EFFECT OF NITROGEN FERTILIZER RATE AND SPLIT APPLICATION ON GROWTH AND YIELD OF SELECTED RICE VARIETIES IN MWEA IRRIGATION SCHEME

BY

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A THESIS SUBMITTED TO GRADUATE SCHOOL IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE IN AGRONOMY

DEPARTMENT OF PLANT SCIENCE AND CROP PROTECTION

FACULTY OF AGRICULTURE

UNIVERSITY OF NAIROBI

2019

DECLARATION

This thesis is my original work and has not been presented for an award of a degree in any other university.

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ABBREVIATIONS

AEZ	Agro Ecological Zone
ASL	Above Sea Level
BRRI	Bangladesh Rice Research Institute
DAS	Days After Sowing
DAT	Days After Transplanting
ESA	East and Southern Africa
KALRO	Kenya Agricultural and Livestock Research Organization
KARI	Kenya Agricultural Research Institute
K	Potassium
MIAD	Mwea Irrigation and Agricultural Development centre
MoA	Ministry of Agriculture
MOP	Muriate of Potash
MT	Metric Tons
NIB	National Irrigation Board
N	Nitrogen
P	Phosphorous
RCBD	Randomized Complete Block Design
RYMV	Rice Yellow Mottle Virus
SA	Suphate of Ammonia
TSP	Triple Superphosphate
Zn	Zinc

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DEDICATION

This thesis is dedicated to my loving husband Moffat Muthama, my dad Patrick Sammy, my mum Alice Nduku, my sisters Irene Kivivya and Joyce Mutunge and finally to my one and only brother Dennis Masila.

ACKNOWLEDGEMENT

I would first like to thank Almighty God for his continued blessings and for enabling me complete my research work and prepare this thesis.

I would particularly like to thank my supervisors Prof. George. N. Chemining'wa, Dr. Josiah .M. Kinama and Dr. Rosemary Murori for your guidance during the writing of this thesis. I do not take your efforts and sacrifices for granted.

I am also indebted to the International Rice Research Institute Kenya office for allowing me to undertake my research work in their experimental fields at Mwea Irrigation and Agricultural Development center.

To my friend and colleague Agnes Kavinya, thank you so much for sticking with me during the entire research period. You made the stay lively and the struggles easier. You made the ride smooth even when the road was bumpy. I'm glad we went over the hurdles together. It was worth it. I would also like to appreciate Mr. David Opar and Mr. Wilson Oyange for their assistance with the fieldwork.

Lastly, I thank my family for believing in my potential. Thank you for your financial support, prayers and encouragement. This is our success.

GENERAL ABSTRACT

Irrigated rice production is the main source of livelihood for a majority of farmers in Mwea Irrigation Scheme and its environs. The rice yields have, however, been declining progressively and this can be partly associated with poor fertilizer management techniques. Thus, a field experiment was conducted at Mwea Irrigation and Agricultural Research (MIAD) center for two seasons (March to July, 2015 and August to December, 2015) with three specific objectives: (1) to document existing soil fertility management practices for rice production; (2) to determine the effect of different nitrogen fertilizer rates on the growth and yield of three rice varieties; and (3) to determine the effect of split nitrogen fertilizer application on the growth and yield of three rice varieties. To achieve the first objective, a survey was carried out in five sections of the irrigation scheme namely, Karaba, Tebere, Thiba, Wamumu and Mwea using a semi-structured questionnaire that was administered to 200 farmers (40 farmers randomly selected from each section). Data collected included; soil fertility maintenance practices, types, sources and rates of organic and inorganic fertilizers used by the farmers, and the status of major weeds and diseases and their control measures. Statistical Package for the Social Sciences (SPSS) program version 20 was used to analyze the data obtained from the survey. In the second and third objectives, a field experiment was conducted in which four nitrogen fertilizer rates (0, 40, 80 and 120 kg/ ha) and split N fertilizer application (Basal + one top-dressing at panicle initiation stage and Basal + two topdressings at tillering and panicle initiation stages) were tested against three rice varieties (IR 05N 221, ITA 310 and BW 196) in a randomized complete block design with a split-split plot arrangement. Data collected included: plant height (cm), number of tillers per plant, panicle length, and days to 50% flowering, 1000 grain weight and grain yield (kg) at 14% moisture content. The data collected were subjected to analysis of variance (ANOVA) using GENSTAT 15th edition and comparison of treatment means tested at $p = 0.05$ using the least significant difference (LSD) test. All the farmers interviewed reported to use fertilizers in rice production with sulphate of ammonia (SA) being the most widely used fertilizer. However, only 2% of those interviewed had their soil tested at least once since they started rice production. More than half of the interviewed farmers bought their fertilizers from either input dealers or commercial farmers. Lack of enough water for irrigation, high input prices, low market prices for the harvested produce, pests and diseases, weeds, poor infrastructure especially the roads, labour expenses and birds' infestations were cited as the major challenges in rice production by farmers across the five sections. Majority of the farmers (95.8%) did not rotate rice with any other crop in their fields. In all the five sections of the scheme, only (17.98%) of the farmers had received training on soil fertility management which was cited as the leading need to help them improve soil fertility. Azolla was the most common weed and water shortage was cited as the greatest challenge faced by the farmers in rice production. Rice variety ITA 310 had significantly taller plants in both seasons than variety IR 05N 221 and BW 196. Variety IR 05N 221 had significantly more tillers per plant than varieties BW 196 and ITA 310 in both seasons. Variety BW 196 had more panicles per plant in the first season while IR 05N 221 had more panicles per plant in the second season. Variety BW 196 had longer panicles in both seasons of the experiment compared to varieties IR 05N 221 and ITA 310. Variety BW 196 had significantly more net grain yield in both seasons in comparison with varieties IR 05N 221 and ITA 310. Nitrogen application rate of 80kg N/ha had significantly higher number of panicles per plant and net grain yield in both seasons. Split nitrogen application regime of a basal plus top dressing at tillering and panicle initiation stages had more tillers per plant in the first season while that of a basal plus top dressing at tillering stage had more tillers per plant in the second season. The split application regime of a basal plus top dressing at tillering and panicle initiation had taller plants in both seasons. There were significant differences

in split application of nitrogen fertilizer. Split application of nitrogen as a basal plus top dressing at tillering recorded more yield than that of a basal plus top dressing at tillering and panicle initiation stages.

From the study, it can be concluded that application of nitrogen fertilizer in splits can increase the productivity of rice.

CHAPTER ONE: INTRODUCTION

1.1 Background information

On a global basis, rice is ranked second after wheat with respect to the area of production, though it's a major energy food compared to all the cereals. It's an important cereal crop of the world. This is based on food, area under cultivation and production levels (Emong'or *et al.,* (2009). Asia produces nearly 90% of all the rice (640 million tons in 2010) (USAID, 2010).

China accounts for 19 per cent of the area under rice production in the world and supplies 29 per cent of the total production the world over according to FAO (2010). Anaerobic conditions are more ideal for rice cultivation because of the availability of NH_4^+ (Freney *et al.,* 1985). In previous years, China has used nitrogen fertilization rate averaging 300-350kg Nha^{-1} to obtain maximum yields (Wang *et al.,* 2004). However, the high nitrogen application rate has in fact decreased grain yields (Zhang et *al.,* 2009; Qiao *et al.,* 2012; Sun *et al.,* 2012)

Rice in Kenya is grown by about 300,000 small-scale farmers for sale and direct consumption (USAID, 2010; MOA, 2009). It was considered a cash crop in the past but this has changed in the recent past as many people have started considering it as a source of food. This is especially in Africa as evident from the continent's highest consumption rate in the world. Farmers in sub-Saharan Africa grow rice on small farms of 0.5-3 hectares and produce about 19 million tons (USAID, 2010).

Kenya started producing rice back in 1907 originating from Asia (MOA, 2009). Despite its importance, Kenya only produces 20% of its national demand. The total rice production globally is more than 700 million tons per annum and paddy rice contributes 80% of the total rice production which is done under irrigation (MOA, 2009). Rain fed production is carried out at the coast, Kwale, Kilifi and Tana River and in the Western province in Teso and Bunyala in Busia only (USAID, 2010). Nutrient deficiency is among the constraints to rice production. According to a survey carried out by Emodi in 2012 in south-east Nigeria, soil infertility and low use of chemical fertilizers were the two major factors limiting growth in rice production.

1.2 Problem statement and justification

Farmers carry out nutrient management practices based on their experiences, but scientific reviews of recommendations are yet to be done owing to the many new varieties that have been released to the farmers. For new varieties like IR 05N221, the specific amount of nitrogen fertilizer required and the appropriate time of application have not been established. In general, half of the nitrogen applied is used up by the rice plant with the rest being lost through processes like volatilization, and leaching, leading to low levels of nitrogen use efficiency. This may, however, be improved by application of suitable level and split applications (Ehsanullah *et al.,* 2001). The source of N and its timing of application in the crop production cycle help the farmers to efficiently manage it (Fajeria *et al.,* 2011). Research indicates that split nitrogen application enhances paddy rice productivity. Sahoo *et al.,* (1989) and Raza *et al.,* (2003) divided nitrogen into three splits and it produced the maximum tillers per hill. When they applied nitrogen at planting, tillering and panicle initiation stages, Krishnan and Nayak (2000) observed more yield as well as harvest index. Similar studies have, however, not been done in Kenya. Applying nitrogen late in the crop growing can also increase yield. In planted fields, it's recommended that the field should be kept moist while applying nitrogen fertilizer. It's a vital nutrient in rice production, but excessive nitrogen application often leads to increased production costs, decline in the quality of rice and environmental pollution (Kundu *et al.,* 2017). Applying too much nitrogen fertilizer will often reduce yields as much as applying too little nitrogen. To save on application costs, especially in large fields, farmers often prefer applying nitrogen fertilizer once in a season with ground equipment before flooding. Rigorous cultivation, growing of in-depth crops, imbalanced and insufficient crop nutrition mainly through chemical fertilizers has greatly made the soils lack essential nutrients with the over application of nitrogen making the condition deteriorate (Singh *et al.,* 2008). In Mwea, majority of the farmers only apply nitrogen fertilizer twice in a season; at planting and when they top-dress.

Rice consumption in Kenya can be estimated at 538.000 MT with a production of 126,400 MT per annum (GAIN Report, 2015). The imbalance is met through imports of over 13.8b in the year 2014 (GAIN Report, 2015). Kenya has a potential of 540,000 ha that can be put under rice irrigation but only 105,000 ha of these are being exploited (MOA, 2009). Decreasing soil fertility is seen as the main cause of poor yields in sub-Saharan African countries (Sanchez, 2002). Therefore, this study seeks to determine: the existing soil fertility management practices for rice production, nitrogen fertilizer rate effects on the growth and yield of three rice varieties and the effect of split nitrogen fertilizer application on their growth and yield.

1.3 Objectives

The main objective of the study was to develop appropriate nitrogen management options for enhancing productivity of selected rice varieties in Mwea Irrigation Scheme.

The specific objectives were:

1. To determine the current soil fertility management practices for rice production in Mwea Irrigation Scheme.

2. To determine the effect of different nitrogen fertilizer rates on growth and yield of three rice varieties in Mwea Irrigation Scheme.

3. To determine the effect of split nitrogen fertilizer application on growth and yield of three rice varieties in Mwea Irrigation Scheme.

1.4 Hypotheses

1. Farmers are utilizing varied fertilizer management practices in Mwea Irrigation Scheme.
2. Increasing fertilizer rates will enhance growth and yield of the three selected rice varieties in Mwea Irrigation Scheme.
3. Split nitrogen fertilizer application will increase growth and yield of the three selected rice varieties in Mwea Irrigation Scheme.

CHAPTER TWO: LITERATURE REVIEW

2.1 Constraints to rice production

Rice production constraints can be grouped into four; biotic, abiotic, socio economic and management related (FAO, 2013). The biotic constraints include; weed competition, leaf, stem and panicle diseases, leaf and stem pests, rodent damages, storage pests and root and soil diseases. The abiotic ones on the hand include; drought stress, heat stress, soil fertility depletion, nitrogen deficiency, deficiency of micronutrients and low temperature/cold stress. Lack of enough irrigation water, poor quality seed, expensive nitrogen fertilizer, inadequate farmer knowledge/ training and high input prices rather than nitrogen are considered as the socio-economic constraints. Management-related constraints include; inadequate water management, poor fertilizer use, late planting of crop, use of low yielding or old varieties, poor disease management and field crop establishment difficulties. Some of the diseases of rice are bacteria blight, Rice Yellow Mottle Virus (RYMV) and Blast (*Pryicularia oryzae*).

