DECLARATION

This Thesis is my original work and has not been presented for a degree in any other university.

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This Thesis has been submitted for examination with our approval as the university supervisors.

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DEDICATION

I dedicate this work to the Almighty God for giving me strength and courage to complete it. Also to my parent Mary for the encouragement throughout my studies. And to my sisters Naomi, Nancy, Emma and Tabby.

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Firstly, I would like to thank God for the gift of life. I am heavily indebted to several people who have contributed to the successful completion of this work. I would like to express my heart felt gratitude to the University of Nairobi for awarding me a scholarship to pursue my Master of Science degree in Agronomy.

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Finally, I thank my mum for continuous encouragement which was a great source of inspiration in my study.

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ABSTRACT

One of the major constraints to bean production is the high labor requirements that farmers face in land preparation, planting and weed control. The conventional methods of weed control in many parts of Kenya and Africa is using a hoe and a machete, which is tedious and time consuming. A field experiment was therefore conducted during the 2009 long rains and short rains seasons at the University of Nairobi's Kabete Campus Field Station to determine the effectiveness of various weed management options and nitrogen fertilizer application in improving the performance of a dry bean crop. The following weed management options were evaluated:

1) mowing the weeds at the ground level and planting without hoeing the plot.,

2) hoeing the plots removing all the weeds;

3) hoeing the plots and then incorporating the weeds into the soil;

4) hoeing the plots and then leaving the weeds on the ground to act as mulch;

5) spraying the plots with a herbicide and then leaving the weeds on the ground to decompose and planting without hoeing the field. Emerging weeds were controlled by hoeing;

6) spraying the plots with a herbicide and then leaving the weeds on the ground to decompose and planting without hoeing the field. Emerging weeds were controlled by mowing. The N treatments consisted of 0 kgN/ha and 30 kgN/ha. The treatments were laid out in a randomized complete block design with a factorial arrangement. Bean variety Mwezi moja was used as the test variety. Data collected included: percent emergence, plant height, number of nodules per plant, nodule dry matter, root dry matter, shoot dry matter, number of days to 50% flowering, number of seeds per pod, number of pods per plant, weight of 100 seeds, total seed weight, soil moisture content, weed population by species, total number of weeds and soil N before and after the experiment. All data were subjected to analysis of variance using General Statistics package (GENSTAT) for windows and means separated

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One of the major constraints to bean production is the high labor requirements that farmers face in land preparation, planting and weed control. The conventional methods of weed control in many parts of Kenya and Africa is using a hoe and a machete, which is tedious and time consuming. A field experiment was therefore conducted during the 2009 long rains and short rains seasons at the University of Nairobi's Kabete Campus Field Station to determine the effectiveness of various weed management options and nitrogen fertilizer application in improving the performance of a dry bean crop. The following weed management options were evaluated:

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using the least significant difference (LSD) test at 5% level of significance.

The results showed that use of mulch increased soil moisture content, bean nodulation, grain yield and yield components, delayed emergence and flowering and reduced weed population. Incorporating the weeds into the soil had similar effects as mulch although it did not increase the yield and yield components relative to mulching. Relative to mulching, mowing and herbicide application resulted to reduced soil moisture, nodulation, yields and yield components and delayed emergence but hastened flowering. Hoeing the field resulted in reduced soil moisture content, weed population, yield and yield components but hastened germination and flowering. Application of N at the rate of 30 kg/ha did not significantly increase grain yield of bean relative to zero N.

It was concluded that mulching a bean crop is more effective in conserving soil moisture and hence having a good crop performance and yield than conventionally opened plots, plots with weeds incorporated in the soil or herbicide treated plots. The effectiveness was attributed to the high moisture content conserved in these plots. The evidence from the crop performance in terms of height, flowering, nodulation, yield and yield components suggested that mulching is the most promising weed management practice followed by incorporating the weeds in the soil, hoeing and herbicide application, especially to small scale farmers who cannot afford the high costs of herbicides and the expertise required in their application. It was also concluded that application of nitrogenous fertilizer at a rate more than 30 kgN/ha could improve the bean crop growth and yield.

It was therefore recommended that studies needed to be done to determine whether rates of N fertilizer more than 30kg/ha are beneficial, hoeing the field and leaving the crops and weed residual in the field to decompose should be undertaken as a means of conserving moisture in a bean crop and hence improving overall yield and further investigations to be undertaken to determine the best mulching material for a bean crop and its cost implication, especially to a small scale farmer. Studies should be done to determine the weeds that leave a lot of weed seed on the field for farmers to avoid them as mulch.

CHAPTER ONE: INTRODUCTION

1.1 Background information

Phaseolus vulgaris (L.) bean or dry bean is the world's most important food legume. World production for dry beans for the year 2008 was 18 million metric tonnes. The area harvested under dry beans was over 25 million hectares. The global dry bean harvest of 18 million metric tonnes annually has an estimated value of US $ 11 billion (Peterson *et al.*, 2006). Latin America is the most important dry bean producing region, its 8 million hectares accounting for nearly half of the global output, with Brazil and Mexico being the major dry bean producers (Fageria *et al.*, 2006). Africa is considered to be the secondary centre of dry bean genetic diversity. In Africa, small farms are the primary dry bean growers. Farmers plant about 3 million hectares of dry beans annually in eastern, central and southern Africa, usually as a mixture of varieties (Laing *et al.*, 2004)

Dry bean has high quality protein, it provides vitamin B and 25-30% of daily recommended iron level important for pregnant mothers. Similarly, dry bean provides 25% of the daily requirements of Mg, Cu and 15% of K and Zn (Adams, 2005). Dry bean production is more than twice that of chick pea which is the second most important grain legume worldwide. Eight of the ten major producers of dry bean are developing countries which collectively produce 86% of worldwide bean production (Fageria *et al.*, 2007).

Dry bean is an attractive crop to farmers because of its adaptability to different cropping systems and short growing cycle. The disadvantage, however, of the dry bean plant is its susceptibility to diseases (e.g. bean rust, angular leaf spot, and common bacterial blight), pests (e.g. bean stem maggot) and abiotic stresses such as drought, soil acidity and nutrient deficiency. About 60% of dry bean production in the developing countries suffers from low phosphorous availability in the soil (Acklands and Francis, 1995). Soil related constraints become important as dry bean production is increasingly concentrated in more marginal lands, with high pH due to accumulation of bases and high P fixation (Fageria *et al.*, 2006). Farmers' economic inability or reluctance to use inputs also contributes heavily towards low production of dry bean (Gepts and Debouks, 2005).

Although there has been an increase in dry bean production, resulting from extension of cultivation into marginal areas, its productivity per unit area has continued to decline (Denis and Adams, 2001). Low and unstable dry bean yields are in most cases caused by planting beans in environments that they are not physiologically adapted. Cultivars with a determinate, erect and bush growth habitat can be grown in areas well suited to intensive cultivation with some degree of mechanization (Hardwick, 2002). An equally important constrain in dry bean production is labor requirements that farmers face when opening the field and planting. The conventional method of weed control in many parts of Kenya and Africa is by cultivation using a hoe and a machete, which is tedious and time consuming (Blevins *et al.*, 2000).

1.2 Statement of the problem and justification

The conventional method of field tillage and weed control in many parts of Kenya and Africa is cultivation using a hoe and /or machete, which is tedious, costly and time consuming. In addition, most of the herbicides used to control weeds are expensive and therefore out of reach of most small holder farmers. Further, herbicides are expensive to apply and leave undesirable residual effects in the soil when continuously applied. Any system of crop production, which will make it possible to have early planting and minimize weed problems, has the potential to improve dry bean crop yields. Hence, there is need to develop cost effective weed control measures that will reduce the labor requirements during opening up of the field.

Conservation agriculture has the potential to be an alternative production system for small scale famers. This system requires less labor and alleviates the problem of labor shortage in small holder farms. Furthermore, increased concerns about environmental degradation, reduced biodiversity, and high production costs for dry bean have increased farmers' interest in reduced or no tillage systems in combination with low cost and environmentally friendly weed management.

Frequent tillage operations are often costly and rarely beneficial. Less cultivation in many soils particularly volcanic ones would lead to greatly reduced erosion, better moisture conservation and increased yield. This approach to farming is very attractive to farmers in Africa since it boosts yields, saves labour and money and conserves soil and the environment. It appeals to all categories of farmers from small scale subsistence farmers to high technology commercial producers. Conservation agriculture can be used in all climates and on all soils where it is possible to grow crops. Conservation agriculture can contribute significantly to the achievement of the millennium development goals which include eradicating poverty and hunger by helping famers produce more food for themselves and for the market.

Most research on weed management practices based on reduced tillage has been conducted in North America and Latin America but limited research has been conducted in Kenya. Weed population and yield of common bean under different methods of weed control during field preparation and weeding in a bean crop have produced varied results. This study therefore seeks to determine the effect of different weed management options and nitrogen on growth and yield of dry bean.

1.3 Objectives

The overall objective of this study was to develop effective weed management options for the production of dry bean. The study addressed the following specific objectives:

1. To determine the effect of different weed management options on seedling emergence, growth and yield of dry beans.
2. To determine the effect of different weed management options on soil moisture and soil nitrogen in dry bean plots.
3. To determine the effect of different weed management practices on weed population in dry bean plots.
4. To determine the effect of nitrogen on seedling emergence, growth and yield of dry bean under different weed management options.
5. To determine the effect of nitrogen application on weed population in dry bean plots.

