UPLAND RICE GROWTH AND YIELD RESPONSE TO WEED MANAGEMENT PRACTICES UNDER RAINFED CONDITIONS

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ABSTRACT

Field experiments were conducted in two seasons at Sokoine University of Agriculture farm in Morogoro, Tanzania (6.85^{0}S; 37.64^{0}E and 568 m.a.s.l.) during the short rain (November 2014 to January 2015) and the long rain (March to June 2015). The experiment was a split plot in a randomized complete block design (RCBD) with 4 replications. Weed management practices (pre-emergence (ULTRA 2, 4-D), post-emergence (Hansunil), hoe weeding (3x) and weedy) were the main plot treatments and four rice genotypes (NERICA-1, NERICA-4, NERICA-7 and Mwangaza) were the subplots. Significant differences ($P<0.05$) were recorded for weed counts among weed management practices. The dominant weed group, as determined by the Summed Dominance Ratio (SDR), in both experiments was broadleaf species (50.8%) followed by sedges (25.2%) and grasses (24.0%). Post-emergence (8.6%) and hoe weeding (12.3%) significantly reduced weed dry biomass compared to pre-emergence (17.8%) and weedy (61.3%) in 2014/15 and 2015 experiments respectively. Significant differences ($P<0.05$) were recorded among the rice variables. Mwangaza and NERICA-1 were recorded with the tallest and shortest plant height (129.8cm and 39.1cm) respectively for weed management practices in both experiments. Mwangaza and NERICA-1 was recorded with the highest and lowest tiller (35.3/m^2 and 7.5m^2) respectively. Mwangaza and NERICA-7 was recorded with the lowest and highest LAI (2.5 and 4.5) and NERICA-7 showed the highest and lowest (1603g/m^2 and 305.1g/m^2) straw biomass in both experiments. Rice grain yield were highest for NERICA-1 in hoe weeded and plots applied with post-emergence herbicide (2187.5kg/ha and 1562.5kg/ha) > pre-emergence (965.9kg/ha) and weedy plots (0.0kg/ha) 2014/15 experiment and post-emergence and hoe weeded plots (4630.6kg/ha) and (4176.1kg/ha) > pre-emergence (3323.8kg/ha) and weedy plots (0.78kg/ha) 2015 experiment. The highest net return (3 352 846 Tshs) was obtained on NERICA-1 in post-emergence plots, this was also similar ($P<0.05$) to hoe weeding plots. Hansunil was also effective in weed control and had significant effect on profit analysis should be used in combination with hoe weeding under integrated weed management.

Key words: weeds, management, upland rice, yields, growth, profitability

DECLARATION

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

____________________ __________________

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The above declaration confirmed

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Prof. K. P. Sibuga Date

(Supervisor)

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LIST OF ABBREVIATIONS

DAS	Day After Sowing
FAO	Food and Agriculture Organization
FAORMM	Food and Agriculture Organization rice monitoring
FAOSTAT	Food and Agriculture Organization statistic
MAFC	Ministry of agriculture and food cooperation
NERICA	New Rice For Africa
RLDC	Rural livelihood development cooperation
RYMV	Resistant to Rice Yellow Mottle Virus
SSA	Sub-Sahara Africa
WARDA	West African rice development association

CHAPTER ONE

1.0 INTRODUCTION

Rice (*Oryza sativa* L.) is the most important cereal crop in agriculture and the economy of the world (MOAC, 2007). More than one third of the world's population depends on rice for their food requirements (Labrada, 2003). According to FAO (2008) one third of the world's population depends on rice for 50% of their daily caloric intake. Tanzania is the second largest producer of rice in Southern Africa after Madagascar with production level of 1.1 million tons Rice is the second most important food and commercial crop after maize; it is among the major sources of employment, income and food security for Tanzanian farming households (FAOSTAT, 2010).

The rice cultivated area by 2012 was 720 000 hectares and the 10-year (2003-2012) average yield was very low, estimated at 1.8 tons per ha as compared to Madagascar of which production is 2.5 tons per hectare (FAO, 2014). The average consumption of rice from 2002 to 2007 was 200 Kcal/capita/day compared to 553 cal/capita/day of maize and 208 Kcal/capita/day of cassava. Since rice is generally more expensive than maize and other staple foods, it is more important in the diets of high and middle income consumers in both urban and rural areas.

In addition to being a staple food for medium and high income consumers, rice is also the preferred dish for many households during social functions. Furthermore, it is often preferred by urban households because it is convenient to prepare. Thus, shifting consumer preferences from conventional foods to rice, increasing per capita incomes and rapid urbanization in recent years has resulted in a substantial increase in annual per capita rice consumption by nearly 20 percent to about 25 -30 kg/year (Kibanda, 2008). This growth in per capita rice consumption has stimulated both domestic production and rice imports (Minot, 2010).

However, imported rice is considered inferior in quality compared to local rice by consumers and, therefore, imported rice is sold at lower prices compared to domestic rice (Minot, 2010). The major production areas in the country include, Mwanza, Shinyanga, Tabora, Kilimanjaro, Coast, Mbeya, Rukwa and Morogoro regions. The latter two regions account for 25% of the national rice production (FAOSTAT, 2010). Agriculture is the backbone of the Tanzania's economy through employment, food production and export (MAFC, 2011). Upland rice is an important cash crop in many areas of eastern and southern Tanzania; including Morogoro. According to Kinyau *et al*. (2013), Morogoro is one of the major rice producing regions in Tanzania and rice production in Morogoro accounts for 45.6 % of the total rice produced in Tanzania (RLDC, 2009).

Weeds cause important yield reductions in rice, millet, sorghum, maize, and cowpea (Gbehounou and Assigbe, 2003; Maiti and Singh, 2004). Weeds are major constraint to rice production. Globally, weeds are estimated to account for 32% potential and 9% actual yield losses in rice (Oerke and Dehne, 2004). Weeds are among the greatest yield-limiting constraints to rice production in Africa (WARDA, 1996) including Tanzania, (Anwar *et al*., 2011). In Tanzania, rice farmers have witnessed a progressive decline in yield of rice associated with an increased severity of weed infestations (Mbwaga and Riches, 2006).

In irrigated production systems where rice is direct seeded, weeds are the major yield constraints (Becker *et al*., 2003). Uncontrolled weed growth is reported to cause yield losses in the range of 28–74% in transplanted lowland rice, 28–89% in direct-seeded lowland rice and 48–100% in upland ecosystems in West Africa (Diallo and Johnson, 1997). The risk of yield loss from weeds in direct-seeded rice is greater than transplanted rice (Rao *et al*., 2007). Ramzan (2003) reported yield reduction due to weed infestation up to 48% and 53% in transplanted and direct seeded-flooded rice, respectively. Sunil *et al*. (2010) also reported that season-long weed competition in direct seeded rice may cause yield reduction up to 80%.

Weed infestation has been mentioned as a major cause of yield gap under rain fed agriculture in the tropics thus contributing to about 25% yield loss in cereal crops according to Affholder *et al.* (2013). Inappropriate weed management practices have been highlighted as constraints in rice producing regions in Tanzania including Bagamoyo and Morogoro where hoe weeding was found to be as the most preferred management option for small holder farmers due cost and lack of basic knowledge on the use of modern agricultural technologies (Mkanthama, 2012). Given the numerous challenges faced by smallholder farmers in weed management, this study seeks to identify appropriate and effective weed management strategies in order to help reduce losses caused by weed thereby optimizing yield hence profitability. Weed control is important to prevent losses in yield and productions cost and preserve good grain quality (Ze Pu Zhang, 2001). Therefore, it is important to develop effective weed management strategies to control the damage of the weed in rice field. Effective control and management of weeds in upland rice farming will enable farmers to maximize and enhance sustainable rice production. The overall objective of this study was to develop effective weed management options for upland rice production. The specific objectives were:

i. To determine the efficacy of different weed control methods for management of weeds in upland rice farming.
ii. To quantify yield losses due to weed infestation in upland rice.
iii. To determine relative profitability of weed management practices for upland rice farming.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Rice production systems worldwide

According to (Balasubramanian *et al.*, 2007; FAO, 2009), rice (*Orzya sativa* L) is cultivated in five major ecosystem for production in different parts of the World; this can be distinguished based on water availability and topography: (i) rain fed upland rice on the plateau and hydroponic slopes (39%), (ii) rain fed lowland rice in the valley bottoms and flood plains (33%), (iii) irrigated rice delta flood plains and highlands (19%), (iv) deep-water floating rice along the river and (v) mangrove-swamp rice in lagoons and delta (9%).

2.2 Rice production in Africa

Rice is becoming an increasingly popular food in Africa due to easy storage and cooking; it is tasty and can be used for a large variety of dishes. It is grown in more than 75% of African countries, with annual forecast of 26.4 million tons Food and Agriculture Organization Rice Market Monitor (FAORMM, 2012). Much of the growth comes from Egypt, Mali, Ghana, Mozambique, Sierra Leone, Tanzania and Nigeria (FAO, 2012).

According to Seck *et al.* (2010) and FAO, (2014) rice production in Africa is second after maize, the most important cereal in Africa, with a total production of 29.0 Mt in 2013. Traditionally, rice is a main staple in West Africa and Madagascar. However, rice consumption is growing at 4.5% yearly throughout Africa and has become one of the main staple food crops in sub-Saharan Africa (SSA).

2.3 Rice Production in Tanzania

Rice is grown under three major ecosystems namely rain fed low land, upland or dry land and irrigated rice ecosystems (MAFC, 2009). Rain fed low land rice ecosystem occupies about 74%, rain fed upland rice ecosystem 20% and irrigated rice ecosystem is 6% in Tanzania (Kanyeka *et al.,* 1994). Production covers approximately 681 000 ha, representing 18 percent of cultivated land (Sagcot, 2010).

2.3.1 Upland Rice production system

Upland or dry land rice is grown in rain fed fields prepared and seeded when dry. The dry land or upland ecology where rain-fed rice is developed lacking prominence water represents about 40% of the total area under rice farming in West and Central Africa where it employs about 70% of rice farmers in the region (Africa Rice Centre, 2008). In Tanzania, upland rain-fed rice ecosystem is about 20% of the total rice cultivated area (Kanyeka *et al.*, 1994; Kajiru *et al.*, 2011). Many upland or dry land rice producers' plant land races that do not respond well to improved management practices, but these land races are well adapted to their environments and produce grains that meet local needs (Rosemary *et al.,* 2010).

Upland rice is grown in diverse systems, ranging from shifting cultivation to relatively intensive systems, utilizing hand, animal or mechanized tillage and rotations with other crops, including cotton, legumes and other cereals. Upland or dry land rice is drilled, broadcast, or row seeded (De Datta, 1981). Upland or dry land rice is grown naturally under rain fed since it cannot withstand water logging (Khanal *et al*., 2012; Ahmadi, 2004).

Upland or dry land rice is grown on both flat and sloping fields that are not bunded, but are prepared and seeded under dry conditions and depend on rainfall for moisture (De Datta, 1975; Fageria *et al.*, 1997). Upland or dry land rice does not need water ponding in the fields during its crop growing period (Fageria, 2010). According to Fageria *et al.* (1997), the overriding difference distinguishing upland or dry land rice from low land rice production systems is the soil moisture regime. Upland rice soils are not either submerged or saturated with water for any appreciable part of the growing season.

Upland land rice adjusts itself to a diametrically opposite environment of dry and aerobic soils (Ponnamperuma, 1975). Ceesay (2004) reported that adequate and assured soil moisture reserves during the critical periods of crop growth, evenly distributed rain fall during the cropping season and fertile soils with minimum risks of erosion are the favorable and sustainable environments for upland rice production. Upland land rice varieties include any rice cultivar of *Oryza sativa* or *O. glaberrima* that is suited for upland land rice farming; such upland rice varieties include the 18 (NERICA) named upland rice and WAB (Africa Rice Centre, 2008).

2.3.2 Suitable soils for upland rice production

Rice is adapted to a wide range of soil conditions and can be grown on sandy loams to heavy clays provided there is adequate soil moisture (Fageria *et al*., 1997). It is an acid tolerant crop with an optimum soil pH at about 5 for upland rice culture (Fageria and Zimmermann, 1996). It is considered to be moderately susceptible to soil salinity, with threshold salinity of about 3 dSm^{-1} (Maas and Hoffman, 1977). Upland rice is grown in a wide range of soil pH values, but most upland soils have pH ranging from 4.5 - 6.5 which is suitable for rice production.

Upland rice is rarely grown on saline and sodic soils, because of salinity problems which inhibit water and mineral uptake from the soil. Upland rice soils range from eroded and badly leached to fertile volcanic soils. The textures, water holding capacities, cation exchange capacities (CEC), nutrient status and soil related problems of such soils vary greatly (Martinez-Beltran and Manzur, 2005).

Soil texture is an indication of the soils' suitability for rice as it influences water movement and storage, air flow and ability of a soil to supply nutrients to plants and it is very important in rice production system or practice. However, clay soils which have larger surface areas and higher water retention capacity are good for upland rice production (De Datta and Feuer, 1975).

2.4 Weed and Crop Competition

Crop competitiveness against weeds is composed of tolerance to weed infestation, which is the ability to maintain high yields under weedy conditions, and weed suppressive ability, which is the capacity to suppress weed growth in terms of dry matter accumulation (Fischer *et al*., 1997). Screening weed-competitive genotypes could offer an opportunity for using them as a component of integrated weed management strategies in dry seeded rice. However, only few genotypes of rice with superior weed competitiveness are known (Haefele *et al*., 2004). Hybrids, due to their early vigor, may have the potential to complement the limited set of available competitive germplasm for dry seeded rice. Dry seeded rice genotypes with yield potential, high environmental adaptation, early vigor, have favorable growth traits for weed suppression. Empirical evidence of superior performance of hybrids and new inbred lines adapted to dry seeded rice, in particular, the ability to better cope with weeds is still awaited. Various authors have suggested the evaluation of hybrids in dry seeded rice be conducted to confirm the possession of weed competitive traits and provide farmers with a wider choice of options when cultivating dry seeded rice (Chauhan *et al*., 2012).

Morphological, physiological, and biochemical traits are thought to control plant competitiveness (Lemerle *et al*., 2001). Plant height plays a role in the competitive ability of rice (Garrity *et al*., 1992). Crop height appeared to have the greatest impact on competitive ability, with the shortest cultivars experiencing the largest yield reductions and allowing the greatest weed growth. However, height alone does not explain competitive ability because some shorter cultivars have been found to be good competitors in rice (Gibson *et al*., 2001). Some workers found that rice leaf area index (LAI) to be negatively correlated with specific leaf area, dry matter partitioning of leaves, and mean tip elevation angle (Dingkuhn *et al*., 1999).

Dingkuhn *et al*. (1999), concluded that specific leaf area and tillering ability are major determinants of vegetative vigor. Vegetative vigor and crop duration affecting the ability of genotypes to recover from early competition are the useful traits in the selection of weed competitive rice. Early season ground cover also reduces subsequent weed biomass which was reported by many researchers (Richards and Whytock 1993; Hucl, 1996 and Zhao *et al*., 2006). A mechanism through which a rice genotype becomes more hostile or competitive to weeds would not only serve to assist plant breeders in developing competitive cultivars more quickly and effectively but would also justify the use of plant breeding to increase crop-competitive ability against weeds (Zhao *et al*., 2006).

According to Wang *et al*. (2002), yield gains of 7–9% have been identified in "competitive" aerobic cultivars when compared with "noncompetitive" cultivars. The critical period of weed control is an intermission in the life cycle of a crop which must be kept weed free to prevent yield loss (Knezevic *et al*., 2002). In rice, this is before it has formed a clogged canopy, when the crop is tillering (Chauhan *et al*., 2011). Johnson (1996) reported that weed management during the early growth stages of rice is essential to reduce the competition for light, nutrients and water. In reference to direct seeded rice, this is roughly 40 days after seeding.

Understanding of critical period of weed control is one of the most important tools in integrated weed management according to Swanton and Weise, (1991). Weed species differ in their ability to compete with rice. The relative competitive ability between annual and perennial weeds largely depends on the weed species and the growing conditions (Ampong-Nyarko and De Datta, 1991).

Kropff *et al.* (1993b) reported that the critical period of weed struggle is defined as the time interval between the highest weed-infested period, and the length of time that the crop must be free of weeds after emergence. According to Hall *et al.* (1992), the critical period of weed competition is not necessarily the time of the most intense interference, rather the critical period is the number of weeks after crop emergence during which a crop must be weed-free in order to prevent yield losses.

2.4.1 Weeds in upland rice production system

A wide range of weeds infest upland rice, many of which are pan-tropical, including the grass weeds: *Digitaria* spp. (crabgrass), *Echinochloa colona (*Jungle rice), *Eleusine indica (*crowsfoot grass), *Paspalum* spp. (swamp couch), and *Rottboellia cochinchinensis (*guinea-fowl grass), and the broadleaf weeds: *Commelina* spp. (dayflowers), *Ageratum conyzoides (*goat weed), *Portulaca oleracea (*little-hogweed), *Amaranthus* spp (pigweed). and *Euphorbia* spp.(apple ring acacia). The variability of weed species composition in upland rice tends to be greater than in the other production systems, and is dependent upon ecology, the cropping system and management practice (De Datta, 1981).

