EFFECTS OF PLANTING METHOD AND WEEDING FREQUENCY ON PERFORMANCE OF SELECTED NEW RICE FOR AFRICA (NERICA) VARIETIES IN KERIO VALLEY AND MARIGAT, KENYA

BY

WILSON KIPSIGEI BII

A THESIS SUBMITTED IN PARTIAL FULFILMEMT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN AGRONOMY, UNIVERSITY OF ELDORET, KENYA

2014

DECLARATION

Declaration by the Student

This Thesis is my original work and, to the best of my knowledge, has not been presented for a degree in any other University. No part of this Thesis may be reproduced without prior written permission of the author and/or University of Eldoret.

Sign……………………………………..Date………………………….

Bii Wilson Kipsigei

Reg. No. **AGR/PGC/04/12**

Declaration by the Supervisors

This Thesis has been submitted for examination with our approval as the University Supervisors.

1. Sign…………………………………………Date……………………………

Dr. Lucas Ngode

Department of Seed, Crop and Horticultural Sciences

School of Agriculture and Biotechnology

University of Eldoret, Kenya.

2. Sign………………………………………….Date…………………………..

Prof. Elmada O. Auma

Department of Seed, Crop and Horticultural Sciences

School of Agriculture and Biotechnology

University of Eldoret, Kenya.

DEDICATION

I dedicate this work to my beloved wife, Mary, and my children; Melody, Valeria, Cornelius, Lawrence and Clare for their collective moral support. I also dedicate the same to all my friends for their encouragement which kept me focused throughout the preparation of this work.

ABSTRACT

New Rice for Africa (NERICA) was developed to improve rice production in Africa and farmers in Kenya are beginning to adopt it. Attempts have been made to choose methods of planting and weed control but their effectiveness on performance of NERICA rice have not been well understood. This study was therefore to investigate the effects of planting method and weeding frequency on performance of selected NERICA varieties. The experiment was carried out for one season in two sites; Kerio Valley in Elgeyo-Marakwet County and Marigat in Baringo County, from September 2013 to January 2014. The two areas are classified as Arid and Semi-arid Lands (ASALs). Drilling and broadcasting methods of planting and two weeding regimes (weeding twice and weeding thrice) were evaluated for their effects on performance of NERICA 4 and NERICA 11 which are among the four varieties of NERICA released to farmers for production. The trial was a 2 x 2 x 2 factorial experiment laid out in randomized complete block design (RCBD). The treatments were replicated 3 times and each plot measured 4 m x 3 m. The parameters measured included plant height, number of productive tillers/hill, number of spikelets/panicle, weed dry matter, 1000-grain weight, grain yield, harvest index, mortality and identification of major weeds. The data obtained was subjected to Analysis of Variance (ANOVA) and the effects of treatments were separated using Tukey's Honestly Significant Difference (HSD) test at $p \leq 0.05$. The results showed that planting method, weeding frequency and variety significantly influenced the performance of NERICA in both Kerio Valley and Marigat ($p \leq 0.05$). Drilling was significantly better than broadcasting, and weeding thrice was significantly superior to weeding twice while NERICA 11 significantly outperformed NERICA 4 in terms of plant height, number of productive tillers/hill, weed dry matter, 1000-grain weight, grain yield, harvest index and mortality of weeds. However, their effects on the number of spikelets/panicle were not significant. Drilling in combination with three weeding regime and NERICA 11 gave the best performance in the two areas and significantly outperformed all other combinations in Marigat with respect to grain yield. Major weeds identified in the study sites were: *Echinochloa pyramidalis*, *Cyperus rotundus* and *Echinochloa colona.* This study, therefore, recommends drilling method of planting, three weeding regime and NERICA 11 for Kerio Valley and Marigat.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ACKNOWLEDGEMENT

I wish to acknowledge the invaluable and well-articulated support from my supervisors Dr. Lucas Ngode and Prof. Elmada Auma who guided me throughout the preparation and submission of this work. I also appreciate the work of Mary Pepela; the Laboratory technician and her colleagues who assisted me during the soil analysis. I thank the Farmer in Kerio Valley Mr. William Kiplagat and the KARI-Perkerra centre Director Mr. T. Moi for allowing me to use their land for my experiments in site 1 and site 2 respectively. I cannot forget the work of my Research Assistant Mr. Ezra Kipkoech for his thoroughness in collecting the data, and Mr. Philiph Lang'at, the KARI-Perkerra Farm Manager for supervising my work in the field. Special gratitude goes to the Project Coordinator; Eastern Africa Agricultural Productivity Project (EAAPP) for sponsoring my studies without which I would not have come this far. Last but not least I thank my colleagues and friends whom I am indebted for their moral and intellectual support during the entire period of my studies for M.Sc degree in Agronomy.

Finally, I wish to acknowledge the constant support from my wife, Mary, and the cheerful interest of my children Melody, Valeria, Cornelius, Lawrence and Clare whose time I borrowed to do this project.

CHAPTER ONE

INTRODUCTION

1.1 Importance of rice

Rice is the third most important cereal crop worldwide after maize and wheat, and it is a staple food for about half of the Kenya's population (USDA, 2013). It is a principal source of carbohydrate, protein and fat. Straw can be used as Livestock feed, mulching and making of strawboards. The Industrial use of rice bran is making of soap and insecticides. Rice also serves as a cash crop for rural households (Kega *et al*, 2006). Upland rice cultivation offers a more viable alternative to paddy rice growing as an income generating crop which can also support environmental conservation (Oonyu, 2011). The New Rice for Africa (NERICA) which is grown under upland conditions is both food and cash crop and thus providing farmers with new opportunities as an alternative source of income (Atera *et al*, 2011).

1.2 Demand and production statistics for rice

The demand for rice is increasing in almost all African countries in pace with the rising population but production has failed to keep up and most countries including Kenya depend on imports to meet the shortfall (Etsuo, 2005). Its demand in Kenya stands at about 500,000 tons against the production of 129,000 tons (Ministry of Agriculture Economic Survey publication, 2014). Sub-Saharan Africa produced about 21.6 million tons of rice in 2006 and imported 32 % of its requirement in the International market to meet its demand (Somado *et al*, 2008; FAO, 2007). The cost of importing rice remains a heavy burden on trade balances in the region.

Due to population growth (4% per annum), rising incomes and a shift in consumer preferences in favour of rice, especially in urban areas, the relative growth in demand for rice is faster in this region than anywhere in the world (Balasubramanian *et al.*, 2007). Africa's share of world rice imports is 30 percent, a potentially very risky and unsustainable situation, (West Africa Rice Development Association, WARDA, 1999). This is due to several production challenges facing farmers in Africa, Kenya included. Low yield constitutes one of the main challenges in rice production.

1.3 Introduction of New Rice for Africa (NERICA)

In order to narrow the gap between import and production of rice, NERICA, a result of the inter-specific hybridization between Asian rice (*Oryza sativa*) and African rice (*O. glaberrima*) was introduced (Atera *et al*, 2011). The progeny was developed by West Africa Rice Development Association (WARDA) combining traits from the hardy African rice resistant to pests, weeds and problematic soils and the high yielding, good response to mineral fertilization and non-shattering characteristics of the Asian rice (Dzomeku *et al*, 2007, Kijima *et al*, 2006, WARDA, 2001).

It has been recorded that the first generations of NERICA cultivars were effective to smother out weeds due to their vigorous growth at their early stages of development (Kaneda, 2007, Johnson *et al,* 1998). NERICA has the potential as an alternative food security and an income generating crop in the Arid and Semi-arid Lands (ASALs) which is attributed to its unique features as a drought resistant cultivar. It helps in reducing rice imports and saving the foreign exchange earning to the country.

The Kenyan sector has benefited from strong support from the Government in recent years to expand irrigation capacity and promote the adoption of NERICA varieties (FAO, 2013).

Four NERICA varieties were released in Kenya in 2009 (Table 1), and since then the cultivar has gained popularity with farmers in the Arid and Semi-arid Lands.

Table 1: NERICA Varieties released in Kenya during 2009

Cultivar Line	Common Name
WAB 450-I-B-P38-HB	NERICA 1
WAB 450-I-B-P91-HB	NERICA 4
WAB 450-11-1-1-P41-HB	NERICA 10
WAB 450-16-2-BL2-DV1	NERICA 11

Source: Ministry of Agriculture, Keiyo, 2011

NERICA was introduced in Kerio Valley in 2005 with the assistance of the Community Agricultural Development in Semi-arid Lands Project (CADSAL) and Marigat in 2010. Some of the cultivars tested in Kerio Valley between 2003 and 2005 produced high yields under low soil moisture (Kouko *et al*, 2005). This Research aimed at elucidating some of the factors that contribute to poor performance of NERICA which include wrong choice of planting method, weed menace and inappropriate cultivars among other reasons.

Under field conditions, variance in the yields of NERICA 11 and NERICA 4 may be related to differences in response to the method of planting used and suppression effects to weeds.

In the present study, effects of two planting methods and two levels of weeding on performance of two NERICA varieties were assessed.

1.4 Problem Statement

About 70% of the households in Kerio Valley and Marigat experience food shortage for up to five months per year. Following the introduction of NERICA rice in Kenya in 1990’s and successful National Performance Trials (NPTs) carried out in Kerio Valley between 2005 and 2010 vis-à-vis farmers practice, some of the problems that emerged included low yields on the farmers’ fields caused by poor agronomic practices (planting method, weed management and choice of variety among others). Farmers in these areas lack technical knowledge on rice production.

1.5 Justification of the Study

Rice yield losses lead to food and nutrition insecurity. In Kenya where maize has been the dominant food crop, the changing diets and food habits of majority of the people are increasingly rendering rice an important crop (FAO, 2004). The demand for rice in Kenya is increasing in pace with the rising population but production is much below the demand. Therefore the country depends on imports to meet the shortfall. Farmers and extension agents in Kerio Valley and Marigat have limited knowledge of the effects of planting method and weeding frequency on performance of NERICA 4 and NERICA 11 varieties. The development and release of NERICA has given a new hope for food security in the Arid and Semi-arid Lands of Kenya with special reference to Kerio Valley and Marigat especially where supplementary irrigation is possible.

Four NERICA varieties which were released in Kenya in 2009 (NERICA 1, 4, 10 and 11) were subjected to adaptability trials by the Ministry of Agriculture in Kerio Valley from 2005 to 2010 and the results showed that these varieties are suitable for the two areas (Ministry of Agriculture, Keiyo, 2011).

NERICA varieties mature early and past studies have shown that the varieties exhibit most of the desirable characteristics for growing in the upland conditions.

However, NERICA is not fulfilling its promise because of poor agronomic practices and this raises significant concerns about both its performance and its long-term effects. It is being accepted by many rice farmers and the challenge remains to be weed control, choice of planting method and variety.

The present study in the two areas was, therefore, carried out in order to shed more light on how to address these challenges.

1.6 Objectives

1.6.1 Overall objective

To contribute to increased rice production in Kenya by choosing the right planting method and variety, and carrying out proper weed control.

1.6.2 Specific objectives

i. To compare the performance of NERICA 4 and NERICA 11 between drilling and broadcasting methods of planting.

ii. To determine the effects of weeding frequency on performance of NERICA 4 and NERICA 11.

iii. To identify major weeds in fields of NERICA varieties in Kerio Valley and Marigat.

1.7 Research Hypotheses (HA)

i. Drilling and broadcasting methods of planting significantly influence the performance of NERICA 4 and NERICA 11.

ii. The frequency of weeding significantly affects the performance of NERICA 4 and NERICA 11.

iii. There is a significant difference in performance between NERICA 4 and NERICA 11 varieties of upland rice.

iv. Certain weeds are more problematic in NERICA rice fields in Kerio Valley and Marigat than others.

.

CHAPTER TWO

LITERATURE REVIEW

2.1 Classification of rice

Rice is classified as upland or lowland according to the growing areas and moisture regime (WARDA, 2000). The term upland rice means any rice cultivar of *Oryza sativa* or *O. glaberrima* that is suited to upland conditions, in non-flooded fields but dependent on rain fall and supplemented irrigation if need be. On the other hand, lowland rice (paddy) is grown in flooded fields for at least part of the growing season (WARDA, 2000).

The maturity period for upland rice is shorter (90-110 days) as compared to paddy rice which takes 120 days or longer.

2.2 Characteristics of NERICA and its parents

The New Rice for Africa is an upland rice bred through inter-specific hybridization between Asian rice (*Oryza sativa*) and African rice (*Oryza glaberrima*) (Atera *et al*, 2011). *O. glaberrima* is well adapted to local rice production systems and it has some resistance to biotic and abiotic stresses such as weeds (Jones *et al,* 1997). It has profuse early vegetative growth and thus enables the crop to smother and out-compete weeds (WARDA, 2001). However, it possesses some traits of lodging and seed shattering and it is more susceptible to weeds than the lowland Rice. *O. sativa* possesses good agronomic traits coupled with high grain yield potential, but it has limited resistance to many of the biotic and abiotic stresses (Jones *et al*, 1997). It has an upright growth at reproductive stage which enables it to support heavy seed heads through maturity to harvest, non-shattering grains and secondary branches on panicles (WARDA, 2001).

NERICA smothers grain-robbing weeds like its African parents, resists droughts and pests, and is able to thrive in poor soils (Manners, 2001). The trait of higher productivity conferred by its Asian parents is also present; meaning that with few additional inputs, the farmers growing NERICA can double production and raise incomes. The cultivar has carved a special niche as it perfectly adapts to upland conditions where smallholders lack means of irrigation (Atera *et al*, 2011).

