical difference observed on treatment of SSNM but increase rate of 7.6 % compare to FFP and 11% of increase between Basal treatment and FFP were observed.

4.8 Dry matter parameter

Dry matter refers to material remaining after removal of water, the dry weight of each subsample was determined after oven –dry at 80 ^{0}C. as indicated on figure 3 below

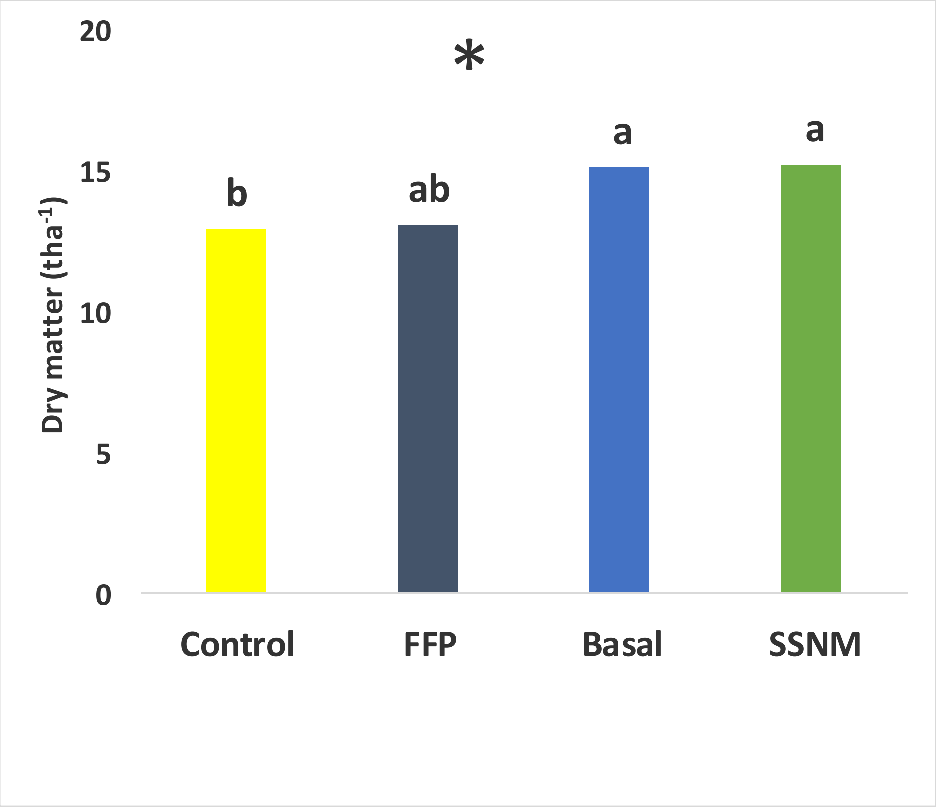


Figure 3: Dry matter Parameters

As the graph shows the significant difference at probability level of 5% have been identified for T1 (control treatment) have 12.9t/ha^{-1} compare to T2 (basal treatment) of 15.18 t/ha^{-1}and T3 (SSNM treatment) of 15.2t/ha^{-1} but no significant difference observed at $P<0.05$ for T1 (FFP) of 13.13 treatment for either T0 nor T2 and T3. The increasing rate of dry matter of the performed treatment (Basal) is 15.18% compared to the FFP and 16.3% of (SSNM) compare to FFP.

4.9 correlation parameters of yield and yield component

Being studying the coherence between parameters scrutinized, Pearson’s correlation coefficient (statistical method of quantifying the association, between two variables) were used as figure 4 below demonstrated.