The most important biotic constraint to upland rice farming is weeds (Ahmadi, 2004). Kone *et al.* (2014) reported that the weeds most likely to thrive in the upland rice fields are those which require less water or high temperature to break seed dormancy. The most abundant weed in upland rice farming in Tanzania is *Digitaria* spp. (crabgrass). Others are *Cyperus rotundus (nut grass), Echinochloa colona (*Jungle rice)*, Imperatha cylindricall (*Red Baron grass)*, Chromolaena odorata (*Siam Weed)*, Ageratum conyzoides (*goat weed), Striga *spp.* (witchweed) and *Euphorbia heterophylla(*Mexican fireplant). (Rodenburg and Johnson, 2009; Kone *et al.,* 2014).

2.4.2 Factors affecting rice weed competition

The availability of light, water, and nutrients affects the growth and competitiveness of plants. In theory, the amount of these resources in a given rice environment is fixed whatever is used by one plant species is not available for another. This means that resources taken by weeds are lost to rice, and vice versa. In general, rice dry matter yield is reduced by 1kg for every kilogram of weeds produced in the same area. Weed species differ in their ability to compete with rice (Gibson *et al*., 2004).

The degree of rice-weed competition depends on rainfall, rice variety, soil factors, weed density, duration of rice; weed growth and crop age when weeds started to compete, and nutrient resources, among other variables. The relative competitive ability between annual and perennial weeds largely depends on the weed species and the growing conditions (Ampong-Nyarko and De Datta, 1991).

2.4.2.1 Rainfall

Rain fall is the most variable and least predictable agro-climatic element. Its amount and distribution determine the upland rice cropping season. Rice is so sensitive to water stress, as such rainfall distribution is more important than seasonal entirety (Jana and De Datta, 1971) showed that water deficits reduced yields in experiments in the Philippines even when annual rainfall was more than 2,000mm. Three basic tropical rainfall regimes affect upland rice culture: generally even rainfall throughout the year, a mono-modal annual peak, and bimodal annual peaks. Most seasonal and spatial rainfall variation is associated with movement of the inter tropical convergence zone (ITCZ). The ITCZ is a function of the displacement and intensities of semi permanent temperate high pressure systems Jackson (1977).

Upland rice is planted as alternative crops of farmers for household consumption or for sale in local market. However, one of the major problems of upland rice in southern Thailand is a drought that causing lack of rain, specifically during the rainy season when the rainfall is less than 1 mm/day with more than 15 consecutive days. Drought during the rainy season is incidentally caused by climate change, which would seriously affect growth and yield of upland rice (Nokkoul *et al.*, 2011). Tillering and leaf canopy development are known important traits affecting interspecific competition. Increased CO_2 levels are likely to be accompanied with higher temperatures favoring C_4 weeds over C_3 crops (Fuhrer, 2003). The same outcome can be expected under increased or prolonged drought conditions (Bjorkman, 1976). Even though precise changes in rainfall are difficult to predict, precipitation is likely to become more unreliable with more accustomed droughts and floods (Giannini *et al.*, 2008).

2.4.2.2 Rice varieties

In a plant community, competition occurs when the environmental resources are limited. Competition for limited resources is the primary cause of crop loss from weeds. Crop cultivars that better compete with weeds or prevent resources from weeds may benefit an integrated weed management program (Jordan 1993; Lemerle *et al.,* 1996; Lindquist and Kropff, 1996). The competitive ability of a plant has two components, the competitive effect-ability of an individual to suppress other individuals and the competitive response-ability of an individual to avoid being suppressed corresponding to different abilities of plants to acquire and use resources (Goldberg, 1990). Competitive effect is related to resource acquisition, with large or tall plants being able to competitively depress smaller ones (Gaudet and Keddy, 1988; Keddy and Shipley, 1989; Aarssen, 1992).

Plants avoid being suppressed by acquiring resources by means of foraging strategy, shift resource acquisition site or time relative to neighbors by means of escaping strategy, or conserve scarce resources by means of persistent strategy (Navas and Moreau-Richard 2005). The development of competitive crop cultivars is an important aspect of integrated weed management and can reduce reliance on herbicides (McDonald, 2003). The ideal weed competitive cultivars are high yielding under both weed free and weedy conditions and have strong weed suppressive ability. Weed suppressive ability is the ability to suppress weed growth and reduce weed seed production and, hence, benefit weed management in the subsequent growing season (Jannink *et al*., 2000; Zhao *et al*., 2006).

Dingkuhn *et al*. (1999) also considered relative yield (the ratio of grain yield under weedy conditions and grain yield under weed-free conditions) as an indicator of weed competitiveness and Rodenburg *et al*. (2009) showed that longer duration and higher yield under weed-free conditions were associated with higher grain yields under weedy conditions.

In a general view, crop competitive ability can be divided into two practical perspectives; crop tolerance which is the ability of the crop to endure competitive stress from the presence of weeds without substantial reduction in growth or yield and weed suppressive ability which is the ability of the crop to reduce weed growth and fecundity (So *et al*., 2009; Spies *et al.,* 2011). However, Saito *et al.* (2010) noted that stronger weed suppressive ability is not always associated with higher yield under weedy conditions.

Ideally, a competitive cultivar should both tolerate weeds and suppress their growth (Jordan, 1993). The tolerance of a crop cultivar to weeds is the ability of that cultivar to maintain high seed yields when weeds are present. The weed suppression ability of a crop cultivar is the ability of that cultivar to reduce weed growth and subsequent seed production (Spies *et al*., 2011).

2.4.2.3 Soil factors

Soils are formed through the interaction of five major factors; time, climate, parent material, topography and relief, and organisms. The relative influence of each factor varies from place to place, but the combination of all five factors normally determines the kind of soil developing in any given place. However, in the tropics soil degradation is a widespread phenomenon which only sometimes is reversible. Surface sealing development in some intensively tilled soils, the consequence of a number of soil management practices, such as the use of pre-emergence herbicides, harrowing, ploughing and weeding, is one of those processes which are reversible. Depending upon certain conditions, these practices can induce erosion and losses of soil, water and organic matter. Recognition of the fact that erosivity of rain in the humid tropics is substantially greater than in the temperate is recent (Greenland, 1994).

Healthy, high organic matter soils host a greater diversity of soil microorganisms and invertebrates, which can enhance both weed seed decay and predation (Gallandt *et al*., 1998). In fact, carabid beetles known to be effective weed seed predators were measured in high numbers at Biodesign in a 2006 beneficial insect study (Fennimore and Jackson, 2003). There is some evidence that weeds may be more competitive with crops in higher soil nutrient level fields, especially high nitrogen levels (Di Tomaso, 1995). Some studies suggest that low early season nitrogen levels could result in selective weed suppression (Liebman and Davis, 2000).

However, the problem of soil erosion remains one of the most serious, threatening the future of mankind (Greenland, 1979a). In the tropics, little is known about the effects of various weed control strategies on soil structure, water dynamics and other physical properties, like micro structural reorganization (Hall, 1990; Kooistra *et al.,* 1990). For tree crops, where the use of ground vegetation to protect the surface has long been a common practice, herbicides are increasingly applied to soils prone to erosion, thus replacing traditional hand-weeding, hoeing and cultivation. In the highlands, traditional farming systems are widespread, based on small-scale farmers, who rely on hand cultivation and simple ploughs to prepare their lands (Monteiro and Resende, 1988). These traditional farmers produce subsistence crops of bean, rice and corn, as well as perennials. The crops are grown mainly on clayey terrace soils, covering approximately one third of available land (Ker and Schaefer, 1995).

2.4.2.4 Weed density

A weed density that causes a 5% yield loss is often used as a threshold value at which herbicidal control is necessary to prevent intolerable loss (Brainard *et al.,* 2013). Weed response to soil applied herbicides is dependent on weed density with herbicide efficacy decreasing with increasing weed density. The soil in this case is merely the medium supporting the weed. Soil texture, organic matter and pH influence the bioavailability of soil applied herbicides. Application rates of many soil applied herbicides vary with soil properties in order to 'provide' a constant quantity of biologically active herbicide to interact with the weed (Hoffman and Lavy, 1978).

Even with herbicide rates adjusted to compensate for soil properties there is a weed density effect on herbicide activity. Since we are actually treating the weed rather than the soil the more weeds present the greater the amount of herbicide required for the same level of activity. This is due to competition between plants for the available herbicide even though this competition is harmful to the plant. With a constant amount of herbicide present as weed population increases the amount of herbicide available for each weed decreases consequential in decreased activity (Hoffman and Lavy, 1978).

2.4.2.5 Nutrient resources

A suitable nutrient management program can be an effective tool to control weeds in cropping systems. The competitive relationship between crop and weeds is highly dependent on supply and availability of nutrients (Evans *et al*., 2003; Di Tomaso, 1995). Sibuga and Bandeen (1980) also reported that weed may be more competitive when fertility is enhanced with N addition because of the superior up take efficiency of many weed species. Therefore, management of soil fertility, whether using organic or inorganic amendments should be considered as an important component of long-term weed management programs and effective fertilizer management is an important component of integrated weed management systems (Blackshaw *et al*., 2007; Di Tomaso, 1995).

Nutrients applied to soils are also available for weeds. In most farming systems, competition for N is the most important source of nutrient interference (Di Tomaso, 1995). Walker and Buchanan (1982) also reported that of all nutrients, plant response to nitrogen (N) fertilizer is the most widely observed and the manipulation of soil N supply offers the most promise in the short term as a means by which crop weed competitive outcomes can be influenced. Therefore, it is important to develop fertilization strategies for crop production that enhance the competitive ability of the crop, minimize weed competition, and reduce the risk of nonpoint source pollution from nitrogen (Cathcart and Swanton 2003; Di Tomaso, 1995).

2.4.2.6 Competition for water

According to Chhokar *et al.* (1999), producing equal amounts of dry matter, weeds transpire more water than most of crop plants. It becomes increasingly critical with increasing soil moisture stress, as found in arid and semi-arid areas. As a rule, C_4 plants utilize water more efficiently resulting in more biomass per unit of water. *Cynodon dactylon* had almost twice as high transpiration rate as pearl millet. In weedy fields soil moisture may be exhausted by the time the crop reaches the fruiting stage, i.e. the peak consumptive use period of the crop, causing significant loss in crop yields.

2.4.2.7 Light competition

Competition for light can occur throughout rice growth. Most weeds and rice have maximum photosynthesis and growth in full sunlight. Competition for light occurs when new leaf shades another. Weeds compete with rice by growing faster and by shading rice with large, horizontal leaves. Tall plants have an advantage over short plants. For example, when *Rottboellia cochinchinensis* was allowed to grow with rice, *R. cochinchinensis* was 150 cm tall and rice was 50 cm tall at 8 week after seeding. The amount of light received at 25 cm within the rice canopy was only 3% of the light at the top of the weed canopy. In this situation, the weed clearly had an advantage (Labrada, 1996). In dry land agriculture in years of normal rainfall the crop-weed competition is limited to nitrogen and light. Unlike competition for nutrients and moisture once weeds shade a crop plant, increased light intensity cannot benefit it (Roberts, 1982).

2.4.2.8 Space competition

Crop-weed competition for space is the requirement for CO_2 and the competition may occur under extremely crowded plant community conditions. A more efficient utilization of CO_2 by C_4 type weeds may contribute to their rapid growth over C_3 type of crops. Resource independent effects such as hormonal and light quality signals can also play an important role in determining the outcome of crop–weed competition. The plant's ability to detect signals can be viewed within the context of competition as a communication pathway that may allow a plant to prepare, physiologically or morphologically, a preemptive response to impending competition (Ballaré 1999; Ballare *et al.,* 1990; Smith and Whitelam 1997). Photo sensory systems allow plants to monitor changes in light wavelength, intensity, and direction (Quail 2002; Smith, 2000). Competition between weeds and crops is expressed by altered growth and development of both species. Interspecific competition occurs when two or more species coexist in time and space and simultaneously demand limited resources. The evolution and survival of a species depends on the success of its interactions with its neighbors and its environment. Plants can interact with each other both negatively and positively, either directly or indirectly (Brooker *et al*., 2008).

Competition between plants for limiting resources is an example of a negative interaction. It is thought to drive the evolution of traits allowing species to occupy different niches, and therefore to access separate resources, either in space or time (Tilman, 1990; Grime, 2001). An example of a positive interaction is facilitation, whereby benefactor plants provide the environment or resources for beneficiary plants to establish themselves (Brooker *et al*., 2008). Thus, both negative and positive interactions can promote the coexistence of species and, through their complementarity, increase the productivity of an ecosystem (Bessler *et al*., 2012). Many interactions between neighbouring plants occur below ground. Competitive interactions often dominate in environments with ample supplies of mineral elements (Trinder *et al.,* 2012).

2.4.3 Yield losses due to weeds

On average, rice yield loss due to weed ranges from 15 to 20%, but in severe cases the yield loss may exceed 50% (Hasanuzzaman *et al.,* 2009) or even 100% (Mishra and Singh, 2007; Jayadeva *et al.,* 2011). Weeds were reported to reduce rice yields by 12 to 98% depending on the type of method of rice establishment. Rice yield losses due to uncontrolled weed growth and weed competition were least (12%) in transplanted rice (Singh *et al*., 2011), the highest in aerobic direct seeded rice on a furrow irrigated raised bed systems (Singh *et al.,* 2008) and in dry-seeded rice sown without tillage (Singh *et al*., 2011).

Threshold levels for a few weed species were also worked out; for example: *Cyperus iria* at density of $30m^{-2}$ and *Echinochloa crus-galli* density of $20m^{-2}$. This is considered the threshold level for transplanted rice, as it causes the minimum loss of 6.57% and 8.74%, respectively in grain yield above which control measures are to be undertaken (Singh and Angiras, 2003; 2008).

Grass weed seedlings that emerged in rice seedling nursery are unintentionally transplanted with rice seedlings (Rao and Moody, 1987). Average rice yield reductions from transplanted rice caused by *E. glabrescens* ranged from 6% at the 5% infestation level to 73% at the 40% infestation level (Rao and Moody, 1992). An on farm study indicated that the yield loss from weeds in un-weeded plots was highest in the rice-wheat system. Followed by rice-pea-rice, and was least in the sugarcane system. Weeds not only cause huge reductions in rice yields but also increase cost of cultivation, reduce input efficiency, interfere with agricultural operations, impair quality, act as alternate hosts for several insect pests, diseases, they affect visual look of the ecosystem as well as native biodiversity, affect human and cattle health (Singh *et al*., 2005).

The risk of greater crop yield losses due to weed competition in direct-seeded rice systems than in transplanted rice is mainly because of the absence of the seedling size differential between rice and weeds and the absence of the suppressive effect of standing water on weed emergence and growth at crop emergence time. Weeds in different direct-seeded systems can cause rice yield losses of up to 50% and these losses are after one hand weeding (or partial weed free conditions) in weed infested fields. In Asia, manual weeding and/or herbicides are commonly used to control weeds.

Weeds have been reported to cause considerable yield reduction in activated rice due to their competition for resources. Thus the extent of yield loss depends on density and diversity of weeds. Weeds are among the major causes of crop yields losses in rice (Cao *et al.*, 2007). They do this by competing with the rice crop for resources, such as soil nutrients, sunlight and water as well as space. The extent of yield loss will however depend on the weed density (Fisher and Ramirez, 1993), category of weeds (Diana *et al.,* 2002) and the competition duration (Kwon *et al*., 1991). Yield loss due to weed infested rice can be expressed not only in quantity of rice harvest (Estomenas *et al*., 2000) but also in a decreased quality of the grain (Kwon *et al.,* 1991; Pautone and Baker, 1991). Weeds have been reported to reduce yield in upland rice by over 80% (Tsuboi, 2005).

2.5 Weed Management

Successful weed control is essential for economical rice production. Weeds reduce rice yields by competing for moisture, nutrients, and light during the growing season. Weed infestations can also interfere with combine operation at harvest and can significantly increase harvesting and drying costs. Weed seed contamination of rice grain lowers grain quality and may lower the cash value of the crop. As with any biological system, an effective weed management program must consider many factors that vary from crop to crop and year to year. The most important of these factors include planting date, climatic conditions, seedbed preparation, seed quality, stand establishment, and water management (Sankaran and De Datta, 1985).

Weed management may begin before seeding or transplanting and in between the life cycle. No one method can be used to control weed, hence an integrated weed management system is advised. The use of varieties with improved competitiveness with weed and other practices have a potential to manage weed efficiently and in turn improve yield of rice (Kone *et al*., 2014).

2.5.1 Weed survival

Weeds are nourished by the same nutrients and environmental elements needed by the crop. Weeds interfere with rice growing by competing for one or more growth limiting resources, such as light, nutrients and water. Because of the limited supply of these vital elements, their association, therefore, leads to competition for these elements of survival.

During the cropping period, there is a particular duration, the critical period of competition, the presence of weeds above a certain density, critical threshold level, will cause a significant reduction in yield (Mercado, 1979).