2.2: Disease expression

Mitchell *et al.,* (2003) states that oversupply of nitrogen may cause plants to be more pathogen prone. Long *et al.,* (2000) showed that increase in rice blast, was highest at panicle initiation despite nitrogen application and progressively reduced. Veresoglou *et al.,* (2013) reported that disease severity increased after applying phosphorous together with nitrogen. Rice yellow mottle virus (RYMV) is known as the main viral disease of rice in Africa (Sere *et al.,* 2008). Yield losses as a result of RYMV-infected rice cultivars of between 10-95% have been reported in several West African countries (Mogga *et al.,* 2012). Healthy host plants contribute to virus duplication. This is predominantly true for nitrogen (Spann and Schumann, 2010). Myint *et al.,* (2007) reported that disease incidence of bacterial blight of rice could be made more severe by continued use nitrogen fertilizer. They also discouraged the use of urea above 125.5 kg/ha to help maintain disease severity at manageable levels and minimize yield losses resulting from the disease.

2.3 Nitrogen nutrition and dynamics in irrigated rice production systems

Nitrogen is an important to plants and is the most frequently deficient of all nutrients in agricultural production systems (Balkos *et al.,* 2010). Plants need nitrogen in fairly larger amounts than other elements (Wang and Schjoerring, 2012). Nitrogen is needed and absorbed by the rice plant at almost all the growth stages thus it's important in rice plant growth and yield. It's absorbed by the plants as nitrate (NO_3^-) and ammonium (NH_4^+) ions. Enough nitrogen supply is connected with high photosynthetic processes and growth (Mengel *et al.,* 1987). A surplus supply of nitrogen together with nutrients like phosphorous, potassium and sulphur can significantly interrupt crop maturity (Romheld *et al.,* 1991). Stimulation of heavy vegetative growth by nitrogen early in the growing season can be a disadvantage in regions where moisture stress limits plant growth.

Ghanbari-Malidareh (2011) observed that nitrogen is the main nutrient linked with yield as it contributes to production of spikelets. According to Samuel *et al.,* (1985), nitrate absorption is normally higher than NH_4^+ and it freely moves to the plant roots by mass flow and diffusion. Age, type and environment are key factors in the preference for uptake of nitrate or ammonium by plants. Rice, corn, pineapple, beats and rye grass use either form. Ideally, ammonium is the preferred nitrogen source since energy will be saved when it's used instead of nitrate ions for synthesis of protein. Rhizosphere pH decreases when plants take up ammonium ions (Samuel *et al.,* 1985). Dobermann and Fair Hurst (2000) found out that nitrogen was more available in poorly aerated soils. The nitrification of nitrate to nitrite occurs mostly near the surface where oxygen is available. NH_4^+ easily moves to the soil layers below and is lost as a gas. $NH_4^+$and NO_3^- are taken up equally irrespective of NH_4^+ being the more dominant form of mineral nitrogen in paddy fields.

Khind *et al.,* (1991) also reported that the crop removal and leaching contribute to soil nitrogen loss. However, denitrification and ammonia volatilization occur under specific conditions. According to the same author, several autotrophs involved include *Thiobacillus denitrificans* and *T. thioparus.* Denitrification is influenced by various factors like soil temperature and pH, organic matter and nitrogen available. According to a study by Suter *et al.,* (2013), nitrogen volatilization is a mechanism of nitrogen loss that occurs naturally in all soils. Loss of ammonium through volatilization is greatly determined by the amount of time between fertilizer applications and flooding. High soil temperature enhances volatilization because it enhances the conversion from NH_4^+ to NH_3 (Suter *et al.,* 2013).

Aulakh *et al.,* (1997); Holcomb *et al.,* (2011) showed that losses of nitrogen through ammonia volatilization can be reduced by applying nitrogen fertilizer before irrigation or the rainfall. Ammonium nitrogen that has been transported deep into the soil by percolating water remains held deep in the soil. It's also advisable to avoid broadcasting if using urea and if it's the only feasible option, then it should be quickly followed by incorporation (Engel *et al.,* 2011; LeMonte *et al.,* 2013). Suter *et al.,* (2013), argued that maintaining nitrates at least levels for plant growth through split application and fertigation can help reduce nitrogen losses. The International Plant Nutrition Institute (IPNI) research in 2013 showed that use of nitrification inhibitors like 3, 4-dimethylpyrazole phosphate (DMPP) added to nitrogen fertilizer temporarily restricted nitrosomonas bacteria from converting ammonia to nitrite. Proper nitrogen inputs are the major considerations that are put to help in the control of nitrate leaching (Guo, 2006). According to Waddell (2000), nitrogen should also be applied when it's required by the plant for quick absorption. Logsdon (2002) argued that cover crops prevent too much nitrate loss. Nitrification inhibitors like dicyandiamide (DCD) reduce denitrification by slowing the process, allowing nitrogen to stay in the immobile ammonium state. Low soil moisture also limits denitrification and therefore nitrogen loss (Luo *et al.*, 1999).

2.4 Effect of varying nitrogen fertilizer rates and split application on growth and yield of rice

Chaturvedi (2005) found that the significant nitrogen fertilizers increased plant height. He attributed this to the ability of the nitrogen fertilizer to increase the rate of food production by the plant leaves for translocation to the rest of the plant parts. These results concur with those of Mandal *et al.*, (1992) and Maske *et al.,* (1993). Rupp and Hubner (1995) also reported increased levels of leaf N with applied nitrogen fertilizer. According to Fageria and Baligar (2005), N application increases rice height, length of the panicles and the number of effective tillers. Maske *et al.*, (1993) found that applying nitrogen at levels of 40, 80 and 120kg/ha resulted in increase in height. Kumar *et al.*, (1998) observed taller plants at nitrogen level of 120 kg/ha. According to Islam *et al.*, (2009), fertilizer N was more effective at 65 and 90 days after transplanting positively affecting its height.

Chaturvedi (2005) argued that tillers are essential components of yield in rice. He also argued that the more they are, especially productive tillers, the more yield will be realized from that unit area. Mirza *et al.*, (2010) showed that different fertilizer combinations increased the tiller numbers per plant. Liu et al., (2011), however, showed that grain yield reduced as a result of excessive tillering with high tiller abortion. Irshad *et al.*, 2000 suggested that to obtain maximum yield, at least some nitrogen must be applied at tillering stage along with that applied at transplanting. Irshad *et al.*, (2000) showed that if nitrogen application is done at transplanting or some of it is delayed till panicle emergence, then this would result in minimum number of tillers per hill.

According to Salem (2006), applying farm yard manure together with fertilizer N can increase the panicle numbers, length, weight and filled panicles. This is in line with the findings of Haque et al., (2016), who found that the number of panicles per hill increased with increased level of nitrogen. Mohammed *et al.,* (2015) reported significant positive responses of panicle weight, number of panicles and length and 1000 grain weight to nitrogen rate.

Yoshida *et al.,* (1972) showed that nitrogen increased grain weight. This they attributed the role of nitrogen in crop maturation, flowering and fruiting as well as in seed formation. These results tally with those of Ahmad (1989). Mirza *et al.,* (2010) observed differences in 1000-grain weight in rice as an effect of variation in nitrogen fertilizer rates. These findings concur with those of Channabasavanna and Biradar (2001). Kaushal *et al.,* (2010) in a research carried out in paddy fields of Iran found rising fertilizer N levels from 90 to 120 kg N per ha improved rice grain yield.

Management of nitrogen is important when growing rice under paddy conditions because nitrogen use efficiency is estimated to be between 40 to 60%. According to Devi *et al.,* (2012), applying nitrogen fertilizer when it's needed is among the most important solutions for improving NUE. Dobermann and Fairhurst (2000) showed that some of the most promising nitrogen management techniques include split application, amount and the time of nitrogen application, all which are critical for optimum grain yield. They found that applying half of the nitrogen fertilizer at planting, a quarter at tillering and the rest at the heading stage led to more nitrogen uptake by the plants followed by nitrogen application as ¼ basal, ½ at tillering and ¼ at panicle initiation. Excessive nitrogen or unbalanced fertilizer application may reduce yield. However, splitting nitrogen fertilizer rates of 60 kg N per ha and above into two or more splits for varieties that mature late in the season can potentially improve yield (Dobermann and Fairhurst, 2000). When nitrogen was applied in three equal splits; at planting, tillering and panicle initiation, an increase in rice yields was observed by Hirzel *et al.,* (2011). According to Symon *et al.,* (2018), the current nitrogen fertilizer application rate in Kenya is 75 kg N per ha. However; no current nitrogen application rates for split nitrogen fertilizer have been passed down to the farmers.

Mandana *et al.*, (2014) showed a negative relationship between amount of nitrogen and amylose content of the rice grains. These results were supported by Ju-Young (2006) and later by Dong *et al.,* (2007) who found out that increasing nitrogen fertlizer to 120 kg N PERha from zero increased the starch branching enzymes due to the increase in the percentage of amylopectin while amylose content decreased in Japan's varieties. Mandana *et al.,* (2014) showed significant effects of fertilizer N amounts on gel consistency where it increased (gel consistency) as N was increased up to a certain point and then stared decreasing. Zhu et al., (2017) found that rice grain size and chalkiness increased as the nitrogen levels increased. A previous study by Liu *et al.*, (2017) reported that milling quality and gliadin increased due to nitrogen.

CHAPTER THREE

FARMERS' SOIL FERTILITY MANAGEMENT PRACTICES BY RICE FARMERS IN MWEA IRRIGATION SCHEME

3.1: Abstract

A survey to document the existing farmers' soil fertility management practices for rice production in Mwea Irrigation Scheme was carried out in February 2016. Two hundred farmers (40 farmers per section) drawn from five sections of the scheme (Mwea, Karaba, Thiba, Tebere and Wamumu) were selected using a stratified random sampling strategy. The information captured included: soil fertility maintenance practices, and types, sources and rates of both organic and inorganic fertilizers used by the farmers and the status of major weeds, diseases and their control measures.

Inorganic fertilizers like diammonium phosphate, triple super phosphate, muriate of potash and sulphate of ammonia were mainly used for nutrient maintenance in the farmers' rice fields. These fertilizers were mainly obtained from local input dealers. A very small fraction of the farmers (1.98%) had ever tested the fertility levels of their field. Lack of enough water for irrigation, high input prices, low market prices for the harvested produce, pests and diseases, poor infrastructure especially the roads, weeds, labour expenses and birds' infestations were cited as the major challenges in rice production by farmers across the five sections. Majority of the farmers (95.8%) did not rotate rice with any other crop in their fields. In all the five sections of the scheme, only 17.98% of the farmers had been trained on soil fertility and majority cited it as the leading need to help them improve soil fertility.

There is need to educate the farmers on proper use of fertilizers (organic and inorganic) as a means to help them increase rice productivity in their farms as the farmers in Mwea Irrigation Scheme are using varied fertilizer management practices.

Keywords: Azolla, organic and inorganic fertilizers and rice yields.

3.2: Introduction

Rice is the 3rd most important cereal crop in Africa after maize and wheat (MOA, 2007). It's cultivated mainly for the grain and is a staple food in many countries, especially in Asia. Lack of adequate water and fertilizers are the major challenges limiting Sub-Saharan countries from being food self-sufficient. Agriculture in this part of the world is mostly rain-dependent, a reason for the low agricultural output (Sahar, 2012). Experts say that Kenya lost up to 10 million bags of maize in 2017 due to post-harvest losses. FAO estimated 3.6 million tonnes in 2017 as the amount of cereals produced.

According to Kinyanjui *et al.* (2000), the reducing soil fertility levels and lack of enough rainfall which cannot be predicted contribute to low agricultural productivity in Kenya. The major challenges facing productivity being low soil fertility and poor soil management (Muzari *et al.*, 2012). In their study, Ugboh and Ulebor (2011) found that only about ½ a billion ha of the more than three billion ha of land under cultivation in Africa are free of both chemical and physical challenges. 13% of these struggles with soil fertility issues and another 17% have high pH levels. This affirms that most African soils lack the most essential of crop nutrients. According to Keino *et al.,* (2015), in some East-African countries like Tanzania, Kenya and Uganda, low yields can be linked to low soil fertility. Abe *et al.,* (2010) found that some West African production systems are deficient of zinc, while a nutrient like phosphorous is unavailable as a result of the accumulation of Fe and Al oxides in the soils as well as low soil pH (de Valença and Bake, 2016). Tittonell *et al.,* (2008) stated that more than 80% of farmlands under small holder farmers for maize production in Kenya are very low in phosphorous. Most of the soils in East Africa have more nitrogen compared to phosphorous and potassium which occur in equal amounts (Ganga *et al.*, 2012). Dissemination of research work findings to farmers on soil fertility management is a big challenge. Embanyat and Bekunda (2001) reported that research findings should be presented in a way that's understandable by anyone in need of the information. Davies *et al.,* (2001) suggested the use of more manure and compost, minimizing gaseous losses, rotating crops and applying liquid manure as ways of improving soil fertility.