According to Somado *et al* (2008), NERICA varieties shade out weeds and mature 30–50 days earlier than traditional varieties and thus allow farmers to grow extra crops like vegetables or legumes. Moreover, they produce 400 grains per plant (as opposed to 75–100 in the older varieties) and contain 2% more proteins (Olga, 2002, Manners, 2001). NERICAs typically mature in 90–110 days compared to typical improved upland *sativas* that mature in 120–140 days, thus escaping the escalating effects of weeds at later stages (WARDA, 2001). NERICA varieties have desirable agronomic traits that are potentially useful for high competitiveness including good vigour at seedling and vegetative stages for weed suppression, intermediate to tall stature and moderate tillering ability making them superior to the local landraces (Kaneda, 2007). In addition, they have characteristic wide, droopy leaves that could suppress weeds but require at least 6 weeks of weed free for the formation of good canopy to enable them out-compete weeds (Dzomeku *et al,* 2007). With the use of fertilizers and good care, the yield of NERICA varieties can be doubled or even tripled (Olga, 2002). According to Apaseku and Dowbe (2013), the grain yield of NERICA increases significantly by increasing N and P supply to soils. Oikeh *et al* (2007) also showed that NERICA yield increases significantly through addition of N and P fertilizers to soils in humid forests and Semi-arid Lands, and recommended application of 60 kg N/ha to double NERICA grain yield as compared to zero N-fertilizer application (low to moderate input).

Kijima *et al* (2006) stated that NERICA's yield in Uganda was twice as much compared to traditional upland rice varieties in the sub-Saharan Africa with an average yield in the farmers' fields being 2.2 tons/ ha. Most researchers have recognized the importance of sink size in enhancing the grain yield of NERICA. Yao *et al*. (2000) defined yield sink as the product of the number of panicles per unit area and the number of spikelets per panicle. From 2005 to 2010, on-farm trials were carried out by the Ministry of Agriculture in Kerio Valley and NERICA yields of up to 4.4 tons per hectare were achieved in the NPTs done in the area through proper weed control and drilling method of planting (CADSAL Report, 2011). Four varieties which were released in Kenya in 2009 were planted; NERICA 1, NERICA 4, NERICA 10 and NERICA 11. The varieties gave consistent results with NERICA 4 and NERICA 11 being the most promising varieties in performance but limited by weed infestation and show variability depending on planting method, and farmers in Kerio Valley and Marigat get yields as low as 1 ton per hectare.

Performance of NERICA is reflected through plant establishment and the grain yield, and this can be affected by weeds and choice of planting method and variety. Plant height and number of tillers are some of the most important indicators of plant establishment (Auma, 1971).

2.3 Ecological requirements of NERICA

NERICA varieties do well in hot and humid areas with temperatures of 21-37^{o}C, optimum pH range of 5.5-6.5 and rainfall of 800 to 1200 mm per annum during the growing period (Michael and Brigitte, 1993; WARDA, 2002). It is grown in soils ranging from sandy loams to heavy clay soils and altitude between 0-1700 m above sea level. Rice is a short-day and self-fertilizing plant (Guei and Fagade, 2002). It matures in 3-5 months after planting depending on variety (Michael and Brigitte, 1993).

2.4 Common weeds in rice, effects and management

2.4.1 Common weeds in rice

Barnyard grass: Barn yard grass (*Echinochloa colona*) is an annual grass belonging to Poaceae family which is widely distributed in the tropics and subtropics throughout the world and it propagates mostly by seeds but also vegetatively (Johnson, 1997, Ivens, 1989).

Antelope grass: Antelope grass (*Echinochloa pyramidalis*) is an important Perennial weed grass in rice belonging to Poaceae family and it is a common weed in the Tropical zones of Africa, Southern Africa and widespread in West Africa (Akobundu *et al*, 1998, Caamal-Maldonado *et al*, 2001). It reproduces from seeds and rhizomes. It grows best at altitudes ranging from sea-level to 300-1500 m, on badly drained alluvial black clays and alkaline soils (FAO, 2010). It is a highly productive C4 plant with an optimum growth temperature above 30°C and can withstand long periods of drought.

Nut grass: Nut grass (*Cyperus rotundus*) belongs to the family Cyperaceae and it is the most troublesome Cyperus in most parts of East Africa because of its extensive subterranean tuber system (Ivens, 1989). It reproduces primarily through tubers and spreads through rhizomes.

Star grass: Star grass (*Cynodon dactylon*) of Poaceae family is also one of the major weeds in rice occurring worldwide and it spreads rapidly by rhizomes and stolons, and by seed dispersal (Johnson, 1997, Ivens, 1989).

Red rice: Red rice (*Oryza punctata*) is an annual and perennial grass weed similar to cultivated rice and it belongs to Poaceae family (Sibuga, 2009).

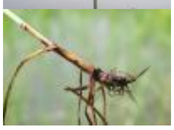
Pinklady: Pinklady (*Heterotis rotundifolia*) of Melastomataceae family is a broadleaf perennial herb which reproduces by seeds and stolons, and it is wide spread in Tropical Africa in paddy rice (Akobundu *et al*, 1998, Tavs *et al*, 2010).

Cinderella weed: Cinderella weed (*Synedrella nodiflora*) belongs to Asteraceae family and it is a broadleaf sub-woody annual herb which is widespread in East Africa over a range of altitudes (Akobundu *et al*, 1998, Johnson, 1997, Suptotthita *et al*, 2005).

Bristle grass: Bristle grass (*Setaria geminata*) of Poaceae family is a rhizomatous perennial grass and it spreads by stolons or rhizomes and by seed (Grard, 2006).

Some of the common weeds in Kerio Valley and Marigat are shown in Table 2.

Table 2: Some of the common weeds in Kerio Valley and Marigat

Weed species	Potential rice yield loss (%)	Critical time to control	Pictorial
Red rice (*Oryza punctata)*	82	Early stage of crop growth	
Barnyard grass (*Echinochloa colona*)	70	Early stage of crop growth	
Nut grass *(Cyperus rotundus)*	70	Early stage of crop growth	 

Source: Ministry of Agriculture, Keiyo South and Marigat, 2012

2.4.2 Weed effects

In the rain fed and irrigated rice ecologies, weeds are the main constraints, reducing production by up to 40% and potentially causing total crop failure if left uncontrolled (WARDA, 1999). Weed competition is the most important yield-reducing factor (Johnson *et al*, 1998). Weeds interfere with the growth of upland rice by competing for nutrients, water, light and also harbouring pests. Barnyard grass (*Echinochloa colona*) mimics rice plants during their vegetative phase and it adversely affects the number of panicles per plant, number of spikelets per panicle and the grain yield. *E. colona* and *Oryza longistaminata* are also alternate hosts of rice blast and yellow mottle virus respectively. In addition, the roots of these weeds produce exudates that suppress crops (Dzomeku *et al*, 2007).

Nut grass (*Cyperus rotundus*); considered the worst weed in the world by virtue of its plasticity in adapting to different environments in tropical and subtropical areas is a major threat in rice production in many parts of Africa while red rice; comprising annual and perennial species have high adverse effects on cultivated rice (Sibuga, 2009).

Johnson (1996) reported that 20 - 100% of yield loss in rice fields is caused by weed infestation depending on farmers' control of weeds. Weeds represent the most economically serious pest complex reducing world food and fibre, and they account for significant costs in all agricultural systems (Sibuga, 2009).

The FAO (2009) report indicated that weeds are the number one cause of stagnating rice yields and production particularly in Africa where control relies heavily on manual labour and it has estimated food production losses due to weeds as USD 95 billion/year of which more than 70% is lost in poor countries.

Weed competition in upland rice reduces plant height, number of shoots/m^2, dry matter production, grain yield, panicle number and panicle weight (Gunasena, 1974). Yield losses due to uncontrolled weed growth of upland rice in Africa can be within the range of 28-100% (Johnson, 1996). Rice is an inherently weak competitor with most weeds and consequently, yield losses due to weed competition can be high (Oerke *et al*, 1994). Comparative cereal crop yield losses due to weeds for rice, wheat, barley and maize are 15.6 %, 12.3 %, 10.6 % and 13.1 % respectively (Oerke *et al*, 1994).

Common agronomic factors that contribute to weed problems include inadequate land preparation, labour shortages for hand weeding, delayed and incorrect use of herbicide applications and non-use of weed competitive varieties (Becker *et al*, 1999, 2001, DeVries *et al*, 2010).

2.4.3 Weed management

Growing a competitive and high yielding variety in conjunction with reduced herbicide application of Rice Force (Pe) and Buta Force (Pe) could be an effective and economical weed management strategy for rice (Harding *et al,* 2012).

Herbicides are undeniably the most effective and reliable technology available today for weed control in rice (Marwat *et al*, 2004). However, an integrated approach involving minimal use of chemicals with proper use of cultural weed control and management techniques such as good land preparation and/or use of weed suppressive varieties will reduce the farmer's dependence on heavy application of herbicides and thus offers the best hope for increasing food production (Shakoor *et al*, 2000).

Smallholder rice farmers in Africa have a limited number of options for preventing weed infestations and concomitant crop losses due to changing environmental conditions. This may result in reduced efficiencies of existing weed control practices (Rodenburg *et al,* 2011).

Therefore it requires the use of rice varieties that could compete or tolerate weeds, identification of the right types of herbicides for different ecologies and integrated approaches to prevent species invasion (Rodenburg *et al*, 2011). Oxadiazon and Propanil herbicides are effective in controlling weeds and also in increasing yields of rice in the direct sown upland rice (Adeosun *et al,* 2009, Ikuenobe *et al*, 2005, Rao *et al*, 2007). NERICA requires 3 to 4 rounds of weeding to maintain a weed free field.

The use of 2, 4-D or MCPA at relatively high rates give some degree of Nut grass control and the tops of young plants are killed and re-growth may be delayed but the tubers themselves are little affected (Ivens, 1989). *Cynodon dactylon* can be controlled through dry-season cultivations especially with tractor-drawn implements and by use of glyphosate application under non cropped area effectively in upland rice (Johnson, 1997, Ivens, 1989). Cultivation during early growth and pre-emergence application of butachlor controls *E. colona* (Johnson, 1997, Ivens, 1989). *Heterotis rotundifolia* can be controlled through hand weeding (Akobundu *et al*, 1998, Tavs *et al*, 2010).

2.5 Methods of rice planting

Methods of direct sowing of rice are: Dibbling, broadcasting and drilling (www.knowledgebank.irri.org/ericeproduction/PlantingRice.pdf-accessed on 3/7/2013).

- Dibbling: opening up a spot in the soil and sowing 5-8 seeds at a depth of 2–3 cm.
- Drilling: making a small groove, 2–3 cm deep in the soil, and sowing the seeds sparsely in the groove and covering with soil.
- Broadcasting: spreading the seeds on the soil surface without any specific pattern.

When sowing by drilling, inter-row spacing of 30 cm is recommended for NERICA lines (Somado *et al*, 2008).

This can be done manually or by drilling machine depending on soil type, (Asea *et al*, 2010). A smooth, level seedbed is necessary to ensure that seeds are not planted at depths greater than 3 to 5 cm. The benefit of drill seeding is that fertilizer can be applied at the same time as the seed. Manual weeding is also much easier in drill seeded crops than in broadcast of crops, (Asea *et al*, 2010).

In broadcasting, seed is distributed or placed onto the soil surface with almost equal distances, in every direction (Carver, 2005). This method exposes the seeds to unfavourable environmental conditions and pests (Mbomi *et al*, 2012). There is also poor soil contact in this method since seeds are not fully covered thereby hampering germination. In addition, seeds can easily be blown away by wind or washed off by rain. According to Mbomi *et al*, 2012, drilling is not affected by these unfavourable conditions since the seeds are covered fully thereby providing better protection and more favourable conditions for germination.

Little information has been given on which of drilling and broadcasting methods of planting is superior to another, and on the number of times for weeding that gives maximum performance of NERICA. Also there is no information to show which of the two NERICA varieties (NERICA 4 and NERICA 11) performs better than the other.

The present study was, therefore, designed to compare the performance of NERICA varieties between drilling and broadcasting methods of planting and assess the effects of two levels of weeding. This would help to choose the best performing options of planting method, weeding regime and NERICA variety.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study sites

3.1.1 Location of the study sites

The study was carried out in two sites. The first site was Kerio Valley, Soy Ward in Elgeyo-Marakwet County at Mr. William Kiplagat's farm which is 3 km off Eldoret-Kabarnet Road (Figure 1). It stands at an altitude of 1132 m above sea level and it is situated at 0°29'14" North (N) and 35°33'31" East (E). It falls in the agro-ecological zone 6 (LM 6) with sandy loam soils, temperature range 16-30^{o}C, altitude 900-1500 m above sea level and receiving rainfall ranging from 400 to 800 mm per annum (Ministry of Agriculture, Keiyo, 2011).

The second site for the study was Kenya Agricultural Research Institute (KARI)-Perkerra in Marigat, Baringo County, which is situated at 0°28'0" N and 36°1'0" E, about 100 km North of Nakuru town (Figure 2). It lies at an altitude of 1067 m above sea level and falls in agro ecological zone 5 (LM 5). Annual rainfall mean is 654 mm and temperature range is 16 - 34^{o}C (Ministry of Agriculture, Marigat, 2012).

The two sites were chosen because they fall under Arid and Semi-arid Lands of Kenya that are recommended for growing of NERICA rice and soil pH near or neutral (6.5 – 7.5).