1.4 Hypotheses

1. Weed management practices with reduced tillage can improve seedling emergence, growth and yield of dry bean.

2. Weed management practices with reduced tillage can improve soil moisture content and soil nitrogen.

3. Weed management practices with reduced tillage can reduce weed population in dry bean plots.

4. Nitrogen application can improve growth and yield of dry bean grown under different weed management options.

5. Nitrogen application can increase weed population in dry bean plots.

CHAPTER TWO: LITERATURE REVIEW

2.1 Botany, ecology and importance of common bean

The dry bean (*Phaseolus vulgaris L.*) is the most widely grown of the four cultivated species of *Phaseolus* all of which have their origin in America (Gepts and Debouck, 2005). The crop is a member of the *Fabae*, tribe *phaseoleae* and sub family *papilionoidae* (Afolani and Cavene, 1997). It is the most important economic variety of the genus *Phaseolus*, and is grown in all parts of the world (Acklands and Francis, 1995). The cultivated forms are herbaceous annuals, determinate or indeterminate in growth and they show considerable variations in vegetative character, flower size, flower colour, and colour of pods and seeds (Dorker *et al.*, 1999). The *pappilionaceous* flowers are borne on the auxiliary and terminal racemes. All bean forms have well developed tap root systems which grow rapidly, sometimes reaching a depth of 90 cm or more. The lateral roots are confined mainly to the top 15 cm of the soil and they bear spherical or irregular nodules approximately 6 mm in diameter (Gepts and Debouks, 2005). The stems are slender, twisted, angled and ribbed. Leaves are alternate, trifoliate and often hairy with long petiole. Dry bean is usually self fertilized, pollination occurring at the time the flower opens (Ssali and Keya, 2002).

Bean germination is epigeal and requires 5-6 days at a soil temperature of 16°C. The time of flowering which varies with cultivar, temperatures and the photoperiod, is usually between 28 and 42 days (Adams, 2005). Dry beans are planted in rows with inter row spacing of 45 cm and intra row spacing of 10 cm (Afolani and Cavene, 1997). Depth of planting ranges from 2 to 5 cm depending on soil type and the moisture conditions. Well drained and aerated soils are recommended. Seeding rate varies from 22 to 55 kg/ha depending on the intra row and inter row spacing (Evans and Wardlaw , 1999)

Dry bean growth cycle is divided into vegetative and reproductive growth stages. During the vegetative stage, development of roots, trifoliate, node and branches take place. The main features of the reproductive growth stage are flowering, pod and grain formation. Important plant traits associated with yield are root and shoot dry matter yield, pod number, 100 grain weight, leaf area index, grain harvest index, and nitrogen harvest index (Brothers and Kelly, 2003). Under normal conditions, in a 97 days growth cycle cultivar (sowing to physiological maturity), flowering starts at about 43 days after sowing, pod formation at about 45 days after sowing and grain growth at about 65 days after sowing (Tanaka and Fujita, 2001). Premature abscission of reproductive organs is a critical physiological trait determining the harvestable yield of legume crops, including dry bean (Brown *et al.*, 1999). Mature seeds of dry bean do not have a dormancy period. Most of the dry bean cultivars cultivated for dry seeds complete their life cycle in 70–90 days (Sinclair, 1998).

Dry bean is the most important pulse crop in Kenya (Ssali and Keya, 2002). It is recognized as an important protein source in the diet of the populations of the tropical areas of the world (Fageria, 2006). It forms an important part of the human diet in Kenya where it is the main source of protein to a large number of people in the low income group. The value of common bean protein source has been found to be very satisfactory, with relatively high amounts of lysine and methionine, being in the range of 20-30% (Wallace *et al.*, 2002).

Dry beans are extensively grown in Kenya where they are often intercropped with maize and sorghum. Various varieties are suited to different Agro-ecological zonnes, with the greatest production in eastern and central Kenya with yields ranging from 300 to 700 kg/ha (Afolani and Cavene, 1997).

2.2 Time of planting dry beans

Many tropical soils are difficult to plough during the dry season thus making it necessary to wait for the first rain showers before planting. This often leads to late planting and consequent reduction in yields (Macqueen *et al.,* 2003). Yield reduction in beans due to late planting has been well documented. Blad *et al.*, (1999) planted beans on six different planting dates starting at the end of March and planting one acre every two weeks through the first week of June. Three varieties were planted each time, an earlier maturing variety, medium and late maturing varieties. They observed that at earlier planting date's protein contents were higher than at later dates. They also found out that there is a reduction in yield by 5-10% due to late planting.

A study by Dorker *et al.*, (1999) in which two bean cultivars were seeded at four different dates of 15 days interval showed that early seeding resulted in significantly higher seed yield and total dry matter. However, late seeding resulted in a 62% and 46% decrease in yield. The harvest index values significantly declined with delayed seeding. According to (Lal, 2000) late planted beans are harvested at a later date, reach the market when there is oversupply of early planted beans and are therefore likely to fetch lower prices. Dorker *et al.*, (1999) showed yield reduction in beans due to late planting. Their study showed that a delay by one day resulted in 5-6% loss in yields. Hence, they concluded that it is important to plant beans at the beginning of the rain since delays could reduce yield linearly by as much as 50 kg/ha for every day delayed.

2.3 Weed control in dry bean

Poor weed control results in bean yield losses in Kenya. Weeds often compete with plants for resources such as light, nutrients and moisture that are vital for yield increases in crops (Parker *et al.*, 1999). Weeds also increase crop protection costs because they harbor pests. Weed control operations from hand hoeing to herbicide application cost money. These costs are often necessary to prevent serious crop losses and crop failure and can be perceived as necessary to gain profits (Blad *et al.*, 1999).

Yield reduction due to weed competition has been well documented. The reduction in yield due to weed competition is caused by negligence on the part of the farmer and late weed control due to tedious weed control methods (Parker *et al.*, 1999). Bean yield losses of 28 to 50% have been reported when weeding was delayed by more than one month (Berets *et al.*, 1997). Wallace *et al.*, (2002) found that over 70% reduction in yield occurs when weeds were not controlled at all in beans. Tilling the land is usually done during seedbed preparation and subsequent weed control to reduce these beans losses in many parts of the world (Xu and Pierce, 1999).

In Kenya the hoe is the most commonly used cultivation tool for seedbed preparation and for post emergence weed control; hoeing is, however, slow and tedious (Mannering and Fenster, 2003). This results in delayed land preparation and weed control, which reduces the bean yields significantly. It also results in small sizes of farms being opened up, thereby lowering bean production. Chemical control of weeds under minimum tillage offers an alternative for small scale farmers (Lal, 2000). Tillage has the disadvantage of exposing the land to soil erosion and soil moisture loss through evaporation. It also exposes soil aerating organisms to harsh environmental conditions and hence reduction in their populations in the soil (Parker *et al.*, 1999). Hence, conservation agriculture is a potential solution to both large scale and small scale famers since it reduces the amount of labor required to prepare land and to weed. It also saves time and therefore allows famers to plant early and fetch good prices bean prices. Conservation agriculture may help famers realize higher yields since growth factors such as water, nutrients and light are used conservatively (Smith and Barber, 2000).

Stobble *et al.*, (1999) reported that weed populations are usually lower under zero tillage than under conventional or minimum tillage. In Nigeria Laing *et al.*, (2004) reported that weed control under zero tillage was greatly reduced compared to conventional tillage. In contrast, Mascianica *et al.*, (2000) studied the effect of different tillage systems and found that no tillage systems yielded pod levels that were equal to or exceeded those of conventional tillage. Powell and Renner (1999) reported that weed control in common bean was improved in no till systems compared with conventional systems. Salmeron (1996) found conventional tillage working better at reducing the weed population than the reduced or no tillage system.

Swanton *et al.*, (1993) reported that shifts toward grass, perennial weeds, and volunteer crop occurred under conservation tillage. Derksen *et al.*, (1995) found differences in the composition of weed communities among tillage systems before herbicide application. However, Hooker *et al.*, (1997) did not find any influence of tillage on the relative proportion of annual broadleaf weed species. They reported that weeds were effectively managed with reduced herbicide inputs in conservation tillage systems. Buhler (1998) stated that changing the tillage system will change the distribution and density of weed seeds in agricultural soils

2.4 Effect of tillage practices on soil properties

Tillage refers to any physical soil manipulation which changes the structure of the soil and kills the weeds (Skarphol and Corey, 2001). Brown and Arnon (2000) defined minimum tillage as a method aimed at reducing tillage to the minimum necessary for ensuring good seedbed, rapid germination, satisfactory stand and favorable growing conditions. Minimum tillage also covers systems which employ overall cultivation but where operations are speeded up by use of herbicides before and after cultivation, and it can also refer to trash farming (Thurston *et al.*, 1994).

In conventional tillage, farmers remove the crop residues in the soil with a plough or a hoe. The soil is left bare and so it is easily washed away by rain or blown away by wind. Studies have shown that frequent tillage operations are rarely beneficial in addition to being costly (Brown and Arnon, 2000). Macqueen *et al.*, (2003) reported that less cultivation on many soils particularly volcanic ones would lead to greatly reduced erosion, better moisture conservation and increased bean yield. When the amount of tillage is reduced, the stubble or plant residues are not completely incorporated, and most or all remain on top of the soil rather than being ploughed or disked into the soil. Weeds are controlled with cover crops or herbicides rather than by cultivation (Morse *et al.*, 1999). With regard to N leaching, Mannering and Fenster (2003) suggested that nitrate concentration is lower in the drainage and run off water from no till or reduced tillage field than from conventionally mould board ploughed and cultivated ones.