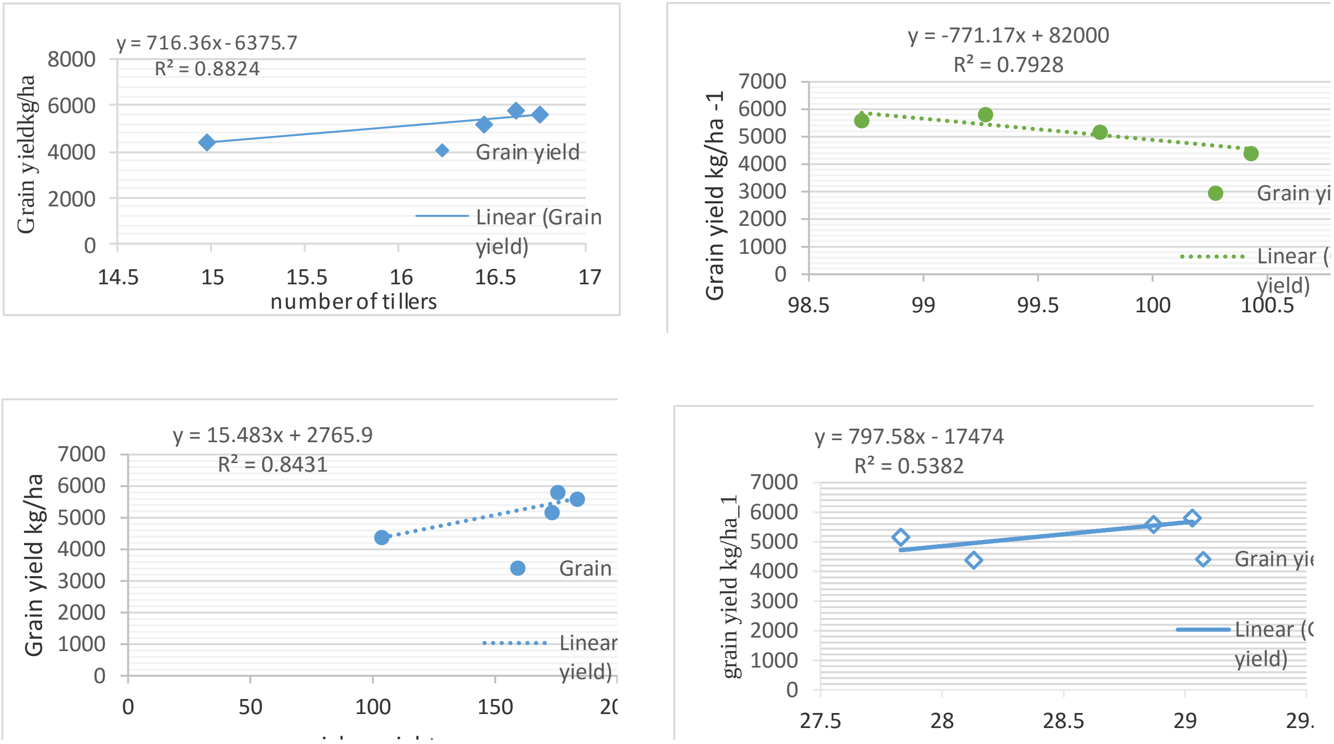


Figure 4: correlation between yield and its parameters

Yield components are formed during rice growth cycle. plant height, number of tillers are determined during vegetative stages, panicles, and grains are produced during reproductive and maturity stages. In this study plant height showed negative correlation with yield r= -0.88 and positive correlation between number of tillers and yield r = 0.93

Panicle weight and 1000 grain weight have positive correlation with grain yield of r = 0.4486 and r= 0.7336 in that order.

4.10. Nitrogen uptake parameters

Nitrogen uptake is the N concentration in plant tissues multiplied by dry matter accumulation by the plant part as presented on figure 5.