2.5.2 Weed prevention in rice field

Prevention of weed introduction and spread is the most important strategy in managing weeds regardless of crop, establishment method, and ecosystem. The equipment used for tillage, planting, harvesting, and threshing should be clean (free from weed seeds) before moving them from one field to another. The most important preventive measure is the use of clean rice seeds. Weedy rice, for example, has spread in many Asian countries through contaminated rice seeds (Chauhan, 2013b). In a survey in Vietnam, more than one-third of the collected rice seed samples were found contaminated with weed seeds (Mai *et al.,* 2000). Managing weeds on bunds or levees and roads can also help in preventing invasion of weeds in rice fields.

The most basic of all weed control method is weed prevention. This includes the used of weed free seeds, maintain clean fields, irrigation canals and borders. However weeds have been known to adapt to these practices due to their ability to change their morphology according to (Buhler *et al*., 2000).

De Datta and Baltazar (1996) reported that preventive measures include using weed-free seeds, maintaining clean fields, borders, and irrigation canals, and cleaning farm equipments. Mai *et al.* (1998) reported on average 466 weed seeds/kg rice seeds including 314 weedy seeds in Vietnam, this is forty-seven-fold higher than permitted national purity level. Cousens and Mortimer (1995), reported that evident from the small grain crops that use of certified seed could significantly contribute to weed management.

2.5.3 Physical control of weeds in rice

Physical weed control is directly suppressing or removing weed plants in the field to enhance the competitiveness of the crop. Physical control methods include both mechanical and thermal weed management. As regards mechanical weed control, weeds are affected by tillage and soil cultivation in different ways; growing weeds and perennating organs are uprooted, dismembered, and buried; the soil environment becomes changed in such a way that germination and establishment of weeds is promoted; and weed seeds are moved vertically and horizontally which will affect the emergence, survival and competition of the weeds according to Mohler (2001).

2.5.4 Chemical control of weed in rice production

The use of herbicides is the most effective means of controlling weeds. Herbicides have gained their popularity due to the rapid effects and lower costs compared to traditional methods (Hassanuzaman *et al*., 2008). Herbicides are also likely to be useful in areas with a short supply of labor (Rodenburg and Demont, 2009). Herbicides are important control methods in the lowlands, and in upland rice grown in rotation with cotton (Johnson, 1997).

The use of herbicides is economically attractive as it requires less overall weeding time and it enables the farmer to use time- and labor-saving planting methods such as direct (broadcast) seeding (Riches *et al.*, 2005). Herbicides are likely to be particularly useful in areas where labor is in short supply. Farmers should also have sufficient financial resources to invest in herbicides and the return of such investments should be high enough (Posner and Crawford, 1991). Herbicides are often used in combination with other control options and, most farmers rely on chemical weed control followed by hand weeding (Haefele *et al*., 2002).

2.5.5 Herbicides

Herbicides are one of the most important tools for managing weeds in rice fields. Herbicide use is also very important where there is a morphological resemblance between weeds and rice, especially in broadcast rice (Naylor, 1994a). To achieve effective weed control, the use of pre-emergence herbicides is a must in direct-seeded rice systems, especially in dry-seeded ones. Some pre-emergence herbicides (e.g. oxadiazon), however, can be phytotoxic to crop emergence if heavy rain occurs immediately after herbicide application. This could be a serious problem where farmers use very low seeding rates Chauhan and Abugho (2012e).

The broad range of weeds in direct-seeded rice systems, especially aerobic rice systems, is a need to use mixtures of different compatible herbicides. Even after using herbicide mixtures, some weed species are not controlled effectively. Furthermore, due to high seed dormancy, some weed species (e.g., *Rottboellia cochinchinensis*) keep emerging throughout the crop season. Therefore, it is important to performed hand weeding to get rid of escaped weed species. Where farmers integrate herbicide use with other weed management strategies, such as high seeding rates, there may not be a need for hand weeding. However, direct-seeded rice sown at low seeding rates or using hybrids may need one hand weeding as canopy closure in such crops takes a longer time (Blumhorst *et al.,* 1990).

In the modern era, the use of herbicide-resistant rice is increasing. Non-transgenic herbicide resistant rice cultivars may gain popularity in the near future where weed is becoming a problem in direct seeded rice systems. No selective herbicide controls weed in a rice crop and therefore the use of herbicide resistant rice cultivars may manage weed and other problematic weeds very effectively. As herbicide use is expected to increase in the future, it is very important to understand the right application methods for herbicides. Improper and ineffective methods of herbicide application may result in damage to nontargeted plants; a great waste of chemicals, resulting in environmental pollution; and negative effects on human health (Carter, 2000).

Herbicides are the newest and often the most efficient weed management tool. Although herbicides have become a necessity in most crop production systems, most growers equate weed management solely with herbicides. Remember that herbicides are only one of the available weed control tools and that weed management is most successful and economical when all the tools for weed control are utilized in an integrated program. An herbicide or herbicide combination should be selected on the basis of its effectiveness on the different weed species in the field. The correct herbicide rate must be used to obtain good weed control results and to minimize crop injury. Apply the proper herbicide at the prescribed time and rate with a carefully calibrated applicator to provide the best return on your investment (Case and Mathers, 2006).

The underlying strategy behind using herbicides for weed control in rice is to kill or stunt the growth of weedy plants while allowing the rice plants to grow and achieve a competitive height advantage. Maintaining an effective height differential between the rice and weeds will allow the flood water to control weed growth by keeping them submerged while the rice plants grow above the water surface after the permanent flood is applied. If a good height differential exists between the weeds and the rice near the time of permanent flood, herbicide application may not be necessary (Chauhan and Abugho, 2012).

2.5.6 Allelopathy

The term allelopathy was first introduced by Hans Molisch in 1937 and refers to chemical exchanges among plants, as well as those mediated by microorganisms. Rice (1984) defined allelopathy as the special effects of one plant (including microorganisms) on another plant during the release of a chemical compounds into the environment. The utilization of allelopathy in agricultural practices as a tool for weed control has shown weed decrease, pathogen avoidance and soil enhancement (Kohli *et al*., 1998).

Crop cultivars differ in their allelopathic ability and thus superior cultivars can be selected for weed management programs (Wu *et al.,* 1999; Olofsdotter *et al.,* 2002). Differences in allelopathic potential between genotypes has been showing among accessions (genetical different lines or strains of a species) of barley, cucumber (*Cucumis sativus*), oats, soybean (*Glycine max*), sunflower, sorghum (*Sorghum bicolor*), rice and wheat (Copaja *et al.,* 1999, Dilday *et al*., 1994, Narwal, 1996, Miller, 1996, Yoshida *et al*., 1993, Wu *et al*., 1998). Many weed species are most susceptible to allelochemicals in the seed and seedling stages. Moreover, ideal allelopathic cultivar release allelochemicals in bioactive concentrations before the target weeds grow to old. However, the both critical developmental stage where the crop starts releasing allelochemicals and the critical sensitive stage of the target weeds is therefore essential (Inderjit and Olofsdotter, 1998).

Weed suppressive effects of crop residues have been explained by different mechanisms, including initial low nitrogen availability following cover crop incorporation (Dyck and Liebman 1994; Kumar *et al.,* 2008; Samson, 1991). Allelopathic compounds released from crop residues during decomposition can reduce both emergence and growth of weeds. Allelochemicals can be released either through leaching, decomposition of residues, volatilization or root exudation (Chou, 1999). In production systems with no-till or conservation tillage that leave nearly all crop residues on the soil surface, the release of allelochemicals from both the growing plants and during residue decomposition could be advantageous (Kruse *et al.,* 2000).

According to literature reviewed, it seems that weeds have been a persistent problem in rice culture since the beginning of agriculture (Naylor, 1996). Various losses caused by weeds have been reported from different areas and a serious weed problem still remains. However, different weed control practices have been applied for the purpose of reducing losses due to weeds. Manual weeding is traditionally the main method of reducing weed damage in paddy fields. However, manual weeding is not effective against certain weeds like those with underground propagative organs and weeds which are similar to rice plant like barnyard grass. Therefore in these fields application of other methods like herbicides is appropriate.

A biological control method includes insects and plant pathogens that damage and kill weeds but are harmless to crops. This method is advancing and gaining popularity. If a farmer's field is infected with weed for which a biological agent is obtainable and can effectively control the weed, it is worthwhile to used biological control as it has a benefit of being cheap and with little or no hazards effects to the environment. Allelopathy is another promising method of weed control that involves the use of natural chemical substances, which occur naturally in many plants including rice to slow down the germination of weeds.

Cultivars with excellent allelopathic effects to weeds are important to farmers whose fields are infested with weeds such as *Echinochloa colona* and broad leaf weeds species. Cultural method involves the use competitive cultivars, close plant population and flooding is important for their low cost and safety to the environment. Chemical herbicides are important and will continue to play an important role in integrated weed management, especially in the humid tropics where weed growth is often very rapid. For the farmer, it depends on the weed flora and the economics of using herbicides. Herbicides like 2, 4-D, Propanil, Fenoxaprop, Cinmethilin, Pretilachlor, Oxadiazon, Butachlor, Pendimethalin, and many others have proven effective against most weeds. Therefore, it is with the view of the farmer to choose among the methods taking into consideration the type of weed flora present in his field, rice culture, economics of the method and availability of resources.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Location

Field experiments were conducted in two seasons at Sokoine University of Agriculture farm during the short rain (November, 2014 to February, 2015) and long rain seasons (March to June 2015). The location lies within latitude 6.85^0 South and longitude 37. 64^0 East at an elevation of 568 meters above sea level (m.a.s.l.), in Morogoro region, Tanzania. The soil type in the area is characterized by clay texture, with red to redish brown color. The soil pH is medium acidic (5.54).

3.2 Land Preparation

Existing vegetation from the selected site was slashed and removed. Land was ploughed and harrowed using tractor mounted equipment. Soil colds were broken down to have the field level. The experimental area selected has been under fallow from previous season. The experiment was split plot laid out in randomized complete block design (RCBD) with four replications and sixty four treatment combinations. The dimensions of the entire field; length 43m, width 15m (645m^2), main plot length 9.5 m and width 3 m (28.5 m^2 area). The subplot was 3m x 2m (6m^2). There was an alley accounting to 1m between replications and main plots; split plot alley 0.5m. The crop geometry of rice was 20×20 cm^2 (hill to hill and row to row spacing) with two seedlings per hill and 10 rows in each plot having 15 plants in each row. The 8 rows in the middle of each subplot were treated as the net plot rows for harvesting, and the remaining 2 rows were used as a border road to prevent the crop against any genetic or environmental invasion.

3.2.1 Treatment details

Three seeds were sowed per hill and thinned to two after germination. Pre-emergence herbicide Ultra 2, 4-D was applied four days after seeds were sowed. Post-emergent (Hansunil) was also applied 3 weeks after seeds sowed, weeds and crop emerged. Hoe weeding was done at 3 weeks intervals (3, 6; 9 week) commencing from the 3rd week after seeds were sown, weedy plots was the control. The experimental trial consisted of 8 treatments with factor A having 4 weed management practices, i.e., 1) Pre-emergence herbicide, 2) Post-emergence herbicide, 3) Hoe weeding, 4) Weedy; factor B having 4 rice genotypes, i.e., 1) NERICA-1, 2) NERICA-4, 3) NERICA-7 and 4) Mwngaza. The description of treatments is detailed in (Table 1).

Table 1: List of Treatments

Treatments Main Plot	Description	Liter/ha	ai/ha (kg)
Pre-emergence herbicide (ULTRA 2, 4-D 720 EC)	Herbicide was applied four days after sowing the seeds.	4	2.88
Post-emergence herbicide (Hansunil 600 EC) and one hoe weeding	Herbicide was applied after weed and crop emerged (three weeks after sowing), followed by one hoe weeding.	8	4.8
*Hoe weeding	Weeding using a hand hoe in 3 intervals (3,6, 9 week), starting from 3 weeks after seeds were sowed		
Control plot, one hoe weeding	weeding using a hand hoe done once at the 42 days after sowing		
Subplots			
NERICA1	Three seeds sowed per hill thinned to two after germination		
NERICA4	Three seeds sowed per hill thinned to two after germination		
NERICA7	Three seeds sowed per hill thinned to two after germination		
Mwangaza	Three seeds sowed per hill thinned to two after germination		

*The current farmer practice is hoe weeding

3.1.2 Rice varieties used in the experiment

Four rice genotypes were used namely (NERICA - 1, NERICA - 4, NERICA - 7) New Rice for Africa and Mwangaza. NERICA, the genus Oryza belongs to the family and sub-family Grammineae and Bambusoideae, respectively. There are two cultivated species of the genus of which, *O. sativa* is of Asian and *O. glaberrima* is of African origin (Clayton and Renvioze, 1986).Varieties of NERICA (NEW RICE for AFRICA) are interspecific hybrid progenies developed by WARDA (1999) by combining the hardsness of *O. glaberrima* with the productivity of *O. sativa.* The African parent endows the new rice with resistance to drought, diseases, weeds and problematic soils, while the Asian rice transfers high yielding characters.

3.1.2.1 NERICA

The NERICA rice is the result of extended family of several 3,000 siblings. They are outcome of crosses between two most commonly cultivated rice species, African rice (*Oryza glaberrima* steud) which has the ability of surviving in cruel environment, and Asian rice *(Oryza sativa* L) with high yield potential (WARDA, 2008). NERICA varieties have improved African rice production in many countries, Tanzania being among them (FAO, 2007).

NERICA varieties have high yielding potential and short growth cycle. Several of the NERECA genotypes including NERICA1, NERICA4 and NERICA7 possess early vigor during the vegetative growth phase and this is a potentially useful trait for weed competitiveness. Likewise, a number of the NERICA genotypes are resistant to African pests and such as the devastating rice blast (*Magnaportha grisea*), to rice stem borers (*Papaipema nebris*) and termites (Isoptera spp.). NERICA genotypes also have higher protein content and amino acid balance than most of the imported rice varieties.

3.1.2.2 Mwangaza

Mwangaza is a variety released for cultivation in the inland of Tanzania. It is resistant to rice yellow mottle virus (RYMV) disease (Sober movirus spp.), a devastating disease mainly occurring in the African region. This variety performs well in areas of high RYMV infection; it is also being used as RYMV resistant germplasm for breeding new varieties.

3.1.3 Herbicide characteristics

Generally speaking, herbicides are applied either pre-emergence or post-emergence. That means they are applied either before or after weeds emerge from the soil and begin to grow. Pre-emergence herbicides kill weeds shortly after they germinate or emerge through the soil surface. Post-emergence herbicides control weeds that are already growing and easily visible.

The following commercial formulation of triazine or triazine based products was used in each experiment. All the trade name of the herbicides used viz: Ultra 2, 4-D Amine 720EC and Hansunil 600EC are registered Pesticides in Tanzania. The characteristics are summarized below:-

Amine 2, 4-D is a formulation of one of the oldest and widely used herbicide families. Amine 2, 4-D belongs to a group of herbicides called phenoxy-carboxylic acids. This group of herbicides was developed in the mid-1940s by the U.S. military for vegetation control. In 1945, Imperial Chemical Industries Ltd. reported using a phenoxy to control wild mustard (Klingman and Ashton 1982). The compounds in this herbicide group act on susceptible plants in the way the plant’s growth hormones work. That is why this group and others like it are often referred to as auxin-like herbicides or growth regulator herbicides; auxins being plant hormones involved in growth. One characteristic about amine 2, 4-D is that it is used to control annual, biennial, and perennial broadleaf weeds, but has little effect on grasses. It is this selectivity that makes 2, 4-D one of the most popular herbicides for use in lawns. However, the herbicide 2, 4-D can injure grass crops if applied at specific times. Although labeled for use in corn, sorghum, and wheat, the herbicide 2, 4-D can damage corn by causing brittle stems or fused brace roots and may reduce yield when applied late in the growing season. Use of the herbicide 2, 4-D after jointing in wheat can induce malformed seed heads, thus reducing yield.

Herbicides with 2, 4-D are often implicated in noticeable drift situations. This is partly due to the fact that many broadleaf plants can be sensitive to 2, 4-D, even at low rates. Such sensitive broadleaf plants include, but are not limited to, soybeans, tomatoes, grapes, and maples. Characteristic symptoms of 2, 4-D drift are leaf puckering and strapping. Larger amounts of 2, 4-D can twist and bend the stems. In some cases, drift is a result of 2, 4-D volatility, the herbicide's ability to turn into a vapor and move off site. This is how the amine formulations can differ. The application rates of the herbicides vary from 0.4 kg a.i./ha to 0.8 kg a.i./ha.

Hansunil 600EC: The formulation contains propanil and thiobencarb. The mixture is a broad spectrum herbicide for post-emergence control of sedges, grass and broad leaves weeds in rice farming and other crop like sugar cane and others. The characteristics of individual herbicides are described as indicated below:
Propanil has been the primary herbicide used for rice weed control for over 40 years. Propanil is a contact herbicide and, when used alone, generally requires a second application before the permanent flood is established for complete grass control. Good spray coverage with weed foliage is important for successful control. Weed foliage must not be covered with water at time of application. Propanil does not have any residual activity for weed control from application to the soil. Propanil activity is temperature-

dependent; poor weed control may occur when temperatures are cool and rice injury can occur when temperatures are hot. Many different propanil formulations (i.e., dry flowable, SC and EC) are available and require different spray techniques. The rate of application of propanil ranges from 3 kg a.i./ha to 4 kg a.i./ha. The herbicide is applied 10 to 20 DAT, or 10 to 20 days after sowing pregerminated seeds.