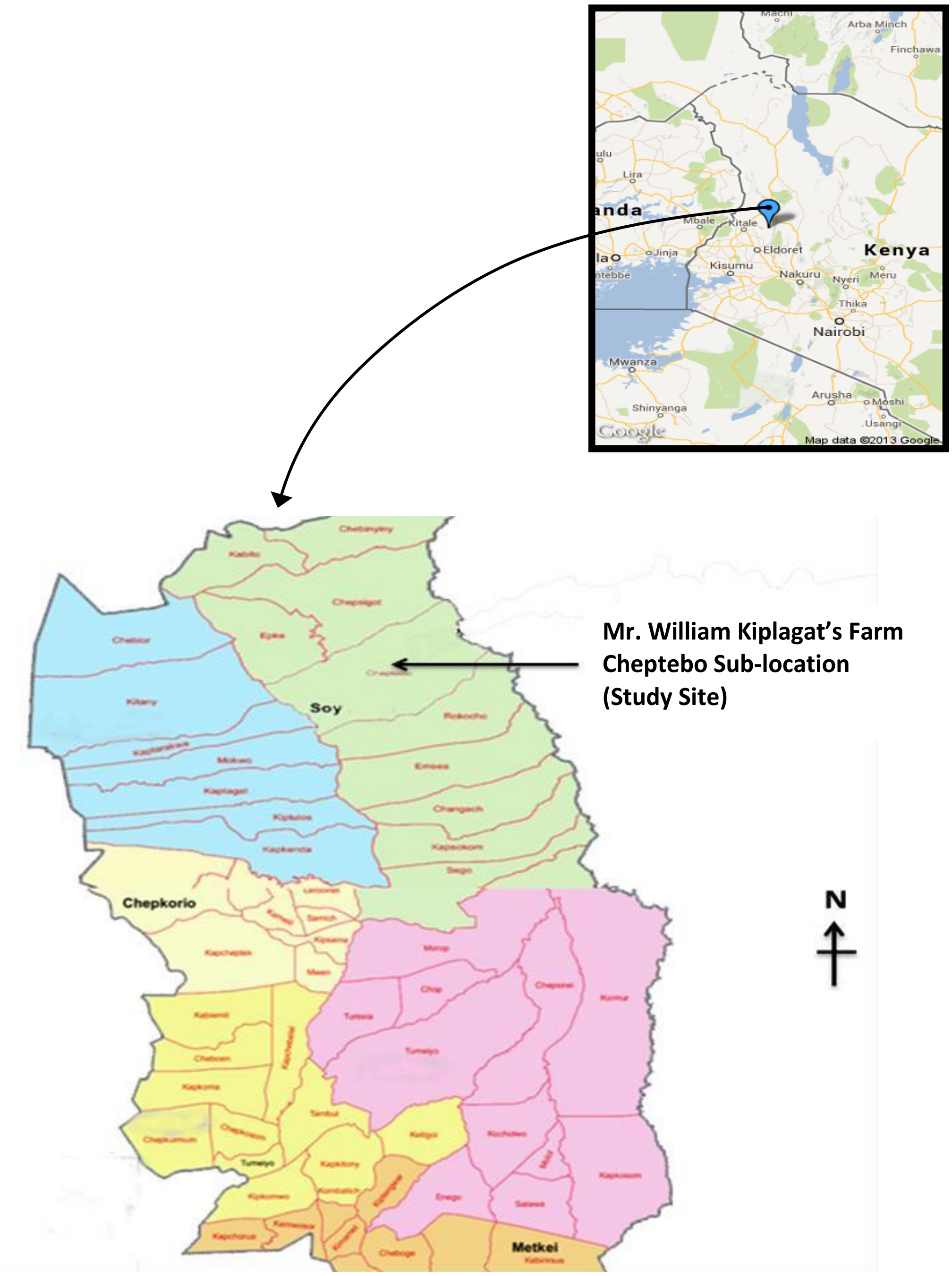


Figure 1: Map of Keiyo South Sub-County showing the first study site, Kerio Valley

Source: Ministry of Agriculture, Keiyo South (2012)

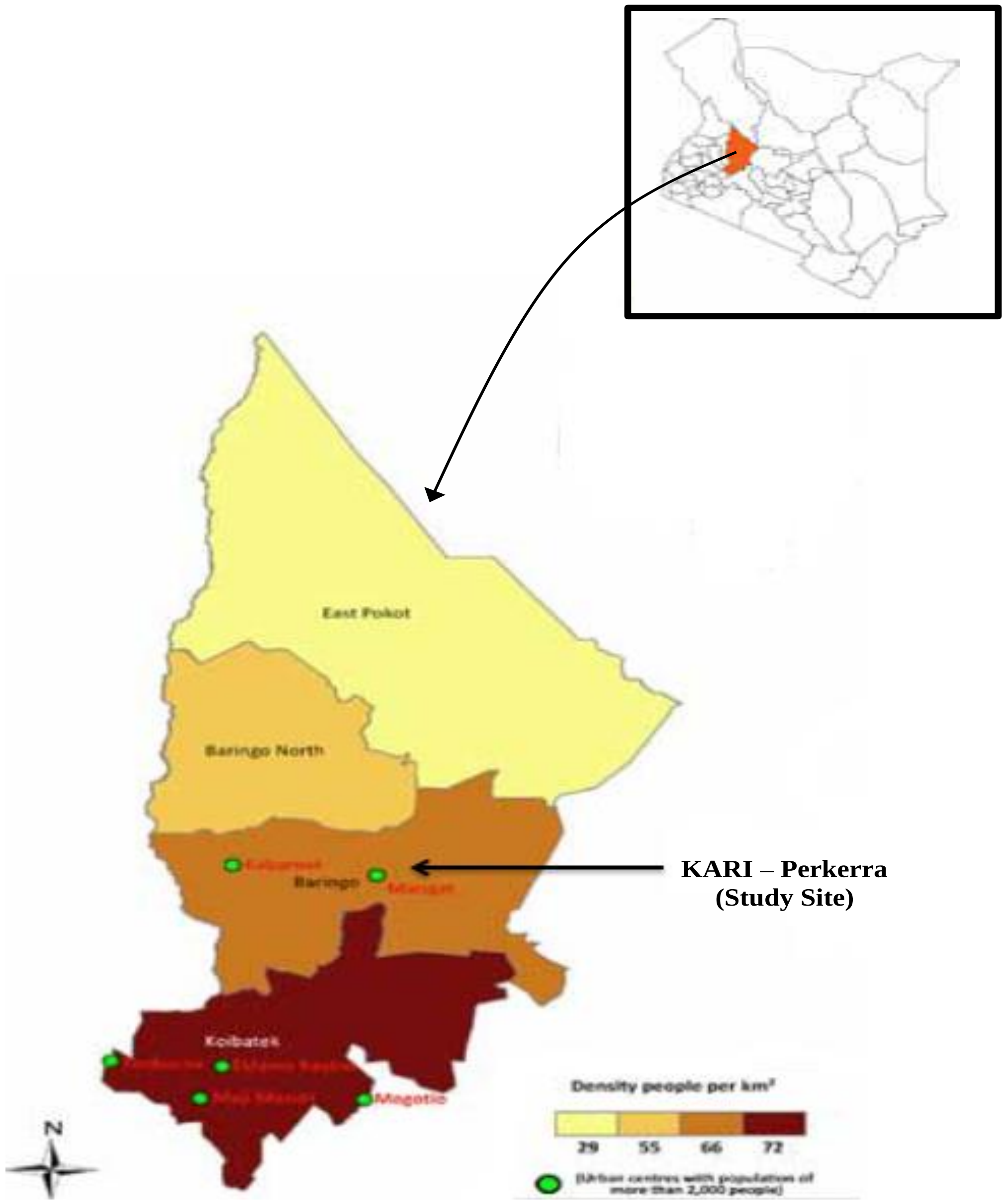


Figure 2: Map of Baringo County showing the second study site (KARI-Perkerra, Marigat)

Source: Ministry of Agriculture, Marigat, 2012

3.1.2 Soil characterization

Soil samples were taken from each site and analyzed in the laboratory for status characterization of the sites to determine the soil pH, total Nitrogen and available soil Phosphorus (Olsen) as described in Okalebo *et al* (2002). The results of the test showed that the soil in Kerio Valley had a pH of 6.51 which is slightly acidic while Marigat had a pH of 7.20 which is slightly alkaline.

The total Nitrogen in the soil in Kerio Valley and Marigat was found to be 0.09 % and 0.05 % respectively while available Phosphorus was recorded as 28.80 and 13.29 mg/kg respectively.

3.2 Treatments

3.2.1 Planting methods

Planting methods used in the experiment were drilling and broadcasting. In the drilling method, seed was planted in furrows @ 30 cm apart while in broadcasting, the seed was broadcasted on top of the soil and covered.

3.2.2 Weeding frequency

Weeding frequency involved weeding twice at 18 and 42, and weeding thrice @ 18, 42, and 63 days after planting as recommended by Somado *et al*, 2008. The two weeding regime represented the farmers practice while three weeding one was the recommended practice. In the third weeding, some plots were left un-weeded as per the treatment.

3.2.3 Varieties

Two NERICA varieties were studied: NERICA 4 and NERICA 11 which were selected from the list of released varieties in Kenya. These were chosen because they have been recommended for Kerio Valley and Marigat by the Ministry of Agriculture.

Characteristics of the two varieties are shown in the Table below.

Table 3: Characteristics of NERICA 4 and NERICA 11

	NERICA 4	NERICA 11
Type	Interspecific	Interspecific
Species	Oryza sativa x O. glaberrima	Oryza sativa x O. glaberrima
Maturity period	95 – 100 days	75 – 85 days
1000-grain wt	29 g	28.4 g
Potential yield	5 tons/ha	7 tons/ha

Source: Somado *et al*, 2008

3.2.4 Treatment combinations

The treatments were combined as follows: P1V1W2, P1V1W3, P1V2W2, P1V2W3, P2V1W2, P2V1W3, P2V2W2 and P2V2W3 giving a total of 8 treatments;

Where, P1 = Drilling

P2 = Broadcasting

W2 = weeding twice

W3 = Weeding thrice

V1=variety 1(NERICA 4)

V2 =variety 2 (NERICA 11).

3.3 Experimental Design and Field layout

3.3.1 Experimental Design

The experiment design was a 2 x 2 x 2 factorial arrangement in Randomized Complete Block Design (RCBD) with 2 planting methods (Drilling and Broadcasting), 2 levels of weeding (weeding twice and weeding thrice) and 2 varieties (NERICA 4 and NERICA 11). The treatments were replicated 3 times making 24 plots in each site. Each plot measured 4 m x 3 m.

3.3.2 Field Layout

The field was laid out as shown in Figure 3.

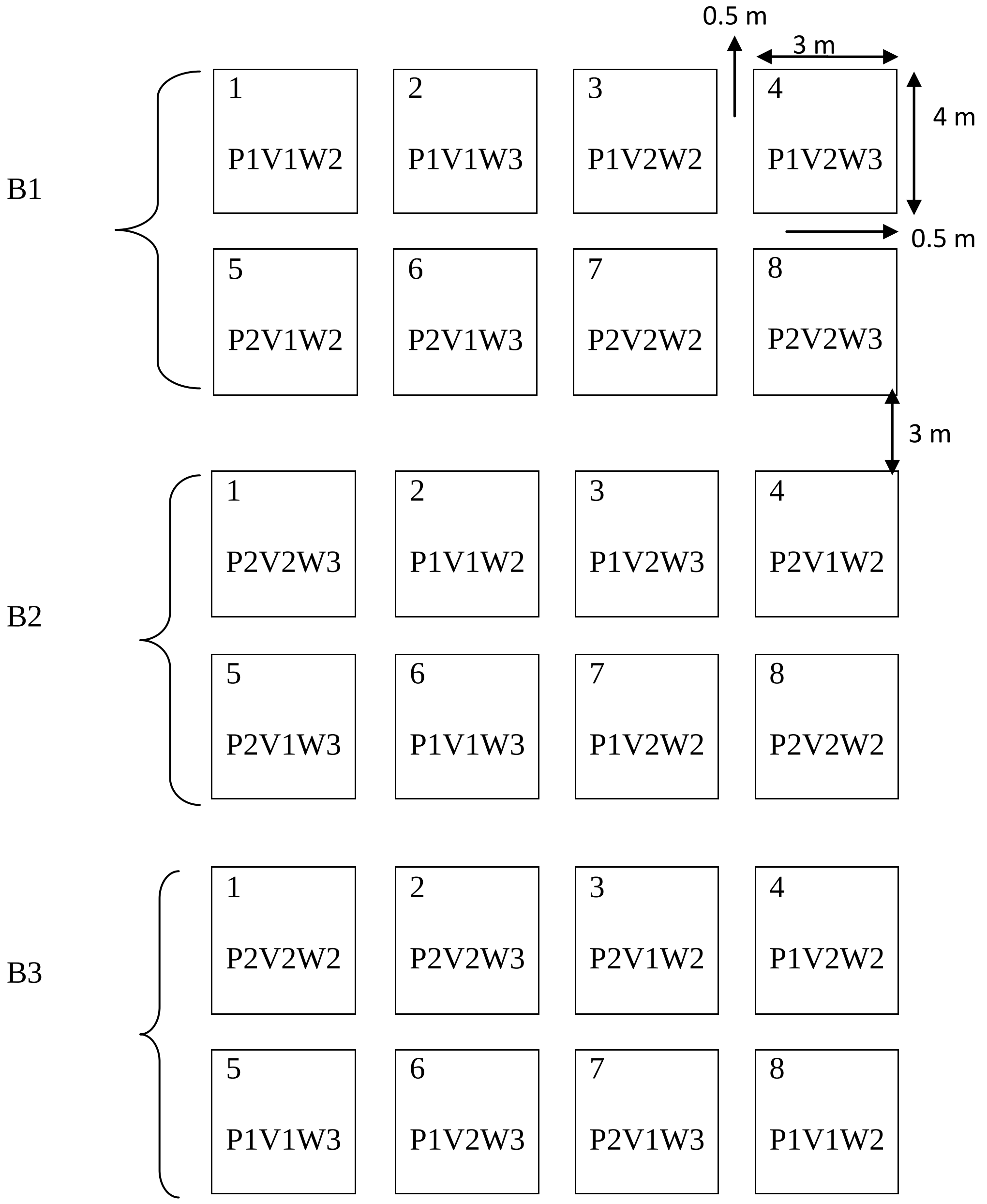


Figure 3: Field layout

Key: B1 – Block 1

B2 – Block 2

B3 – Block 3

P1- Drilling

P2- Broadcasting

V1 – Variety 1 (NERICA 4)

V2 - Variety 2 (NERICA 11)

W2- Weeding twice

W3- Weeding thrice

3.4 Cultural practices

3.4.1 Land preparation

Land preparation was done in August and September 2013 in both sites using a tractor for the first and second ploughing and then harrowing was done by hand.