Fertilizers are quite expensive especially to the resource-poor farmers. How much fertilizers to apply and when to apply have not been established through research. In Africa, at least 60% of the smallholder farmers don't use inorganic fertilizers due to their high prices, making the cost of production go up (Chianu *et al.*, 2010). Africa imports most of its organic fertilizers with the main aim of using it commercially for agricultural production. FAO (2015) 2013 statistics show that less fertilizer is used in African countries as compared to the other continents. Sanou *et al.,* (2015) attribute this to the low backings from most governments in the region to their farmers, weakly formulated fertilizer regulations and extremely high input prices. Inorganic fertilizer can be used as a short-term solution to help increase crop yields in Africa. Sommer *et al.,* (2013) suggest increasing the current fertilizer use by 10 to 18% per annum for this target to be achieved.

Majority of the farmers in rice production have not yet adopted modern technologies leading to a stagnation in quality and the quantity of their produce. Pepitone and Jullanne (2016) reported that yields can be improved by reducing nutrient amounts by using good crop management methods. Arama (2016) found that modern technologies like the use of mobile telephones are helping farmers in the underdeveloped countries carry out their farming practices with more ease than before.

This study was therefore carried out to document the current soil fertility management practices for rice production in Mwea Irrigation Scheme.

3.3: Materials and methods

3.3.1: Description of the study area

The study done in Mwea Irrigation Scheme located in Kirinyaga County, Mwea West sub-county within the central part of Kenya. The study area included the five sections: Mwea, Karaba, Wamumu, Tebere and Thiba. It's located 1159 meters above sea level on latitude 0°37' S and longitude 37°27' E. The rainfall pattern is bimodal. The long rains season is between March and May and the short rains season is between October and December. It receives between 950 and 1500 mm of rainfall in a year and is characterized by heavy, black cotton soils (vertisols) which are prone to cracking upon drying. The mean temperature is 22°C with a range of 17°C to 28°C (Ndiiri *et al.,* 2013). The Scheme is supplied with water by two rivers; Nyamindi and Thiba.

3.3.2: Sampling design

A field survey was conducted in February 2016 using a stratified random sampling approach to find out the management practices employed by the farmers on soil fertility in their fields. This study was done in the five sections of the Scheme. A total of 200 farmers were randomly interviewed, 40 from each of the five sections using a semi-structured questionnaire which was pre-tested by 20 farmers (Appendix1). The questionnaire covered; the use and sources of inorganic fertilizers, azolla weed and its management, soil testing, manure storage, indicators of soil fertility, soil fertility maintenance practices, pests and disease management and the major constraints in rice production.

3.3.3: Data analysis

Data from the survey was analyzed using the Statistical Package for Social Sciences (SPSS) Version 20.

3.4: Results

3.4.1: Management of nutrients and sources of inorganic fertilizers and farmyard manure

Karaba section had the highest number of farmers using inorganic fertilizers for nutrient management in their farms (53%) compared to Mwea, Wamumu, Tebere and Thiba. Mwea section had the highest number of farmers (39.5%) using organic fertilizers. The largest number of farmers using both organic and inorganic fertilizers for nutrient management was from Tebere section. On average, 45.7% of the farmers preferred using inorganic fertilizers, 17.9% used organic fertilizers with the remaining 36.5% using both organic and inorganic fertilizers.

Wamumu section had the highest number of farmers (89.5%) who obtained inorganic fertilizers and manure from input dealers. 22.5% of the farmers in Thiba section obtained their inorganic fertilizers from the government subsidy program. No farmer from the five sections reported obtaining inorganic fertilizers from fellow farmers, making from their own material or purchasing from commercial farmers.

Majority of the farmers in Wamumu section (59%) made manure from their own material. Tebere section had the highest number of farmers (41%) obtaining manure from fellow farmers as shown in table 3.1.

Table 3.1 Use and sources of fertilizers

	Sections in Mwea Irrigation scheme					
N = 200	Mwea	Karaba	Tebere	Wamumu	Thiba	**Mean**
Inorganic fertilizer (%)	34.2	53.1	48.7	47.4	45.0	45.7
Organic fertilizer (%)	39.5	14.3	5.1	10.5	20.0	17.9
Both inorganic and organic fertilizers (%)	26.3	32.7	46.2	42.1	35.0	36.5
None (%)	0.0	0.0	0.0	0.0	0.0	0.0
Sources of inorganic fertilizers						

Input dealers (%)	78.9	87.8	76.9	89.5	75.0	81.6
Fellow farmers (%)	0.0	0.0	0.0	0.0	0.0	0.0
Homemade (own material) (%)	0.0	0.0	0.0	0.0	0.0	0.0
Purchased from commercial farmers (%)	0.0	0.0	0.0	0.0	2.5	0.5
Government subsidy program (%)	21.1	12.8	23.1	10.5	22.5	18.0
Others (%)	0.0	0.0	0.0	0.0	0.0	0.0
Sources of manure						
Input dealers (%)	31.6	46.9	0.0	50.0	42.5	34.2
Fellow farmers (%)	18.4	14.3	41.0	10.5	5.0	17.8
Homemade (own material) (%)	50.0	38.8	59.0	39.5	42.5	46.0
Others (%)	0.0	0.0	0.0	0.0	0.0	0.0

Others: - Commercial farmers and government subsidies.

3.4.2: Azolla management

More than half of the farmers interviewed (55.04%) admitted to having azolla in their farms with 61.1% of them weeding it out and 38.9% leaving it in the farms (Table 3.2). It was more prevalent in Karaba (61.2%), Thiba (60%), Wamumu (55.3%) and Mwea (50%) respectively. Tebere had the least Azolla prevalence (48.7%).

Table 3. 2: **Azolla and its management**

Presence of azolla	Sections in Mwea Irrigation scheme					
N = 200	Mwea	Karaba	Tebere	Wamumu	Thiba	**Mean**
YES (%)	50.0	61.2	48.7	55.3	60.0	55.0
NO (%)	50.0	38.8	51.3	44.7	40.0	44.0
Management						
Weed it out (%)	57.9	65.3	59.0	65.8	57.5	61.1
Leave it in the farm (%)	42.1	34.7	41.0	34.2	42.5	38.9

3.4.3: Soil testing frequency

All the farmers in Tebere and Thiba sections had not done soil tests in their farms. Wamumu section had the highest number (5.3%) of farmers who had carried out soil tests in their farms followed by Mwea (2.6%) and then Karaba (2%). On average, majority of the farmers (98.0 %) had not done soil tests in their farms with only 2.0% having carried out soil tests for their farms as shown in Table 3.3 below.

Table 3. 3: Number of times the farmers have tested their soil fertility (% respondents)

Soil test	Sections in Mwea Irrigation scheme					
N = 200	Mwea	Karaba	Tebere	Wamumu	Thiba	**Mean**
YES (%)	2.6	2.0	0.0	5.3	0.0	2.0
NO (%)	97.4	98.0	100.0	94.7	100.0	98.0
Frequency of soil test						
Once every season (%)	2.6	2.0	0.0	2.7	0.0	1.5
Twice every year (%)	0.0	0.0	0.0	2.6	0.0	0.5
Never done (%)	97.4	98.0	100.0	94.7	100.0	98.0

3.4.4 Manure storage

As shown in Table 3.4, it is only in Tebere and Thiba where farmers stored their manure covered by earth and grass. The small percentage (2.6%) that stored their manure in a store came from Tebere. Wamumu section had the highest number (89.5%) of farmers storing their manure in open space while Tebere had the least (82%). Majority of the farmers interviewed (86.7%) stored their manure in open space, 10.7% in compost pits and a small percentage (2.0% and 0.5%) covered by earth and grass and in a store respectively.

Table 3. 4: Storage of manure by the farmers before application on the farms

	Sections in Mwea Irrigation scheme					
N = 200	Mwea	Karaba	Tebere	Wamumu	Thiba	**Mean**
In open space (%)	86.8	87.8	82.0	89.5	87.5	86.7
In a store (%)	0.0	0.0	2.6	0.0	0.0	0.5
In a compost pit (%)	13.2	12.2	10.3	10.5	7.5	10.7

Covered by earth and grass (%)	0.0	0.0	5.1	0.0	5.0	2.0
Others (%)	0.0	0.0	0.0	0.0	0.0	0.0

3.4.5: Soil fertility indicators

Majority of the farmers in Mwea (63.2%), Tebere (48.7%) and Wamumu (55.3%) used crop colour as an indicator of soil fertility. In Karaba, yield output from the land was the most used fertility indicator by the farmers (49%). Farmers in Thiba used both yield output from land and crop colours as indicators of soil fertility in equal measures (45%) as shown in Table 3.5. Majority of the farmers (50.6%) used crop leaf colour as the major indicator followed by yield output, colour of the soil, water holding capacity and type of vegetation being the least used (1.8%). The quantity of inorganic fertilizer or manure applied was not used as one of the fertility indicators by any of the farmers interviewed. Crop colour and yield output from the land were used across all the sections.

Table 3. 5: Indicators used by the farmers to estimate soil fertility

	Sections in Mwea Irrigation scheme					
N=200	Mwea	Karaba	Tebere	Wamumu	Thiba	**Mean**
Appearance of the soil (colour of soil) (%)	0.0	4.1	2.6	5.3	2.5	2.9
Type of vegetation on the land (%)	2.6	4.1	2.5	0.0	0.0	1.8
Yield output from the land (%)	34.2	49.0	46.2	36.8	45.0	42.2
Soil water holding capacity (%)	0.0	2.0	0.0	2.6	7.5	2.4
Colour of the crop (%)	63.2	40.8	48.7	55.3	45.0	50.6
Quantity of fertilizer/manure applied (%)	0.0	0.0	0.0	0.0	0.0	0.0

3.4.6 Rate of inorganic fertilizer use as a source of plant nutrients

Diammonium phosphate (DAP), muriate of potash (MOP), triple super phosphate (TSP), sulphate of ammonia (SA) and urea were the fertilizers used by the interviewed farmers. The most used fertilizer by the farmers was SA (Table 3.6), which was used by 84.3% of the farmers, followed by MOP (57.8%), TSP (53.9%), DAP (37.7%) while urea (14.2%) was the least used. Fertilizer application rates differed depending on the type of fertilizer being used though majority of the farmers used 125 kg/ha for all the fertilizers. The maximum rate the farmers applied on their farms in a single season was 300kg/ha for all the fertilizers except for muriate of potash (250kg/ha).

Table 3. 6: Rates of inorganic fertilizers used by farmers and time of application on the farms (% respondents)

		Rate of use				
Fertilizer type	Use fertilizer	62.5kg/ha	125kg/ha	187.5kg/ha	250kg/ha	300kg/ha
DAP	37.7	16.7	70.5	3.8	7.7	1.3
Urea	14.2	13.8	41.4	0.0	34.5	10.3
TSP	53.9	14.4	78.4	1.8	3.6	1.8
MOP	57.8	29.4	63.0	1.7	5.9	0.0
SA	84.3	4.1	40.1	4.1	39.5	12.2

Where; DAP is diammonium phosphate, TSP is triple super phosphate, MOP is muriate of potash and SA is sulphate of ammonia.

3.4.7 Time of inorganic fertilizer application

The time of application depended on the type of fertilizer being used as shown in Table 3.7. None of the farmers used diammonium phosphate and muriate of potash for topdressing at tillering stage of the crop. Sulphate of ammonia ($NH_42\ (SO_4)$) was the most used fertilizer for top-dressing at the heading stage of the crop growth. Urea was used for topdressing 2 weeks after planting while diammonium phosphate and triple super phosphate (TSP) were majorly used at planting.

Table 3. 7: Time of inorganic fertilizer application

	Before planting	At planting	2 wks after planting	At tillering	At panicle initiation	At maturity
DAP	10.3	67.9	20.5	0.0	1.3	0.0
Urea	3.4	27.6	44.8	6.9	13.8	3.4
TSP	15.5	68.2	11.8	0.9	3.6	0.0
MOP	17.8	59.3	15.3	0.0	6.8	0.8

SA	0.6	8.7	33.7	3.5	46.5	7.0

Where; wks is weeks, DAP is diammonium phosphate, TSP is triple super phosphate, MOP is muriate of potash and SA is sulphate of ammonia.

3.4.8: Manure use

Cattle manure was the most used type of manure by the farmers (52%) while chicken, green and farm yard manures were only used by one farmer each as shown in Table 3.7. Application of 7.5t/ha was the most preferred practice of manure use. It's only cow manure that was used at a rate of more than 25 tons/ha.