Thiobencarb is a thiocarbamate. Thiobencarb is the common name for S-((4-chlorophenyl) methyl) diethylcarbamothioate (CAS 28249-77-6). Thiobencarb is a systemic, pre-emergence herbicide that acts by inhibiting shoots of emerging seedlings. It is used to control grasses, sedge and broadleaf weeds in food crops such as rice (nationwide rice represents 95% of use), lettuce, celery, and endive. Thiobencarb was first registered for use on rice in 1982. In 1991, thiobencarb was issued regional tolerances for use on celery, endives, and lettuce in the State of Florida. Thiobencarb is effective for control of Echinochloa spp. in rice. Active labels within the action area allow a maximum single and seasonal application rate of up to 1-2 kg a.i/ha.

3.3 Methods

3.3.1 Irrigation management

Irrigation was provided only to maintain the field in moist soil condition but not flooded condition. Supplemental irrigation was done during the hot weather of the short rain season 2014. The field was flooded to optimum field moisture content and the water stay for three days after which seeds were sowed. During this hot weather period, watering was done two times a week to maintain field moisture for the crop sustainability. This was done every week until rain was available to the crop in the field.

3.3.2 Insect-pest management

Insect damage was observed during heading and milking stage of crop growing period. Spraying of Cypermathin 25 EC at 1 ml/liter of water at these phenological stages was done. Birds control was done manually. An installation of materials that create sounds to drive away birds such as lines and plastic twines. Rodent control was done by distributing poison (bait) mixed with maize, sorghum, millet or rice in boxes or containers in the un-cropped margins and alleys of the experimental field.

3.3.3 Harvesting and threshing

The crop from the net plot area was harvested manually by using kitchen knife. Harvested plants were placed in the field for 5 days for sun drying. Threshing was done manually, and grains were obtained by winnowing and were weighed at 12% moisture content.

3.3.4 Fertilizer application

Fertilizer application was done as current agronomic practices. Nitrogen was applied at the recommended rate of 100kg/ha. 50% (50kg N/ha) of the recommended N was applied 21 DAS as a basal application. The remaining 50kg N/ha was applied as a topdressing 35 DAS using Urea (46% N). All fertilizer application was done using broadcasting method (Kanyeka *et al*., 2007).

3.4 Weed Management

3.4.1 Herbicide application

The herbicide UTRA 2, 4-D 720EC at 2.88kg a.i. /ha was applied four days after sowing using knapsack sprayer at (6lit./Volume of water). Hansunil 600 EC at 4.8kg a.i. /ha treatments (12lit. /volume of water) was applied 21 days after sowing using the same method as mentioned above; at this time, all emerged weeds in the field had developed 3-4 leaves minimum. The experimental field was watered to field capacity for an optimum uptake of the herbicide.

3.4.2 Hoe weeding

The first hoe weeding was done 21 days after sowing going in line with the herbicide application. Second hoe weeding was done 42 days after sowing and the third hoe weeding was done 63 days after sowing in order to complete the required cycle of hoe weddings. During the 2014/15 experiment, none of the rice genotypes survived under un-weeded conditions. As a result, slight modifications were made to the un-weeded control treatment by replacing it with one weeding done late to mimic farmer conditions.

3.5 Data Collection for Experiment 2014/2015 and 2015

3.5.1 Weed data

Weed counts were done 20 days after sowing using 0.5m x 0.5m quadrat placed randomly in the net harvestable area (3.52m^2) in each subplot. Two counts were made on each subplot, the calculated average was recorded. Weed counts from each quadrat were summed to find a total number of weeds by group (broad leaves, grasses and sedges species). This was done before and after treatments application. Six weeks after sowing or 42 days after sowing, weed counts was also done by using 0.5m x 0.5m quadrat. This was done before the second hoe weeding. Sampled weeds were classified according to species. Weed dry biomass was determined at 63 DAS by throwing 0.5m quadrant at either ends of each subplot. The weeds inside the two measured 0.5m quadrant areas were uprooted and arranged by group and by species. This was later taken to the oven for 72 hours oven dry at 70 ^{o}C. The 0.5 x 0.5 quadrat was preferred in order to get the full representation of weeds density within a given measured area considering 1m^2 quadrat as the measurement for weed population. The contribution of individual weed species to the weed community was determined by the Summed Dominance Ratio (SDR) calculated using relative density (RD) and relative dry weight (RDW) (Janiya and Moody, 1989) as follows:

$$SDR = \frac{RD+RDW}{2}$$

Where $$RD\% = \frac{\text{Density of a given species}}{\text{Total density of all species}} \times 100$$

And $$RDW\% = \frac{\text{Dry weight of a given species}}{\text{Total density of all species}} \times 100$$

3.5.2 Rice data

3.5.2.1 Plant height

Five plants from the net harvestable area (3.52m^2) of each subplot were randomly selected and tagged. The height of each tagged plant was taken at three intervals 39, 62 and 83 days after sowing using a 200cm-meter ruler. Plant height was determined by placing a meter rule at the soil surface to the tip of the flag leaf of each tagged plant and the mean calculated and recorded in cm. The five plants selected were used to record all other rice variable data such as tillers, panicle, leaf area index and spikelet fertility.

3.5.2.2 Number of productive tillers

Tillers were considered as the young plants arising from the main culm in an alternate pattern and typically including leaves, culm and roots, but which did or did not develop panicle. Productive tillers were considered as those tillers that produced spikelets with or without filled grains. Five plants were selected randomly in the net harvestable area (3.52m^2) of each subplot and tagged at 39 days after sowing. Tiller count was done at the 85 days after sowing from each of the selected plants to determine the productive tillers.

3.5.2.3 Panicle count

Five plants were selected randomly in the net plot or harvestable area of every subplot and counted at 89 days after sowing. The number of panicle from each hill was counted and the mean recorded.

3.5.2.4 Leaf Area Index (LAI)

The leaf area index measurement was taken from five tagged plants per each subplot per $1m^2$. A 50 cm ruler and a digital caliper were used measuring the length and width of the first, middle and flag/last leaf of each tagged plant. The calculated averages obtained were used to determine the leaf area index. Leaf width and length were recorded in centimeter (cm) per plant. The relationship is LAI = L x W x N x P x 0.72/A, Where, L = Length of leaves, W = Width of leaves, N = number of leaves per plant, P = plant per area covered. A = area covered per plant and the 0.72 is constant for the determination of leaf area index of rice (Watson, 1952). The leaf area index data was used to determine the performance of rice plant against weed-free and weed-infested plots.

3.5.2.5 Spikelet fertility

The spikelet fertility percent is calculated as:

(Number of unfilled grains×100)/ total number of grains.

Total unfilled grains per panicle were obtained on panicles from five plants and the mean was used to calculate spikelet fertility percentage as per the following formula. Each floret was pressed between the thumb and forefinger to determine if the grain was filled or not. Spikelet fertility was expressed as percentage. The total number of filled grains and unfilled grains were also recorded. This was done by collecting 5 plants from the net harvestable area ($3.52m^2$) in every subplot threshed by panicle; separated filled spikelet's and unfilled spikelet. To determine percent fill grain.

3.5.2.6 Grain yield

The grain yield was obtained from the harvestable or net plot area ($3.52m^2$) of each subplot. This was done from a measured area ($3.52m^2$) of each subplot leaving 2 lines from either side of every subplot as guard rows. The grains were threshed; sun dried and weighed on an electronic beam balance. Grain yield (adjusted to 14% moisture content) was determined at harvest using the yield components (Yoshida, 1981) obtained. Yield = (Number of panicles per unit area x Number of spikelet's per panicle x % Grain filling).

3.5.2.7 Grain: straw weight

The harvested or net plot area of $3.52m^2$ was slashed at the soil surface of each subplot after final harvest; Straws were placed in the sun for a day, tied and dried in an oven (70^0C for 72 hours) to a constant weight and weighed on an electronic beam balance. Grain: straw was determined as the ratio of dry grain yield to dry straw weight; this was measured by the given ratio:

$$\frac{\text{Dry grain yield}}{\text{Dry straw weight}}$$

3.6 Data Analysis

Data obtained from the experiments were subjected to statistical analysis; analysis of variance (ANOVA) using the computer programme GENTSAT statistical package 14th edition (2012). The treatments mean separation were done using Tukey's honestly significant test.

3.6.1 Specific objective 3. To determine relative profitability of weed management practices for upland rice farming

3.6.1.1 Profit analysis

Cost of production was calculated on the basis of local charges for different agro inputs, viz., labour, fertilizer, and other necessary materials. The cost of weed management practices and farm operation was obtained and calculated as indicated in (Table 2).

3.6.1.2 Net profit

This was calculated by subtracting the cost of production from the gross return. Whereas Profit is equal Revenue minus Total costs.

3.6.1.3 Return on investment

This was calculated based on procedure developed by Jolly and Clonts (1993), expressed as:

$$\text{Return on Investment (\%)} = \frac{\text{Net profit}}{\text{Investment}} \text{ X } 100\%$$

The inputs or variable costs were as followed:

Table 2: Production cost

Item/variable	**Unit**	**Quantity Applied** lit **/ha**	**Unit price (Tshs)**	**Total (Tshs)**
ULTRA 2, 4-D 720 EC	Litre	2.8	12 000 Tshs/Lit	205 809 Tshs
Hansunil 600 EC	Litre	4.8	25 000 Tshs/Lit	291 249 Tshs
Hoe weeding	Man day	113	3 225 Tshs/day	640 174 Tshs
Herbicide application	Man day	2	5 000 Tshs/day	10 000 Tshs
Labour for management	Manday/month	210	3 225 Tshs/day	257 140.7 Tshs

The exchange rate from Tshs to US$ during the experiment: Tshs 2 000 to US$ 1.

The revenue generated was calculated from the prices of a bag of rice; a bag of rice (80kg) is cost Tshs 160 000. The total variable costs were herbicide cost, herbicide application cost, labor cost for hoe weeding and all of which were compiled for each treatment. The net profit was the different between the total revenue and total costs which vary per treatment. The total revenue and total costs that vary per treatment were utilized to determine the profit of each treatment. The value for net profit and profit cost were subjected to ANOVA.

3.7 Statistical Analysis

All recorded data were tabulated according to treatment-wise under four replications. The data entry was done to develop an ANOVA table. A mean separation technique was applied to identify the most efficient treatment using Tukey's honestly significant test. Regarding the software programs used, Microsoft Word 2007 was used for word processing; Microsoft Excel for tables and graphs; and GENTSAT statistical package 14th edition was for running statistical analysis. ANOVA was done to test the significance difference for each parameter. Calculation was done at 5% significance level.

3.8 Weather Data

Daily weather data was collected on rainfall (mm), minimum and maximum temperature (^{o}C) and percentage relative humidity (RH %) from the Tanzania Meteorology Agency (TMA), Morogoro branch situated within Sokoine University of Agriculture Campus. Data on maximum temperature from November 2014 to March 2015 were not recorded because the max thermometer was broken.

CHAPTER FOUR

4.0 RESULTS

4.1.1 Rainfall (mm)

The rainfall amount during the growing seasons is as indicated in Figure 1. The highest rainfall amount during the first experiment was 155.5mm and 84.6mm in the month of December 2014 and January 2015, respectively. The repeat experiment begins with a high rainfall of 144.3mm in the month of March 2015 (Figure 1).

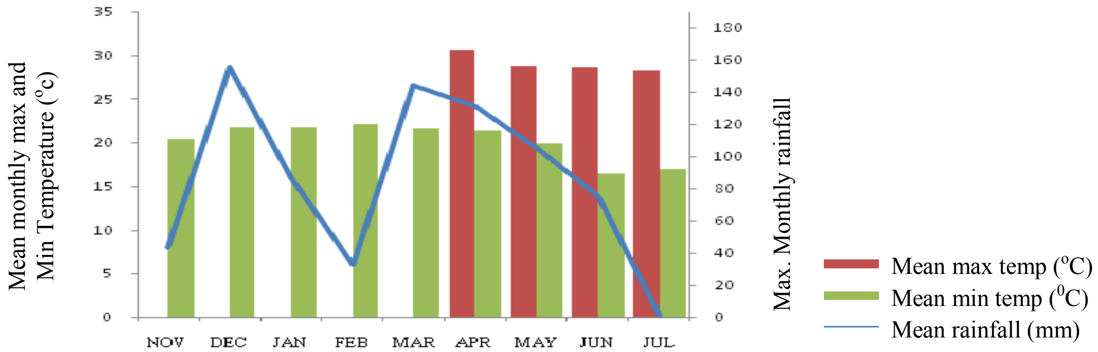

Figure 1: The mean monthly values for maximum, minimum temperature and rainfall for the growing season of 2014/2015.

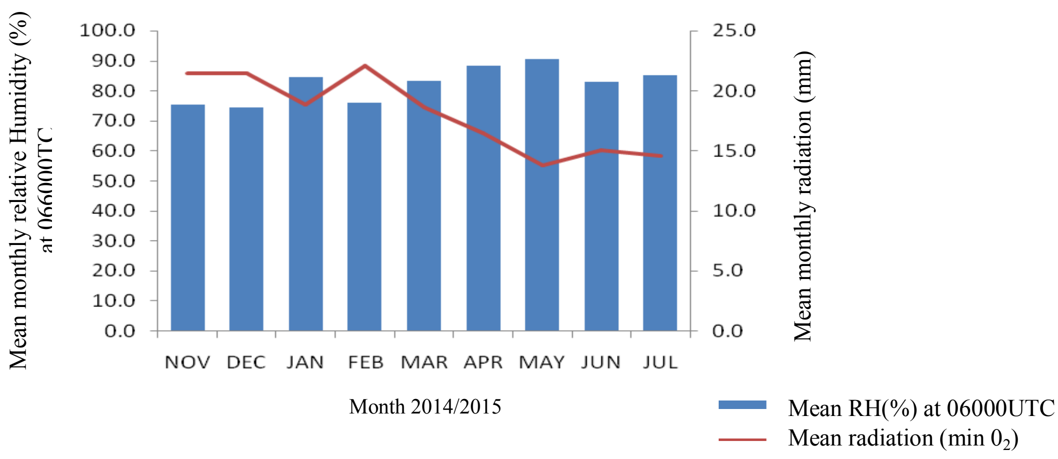

Figure 2: The mean monthly values for relative humidity and radiation for the growing season of 2014/2015.

4.1.2 Temperature (^oC) and relative humidity (%)

The recorded mean maximum temperature during growing season was 30.7 while the mean minimum temperature during the period was 22.1^{o}C, respectively. Relative humidity ranged from 74.4 to 84.6 December 2014 to January 2015 as shown in (Figure 2). The mean RH during the growing season was 90.4%. The mean values for rainfall, maximum and minimum temperature, relative humidity and radiation for past 10 years was collected to contrast the trend and impact of climate change of the given parameters since 10 years as compared to present climatic condition in respective of crop growth and development (Figure 3and 4). The summary of ANOVA was done to clearly explain the significant responses of the recorded Variables (Table 3 and 4).