3.4.2 Preparation of seed

NERICA 4 and NERICA 11 variety seed was sourced from KARI – Mwea and germination test was carried out to know whether the seed was viable. The germination percentage of each variety was calculated using the formula below:

$$\text{Germination } \% = \frac{\text{Number of seed germinated}}{\text{Total number of seed sown}} \times 100$$ (Asea *et al*, 2010)

The results of the germination test showed a germination percentage of 97 % and 96 % for NERICA 4 and NERICA 11 respectively, and therefore the seeds were of good quality (> 80 %).

3.4.3 Planting

The seed was uniformly planted to field plots by drilling and broadcasting at a rate of 100 kg ha^{-1} as per the recommendation of Asea *et al* (2010). In the drilling method, furrows were made using pointed sticks and the seed was planted manually along the furrows and covering with soil. Each plot planted using drilling method consisted of ten rows (4 m in length) and 30 cm apart as recommended for NERICA lines (Somado *et al*, 2008). In broadcasting method, the seed was planted by dropping on top of the soil in different directions and covering by pulling tree branches over the seed bed.

3.4.4 Fertilizer application

Basal fertilizer; Diammonium Phosphate (DAP) was applied uniformly to all the plots at the rate of 65 kg ha^{-1} at planting in both sites and the crop was later top dressed with 120 kg ha^{-1} of Urea in two splits at 21 days and 50 days after planting as recommended for upland rice (Oikeh *et al*, WARDA, www.warda.org – accessed on 3/7/2013).

The DAP used supplied 11.7 kg N/ha in the experiment and an additional of 55.2 kg N from Urea bringing the total to 66.9 kg N/ha. Phosphorus supplied in form of DAP was 30 kg P_2O_5/ha. This type of fertilizer was chosen due to the near neutral pH nature of the soil. The rates were based on the results of the soil test for the experiment which showed the percentage of Nitrogen in Kerio Valley and Marigat as 0.09 % and 0.05 % respectively (low), while available Phosphorus was 28.80 and 13.29 mg/kg respectively depicting high availability in Kerio Valley and medium in Marigat.

3.4.5 Weeding

This was done by hand weeding at 18, 42 and 63 days after planting.

3.4.6 Pest and water management

Incidences of pests were monitored and broad spectrum insecticides were applied to keep insect pests at bay while scarecrows were put up and some casuals were hired to scare away birds and monkeys. Supplemented irrigation was done to all the plots as need arose.

3.4.7 Harvesting

The crop was harvested at physiological maturity by cutting the stems 10 cm above the ground using a sickle, and then dried and threshed.

3.5 Parameters measured

The following parameters were measured:

a) **Plant height:** A 1 m x 1 m grid/quadrat was placed at the centre of each plot and plant height was scored at milky stage by tossing a piece of stone within the quadrat and measuring the height of the plant on which the stone fell. A ruler was used to measure the height from the ground level up to the tip of the plant.

b) **Number of productive tillers/hill:** The number of productive tillers per hill was counted at harvest within the quadrat by tossing a stone in the same way as plant height and picking a hill on which the stone fell.

c) **Number of spikelets/panicle:** The number of spikelets per panicle was counted at harvest selected in the same way as for plant height.

d) **One thousand-grain weight:** The 1000-grain weight of each variety was determined at harvest by weighing 1000 seeds picked at random from the harvested grain of each plot.

e) **Harvest index:** The ratio of reproductive or economical yield to total dry weight is referred to as the harvest index (HI). It is a useful index in evaluating treatment effects on partition photo-assimilates to grain within a given environment (Fageria 2009). The HI is an important plant trait for improving grain yield in cereals (Fageria, 2007).

HI in the experiment was derived from the weight of grain of each variety from 1.2 m^2 at the centre of each plot and dividing by the weight of grain plus straw and multiplying by 100.

$$\text{Harvest Index (HI)} = \frac{\text{Grain yield}}{\text{Grain plus straw yield}} \times 100$$ (Fageria 2009)

f) **Grain yield:** The grain yield was determined at harvest by weighing the amount of grain for each variety from 1.2 m^2 at the centre of each plot.

g) **Weed dry matter:** This was determined at harvest by harvesting all the weeds within 1.2 m^2 of each plot, then drying and weighing.

h) **Weed mortality:** Weed mortality refers to the number of weeds killed during weeding expressed as percentage. Weed mortality was determined by placing a 1 x 1 m quadrat at the centre of each plot and counting the number of each type of a common weed just before 1st weeding and immediately after the 2nd weeding (at 18 and 42 days after planting respectively), and then calculating using the formula;

$$\text{Weed mortality (\%)} = \frac{x-y}{x} \times 100$$ (Roberts, 1982)

Where x = number of weeds per m^2 before weeding

Y = mean number of weeds per m^2 after weeding.

i) **Weed types determination:** The type and number of weeds in each plot were determined by placing a1 m x 1 m quadrat at the centre of each plot; then identifying and counting the number of the weeds within the quadrat. Identification of the weeds was done by observation, taking photographs and comparing with those in the literature (Ivens, 1989, Akobundu *et al*, 1998, Sibuga, 2009 and Tavs *et al*, 2010).

3.6 Data analysis

The data obtained was subjected to Analysis of Variance (ANOVA) and the means of effects were separated using Tukey's Honestly Significant Difference (HSD) Test at $P \leq 0.05$ (SAS Institute, Inc., 1987).

The statistical model used was:

$$Y_{ijklm} = \mu + B_i + P_j + W_k + V_l + PW_{jk} + PV_{jl} + WV_{kl} + PVW_{jkl} + \epsilon_{ijklm}$$

Where, Y_{ijklm} = Observations on experimental units due to $_{ijklm}{}^{th}$ factors

μ = General mean

B_i = Effect due to $_i{}^{th}$ block

P_j = Effect due to $_j{}^{th}$ planting method

W_k = Effect due to $_k{}^{th}$ level of weeding

PW_{jk} = Interaction effect of $_j{}^{th}$ planting method and $_k{}^{th}$ level of weeding

V_l = Effect due to $_l{}^{th}$ variety

PV_{jl} = Interaction effect of $_j{}^{th}$ planting method and $_l{}^{th}$ variety

WV_{kl} = Interaction effect of $_k{}^{th}$ level of weeding and $_l{}^{th}$ variety

PWV_{jkl} = Interaction effect of $_j{}^{th}$ planting method, $_k{}^{th}$ level of weeding and $_l{}^{th}$ variety.

ϵ_{ijklm} = Experimental error.

3.7 Skeleton analysis of variance (ANOVA)

Table 4 below shows a skeleton ANOVA for the study.

Table 4: Skeleton ANOVA

Source of variation	df	SS	MS	F value	P
Replicates	2				
Planting method	1				
Weeding	1				
Variety	1				
Planting method x weeding	1				
Planting method x variety	1				
Weed control level x variety	1				
Planting method x Weeding x variety	1				
Error	14				
TOTAL	23				

Key: df – Degrees of freedom

SS – Sum of squares

MS – Mean squares

F value – Value for F test

P – Probability

CHAPTER FOUR

RESULTS

4.1 Effects of planting method, weeding frequency and variety on plant height (cm) of NERICA rice

Planting method and weeding influenced plant heights of NERICA 4 and NERICA 11 with significant ($p \leq 0.05$) differences as shown in Table 5 and Appendices Ia and Ib, In Kerio Valley, drilling method significantly differed with broadcasting with mean heights of 104.0 cm and 94.8 cm respectively. Weeding 3 differed significantly with weeding 2 and had means of 107.0 cm and 91.9 cm respectively. There were also significant differences between NERICA 11 and NERICA 4 with means of 102.0 cm and 96.8 cm respectively.

In Marigat, the performance of drilling was significant ($p \leq 0.05$) as compared to broadcasting with means of 98.2 cm and 85.6 cm respectively, (Table 5 and Appendix Ib). Weeding 3 significantly differed with weeding 2 with means of 94.3 cm and 89.5 cm respectively while NERICA 11 was significantly different from NERICA 4 with means of 95.3 cm and 88.5 cm respectively.

Table 5: Effects of planting method, weeding frequency and variety on plant height (cm) of NERICA rice in Kerio Valley and Marigat

	Kerio Valley			Marigat		
Treatment	NERICA 4	NERICA 11	**Mean**	NERICA 4	NERICA 11	**Mean**
Drilling	101.4	106.7	**104.0a**	93.5	102.9	**98.2a**
Broadcasting	92.3	97.4	**94.8b**	83.5	87.7	**85.6b**
$HSD_{0.05}$			8.3			5.3
Weeding 2	88.9	94.8	**91.9b**	88.5	90.5	**89.5b**
Weeding 3	104.8	109.3	**107.0a**	88.5	100.1	**94.3a**
$HSD_{0.05}$			5.8			4.5
Mean	**96.8b**	**102.0a**		**88.5b**	**95.3a**	
$HSD_{0.05}$		3.7			4.4	
CV (%)			6.6			8.9

Key: Means within a row or column with different letters are significantly different ($p \leq 0.05$)

4.2 Effects of planting method, weeding frequency and variety on the number of productive tillers/hill of NERICA rice

Planting method and weeding had significant ($p \leq 0.05$) effects on performance of NERICA varieties in terms of the number of productive tillers/hill as shown in Table 6 and Appendices IIa and IIb. In Kerio Valley, drilling was significantly different from broadcasting with a mean of 3.4 productive tillers/hill as compared to broadcasting with 2.8, while weeding 3 and weeding 2 had significant difference with means of 3.6 and 2.8 respectively.

NERICA 11 and NERICA 4 also recorded a significant ($p \leq 0.05$) difference with means of 3.8 and 2.6 respectively.

In Marigat, drilling and broadcasting differed significantly with means of 6.6 and 4.8 productive tillers/hill respectively, (Table 6 and Appendix IIb), while NERICA 11 was significantly different from NERICA 4 with means of 6.6 and 4.8 respectively. Generally, means of the number of productive tillers/hill in Marigat were higher than those of Kerio Valley. Weeding had no significant effect on the number of productive tillers/hill in Marigat.

Table 6: Effects of planting method, weeding frequency and variety on the number of productive tillers/hill of NERICA rice in Kerio Valley and Marigat

	Kerio Valley			Marigat		
Treatment	NERICA 4	NERICA 11	**Mean**	NERICA 4	NERICA 11	**Mean**
Drilling	2.7	4.2	**3.4a**	5.3	7.8	**6.6a**
Broadcasting	2.5	3.3	**2.8b**	4.3	5.3	**4.8b**
$HSD_{0.05}$			0.5			0.8
Weeding 2	2.0	3.5	**2.8b**	4.5	6.3	**5.4**a
Weeding 3	3.2	4.0	**3.6a**	5.2	6.8	**6.0**a
$HSD_{0.05}$			0.4			1.2
Mean	**2.6b**	**3.8a**		**4.8b**	**6.6a**	
$HSD_{0.05}$		0.6			1.1	
CV (%)			10.9			15.9

Key: Means within a row or column with different letters are significantly different ($p \leq 0.05$)

4.3 Effects of planting method, weeding frequency and variety on the number of spikelets/panicle of NERICA rice

Planting method, weeding and variety had no significant ($p > 0.05$) effects on the number of spikelets/panicle of NERICA rice in both Kerio Valley and Marigat, (Table 7 and Appendices IIIa and IIIb).

Table 7: Effects of planting method, weeding frequency and variety on the number of spikelets/panicle of NERICA rice in Kerio Valley and Marigat

	Kerio Valley			Marigat		
Treatment	NERICA 4	NERICA 11	**Mean**	NERICA 4	NERICA 11	**Mean**
Drilling	9.0	10.3	**9.7a**	8.2	9.3	**8.8**a
Broadcasting	9.2	9.3	**9.3a**	7.0	8.0	**7.5a**
$HSD_{0.05}$			0.8			1.6
Weeding 2	8.8	9.5	**9.2a**	7.0	8.0	**7.5 a**
Weeding 3	9.3	10.2	**9.8a**	8.2	9.3	**8.8 a**
$HSD_{0.05}$			0.9			1.6
Mean	**9.1a**	**9.8a**		**7.6a**	**8.7a**	
$HSD_{0.05}$		0.9			1.6	
CV (%)			11.0			22.4

Key: Means within a row or column with the same letters are not significantly different ($p > 0.05$*)*

4.4 Effects of planting method, weeding frequency and variety on weed dry matter (tons/ha) for NERICA rice

Weeding frequency had significant ($p \leq 0.05$) effects on weed dry matter of the two varieties under study, (Table 8 and Appendices IVa and IVb). In Kerio Valley, there was significant difference between weeding 2 and weeding 3 in terms of weed dry matter with means of 1.68 and 0.48 tons/ha respectively.