Studies on the effect of conservation tillage on plant available soil water have varied in literature. Donalhne (2003) reported that there was no significant difference in the rate of infiltration at any time between direct drilled and conventionally cultivated soils. Smith and Barber (2003) observed that the top soil in the conventional tillage treatment held more water than did the no till treatment. The amount of water available to the plants at 0.3 m depth was twice as much in the sub soiled and roto tilled plots as in the compacted untilled, ploughed and chiseled plots. Hanks, (1998) reported that conservation tillage improved soil water availability throughout the fallow periods, likely via a combination of lower evaporative losses, faster redistribution of soil water fluxes and better overwinter precipitation conservation efficiency. Intensive soil tillage for crop production can deplete soil organic matter and nutrients. It also requires inputs like fertilizer, pesticides and water to maintain crop productivity and quality (Thurston, 1994).

Alvaves -Solis *et al.*, 2000 and Mascianica et al., (2000) reported larger yield of dry beans in no tillage than in conventional tillage plots. In contrast, Mulling *et al.*, (2000) reported higher yields of dry bean in conventional tillage than in no till in a series of experiments. Skarphol and Corey (2001) reported that yields from no till were comparable to or greater than those obtained with conventional tillage in a series of experiments dealing with tillage. In addition, Sandoval-Avilla *et al.*, (2001) found no significant effect of tillage practice on bean yield. In a related study, Tapia and Camacho (2000) reported that whereas reduction in tillage intensity may not necessarily result in an increase in yield, it is associated with lower production costs and conservation of resources such as water and organic matter in the soil. Liebman *et al.*, (1995) tested reduced tillage with mulching systems which resulted in greater weed infestation and lower crop yields. Smith and Barber (2003) investigated no till and reduced till for bean yield and the results showed that the crop yield from the no till and reduced till systems compared favorably with those from the conventional tillage. Stobble *et al.*, (1999) observed a more stunted growth of beans when grown on a minimum tilled, medium textured soil than when grown on a deeper tilled soil. Mascianica *et al.*, (2000) reported that there is no significant yield difference between the tilled plots and the mulched ones. The effect of different weed management practices on soil water conservation and crop performance was investigated in semi arid environment of eastern Kenya. The study proved that manure and mulching with minimum tillage have a greater effect on soil water, bean emergence and overall yield. There was an increase in steady infiltration rates, amount of soil water stored in the soil, better drainage and increased yields (Griffith et al., 2000).

2.5 Effects of N on growth and yield of common bean

There is a positive yield response when N is applied to common bean plants that are grown on N poor soils (Welch and Young, 2003). Nitrogen applied during the vegetative stages produced higher seed yield than N applied during planting, flowering or pod set. Nitrogen applied at planting or during vegetative growth increased pod set, while application at reproductive stages increased seed weight (Smith and Barber, 2000). Based on these results the best management system using N fertilizers was an application during vegetative growth (Smith and Barber, 2000).

Although common bean (*Phaseolus vulgaris* L.) has good potential for N_2 fixation, some additional N provided through fertilizer usually is required for a maximum yield. Thurston (1994) investigated the effect of N on nodulation in unfertile soil under greenhouse conditions with different levels of fertility and reported that overall average nodule number and weight increased under high fertility levels. At low N applications, nitrogen had a synergistic effect on N_2 fixation, by stimulating nodule formation, nitrogenase activity and plant growth. The results indicated that a suitable balance of soil nutrients is essential to obtain high N_2 fixation rates and yield in common beans (Brown and Arnon, 2000).

Beans are normally expected to receive most of their N requirement from symbiotic N fixation. However, many experiments have shown that if soil is low in available N, N fixation is essential for higher seed yield. Peterson *et al.*, (2006) found that N fertization resulted in a significant increase in bean pod yields and in N content of the bean leaves. Ssali and Keya (2002) found that application of 20 kgN/ha had little effect on nodulation for all the bean cultivars and did not increase yield in all cases. However, application of 40 kgN/ha severely decreased nodulation and increased yield in all cases. Candisch and Clark (2005) found that N fixation in beans decreased with increasing level of soil nitrates. Scarisbrick *et al.,* (2002) reported that application of N fertilizer in many bean varieties resulted to higher seeds yield due to increased number of pods per plant. Edge *et al.,* (2000) found that mean seed yield of beans were increased by application of N fertilizer at rates higher than 40 kg/ha. Haag *et al* ., (1999) found significant difference among 124 genotypes of beans in response to N levels. Overall, the high fertility levels significantly increased seed yield per plant, pods per plant and individual seed weight. They observed that whereas genotypes responded differently to added fertilizer for all the above components, pods per plant exerted a predominant influence on bean yield at all the fertility levels. Smith and Barber (2000) found that shortage of N during the pod and seed development stages resulted in pod abortion, lower yields and poor quality seeds. However too much N caused excessive vegetative growth and proneness to lodging and diseases. Delbert and Thomas (1998) found that increased bean pod yield with N application only up to 50 kgN/ha. Santos *et al.*, (2007) found that higher rates of N fertilization up to 80 kgN/ha produced significantly higher number of pods per plant than did lower rate of 20 kg/ha.

Molinna (2005) found that dry matter production of six bean cultivars increased with N application of 40 kg/ha and above. Candisch and Clark (2005) also found significant increases in bean dry matter with N application of 40 kg/ha. Smith and Barber (2000) found that bean biomass was increased to a much greater extent than grain yields by addition of N. Scarisbrick *et* *al.*, (2001) reported that although the magnitude of bean response to N varied between seasons and sites, the overall evidence indicates that significant benefits were achieved from using up to 100 kgN/ha.

2.6 Effect of mulching on soil, weeds and crop performance

The use of mulch is an important cultural practice especially in the tropics and is recommended for soil and water conservation (Perreira and Jones, 1999). Mulch can also be used to increase or reduce soil temperatures and suppress weed growth (Othieno *et al.*, 2000). Mulches are known to increase water holding capacity of the soil. This increase in infiltration is accomplished through some reduction of the surface run off and evaporation (Lal, 2000). A study by Unger (1999) showed that surface mulches can increase water storage during fallow compared with no residual mulch. The author further reported that precipitation storage as soil moisture was significantly affected by mulch rates.

Mulches are known in general to maintain soil moisture through the dissipation of kinetic energy of falling rain drops and hence preventing soil capping and crusting (Pereira and Jones, 1999). On bare soils, the impact of the falling drops detaches the soil particles from aggregates and thus causing surface sealing and capping of the soil. Organic mulch is known to add organic matter in the soil which brings about aggregation of the soil particles and hence forming a stable soil (Rodriguez, 2000). Mulch could drastically reduce soil water losses by reducing soil temperatures, impeding vapor diffusion, acting as periodic focal points for temporary vapor condensation and absorption in the mulched material and reducing weed velocity at soil atmosphere surface (Hanks, 1998).

Evidence presented by Pereira and Jones (1999) indicates reduction of the soil temperatures by mulches significantly reduces evaporation process. Surface mulches of any kind have a greater effect upon the thermal regime of the soil than upon evaporation water losses. The rate of loss of water or water vapor flux through mulches is generally slow in comparison to the rate of loss of water from a moist surface and therefore mulch reduce evaporation by intercepting the solar energy that reaches the soil surface.

Weed control due to mulch is possible due to shading and mechanical suppression of weeds. Mulches when placed on the soil surface control weeds and may have effect on various properties of the soil and weed growth (Rodriguez, 2000). Residual mulch can reduce labor for weeding and aid in germination and seedling growth which is one of the most important critical period in the life cycle of plant growth (Peterson *et al.*, 2006). Mulching is also known to slow down seed germination due to diurnal temperature changes of surface soil (Peterson *et al.*, 2006). Brown *et al.*, (2000) found that bean emergence was delayed in the mulched plots and this was attributed to the mulch material hindering the beans to emerge. Residual mulches can increase growth and yield of beans through increased water availability and nutrient uptake in coarse textured soils (Stobble *et al.*, 1999).

In an experiment on the application of various rates of mulches, it was found out that plants in plots with high mulch rates grew slower than those in plots with low mulch rate (Lal *et al.*, 2000). Later in the season when the soil moisture limited plant growth, plants on the high mulch rates grew more than the other plots because of the high water content conserved. Research conducted in Nigeria on tillage systems showed that zero tillage with mulch had higher yields than conventional tillage of ploughing and harrowing. From research done in Kenya, it was found that grain and dry matter yield of beans was higher in the mulched plots than in the conventionally tilled plots (Lal *et al.*, 2000). When the crop residual was applied as mulch, it increased the crop yield due to an increase in available water and reduction of the soil temperatures relative to the unmulched plots (White and Morris, 1999).

CHAPTER THREE: MATERIALS AND METHODS

3.1 Experimental site

A field study was conducted during the long and short rains season at the University of Nairobi Upper Kabete Campus Field Station in 2009. The site lies at an altitude of 1940 meters above sea level and between latitude 1° 14′ 20′ South to 1° 15′15′ North and longitude 36° 44′ East to 36° 45′ East. The site receives bimodal rainfall averaging 1000 mm annually. The long rains last from March to May, whereas short rains last from October and December. Mean monthly maximum and minimum temperatures are 23°C and 12°C, respectively. The weather data during the experimental duration for both seasons are shown in appendix 1. The soils at the site are reddish brown clays overlying dark and red clays. They are classified as humic nitisols deep, fertile, well drained and with thick acid top soils that are resistant to erosion. The soils have a blocky structure which allows good root penetration and development. The clay minerals are predominantly kaolinite. The experiment was carried out in the long rains and short rain season of the year 2009, and the crop relied on rain water though supplementary irrigation was done when the plants exhibited severe moisture stress. Prior to planting, the soils were sampled for macro nutrient N, moisture content and organic carbon.