Table 3. 8: Manure use by the farmers (% respondents)

	Rate of use							
Type of manure	Use manure	5t/ha	7.5 t /ha	10t/ha	12.5t/ha	15 t/ha	17.5t/ha	>25t/ha
Compost	8.3	55.6	22.0	5.6	0.0	16.7	0.0	0.0
Cattle manure	52.0	36.2	20.0	8.6	7.6	6.7	15.2	5.7
Chicken manure	0.5	0.0	100.0	0.0	0.0	0.0	0.0	0.0
Goat manure	2.0	0.0	33.3	66.7	0.0	0.0	0.0	0.0
Green manure	0.5	0.0	100.0	0.0	0.0	0.0	0.0	0.0
Farm Yard Manure	0.5	100.0	0.0	0.0	0.0	0.0	0.0	0.0

3.4.9: Time of manure application by the farmers

The most preferred time for chicken and green manure application according to the survey was before planting. The other types of manures were applied before planting, at planting and after planting except for farm yard manure which was all used at planting (Table 3.8). The interviewed farmers used all the farm yard manure at planting while cow manure was the only manure used to top-dress at the tillering and panicle initiation stages.

Table 3. 9: Time of manure application

	Time of application				
Type of manure	Before planting	At planting	2 wks after planting	At tillering	At P.I
Compost	72.2	5.6	22.2	0.0	0.0
Cow manure	92.6	4.7	0.9	0.9	0.9
Chicken manure	100.0	0.0	0.0	0.0	0.0
Goat manure	66.7	0.0	33.3	0.0	0.0
Green manure	100.0	0.0	0.0	0.0	0.0
Farmyard manure	0.0	100.0	0.0	0.0	0.0

Where:- Wks is weeks and P.I is panicle initiation

3.4.10: Training on soil fertility management

The proportion of respondents who had received soil fertility related training ranged from 12.2% (Karaba) to 23.7% (Mwea) (Table 3.9). On average, 18.0% of the farmers interviewed had received some form of soil fertility training across the five sections as shown in Table 3.9.

Table 3. 10: Farmers trained on soil fertility management

	Sections in Mwea Irrigation scheme					
N = 200	Mwea	Karaba	Tebere	Wamumu	Thiba	**Mean**
YES (%)	23.7	12.2	23.1	18.4	12.5	18.0
NO (%)	76.3	87.8	76.9	81.6	87.5	82.0

3.4.11: Farmers' suggestions to improve soil fertility

Farmers across the five sections suggested soil fertility management training, incorporation of fertilizers, setting soil fertility policies, fertilizer subsidies and focusing on soil fertility research as ways of improving soil fertility in their farms (Table 3.10). Soil fertility management was most suggested by farmers in Mwea (52.6%) while incorporating fertilizers, soil fertility policies, fertilizer subsidies and soil fertility research were most suggested in Mwea and Wamumu (2.6%), Tebere (7.7%), Karaba (34.7%) and Mwea (36.8%) respectively. On average, soil fertility management training was the most suggested way of improving soil fertility across the five sections with only 1.5 % of the respondents seeing no need to improve soil fertility.

Table 3. 11: Suggestion on how to improve soil fertility by the farmers

	Sections in Mwea Irrigation scheme					
N = 200	Mwea	Karaba	Tebere	Wamumu	Thiba	**Mean**
Soil fertility management training (%)	31.6	46.9	41.0	52.6	50.0	44.4
Incorporating fertilizers (%)	2.6	2.0	0.0	2.6	0.0	1.4
Soil fertility policy (%)	0.0	6.1	7.7	0.0	0.0	2.8
Fertilizers subsidies (%)	28.9	34.7	17.9	31.8	17.5	26.2
Soil fertility research (%)	36.8	10.2	30.8	13.2	27.5	23.7
Others (No need) (%)	0.0	0.0	2.6	0.0	5.0	1.5

3.4.12: Crops grown in rotation with rice

Beans, green grams, soybeans, tomatoes and maize were the crops the farmers preferred to grow in rotation with rice (Table 3.11). In Mwea section, no other crop was grown. Maize was grown as a rotational crop with rice only in Tebere. Tomatoes were grown in Wamumu and Thiba while in Karaba beans, green grams, soybean and tomatoes were grown. On average, most of the farmers did not grow any crop in rotation with rice (95.8%). Tomatoes were the most grown crops (2%) while green grams and soybean were the least grown crops (0.4% each).

Table 3. 12: Crops grown in rotation with rice

	Sections in Mwea Irrigation scheme					
N = 200	Mwea	Karaba	Tebere	Wamumu	Thiba	**Mean**
Beans (%)	0.0	2.0	0.0	2.6	0.0	0.9
Green grams (%)	0.0	2.1	0.0	0.0	0.0	0.4
Soybean (%)	0.0	2.1	0.0	0.0	0.0	0.4
Tomatoes (%)	0.0	2.0	0.0	5.3	2.5	2.0
Maize (%)	0.0	0.0	2.6	0.0	0.0	0.5
None (%)	100.0	91.8	97.4	92.1	97.5	95.8

3.4.13: Pest and disease management

All the farmers (100%) used chemicals for pest and disease management as indicated in Table 3.12 below. Stem borer was the most mentioned pest by the respondents while stem rot and rice blast were the leading diseases.

Table 3. 13: Pest and disease management

	Sections in Mwea Irrigation scheme					
N = 200	Mwea	Karaba	Tebere	Wamumu	Thiba	**Mean**
Use of chemicals (%)	100.0	100.0	100.0	100.0	100.0	100.0
Crop rotation (%)	0.0	0.0	0.0	0.0	0.0	0.0
Biological control (%)	0.0	0.0	0.0	0.0	0.0	0.0

3.4.14: Major challenges in rice production

As shown in Table 3.13, the leading challenge on average across the five sections was inadequate water for irrigation (63%). High input prices (37%), low market prices (26%), pests and diseases (25%), poor infrastructure (21%), weeds (13%), labour expenses (10.8%) and bird infestation (4.4%) were also noted as major challenges in rice production. Inadequate water for irrigation was mentioned as the leading challenge in each of the five sections. Pests and diseases were mostly mentioned in Tebere (38.5%) while high input prices, low market prices, poor infrastructure, weeds, labour expenses and bird's infestation were mostly mentioned in Mwea (44.7%), Wamumu (34.2%), Wamumu (34.2%), Tebere (20.5%), Mwea (21.1%) and Wamumu (7.9%) respectively. *Echinochloa crus-galli* (barnyard grass) was the most common weed among the respondents.

Table 3. 14: Challenges encountered by the farmers in rice production

	Sections in Mwea Irrigation scheme					
N = 200	Mwea	Karaba	Tebere	Wamumu	Thiba	**Mean**
Inadequate water for irrigation (%)	71.1	49.0	69.2	73.7	52.5	63.1
Pests and diseases (%)	36.8	0.0	38.5	13.2	35.0	24.7
High input prices (%)	44.7	40.8	35.9	28.9	32.5	36.6
Low market prices for produce (%)	26.3	18.4	25.6	34.2	27.5	26.4
Poor infrastructure (%)	10.5	32.7	12.8	34.2	12.5	20.5
Weeds (%)	5.3	20.4	20.5	7.9	10.0	12.8
Labour expenses (%)	21.1	12.2	2.5	10.5	7.5	10.8
Birds' infestation (%)	2.6	4.1	0.0	7.9	7.5	4.4

3.5: Discussion

About 37 % of the farmers reported to using fertilizers to improve soil fertility in their farms. The most preferred inorganic fertilizer by the farmers was sulphate of ammonia (SA) (84.3%). The use of sulphate of ammonia was reported to increase rice yields.in their study on twenty (20) rice varieties , Singh et al., (1998) discovered that yield was maximum at nitrogen rates of 150-200kg N per ha. Aulakh *et al.*, (2000) showed similar results where rice respondend to nitrogen rates of 120 kg N per ha. Fageria *et al.*, (2010) reported a decrease in soil pH with increasing sulphate of ammonia (0 to 210 kg N per ha) from 5.8 at 0kg N per ha to 5.2 at 210 kg N per ha.

Potassium is essential as a nutrient as it enhances the growth of roots and at the same time reduces lodging in plants while still giving it vigour. 57.8% of the respondents said their source of potassium was muriate of potash which was mostly used at a rate of 125 kg/ha (78.4%). At optimum plant nutrition, the rice crop takes up around 16 kg potassium per ton of grain yield (IRRI). Fageria *et al.*, (2014) classified TSP as a great supplier of phosphorous (P) because of its effect on grain yield. Phosphorous increased the height and grain yield of lowland rice with the highest yield being recorded at 143 kg P_2O_5. However, he reported a decrease in phosphorous-use efficiency with increasing P rate. The chemical, physical and biological root growth environments can be improved by incorporating organic due to its beneficial effects (Yang *et al.,* 2004).

Azolla was mentioned as a weed by majority of the interviewed farmers (55%). Azolla is a floating fern that can fix N in conjunction with cyanobiant *Anabaena azollae* (Moore, 1969). It's a plant that can double in mass within 10 days and has a yield potential of 8 to 10 tonnes on a fresh weight basis per. Hasan *et al.,* (2009) reported that it has the capacity to produce 3708 t fresh weight/ha. Hasan *et al.,* (2009) in their study in South East Asia stated that azolla can be used as an alternative source of nitrogen in rice growing fields. According to a study by Serrem *et al.,* (2013), application of azolla in lowland rice fields of western Kenya showed improvement of soil nutrient status and rice yields. The interviewed farmers did not seem to understand the benefits of using azolla as a source of nutrients in their farms, leading to a majority of them (61.1%) weeding it out instead of incorporating it in the soil. This could be one of the reasons for the poor crop yields coupled with other challenges like inadequate water for irrigation and high input prices.

Only 2% of the farmers reported to having had their soils tested since they started farming. Soil analyses gives important information for improving agricultural productivity. The FAO of the United Nations points at the lack of funding for agricultural implements and the use of inadequately trained personnel as the main contributors to the low percentages of tested soils in African countries. (Adepetu *et al.,* 2000). Gerald and Rhue (2003) outlined the importance of soil testing as helping you find out the makeup of your soil and helps determine how much fertilizer you need to apply and the cation exchange capacity(CEC). They also recommend that soil testing should be done once in three years or when a problem is detected during the cropping season.

Majority (86.7%) of the farmers stored their manure in open space with only a small percentages (10.7% and 2.5%) storing in compost pits and stores respectively. The storage for manure should be able to keep the manure from washing away and its nutrients from leaching into the ground water. It should also keep odours to a minimal. The common types of storage include; covered pit, earthen pit and large tanks, roofed buildings and covered dry stack (NRCS). The farmers' practice of storing manure in open space could lead to loss of nutrients like nitrogen to volatilization as well as through leaching when it rains.

Majority of the farmers (50.6%) used crop colour as the major indicator of soil fertility. Other indicators used by the farmers included yield output, vegetation type, water holding capacity and the soil colour. According to Barrios *et al.,* (2000); Beare *et al.,* (19970; Doran and Safley (1997), the fertility levels of a soil can be indicated by its physical features. These include colour of the soil, soil texture and soil moisture retention capacity. Infertile soils on the other hand are characterized by low yields even with the use of fertilisers. The use of visual soil fertility indicators alone without soil testing cannot be adequate in determining the plant nutrient requirements.

Yang *et al.,* (2004) reported that more yields were obtained with the use of green manure as it helped improve soil properties due to its richness in nutrients like nitrogen. He also attributed this to availability of important nutrients during tillering and heading stages. Yang *et al.,* (2004) argue that organic manure can be used to improve the quality of different soils and help cut down on the cost of production. Organic manure increases yield as shown in a study carried out by Babu *et al.,* (2001). Jogioy e*t al.,* (2006) found that using more manure in conjunction with inorganic fertilisers yielded more plant chlorophyll. A study by Buresh and Dobermann (2010) showed that organic materials were more beneficial to the biological, physical and chemical properties of aerobic soils than for submerged soils. They also advised that the use of some synthetic manufactured fertilizer can help in ensuring a balanced supply of nitrogen, phosphorous and potassium. There are several advantages linked to the use of compost (Uphoff, 2001), but in the absence of organic manure, chemical fertilizer use is encouraged to increase productivity. Satyanarayana *et al.,* (2002) obtained more grain yield after applying 10 t/ha of organic manure together with inorganic fertilizers at 120 N, 60 P_2O_5 and 45 K_2O ha^{-1}.

Majority of the farmers (95.8%) did not rotate rice with other crops. The percentage that rotated rice with another crop did so with beans, green grams, soybeans, tomatoes and maize. In China, farmers use their fields to grow upland crops after harvesting (Li, 1992). In the same country, paddy-upland crop rotation is a practiced along the Yangtze river basin (Rukun *et al.,* 2000 and Chu *et al.,* 2007) and the main patterns of rice-oilseed, rice-wheat, rice-ryegrass and rice-milk vetch (Witt *et al.,* 2000). According to Teetes and Pendleton (1999), the advantages of rotating crops include: maintenance of soil fertility, reduction of soil erosion, pests and disease control, prevention of diseases and weed control.