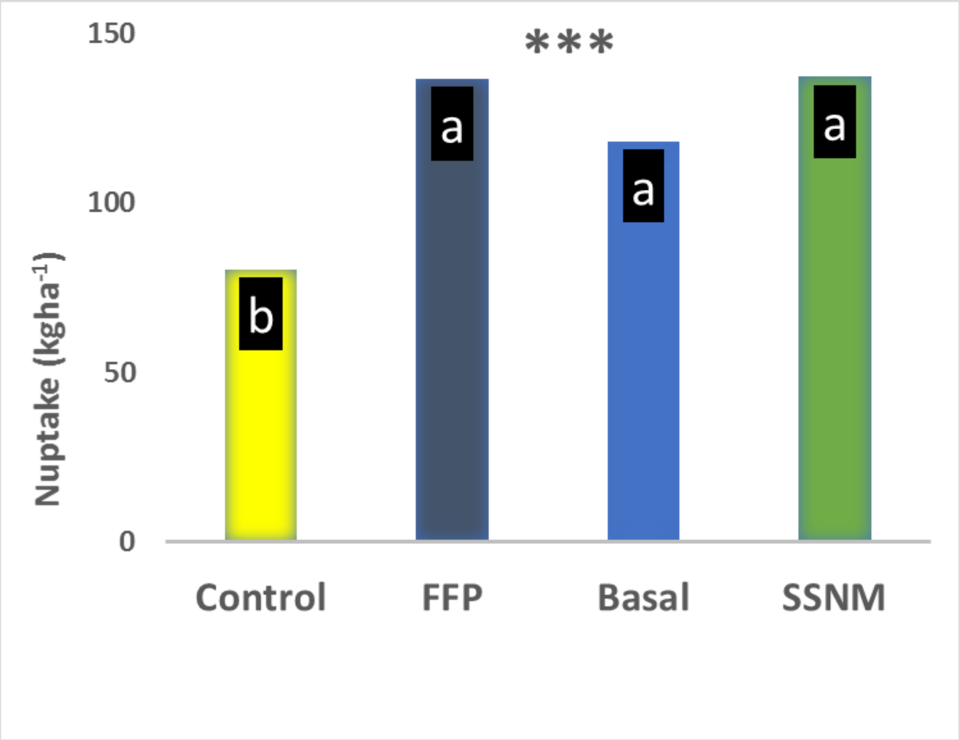


Figure 5: Nitrogen uptake kgh^{-1}

Nitrogen uptake have shown high significance difference at $p < 0.05$. For T1 control with 80.5kg/ha^{-1} compare to other treatments however no significant differences observed among T1 (FFP treatment) with 136.6kg/ha-^{1}, T2 (basal treatment) with 118.2 kg/ha^{-1}, T3 (SSNM treatment) with 137.3 kg/ha^{-1}.

4.11 Nitrogen use efficiency

4.11.1 Partial Factor Productivity

Mosier et al., (2004) described Partial Factor productivity (PFP) as one of Nutrient use Efficiency, The PFP $= \frac{Yield\ Kg}{FertilizerKg}$, which means How much kg rice is produced with 1 kg of N, though in the case of high rate is one of the NUE, was calculated by the ratio between grain yield (kgha^{-1}) and the amount of N applied (kgha^{-1}) in order to know how much yield produced for each kg of N applied. Table 8 explain the result.

Table 8 Partial factor productivity

Treatment	**Type of Fertilizer**	**Application Method**	**(PFP)**
		kg/kg	
T_1	**Urea**	**FFP**	**65**
T_2		**Basal**	**73**
T_3		**SSNM**	**100**

Partial productivity measures the contribution of one factor to output growth keeping the other factors constant in our research we considered only nitrogen the result above shows, SSNM treatment has the high PFP of 100, this mean that 1kg of nitrogen without considering other factors produce 100kg of rice followed by basal treatment with PFP of 73kg produced by 1kg of nitrogen applied, FFP had the lower FPF of 65 kg produced by 1kg of nitrogen applied.

4.11.2 N Recovery Efficiency (%)

Rex et al., (2017) defined Nitrogen recovery efficiency (NRE) (%) as = [Nutrient uptake (fertilized plot) – Nutrient uptake (unfertilized plot)/Quantity of nutrient applied x 100]. Nitrogen recovery efficiency is kg nutrient taken up per kg nutrient applied table 9 shows the result

Table 9 :Recovery efficiency

Treatment	**Type of Fertilizer**	**Application Method**	**N Recovery Efficiency%**
%			
T_1		**FFP**	**70**
T_2	**Urea**	**Basal**	**60**
T_3		**SSNM**	**78**

From result T3 (SSNM) have shown high recovery efficiency of 78% followed by T1 (FFP) with 70 %, T2 express low nitrogen recovery efficiency of 60%. This means SSNM method might use up to 78% of nitrogen applied.