3.2 Experimental design, treatments and crop husbandry

The treatments involved weed management practices and nitrogen application in the form of calcium ammonium nitrate (CAN). The tillage treatments were:

(i) seed bed preparation by hoeing the plots and removing all the weeds. Later the plots were weeded with a hoe and all the weeds removed from the plot to leave a clean field. This is what most farmers do and it constitutes the control treatment;

(ii) opening up the plots with a hoe and ploughing the weeds under the soil. This involved use of a hoe to burry all the weeds and completely covering them with the soil. Subsequent emerging weeds were hoed again with a jembe and incorporated in the soil;

(iii) killing all the weeds by applying glyphosate herbicide (Round up®) to the plots at the rate of 20ml/20 litres of water before planting. This translated to 5litres of water per plot. Intra row and inter row weeding was done using a jembe to control subsequent emerging weeds;

(iv) opening up the plot using a hoe and spreading dug out weeds in between and within rows at the rate of 5 tonnes/ha on fresh weight basis. Emerging weeds were rogued with hands;

(v) mowing the weeds at ground level using a sickle and removing them from the plots. Emerging weeds were mowed using a sickle;

(vi) applying Glyphosate herbicide at planting followed by inter row and intra row slashing of weeds at the ground level.

The N treatments were: 0 kgN/ha and 30 kgN/ha, supplied in form of CAN in two splits; planting and pre-flowering. The treatments were laid out in a randomized complete block design with a factorial arrangement and replicated three times. Bean variety Mwezi moja was used as the test variety. Plots measured 3 m by 2 m. Beans were sown 45 cm apart in rows, while intra row spacing was 10 cm. Two guard rows were planted around the experimental plots. Phosphorous fertilizer was applied in each planting hole at the rate of 50 kg $P_2 0_5$/ha during planting in form of triple superphosphate. Plots were sprayed with Duduthrin® (Lambda cyhalothrin) immediately after emergence at the rate of 20 ml per 20 litres of water to control bean flies immediately after emergence and at pre-flowering to control whiteflies and aphids. In the mowing and the herbicide treated plots that involved the use of a sickle to control emerging weeds, a lot of care had to be taken when slashing the weeds to avoid slashing the crop. It was hard to slash the intra row weeds after the 8^{th} week of growth since the adjacent bean crops had merged their canopies. The same challenge was observed when using a hoe.

3.3 Data collection

Data collected included: percent emergence, plant height, number of nodules, nodule dry matter, root dry matter, shoot dry matter, number of days to 50% flowering, number of seeds per pod, number of pods per plant, weight of 100 seeds, grain yield in kg/ha, soil moisture content, weed population by species, total number of weeds and soil N before and after the experiment. At two weeks after planting, number of emerged plants from each plot were counted and expressed as a % of the expected total number of plants. Plant height was determined by selecting five plants at random and vertical length measured after every two weeks, from forth week after emergence up to 10^{th} week. Flowering was monitored and the number of days to 50% flowering in all plots recorded.

At eight weeks after emergence, 10 plants were randomly selected and uprooted carefully from each plot and put in moist bags. Soil was washed off from the roots in running water, nodules removed and counted. Each nodule was dissected to determine whether it was actively fixing N. The nodules with pink coloration were recorded as actively fixing N. Five of the 10 plants were put in a manila paper and dried to a constant weight at 60°C for 72 hours. The weight of dry nodules, shoot and root were then determined.

At physiological maturity, 10 plants were randomly sampled from each plot and the number of pods per plant recorded. The number of seeds per pod was determined by dividing number of seeds per plant by total number of pods per plant. At maturity, bean plants were harvested from the four middle rows ($3\ m^2$) in each plot, pods picked, shelled and bean grains dried and total weight recorded. A hundred seed weight was determined by weighing 100 seeds randomly selected from each plot lot.

Types and number of weeds were determined by throwing a quadrant measuring 0.5 m by 0.5 m inside the plot three times. The numbers and types of weeds within the quadrant were then determined. Weed count was done before weeding and at 4 and 8 weeks after emergence.

Soil moisture content was determined before planting and during the experiment. Moist soil samples were obtained from each plot at 15 cm depth and dried in an oven at 80^0C to a constant temperature. The final soil dry weight was then determined. Soil moisture content was then calculated as:

$$\% \text{ soil moisture content} = [(W1-W2)/W1] \times 100$$

W1 –Weight of moist soil and container.

W2- Weight of dry soil and container.

Soil nitrogen and carbon content were determined before and after the experiment. Soil was sampled at 15 cm depth and analyzed for total N and total organic carbon using wet oxidation method and colorimetric methods respectively, in the Soil Science Laboratory of the University of Nairobi.

3.4 Data analysis

All data were subjected to analysis of variance using General Statistics package (GENSTAT) edition three for windows and means separated using the least significant difference (LSD) test at 5% level of significance (Steel and Torrie, 1991).

CHAPTER FOUR: RESULTS

4.1 Effect of weed management practices and nitrogen application on bean emergence

Weed management practice had a significant effect ($p \leq 0.05$) on bean emergence during both seasons (Table 1; Appendices 2 and 3). During both seasons, hoeing plus weed removal and hoeing plus weed incorporation into the soil treatments had significantly higher bean emergence than mowing plus weed removal, mulching, herbicide plus hoeing and herbicide plus mowing treatments. Hoeing plus weed removal and mulching treatments had significantly the highest and lowest bean emergence, respectively. There was no significant effect ($p \leq 0.05$) of nitrogen application on emergence of beans during both long and short rain seasons (Table 1; Appendices 2 and 3). Similarly, the effect of weed management practice by nitrogen application interaction on bean emergence was not significant ($p \leq 0.05$) during both seasons (Table 1; Appendices 2 and 3).

4.2 Effect of weed management practices and nitrogen application on bean plant height

Significant ($p \leq 0.05$) effects of weed management practice on plant height were observed during both seasons and at all the sampling periods (Tables 2-5; Appendices 4-11). At 4 WAP, mulching had significantly ($p \leq 0.05$) taller plants than all the other treatments during both seasons, except that there was no significant difference in plant height between hoeing plus weed incorporation in the soil and mulching treatments during the short rains. In the long rains, mowing plus weed removal, herbicide application plus hoeing and herbicide application plus mowing treatments were not significantly different in plant height (Table 2 ; Appendices 4 and 5).

Table 1: Mean percentage emergence of beans, two weeks after planting, in plots subjected to different weed management practices and nitrogen fertilizer during the long rain season (March, to May) and short rain season (October to December) in 2009.

	Long rains			Short rains		
	Nitrogen level (N)			Nitrogen level (N)		
Weed control (W)	0 kgN/ha	30 kgN/ha	Mean	0 kgN/ha	30 kgN/ha	Mean
Mulching	83.33	84.33	83.80	85.33	87.33	86.33
Mowing + weed removal	86.67	85.67	86.17	87.67	86.67	87.17
Herbicide + hoeing	87.00	87.33	87.16	85.67	87.67	86.60
Herbicide + mowing	88.67	88.67	88.60	85.60	85.60	85.60
Hoeing+ incorporation	91.00	92.67	91.80	90.33	91.67	91.00
Hoeing + weed removal	92.33	93.67	93.00	93.67	92.67	93.17
Mean	88.16	88.72		88.04	88.60	
$LSD_{(P\leq 0.05)}$ (W)	2.80			3.20		
$LSD_{(P\leq 0.05)}$ (N)	NS			NS		
$LSD_{(P\leq 0.05)}$ (WXN)	NS			NS		
CV%	2.70			3.10		

Table 2: Mean bean plant height (cm) in plots subjected to different weed management practices and nitrogen fertilizer at four weeks after planting during the long rain season (March to May) and short rain season (October to December) in 2009.

	Long rains			Short rains		
	Nitrogen level (N)			Nitrogen level (N)		
Weed control (W)	0 kgN/ha	30 kgN/ha	Mean	0 kgN/ha	30 kgN/ha	Mean
Mulching	4.81	4.95	4.88	5.40	5.60	5.50
Mowing + weed removal	4.08	4.23	4.15	4.40	4.60	4.50
Herbicide + hoeing	3.98	4.10	4.04	4.30	4.50	4.40
Herbicide + mowing	4.05	4.22	4.13	4.30	4.50	4.40
Hoeing+ incorporation	4.08	4.80	4.44	5.20	5.60	5.40
Hoeing + weed removal	4.55	4.65	4.60	4.90	5.14	5.02
Mean	4.25	4.39		4.75	4.99	
$LSD_{(P\leq 0.05)}$ (W)	0.16			0.17		
$LSD_{(P\leq 0.05)}$ (N)	0.15			0.15		
$LSD_{(P\leq 0.05)}$ (WXN)	NS			NS		
CV%	2.22			4.10		

At 6 WAP, mulching treatments had significantly taller plants than all the other treatments during both seasons (Table 3; Appendices 6 and 7). At 8 WAP, mulching treatments had significantly taller plants than all the other treatments during both seasons. Hoeing plus weed removal, herbicide plus hoeing and herbicide plus mowing treatments had significantly shorter plants than mulching and hoeing plus weeds incorporation into the soil treatments (Table 4; Appendices 8 and 9). At 10 WAP, mulching treatments had significantly taller plants than all the other treatments. However, hoeing plus weed removal and hoeing plus weed incorporation into the soil had significantly taller plants than herbicide plus hoeing, herbicide plus mowing and mowing plus weed removal treatments (Table 5; Appendices 10 and 11).