3.6: Conclusion

The farmers don't know the fertility levels of their farms and rely on factors like yield and type of vegetation to estimate the fertility. They, however, prefer using fertilizers in rice production.

Sulphate of ammonia was the most preferred inorganic fertilizer while cattle manure was the most used organic fertilizer which was mostly stored in open space.

CHAPTER FOUR

EFFECT OF DIFFERENT NITROGEN FERTILIZER RATES AND SPLIT APPLICATION ON THE GROWTH AND YIELD OF THREE SELECTED RICE VARIETIES

4.1: Abstract

Kenya imports rice due to a huge deficit in rice production. This can be attributed to the farmers adjusting their plant nutrient requirements based on their knowledge because they do not have the scientific information to rely on. An increase in fertilizer use by the farmers has been observed and is attributed to the ever increasing demand for food as a result of population growth. An effective strategy would be to apply the fertilizer according to the different stages of the crop growth period. A field experiment was conducted at Mwea Irrigation Scheme for seasons running from March - July and August – December, 2015 with the aim of determining N fertilizer rate split application effects on the growth and yield of selected rice varieties. It was set up in a randomized complete block design (RCBD) with a split-split plot arrangement and replicated three times. The treatments consisted of four nitrogen fertilizer rates (0, 40, 80 and120 Kg N /ha), two split nitrogen fertilizer application regimes (basal N application plus top-dressing at panicle initiation and basal N application plus top-dressings at the tillering and panicle initiation stages) and three rice varieties (IR 05N 221, ITA 310 and BW 196). Data collected included: number of panicles, plant height, panicle length, and number of tillers, 1000-grain weight and grain yield at14% mc. The data was analyzed using Genstat 15th edition and the treatment means compared using the least significant difference (LSD) test at *p*=0.05.

Rice variety BW 196 had significantly taller plants, longer panicles and more net grain yield than varieties IR 05N 221 and ITA 310. Variety IR 05N 221 had significantly more tillers per hill than varieties BW 196 and ITA 310 in both seasons and more panicles per plant in the second season.

Nitrogen application rate of 120 kg N per ha had significantly more number of panicles per hill and net grain yield than those of 40 and 80 kg N per ha in both seasons. Basal N application plus top dressing with N at tillering and panicle initiation stages had more tillers per hill in the first season than basal N application plus a top dressing at panicle initiation while that of basal N application plus a top dressing at panicle initiation had more tillers per hill than basal N application plus top dressing with N at tillering and panicle initiation stages in the second season. The split application regime of basal N application plus top dressing with N at tillering and panicle initiation stages had taller plants in both seasons. Application of nitrogen as basal N plus a top dressing at panicle initiation recorded more yield than that of basal N plus top dressing with N at tillering and panicle initiation stages. This study has shown that cultivation of variety BW 196 and application of nitrogen fertilizer as basal N plus a top dressing at panicle initiation can improve rice productivity in Mwea Irrigation Scheme.

Key words: Import, nutrients, top dressing and treatments.

4.2: Introduction

In Kenya, food consumption trends are changing and increasing fast as a result of an increase in net income and a majority of the people realizing the need to include rice in their diets (GAIN, 2017). Kenya has potentially 540,000 ha that could be used for production of irrigated rice, but of these, only 105,000 ha are under paddy rice production (MOA, 2009). The average paddy rice production is estimated at 7 t/ha for non-aromatic and 5.5 t/ha for the aromatic varieties (GAIN, 2017). Challenges in rice production in Kenya include; low soil fertility, unavailability of quality seeds, high input prices and low market prices, inadequate water for irrigation, lack of adequate farmer training on rice production practices, pests and diseases, poor infrastructure, labour scarcity, high temperatures and very low temperatures (Emong'or *et al* ., 2009). To obtain high rice yield and nitrogen use efficiency, nitrogen management strategies like site-specific nitrogen management can be used (Dobermann *et al.*, 2002). Liang, H. 2016 showed that rice yields can be improved by good nutrient management leading to a reduction in the rate of nitrogen applied. The increasing trend in the production of rice will have to be continued to cater for the needs of the projected global population. After the Green Revolution era, fertilizer use has continually increased rice production (Singh and Singh 2017).

The sources of fertilizer together with time of application help in determining nitrogen use efficiency which ranges between 20 and 80%, with an average of 30 to 40% (Fageria *et al.,* 2003). Splitting its application after the basal application leads to an enhanced efficiency in nitrogen fertilizer use (Westcott *et al.*, 1986). Some of the varieties with farmers respond well to fertilization especially if good management practices are employed. This experiment therefore, was conducted to determine how varied nitrogen fertilizer rates applied in splits affect the growth and yield of three rice varieties in Mwea Irrigation Scheme.

4.3: Materials and methods

4.3.1: Site description

The experiments were carried out in Mwea Irrigation and Agricultural Development (MIAD) centre in Kirinyaga County within the central part of Kenya, which is almost 100 km North East of Nairobi County. It's among the seven public schemes managed by the National Irrigation Board (NIB) of Kenya and has 4000 acres under irrigated rice production. According to the Mwea Irrigation and Development centre, the site is partitioned into five sections, consisting of 77 units and almost 5000 homes mainly for the rice farmers. Irrigation water used is sourced from rivers Thiba and Nyamindi and is channelled to the irrigation scheme through canals by use of gravity. The area is characterised by heavy, black cotton soils and receives rainfall amounts of between 950 and 1500 mm in a year.

The mean temperature is 22^{0}C with a range of 17^{0}C to 28^{0}C. Soils were sampled at the experimental site at depths of 0-15 cm and 15-30 cm and then analysed for pH, N, K, Ca, Mg and cation exchange capacity (Table 4.1) and were found to be adequate.

Table 4. 1: Soil chemical composition at the Mwea Irrigation Scheme experimental site

Parameter	pH	%N	%K	%Ca	%Mg	CEC
Top soil (0-15 cm)	5.90	0.17	0.17	32.43	22.61	64.00
Sub soil (15-30 cm)	6.90	0.09	1.40	51.29	36.56	46.00
Average	6.10	0.13	0.79	41.86	29.59	55.00

Where CEC is cation exchange capacity

4.3.2: Experimental design and treatments

A randomized complete block design (RCBD) with a split-split plot arrangement replicated three times for two seasons was used. Nitrogen fertilizer rates (0, 40, 80 and 120 kg N per ha) were assigned to the main plot, split application treatments (basal N application plus a top-dressing at panicle initiation and basal N application plus two top-dressings at tillering and panicle initiation stages) to the sub plot and varieties (IR 05N 221, ITA 310 and BW 196) to the sub-sub plot level. The trial was a 4×2×3 factorial giving a total of 72 plots of 3×3 m each. The source of N was sulphate of ammonia. Triple super phosphate (TSP) and muriate of potash (MOP) both at a rate of 60 kg P_20_5 /ha and 60 kg K_2O /ha respectively were combined in all the experimental plots three days before transplanting. To stop the leakage of water and nutrients from one plot to the other, the main plot was bounded by bunds which had half a meter deep plastic sheets. Water ways 2 m wide were left across plots for ease of availing irrigation water. Varieties BW 196 and ITA 310 were chosen because they are popular local varieties and are grown by rice farmers, while IR 05N221 is a new variety with a high yield potential and important traits like high milling recovery, aroma and resistance to diseases. Table 4.2 shows the origins and characteristics of the varieties used.

Table 4. 2: Origin and characteristics of the rice varieties used in the study

Variety	Origin	Characteristics
ITA 310	Kenya	Non-aromatic, susceptible to major insect pests e.g. white stem borer, spotted stem borer and stalk eyed fly (Fageria *et al.*, 2011).
BW 196	Kenya	Susceptible to major insect pests e.g. white stem borer, spotted stem borer and stalk eyed fly; it's tolerant to blast; it's non-aromatic and it's late maturing (135 days). It has good cooking quality and a yield potential of 9.0 t/ha (Karen *et al*., 2003).
IR 05N221 (Komboka)	Tanzania	Aromatic with a yield potential of 6.5-7 tons per ha. It has medium-slender and translucent grains with a soft texture when cooked; it is early maturing and has moderate resistance to diseases such as leaf blast and bacterial leaf blight.

4.3.3: Crop husbandry

The three varieties; IR 05N221, ITA 310 and BW 196 were transplanted 21 days after sowing and grown at a spacing of 20 by 20 cm, which gave 256 hills per 3 × 3 m plot. The straight line method was used to transplant the seedlings (Surajit, 1981). A 500 gauge black polythene sheet was used to band around the sub plots as well as around the main plots at a depth of 2 m to prevent lateral nutrient mobility. The seeds were dressed with a fungicide, Thiram 750 WP (trade name-Thiram and active ingredient-Thiram 750g/kg) and soaked for three days under warm conditions to enable pre-germination before transplanting to the seedbed. The field was rotavated three weeks prior to transplanting. This was followed by puddling using ox-drawn ploughs and later hand puddling and leveling to make the field more uniform with a fine tilth to enhance the germination process. A seedling per hole was transplanted by hand at the age of 21 days. The experimental field was continuously flooded at a water level of 5 cm until two weeks to harvesting when the fields were drained to promote ripening of the grains and make harvesting easier. The fields were hand weeded three times each season. Spot-weeding was, however, done throughout the season to remove any weeds that appeared after the main weeding. This was to help reduce competition and the chance of diseases which may have been harbored by the weeds.

4.3.4: Data collection

Data was collected, according to the standard evaluation system (SES) of rice (IRRI 2008); on : plant height, number of tillers, panicle length, days to 50% heading, number of effective tillers, 1000 grain weight and grain yield (adjusted to 14% moisture content). A transect line with ten plants was chosen at random in every sub-sub plot at the beginning of the trial for sampling and was maintained throughout the season. Growth observations were done on the 10 plants in each sub-sub plot at 14 DAT, vegetative/tillering, panicle initiation, maturity and harvest stages which were 30-35, 50-55, 70-75 and 105-120 days after transplanting respectively. Panicle length was measured from ten panicles after harvesting using a meter rule and the grains from the ten plants were used for the 1000 grain weight determination. The rice grains were then sun-dried before measuring their moisture content level. Grain weight was attuned to 14 % seed moisture content through statistical computations. A grain counter was then used to tally 1000 grains for the 1000-grain weight determination using a sensitive scale. Grain yield was obtained by mixing grains harvested in the sub-sub plots according to variety as well as treatments.

4.3.5: Data analysis

Data were subjected to analysis of variance (ANOVA) using GENSTAT 15th edition and comparison of treatment means tested at $p = 0.05$ using the least significant difference (LSD) test.

4.4: Results

4.4.1: Effect of variety on rice plant height

Variety and nitrogen fertilizer significantly affected plant height in both seasons (Table 4.3). In the first season, variety ITA 310 had significantly taller plants than IR 05N 221 and BW 196 at most growth stages. Variety BW 196 had taller plants than IR 05N 221 at the vegetative, panicle initiation and maturity but not at 14 DAT. In the second season, similar observations were made except at 14 DAT where variety IR 05N221 had taller plants than varieties ITA 310 and BW 196.

Table 4. 3: Effect of variety on plant height (cm) at different growth stages of rice

First season				
Variety (V)	14 DAT	Vegetative	Panicle initiation	Maturity
IR 05N221	48.59	58.00	72.15	81.38
ITA 310	49.50	67.55	87.50	87.26
BW 196	47.06	61.40	81.79	84.42
p-value	0.031	<.001	<.001	<.001
$LSD_{0.05}$(V)	1.81	2.30	3.19	3.10
CV %	2.20	2.00	2.00	2.40
Second season				
IR 05N221	30.37	38.31	41.80	50.42
ITA 310	28.95	40.05	52.39	71.06
BW 196	29.79	40.03	50.72	67.16
p-value	0.019	0.014	<.001	<.001
$LSD_{0.05}$ (V)	0.97	1.30	1.33	1.79
CV %	0.70	1.80	0.60	1.40

Where, DAT is days after transplanting, NS is not significant and vegetative is 35 DAT.

4.4.2: Effect of variety on the number of tillers

Significant differences were noted among varieties tiller numbers at 14 DAT, panicle initiation and maturity stages in the first season and at all growth stages in the second season except at 14 DAT (Table 4.4). Varieties IR 05N 221 and BW 196 had significantly more tillers per plant than variety ITA 310 in both seasons except at 14 DAT in the second season. Variety IR 05N221 had more tillers per plant than variety BW 196 at 14 DAT in the first season and at panicle initiation and maturity in the second season. The tiller numbers per plant in the first season ranged from 18.25 to 29.64 and from 15.02 to 23.17 in the second season.