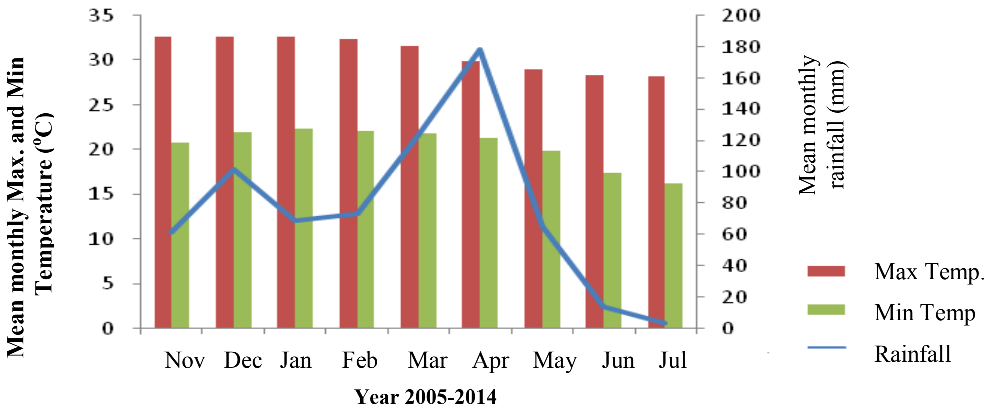

Figure 3: Mean monthly maximum, minimum temperature and rainfall for the last 10 years from 2005-2014

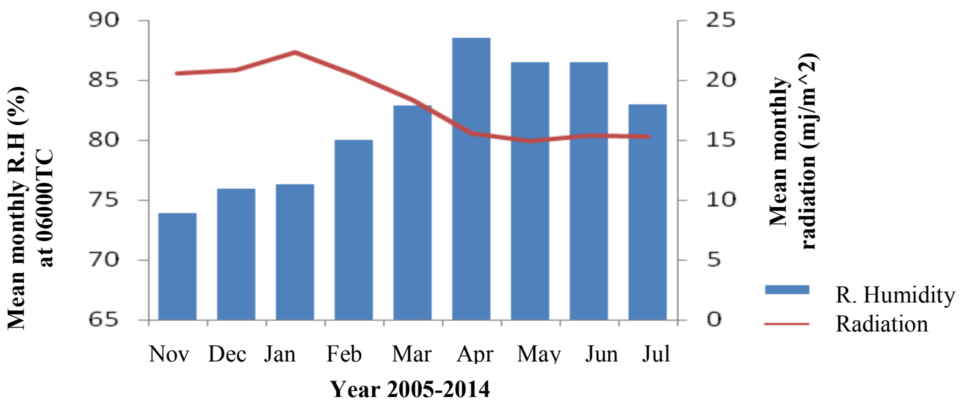

Figure 4: Mean monthly relative humidity and radiation for the last 10 years from 2005-2014

Table 3: Value of mean square and F probability for 2014/15 experiment

Variables	Main Plot	Sub Plot	A X B Interaction
Grain yield	1093952*	175709*	43530*
Plant height 39DAS	417.7*	443.2*	21.8^{NS}
Plant height 62DAS	29024.72*	1585.58*	222.68*
Plant height 83DAS	45217.97*	1100.82*	263.14*
Panicle count	29900.93*	457.81*	212.14*
Spikelet count	1418.282*	58.677*	24.37*
Tiller count	3222.029*	18.535*	31.206*
Broadleaf biomass	56390.89*	1571.27*	914.77*
Grasses biomass	252246.51*	2215.57*	1950.5*
Sedges biomass	793454*	34243*	64569*
Broadleaf No./m^2	1408.55*	52.3^{NS}	384.63*
Grasses No./m^2	1837.2*	1244.04*	1168.17*
Sedges No. /m^2	3110.973*	292.8*	526.927*
Straw dry biomass	1669069*	99652*	54684*
Percent filled grain	62237*	7051.3*	1102.4*
Leaf area index	0.0107599*	0.0007474*	0.00017378*

Key: DAS means day after sowing; $p<0.05$= Significant =* and NS means not significant.

Table 4: Value of mean square and F probability for 2015 experiment

Variables	Main Plot	Sub Plot	A X B Interaction
Grain yield	676845*	131217*	96091*
Plant height 39DAS	417.43*	1056.01*	19.93^{NS}
Plant height 62DAS	232.07^{NS}	3324.06*	39.87^{NS}
Plant height 83DAS	397.93*	3480.94*	68.09^{NS}
Panicle count	255.04*	650.21*	32.83^{NS}
Spikelet count	9.709*	25.971*	1.347^{NS}
Tiller count	11.46*	31.914*	1.849^{NS}
Broadleaf biomass	15.3750*	3.0833*	2.5417*
Grasses biomass	221.12729*	248.08354*	336.73465*
Sedges biomass	528.9913*	356.6179*	333.1867*
Broadleaf No./m^2	82884.4*	228.9^{NS}	559.1^{NS}
Grasses No./m^2	702.75*	2838.75*	3140.306*
Sedges No. /m^2	31073.1*	3194.4*	5179.3*
Straw dry biomass	1480071*	229790*	83774^{NS}
Percent filled grain	114.42*	172.01*	9.91^{NS}
Leaf area index	0.05415^{NS}	0.18892*	0.01177^{NS}

Key: DAS means day after sowing; $p<0.05$= Significant =* and NS means not significant.

4.2 Weed Occurrence

Study conducted during the short rain 2014/15 and long rain 2015, weeds observed in the experimental plots were composed of broadleaf, grasses and sedges as listed. *Cyperus rotundus* (39.7%) was the most prevalent weed species fallowed by *Echinochloa colona* (33.9%) and *Cyperus eculentus* (26.4%) in the 2014/15 experiment and *Amaranthus retroflexus* (37.6%), as the most prevalent weed species fallowed by *Panicum maximum* (34.7%) and *Cyperus eculentus* (27.7%) in 2015 experiment in species (Tables 5 and 6).

Broadleaf was the most dominant weed group and grasses species the least dominant in both experiments. In the 2014/15 experiment, sedges were recorded in pre-emergence plots as the second most dominant weeds and grasses were recorded in post-emergence, hoe weeding and weedy plots as the second most dominant weeds group. In the 2015 experiment, plots applied with pre-emergence, post-emergence and hoe weeded showed sedges as the second most dominant weed recorded while grasses were the second higher in weedy plots (Figure 5 and 6).

Table 5: Weed species recorded, total number, and summed dominant ratio during the 2014/15 experiments

Treatment	Weed group	Weed species	Family name	Total Number/m^2	SDR %
Pre-emergence	Broad leaves	*Mimosa pudica L.*	Mimosaceae	64	24.4
		Amaranthus retroflexus	Amaranthaceae	61	23.3
		Commenlina benghalensis L.	Commelinaceae	49	18.7
		Launaea spp.	Asteraceae	43	17.2
		Richadria	Rubiaceae	45	16.4
	Grasses	*Echinochloa colona*	Poaceae	47	52.2
		Sorghum halepa	Poaceae	27	30.0
		Cynodon dactylon	Poaceae	16	17.8
		Panicum Maximum	Poaceae	-	-
	Sedges	*Cyperus rotundus*	Cyperaceae	106	60.9
		Cyperus esculentus	Cyperaceae	68	39.1
Post-emergence	Broad leaves	*Mimosa pudica L.*	Mimosaceae	77	23.4
		Amaranthus retroflexus	Amaranthaceae	75	22.9
		Commenlina benghalensis L.	Commelinaceae	62	18.9
		Richadria	Rubiaceae	58	17.7
		Launaea sp	Asteraceae	56	17.1
	Grasses	*Echinochloa colona*	Poaceae	51	54.2
		Panicum Maximum	Poaceae	28	29.8
		Cynodon dactylon	Poaceae	9	9.6
		Sorghum halepa	Poaceae	6	6.4
	Sedges	*Cyperus rotundus*	Cyperaceae	48	62.3
		Cyperus esculentus	Cyperaceae	29	37.7
Hoe weeding	Broad leaves	*Mimosa pudica L.*	Mimosaceae	68	24.7
		Amaranthus retroflexus	Amaranthaceae	64	23.3
		Commenlina benghalensis L.	Commelinaceae	51	18.5
		Richadri	Rubiaceae	47	17.1
		Launaea spp.	Asteraceae	45	16.4
	Grasses	*Echinochloa colona*	Poaceae	62	44.6
		Panicum Maximum	Poaceae	58	41.7
		Cynodon dactylon	Poaceae	12	8.6
		Sorghum halepa	Poaceae	7	5.0
	Sedges	*Cyperus rotundus*	Cyperaceae	55	57.9
		Cyperus esculentus	Cyperaceae	40	42.1
Weedy	Broad leaves	*Mimosa pudica L.*	Mimosaceae	79	23.6
		Amaranthus retroflexus	Amaranthaceae	76	22.7
		Commenlina benghalensis L.	Commelinaceae	64	19.1
		Richadria	Rubiaceae	59	17.6
		Launaea spp	Asteraceae	57	17.0
	Grasses	*Echinochloa colona*	Poaceae	60	46.2
		Panicum Maximum	Poaceae	56	43.1
		Cynodon dactylon	Poaceae	9	6.9
		Sorghum halepa	Poaceae	5	3.8
	Sedges	*Cyperus rotundus*	Cyperaceae	26	63.4
		Cyperus esculentus	Cyperaceae	15	36.6

Key: SDR = Summed Dominant Ratio

Table 6: Weed species recorded, total number, and summed dominant ratio during the 2015 experiments

Treatment	Weed group	Weed species	Family name	Total Number/m^2	SDR % 2015
Pre-emergence	Broad leaves	*Mimosa pudica L.*	Mimosaceae	181	31.4
		Amaranthus retroflexus	Amaranthaceae	135	23.4
		Launaea spp.	Asteraceae	98	17.0
		Richadria	Rubiaceae	85	14.7
		Commenlina benghalensis L.	Commelinaceae	78	13.5
	Grasses	*Panicum Maximum*	Poaceae	202	66.7
		Echinochloa colona	Poaceae	57	18.8
		Sorghum halepa	Poaceae	23	7.6
		Cynodon dactylon	Poaceae	21	6.9
	Sedges	*Cyperus rotundus*	Cyperaceae	276	52.0
		Cyperus esculentus	Cyperaceae	255	48.0
Post-emergence	Broad leaves	*Mimosa pudica L.*	Mimosaceae	66	24.0
		Amaranthus retroflexus	Amaranthaceae	64	23.3
		Commenlina benghalensis L.	Commelinaceae	51	18.5
		Richadria	Rubiaceae	48	17.5
		Launaea spp.	Asteraceae	46	16.7
	Grasses	*Echinochloa colona*	Poaceae	93	35.8
		Panicum Maximum	Poaceae	69	26.5
		Sorghum halepa	Poaceae	50	19.2
		Cynodon dactylon	Poaceae	48	18.5
	Sedges	*Cyperus esculentus*	Cyperaceae	197	53.0
		Cyperus rotundus	Cyperaceae	175	47.0
Hoe weeding	Broad leaves	*Mimosa pudica L.*	Mimosaceae	59	25.5
		Amaranthus retroflexus	Amaranthaceae	56	24.2
		Commenlina benghalensis L.	Commelinaceae	42	18.2
		Richadria	Rubiaceae	38	16.5
		Launaea spp	Asteraceae	36	15.2
	Grasses	*Echinochloa colona*	Poaceae	91	37.0
		Panicum Maximum	Poaceae	84	34.1
		Cynodon dactylon	Poaceae	38	15.4
		Sorghum halepa	Poaceae	33	13.4
	Sedges	*Cyperus esculentus*	Cyperaceae	140	53.4
		Cyperus rotundus	Cyperaceae	122	46.6
Weedy	Broad leaves	*Mimosa pudica L.*	Mimosaceae	182	21.4
		Amaranthus retroflexus	Amaranthaceae	179	21.1
		Commenlina benghalensis L.	Commelinaceae	167	19.7
		Richadria	Rubiaceae	162	19.1
		Launaea spp.	Asteraceae	159	18.7
	Grasses	*Echinochloa colona*	Poaceae	89	35.7
		Panicum Maximum	Poaceae	85	34.1
		Cynodon dactylon	Poaceae	39	15.6
		Sorghum halepa	Poaceae	36	14.5
	Sedges	*Cyperus esculentus*	Cyperaceae	75	52.1
		Cyperus rotundus	Cyperaceae	69	47.9

Key: SDR = Summed Dominant Ratio

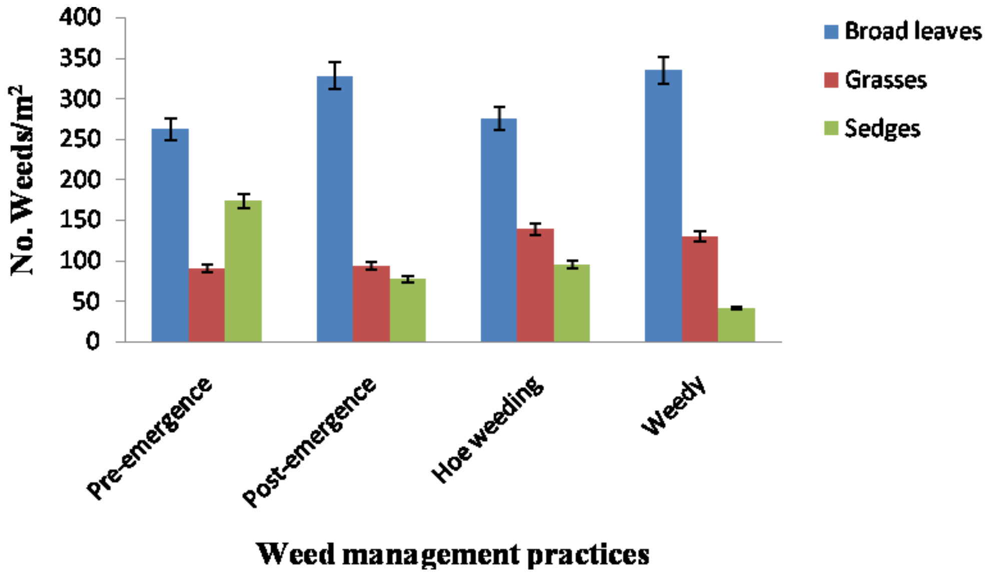

Figure 5: Weed counts before treatments application during 2014 /15 experiment

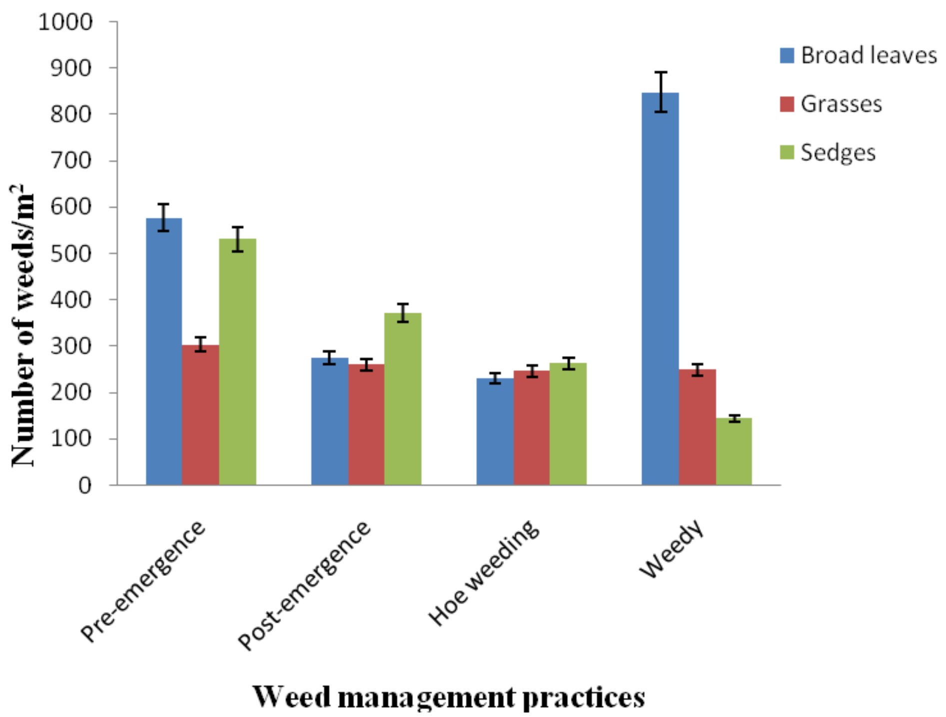

Figure 6: Weed counts before treatments application during 2015 experiment

The weed management practices significantly influence weed control in both experiments. Weed management practices effects on weed control during both experiments was clearly revealed by weed counts when recorded after application of the various treatments as indicated by graph (Figures 7 and 8).

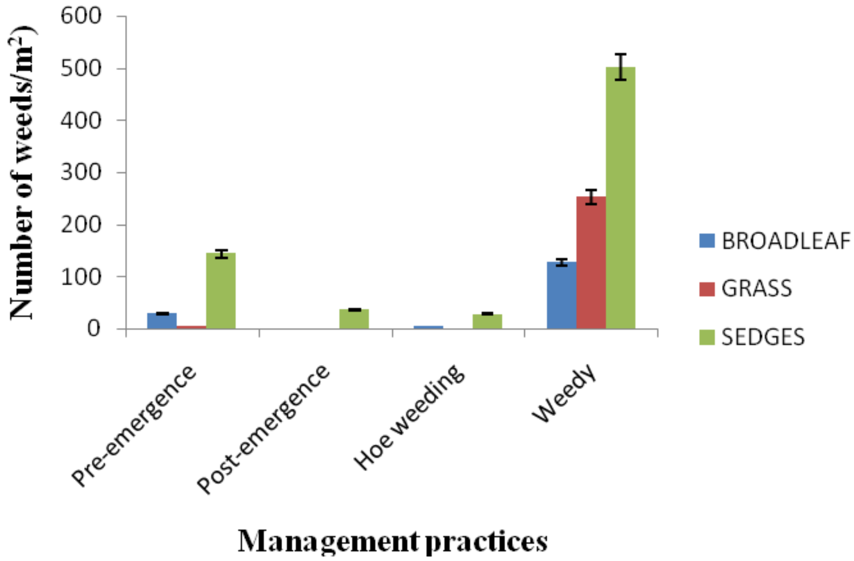

Figure 7: Weed counts after treatments application during 2014 /15 experiment

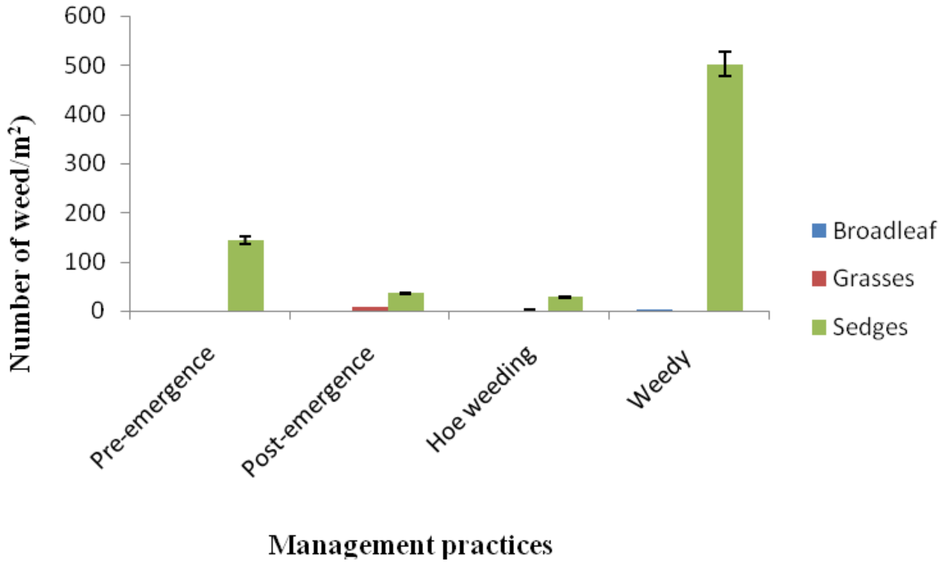

Figure 8: Weed counts after treatments application during 2015 experiment

4.3 Weed Counts

In 2014/15 experiment, broadleaf weed counts was recorded with significant difference ($p \leq 0.05$) among weed management practices, management practices and varieties interaction. The difference between treatments pre-emergence and hoe weeding, also post-emergence and weedy, as well as treatments interaction, was not statistically significant. No significant difference was recorded among the varieties. The highest and lowest counts broadleaf (90 and 51/m^2) were recorded on Mwangaza in weedy plots and plots applied with pre-emergence (UTRA 2, 4-D). Similar results were recorded in the 2015 experiment with no significant difference recorded on varieties and treatments interaction. The highest and lowest counts (229 and 41 broadleaf /m^2) was recorded on NERICA-7 in weedy and hoe weeding plots (Table 6). Weed counts for grasses were generally low. Differences in grass weeds were significant ($p \leq 0.05$) among weed management practices and varieties, but between treatments interaction was not statistically different.