Nitrogen application significantly ($p \leq 0.05$) increased the bean plant height in both seasons at 4 WAP (Table 2 and appendices 4 and 5) and in the short rains at 8 and 10 WAP (Tables 4 and 5; Appendices 8-11). However, it had no significant effect on plant height at 6 WAP (Table 3; Appendices 6 and 7) in both seasons and at 8 and 10 WAP (Tables 4 and 5; Appendices 8 and 10) during the long rains. Weed management practice and its interaction with nitrogen application had a significant ($p \leq 0.05$) effect on plant height at 8 WAP during the short rains (Table 4; Appendix 9). At 30 kg N/ha, mulching treatments had significantly taller plants than all the other treatments except that it was not significantly different from hoeing plus weed incorporation into the soil treatments. Application of 30 kgN/ha significantly increased plant height in all weed management practice except in mowing plus weed removal and herbicide application plus mowing treatments.

Table 3: Mean bean plant height (cm) in plots subjected to different weed management practices and nitrogen fertilizer at six weeks after planting during the long rain season (March to May) and short rain season (October to December) in 2009.

	Long rains			Short rains		
	Nitrogen level (N)			Nitrogen level (N)		
Weed control (W)	0 kgN/ha	30 kgN/ha	Mean	0 kgN/ha	30 kgN/ha	Mean
Mulching	15.76	15.81	15.78	16.30	16.50	16.40
Mowing + weed removal	14.49	14.54	14.46	15.75	15.81	15.78
Herbicide + hoeing	14.43	14.58	14.50	15.40	15.50	15.45
Herbicide + mowing	14.56	14.58	14.57	14.80	15.20	15.00
Hoeing+incorporation	15.50	15.70	15.60	15.20	15.30	15.25
Hoeing + weed removal	15.38	15.52	15.45	16.10	16.20	16.15
Mean	15.02	15.06		15.59	15.75	
$LSD_{(P\leq 0.05)}$ (W)	0.18			0.19		
$LSD_{(P\leq 0.05)}$ (N)	NS			NS		
$LSD_{(P\leq 0.05)}$ (WXN)	NS			NS		
CV%	2.20			1.60		

Table 4: Mean bean plant height (cm) in plots subjected to different weed management practices and nitrogen fertilizer at eight weeks after planting during the long rain season (March to May) and short rain season (October to December) in 2009

	Long rains			Short rains		
	Nitrogen level (N)			Nitrogen level (N)		
Weed control (W)	0 kgN/ha	30 kgN/ha	Mean	0 kgN/ha	30 kgN/ha	Mean
Mulching	30.74	31.02	30.88	33.30	34.20	33.75
Mowing + weed removal	26.30	27.12	26.71	31.00	29.50	30.25
Herbicide + hoeing	26.00	26.80	26.40	29.60	31.20	30.40
Herbicide + mowing	26.22	26.51	26.36	30.66	31.30	30.98
Hoeing+ incorporation	29.79	30.05	28.92	32.80	33.50	33.15
Hoeing + weed removal	29.06	29.39	29.22	31.40	32.10	31.75
Mean	28.01	28.39		31.06	31.96	
$LSD_{(P\leq 0.05)}$ (W)	0.92			0.73		
$LSD_{(P\leq 0.05)}$ (N)	NS			0.22		
$LSD_{(P\leq 0.05)}$ (WXN)	NS			0.65		
CV%	4.70			3.10		

Table 5: Mean bean plant height (cm) in plots subjected to different weed management practices and nitrogen fertilizer at ten weeks after planting during the long rain season (March to May) and short rain season (October to December) in 2009.

	Long rains			Short rains		
	Nitrogen level (N)			Nitrogen level (N)		
Weed control (W)	0 kgN/ha	30 kgN/ha	Mean	0 kgN/ha	30 kgN/ha	Mean
Mulching	33.00	34.09	33.54	35.00	36.20	33.54
Mowing + weed removal	28.00	28.32	28.16	30.70	32.20	28.16
Herbicide + hoeing	27.67	28.48	28.07	31.10	31.70	28.07
Herbicide + mowing	28.77	28.85	28.81	31.50	31.62	28.81
Hoeing+incorporation	32.13	32.94	32.53	34.30	35.80	32.53
Hoeing + weed removal	28.48	29.39	28.00	32.80	33.40	28.00
Mean	29.67	30.34		29.47	30.34	
$LSD_{(P\leq 0.05)}$ (W)	1.29			0.86		
$LSD_{(P\leq 0.05)}$ (N)	NS			0.66		
$LSD_{(P\leq 0.05)}$ (WXN)	NS			NS		
CV%	2.7			1.9		

4.3 Effect of weed management practices and nitrogen application on bean flowering

A significant ($p\leq 0.05$) effect of weed management practice on the number of days to 50% flowering was observed during both seasons (Table 6; Appendices 12 and 13). During the long rain season, beans in the mulching treatments took significantly more days to achieve 50% flowering than beans in all the other treatments. A similar observation was made during the short rain season but there was no significant difference in time taken to achieve 50% flowering between mulching and hoeing plus weed incorporation into the soil treatments. The effect of nitrogen treatment on number of days to 50% flowering was not significant ($p\leq 0.05$) during both seasons (Table 6; Appendices 12 and 13). Similarly, the interaction between weed management practice and nitrogen application had no significant effect ($p\leq 0.05$) on the number of days to 50% flowering during both seasons (Table 6; Appendices 12 and 13).

Table 6: Mean number of days to 50% flowering of beans subjected to different weed management practices and nitrogen fertilizer during the long rain season (March to May) and short rain season (October to December) in 2009.

	Long rains			Short rains		
	Nitrogen level (N)			Nitrogen level (N)		
Weed control (W)	0 kgN/ha	30 kgN/ha	Mean	0 kgN/ha	30 kgN/ha	Mean
Mulching	46.00	47.00	46.70	46.33	46.00	46.16
Mowing + weed removal	43.33	43.33	43.33	42.67	43.67	43.16
Herbicide + hoeing	43.67	44.00	43.80	44.00	44.33	44.16
Herbicide + mowing	43.67	43.00	43.33	43.00	43.33	43.16
Hoeing+incorporation	44.67	44.33	44.50	46.00	45.67	45.83
Hoeing + weed removal	41.67	43.67	42.67	43.33	43.00	43.16
Mean	43.85	42.67		44.22	44.33	
$LSD_{(P\leq 0.05)}$ (W)	1.35			0.88		
$LSD_{(P\leq 0.05)}$ (N)	NS			NS		
$LSD_{(P\leq 0.05)}$ (WXN)	NS			NS		
CV%	2.9			4.0		

4.4 Effect of weed management practices and nitrogen application on bean shoot and root dry matter production

There were significant ($p\leq0.05$) effects of both weed management practice and nitrogen application on root dry matter during both seasons (Table 7; Appendices 14 and 15). During the long rains, mulching, herbicide application plus mowing, hoeing plus weed incorporation into the soil and hoeing plus weed removal treatments were not significantly ($p\leq0.05$) different in root dry matter, however, these treatments had significantly higher root dry matter than the mowing plus weed removal and herbicide application plus hoeing treatments. In the long rains, application of 30 kgN/ha resulted in significantly higher root dry matter than treatments without nitrogen fertilizer (0 kgN/ha). The interaction between weed management and N fertilizer application had a significant effect on root dry matter production only in the short rains (Table 7;

Appendix 15). During the short rains, at both 0 kgN/ha and 30 kgN/ha, mulching had significantly higher root dry matter than all the other treatments, except hoeing plus weed removal. Application of 30 kgN/ha significantly ($p \leq 0.05$) increased root dry matter in mulched plots but had no significant effect in the plots with the other treatments. Mulching had significantly higher root dry matter than all the other treatments. Herbicide plus hoeing, herbicide plus mowing, hoeing plus weed incorporation into the soil and hoeing plus weed removal treatments were not significantly different in root dry matter.

Table 7: Mean root dry matter (g/m^2) of beans sampled at 6, 8 and 10 weeks after emergence in plots subjected to different weed management practices and nitrogen fertilizer during the long rain season (March to May) and short rain season (October to December) in 2009.

	Long rains			Short rains		
	Nitrogen level (N)			Nitrogen level (N)		
Weed control (W)	0 kgN/ha	30 kgN/ha	Mean	0 kgN/ha	30 kgN/ha	Mean
Mulching	26.96	30.68	28.82	32.40	46.00	39.20
Mowing+ weed removal	14.03	18.40	16.22	18.40	21.20	19.80
Herbicide + hoeing	17.57	18.60	18.08	20.40	23.00	21.70
Herbicide + mowing	21.95	26.63	24.29	22.20	25.80	24.00
Hoeing+incorporation	24.92	26.78	25.85	24.40	26.80	25.60
Hoeing + weed removal	25.90	29.85	27.88	30.40	26.70	28.50
Mean	21.89	25.16		24.70	28.20	
$LSD_{(P \leq 0.05)}$ (W)	5.18			7.71		
$LSD_{(P \leq 0.05)}$ (N)	3.12			2.22		
$LSD_{(P \leq 0.05)}$ (WXN)	NS			10.00		
CV%	18.30			24.00		

Weed management practice and nitrogen application had significant ($p \leq 0.05$) effects on shoot dry matter during both seasons (Table 8; Appendices 16 and 17). In the long rains, mulching had significantly higher shoot dry matter than mowing plus weed removal and herbicide treatments, however there were no significant differences in shoot dry matter among the mulching, hoeing plus weed incorporation into the soil and hoeing plus weed removal treatments. During the short rains season, bean plants in the mulched plots had significantly higher shoot dry matter than bean plants in the plots with the other treatments. In the long rains, bean plots that received 30 kgN/ha had significantly higher shoot dry matter than the bean plots without nitrogen. A similar observation was made in the short rains, except that there were no significant differences among hoeing plus weed removal, herbicide plus mowing, herbicide plus hoeing and mowing plus weed removal treatments. The interactive effect of weed management practices and nitrogen application on shoot dry matter production was not significant ($p \leq 0.05$) during both seasons (Table 8; Appendices 16 and 17).