Table 4. 4: Effect of variety on the number of tillers per plant at different growth stages of rice

First season

Variety (V)	14 DAT	Vegetative	Panicle initiation	Maturity
IR 05N221	24.89	37.61	36.92	34.39
ITA 310	19.01	24.08	19.96	17.49
BW 196	20.30	34.74	33.55	31.82
p-value	<.001	<0.01	<.001	<.001
$LSD_{0.05}$ (V)	2.49	6.22	8.4	3.71
CV %	5.50	8.5	12.3	7.20
Second season				
IR 05N221	6.77	19.81	26.01	26.13
ITA 310	6.58	17.32	17.28	13.60
BW 196	6.78	19.22	20.30	18.20
p-value	0.68	0.007	<.001	<.001
$LSD_{0.05}$ (V)	NS	1.56	1.53	1.54
CV %	5.8	6.20	3.20	13.00

Where, DAT is days after transplanting, NS is not significant and vegetative is 35 DAT.

4.4.3: Effect of variety on number of panicles per plant and panicle length

Among varieties, significant differences were seen in the number of panicles in both seasons (Table 4.5). Varieties BW 196 and IR 05N 221 had significantly a greater number of panicles per plant than variety ITA 310 in the first season. Variety IR 05N 221 had more panicles per plant than variety BW 196 which in turn had more panicles per plant than variety ITA 310 in the second season. Panicle length differed significantly among varieties in both seasons. Variety BW 196 had significantly longer panicles than varieties ITA 310 and IR 05N 221 in both seasons. Varieties IR 05N221 and ITA 310 had no significant difference in panicle length in both seasons.

Table 4. 5: Effect of variety on the number of panicles per plant and panicle length (cm) at different growth stages of rice

Variety (V)	Number of panicles per plant	Panicle length (cm)
First season		
IR 05N221	20.43	19.98
ITA 310	14.81	21.04
BW 196	21.10	23.27
p-value	<.001	<.001
LSD $_{0.05}$ (V)	2.18	1.58
CV %	6.60	1.20
Second season		
IR 05N221	19.39	22.09
ITA 310	11.66	22.12
BW 196	15.85	25.84
p-value	<.001	<.001
LSD $_{0.05}$ (V)	0.98	0.86
CV %	1.70	2.00

4.4.4: Effect of variety on 1000-grain weight and net grain yield

Varieties BW 196 and ITA 310 had more grain yield than IR 05N221 in the first season (Table 4.6). There was no significant difference in grain yield among varieties BW 196 and ITA 310. In the second season, varieties BW 196 and ITA 310 had more grain yield than ITA 310. There was, however, no significant difference in grain yield between varieties IR 05N221 and BW 196. There was no significant difference in 1000 grain weight among the varieties in season one. In the following season, variety IR 05N221 had heavier 1000 grains than variety ITA 310 which in turn had more heavier 1000 grains than variety BW 196.

Table 4. 6: Effect of variety on 1000 grain weight (g) and net grain yield (t/ha)

Variety	Net grain yield	1000 grain weight
First season		
IR 05N221	1.35	21.51
ITA 310	2.03	21.88
BW 196	2.23	21.63
p-value	0.006	0.966
$LSD_{0.05}$ Variety	0.54	NS
CV %	27.40	3.6
Second season		
IR 05N221	5.20	29.76
ITA 310	4.81	26.37
BW 196	5.27	21.34
p-value	0.022	<.001
$LSD_{0.05}$ Variety	0.35	1.40
CV %	1.40	0.70

Where, NS is not significant

4.4.5: Effect of nitrogen application rates on rice plant height

There were significant differences among nitrogen application rates in plant height at all the growth stages except at 14 DAT in the second season (Table 4.7). Nitrogen application significantly increased plant height at most growth stages in both seasons. In the first season, plant height did not differ among 40, 80 and 120 kg N per ha rates at 14 DAT, vegetative and panicle initiation stages. However, 80 kg N per ha had significantly taller plants than 120 kg N per ha at maturity stage. Application of 40, 80 and 120 kg N per ha significantly increased plant height at all the growth stages except at 14 DAT in the second season. No differences in plant height were noted between 80 and 120 kg N per ha at all the growth stages. Plant height ranged from 44.66 cm (no-fertilizer control) to 97.11 cm (80 kg N per ha) in the first season and 29.03 cm (40 kg N per ha) to 87.18 cm (80 kg N per ha) in the second season.

Table 4. 7: Effect of nitrogen rates on height (cm) at different growth stages of rice

N-rate	14 DAT	Vegetative	Panicle initiation	Maturity
First season				
0 Kg N/ ha	44.66	54.98	69.71	87.72
40 Kg N per ha	49.93	64.27	82.93	96.67
80 Kg N per ha	49.98	66.32	85.44	97.11
120 Kg N per ha	48.97	63.71	83.85	92.42
p-value	0.006	<.001	<.001	<.001
$LSD_{0.05}$ N-rate	2.51	2.97	2.72	4.44
CV %	2.60	2.40	2.30	1.30
Second season				
0 Kg N/ ha	30.02	37.45	45.49	59.31
40 Kg N per ha	29.03	38.19	46.59	60.98
80 Kg N per ha	30.52	41.11	50.37	65.33
120 Kg N per ha	29.25	41.11	50.77	65.91
p-value	0.054	0.003	<.001	<.001
$LSD_{0.05}$ N-rate	NS	1.66	0.65	2.15
CV %	1.90	2.10	0.70	1.40

Where, DAT is days after transplanting and NS is not significant.

4.4.6: Effect of nitrogen application rate on the number of tillers

There were significant differences among the nitrogen application rates in the number of tillers per plant except at 14 DAT in both seasons and at the vegetative stage in the first season (Table 4.8). In the first season, applying 120 kg N per ha increased the number of tillers per plant significantly at panicle initiation stage. After applying 80 kg N per ha the number of tillers increased at maturity stage. However, no differences were noted between 40 and 80 kg N per ha at panicle initiation and maturity stages and between 80 and 120 kg N per ha at maturity stage. In the second season, application of 120 kg N per ha had significantly more tillers per plant than 40 and 80 kg N per ha at all the growth stages except at 14 DAT. No significant differences were noted between 40 &80 kg N per ha at 14 DAT, vegetative and panicle initiation stages. However, 80 kg N per ha had more tillers per plant relative to the no-fertilizer control.

Table 4. 8: Effect of nitrogen application rates on the number of tillers at different growth stages of rice

N-rate	14 DAT	Vegetative	Panicle initiation	Maturity
First season				
0 Kg N/ ha	17.84	25.65	22.82	21.33
40 Kg N per ha	22.16	31.43	27.44	27.49
80 Kg N per ha	22.01	32.08	30.22	28.70
120 Kg N per ha	23.58	39.42	40.09	34.08
p-value	0.072	0.058	0.07	0.018
$LSD_{0.05}$ N-rate	NS	NS	12.61	6.55
CV %	5.5	7.7	16.8	11.70
Second season				
0 Kg N/ ha	7.11	16.90	17.93	16.23
40 Kg N per ha	6.61	17.77	19.84	17.86
80 Kg N per ha	6.36	18.90	21.39	19.58
120 Kg N per ha	6.78	21.57	25.62	23.58
p-value	0.187	0.010	0.001	0.007
$LSD_{0.05}$ N-rate	NS	2.26	2.47	3.29
CV %	7.9	6.00	5.80	8.50

Where, DAT is days after transplanting and NS is not significant.

4.4.7: Effect of nitrogen rates on panicle length, number of panicles per plant, 1000 grain weight and net grain yield.

There were no significant differences among nitrogen rates in panicle length in both seasons (Table 4.9).

There were no significant differences among nitrogen rates in number of panicles per plant in the first season. In the second season, an increase in nitrogen rate led to an increase in the number of panicles per plant. No significant differences were noted between the control and 40 kg N per ha. However, when 80 and 120 kg N per ha were applied, the panicle numbers increased.

There were significant differences among nitrogen rates in 1000 grain weight in the first season but not in the second season. In the first season, when 120 kg N /ha was applied, the 1000 grain weight increased relative to the control (no fertilizer) and application of 40 and 80kg N per ha had no effect on 1000 grain weight relative to the no-fertilizer control.

N rates differed significantly in net grain yield in both seasons. In the first season, application of 80 and 120 kg N per ha led to a significant increase in net grain yield while application of 40 kg N per ha had no effect on grain yield. There was no significant difference between 40 and 80 kg N per ha and between 80 and 120 kg N per ha. In the second season, application of 40 kg N per ha and above significantly increased grain yield. There were no significant differences in grain yield noted among 40, 80 and 120 kg N per ha.

Table 4. 9: Effect of nitrogen rates on panicle length (cm), number of panicles per plant, 1000 grain weight (g) and net grain yield (t/ha).

N-rate	Panicle length	No. of panicles	1000 grain weight	Net grain yield
First season				
0 Kg N per ha	22.35	17.5	24.04	0.91
40 Kg N per ha	21.15	18.27	23.47	1.66
80 Kg N per ha	22.23	18.87	23.22	2.16
120 Kg N per ha	20	20.48	15.97	2.74
p-value	0.329	0.686	0.003	0.14
LSD $_{0.05}$ N-rate	NS	NS	3.31	0.92
CV %	1.2	6.6	7.70	27.4
Second season				
0 Kg N per ha	22.77	13.47	25.86	4.25
40 Kg N per ha	23.02	14.42	26.08	5.05
80 Kg N per ha	23.73	16.11	26.20	5.50
120 Kg N per ha	23.86	18.54	25.15	5.56
p-value	0.56	0.003	0.699	0.016
LSD $_{0.05}$ N-rate	NS	1.88	NS	0.73
CV %	1.90	6.00	3.60	7.20

Where, No. is number and NS is not significant.

4.4.8: Effect of split nitrogen application on the number of tillers

There were no significant differences between split nitrogen applications in the number of tillers per plant at all the growth stages in both seasons except at the vegetative stage in the second season (Table 4.10). In the second season at the vegetative stage, basal N application plus topdressing N at tillering and panicle initiation had significantly more number of tillers than basal N application plus topdressing at panicle initiation.

Table 4. 10: Effect of split nitrogen application on the number of tillers per plant of rice crop

First season				
Split application	14 DAT	Vegetative	Panicle initiation	Maturity
Basal+one top dressing	21.7	32	29.47	27.77
Basal+two top dressings	21.43	32.29	30.82	28.03
p-value	0.948	0.771	0.415	0.882
$LSD_{0.05}$ Split	NS	NS	NS	NS
CV %	5.5	7.7	16.8	7.2
Second season				
Basal+one top dressing	6.77	17.83	21.1	18.7
Basal+two top dressings	6.65	19.73	21.29	19.93
p-value	0.628	0.006	0.806	0.095
$LSD_{0.05}$ Split	NS	1.18	NS	NS
CV %	7.9	6.20	3.2	13

Where, DAT is days after transplanting and NS is not significant.

4.4.9: Effect of split nitrogen application on the height of rice plant

There were no significant differences between the split nitrogen application regimes in plant height in both seasons except at the vegetative and panicle initiation stages in the second season (Table 4.11). Split application regime of basal plus topdressing at tillering at vegetative stage had taller plants than basal plus topdressing at tillering and panicle initiation while application of basal plus topdressing at tillering and panicle initiation had taller plants than basal plus top dressing at panicle initiation at the panicle initiation stage.

Table 4. 11: Effect of split nitrogen application on the height of rice crop at different growth stages

First season				
Split application	14 DAT	Vegetative	Panicle initiation	Maturity
Basal+one top dressing	47.79	61.29	78.82	92.76
Basal+two top dressings	48.97	63.35	82.14	94.2
p-value	0.191	0.157	0.087	0.494
LSD $_{0.05}$ Split	NS	NS	NS	NS
CV %	2.2	2	2	1.3
Second season				
Basal+one top dressing	29.67	39.83	47.08	61.86
Basal+two top dressings	29.74	39.10	49.52	63.9
p-value	0.841	0.004	0.003	0.074
LSD $_{0.05}$ Split	NS	0.42	1.34	NS
CV %	0.7	1.80	0.60	1.4

Where, DAT is days after transplanting and NS is not significant.

4.4.10: Effect of nitrogen rate ×variety interaction on the number of panicles of rice plant

The interaction between nitrogen rate and variety had a significant effect on the number of panicles of rice per plant in both seasons (Table 4.12). In the first season, application of nitrogen fertilizer did not increase the number of panicles per plant in varieties IR 05N 221 and BW 196. After applying 120 kg N per ha the number of panicles in variety ITA 310 were significantly increased. Under no-fertilizer control plots, varieties IR 05N 221 and BW 196 had significantly more panicles per plant than ITA 310. In the second season, fertilizer application had no effect on panicle numbers in varieties ITA 310 and BW 196. There were no significant differences between IR 05 N221 and BW 196 except at 120 kg N per ha. Variety BW 196 had significantly higher number of panicles per plant than varieties IR 05N 221 and ITA 310. However, there were no significant differences between the latter two in number of panicles per plant.