In Marigat, weeding 2 was significantly different from weeding 3 with mean weed dry matter weights of 2.04 and 0.39 tons/ha respectively.

Table 8: Effects of planting method, weeding frequency and variety on weed dry matter (tons/ha) of NERICA rice in Kerio Valley and Marigat

	Kerio Valley			Marigat		
Treatment	NERICA 4	NERICA 11	**Mean**	NERICA 4	NERICA 11	**Mean**
Drilling	0.68	0.45	**0.57a**	0.93	0.55	**0.74a**
Broadcasting	1.77	1.43	**1.60a**	2.12	1.27	**1.69a**
$HSD_{0.05}$			1.18			1.49
Weeding 2	1.80	1.57	**1.68a**	2.55	1.53	**2.04a**
Weeding 3	0.65	0.32	**0.48b**	0.50	0.28	**0.39b**
$HSD_{0.05}$			1.14			1.32
Mean	**1.23a**	**0.94a**		**1.53a**	**0.91a**	
$HSD_{0.05}$		1.21			1.47	
CV (%)			117.8			125.6

Key: Means within a row or column with different letters are significantly different ($p \leq 0.05$)

4.5 Effects of planting method, weeding frequency and variety on 1000-grain weight (g) of NERICA rice

Weeding significantly ($p \leq 0.05$) influenced performance of NERICA in terms of 1000-grain weight in Kerio Valley with weeding 3 being significantly different from weeding 2 with a mean weight of 28.9 g against 27.7 g for weeding 2, (Table 9 and Appendix Va). In Marigat, NERICA 11 significantly differed with NERICA 4 with mean weights of 28.3 g and 26.4 g respectively (Table 9 and Appendices Vb).

Table 9: Effects of planting method, weeding frequency and variety on 1000-grain weight (g) of NERICA rice in Kerio Valley and Marigat

	Kerio Valley			Marigat		
Treatment	NERICA 4	NERICA 11	**Mean**	NERICA 4	NERICA 11	**Mean**
Drilling	28.3	29.0	**28.7a**	26.7	28.8	**27.7 a**
Broadcasting	27.7	28.3	**28.0**a	26.1	27.8	**27.0a**
$HSD_{0.05}$						1.1
Weeding 2	27.2	28.3	**27.7b**	26.2	27.9	**27.1a**
Weeding 3	28.8	29.1	**28.9a**	26.5	28.7	**27.6a**
$HSD_{0.05}$			0.7			
Mean	**28.0a**	**28.7a**		**26.4b**	**28.3 a**	
$HSD_{0.05}$		0.9			1.1	
CV (%)			2.8			5.2

Key: Means within a row or column with different letters are significantly different ($p \leq 0.05$)

4.6 Effects of planting method, weeding frequency and variety on the grain yield of NERICA rice

As shown in Table 10 and Appendices VIa and VIb, planting method and weeding had significant ($p \leq 0.05$) effects on performance of NERICA varieties in terms of the grain yield with drilling being significantly different from broadcasting in Kerio Valley with means of 4.83 and 3.63 tons/ha respectively. Weeding 3 similarly performed significantly different from weeding 2 with means of 5.11 tons and 3.34 tons respectively while NERICA 11 differed significantly with NERICA 4 by a mean of 4.98 to 3.48 tons/ha for NERICA 4.

In Marigat, the difference between drilling and broadcasting was significant ($p \leq 0.05$) with the grain yield means of 5.31 and 3.00 tons/ha respectively, (Table 10 and Appendix VIb). Weeding 3 posted significant mean yield of 4.97 as compared to weeding 2 with 3.34 tons/ha in Marigat. Likewise, NERICA 11 significantly differed with NERICA 4 recording a mean of 4.66 tons/ha as compared to NERICA 4 at 3.65 tons/ha.

Table 10: Effects of planting method, weeding frequency and variety on the grain yield (tons/ha) of NERICA rice in Kerio Valley and Marigat

	Kerio Valley			Marigat		
Treatment	NERICA 4	NERICA 11	**Mean**	NERICA 4	NERICA 11	**Mean**
Drilling	3.77	5.90	**4.83a**	5.05	5.57	**5.31a**
Broadcasting	3.19	4.07	**3.63b**	2.25	3.75	**3.00b**
$HSD_{0.05}$			1.20			1.02
Weeding 2	2.67	4.02	**3.34b**	3.18	3.50	**3.34b**
Weeding 3	4.28	5.95	**5.11a**	4.13	5.82	**4.97a**
$HSD_{0.05}$			1.05			1.28
Mean	**3.48b**	**4.98a**		**3.65b**	**4.66a**	
$HSD_{0.05}$		1.29			1.46	
CV (%)			20.42			10.75

Key: Means within a row or column with different letters are significantly different ($p \leq 0.05$)

4.7 Interaction between planting method, weeding frequency and variety on the grain yield (tons/ha) of NERICA rice in Kerio Valley and Marigat

Interaction between drilling, weeding 3 and NERICA 11 resulted to significant ($p \leq 0.05$) mean yield of 6.17 tons/ha as compared to 5.50 tons for the interaction of drilling, weeding 3 and NERICA 4 in Marigat (Table 11 and Appendix VIb). On the same note, interaction between broadcasting, weeding 3 and NERICA 11 posted significant difference from the combination of broadcasting, weeding 3 and NERICA 4 with mean yields of 5.47 and 2.75 tons/ha respectively.

Interaction between drilling, weeding 3 and NERICA 4 was significantly different from the interaction between drilling, weeding 2 and NERICA 4 with 5.50 and 4.61 tons/ha respectively. Also interaction between broadcasting, weeding 3 and NERICA 4 was significantly different from the interaction between broadcasting, weeding 2 and NERICA 4 with 2.75 and 1.75 tons/ha respectively. Likewise, combination of drilling, weeding 3 and NERICA 11 posted significant performance of 6.17 tons/ha as compared to the combination of drilling, weeding 2 and NERICA 11 at 4.97 tons/ha. Interaction between broadcasting, weeding 3 and NERICA 11 yielded a significant mean yield of 5.47 tons/ha as compared to interaction between broadcasting, weeding 2 and NERICA 11 with 2.03 tons/ha. The interactions between planting method, weeding and variety in Kerio Valley were not significant ($p > 0.05$).

Table 11: Interaction between planting method, weeding frequency and variety on the grain yield (tons/ha) of NERICA rice in Marigat

		Marigat		
Treatment		NERICA 4		NERICA 11
Drilling	Weeding 2	4.61c		4.97c
	Weeding 3	5.50b		**6.17a**
Broadcasting	Weeding 2	1.75f		2.03e
	Weeding 3	2.75d		5.47b
$HSD_{0.05}$			0.39	
CV (%)			10.75	

Key: Means with different letters are significantly different ($p \leq 0.05$)

4.8 Effects of planting method, weeding frequency and variety on harvest Index (%) of NERICA

Weeding frequency and variety had significant ($p \leq 0.05$) effects on harvest index in Kerio Valley with means of 44.6 and 34.0 % for weeding 3 and weeding 2 respectively while NERICA 11 yielded 44.0 % against 34.7 % for NERICA 4, (Table 12 and Appendix VIIa).

In Marigat planting method, weeding frequency and variety had significant effects on harvest index (Table 12 and Appendix VIIb). Drilling differed significantly with broadcasting with harvest indices of 44.9 and 34.8 % respectively while weeding 3 and weeding 2 were significantly different recording 43.2 and 36.5 % respectively. NERICA 11 was also significantly different from NERICA 4 in terms of harvest index with 42.5 and 37.3 %.

Table 12: Effects of planting method, weeding frequency and variety on harvest index (%) of NERICA rice in Kerio Valley and Marigat

	Kerio Valley			Marigat		
Treatment	NERICA 4	NERICA 11	**Mean**	NERICA 4	NERICA 11	**Mean**
Drilling	37.6	43.9	**40.7a**	43.1	46.9	**44.9a**
Broadcasting	31.7	44.2	**38.0a**	31.5	38.1	**34.8b**
$HSD_{0.05}$			7.6			4.9
Weeding 2	27.4	40.7	**34.0b**	33.2	39.8	**36.5b**
Weeding 3	41.9	47.4	**44.6a**	41.4	45.1	**43.2a**
$HSD_{0.05}$			5.5			6.1
Mean	**34.7b**	**44.0a**		**37.3b**	**42.5a**	
$HSD_{0.05}$		6.6			5.0	
CV (%)			15.5			8.0

Key: Means within a row or column with different letters are significantly different ($p \leq 0.05$)

4.9 Effects of planting method, weeding frequency and variety on mortality of common weeds in NERICA rice fields

Planting method, weeding frequency and variety had significant ($p \leq 0.05$) effects on mortality of common weeds in both sites. In Kerio Valley, drilling and broadcasting were significantly different for Antelope grass, Nut grass and Star grass with % mortality means of 58.0, 73.8 and 89.7 respectively under drilling as compared to broadcasting with 46.1, 56.5 and 82.1 % respectively, (Table 13 and Appendices VIII, IXa and X).

Weeding 3 posted significant mortality means for Antelope grass, Nut grass and Star grass of 61.0, 75.6 and 91.2 respectively against 43.1, 54.6 and 80.6 % respectively for weeding 2.

In Marigat, drilling and broadcasting differed significantly with drilling significantly yielding mortality means for Nut grass, Barn yard grass and Pinklady of 69.1, 80.2 and 98.1 % respectively as compared to broadcasting which recorded 51.8, 63.9 and 93.2 respectively, (Table 13 and Appendices IXb, XI and XII). Weeding 3 and weeding 2 also differed significantly in mortality means for Nut grass, Barn yard grass and Pinklady with 71.3, 83.6 and 98.9 % respectively under weeding 3 against mortality means of 49.5, 60.5 and 92.5 respectively under weeding 2. NERICA 11 differed significantly with NERICA 4 and had mortality means of 78.0 and 66.1 % respectively for Barnyard grass.

Table 13: Effects of planting method, weeding frequency and variety on mortality (%) of common weeds in NERICA rice fields in Kerio Valley and Marigat

	Kerio Valley			Marigat		
Treatment	Antelope grass	Nut grass	Star grass	Nut grass	Barnyard grass	Pinklady
Drilling	58.0a	73.8a	89.7a	69.1a	80.2a	98.1a
Broadcasting	46.1b	56.5b	82.1b	51.8b	63.9b	93.2b
$HSD_{0.05}$	10.6	12.6	6.5	11.7	13.3	4.2
Weeding 2	43.1b	54.6b	80.6b	49.5 b	60.5b	92.5b
Weeding 3	61.0a	75.6a	91.2a	71.3a	83.6a	98.9a
$HSD_{0.05}$	8.2	11.2	5.4	9.6	9.7	3.7
NERICA 4	54.2a	62.4a	84.3a	60.3a	66.1b	96.4a
NERICA 11	49.8a	67.9a	87.5a	60.5a	78.0a	94.9a
$HSD_{0.05}$	6.6	7.3	4.2	4.7	6.3	2.7
CV (%)	12.9	5.6	14.4	8.9	9.9	3.2

Key: Means within a column with different letters are significantly different ($p \leq 0.05$)

4.10 Identification of major weeds in NERICA rice fields

The following major types of weeds were identified in the study sites as shown in Table 14.

Table 14: Types of major weeds identified in Kerio Valley and Marigat

Weed species	Study site where found	Family and Characteristics	Pictorial
Antelope grass (*Echinochloa pyramidalis*)	Kerio Valley	Poaceae: Numerous seed spores on spikes, slender stem and rhizomes	
Nut grass *(Cyperus rotundus)*	Kerio Valley and Marigat	Cyperaceae: Flat spikes, tubers and rhizomes.	
Barnyard grass (*Echinochloa colona*)	Marigat	Poaceae: Long inflorescence, high number of seeds and tillers	

Other types of weeds identified were star grass (*Cynodon dactylon*) and Pinklady (*Heterotis rotundifolia*) which were found in Kerio Valley and Marigat respectively.

CHAPTER FIVE

DISCUSSION

5.1 Effects of planting method, weeding frequency and variety on plant height of NERICA rice

From the study, drilling posted significantly ($p \leq 0.05$) taller plants in both sites as compared to broadcasting. This agrees with the findings of Abbas *et al* (2009) who worked on wheat. This could be due to the fact that there were more seeds that were uniformly distributed with more space and nutrients to enhance good crop establishment and growth as compared to broadcasting method which had more tendencies of uneven distribution and crowding at some points causing higher competition for nutrients. The significantly taller plants exhibited by weeding thrice in the experiment as compared to weeding twice in both sites conforms to Hassan *et al* (2010) whose results revealed that three hand weeding produced the tallest plants of transplanted rice while the shortest plants were observed in zero weeding regime. This might be due to the availability of more nutrients from a weed free environment. The study also showed that NERICA 11 was significantly better than NERICA 4 in terms of plant height in both Kerio Valley and Marigat. This means NERICA 11 is probably more genetically suited to the two areas than NERICA 4.

5.2 Effects of planting method, weeding frequency and variety on the number of productive tillers/hill of NERICA rice

The findings of the study that showed significantly higher number of productive tillers/hill in drilling than broadcasting in both sites conforms to those of Ali *et al* (2012) who concluded that the number of productive tillers m^{-2} recorded for drilling was higher than in broadcasting method of planting in paddy rice. This might be due to optimal spacing in drilling for growth of the plants.