Table 8: Mean shoot dry matter (g/m^2) of beans sampled at 6, 8 and 10 weeks after planting in plots subjected to different weed management practices and nitrogen fertilizer during the long rain season (March to May) and short rain season (October to December) in 2009.

	Long rains			Short rains		
	Nitrogen level (N)			Nitrogen level (N)		
Weed control (W)	0 kgN/ha	30 kgN/ha	Mean	0 kgN/ha	30 kgN/ha	Mean
Mulching	279.10	298.40	288.80	324.90	339.90	332.40
Mowing + weed removal	155.90	173.60	164.80	176.60	235.10	205.90
Herbicide + hoeing	180.90	182.00	181.50	216.40	216.80	216.60
Herbicide + mowing	216.40	233.60	225.00	216.40	233.60	225.00
Hoeing+incorporation	269.00	274.44	271.70	249.20	278.70	264.00
Hoeing + weed removal	256.20	273.50	264.90	207.30	261.6	234.40
Mean	226.20	239.30		231.80	261.00	
$LSD_{(P\leq 0.05)}$ (W)	46.44			46.83		
$LSD_{(P\leq 0.05)}$ (N)	7.71			20.65		
$LSD_{(P\leq 0.05)}$ (WXN)	NS			NS		
CV%	17.89			15.80		

4.5 Effect of weed management practices and nitrogen application on nodulation of bean plants

Weed management practice had a significant ($p \leq 0.05$) effect on the number of active nodules per plant during both seasons (Table 9; Appendices 18 and 19). In the long rain season, mulching, mowing plus weed removal and hoeing plus weed incorporation into the soil treatments had significantly higher number of active nodules than herbicide treated plots. During the short rain season, mulching and hoeing plus weed incorporation into the soil treatments had significantly higher number of active nodules than all the other plots. Mowing plus weed removal and herbicide plus hoeing treatments had significantly higher number of active nodules than hoeing with weed removal and herbicide with mowing treatments. Application of nitrogen significantly ($p \leq 0.05$) decreased the number of active nodules during both seasons (Table 9; Appendices 18 and 19).

The interactive effects of nitrogen application and weed management practices on the number of active nodules were significant ($p \leq 0.05$) in both seasons (Table 9; Appendices 18 and 19). During the long rains, at 0 kgN/ha, hoeing plus weed incorporation into the soil treatment had significantly higher number of active nodules than the two herbicide treatments., however, this treatment was significantly different in the number of active nodules from mulching, hoeing plus weed removal and mowing plus weed removal treatments. At 30 kgN/ha, there were no significant differences in the number of active nodules among all the treatments. Application of nitrogen at the rate of 30 kg/ha significantly decreased the number of active nodules only in the treatment with mulching and hoeing plus weed incorporation into the soil. During the short rains, at 0 kgN/ha, mulching had significantly higher number of active nodules than herbicide plus mowing and hoeing plus weed removal treatments, however, this treatment was not significantly different in the number of active nodules from mowing, herbicide plus hoeing and hoeing plus weed incorporation into the soil treatments. At 30 kgN/ha, there were no significant differences among all the treatments in the number of active nodules. Application of nitrogen at the rate of 30 kg/ha significantly decreased the number of active nodules only in the mulching and mowing plus weed removal treatments.

Table 9: Mean number of active nodule per bean plant in plots subjected to different weed management practices and nitrogen fertilizer at eight weight weeks after planting during the long rain season (March to May) and short rain season (October to December) in 2009.

	Long rains			Short rains		
	Nitrogen level (N)			Nitrogen level (N)		
Weed control (W)	0 kgN/ha	30 kgN/ha	Mean	0 kgN/ha	30 kgN/ha	Mean
Mulching	5.05	2.58	3.81	5.40	2.80	4.10
Mowing + weed removal	4.60	2.50	3.55	4.60	2.22	3.40
Herbicide + hoeing	2.85	2.10	2.47	4.25	2.22	3.22
Herbicide + mowing	3.05	2.10	2.57	2.35	2.08	2.21
Hoeing+incorporation	5.55	3.10	4.32	4.80	2.95	3.87
Hoeing +weed removal	3.95	2.32	3.13	2.50	2.40	2.45
Mean	4.17	2.45		3.98	2.43	
$LSD_{(P\leq 0.05)}$ (W)	0.84			0.68		
$LSD_{(P\leq 0.05)}$ (N)	1.57			1.38		
$LSD_{(P\leq 0.05)}$ (WXN)	2.19			2.24		
CV%	23.80			18.80		

Weed management practices had a significant ($p\leq0.05$) effect on the total number of nodules during both seasons (Table 10; Appendices 20 and 21). In the long rains, mulching and hoeing plus weed incorporation into the soil treatments had significantly higher number of total nodules than all the other treatments. During the short rains, similar observations were made except that the former two treatments were not significantly different in the total number of nodules from hoeing plus weed removal treatment. Application of nitrogen at the rate of 30 kgN/ha significantly ($p \leq 0.05$) decreased bean nodulation during both rain seasons (Table 10; Appendix 21). The weed management practice by N application interaction did not have a significant ($p \leq 0.05$) effect on the total number of nodules during both rain seasons (Table 10; Appendices 20 and 21).

Table 10: Mean total nodule number per bean plant in plots subjected to different weed management practices and nitrogen fertilizer at eight weeks after planting during the long rain season (March to May) and short rain season (October to December) in 2009.

	Long rains			Short rains		
	Nitrogen level (N)			Nitrogen level (N)		
Weed control (W)	0 kgN/ha	30 kgN/ha	Mean	0 kgN/ha	30 kgN/ha	Mean
Mulching	11.45	9.55	10.55	12.22	7.50	9.86
Mowing + weed removal	9.17	6.89	8.03	8.93	5.15	7.04
Herbicide + hoeing	7.19	6.87	7.03	8.87	5.99	7.43
Herbicide + mowing	9.30	7.36	8.33	8.79	7.27	8.03
Hoeing+incorporation	10.90	8.90	9.95	12.11	7.47	9.79
Hoeing +weed removal	9.83	6.20	8.01	10.34	9.00	9.67
Mean	9.64	7.62		10.21	7.06	
$LSD_{(P \leq 0.05)}$ (W)	1.48			2.00		
$LSD_{(P \leq 0.05)}$ (N)	1.01			1.21		
$LSD_{(P \leq 0.05)}$ (WXN)	NS			NS		
CV%	29.10			19.20		

Weed management practice, nitrogen application and their interaction had a significant effect ($p \leq 0.05$) on active nodule dry weight during both seasons (Table 11; Appendices 22 and 23). During long rains, at 0 kgN/ha, herbicide plus mowing and hoeing plus weed removal treatments had significantly lower dry weight of active nodules than mulching and hoeing plus weed incorporation into the soil treatments. However, there were no significant differences in weight of active nodules among mulching, mowing plus weed removal, herbicide plus hoeing and hoeing plus weed incorporation into the soil treatments. At 30 kgN/ha, there were no significant differences in the weight of active nodules among all the treatments. Application of N at the rate of 30 kgN/ha significantly reduced the weight of active nodules only in the mulching, mowing plus weed removal and hoeing plus weed incorporation into the soil treatments. During the short rains, at 0 kgN/ha, hoeing plus weed removal treatment had significantly lower dry weight of active nodules than mulching and hoeing plus weed incorporation into the soil treatments. At 30 kgN/ha, there were no significant differences among all the treatments in the dry weight of active nodules. Application of N at the rate of 30 kgN/ha significantly reduced the weight of active nodules in mulching, mowing plus weed removal and hoeing plus weed incorporation into the soil treatments but not in the other treatments.

Table 11: Mean active nodule dry weight (mg/plant) of beans in plots subjected to different weed management practices and nitrogen fertilizer at eight weeks after planting during the long rain season (March to May) and short rain season (October to December) in 2009.

	Long rains			Short rains		
	Nitrogen level (N)			Nitrogen level (N)		
Weed control (W)	0 kgN/ha	30 kgN/ha	Mean	0 kgN/ha	30 kgN/ha	Mean
Mulching	663.00	238.00	450.00	621.00	250.00	436.00
Mowing + weed removal	564.00	216.00	390.00	551.00	262.00	406.00
Herbicide + hoeing	428.00	310.00	369.00	471.00	307.00	389.00
Herbicide + mowing	393.00	263.00	328.00	411.00	257.00	334.00
Hoeing+incorporation	670.00	260.00	465.00	614.00	263.00	439.00
Hoeing + weed removal	398.00	237.00	318.00	346.00	245.00	295.00
Mean	519.00	254.00		502.00	264.00	
$LSD_{(P\leq 0.05)}$ (W)	110.90			93.40		
$LSD_{(P\leq 0.05)}$ (N)	213.00			176.00		
$LSD_{(P\leq 0.05)}$ (WXN)	246.80			216.00		
CV%	27.71			20.20		

Weed management practice had a significant effect ($p \leq 0.05$) on total nodule dry weight during both seasons (Table 12; Appendices 24 and 25). During the long rains, mulching and hoeing plus weed incorporation into the soil treatments had significantly higher total nodule dry weight than all the other treatments except hoeing plus weed removal. During the short rains, mulching had significantly higher total nodule dry weight than all the other treatments except herbicide plus mowing treatment. N application significantly ($p \leq 0.05$) decreased the total nodule dry weight during both seasons. The interaction between weed management practice and N application did not have a significant effect ($p \leq 0.05$) on the total nodule dry weight during both seasons (Table 12; Appendices 24 and 25).