Table 4. 12: Effect of nitrogen rate × variety interaction on the number of panicles per rice plant

First season			
	Variety		
N-rate	IR 05N221	ITA 310	BW 196
0 Kg N/ ha	22.05	11.15	19.30
40 Kg N per ha	22.92	15.07	16.82
80 Kg N per ha	20.87	16.12	19.63
120 Kg N per ha	15.88	16.90	28.67
Mean	20.43	14.81	21.11
p-value variety	<.001		
p-value N-rate	0.686		
p-value N-rate×Variety	<.001		
LSD $_{0.05}$ Variety	2.18		
LSD $_{0.05}$ N-rate	6.07		
LSD $_{0.05}$ N-rate×Variety	7.07		
CV (%)	6.60		
Second season			
0 Kg N/ ha	21.66	21.68	24.98
40 Kg N per ha	20.62	22.17	26.27
80 Kg N per ha	23.10	22.35	25.75
120 Kg N per ha	22.98	22.27	26.34
Mean	22.09	22.12	25.84
p-value variety	<.001		
p-value N-rate	0.003		
p-value N-rate×Variety	0.028		
LSD $_{0.05}$ Variety	0.86		
LSD $_{0.05}$ N-rate	0.87		
LSD $_{0.05}$ N-rate×Variety	1.57		
CV (%)	2.00		

4.4.11: Effect of nitrogen rate × variety interaction on 1000 grain weight

The interaction between nitrogen rate and variety had significant effects on 1000 grain weight only in the first season (Table 4.13). Application of nitrogen fertilizer didn't increase the weight of 1000 grains in all the varieties in both seasons. In the first season, there were no significant differences among varieties in 1000 grain weight at nitrogen rates 40, 80 and 120kg N per ha. However, variety IR 05N 221 had significantly higher 1000 grain weight than varieties ITA 310 and BW 196.

Table 4. 13: Effect of nitrogen rate × variety interaction on 1000 grain weight (g)

	Variety		
N-rate	IR 05N221	ITA 310	BW 196
First season			
0 Kg N/ ha	29.46	20.56	22.10
40 Kg N per ha	25.92	22.97	21.54
80 Kg N per ha	24.05	22.78	22.82
120 Kg N per ha	26.60	21.23	20.07
Mean	21.51	21.89	21.63
p-value variety	0.966		
p-value N-rate	0.003		
p-value N-rate×Variety	<.001		
LSD $_{.05}$ Variety	2.98		
LSD $_{.05}$ N-rate	3.31		
N-rate×Variety	5.57		
CV (%)	3.60		
Second season			
0 Kg N/ ha	30.43	26.21	20.94
40 Kg N per ha	30.24	26.66	21.35
80 Kg N per ha	28.36	27.57	22.68
120 Kg N per ha	30.01	25.06	20.38
Mean	29.76	26.38	21.34
p-value variety	<.001		
p-value N-rate	0.699		
p-value N-rate×Variety	0.327		
LSD $_{.05}$ Variety	1.40		
LSD $_{.05}$ N-rate	2.31		
LSD $_{.05}$ N-rate×Variety	NS		
CV (%)	0.70		

Where; NS is not significant.

4.4.12: Effect of nitrogen rate × variety interaction on the number of tillers

The interaction between nitrogen rate and variety had significant effects on the number of tillers per plant at the vegetative and panicle initiation stages in the first season and maturity stage in the second season (Table 4.14). Application of 120 kg N per ha increased the number of tillers per plant in variety BW 196 at the vegetative stage in the first season and the panicle initiation stage in the second season. In the first season, variety IR 05 N221 had significantly more number of tillers per plant than variety ITA 310 except at the no-fertilizer control plots at the vegetative stage. There was no difference between varieties IR 05 N221 and BW 196 and between ITA 310 and BW 196 in number of tillers per plant at the vegetative stage. There was no significant difference between application of 40 and 80 kg N per ha. In the second season, variety IR 05 N221 and BW 196 had more tillers per plant than ITA 310 at maturity stage. Application of 80 kg N per ha and above significantly increased the number of tillers per plant in variety IR 05 N221. Application of 40 kg N per ha did not have an effect on tiller numbers relative to the no-fertilizer control plots.

Table 4. 14: Interaction effect between N-rate and variety on the number of tillers at different crop growth stages

	Variety											
	14 DAT			Vegetative			Panicle initiation			Maturity		
N-rate	V1	V2	V3	V1	V2	V3	V1	V2	V3	V1	V2	V3
0 Kg N/ ha	19.0	16.6	18.0	28.5	20.1	28.4	27.0	15.3	26.2	26.3	12.9	24.8
40 Kg N per ha	26.3	21.4	18.8	38.4	26.1	29.8	36.1	19.3	26.9	36.6	18.3	27.6
80 Kg N per ha	25.5	19.4	21.2	37.2	25.6	33.5	36.8	22.7	31.2	35.1	19.4	31.6
120 Kg N per ha	28.8	18.7	23.2	46.4	24.5	47.3	47.8	22.5	50.0	39.6	19.4	43.3
Mean	24.9	19.0	20.3	37.6	24.1	34.7	36.9	20.0	33.6	34.4	17.5	31.8
p-value variety	<.001			<.001			<.001			<.001		
p-value N-rate	0.072			0.058			0.070			0.018		
p-value N-rate×Variety	0.23			0.002			0.015			0.092		
LSD $_{.05}$ Variety	2.49			2.99			4.04			3.71		
LSD $_{.05}$ N-rate	4.30			9.30			12.61			6.55		
LSD $_{.05}$ N-rate×Variety	NS			9.84			13.35			NS		
CV (%)	5.5			14.50			20.90			7.2		
Second season												
0 Kg N/ ha	7.0	7.1	7.2	18.4	16.0	16.3	22.4	15.1	16.3	21.8	12.0	15.0
40 Kg N per ha	6.6	6.5	6.2	17.8	16.5	18.9	22.9	16.8	19.8	23.0	13.3	17.3
80 Kg N per ha	6.3	5.9	6.9	19.6	17.8	19.3	26.5	16.8	21.0	26.9	13.7	18.1
120 Kg N per ha	7.2	6.8	6.4	23.4	19.0	22.3	32.3	20.5	24.2	32.9	15.4	22.5
Mean	6.8	6.6	6.7	19.8	17.3	19.2	26.0	17.3	20.3	26.1	13.6	18.2
p-value variety	0.676			0.007			<.001			<.001		
p-value N-rate	0.187			0.010			0.001			0.007		
p-value N-rate×Variety	0.43			0.612			0.132			0.019		
LSD $_{.05}$ Variety	0.57			1.56			1.53			1.54		
LSD $_{.05}$ N-rate	0.73			2.26			2.47			3.29		
LSD $_{.05}$ N-rate×Variety	NS			NS			NS			3.84		
CV (%)	7.9			6.20			3.2			13.00		

Where, DAT is days after transplanting, V1 is variety IR 05N 221, V2 is variety ITA 310 and V3 is variety BW 196 and NS is not significant

4.4.13: Effects of nitrogen rate × split nitrogen application interaction on grain yield

The interaction between nitrogen rate and split nitrogen application had significant effects on grain yield in the first season only (Table 4.15). An increase in the rate of nitrogen fertilizer applied did not increase net grain yield in the first season. There were no significant difference among N rates except between the no-fertilizer control and 40 kg N per ha at the basal plus topdressing at tillering and panicle initiation nitrogen fertilizer application regime. The two nitrogen fertilizer application regimes had no significant differences.

Table 4. 15: Effects of nitrogen rate × split nitrogen application interaction on grain yield

First season	Split application	
N-rate	Basal+one top dressing	Basal+two top dressings
0 Kg N per ha	2.52	2.97
40 Kg N per ha	2.49	1.83
80 Kg N per ha	1.81	1.64
120 Kg N per ha	0.93	0.9
Mean	1.94	1.84
p-value split	0.006	
p-value N-rate	0.014	
p-value N-rate×split	0.047	
LSD $_{.05}$ Split	0.42	
LSD $_{.05}$ N-rate	0.92	
LSD $_{.05}$ N-rate×Split	1	
CV (%)	27.4	
Second season		
0 Kg N per ha	4.21	4.30
40 Kg N per ha	5.02	5.07
80 Kg N per ha	5.65	5.36
120 Kg N per ha	5.58	5.53
Mean	5.11	5.07
p-value split	0.711	
p-value N-rate	0.016	
p-value N-rate×split	0.721	
LSD $_{.05}$ Split	0.30	
LSD $_{.05}$ N-rate	0.73	
LSD $_{.05}$ N-rate×Split	0.78	
CV (%)	1.40	

4.5: Discussion

Nitrogen fertilizer application rates had significant effects on height at most growth stages of the rice crop in both seasons. Application of 40, 80 and 120 kg N per ha significantly increased plant height at most growth stages in the second season. Mohammad *et al.,* (2002); Chamely *et al.,* (2015) and Chowdhury *et al.,* (1993) stated that the variation in genetic makeup of a plant that might be influenced by heredity and environmental conditions might be the reasons for plant height differences. Chaturvedi (2005) discovered that after applying nitrogen fertilizer, the rice height increased significantly. These results were supported by Mandal *et al.,* (1992) and Chamely *et al.,* (2015).

There were significant differences among nitrogen fertilizer application rates in the number of tillers per plant in both seasons. Application of 120 kg N per ha increased the number of tillers per plant at the panicle initiation stage in both seasons. Tillering is essential in determining the overall grain yield to be realized (Ling, 2000). The number of tillers can be increased by applying nitrogen fertilizer (Liu *et al.,* 2011). In addition, it also enhances the development of tillers (Sakakibara *et al.,* 2006).Rajput et al., (1988) concluded that nitrogen was responsible for the increase in the number of tillers per hill due to its important role in the division of plant cells. Yorshida et al., (1981) showed that an increase in the amount of nitrogen led to an increase in tillers per hill.

There were no significant differences among nitrogen rates in panicle length in both seasons. When Shirame and Muley (2003) carried out an experiment on rice varieties they did not find any significant differences in their panicle lengths. Nitrogen rates did not have significant effects on the number of panicles per plant in the first season. In the second season, an increase in nitrogen rate led to a corresponding increase in the number of panicles per plant. Application of 40 kg N per ha had no significant effect on panicle numbers per plant. However, application of 80 and 120 kg N per ha led to an increase in the number of panicles per plant. According to Artacho *et al.*, (2009), the number of panicles per plant increased as a result of an increase in nitrogen fertilizer application rate. Hossain *et al.*, (2008) shares the same opinion.

There were significant differences among nitrogen rates in 1000-grain weight in the first season but not in the second season. Applying 120 kg N per ha increased 1000 grain weight in the first season. Chandra *et al.,* (1992) found that changing nitrogen levels from 120 kg N per ha to 150 kg N per ha significantly increased 1000-grain weight. Awasthi and Bhan (1993) and Maqsood et *al.,* (2002) showed similar results for 1000 grain weight in relation to increasing nitrogen levels.

Significant differences among nitrogen rates in grain yield were noted in both seasons. In the first season, application of 80 and 120 kg N per ha significantly increased net grain yield while in the second season, application of 40 kg N per ha and above significantly increased net grain yield. Artacho *et al.*, (2009) in their study showed significant and positive yield responses when they applied nitrogen fertilizer. Conry (1995) also showed a positive response of yield to proper fertilizer use. Jing (2007) observed a similar result with regard to yield by using different N rates. According to an experiment by Beşer (2001), some rice varieties from Turkey performed excellently at nitrogen levels of 140 and 160 Kg N per ha and that the application of nitrogen should be done at least twice. In their studies, Ortega (2007) and Artacho *et al.*, (2009) found that nitrogen rates positively affected grain yield. Significant variations in the grain yield of rice varieties have been reported by Ajeet *et al.,* (2005), Mittoyila (2006) and Singh and Tripathi (2008).

Variety ITA 310 had significantly taller plants than varieties IR 05N 221 and BW 196 in both seasons. Variety IR 05N 221 had significantly more productive tillers per plant than varieties ITA 310 and BW 196 in both seasons. Variety BW 196 had significantly longer panicles per plant, more number of panicles per plant as well as higher grain yield than varieties IR 05N 221 and ITA 310 in both seasons. Karen *et al.,* (2003) showed that variety BW 196 has a high yield potential of 8-10 t/ha. A high grain yield in the second season can be attributed to the favorable temperatures at the grain-filling stage. Low temperatures (12^0C and below) negatively affect flowering and pollination in rice crop and may cause spikelet sterility resulting in empty panicles. The problem can be worsened by the use of cold water for irrigation. For example, 10% decrease in yield was reported in the Philippines for each 1°C drop in the minimum air temperature averaged over the growing season (Brown, 2009). The low grain yield in the first season can be attributed to heat stress (Appendix 2). According to Bita and Gerats (2013), the reduction in grain weight as well as in its quality can be attributed to incidences of very high temperatures during the flowering stage. Teixeiria *et al.*, (2013) observed that yield can be severely affected by high temperatures even if this occurs for a short period of time especially if it's high during the reproductive phase.