4.11.3 N Agronomic efficiency

for knowing how much productivity improvement was gained by use of nutrient input, Agronomic efficiency is calculated using formula of Dobermann, (2007). NAE = (yield of plot with nutrient –yield without nutrient) /N Fertilizer applied. table 10 display the result on NAE

Table 10 N Agronomic efficiency

		kg/ha	
Treatment	**Type of Fertilizer**	**Application Method**	**NAE**
T1	Urea	FFP	9.73
T2		Basal	17.78
T3		SSNM	21.1

Yield was increased up to 21.1 kg per 1 kg of nitrogen applied, in T3 (SSNM treatment) while 17,78 kg added per 1kg of nitrogen in T2 (treatment of basal) the minimum of 9,73 kg per 1 kg of nitrogen applied were added in T1(FFP treatment)

II. Discussions

The initial purpose of this study, being to evaluate the rice response to nitrogen applications on different growing stage. Comparison have been made in four treatments on the response on growth parameters, correlation between yield and yield parameters and nitrogen use efficiency.

Objective one: To evaluate the rice growth and yield response to nitrogen supplied under different fertilizer application method

Objective one, set out to assess rice response on growth and yield parameters when nitrogen is applied using different methods; farmer farming practices (FFP), all fertilizers applied as basal (Basal) and site specific nitrogen management (SSNM) apropos to untreated treatment. Parameters considered were plant height, number of tillers and chlorophyll content on the leaf, panicle weight ,1000 grain weight and grain yield.

For plant height the result showed that T0 control treatment had the tallest plant at harvest time compare to other treatment this is in contrast of finding of (Mohammad et al., 2017). Who Reported that nitrogen fertilizer exhibits greater plant height than untreated treatment (Control)

For number of tillers the lowest number have been recorded on T0 treatment without Nitrogen this may be due to insufficiency nitrogen which lead to ineffective way of nitrogen to enhance tiller population as it increases cytokinin content within tiller nodes, this is supported by Liu et al.,2011. Similarly, to Sakakibara et al.,2006 evoked that Nitrogen promote significantly tiller development.

At mid tillering all treatment shown high values of chlorophyll content, the SPAD values was generally < 35 in the same range as control treatment, this have may be occurred because the results are from first year of experiment with indigenous nitrogen, moreover WAT variety used in this study is hybrid. Kobayashi (1995) reported that hybrid rice has high Nitrogen absorption fevered by of root system heterosis which increases N absorptive capability. In additional SPAD Values helped to skip application of nitrogen at Mid tillering which saved the quantity and cost of Nitrogen application for

SSNM treatment, this is supported by (Reeves at al., 1993) suggest that proper interpretation of SPAD value could be useful in developing N fertilizer program

Regarding 1000-grain weight as shown in (table 8) Nitrogen fertilizer exhibited differences among treatments the highest was (29.03) While minimum 1000 grain weight (27.83) in control treatment. Mandana et al.,2012 illustrated the same result. it therefore appears that the application of nitrogen increases protein % which in turn increased the grain weight.

Even though no statistical difference observed on grain yield among treatments as (figure 2) shows. Treatment of SSNM have increasing rate of 7.6 % compare to FFP while 11% of increasing rate were observed between Basal treatment and FFP. Corny (1995) revealed that proper use of fertilizer can distinctly increase the yield similar result had find in this research Nitrogen fertilizer application had effect on grain yield, low yield in control treatment may possibly cause by insufficiency of nutrient.
The increasing rate of dry matter of the performed treatment 16.3% of (SSNM) compare to FFP and (Basal) is 15.18% compared to the FFP and

Objective two: To study correlation between growth parameters and yield

This objective aim at evaluating coherence between yield and its components as long as growth parameter contribute to yield is essential to analyse influence of yield parameters on yield this have been done using regression analysis Pearson’s correlation coefficient on following parameters; plant height, number of tillers, panicle weight ,1000grain weight and grain yield.

The studies revealed that grain yield showed significant positive association with, number of tillers, panicle weight, grain yield ,1000 grain weight. Similar kind of association was reported by Kylan et al., 2017) its seems that crop yield is the end product of interaction of a number of other interrelated attributes. Only plant height exhibited negative correlation to grain yield. Dissimilar result was Found by Rajaswari and Nadarajan 2004 who stated that Plant height was positively and y correlated with grain yield, and tiller by Deosarkar et al., 1989.Tahir et al., 1988 found

Objective three: To assess nitrogen recovery and use efficiency from different method of nitrogen application

The third objective forms the main idea of this study, it set to examine plant nitrogen use efficiency in relation toward nitrogen application timing. Paul et al 2014 suggest that it is helpful to use more than one NUE term when evaluating any management practice, allowing for a better understanding and quantification of the crop response to the applied nutrient. in this research three indicator of NUE; partial factor productivity; N recovery efficiency and agronomical efficiency were used.