Table 12: Mean total nodule dry weight (mg/plant) of beans in plots subjected to different weed management practices and nitrogen fertilizer at eight weeks after planting during the long rain season (March to May) and short rain season (October to December) in 2009.

	Long rains			Short rains		
	Nitrogen level (N)			Nitrogen level (N)		
Weed control (W)	0 kgN/ha	30 kgN/ha	Mean	0 kgN/ha	30 kgN/ha	Mean
Mulching	987.00	534.00	760 .00	865.00	678.00	771.00
Mowing + weed removal	674.00	376.00	525.00	665.00	472.00	568.00
Herbicide + hoeing	723.00	343.00	533.00	678.00	543.00	560.00
Herbicide + mowing	507.00	445.00	476.00	564.00	431.00	610.00
Hoeing+incorporation	948.00	654.00	801.00	765.00	335.00	550.00
Hoeing + weed removal	775.00	476.00	625.00	667.00	456.00	561.00
Mean	769 .00	471.00		700.00	485 .00	
$LSD_{(P \leq 0.05)}$ (W)	195.00			176.00		
$LSD_{(P \leq 0.05)}$ (N)	240.00			228.00		
$LSD_{(P \leq 0.05)}$ (WXN)	NS			NS		
CV%	12.54			18.34		

4.6 Effect of weed management practices and nitrogen application on number of pods per plant and number of seeds per pod

Weed management practice had a significant effect ($p \leq 0.05$) on the number of pods per plant during both seasons (Table 13; Appendices 26 and 27). However, nitrogen application did not significantly affect this parameter. During the long rain season, beans in the mulched plots had significantly higher number of pods than beans in the rest of the treatments. Hoeing plus weed incorporation into the soil treatment had significantly higher number of pods per plant than all the other treatments except mulching. Mowing and herbicide plus hoeing had significantly the lowest number of pods per plant. During the short rain season, similar observations were made though there was no significant difference in the number of pods per plant between mulching and hoeing plus weed removal treatments. The effects of weed management practice, nitrogen application and their interactions on the number of seeds per pod were not significant ($p \leq 0.05$) during both seasons (Table 14; Appendices 28 and 29).

Table 13: Mean number of pods per bean plant in plots subjected to different weed management practices and nitrogen fertilizer during the long rain season (March to May) and short rain season (October to December) in 2009.

	Long rains			Short rains		
	Nitrogen level (N)			Nitrogen level (N)		
Weed control (W)	0 kgN/ha	30 kgN/ha	Mean	0 kgN/ha	30 kgN/ha	Mean
Mulching	16.30	17.50	17.00	16.30	18.30	17.30
Mowing + weed removal	10.80	12.22	11.50	11.90	13.90	12.90
Herbicide + hoeing	10.37	12.22	11.28	13.60	14.10	13.85
Herbicide + mowing	12.07	12.27	12.07	11.80	13.20	12.50
Hoeing+incorporation	15.45	16.12	15.78	16.80	17.20	17.00
Hoeing + weed removal	12.85	14.30	13.57	14.90	16.60	15.70
Mean	13.00	13.57		14.21	15.55	
$LSD_{(P \leq 0.05)}$ (W)	0.79			1.08		
$LSD_{(P \leq 0.05)}$ (N)	NS			NS		
$LSD_{(P \leq 0.05)}$ (WXN)	NS			NS		
CV%	4.40			6.60		

Table 14: Mean number of seeds per bean pod in plots subjected to different weed management practices and nitrogen fertilizer during the long rain season (March to May) and short rain season (October to December) in 2009.

	Long rains			Short rains		
	Nitrogen level (N)			Nitrogen level (N)		
Weed control (W)	0 kgN/ha	30 kgN/ha	Mean	0 kgN/ha	30 kgN/ha	Mean
Mulching	5.60	5.80	5.70	5.58	5.51	5.54
Mowing + weed removal	5.22	5.22	5.20	5.38	5.30	5.33
Herbicide + hoeing	5.22	5.22	5.25	5.38	5.54	5.46
Herbicide + mowing	5.22	5.30	5.22	5.26	5.39	5.32
Hoeing+incorporation	5.45	5.40	5.42	5.45	5.56	5.50
Hoeing + weed removal	5.22	5.50	5.35	5.59	5.56	5.57
Mean	5.30	5.35		5.43	5.40	
$LSD_{(P\leq 0.05)}$ (W)	NS			NS		
$LSD_{(P\leq 0.05)}$ (N)	NS			NS		
$LSD_{(P\leq 0.05)}$ (WXN)	NS			NS		
CV%	4.50			2.80		

4.7 Effect of weed management practices and nitrogen application on grain yield and weight of 100 seeds

Weed management practices had a significant ($p\leq0.05$) effect on seed weight during both seasons (Table 15; Appendices 30 and 31). During the short rains, mulching and hoeing plus weed incorporation into the soil treatments had significantly higher seed weight than all the other treatments except hoeing plus weed removal treatment. A similar observation was made in the long rains but there was no significant difference among hoeing plus weed incorporation into the soil, hoeing plus weed removal and herbicide plus hoeing treatments. There was no significant ($p\leq0.05$) effect of N application on seed weight during both seasons (Table 15; Appendices 30 and 31). Similarly, the effect of weed management practice and nitrogen treatment interaction on seed weight was not significant ($p\leq0.05$) during both seasons (Table 15; Appendices 30 and 31).

Table 15: Mean 100 seed weight (g) of beans in plots subjected to different weed management practices and nitrogen fertilizer during the long rain season (March to May) and short rain season (October to December) in 2009.

	Long rains			Short rains		
	Nitrogen level (N)			Nitrogen level (N)		
Weed control (W)	0 kgN/ha	30 kgN/ha	Mean	0 kgN/ha	30 kgN/ha	Mean
Mulching	19.99	20.26	20.08	20.01	20.49	20.25
Mowing + weed removal	19.08	18.59	18.83	18.01	19.24	18.62
Herbicide + hoeing	19.03	19.50	19.26	19.01	19.63	19.32
Herbicide + mowing	19.02	19.05	19.14	19.02	19.05	19.14
Hoeing+incorporation	19.48	20.02	19.75	19.99	20.25	20.12
Hoeing + weed removal	19.17	19.67	19.42	19.56	19.56	19.79
Mean	19.32	19.51		19.18	19.79	
$LSD_{(P\leq 0.05)}$ (W)	0.60			0.65		
$LSD_{(P\leq 0.05)}$ (N)	NS			NS		
$LSD_{(P\leq 0.05)}$ (WXN)	NS			NS		
CV%	4.00			4.20		

Weed management practice had a significant ($p\leq0.05$) effect on grain yield during both seasons (Table 16; Appendices 32 and 33). Nitrogen application had no significant ($p\leq0.05$) effect on grain yield during both seasons. Interactive effect of weed management practice and nitrogen application on grain yield was only significant ($p\leq0.05$) during the long rains (Table 16; Appendices 32 and 33). In the short rains, mulching treatments had significantly higher grain yield than all the other treatments except hoeing plus weed incorporation into the soil treatment. The latter treatment had a significantly higher grain yield than most of the other treatments except hoeing plus weed removal treatment. In the short rains, similar observations were made except that there was no significant difference in grain yield between mulching and hoeing plus weed incorporation into the soil treatments. In the long rains at both rates of N, mulching had significantly higher grain yield than all the other treatments. At 30 kgN/ha, hoeing plus weed incorporation into the soil had significantly higher grain yield than herbicide plus hoeing, mowing plus weed removal and herbicide plus mowing treatments. A similar observation was made at 0 kgN/ha but there was no significant difference between hoeing plus weed incorporation into the soil and herbicide application plus mowing treatments.

Table 16: Mean grain yield of beans (kg/ha) in plots subjected to different weed management practices and nitrogen fertilizer during the long rain season (March to May) and short rain season (October to December) in 2009.

	Long rains			Short rains		
	Nitrogen level (N)			Nitrogen level (N)		
Weed control (W)	0 kgN/ha	30 kgN/ha	Mean	0 kgN/ha	30 kgN/ha	Mean
Mulching	1821	1915	1868	2290	2595	2442
Mowing + weed removal	947	1065	1006	1610	1582	1596
Herbicide + hoeing	859	1089	974	1796	1886	1841
Herbicide + mowing	1114	1158	1136	1991	1883	1937
Hoeing+incorporation	1343	1605	1474	2094	2419	2256
Hoeing + weed removal	1110	1538	1324	1872	2060	1966
Mean	1199	1395		1942	2071	
$LSD_{(P\leq 0.05)}$ (W)	270			328		
$LSD_{(P\leq 0.05)}$ (N)	NS			NS		
$LSD_{(P\leq 0.05)}$ (WXN)	348			NS		
CV%	17			22		

4.8 Effect of weed management practices and nitrogen fertilizer application on soil moisture content, soil nitrogen and soil carbon

During both seasons, a significant ($p\leq 0.05$) effect of weed management practice on soil moisture content was observed at all sampling periods. However, nitrogen application and its interaction with weed management practices had no significant effect on soil moisture content ($p\leq 0.05$) during both seasons (Tables 17-20; Appendices 34 -41). At 4 WAP in the long rains, mulching had significantly higher soil moisture content than the plots with all the other treatments. Hoeing plus weed incorporation into the soil treatment had significantly higher soil moisture content than hoeing plus weed removal. Similar observations were made during the short rain season

(Table 17; Appendices 34 and 35).