Significant differences between split nitrogen applications in the number of tillers per hill were only noted at the vegetative stage in the second season. This was as a result of applying nitrogen as basal N plus top dressing with N at tillering and panicle initiation. Muhammad *et al.*, (2008) recorded more number of tillers per plant after applying N fertilizer in splits of a basal plus two topdressings. These results concur with those of Maske *et al.,* (1997), who realized higher number of tillers per plant with an increase in the number of split application of N and minimum tillers per plant after applying nitrogen during puddling only. Sahoo *et al.*, (1989) also found that applying nitrogen in three splits maximized the tiller numbers per hill. Split N fertilizer application significantly increased the height of rice plant in the second season. Muhammad *et al.,* (2008) found that plant height in rice crop was significantly affected by split application of N. The maximum height was recorded by applying basal N plus two topdressings. These results were supported by Ha and Suh (1993), who reported more plant height by applying N in splits and lower plant height by applying N in one dose. Biloni and Bocchi (2003) in their study showed that applying nitrogen in splits had a positive significant effect on plant height.

The interaction between nitrogen rates and split application of nitrogen fertilizer on plant height, number of tillers, panicle numbers and panicle length and 1000-grain weight was not significant in both seasons. There was, however, significant effect on grain yield in the second season where application of nitrogen fertilizer in both two and three splits did not increase grain yield. Applying nitrogen fertilizer in three splits led to more 1000 grain weight and in return more yield as shown by Raza *et al.,* (2003) and Kenzo (2004). These results were supported by Moridani *et al.,* (2013).

4.6: Conclusion

This study has shown that variety BW 196 had the highest grain yield in both seasons compared to varieties IR 05N 221 and ITA 310. It can therefore be concluded that, cultivating variety BW 196 at a nitrogen rate of 80 Kg N per ha, split into two applications (a basal plus top dressing at tillering) can potentially improve rice productivity in Mwea Irrigation Scheme.

CHAPTER FIVE: GENERAL DISCUSSIONS, CONCLUSIONS AND RECOMMENDATIONS

5.1 Discussion

The farmers used both organic and inorganic fertilizers as sources of nutrients for their rice crop which is a good practice to improve rice productivity. The most widely used inorganic fertilizer among the farmers was sulphate of ammonia while cow manure was the most preferred organic source of plant nutrients. Nutrient management is important and beneficial to the crop. Most of the farmers stored their manure in open spaces. This practice is however not recommended as nutrient like nitrogen can be lost through volatilization due to high temperature and leaching when it rains. Manure storage must be able to keep the manure from losing its nutrients. Only 2% of the interviewed farmers had tested their soils at some point in the cropping period. The FAO (2000) found that soil testing in most African countries was limited mainly because of lack of funding and inadequate trained staff. Soil testing helps determine how much fertilizers you need to apply to the soil to maximize crop yield. Yield, the type of vegetation on the soil and the soil water holding capacity were some of the indicators used by the farmers to tell the level of soil fertility. High yields were associated with fertile soils while appearance of weeds in the farm was a sign of fertility. These physical characteristics can be used to tell whether a soil is fertile or not. The farmers rotated rice with crops like beans, maize, green grams, tomatoes and soybeans. Tomatoes were the most common crop grown in rotation with rice. Crop rotation helps maintain soil fertility, reduce soil erosion, control pests, diseases and weeds. Azolla was reported by more than half of the farmers (55%) with most of them (61.1%) weeding it out. Azolla contributes from 40 to 60 kg N per ha when it's used in rice production under anaerobic conditions. Weeding it out is therefore not a good practice as it reduces its benefits to rice production.

Variety BW 196 had significantly higher number of panicles per plant compared to varieties IR 05 N221 and ITA 310 which translated to high net grain yield. This result is in line with that of Karen *et al.,* (2003) who stated that variety BW 196 had a yield potential of 9.0 t/ha. Variety ITA 310 had significantly taller plants than varieties IR 05N 221 and BW 196 in both seasons. This could lead to lodging which in return may be associated with yield loss. Variety IR 05N 221 had significantly more number of tillers per plant than varieties BW 196 and ITA 310. Chamley *et al.,* (2015) and Chowdhury *et al.,* (1993) stated that the reasons for differences in height and number of tillers per plant might be due to variation in the genetic makeup of the plant that might be influenced by heredity. Application of 40, 80 and 120 kg N per ha significantly increased plant height, panicle length and grain yield while application of 120 kg N per ha significantly increased the number of tillers, 1000-grain weight and the number of panicles. Chaturvedi (2005) found that application of nitrogen fertilizer increased the rice plant height. This result was supported by Mandal *et al.,* (1992) and Chamely *et al.,* (2015). Split nitrogen application of a basal plus top dressing at tillering had taller plants and more number of tillers per plant that the application of nitrogen as a basal plus top dressing at tillering and panicle initiation. Islam *et al.,* (2009) found that application of nitrogen in splits was more effective in increasing plant height in Boro rice genotype than single application. Muhammad *et al.,* (2008) recorded more number of tillers per plant after applying nitrogen in splits. An interaction of 120 kg N per ha and split nitrogen application of a basal + two top dressings produced more tillers per plant. The highest grain yield was obtained in the interaction of 80 kg N per ha nitrogen application and the split application of a basal plus top dressing at tillering stage.

5.2 Conclusion

Findings from the survey showed that majority of the farmers used sulphate of ammonia at the rate of 125 kg/ha as a source of nitrogen fertilizer. Cow manure was also used as a nutrient supplier primarily because of its availability and low cost. These results show that nitrogen fertilizer plays a major role in increasing rice yield. The combination of both organic and inorganic fertilizers can be used to improve rice productivity. All the farmers split their fertilizer into two or three for topdressing.

The results also showed that variety BW 196 had significantly more grain yield than ITA 310 and IR 05N 221. The 80 Kg N per ha fertilizer rate had the highest net grain yield. The two-split nitrogen fertilizer application regime (a basal plus top dressing at tillering) had higher net grain yield than the three split regime (a basal plus top dressing at tillering and panicle initiation). It can therefore be concluded that nitrogen fertilizer management of two split applications of 80kg N per ha for variety BW 196 combined with good agronomic practices can improve rice productivity in the above rice variety.

5.3 Recommendations

From the findings of this study, the following recommendations are made:

1. Since this study was carried out in a small area within the irrigation scheme, more similar on-farm experiments should be done at the farmers' fields.
2. The farmers at the Mwea Irrigation Scheme can be advised to take up the 80 Kg N per ha nitrogen fertilizer application rate.
3. Split application of a basal plus top dressing at tillering stage can be used to improve rice yields.

4. Variety BW 196 is higher yielding than varieties IR 05N 221 and ITA 310 and can therefore be recommended for planting by the farmers in the scheme.
5. Further research on nitrogen fertilizer effects on other crops.

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APPENDICES

Appendix 1: Survey Questionnaire

SOIL FERTILITY MANAGEMENT IN LOWLAND RICE PRODUCTION, MWEA

General objective: To study the farmers' soil fertility management in irrigated lowland rice varieties in Mwea, Kenya.

Specific objectives;

i. Document farmers' soil fertility management practices
ii. Ascertain status of nutrients at the farmers' rice fields
iii. Document the organic and inorganic fertilizers used by the farmers

Name of respondent……………………………Section…………………………….

Phone number………………………… Date of interview……………………………
Interviewer's name…………………………………Phone number………………………

1. How do you ensure nutrients are maintained at your rice field?
1 Application of inorganic fertilizers ☐ **2 Application of organic fertilizers** ☐
3 Application of both organic and inorganic fertilizers ☐
4 Others (specify) _________________

2. Do you use fertilizers in rice production at your farm?
0 No ☐ 1 **Yes** ☐

3. If yes, which types of inorganic fertilizers do you use and what is the time of application and rates?

No.	Type of inorganic fertilizer	Rate of application per acre	Time of application
1.			
2.			
3.			
4.			

Codes for inorganic fertilizers, rate and time of application

Type of inorganic fertilizer	**Rate of application**	**Time of application**
1…DAP	1…25 Kg/acre	1…At planting
2...Urea	2…50 Kg/acre	2…3 weeks after planting
3…TSP	3…75 Kg/acre	3…At panicle initiation
4…MOP	4…80 Kg/acre	4…Before planting
5…SA	5…100 Kg/acre	5…After 2nd weeding
6…Others (specify)	6…150 Kg/acre	6…At knee height of the crop

	7…Others (specify)	7…Others (specify)

4.What types of manures do you use and what is the time of application?

No.	Type of manure	Time of application	Rate of application
1.			
2.			
3.			
4.			

Codes for types of manures and time of application

Type of Manure	**Time of application**	**Rate of Application**
1..Compost	1..At planting	1… 2 tons/ ha
2..Cow manure	2..3 weeks after planting	2… 3 tons/ha
3..Chicken manure	3..At panicle initiation	3… 4 tons/ha
4..Goat manure	4..Before planting	4… 5 tons/ ha
5..Organic sprays	5..After 2^{nd} weeding	5… 6 tons /ha
6..Green manures	6..At knee height of the crop	6… 7-10 tons/ ha
7..Farm yard manure	7.Others (specify)	7… > 10 tons/ ha
8.Others (specify)		8… Others (specify)

5.What is the source of your fertilizers?

	Inorganic fertilizers	**Manure**
1		
2		
3		
4		
5		

Source of fertilizers and Manure

1	Input dealers
2	Fellow farmers
3	Homemade (own material)
4	Purchased from commercial farmers
5	Government subsidy program
6	Others (specify)

6. How often do you use fertilizers?

1 Every season ☐ **2 Skip one season** ☐ **3 Do not use at all** ☐

7. If you use manure, how do you store it?
1In open space ☐ **2In a store** ☐ **In a compost pit** ☐

4 Covered by earth and grass ☐ **5 Others (specify) ________________**

8. Have you ever carried out a soil test at your farm?

0 No ☐ **1 Yes** ☐

9. If your answer in the question above is yes, how often do you do it in a year?
1 Once every season ☐ **2 Twice every year** ☐ **3 Others (specify)**

10. Who does soil test for you?
1 MIAD/NIB ☐ **2 MRGM** ☐ **3 KALRO** ☐

4 Others specify…………..

11. How do you gauge the fertility of your land?

Codes

No.	How you gauge soil fertility	1.	Appearance of the soil (colour of soil)
1.		2.	Type of vegetation on the land
2.		3.	Yield output from the land
3.		4.	Water holding capacity of soil
4.		5.	Colour of the crop
5.		6.	Water holding capacity
6.		7.	Quantity of manure/ fertilizer applied
7.		8.	Others (specify)
8.			

12. Have you ever received any training on soil fertility management?
0 No ☐ **1 Yes** ☐

13. What do you see as the most urgent need if soil fertility at your rice farm is to be improved?

No.	Urgent need		
1.		Code	Needs
2.		1	Training on soil fertility management

3.		2	Incorporating mineral fertilizers and manures in production system
4.		3	Government puts in place a policy on soil fertility management
5		4	Government & other organizations support farmers with fertilizer subsidies
6		5	Increasing research on soil fertility
7		8.	Others (specify)

14. Do you have Azolla in your farm?

0 No ☐ **1 Yes** ☐

15. If yes, how do you deal with it?

1 Weed it out ☐ **2 Leave it in the farm** ☐ **3 Others(Specify)** ____________________

16. How do you manage pests and diseases in your farm?

1 Use of chemicals ☐ **2 Crop rotation** ☐ **3 Biological control** ☐

4 Others (specify) __________________

17. What is your alternative crop to rice? ....

18. Name the three most challenges encountered in crop production. (Start with the most)

i. ………………………………………………………………………………………

ii. ………………………………………………………………………………………

iii. ………………………………………………………………………………………

Appendix 2: Weather data for Mwea Irrigation Scheme from January to December 2015

Month	Rainfall (mm)	Max (°C)	Min (°C)	Wet Days
January	0.8	32.4	10.0	1
February	33.2	34.2	12.8	2
March	24.5	34.4	13.0	6
April	286.9	33.8	17.0	18
May	166.6	29.6	15.0	17
June	28.2	28.6	12.5	6
July	17.0	29.2	12.0	7
August	8.5	29.8	10.0	7
September	0.0	32.6	12.2	0
October	189.1	34.0	14.6	15
November	374.1	29.6	15.2	23
December	115.7	29.8	13.6	12

Where Max and Min are: Maximum temperature and minimum temperature.