Referring on benchmarks of NUE levels for cereal crop done by Meryl et al., (2016) suggest the range where references may be made when assessing NUE

They suggest that:

- Partial factor productivity (PFP) kg grain/kg nutrient for nitrogen have range on 40-90
- Agronomic efficiency (AE) kg grain/ kg nutrient for nitrogen have range on 15-30
- Nitrogen Recovery efficiency (RE) % range on 40-65%

SSNM revealed high NUE in all indicators referring on above ranges; 100 for PFP, 21,1 for AE and 78% for RE as shown on tables (10,11,12). Is identified that right amount of nitrogen synchronized with time of demand increase NUE and reduce losses. related to findings of (Wang et al.,2007) reported that SSNM increase and maintain yield by optimizing the balance between supply and demand of nutrient while reducing N losses.

CHAPTER V: CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This research set out to explore the response of rice on different method of nitrogen application. The aim was to evaluate effect of nitrogen on growth parameters while assessing their correlation with target of finding the method of high Nitrogen use efficiency (NUE). The results obtained testified remarkable performance of SSNM method.

All method investigated showed the notable growth and yield except control, yet Site specific nitrogen management had the best high nitrogen use efficiency.

As conclusion the increase of NUE found in SSNM might enhance yield and farmers' profit by saving form of reduced fertilizer use, without a reduction in yield, it reduces as well N_2O emission, by decreasing the total N application and timing to crop need, thus avoiding N losses to volatilization, leaching and runoff.

5.2 Recommendation

Rice is important crop in Rwandan lives and sources of income for most of farmers for that new method must adopted to farmers and agricultural institutions for extension, among them SSNM could be recommended as is profitable and environment friendly method.

Additionally, further research on this topic on large scale, different site and seasons are recommended for evaluating contribution of different method of SSNM on

- Different varieties
- Protein content
- Level of sterility

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VI. APPENDIX

6.1 Action plan

Action / Period	February	March	April	May	June	July	August	September
Seedbed preparation	■							
Sowing	■							
Land preparation	■							
Transplanting		■						
Irrigation	■	■	■	■	■			
Fertilization		■	■	■				
Data collection		■	■	■	■	■	■	
Weeding		■	■	■				
Pest and disease control	■	■	■	■	■	■	■	■
Harvesting						■		
Threshing						■		
Winnowing						■		
Data analysis				■	■	■		
Drying						■		
Research Writing	■	■	■	■	■	■	■	■

6.2 BUDGET

	Item	Unit cost	Quantity	Total cost
1	**Transport to the field to collect data (ticket, accommodation, 3meals)**	15500	15	232,500
2	**Communication means to facilitate online research by PG students**	21000	3	63,000
3	**Printing material & binding for submission**	0	1	-
4	**Required needs for laboratory analyses**	12000	10	120,000
5	**Other (specify)**	1500	36	54,000
	Subtotal MSc students			469,500
6	**Communication (3 months) for SUPERVISORS**	21000	3	63,000
7	**Field trip support for SUPERVISORS**			388,200
	Subtotal Supervisor (per student)			*451,200*
	TOTAL	920,700		

R1T1				R1T2				R1T3				R1T4			
	Tiller Nber	**Plant height**	**SPAD**		**Tiller Nber**	**Plant height**	**SPAD**		**Tiller Nber**	**Plant height**	**SPAD**		**Tiller Nber**	**Plant height**	**SPAD**
1	20	60	48	1	10	60	47.7	1	12	47	45.00	1	7	56	48.5
2	15	55	44.8	2	10	58	45.4	2	18	53	46.00	2	13	60	45.7
3	20	58	43.7	3	15	59	47.1	3	21	58	48.00	3	16	58	46.2
4	7	60	45.7	4	19	52	44.3	4	9	45	48.00	4	14	56	41.2
5	8	55	41.6	5	16	57	43.5	5	17	48	47.00	5	16	57	39.8
6	22	50	42.3	6	20	58	46.4	6	25	55	45.00	6	22	70	47.3
7	18	52	42.1	7	7	47	34.8	7	9	48	49.00	7	15	57	50.8
8	6	53	41.1	8	10	43	37.3	8	15	49	46.00	8	20	60	48.7