The results of the experiment which indicated that three weeding regime produced a significantly higher number of productive tillers/hill in Kerio Valley than weeding twice also agree with Hassan *et al* (2010) who worked on transplanted rice and found that three hand weeding produced the highest number of effective tillers/hill whereas lowest one was observed in no weeding treatment. This can perhaps be due to more light and nutrients reception of crop from a weed free environment.

The significantly higher number of productive tillers/hill produced by NERICA 11 than NERICA 4 in the study was due to NERICA 11 being more genetically improved than NERICA 4. This was similar to the findings of Birhane (2003) which showed that there were significant differences among varieties with the least number of tillers observed for NERICA 4 as compared to NERICA 3.

5.3 Effects of planting method, weeding frequency and variety on the number of spikelets/panicle for NERICA rice

The lack of statistical significant difference in the experiment between the two planting methods in terms of the number of spikelets/panicle are consistent with what Abbas *et al* (2009) found out on wheat which showed that the number of spikelets/spike in drilling was statistically at par with broadcasting. The results of the study also showed that there were no significant differences between the weeding regimes and between varieties in terms of the number of spikelets/panicle.

5.4 Effects of planting method, weeding frequency and variety on weed dry matter for NERICA rice

The results of the study that showed that weeding thrice siginficantly reduced weed dry matter in both Kerio Valley and Marigat more than weeding twice was due to reduced density of weeds.

This agrees with Ekeleme *et al* (2007) who found significant reduction of weed biomass in two hoe weeding as compared to zero weeding.

5.5 Effects of planting method, weeding frequency and variety on 1000-grain weight of NERICA rice

The present study showed significantly higher 1000-grain weight in weeding thrice than weeding twice in Kerio Valley, which agrees with Hassan *et al* (2010) who recorded the highest 1000-grain weight from three hand weeding in transplanted rice whereas the lowest was observed in no weeding regime. This was probably because of less nutrient competition from weeds.

The results of the experiment which showed significantly greater 1000-weight of NERICA 11 than NERICA 4 in Marigat agree with Atera *et al* (2011) who showed that the 1000-grain weight NERICA 11 was higher compared with other varieties. This might be because of genetics that favour NERICA 11. Grain weight is an important yield component in rice production and it is determined by the supply of assimilates during the ripening period and the capacity of the developing grain to accumulate the translocated assimilates (Ntanos and Koutroubas, 2002).

Insignificant difference between the planting methods in the present study in terms of 1000-grain weight conforms with the findings of Abbas *et al* (2009) who worked on wheat and found that both drilling and broadcasting had similar 1000-grain weight. The results of this study are also consistent with those of Ali *et al* (2012) who found similarities in drilling and broadcasting in paddy rice and Javaid *et al* (2012) whose results revealed non-significant differences between sowing methods in coarse rice in terms of 1000-grain weight.

5.6 Effects of planting method, weeding frequency and variety on the grain yield of NERICA rice

The experiment's findings that drilling method was significantly ($p \leq 0.05$) superior to broadcasting in terms of the grain yield of NERICA in both sites might be due to adequate spacing and less competition for nutrients in drilling than broadcasting. This contradicts Abbas *et al* (2009) who concluded that broadcasting is superior for wheat sowing in sandy loam soils of arid areas as compared to drilling with row spacing of 15 cm and 30 cm.

The present study showed that weeding thrice had a significant higher grain yield than weeding twice in Kerio Valley and Marigat which conforms to the work of Hassan *et al* (2010) who found that the highest grain yield was from three-hand weeding in transplanted rice while the minimum was from no weeding regime. This was supported by Haque *et a l* (2003) who found similar results in wheat. This was because of less competition for nutrients from weeds in the three weeding than two weeding regime.

The experiment found that NERICA 11 posted significantly higher yield means in both Kerio Valley and Marigat as compared to NERICA 4. This means NERICA 11 is more genetically improved variety for upland conditions than NERICA 4. Further to this, the low mean value registered by NERICA 4 might be as a result of the smaller number of productive (fertile) tillers/hill than NERICA 11.

5.7 Interaction between planting method, weeding frequency and variety on the grain yield (tons/ha) of NERICA rice in Marigat

The findings of the study that showed the combination of drilling, weeding 3 and NERICA 11 having significantly ($p \leq 0.05$) higher mean yield than other interactions was due to the additive effects and NERICA 11 being more genetically improved. This interaction gave the highest mean grain yield of 6.17 tons/ha in Marigat.

5.8 Effects of planting method, weeding frequency and variety on harvest Index of NERICA rice

The findings of the experiment that showed that drilling had higher harvest index than broadcasting might be due to more space which allowed ease of weeding.

Weeding 3 in the study was significantly better than weeding 2 in terms of harvest index probably because the former reduced the chuff than the latter weed regime.

The present study found that harvest index for NERICA rice in Kerio Valley and Marigat was in the range 30-45 % which is consistent with the findings of Mae (1997) who reported that the harvest index of traditional rice cultivars is about 30 %, and 50 % for improved, semi-dwarf cultivars. In both sites, NERICA 11 was significantly better than NERICA 4 in terms of harvest index possibly because of NERICA 11 being more genetically improved than NERICA 4. George *et al* (2002) reported that upland rice yield can be significantly improved with developed genotypes of higher harvest index.

5.9 Effects of planting method, weeding frequency and variety on mortality of common weeds in NERICA rice fields

For general purposes, percentage mortality rather than percentage survival should be stated (Roberts, 1982). In the present study, drilling significantly raised the mortality of the major weeds identified in both Kerio Valley and Marigat as compared to broadcasting. This might be due to easier weeding in drilling than broadcasting. Weeding 3 also significantly raised mortality of the major weeds more than weeding 2 probably because of more harm to weeds in three-weeding than two-weeding regime. The significantly higher mortality of Barnyard grass shown by NERICA 11 in Marigat than NERICA 4 might be attributed to NERICA 11 being more genetically resistant to the type of the weed than NERICA 4.

Generally *Echinochloa pyramidalis* and *Cyperus rotundus* were found to be difficult to control in Kerio Valley as shown by their low mortality while in Marigat, *Cyperus rotundus* and *Echinochloa colona* were persistent through weeding. This might be because of their rhizomatous nature of reproduction and high residual number of seed in the soil.

5.10 Identification of major weeds in NERICA rice fields

The study found that Antelope grass *(Echinochloa pyramidalis*) was one of the major weeds which adversely affected NERICA in Kerio Valley. Nut grass (*Cyperus rotundus*) was also identified as a major weed which adversely affected NERICA in both Kerio Valley and Marigat. This agrees with Dzomeku *et al* (2007) who found Nut grass to be one of the dominant weeds in NERICA varieties (NERICA 1 and NERICA 2). Barnyard grass (*Echinochloa colona*) was identified as one of the major weeds of NERICA rice in Marigat. This was similarly found by Hassan *et a*l (2010) to be one of the major weeds in transplanted rice.

Other common weeds identified were *Cynodon dactylon* and *Heterotis rotundifolia* which were found in Kerio Valley and Marigat respectively.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

i) Drilling was significantly better than broadcasting in terms of NERICA performance.

ii) Weeding three times significantly led to better performance of the two NERICA varieties than weeding twice.

iii) NERICA 11 was significantly superior to NERICA 4.

iv) The three major weeds that adversely affected the performance of NERICA rice in Kerio Valley and Marigat were: Antelope grass (*Echinochloa pyramidalis*), Nut grass (*Cyperus rotundus*) and Barnyard grass (*Echinochloa colona*).

6.2 Recommendations

i. Farmers in Kerio Valley and Marigat should plant NERICA by drilling and weed three times.

ii. It is worthwhile for farmers to adopt NERICA 11 variety for improved performance.

iii. Further research is recommended to find out the relationship between the environment and performance of NERICA varieties.

REFERENCES

Abbas, G., Ali, M. A., Azam, M. and Hussain, I. (2009). Impact of planting methods on wheat grain yield and yield contributing parameters. *The Journal of Animal and Plant Sciences*.19 (1): 30-33.

Adeosun, J.O., Dauda, C.K., Gezui, Mando, A., Odunze, A.C., Amapu, I.Y. and Kudp, T. (2009). On-farm weed management in upland rice in three villages of Katsina State of Nigeria. African Crop Science Society. African Crop Science Conference Proceedings. 9: 625-629.

Akobundu, I.O. and Agyakwa, C.W. (1998). A Hand book of West African Weeds. International Institute of Tropical Agriculture, Ibadan, Nigeria.

Ali, R.I., Iqbal, N., Saleem, M. U. and Akhtar, M. (2012). Effect of different planting methods on Economic yield and Grain quality of Rice. Rice Research Institute, Kala Shah Kaku, Punjab, Pakistan.

Apaseku, J.A. and Dowbe, W. (2013). Response of NERICA and *Sativa* rice lines to Nitrogen and Phosphorus rates by number of tillers and shoot biomass yield. *African Journal of Food, Agriculture, Nutrition and Development*.13 (5): 8273-8292.

Asea, G., Onaga, G., Phiri, N. A., Karanja, D.K. and Nzioka, P. (2010). Quality Rice Seed Production Manual; "Transfer and Dissemination of Emerging Agricultural Technologies of New Rice for Africa, (NERICA): Improving Access to Quality Seed through Public-private partnership in Uganda". National Crops Resources Research Institute, Kampala, Uganda.

Atera, E. A., Onyango, J. C., Azuma, T., Asanuma, S. and Itoh, K. (2011). Field evaluation of selected NERICA rice cultivars in Western Kenya; *African Journal of Agricultural Research.* 6(1): 60-66.

Auma, E.O (1971). Studies on the Growth of Lowland Paddy (*Oryza sativa*) with special reference to stand establishment and weed control. M.Sc Thesis, University of Ceylon, Peradeniya.

Balasubramanian, V., Sie, M., Hijmans, R. J. and Otsuka, K. (2007). Increasing rice production in sub-Saharan Africa: Challenges and opportunities. Advances in Agronomy. 94: 55-133.

Becker, M. and Johnson, D.E. (1999). Rice yield and productivity gaps in irrigated systems of the Forest zone of Côte d'Ivoire. Field Crops Research. 60 (3): 201–208.

Becker, M. and Johnson, D.E. (2001). Improved water control and crop management effects on lowland rice productivity in West Africa. Nutrition Cycling in Agro-ecosystems. 59 (2): 119–127.

Birhane, A. (2003). Effect of planting methods on yield and yield components of rice (*Oryza sativa*l.) varieties in Tahtay Koraro Wereda, Northern Ethiopia. *International Journal of Technology enhancements and emerging Engineering Research*.1 (5): 2347-4289.

Caamal-Maldonado J.A., Jimenez J.J., Torres A. & Anaya A. (2001). The use of allelopathic legume cover and mulch species for weed control in cropping systems. *Agronomy Journal*. 93(1): 27-36.

Carver, M .F. F. (2005). The influence of different establishment methods on performance of early-drilled winter wheat. Project Report No. 375.

Community Agricultural Development in Semi-arid Lands Project (CADSAL) (2011). Report.

.

DeVries, M.E., Rodenburg, J., Bado, B.V., Sow, A., Leffelaar, P.A. and Giller, K.E. (2010). Rice production with less irrigation water is possible in a Sahelian environment. Field Crops Research.116: 154–164.

Dzomeku, I.K., Dogbe, W. and Agawu, E.T. (2007). Responses of NERICA rice varieties to weed interference in the Guinea savannah uplands. *Journal of Agronomy*. 6:262-269.

Ekeleme, F., Kamara, A. Y., Oikeh, S.O., Chikoye, D. and Omoigui, L. O. (2007). Effect of weed competition on upland rice production in north-eastern Nigeria. Africa Rice Center (WARDA); Cotonou, 01 BP 2031, Benin Republic. African Crop Science Conference proceedings. 8: 61-65.

Etsuo, K. (2005). Keynote address ICA-WARDA Technical seminar on rice cooperation in East and Southern Africa, AICAD, Nairobi.

Fageria, N. K. (2007). Yield physiology of rice. *Journal of Plant Nutrition*.30: 843-879.

Fageria, N. K. (2009). The Use of Nutrients in Crop Plants. New York: CRC Press.

FAO, (2004). Report presented during International year of rice.

FAO (2007). International Rice Commission Newsletter.Vol. 56. Rome, Italy.

FAO (2009). Possible Approaches for Ecological Weed Management. Food and Agriculture Organization of the United Nation.

FAO (2010). Grassland index. A searchable catalogue of grass and forage legumes.

FAO (2013). Rice Market Monitor. Information update on Rice Production and Market. Trade and Markets Division, Food and Agriculture Organization of the United Nation. 16 (1).

George, T., Magbanua, R. Garrity, D. P., Tubana, B.S. and Quiton, J. (2002). Rapid yield loss of rice cropped successively in aerobic soil. *Agronomy Journal*.94:981-989.

Grard, P. (2006). Biodiversity informatics and co-operation in taxonomy for interactive shared knowledge base (BIOTIK), Pondichery, India.

Guei, R. G. and Fagade, S. O. (2002). Promising Technologies for Rice Production in West and Central Africa, West Africa Rice Development Association (WARDA), Food and Agriculture Organization (FAO).

Gunasena, H. P. M. (1974). Results from cooperative weed control trials in Sri Lanka. Evaluation of herbicides for rainfed upland rice. Paper presented at the International Rice Research Conference, IRRI, Los Banos, Laguna, Philippines.