The highest grass weeds counts (48grass/m^2) were recorded on NERICA- 4 in hoe weeded plots and the lowest grass weeds (16grass/m^2) were recorded on NERICA-7 applied with post-emergence herbicide. Similar results were also recorded during the 2015 experiment while maximum grass weed counts (103grass/m^2) were recorded on NERICA-1 in pre- emergence plots. The minimum grass weed counts (21grass/m^2) were recorded on NERICA-7 in post-emergence plots (Table 5). The influence of management practice on sedges count evidence significant effects ($p \leq 0.05$) due to management practices, varieties, and management practices and varieties interaction in 2014/2015 experiment. Significant difference ($p \leq 0.05$) was recorded between treatments interaction. NERICA-4 recorded the highest sedges counts (51/m^2) in pre-emergence plots. Mwangaza was recorded with the lowest sedges counts (4/m^2) in post-emergence plots. Similar results were recorded in the

2015 experiment, and NERICA-4 was recorded with the highest sedges counts (174 /m^2) in pre-emergence UTRA 2, 4-D plots (Table 7).

Table 7: Mean broadleaf, grass and sedges No. weeds/m^2 during 2014/15 and 2015 experiments

Treatment	2014/15 Broadleaf number	2014/15 Grass number	2014/15 Sedges number	2015 Broadleaf number	2015 Grass number	2015 Sedges number
(A x B) Interaction						
Pre x N-1	84de	22a-c	27e-g	145	614	79cd
Pre x N-4	55ab	24a-c	51i	149	65f	174g
Pre x N-7	72b-e	26a-c	49i	144	61ef	131ef
Pre x MWG	51a	18ab	47i	139	74g	147fg
Post x N-1	81de	21a-c	17cd	71	76g	58bc
Post x N-4	81de	27a-c	32gh	69	65f	53a-c
Post x N-7	82de	16a	24e-g	66	21a	150fg
Post MWG	84de	30a-d	4ab	69	98h	111d-f
Hoe x N-1	60abc	35a-d	27fg	63	34b	75cd
Hoe x N-4	73b-e	48d	21d-f	60	60e	48a-c
Hoe x N-7	69a-d	26a-c	37h	41	54d	99de
H. x MWG	73b-e	30a-d	10bc	67	98h	40a-c
Weedy x N-1	76cde	36b-d	20de	204	30b	52a-c
Weedy x N-4	83de	41cd	0a	225	45c	18a
Weedy x N-7	86de	24a-c	6ab	229	100hi	16a
Weedy x MWG	90e	29a-d	15cd	191	74g	28ab
Mean	**75**	**30.8**	**24.2**	**120.7**	**98.1**	**79.9**
CV (%)	**6.8**	**28.3**	**11.1**	**17.0**	**2.5**	**19.5**
SE +	**5.3**	**8.7**	**2.7**	**20.7**	**1.6**	**15.6**

Figures followed by the same letter (s) in the marginal and interaction means are not significantly different at P< 0.05 according to Turkey's test

4.4 Weed dry Biomass

Significant differences ($p \leq 0.05$) of broadleaf weeds biomass was recorded among weed management practices, varieties, and management practices and varieties interaction in 2014/2015 experiment. The difference between treatments were similar with the highest broadleaf dry biomass (146.7g/m^2) recorded NERICA-4 in weedy plots followed by NERICA-1(143.9g/m^2) also in weedy plots. Similar results ($p \leq 0.05$) were recorded in the 2015 experiment. Highest broadleaf dry biomass (5.0g/m^2) was recorded on NERICA-4 in weedy plots. Mwangaza had the lowest broadleaf dry biomass (1.2g/m^2) in Post-emergence (Table 8). In 2014/2015 experiment, significant influence ($p \leq 0.05$) was recorded on grass dry biomass among weed management practices, varieties, and management practices and varieties interaction. The difference among treatments interaction were statistically similar. Maximum grass weeds dry biomass (310.2 g/m^2) was recorded on NERICA-7 in weedy plots followed by Mwangaza and NERICA-4 (254.8 g/m^2 and 244.5 g/m^2) respectively. The lowest grass weeds dry biomass were recorded on NERICA-1, NERICA-7 and Mwangaza in Post-emergence and NERICA-4 in hoe weeding plots respectively (Table 8).

Similar results ($p \leq 0.05$) were recorded in the 2015 experiment. However, NERICA-4 was recorded with the highest grass dry biomass (34.00 g/m^2) in Plots applied with post-emergence herbicide. This differed from the other treatments. Significant differences ($p \leq 0.05$) in sedges dry biomass was recorded among weed management practices, varieties and the interaction of management practices and varieties. The difference between treatments was statistically similar. Mwangaza was recorded with the highest and lowest sedges dry biomass (647.2g/$m^2$and 8.2g/m^2) in weedy and post-emergence plots. However, in the 2015 experiment, similar significant ($p \leq 0.05$) was recorded. The differences between treatments were not statistically significant from others. Hence, weedy plots were recorded with the highest sedges dry biomass (36.00g/m^2) in plots planted with NERICA-7. Post-emergence and hoe weeding was recorded with no sedges dry biomass (Table 8).

Table 8: Mean broadleaf, grass and sedges weed dry biomass (g/m^2) during 2014/15 and 2015 experiments

Treatment	2014/15 Broadleaf biomass	Grass biomass	Sedges biomass	2015 Broadleaf biomass	Grass biomass	Sedges biomass
(A x B) Interaction						
Pre x N-1	9.0ab	0.7a	151.1cd	1.5a-c	0.0a	0.0a
Pre x N-4	63.6c	4.7a	120.8b-d	1.0a	1.4b	9.6c
Pre x N-7	16.3ab	5.9a	206.6d	1.5a-c	5.6c	10.3c
Pre x MWG	28.0b	7.4a	97.5a-c	1.7a-c	0.0a	16.9d
Post x N-1	0.0a	0.1a	25.6a	1.2ab	0.0a	0.0a
Post x N-4	0.1a	0.0a	77.1a-c	1.5a-c	34.0e	0.0a
Post x N-7	0.0a	0.1a	33.7ab	1.7a-c	0.0a	0.0a
Post MWG	0.0a	0.1a	8.2a	1.2ab	0.0a	0.0a
Hoe x N-1	1.5a	0.0a	11.9a	1.5a-c	8.6d	0.0a
Hoe x N-4	5.0a	0.1a	22.3a	2.5bc	0.0a	0.0a
Hoe x N-7	4.3a	0.2a	38.1ab	1.5a-c	0.0a	0.0a
H. x MWG	4.3a	0.2a	39.1ab	2.0a-c	0.0a	0.0a
Weedy x N-1	143.9e	201.2b	592.9e	2.7c	0.0a	1.8a
Weedy x N-4	146.7e	244.5c	611.8e	5.0d	0.0a	4.4b
Weedy x N-7	101.0d	310.2d	155.9cd	1.7a-c	0.0a	36.0e
Weedy x MWG	116.0d	254.8c	647.2e	4.5d	0.0a	0.0a
Mean	**39.9**	**64.4**	**177.5**	**2.0**	**3.1**	**4.9**
CV (%)	**23.2**	**14.8**	**19.1**	**27.3**	**7.4**	**14.4**
SE +	**9.3**	**9.5**	**33.95**	**0.6**	**0.2**	**0.7**

Figures followed by the same letter (s) in the marginal and interaction means are not significantly different at P< 0.05 according to Turkey's test

4.5 Plant Growth Variables

4.5.1 Rice plant height

In the 2014/15 experiment, differences in plant heights at 39 DAS were significant ($p \leq 0.05$) among weed management practices and varieties. The difference between treatments, pre-emergence and post-emergence, and varieties was not statistically significant. Mwangaza was the tallest in all weed management practices in 2014/15 and 2015; the differences in height with other varieties were not significant. The shortest plants height (39.1cm) was recorded on NERICA-1 in both experiments. In the 2014/15 experiment, NERICA-1 was recorded as the shortest plants' height in Post-emergence plots. No significant difference ($p \leq 0.05$) was recorded among management practices and varieties interaction. In the 2015 experiment, similar results ($p \leq 0.05$) were recorded on plant height 39 DAS among weed management practices and varieties. During the 2014/15 experiment, none of the rice genotypes survived under weedy conditions.

As a result, slight modifications were made to the weedy plots during the 2015 experiment by replacing it with one late hoe weeding done to mimic farmer conditions. The modifications made to the weedy plots during the 2015 experiment responded positively as indicated by 2015 experiment data output compare to 2014/15 experiment data output. During the 2014/15 experiment, plant height 62 DAS showed significant ($p \leq 0.05$) differences among the weed management practices, varieties and treatments interaction. However, the difference was statistically similar among the treatments. Hence, Mwangaza recorded the tallest plant height (109.1cm) in post-emergence plots and the lowest plant height (73.2cm) recorded on NERICA-1 in post-emergence plots. On the other hand, similar results ($p \leq 0.05$) were recorded in the 2015 experiment on plant height 62 DAS with no significant difference ($p \leq 0.05$) recorded among management practices and treatments interaction. However, Mwangaza recorded the tallest plant height (135.8cm) in post-emergence plots and NERICA-1 recorded the shortest plant height (90.5cm) in pre-emergence plot.

At the crop maturity stage during 2014/2015 experiment, data recorded showed significant differences ($p \leq 0.05$) among weed management practices, varieties and treatments interaction on plants height 83 DAS. Statistically, the differences recorded on treatments were similar. Mwangaza recorded the tallest plant height (129.80cm) and NERICA-1 recorded shortest plants height (98.20cm) all in pre-emergence plots. However, the 2015 experiment, recorded similar statistical results with no significant difference ($p \leq 0.05$) on treatments interaction. Though NERICA-7 recorded the tallest plant height (159.1cm) and NERICA-1 recorded lowest plant height (120.0cm) all of hoe weeding plots.

4.5.2 Tiller counts

The number of tillers per meter square was recorded with significant differences ($p \leq 0.05$) in productive tillers among management practices, varieties and treatments interaction during the 2014/2015 experiment. Similar differences ($p \leq 0.05$) were recorded among treatments, as Mwangaza tillered the most (35.3/m^2) in hoe weeding plots followed by NERICA-7 (35.2/m^2) of the same treatment. Regardless of the variety, tillering was generally reduced in plots applied with pre-emergence herbicides. Similar results ($p \leq 0.05$) were recorded in the 2015 experiment with no significant difference ($p \leq 0.05$) on treatments interaction. However, NERICA-7 recorded the highest tiller number (13.7/m^2) followed by NERICA-1 in hoe weeding plots and the lowest tiller number (7.5/m^2) on Mwangaza in pre-emergence plots (Table 9).

4.5.3 Leaf area index

A significant difference ($p < 0.05$) was recorded on leaf area index among management practices, varieties and treatments interaction. NERICA-7 was recorded as the highest leaf area index (1.81) in pre-emergence plots. Mwangaza was recorded as the lowest leaf area index (1.04) in hoe weeded plots (Table 9). In the 2015 experiment, no significant difference ($p \leq 0.05$) was showed among weed management practices and management practices and varieties interaction on leaf area index. NERICA-7 was recorded as the highest leaf area index (4.48) in pre-emergence plots and NERICA-1 was recorded as the lowest leaf area index (2.53) in hoe weeded plots (Table 9).

4.5.4 Straw dry biomass

Straw dry biomass weight (g/m^2) showed significant differences ($p \leq 0.05$) among weed management practices, varieties and interaction of management practices and varieties during the 2014/15 experiment. The significant difference was statistically similar between the treatments. The highest straw biomass weight (950.4g/m^2) was recorded on Mwangaza followed by NERICA-7 (761g/m^2) in hoe weeding plots while the lowest straw biomass weight (305.1g/m^2) was recorded on NERICA-7 in pre-emergence plots. Similar results were recorded in the 2015 experiment. No significant difference ($p \leq 0.05$) was recorded on straw dry biomass weigh among treatments interaction. The highest straw dry biomass weight (1603g/m^2) was recorded on NERICA7 in hoe weeding plots and the lowest straw dry biomass (724g/m^2) was recorded on Mwangaza in pre-emergence plots (Table 9).

Table 9: Mean tiller number /m^2, leaf area index and Straw dry biomass (g/m^2) during 2014/15 and 2015 experiments

2014/15			**2015**			
Treatment	**Tiller number**	**Leaf area index**	**Straw dry biomass**	**Tiller number**	**Leaf area index**	**Straw dry biomass**
(A)Weed mgt. practices						
Pre-emergence	16.3b	1.42c	454.7b	9.8a	3.38	848a
Post-emergence	22.5c	1.27bc	620.4c	10.0a	3.38	1232b
Hoe weeding	34.0d	1.21b	735.3d	11.7b	2.90	1461c
Weedy	0.0a	0.0a	0.0a	10.2a	2.86	842a
Mean	**18.2**	**0.96**	**452.3**	**10.4**	**3.13**	**1095.8**
CV (%)	**5.6**	**22.1**	**4.3**	**7.8**	**17.0**	**8.6**
SE ±	**1.0**	**0.21**	**19.5**	**0.8**	**0.53**	**93.7**
(B)Variety						
NERICA-1	18.7b	0.84a	421.3a	11.4c	2.87a	1096ab
NERICA-4	18.6b	0.98ab	398.3a	10.2b	2.71a	1078ab
NERICA-7	16.6a	1.19b	420.9a	11.5c	3.93b	1241b
Mwangaza	18.9b	0.87a	569.9b	8.6a	3.03a	498a
Mean	**18.2**	**0.96**	**452.6**	**10.4**	**3.13**	**978.3**
CV (%)	**1.8**	**14.2**	**4.2**	**2.4**	**11.8**	**2.6**
SE +	**0.3**	**0.14**	**19.0**	**0.3**	**0.37**	**28.9**
A x B Interaction						
Pre x N-1	16.9b	1.25b	549.8c-e	10.5	3.14	753
Pre x N-4	16.3b	1.31bc	384.0b	9.8	2.83	736
Pre x N-7	14.4b	1.81c	305.1b	10.8	4.48	1181
Pre x MWG	17.9bc	1.31bc	579.8d-f	8.3	3.10	724
Post x N-1	22.8d	1.06b	434.2bc	11.7	2.98	1448
Post x N-4	27.9d	1.38bc	680.6e-g	10.5	2.79	1288
Post x N-7	16.9b	1.44bc	617.4d-g	10.4	4.39	1282
Post MWG	22.5cd	1.19b	749.4gh	7.5	3.39	912
Hoe x N-1	35.1fg	1.06b	701.1f-h	12	2.53	1441
Hoe x N-4	30.5ef	1.25b	528.7cd	10.7	2.60	1490
Hoe x N-7	35.2g	1.50bc	761.1h	13.7	3.71	1603
H. x MWG	35.3g	1.04b	950.4i	10.7	2.76	1309
Weedy x N-1	0.0a	0.0a	0.0a	11.4	2.84	744
Weedy x N-4	0.0a	0.0a	0.0a	10.1	2.64	877
Weedy x N-7	0.0a	0.0a	0.0a	11.4	3.13	899
Weedy x MWG	0.0a	0.0a	0.0a	8.1	2.85	846
Mean	**18.2**	**0.0**	**452.6**	**10.5**	**1.13**	**1095.8**
CV (%)	**9.6**	**18.8**	**12.0**	**8.3**	**4.3**	**21.7**
SE +	**1.8**	**0.0**	**54.4**	**0.9**	**0.13**	**238.1**

Figures followed by the same letter (s) in the marginal and interaction means are not significantly different at P< 0.05 according to Turkey's test

4.6 Yield and Yield Components

4.6.1 Panicle count

In 2014/2015 experiment, number of panicle per square meter showed significant differences ($p \leq 0.05$) among weed management practices, varieties and weed management practices and varieties interaction. NERICA-4 was recorded as the highest panicle counts (109.2/m^2) followed by Mwangaza (103/m^2) in hoe weeded plots and NERICA-7 had lowest panicles count (46.7/m^2) in pre-emergence plots respectively (Table 9). Similar results were recorded in the 2015 experiment. Weed management practices and varieties interaction showed no significant difference ($p \leq 0.05$) on panicle count. The highest panicle count (68.7/m^2) was recorded on NERICA-1 in post-emergence plots and Mwangaza was recorded as the lowest panicle number (43.0/m^2) in control plots (Table 10).