9	22	60	41.2	9	18	51	46.5	9	12	53	48.00	9	17	53	45.8
10	21	55	41.9	10	12	60	45.6	10	15	50	47.00	10	17	57	46.9
Av	15.9	55.8	43.24	Av	13.7	54.5	43.86	Av	15.3	50.6	47.37	Av	15.7	58.4	46.09

R2T1				R2T2				R2T3				R2T4			
	Tiller Nber	**Plant height**	**SPAD**		**Tiller Nber**	**Plant height**	**SPAD**		**Tiller Nber**	**Plant height**	**SPAD**		**Tiller Nber**	**Plant height**	**SPAD**
1	16	57	47	1	15	55	48.4	1	16	58	44.9	1	31	58	46.5
2	18	55	43.8	2	22	50	49.4	2	20	51	40	2	25	60	42.9
3	17	55	44.7	3	16	58	51.9	3	6	49	48.3	3	12	50	45.7
4	12	50	46.7	4	13	53	45	4	19	60	45.1	4	20	60	44.3
5	17	59	44.6	5	26	60	42.9	5	20	60	43.9	5	21	53	44.9
6	19	55	47.3	6	17	60	45.7	6	17	63	41.2	6	21	54	41.9
7	12	52	40.1	7	13	58	45.4	7	16	55	40.4	7	7	41	52.5
8	10	55	43.1	8	11	54	48	8	18	57	44.4	8	12	52	33.8
9	18	50	44.2	9	21	57	43.2	9	23	58	42.2	9	20	57	44.5
10	12	57	43.9	10	14	60	46.7	10	17	1	38.8	10	9	44	40
Av	15.1	54.5	44.54	Av	16.8	56.5	46.66	Av	17.2	51.2	42.92	Av	17.8	52.9	43.7

R3T1				R3T2				R3T3				R3T4			
	Tiller Nber	**Plant height**	**SPAD**		**Tiller Nber**	**Plant height**	**SPAD**		**Tiller Nber**	**Plant height**	**SPAD**		**Tiller Nber**	**Plant height**	**SPAD**
1	15	57	41.5	1	16	45	44.8	1	17	63	43.8	1	12	63	45.8
2	19	59	43.9	2	14	57	24.2	2	22	63	46.6	2	20	55	40.9
3	22	56	32.5	3	16	63	40.3	3	12	55	45.1	3	18	72	48.2
4	24	52	45.3	4	18	57	43.3	4	18	57	40.6	4	11	67	42.1
5	21	60	46.3	5	14	58	46.5	5	21	63	50.7	5	17	65	43.8
6	20	55	51.5	6	16	55	44.2	6	18	62	48.6	6	23	62	44.4
7	14	51	46.8	7	18	59	46.1	7	19	45	35.6	7	13	65	45.6
8	31	54	45.5	8	9	41	45	8	19	54	41.9	8	12	53	41.1
9	11	49	43.3	9	21	62	40.1	9	22	50	44	9	13	55	39.5
10	15	56	47.0	10	3	60	35.1	10	18	55	40.8	10	29	55	41.3
Av	19.2	54.9	44.36	Av	14.5	55.7	40.96	Av	18.6	56.7	43.77	Av	16.8	61.2	43.27

```
Analysis of variance of plant height

Variate: PH

Source of variation            d.f.        s.s.        m.s.     v.r.   F pr.

R stratum                         2      110.82       55.41     1.93

R.*Units* stratum
T                                 3      143.37       47.79     1.67   0.178
Residual                        114     3271.78       28.70

Total                           119     3525.97
```

Analysis of variance of number of tiller

Variate: N T

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
R stratum	2	72.20	36.10	0.85	
R.*Units* stratum					
T	3	47.23	15.74	0.37	0.775
Residual	114	4846.27	42.51		
Total	119	4965.70			

Correlation table

Panicle_weight	1	-				
Number_of_tillers	2	0.9983*	-			
Plant_height	3	-0.8716	-0.8881	-		
Grain_yield	4	0.9182	0.9394	-0.8904	-	
%1000_grain_weight	5	0.4486	0.4987	-0.7377	0.7336	-
		1	2	3	4	5