Harding, S.S., Taylor, D.R., Jalloh, A.B., Mahmood, N., Dixon, C.A. and Johnson, S.D. (2012). Evaluation of the Efficacy of Different Rates of Herbicides on Weed Growth and Grain Yield of Two Rice Varieties in Two Rice Ecologies in Sierra Leone; American Journal of Experimental Agriculture. 2(4): 607-615.

Hassan, N., Ahmed, S., Uddin, J.andHasan, M. (2010). Effect of weeding regime and planting density on morphology and yield attributes of transplant Aman rice cultivar. Brridhan.Pakistan. *Journal of Weed Science Research*. 16(4): 363-377.

Haque, E., Kabir, G., Mondal, M.A.A. and Alam, A.M.S. (2003). Stability for yield components in wheat (*Triticum aestivum* L.). *Bangladesh Journal of Plant Breeding Genetics*. 16 (1): 39-44.

Ikuenobe, C.E., Fadayomi, O., Adeosun, J.O., Gworgwor, N.A., Melifonwu, A.A. and Ayeni, A.O. (2005). State of Adoption of improved weed control technologies by farmers in the three agro-ecological Zones of Nigeria. *Nigerian Journal of Weed Science*. 18: 1-19.

Internet: http://www.africarice.org/publications/nerica-comp/module % 202_Low.pdf - accessed on 3/7/2013. Module 2- NERICA: Origins, nomenclature and identification characteristics.

Internet: http://www.knowledgebank.irri.org/ericeproduction/PDF_&_Docs/PlantingRice.pdf - accessed on 3/7/2013. IRRI, Philippines. Rice Production Training Module.

Ivens G. W. (1989). Eastern Africa weeds control. Oxford University press, Nairobi.

Javaid, T., Awan, I. U., Baloch, M. S., Shah, I. H., Nadim, M. A., Khan, E. A., Khakwani, A. A. and Abuzar, M. R. (2012). Effect of planting methods on the growth and yield of coarse rice. *The Journal of Animal & Plant Sciences*: 22 (2): 358-362.

Johnson, D.E. (1996). Weed management in small holder rice production in the tropics. Natural Resources Institute. University of Greenwich, Kent, UK.

Johnson D. E. (1997). Weeds of rice in West Africa. West Africa Rice Development Association, (WARDA), Bouaké, Côte d'ivoire.

Johnson, D.E., Dingkuhn, M., Jones, M.P. and Mahamane, M.C. (1998). The influence of rice plant type on the effect of weed competition on *Oryza sativa* and *Oryza glaberrima*. Weed Research. 38:207–216.

Jones, M.P., Dingkuhn, M., Aluko, G.K. and Semon, M. (1997). Using backcrossing and doubled haploid breeding to generate weed competitive rice from *Oryza sativa* and *Oryza glaberrima*. In: Interspecific hybridization: Progress and Prospect, pp 61–69. WARDA /ADRAO, Cote d'Ivoire.

Jones, M.P., Dingkuhn, M., Aluko G. K. and Semon, M. (1997). Interspecific *Oryza sativa* and *Oryza glaberrima*. Progenies in upland rice improvement. Euphytica.92: 237–246.

Kaneda, C. (2007). Breeding and dissemination efforts of "NERICA" (2) evaluation of important characteristics. Japan. *Journal of Tropical Agriculture*. 51:41-45.

Kaneda, C. (2007). Breeding and dissemination efforts of "NERICA" (4) efforts for dissemination of NERICAs in African countries. *Journal of Tropical Agriculture*.51:145-151.

Kega, V.M. and Maingu, A. R, Kenya Agricultural Research Institute, Matuga (2006). Evaluation of New Rice for Africa (NERICA) Cultivars in Coastal Lowlands of Kenya.

Kijima, Y., Sserunkuuma, D. and Otsuka, K. (2006). How revolutionary is the NERICA revolution? Evidence from Uganda. Development Economics. 44:252-267.

Kouko, W. O., Atera, E. A., Onyango, J. C., Kore, W. A. O., Wanjogu, R. K., Nyongesa, M., Sanzua, L., Sawe, E. K., Mukhwana, E. and Onyango, M. (2005). Results of NERICA adaptability Trials in Kenya. Seminar paper presented during the second JICA seminar on promotion of Rice production and dissemination in Africa at AICAD, Nairobi, Kenya.

Mae, T. (1997). Physiological nitrogen efficiency in rice: Nitrogen utilization, photosynthesis, and yield potential. Plant Soil.196: 201-210.

Manners, G., WARDA. (2001). NERICA- New Rice Transforming Agriculture for West Africa.

Marwat, K.B., Khan, I.A. and Hassan, G. (2004). Efficacy of different pre-and post-emergence for controlling weeds in chickpea. *Pakistan Journal of Weed Science Research*. 10 (1-2): 51-54.

Mbomi, S. E., Oben, F. T., Adetimirin, V. O. and Lamare, D. M. (2012). Influence of Sowing Methods and Densities during Establishment on Growth, Dry Matter Yield and Persistence of *Tephrosia* Species. *Greener Journal of Agricultural Sciences*.2 (5): 224-232.

Michael, J., and Brigite, C. (1993). Upland rice. CTA, London: Macmillan Press Limited.

Ministry of Agriculture (MOA), Keiyo (2011). Report.

Ministry of Agriculture, Keiyo South (2012). Report.

Ministry of Agriculture, Marigat (2012). Report.

Ministry of Agriculture (2014). Economic Survey publication.

Ntanos, D. A. and Koutroubas, S. D. (2002). Dry matter and N accumulation and translocation for Indica and Japonica rice under Mediterranean conditions. Field Crops Research. 74: 93–101.

Oerke, E.C., Dehne, H.W., Schonbeck, F. and Weber, A. (1994). Crop Production and Protection – Estimated Losses in Major Food and Cash Crops. Elsevier Science, Amsterdam, pp.808.

Oikeh, S.O., Nwilene, F.E., Agunbiade, T.A., Oladimeji, O., Ajayi, O., Semon, M., Tsunematsu, H. and Samejima, H. www.warda.org, Africa Rice Center, (WARDA) - Accessed on 3/7/2013. Growing upland rice: a Production Handbook.

Oikeh, S.O., Diatta, S. and Tsuboi, T. (2007). Soil fertility and NERICA rice nutrition. Module 7.

Okalebo, J.R., Gathua, K.W. and Woomer, P.L. (2002). Laboratory methods of soil and plant analysis: A working manual. Second Edition.

Olga, F. L. (2002). African rice (*Oryza glaberrima*): History and future potential. Smithsonian Tropical Research Institute, Balboa-Ancon, Republic of Panama.

Oonyu, J. (2011). Upland rice growing: A potential solution to declining crop yields and the degradation of the Doho wetlands, Butaleja district-Uganda. *African Journal of Agricultural Research.* 6(12): 2774-2783.

Rao, A.N., Johnson, D.E., Sivaprasad, B., Ladha, J.K. and Mortimer, A.M. (2007). Weed management in direct-seeded rice. Advanced Agronomy. 93: 153–255.

Roberts, H. A. (1982). Weed Control Handbook: Principles, seventh edition. National Vegetable Research Station, Wellesbourne.

Rodenburg, J., Meinke, H. and Johnson, D.E. (2011). Climate Change and Agriculture Paper; Challenges for weed management in African rice systems in a changing climate. *Journal of Agricultural Science*. 149: 427–435.

SAS Institute, Inc. (1987). SAS user's guide: Statistics. Version 6.04. Cary, NC.

Shakoor, A., Islam, S. and Naeem, M. (2000). Efficacy of different herbicides for control of weeds in sorghum (*Sorghum bicolor*) under rain-fed conditions. *Pakistan Journal of Biological Sciences.* 3(3): 463-465.

Sibuga, K.P. (2009). Strategies for weed control to increase sustainable crop production in Africa. African Crop Science Conference Proceedings. 9: 651 – 657.

Somado, E.A., Guei, R.G. and Keya, S.O. (2008). NERICA: the New Rice for Africa – a Compendium. Cotonou, Benin: Africa Rice Center (WARDA); Rome, Italy: FAO; Tokyo, Japan: Sasakawa Africa Association, pp. 210.

Suptotthita C. & Sobhan K. M. (2005). Comparative morphology - anatomical study of some Aspect in *Eleutheranthera ruderalis* (Sw.) Sch.-bip. and *Synedrella nodiflora* (Asteraceae). Department of Botany, University of Kalyani, India. *Journal of Economics.*Tuxon. 2 (9) (2).

Tavs, A. A., Okoto, P. E. and Agoreyo, F. O. (2010). Anti-diarrhoea and toxicological evaluation of the leaf extract of *Dissotis rotundifolia triana* (Melastomataceae). BMC Complement Alternative Medicine.10: 71.

USDA (2013). Grain Report: Global Agricultural Information Network.

West Africa Rice Development Association (WARDA) (1999). Rice Interspecific Hybridization Project: Research Highlights 1999. WARDA, Bouaké, Côte d'Ivoire, pp.34.

WARDA, (2000). Annual Report, Bouaké, Côte d'Ivoire. 74.

WARDA, (2001). NERICA Rice for Life.

WARDA, (2002). Promising Technologies for Rice Production in West and Central Africa. Bouaké, Côte d'Ivoire and FAO, Rome, Italy. 28.

Yao, Y., Yamamoto, Y., Wang, Y., Yoshida, T, Miyazaki, A., Nitta, Y. and Cai, J. (2000). Role of Nitrogen regulation in sink and source formation of high yielding rice cultivars. Soil Science Plant Nutrition. 46:825-834.

APPENDICES

Appendix Ia: ANOVA for plant height – Site 1 (Kerio Valley)

Source of variation	df	SS	MS	F value	Pr> F
Blocks	2	806.8125	403.4063	22.29	<.0001
Planting method	1	508.7604	508.7604	28.11	0.0001
Weeding	1	1372.5938	1372.5938	75.85	<.0001
Variety	1	162.7604	162.7604	8.99	0.0096
Planting method x weeding	1	55.5104	55.5104	3.07	0.1017
Planting method x variety	1	0.0104	0.0104	0.00	0.9812
Weeding x variety	1	3.0104	3.0104	0.17	0.6895
Planting methd x weeding x var	1	11.3438	11.3438	0.63	0.4417
Error	14	253.3542	18.0967		
Total	23	3174.1563			

R-Square	CoeffVar	Root MSE	Plant height Mean (cm)
0.9	4.8	4.3	94.4

Appendix Ib: ANOVA for plant height – Site 2 (Marigat)

Source of variation	df	SS	MS	F value	Pr> F
Blocks	2	18.3958	9.1979	0.36	0.7022
Planting method	1	956.3438	956.3438	37.70	<.0001
Weeding	1	137.7604	137.7604	5.43	0.0352
Variety	1	276.7604	276.7604	10.91	0.0052
Planting method x weeding	1	23.0104	23.0104	0.91	0.3570
Planting method x variety	1	41.3438	41.3438	1.63	0.2225
Weeding x variety	1	137.7604	137.7604	5.43	0.0352
Planting methd x weeding x var	1	31.5104	31.5104	1.24	0.2838
Error	14	355.1042	25.3646		
Total	23	1977.9896			

R-Square	CoeffVar	Root MSE	Plant height Mean (cm)
0.8	6.1	5.0	86.9

Appendix IIa: ANOVA for number of productive tillers/hill – Site 1 (Kerio Valley)

Source of variation	df	SS	MS	F value	Pr> F
Blocks	2	0.3333	0.1667	1.40	0.2791
Planting method	1	1.5000	1.5000	12.60	0.0032
Weeding	1	4.1667	4.1667	35.00	<.0001
Variety	1	8.1667	8.1667	68.60	<.0001
Planting method x weeding	1	0.0000	0.0000	0.00	1.0000
Planting method x variety	1	0.6667	0.6667	5.60	0.0329
Weeding x variety	1	0.6667	0.6667	5.60	0.0329
Planting methd x weeding x var	1	0.1667	0.1667	1.40	0.2564
Error	14	1.6667	0.1190		
Total	23	17.3333			

R-Square	CoeffVar	Root MSE	No. of productive tillers Mean
0.9	10.9	0.3	3.2

Appendix IIb: ANOVA for number of productive tillers/hill – Site 2 (Marigat)

Source of variation	df	SS	MS	F value	Pr> F
Blocks	2	5.0833	2.5417	3.07	0.0783
Planting method	1	18.3750	18.3750	22.21	0.0003
Weeding	1	2.0417	2.0417	2.47	0.1385
Variety	1	18.3750	18.3750	22.21	0.0003
Planting method x weeding	1	0.0417	0.0417	0.05	0.8257
Planting method x variety	1	3.3750	3.3750	4.08	0.0630
Weeding x variety	1	0.0417	0.0417	0.05	0.8257
Planting methd x weeding x var	1	0.0417	0.0417	0.05	0.8257
Error	14	11.5833	0.82738		
Total	23	58.9583			

R-Square	CoeffVar	Root MSE	No. of productive tillers Mean
0.8	15.9	0.9	5.7

Appendix IIIa: ANOVA for number of spikelets/tiller – Site 1 (Kerio Valley)

Source of variation	df	SS	MS	F value	Pr> F
Blocks	2	2.0833	1.0417	0.96	0.4081
Planting method	1	1.0417	1.0417	0.96	0.3447
Weeding	1	2.0417	2.0417	1.87	0.1925
Variety	1	3.3750	3.3750	3.10	0.1002
Planting method x weeding	1	0.0417	0.0417	0.04	0.8477
Planting method x variety	1	2.0417	2.0417	1.87	0.1925
Weeding x variety	1	0.0417	0.0417	0.04	0.8477
Planting methd x weeding x var	1	0.0417	0.0417	0.04	0.8477
Error	14	15.2500	1.0893		
Total	23	25.9583			