4.6.2 Spikelet count

In the 2014/15 experiment, significant differences ($p \leq 0.05$) were recorded on spikelet counts among weed management practices, varieties and treatments interaction. Significant differences ($p \leq 0.05$) recorded on Spikelet counts were similar between treatments. Highest spikelet counts (29.5/m^2) were recorded on Mwangaza in hoe weeded plots and lowest spikelet count (8.8/m^2) was recorded in plots applied with pre-emergence herbicide (Table 10). Similar results were recorded during the 2015 experiment. Weed management practices and varieties interaction had no significant differences ($p \leq 0.05$) in spikelet count. NERICA-1 had the highest spikelet count (13.8/m^2) in post-emergence Hansunil plots and Mwangaza was recorded as the lowest spikelet number (8.6/m^2) in control plots (Table 10).

4.6.3 Grain filling

In 2014/15 experiment, significant differences ($P \leq 0.05$) were recorded on percentage filled grains among weed management practices, varieties and management practices and varieties interaction. The significant differences ($p \leq 0.05$) recorded were similar among treatments. NERICA-7 was recorded as the highest filled grain (98.0%/m^2) on hoe weeded plots. In pre-emergence plots, Mwangaza was recorded as the lowest filled grain (75.4%/m^2). Similar results were recorded during the 2015 experiment with no significant difference ($p \leq 0.05$) recorded on the interaction of management practices and varieties (Table 10).

NERICA-1 had the highest percent filled grain (92.8%/m^2) recorded in pre-emergence UTRA plots and NERICA-4 the lowest percent filled grain (79.8%/m^2) in hoe weeded plots. During both experiments, unfilled grain was determined, the highest unfilled grain in 2014/2015 experiment was recorded on NERICA-1 in pre-emergence (31.4%/m^2) and lowest unfilled grain (16.3%/m^2) was recorded on NERICA-4 in hoe weeded plots. 2015 experiment was recorded with the highest unfilled grain (318.8%/m^2) on NERICA-4 in pre-emergence (ULTRA 2, 4-D 720 CE) plots and lowest unfilled grain (22.0%/m^2) on NERICA-7 in hoe weeding plots (Table 10).

Table 10: Mean panicle number, spikelet number and percent filled grain/m^2 during 2014/15 and 2015 experiments

	2014/15			2015		
Treatment	Panicle number	Spikelet number	Filled grain	Panicle number	Spikelet number	Filled grain
(A)Weed mgt. practices						
Pre-emergence	56.5b	10.3b	90.0b	61.3b	12.2b	88.8a
Post-emergence	76.2c	15.0c	93.6b	64.2b	12.4b	83.4a
Hoe weeding	101.6d	22.2d	90.2b	61.3b	35.6b	85.0a
Weedy	0.0a	0.0a	0.0a	54.8a	10.9a	88.6a
Mean	**58.6**	**11.9**	**68.5**	**60.4**	**17.8**	**86.5**
CV (%)	**7.6**	**5.1**	**6.9**	**6.1**	**4.2**	**3.7**
SE ±	**4.5**	**0.6**	**6.5**	**3.8**	**0.5**	**3.2**
(B)Variety						
NERICA-1	57.4ab	11.6ab	69.62b	64.4b	12.8b	90.7b
NERICA-4	62.0b	12.4bc	70.33b	64.6b	12.9b	82.8a
NERICA-7	51.5a	9.8a	69.09b	61.5b	12.2b	82.7ab
Mwangaza	63.4b	13.7c	64.76a	51.1a	10.2a	85.6ab
Mean	**58.6**	**11.9**	**68.5**	**60.4**	**12.0**	**85.5**
CV (%)	**6.3**	**2.8**	**4.3**	**3.3**	**4.3**	**1.0**
SE +	**3.711**	**0.34**	**4.0**	**1.9**	**0.5**	**0.8**
(A x B) Interaction						
Pre x N-1	46.7b	9.2b	96.1cd	68.2	13.6	92.8
Pre x N-4	68.2cd	14.0bc	94.55cd	65.2	13	84.1
Pre x N-7	46.7b	9.3b	91.05cd	59	11.8	88.4
Pre x MWG	64.2bc	8.8b	78.2b	53	10.6	89.8
Post x N-1	84.0de	16.1cd	95.1cd	68.7	13.8	86.4
Post x N-4	70.5cd	14.0bc	96.1d	66.7	13.3	80.9
Post x N-7	64.7bc	13.4bc	87.4b-d	65.2	12.7	85
Post MWG	85.7def	16.8cd	95.3cd	56.2	11.2	81.4
Hoe x N-1	99.0efg	21.3d	87.3b-d	64.2	12.8	91.4
Hoe x N-4	109.2g	21.6d	90.0cd	68	13.6	79.8
Hoe x N-7	94.7ef	16.5cd	98.0d	60.7	12.1	85.4
H. x MWG	103.7fg	29.5e	85.6bc	52.2	10.4	83.3
Weedy x N-1	0.0a	0.0a	0.0a	56.5	11.3	92.2
Weedy x N-4	0.0a	0.0a	0.0a	58.7	11.7	86.5
Weedy x N-7	0.0a	0.0a	0.0a	61	12.2	88.1
Weedy x MWG	0.0a	0.0a	0.0a	43	8.6	87.8
Mean	**58.6**	**11.9**	**68.4**	**60.4**	**12.0**	**86.5**
CV (%)	**11.4**	**20.0**	**14.5**	**13.9**	**9.4**	**7.2**
SE +	**6.7**	**2.5**	**13.5**	**8.32**	**1.1**	**6.2**

Figures followed by the same letter (s) in the marginal and interaction means are not significantly different at $P< 0.05$ according to Turkey's test

4.6.4 Grain yield

The weed management practices influenced grain yields in all treatments during 2014/2015 and 2015 experiments. Grain yield recorded significant difference ($P\leq 0.05$) among treatments which were similar to others between treatments. NERICA-1 recorded

In the 2014/2015 experiment, highest grain yield (2187.5kg/ha) on hoe weeded plots while the lowest grain yield (482.9kg/ha) was recorded on NERICA7 in post- emergence Hansunil 600 EC plots. In the 2015 experiment, the highest grain yield (4630.6kg/ha) was recorded on NERICA-1 in post-emergence (Hansunil 600 EC at 4.8kg a.i. /ha) plots and the lowest grain yield (2272.7kg/ha) recorded on Mwangaza in weedy plots. During the 2014/15 experiment, none of the rice genotypes survived under weedy conditions. As a result, slight modifications were made to the weedy plots during the 2015 experiment by replacing it with one late hoe weeding done to mimic farmer conditions. The modifications made to the weedy plots during the 2015 experiment responded positively as indicated by 2015 experiment data output compare to 2014/15 experiment data output (Figures 9).

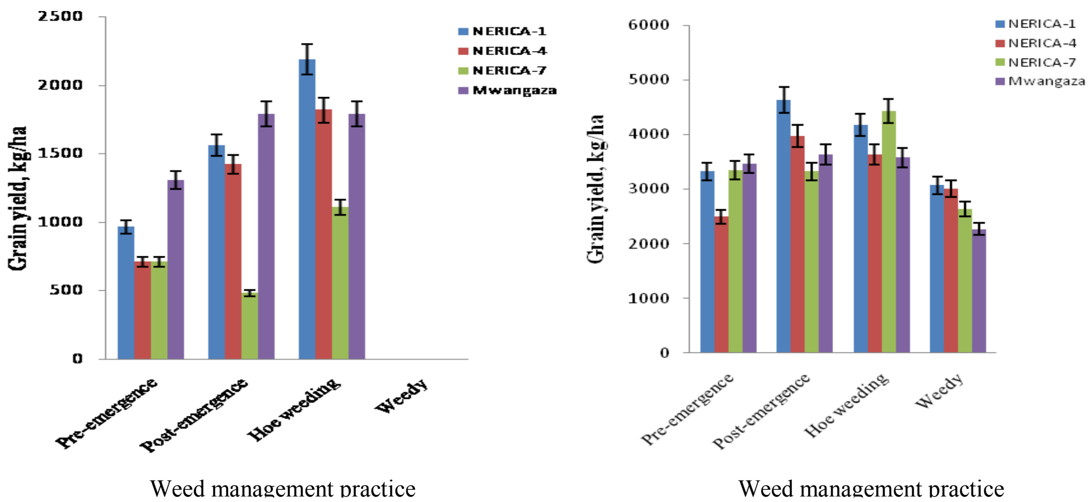

Figure 9: Mean grain yield during 2014/2015 and 2015 experiments

4.7 Herbicide Phytotoxicity on Rice Plants

During the second field experiment, herbicide phytotoxicity was observed on NERICA-7 in plots treated with Pre-emergence herbicide. The visible symptoms observed included stunting of rice plants, yellowing of the leaves and partial leaf scorching. The symptoms were observed a month after the herbicide application. The crop gradually recovered as the leaves turned from (yellowish to greenish), but recovered plants showed retarded growth up to reproductive stage. The observed plots were also noticed to have flowered and matured later than the other treated plots (Figure 10).

Figure 10: **Herbicide Phytotoxicity effects on Rice Plants**

4.8 Correlation Analyses

Correlation analyses to determine the relationship between the variables recorded are summarized on Tables 11 and 12. Negative correlation existed between number of weeds or weed dry biomass and number of tillers, panicle, straw biomass, filled grain, unfilled grain, spikelet, and grain yield. Positive correlation was observed between panicle counts, number of tillers, grain yield, leaf area index, filled grain, and spikelet counts. Significant but negative correlation was obtained between weed dry biomass and unfilled grain. It is weed dry biomass and unfilled grain negatively correlated not weed dry matter. This was possibly because at low crop densities, there is less canopy cover early in the growing season, leaving more resources obtainable for the weeds and thus enabling them to start and grow quickly. The variables that were significant and positively correlated were grain yield, tiller counts, panicle counts, leaf area index, filled grain, and spikelet counts (Table 11).

Table 11: Correlation of variables for the experiment during 2014/2015

	Grain Yield	Straw Bio mass	Plant Height 39 DAS	Plant Height 62 DAS	Plant Height 83 DAS	Panicle Count	Tiller Count	Filled Grain	Spikelet Count	Unfilled Grain	LA I	Sedge Biomass	Broad leaf Biomass	Grass Biomass
Grain Yield	1.00													
Straw Biomass	0.79**	1.00												
Plant Height	0.32*	0.36*	1.00											
Plant Height	0.77**	0.87**	0.41*	1.00										
Plant Height	0.72**	0.85**	0.38*	0.98**	1.00									
Panicle Count	0.86**	0.88**	0.34*	0.83**	0.82**	1.00								
Tiller Count	0.85**	0.92**	0.30*	0.78**	0.78**	0.94**	1.00							
Filled Grain	0.60**	0.73**	0.22	0.78**	0.83**	0.79**	0.77**	1.00						
Spikelet Count	0.84**	0.89**	0.34*	0.79**	0.77**	0.92**	0.93**	0.69**	1.00					
Unfilled Grain	0.59*	0.82**	0.30*	0.85**	0.85**	0.72**	0.70**	0.79**	0.71**	1.00				
L A I	0.53*	0.67**	0.29	0.85**	0.90**	0.67**	0.65**	0.88**	0.59*	0.76**	1.00			
Sedge Biomass	-0.71**	-0.80**	-0.28	-0.80**	-0.82**	-0.82**	-0.79**	-0.75**	-0.78**	-0.74**	-0.72**	1.00		
B .leaf Biomass	-0.77**	-0.87**	-0.31*	-0.88**	-0.90**	-0.86**	-0.85**	-0.86**	-0.80**	-0.84**	-0.80**	0.89**	1.00	
Grass Biomass	-0.74**	-0.85**	-0.31*	-0.93**	-0.94**	-0.86**	-0.83**	-0.89**	-0.80**	-0.86**	-0.88**	0.77**	0.88**	1.00

Key: *Significant at ($P \leq 0.05$) and ($P \leq 0.01$)

Table 12: **Correlation of variables for the experiment during 2014/2015 and 2015 season**

	Filled Grain	Unfilled Grain	Spikelet Count	Plant Height 39 DAS	Plant Height 62 DAS	Plant Height 83 DAS	Tiller Count	L A I	Panicle Count	Grain Yield	Straw Biomass	Broad leaf Biomass	Grass Biomass	Sedge Biomass
Filled Grain	1.00													
Unfilled Grain	-0.30*	1.00												
Spikelet Count	-0.08	0.16	1.00											
Plant Height	-0.29	0.00	-0.31*	1.00										
Plant Height	-0.29	-0.08	-0.49*	0.79**	1.00									
Plant Height	-0.37*	-0.04	-0.27	0.67**	0.76**	1.00								
Tiller Count	0.20	-0.21	0.33*	-0.16	-0.47*	-0.25	1.00							
L A I	-0.17	-0.20	0.09	0.13	0.22	0.52*	-0.07	1.00						
Panicle Count	-0.42*	0.25	-0.10	0.39*	0.29	0.45*	-0.11	0.18	1.00					
Grain Yield	-0.02	-0.35*	0.36*	0.03	-0.12	-0.00	0.34*	0.07	-0.03	1.00				
Straw Biomass	-0.16	-0.09	0.16	0.21	-0.10	0.06	0.49*	0.08	0.19	0.59*	1.00			
Sedge Biomass	0.04	-0.02	-0.30*	0.09	0.20	-0.12	-0.19	-0.21	-0.05	-0.35*	-0.18	1.00		
B .leaf Biomass	-0.15	0.01	0.22	-0.13	-0.16	-0.07	0.04	-0.09	0.21	0.24	0.19	-0.17	1.00	
Grass Biomass	0.12	0.19	-0.06	-0.03	0.02	0.06	-0.04	0.07	0.03	-0.39*	-0.32*	-0.09	-0.13	1.00

Key: *Significant at ($P \leq 0.05$) and ($P \leq 0.01$)

4.9 Return on Investment

Weed management practices involved different production costs. Hoe weeding recorded the highest cost (Tshs 640,174 ha^{-1}) on NERICA-1 during both experiments on the weed management practices. The return on investment indicated significant differences ($p \leq 0.05$) Table 13 and 14. However, hoe weeding recorded highest profit (Tshs 2 806 751) during the first experiment and post-emergence produced the highest profit (Tshs 6 191 591) during the 2015 experiment on NERICA-1. In 2014/15 experiment, the lowest profit (Tshs 384 811) was recorded on NERICA-7 in post-emergence plots and the lowest profit (Tshs 3 294 191) was produced in 2015 experiment on NERICA-4 in pre-emergence plots (Table 13 and 14). Profit analysis showed NERICA-1 in both experiments as the highest (Tshs 3 062 500 and 6 482 840) economic return during the study respectively. The cost of weed control, net revenue and profit analysis in different weed management practices were obtained as indicated in (Appendix 1 and 2). The yield of milled rice was determined as expressed by (Minot, 2010). Data for control treatments were included as indicated on (Table 13 and 14).