R-Square	CoeffVar	Root MSE	No. of spikelets Mean
0.4	11.0	1.0	9.5

Appendix IIIb: ANOVA for number of spikelets/tiller – Site 2 (Marigat)

Source of variation	df	SS	MS	F value	Pr> F
Blocks	2	7.5833	3.7917	1.10	0.3611
Planting method	1	15.0417	15.0417	4.35	0.0558
Weeding	1	5.0417	5.0417	1.46	0.2473
Variety	1	3.3750	3.3750	0.98	0.3400
Planting method x weeding	1	0.0417	0.0417	0.01	0.9142
Planting method x variety	1	0.3750	0.3750	0.11	0.7468
Weeding x variety	1	1.0417	1.0417	0.30	0.5918
Planting methd x weeding x var	1	2.0417	2.0417	0.59	0.4550
Error	14	48.4167	3.4583		
Total	23	82.9583			

R-Square	CoeffVar	Root MSE	No. of spikelets Mean
0.4	22.4	1.9	8.3

Appendix 1Va: ANOVA for weed dry matter – Site 1 (Kerio Valley)

Source of variation	df	SS	MS	F value	Pr> F
Block	2	18.2058	9.1029	5.59	0.0164
Planting method	1	6.4067	6.4067	3.93	0.0673
Weeding	1	8.6400	8.6400	5.30	0.0371
Variety	1	0.4817	0.4817	0.30	0.5952
Planting method x weeding	1	2.4067	2.4067	1.48	0.2443
Planting method x variety	1	0.0150	0.0150	0.01	0.9249
Weeding x variety	1	0.0150	0.0150	0.01	0.9249
Planting methd x weeding x var	1	0.0150	0.0150	0.01	0.9249
Error	14	22.8075	1.6291		
Total	23	58.9933			

R-Square	CoeffVar	Root MSE	weed dry matter Mean (tons/ha)
0.6	117.8	1.3	1.1

Appendix IVb: ANOVA for weed dry matter – Site 2 (Marigat)

Source of variation	df	SS	MS	F value	Pr> F
Block	2	8.1258	4.0629	1.74	0.2114
Planting method	1	5.4150	5.4150	2.32	0.1501
Weeding	1	16.3350	16.3350	6.99	0.0192
Variety	1	2.2817	2.2817	0.98	0.3397
Planting method x weeding	1	3.8400	3.8400	1.64	0.2206
Planting method x variety	1	0.3267	0.3267	0.14	0.7140
Weeding x variety	1	0.9600	0.9600	0.41	0.5318
Planting methd x weeding x var	1	0.3750	0.3750	0.16	0.6947
Error	14	32.6942	2.3353		
Total	23	70.3533			

R-Square	CoeffVar	Root MSE	weed dry matter Mean (tons/ha)
0.5	125.6	1.5	1.2

Appendix Va: ANOVA for 1000-grain weight – Site 1 (Kerio Valley)

Source of variation	df	SS	MS	F value	Pr> F
Blocks	2	1.6300	0.8150	1.28	0.3093
Planting method	1	2.5350	2.5350	3.97	0.0661
Weeding	1	8.8817	8.8817	13.92	0.0022
Variety	1	2.8017	2.8017	4.39	0.0548
Planting method x weeding	1	1.0417	1.0417	1.63	0.2221
Planting method x variety	1	0.0017	0.0017	0.00	0.9600
Weeding x variety	1	1.0417	1.0417	1.63	0.2221
Planting methd x weeding x var	1	0.0817	0.0817	0.13	0.7258
Error	14	8.9300	0.6379		
Total	23	26.9450			

R-Square	CoeffVar	Root MSE	1000-grain wt Mean (g)
0.7	2.8	0.8	28.3

Appendix Vb: ANOVA for 1000-grain weight – Site 2 (Marigat)

Source of variation	df	SS	MS	F value	Pr> F
Blocks	2	4.4800	2.2400	1.09	0.3619
Planting method	1	3.5267	3.5267	1.72	0.2105
Weeding	1	1.9267	1.9267	0.94	0.3485
Variety	1	22.4267	22.4267	10.95	0.0052
Planting method x weeding	1	0.8067	0.8067	0.39	0.5403
Planting method x variety	1	0.2400	0.2400	0.12	0.7372
Weeding x variety	1	0.4267	0.4267	0.21	0.6550
Planting methd x weeding x var	1	0.0000	0.0000	0.00	1.0000
Error	14	28.6667	2.0476		
Total	23	62.5000			

R-Square	CoeffVar	Root MSE	1000-grain wt Mean (g)
0.5	5.2	1.4	27

Appendix VIa: ANOVA for grain yield – Site 1 (Kerio Valley)

Source of variation	df	SS	MS	F value	Pr> F
Block	2	1.9823	0.9911	1.33	0.2962
Planting method	1	8.6760	8.6760	11.63	0.0042
Weeding	1	18.7797	18.7797	25.18	0.0002
Variety	1	13.6353	13.6353	18.28	0.0008
Planting method x weeding	1	2.2387	2.2387	3.00	0.1052
Planting method x variety	1	2.3250	2.3250	3.12	0.0993
Weeding x variety	1	0.1650	0.1650	0.22	0.6454
Planting methd x weeding x var	1	3.3227	3.3227	4.45	0.0533
Error	14	10.4425	0.7459		
Total	23	61.5673			

R-Square	CoeffVar	Root MSE	Yield Mean (tons/ha)
0.8	20.4	0.9	4.2

Appendix VIb: ANOVA for grain yield – Site 2 (Marigat)

Source of variation	df	SS	MS	F value	Pr> F
Block	2	4.2893	2.1447	10.74	0.0015
Planting method	1	32.0628	32.0628	160.53	<.0001
Weeding	1	15.9740	15.9740	79.98	<.0001
Variety	1	6.0803	6.0803	30.44	<.0001
Planting method x weeding	1	2.0768	2.0768	10.40	0.0061
Planting method x variety	1	1.4603	1.4603	7.31	0.0171
Weeding x variety	1	2.8291	2.8291	14.16	0.0021
Planting methd x weeding x var	1	1.7067	1.7067	8.55	0.0111
Error	14	2.7962	0.1997		
Total	23	69.2754			

R-Square	CoeffVar	Root MSE	Yield Mean (tons/ha)
0.95	10.8	0.4	4.2

Appendix VIIa: ANOVA for harvest index – Site 1 (Kerio Valley)

Source of variation	df	SS	MS	F value	Pr> F
Block	2	252.9542	126.4771	3.42	0.0617
Planting method	1	45.2925	45.2925	1.23	0.2870
Weeding	1	673.6301	673.6301	18.22	0.0008
Variety	1	526.8751	526.8751	14.25	0.0020
Planting method x weeding	1	11.5787	11.5787	0.31	0.5846
Planting method x variety	1	58.1259	58.1259	1.57	0.2304
Weeding x variety	1	89.1276	89.1276	2.41	0.1428
Planting methd x weeding x var	1	104.2917	104.2917	2.82	0.1152
Error	14	517.5600	36.9686		
Total	23	2279.4359			

R-Square	Coeff.Var (%)	Root MSE	Harvest index mean (%)
0.8	15.5	6.1	39.3

Appendix VIIb: ANOVA for harvest index – Site 2 (Marigat)

Source of variation	df	SS	MS	F value	Pr> F
Block	2	485.4600	242.7300	24.00	<.0001
Planting method	1	615.8027	615.8027	60.89	<.0001
Weeding	1	273.4425	273.4425	27.04	0.0001
Variety	1	161.2535	161.2535	15.94	0.0013
Planting method x weeding	1	152.4600	152.4600	15.08	0.0017
Planting method x variety	1	11.8863	11.8863	1.18	0.2966
Weeding x variety	1	12.7458	12.7458	1.26	0.2805
Planting methd x weeding x var	1	2.1182	2.1182	0.21	0.6542
Error	14	141.5874	10.1134		
Total	23	1856.7565			

R-Square	Coeff.Var (%)	Root MSE	Harvest index mean (%)
0.9	8.0	3.2	39.9

Appendix VIII: ANOVA for mortality of Antelope grass (*Echinochloa pyramidalis*) – Site 1 (Kerio Valley)

Source of variation	df	SS	MS	F value	Pr> F
Block	2	397.5678	198.7839	3.55	0.0567
Planting method	1	849.6600	849.6600	15.16	0.0016
Weeding	1	1931.7793	1931.7793	34.46	<.0001
Variety	1	117.5723	117.5723	2.10	0.1696
Planting method x weeding	1	10.7201	10.7201	0.19	0.6685
Planting method x variety	1	5.1153	5.1153	0.09	0.7670
Weeding x variety	1	0.5400	0.5400	0.01	0.9232
Planting methd x weeding x var	1	4.5067	4.5067	0.08	0.7809
Error	14	784.7388	56.0528		
Total	23	4102.2002			

R-Square	Coeff.Var (%)	Root MSE	Antelope grass mortality mean (%)
0.8	14.4	7.5	52.0

Appendix IXa: ANOVA for mortality of Nut grass (*Cyperus rotundus*) – Site 1 (Kerio Valley)

Source of variation	df	SS	MS	F value	Pr> F
Block	2	1404.9950	702.4975	9.98	0.0020
Planting method	1	1803.1867	1803.1867	25.62	0.0002
Weeding	1	2638.6551	2638.6551	37.49	<.0001
Variety	1	181.1152	181.1152	2.57	0.1310
Planting method x weeding	1	86.1467	86.1467	1.22	0.2872
Planting method x variety	1	27.8857	27.8857	0.40	0.5392
Weeding x variety	1	0.8251	0.8251	0.01	0.9153
Planting methd x weeding x var	1	158.8776	158.8776	2.26	0.1552
Error	14	985.3564	70.3826		
Total	23	7287.0435			

R-Square	Coeff.Var (%)	Root MSE	Nut grass mortality mean (%)
0.9	12.9	8.4	65.1

Appendix IXb: ANOVA for mortality of Nut grass (*Cyperus rotundus*) – Site 2 (Marigat)

Source of variation	df	SS	MS	F value	Pr> F
Block	2	154.6822	77.3411	2.66	0.1051
Planting method	1	1798.6822	1798.6822	61.80	<.0001
Weeding	1	2843.3797	2843.3797	97.69	<.0001
Variety	1	0.1190	0.1190	0.00	0.9499
Planting method x weeding	1	3.6895	3.6895	0.13	0.7271
Planting method x variety	1	37.4250	37.4250	1.29	0.2759
Weeding x variety	1	64.7802	64.7802	2.23	0.1579
Planting methd x weeding x var	1	4.1417	4.1417	0.14	0.7117
Error	14	407.4834	29.1060		
Total	23	5314.3829			

R-Square	Coeff.Var (%)	Root MSE	Nut grass mortality mean (%)
0.9	8.9	5.4	60.4

Appendix X: ANOVA for mortality of Star grass (*Cynodon dactylon*) – Site 1 (Kerio Valley)

Source of variation	df	SS	MS	F value	Pr> F
Block	2	81.5953	40.7977	1.74	0.2113
Planting method	1	343.0728	343.0728	14.64	0.0019
Weeding	1	670.3494	670.3494	28.60	0.0001
Variety	1	61.1843	61.1843	2.61	0.1285
Planting method x weeding	1	15.4562	15.4562	0.66	0.4303
Planting method x variety	1	0.9362	0.9362	0.04	0.8445
Weeding x variety	1	0.8971	0.8971	0.04	0.8477
Planting methd x weeding x var	1	13.4700	13.4700	0.57	0.4610
Error	14	328.1296	23.4378		
Total	23	1515.0907			

R-Square	Coeff.Var (%)	Root MSE	Star grass mortality mean (%)
0.8	5.6	4.8	85.9

Appendix XI: ANOVA for mortality of Barnyard grass (*Echinochloa colona*) – Site 2 (Marigat)

Source of variation	df	SS	MS	F value	Pr> F
Block	2	363.2633	181.6317	3.55	0.0567
Planting method	1	1581.9384	1581.9384	30.91	<.0001
Weeding	1	3197.2725	3197.2725	62.47	<.0001
Variety	1	858.6084	858.6084	16.78	0.0011
Planting method x weeding	1	21.9842	21.984	20.43	0.5228
Planting method x variety	1	0.0145	0.0145	0.00	0.9868
Weeding x variety	1	201.5501	201.5501	3.94	0.0672
Planting methd x weeding x var	1	4.5850	4.5850	0.09	0.7691
Error	14	716.5581	51.1827		
Total	23	6945.7746			

R-Square	Coeff.Var (%)	Root MSE	Barnyard grass mortality mean (%)
0.9	9.9	7.2	72.1

Appendix XII: ANOVA for mortality of Pinklady (*Heterotis rotundifolia*) – Site 2 (Marigat)

Source of variation	df	SS	MS	F value	Pr> F
Block	2	21.8078	10.9039	1.15	0.3462
Planting method	1	143.8641	143.8641	15.11	0.0016
Weeding	1	250.9067	250.9067	26.36	0.0002
Variety	1	13.2908	13.2908	1.40	0.2571
Planting method x weeding	1	45.0456	45.0456	4.73	0.0472
Planting method x variety	1	4.2842	4.2842	0.45	0.5132
Weeding x variety	1	8.4254	8.4254	0.89	0.3628
Planting methd x weeding x var	1	1.7604	1.7604	0.18	0.6737
Error	14	133.2775	9.5198		
Total	23	622.6623			

R-Square	Coeff.Var (%)	Root MSE	Pinklady mortality mean (%)
0.8	3.2	3.1	95.7