Table 13: Cost of production under different weed management practices during November 2014 to January 2015 experiment

Treatment	Rate Kg ai. /ha	Actual yield kg/ha	Milled yield kg/ha	Market Price/kg (Tshs)	Herbicide Cost Litres/ha (Tshs)	Hoe Weeding cost/ha (Tshs)	App. Cost/ha (Tshs)	Labour Cost/ha (Tshs)	T VC (Tshs/ha)	Revenue (Tshs/ha)	Profit (Tshs/ha)	Rate of return (%/ha)
Pre x N-1	2.88	965.9	676.1	2 000	34 560	-	10 000	161 249	205 809	1 352 260	1 146 451	5.6
Pre x N-4	2.88	710.2	497.1	2 000	34 560	-	10 000	161 249	205 809	994 280	788 471	3.8
Pre x N-7	2.88	710.2	497.1	2 000	34 560	-	10 000	161 249	205 809	994 280	788 471	3.8
Pre x MWG	2.88	1306.8	914.8	2000	34 560	-	10 000	161 249	205 809	1 829 520	1 623 711	7.9
Post x N-1	4.8	1562.5	1093.8	2 000	120 000	-	10 000	161 249	291 249	2 187 500	1 896 251	6.5
Post x N-4	4.8	1420.4	994.3	2 000	120 000	-	10 000	161 249	291 249	1 988 560	1 697 311	5.8
Post x N-7	4.8	482.9	338.0	2 000	120 000	-	10 000	161 249	291 249	676 060	384 811	1.3
Post MWG	4.8	1789.7	1252.8	2 000	120 000	-	10 000	161 249	291 249	2 505 580	2 214 331	7.6
Hoe x N-1	-	2187.5	1531.3	2 000	-	384,425		255 749	640 174	3 062 500	2 422 326	11.0
Hoe x N-4	-	1818.1	1272.7	2 000	-	384,425		255 749	640 174	2 545 340	1 905 166	9.0
Hoe x N-7	-	1107.9	775.5	2 000	-	384,425		255 749	640 174	1 551 060	910 886	5.1
H. x MWG	-	1789.7	1252.8	2 000	-	384,425		255 749	640 174	2 505 580	1 865 406	8.8
Weedy x N-1	-	0	0	2 000	0	-	0	128 999	128 999	0	-128999	-1.0
Weedy x N-4	-	0	0	2 000	0	-	0	128 999	128 999	0	-128999	-1.0
Weedy x N-7	-	0	0	2 000	0	-	0	128 999	128 999	0	-128999	-1.0
Weedy x MWG	-	0	0	2 000	0	-	0	128 999	128 999	0	-128999	-1.0

The yield of milled rice was determine as 70% of actual yield obtained (kg/ha), Pre x N-1=Pre-emergence and NERICA, MWG = Mwangaza, Post x NERICA=Post-emergence and NERICA, Hoe Weeding x NERICA= Hoe weeding and NERICA and cont x NERICA=control and NERICA and Mwangaza

Table 14: Cost of production (Tshs) under different weed management practices during March to June 2015 experiment

Treatment	Dosage Rate Kg a. i. /ha	Actual yield kg/ha	Milled yield kg/ha	Market Price/kg (Tshs)	Herbicide Cost (Tshs/ha)	Hoe Weeding cost/ha (Tshs)	Application Cost (Tshs/ha)	Labour Cost (Tshs/ha)	T VC (Tshs/ha)	Revenue (Tshs/ha)	Profit (Tshs/ha)	Rate of return (%/ha)
Pre x N-1	2.88	3323.8	2326.7	2 000	34 560	-	10 000	161 249	205 809	4 653 320	4 447 511	21.6
Pre x N-4	2.88	2500	1750	2 000	34 560	-	10 000	161 249	205 809	3 500 000	3 294 191	16.0
Pre x N-7	2.88	3352.2	2346.5	2 000	34 560	-	10 000	161 249	205 809	4 693 080	4 487 271	21.8
Pre x MWG	2.88	3465.9	2426.1	2 000	34 560	-	10 000	161 249	205 809	4 852 260	4 646 451	22.6
Post x N-1	4.8	4630.6	3241.4	2 000	120 000	-	10 000	161 249	291 249	6 482 840	6 191 591	21.3
Post x N-4	4.8	3977.2	2784.0	2 000	120 000	-	10 000	161 249	291 249	5 568 080	5 276 831	18.1
Post x N-7	4.8	3323.8	2326.7	2 000	120 000	-	10 000	161 249	291 249	4 653 320	4 362 071	15.0
Post MWG	4.8	3636.3	2545.4	2 000	120 000	-	10 000	161 249	291 249	5 090 820	4 799 571	16.5
Hoe x N-1	-	4176.1	2923.3	2 000	-	384425	-	255 749	640 174	5 846 540	5 206 366	8.1
Hoe x N-4	-	3636.3	2545.4	2 000	-	384425	-	255 749	640 174	5 090 820	4 450 646	7.0
Hoe x N-7	-	4431.8	3102.3	2 000	-	384425	-	255 749	640 174	6 204 520	5 564 346	8.7
H. x MWG	-	3579.5	2505.7	2 000	-	384425	-	255 749	640 174	5 011 300	4 371 126	6.8
Weedy x N-1	-	0.78	0.55	2 000	0	-	0	128 999	257 140.7	1100	-26040.7	-10.12
Weedy x N-4	-	0.76	0.53	2 000	0	-	0	128 999	257 140.7	1060	-256080.7	-99.6
Weedy x N-7	-	0.67	0.47	2 000	0	-	0	128 999	257 140.7	940	-256200.7	-99.6
Weedy x MWG	-	0.57	0.40	2 000	0	-	0	128 999	257 140.7	800	-256340.7	-99.6

The yield of milled rice was determined as 70% of actual yield obtained (kg/ha), Pre x N-1=Pre-emergence and NERICA, MWG = Mwangaza, Post x NERICA=Post-emergence and NERICA, Hoe Weeding x NERICA= Hoe weeding and NERICA and cont x NERICA=control and NERICA and Mwangaza

CHAPTER FIVE

5.0 DISCUSSION

5.1 Weather during the Growing Season

Upland rice production in the tropics is heavily dependent on natural weather, especially rainfall which is not evenly distributed in some regions. Upland rice grows under a wide range of rainfall, ranging from 700-800 mm in areas of 4000 mm in forest areas. The mean values for rainfall during the study period was considered inadequate especially during 2014/15 experiment when mean monthly rainfall mean ranged from (1.5 mm to 5.0 mm and 0.0mm to 4.7 mm) which is crucial to crop growth. Somado *et al*. (2008) reported that Upland rice grows and develops well to give the optimal yield when 1000 mm well distributed rainfall is obtained during the growing season. Irrigation activities were done as a normal practice.

Temperature is a major biotic factor that has considerable effect on growth and development of rice. The recorded mean maximum temperature during growing season was 30.7 ^{o}C while the mean minimum temperature during the period was 25.2 ^{o}C, respectively. This recorded temperature was optimum for rice growth and development (Yoshida and Parao, 1976). Shemanhonge (2013) reported that for higher rice grain yield, a day temperature of 25 to 32^{o}C and night temperature range from 15 to 20 ^{o}C are preferred. Relative humidity (RH) during the experiments was 75%. Relative humidity ranged from 74.4 to 84.6 December 2014 to January 2015. The mean RH during the growing season was 90.4%. Optimum RH range from 60 to 70% is beneficial for crop development according to Oikech *et al.* (2008). The observed RH was above the preferred value required for rice production. The mean values for rainfall, maximum and minimum temperature, relative humidity and radiation for past 10 years was collected to contrast the trend and impact of climate change of the given parameters since 10 years as compared to present climatic condition in respective of crop growth and development.

5.2 Weed Control and Dry Weight

The major weed flora identified in the field during the experiments consisted of broadleaf *(Mimosa pudica L., Amaranthus retroflexus, Commenelina benghalensis L., Launaea spp.* and *Richadria),* grasses *(Echinochloa spp, Sorghum halepa, Cynodon dactylon* and *Panicum Maximum spp)* and sedges (*Cyperus rotundus,* and *Cyperus esculentus).* Weed density and weed species were higher in the experiment; broad leaves weed was the dominant weed species. The average weed prevalence (368.0g/m^2) was observed in control plots during the experiment. This result is supported by the findings of Singh (1996), Bhandari (1986) and Thapa and Jha (2002) who reported on weed management and control in upland rice field in New Delhi, India and Pokhara, Nepal.

Weed dry biomass was reduced for plots treated with Post-emergence herbicide (Hansunil) and hoe weeding while control plots and plots applied with pre-emergence herbicide (ULTRA 2-4 D) recorded higher weed dry biomass, this was due to the effectiveness of hand hoeing and post-emergence treatments on the suppression of weed growth. Broad leaf species were dominant during both experiments and weed infestations were not uniform among treatments. The dominance of the broad leaf weeds was due to the ability of the broad leaf weed to shade the grasses which increased it competition with the sedge species.

Weeds competition with crop affected water and nutrient uptake, space and light; this caused a declined in the growth parameters including plant height, leaf area index, tiller, panicle spikelet and straw biomass. This result is supported by a finding of

Hi-Jinhao *et al*. (1999) on the occurrence of weeds in arid seedling nursery of early rice and their control in Laguna, Philippines. Weed species compete with crop right from germination to harvest, thus adversely affecting the crop yield and biomass accumulation (Patel *et al*., 2003).

Early canopy establishment, due to tillers formation, helped crops to keep weed density at low level by shading the weeds from direct sunlight. However, weed density established under pre-emergence herbicide management practice was high as compared to hoe weeding and post-emergence, this could be attributed to the ineffectiveness of the pre-emergence herbicide used during the experiment. The use of appropriate herbicide can eliminate early competition and increase crop growth and production (Muehbauer *et al*., 1995).

Post emergence was found to be most effective in reducing density of the weed groups (broad-leaf and Grasses) keeping them suppressed up to harvest stages of the crop. Hoe weeding and post-emergence treatments had maximum weed control in both experiments. The results of low weeds biomass by hoe and post-emergence treatments reduced the competition of weed against crop on space, light, moisture and nutrient that support vigorous plant growth by producing high tiller number, straw biomass, leaf area index, panicle count, spikelet count and grain yield. These results are in line with findings in rice field reported by Ismaila *et al*. (2011), that maximum weed suppression in rice was a result of hoe weeding three times (Akbar *et. al*., 2011). Moody and De Datta (1986); and Singh *et al*. (2005) also reported that post-emergence treatment and hoe weeding significantly controlled weeds of rice field.

The control plots showed maximum weeds density during the 2014/15 experiment. In the control plots, the three weed groups grew vigorously; competed with the crop and kept it suppressed throughout the growing season thus competing with the crops on water, space, light, moisture and nutrient which caused all the crops to not survived. The rice plants under this condition could not maintain growth to shade the weeds from reducing supply of light and availability of space and nutrient. However, during the 2015 experiment, control plots were amended with one weeding (63 DAS), this allowed the crops to compete with the weeds for water, space, and light and nutrient resources thus allowing the crops to outperformed the weeds and yield was obtained from the amended plots which made it quite different from the 2014/15 experiment in terms of data output. Under the control plots condition, there was one hoe weeding of all the rice genotypes which was done in the 2015 experiment.

5.3 Crop Growth and Yield Attributes

Crop growth and development was significantly influenced by management practices during both experiments. Low plant growth and yield were observed in control plots for both experiments due to high crop- weed composition. Johnson (1996) observed that the major impediment in the cultivation of rice is heavy weeds infestation particularly in upland ecology, which compete with the crop to such extent that it could get smothered. Similar results were obtained by (Akbar *et al.*, 2011), who reported higher plant height for rice under weed free conditions than weedy conditions. Mean tiller count varied among rice varieties for both experiments with the highest tiller count observed under hoe weeding while control plots recorded the lowest tiller count. Hoe weeding recorded the highest tiller count during both experiments, whereas the lowest tiller counts were observed in control plots. Hoe weeding was labor intensive and time consuming, however, three times hoe weeding reduce the pressure of competition from the weeds;

this resulted in to the increased of tillers, panicle, spikelet, leaf area index, straw biomass and yield. Weeds are more efficient utilizers of available nutrients in soil rice crops; therefore, unweeded plots will result in yield loss as a result of reduction in growth components by weeds (Idem and Showemimo, 2004). Rice growth under hoe weeding treatment suppressed emerging weeds in competition of space light, nutrients and water. These results are in line with results reported by Ullah *et al*. (2009), who observed that effective tillers increased with proper weed management, hence productivity. Ismaila *et al.* (2011) also recommended three times hoe weeding for proper weed suppression and yield improvement in rice fields.

The various weed control practices each had a positive effect on weed biomass accumulation. The weed management practices induced significant variation in grain yields in particular, hoeing and post-emergence were proving to be the most effective management practices. Hoe weeding three times was more effective in controlling weeds, perhaps because it damaged germinating weeds growing within the rows in the crop, thereby delaying their flowering. Post-emergence treatment also reduced weeds pressure on the crop by effectively controlling weeds, possibly this could be that the post-emergence treatment destroyed all single-stemmed weeds germinating within the crop. These results are supported with the findings of Akbar *et al.* (2011) who reported on weed management improves yield and quality of direct seeded rice in Australian.

5.4 Economic Analysis

5.4.1 Cost of weed management

Different weed control practices involved different cost which affected total production cost. Post-emergence was effective on weeds control with the cost of Tshs (291 249 ha^{-1}). Hoe weeding was laborious and more expensive; however, hoe weeding three times gave maximum weed control cost of Tshs (640 174 ha^{-1}) during both experiments respectively

(Table 12 and 13). Herbicide gave lower cost of weed control. Pre-emergence ULTRA 2, 4-D herbicide gave lowest weed control cost of Tshs 205,809 ha^{-1} for the both experiments but recorded the lowest profit (Tables 12 and 13). The benefit of post-emergence and hoe weeding treatments were (37.7%, 33.9%) increased in grain yield, reflecting a good level of control over weeds growing in the experimental plots. The pre-emergence herbicide performed less well, achieving 28.3% benefit over the weed control. These results are in line with findings by Mirza *et al*. (2007) who reported that hand weeding is laborious and gave higher weed control cost while the use of herbicide gave the lower cost of weed control.

The highest revenue (2 505 580Tsh and 6 482 840Tsh) for both experiments was obtained with post emergence plots due to higher grain yield (1789.7 kg/ha and 4630.6kg/ha) and lesser cost of production (291 249 Tshs) compared to three times hoe weeding with highest grain yield (2187.5kg/ha and 4431.8kg/ha) and cost (640 174 Tshs) of production for both experiments respectively.

Pre-emergence ULTRA 2, 4-D herbicide was applied once given low weed control cost (205 809); this was not profitable as the grain yield (1306.8kg/ha and 3465.9kg/ha) was lower than post emergence and hoe weeding for both experiments (Tables 12 and 3). These results are supported by works of Upanhyay and Chaudhary (1979) who reported that hand weeding and hoe weeding three times was more economical than applying herbicide only. Average return on investment for both experiments ranged from 7.5% -12.9% with the highest benefit cost ratio observed in pre emergence, (2, 4-D). This finding is in line with reports by Chakra borty and Majumdar (1973) who obtained best economic return with 2, 4-D. Sabio and Pastories, (1981) also reported that application of herbicides was more economical than manual or hand weeding alone.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATION

6.1 Conclusions

Based on the results obtained from this study, it is concluded that:-

(i) Weeds are a major constraint over the yield of upland rice. The present study has revealed that post-emergence, hoe weeding, and pre-emergence (herbicide) treatments provided a level of control compared to weedy plots (37.8%, 33.9%, and 28.3% respectively. Although hoe weeding was an effective means of control, post-emergence was more economical, delivering a return on investment of 37.8%. Weeds can be effectively and economically controlled in upland rice using post-emergence.

(ii) The most effective weed management practices were hoe weeding and post-emergence herbicide treatment which resulted to the attainment of the high grain yield and subsequent high returns on investment. These treatments offer alternatives for resource-poor and large-scale producers, respectively.

6.2 Recommendation

Based on results from the current study, the following recommendations are made:

(i) Hoe weeding as a management practice is recommended to resource poor farmer based on its influence on yield.

(ii) Hansunil which was also effective in weed control and had significant effect on profit analysis should be used in combination with hoe weeding under integrated weed management.

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APPENDICES

Appendix 1: Cost of weed control in different weed management practices in (Tshs/ha) on the tested genotypes of the first experiment

Treatment	Yield of Milled Rice/kg				Qty. /ha	Herbicide Cost Litres /ha	Labour (Tshs/ha)	Total Cost
	N-1	N-4	N-7	MWG				
Pre-emerg	676.1	497.1	497.1	914.8	2.88	34 560	161 249	205 809
Post-emerg	1093.8	994.3	338.0	1252.8	4.8	120 000	161 249	291 249
H. eeding	1531.3	1272.7	775.5	1252.8	113	384 425	255 749	640 174
Weedy	0	0	0	0	0	0	128 999	128 999

The yield of milled rice was determine as 70% of actual yield obtained (kg/ha),
N- 1=NERICA-1, N- 4 =NERICA-4, N-7 =NERICA-7 and MWG =Mwangaza

Appendix 2: Cost of weed control in different weed management practices in (Tshs/ha) on the tested genotypes of the repeat experiment

Treatment	Yield of Milled Rice/kg				Qty. /ha	Herbicide Cost Litres /ha	Labour (Tshs/ha)	Total Cost
	N-1	N-4	N-7	MWG				
Pre-emerg	2326.7	1750.0	2346.5	2426.1	2.88	34 560	161 249	205 809
Post-emerg	3241.4	2784.0	2326.7	2545.4	4.8	120 000	161 249	291 249
H. Weeding	2923.3	2545.4	3102.3	2505.7	113	384 425	255 749	640 174
Weedy	2147.7	2107.9	1849.4	1590.9	0	0	128 999	257 140.7

The yield of milled rice was determined as 70% of actual yield obtained (kg/ha),
N-1=NERICA-1, N- 4 =NERICA-4, N-7 =NERICA-7 and MWG =Mwangaza;