Table 17: Mean percentage soil moisture content in bean plots subjected to different weed management practices and nitrogen fertilizer at four weeks after planting during the long rain season (March to May) and short rain season (October to December) in 2009.

	Long rains			Short rains		
	Nitrogen level (N)			Nitrogen level (N)		
Weed control (W)	0 kgN/ha	30 kgN/ha	Mean	0 kgN/ha	30 kgN/ha	Mean
Mulching	13.76	12.76	13.26	31.56	30.29	30.90
Mowing + weed removal	11.73	9.30	10.51	25.71	25.71	25.71
Herbicide + hoeing	9.75	11.19	10.47	26.45	24.23	25.34
Herbicide + mowing	10.49	10.11	10.30	25.93	24.79	25.36
Hoeing+incorporation	11.20	11.27	11.23	26.07	26.74	26.40
Hoeing + weed removal	9.65	8.41	9.03	22.58	24.02	22.85
Mean	10.76	10.50		26.30	25.90	
$LSD_{(P\leq 0.05)}$ (W)	1.28			2.26		
$LSD_{(P\leq 0.05)}$ (N)	NS			NS		
$LSD_{(P\leq 0.05)}$ (WXN)	NS			NS		
CV%	9.90			7.20		

At 6 WAP in the long rains, mulching treatments had significantly high soil moisture content than plots with other treatments except mowing plus weed removal and herbicide application with mowing treatments. Hoeing plus weed removal treatment had significantly the lowest soil moisture content. During the short rain season, mulching and hoeing plus weed incorporation into the soil treatments had significantly high soil moisture content than all the other treatments. At 6 WAP, hoeing plus weeds incorporation into the soil treatments had significantly higher soil moisture content than the hoeing plus weed removal treatment during the same sampling period (Table 18; Appendices 36 and 37).

Table 18: Mean soil moisture content (%) in bean plots subjected to different weed management practices and nitrogen fertilizer at six weeks after planting during the long rain season (March to May) and short rain season (October to December) in 2009.

	Long rains			Short rains		
	Nitrogen level (N)			Nitrogen level (N)		
Weed control (W)	0 kgN/ha	30 kgN/ha	Mean	0 kgN/ha	30 kgN/ha	Mean
Mulching	14.58	15.40	14.99	30.19	31.29	30.74
Mowing + weed removal	13.43	13.53	13.40	26.87	26.68	26.44
Herbicide + hoeing	13.80	12.20	13.00	26.28	26.49	26.38
Herbicide + mowing	13.10	13.30	13.20	26.75	27.53	27.14
Hoeing+incorporation	11.20	11.27	11.23	30.32	30.32	30.32
Hoeing + weed removal	9.65	8.41	9.03	27.32	26.12	26.72
Mean	12.60	12.35		27.95	25.90	
$LSD_{(P\leq 0.05)}$ (W)	1.91			1.15		
$LSD_{(P\leq 0.05)}$ (N)	NS			NS		
$LSD_{(P\leq 0.05)}$ (WXN)	NS			NS		
CV%	12.70			3.4		

At 8 WAP during the long rains, mulching treatments had significantly higher soil moisture content than plots with the other treatments except mowing plus weed removal and herbicide plus mowing treatments. Similar observations were made during the short rains, however, mulching treatments were not significantly different from hoeing plus weed removal treatments in soil moisture content (Table 19; Appendices 38 and 39). At 10 WAP during the long rains, mulching treatments had significantly higher soil moisture content than the other treatments except the hoeing plus weed removal treatments. During the short rain season, mulching treatments had significantly ($p\leq 0.05$) the highest soil moisture content. Hoeing plus weed removal and hoeing plus weed incorporation into the soil treatments had significantly higher soil moisture content than mowing plus weed removal, herbicide application plus mowing and herbicide application plus hoeing treatments (Table 20; Appendices 40 and 41).

Table 19: Mean soil moisture content in bean plots subjected to different weed management practices and nitrogen fertilizer at eight weeks after planting during the long rain season (March to May) and short rain season (October to December) in 2009.

	Long rains			Short rains		
	Nitrogen level (N)			Nitrogen level (N)		
Weed control (W)	0 kgN/ha	30 kgN/ha	Mean	0 kgN/ha	30 kgN/ha	Mean
Mulching	16.20	14.33	15.26	27.16	26.44	26.80
Mowing + weed removal	12.80	13.20	13.00	25.94	23.43	24.68
Herbicide + hoeing	12.93	13.30	13.11	23.28	24.53	23.90
Herbicide + mowing	14.50	12.52	13.51	24.79	24.35	24.57
Hoeing+incorporation	12.83	14.33	13.58	25.56	25.22	25.39
Hoeing + weed removal	13.53	12.18	12.85	23.15	23.57	23.86
Mean	13.79	13.31		26.48	27.75	
$LSD_{(P\leq 0.05)}$ (W)	1.13			1.48		
$LSD_{(P\leq 0.05)}$ (N)	NS			NS		
$LSD_{(P\leq 0.05)}$ (WXN)	NS			NS		
CV%	7.00			4.00		

Table 20: Mean soil moisture content in bean plots subjected to different weed management practices and nitrogen fertilizer at ten weeks after planting during the long rain season (March to May) and short rain season (October to December) in 2009.

	Long rains			Short rains		
	Nitrogen level (N)			Nitrogen level (N)		
Weed control (W)	0 kgN/ha	30 kgN/ha	Mean	0 kgN/ha	30 kgN/ha	Mean
Mulching	18.70	21.30	20.00	27.53	28.57	28.00
Mowing + weed removal	13.33	13.70	13.50	23.53	24.76	24.14
Herbicide + hoeing	13.19	14.33	13.76	24.38	24.13	24.25
Herbicide + mowing	13.91	14.60	14.25	25.05	24.79	24.92
Hoeing+incorporation	19.09	14.27	16.68	26.07	26.74	26.40
Hoeing + weed removal	17.53	17.40	17.46	25.67	25.37	26.02
Mean	15.95	15.93		25.63	25.72	
$LSD_{(P\leq 0.05)}$ (W)	3.07			0.96		
$LSD_{(P\leq 0.05)}$ (N)	NS			NS		
$LSD_{(P\leq 0.05)}$ (WXN)	NS			NS		
CV%	16.00			3.10		

have significant ($p \leq 0.05$) effects soil carbon during both seasons (Table 22; Appendices 44 and 45).

Table 22 : Mean soil carbon content (g/kg of soil) in bean plots subjected to different weed management practices and nitrogen fertilizer at the end of the experiment during the long rain season (March to May) and short rain season (October to December) in 2009.

	Long rains			Short rains		
	Nitrogen level (N)			Nitrogen level (N)		
Weed control (W)	0 kgN/ha	30 kgN/ha	Mean	0 kgN/ha	30 kgN/ha	Mean
Mulching	34.00	34.50	34.20	35.00	33.50	34.20
Mowing + weed removal	22.00	18.50	20.50	23.50	20.50	22.20
Herbicide + hoeing	25.00	22.50	23.70	25.50	23.50	24.50
Herbicide + mowing	21.50	23.50	22.50	22.00	24.50	23.20
Hoeing+incorporation	31.00	32.00	31.50	33.50	32.00	32.70
Hoeing + weed removal	21.50	24.00	22.70	25.00	23.00	24.00
Mean	25.90	25.80		27.40	26.10	
$LSD_{(P \leq 0.05)}$ (W)	5.40			3.32		
$LSD_{(P \leq 0.05)}$ (N)	NS			NS		
$LSD_{(P \leq 0.05)}$ (WXN)	NS			NS		
CV%	16.50			23.10		

4.9 Effect of weed management practices and nitrogen fertilizer on number of weed species and total number of weeds

Weed management practice had significant ($p \leq 0.05$) effects on the number of plants of amaranth (*Amaranthus spinosus*), black jacks (*Bidens pilosa*), oxalis (*Oxalis latifolia*), couch grass (*Cynodon dactylon*), Devils horsewhip (*Achyranthes aspera*), nutgrass (*Cyperus rotundus*) and total number of weed plants but had no significant effect on the number of wondering jew (*Commelina benghalensis*) and stargrass (*Heteranthera zosterifolia)* plants (Tables 23-30; Appendices 46-61). In the long rains, herbicide plus mowing treatments had significantly higher number of amaranth plants than herbicide plus hoeing and hoeing plus weed removal treatments. There was no significant difference in the number of amaranth plants among mulching, mowing plus weed removal, herbicide plus mowing and hoeing plus weed incorporation into the soil treatments. During the short rains, weed management practice did not significantly affect the number of amaranth plants (Table 23; Appendices 46 and 47).

Table 23: Mean number/m^2 of amaranth (*Amaranthus spinosus*) plants in bean plots subjected to different weed management practices and nitrogen fertilizer during the long rain season (March to May) and short rain season (October to December) in 2009.

	Long rains			Short rains		
	Nitrogen level (N)			Nitrogen level (N)		
Weed control (W)	0 kgN/ha	30 kgN/ha	Mean	0 kgN/ha	30 kgN/ha	Mean
Mulching	20.00	36.00	28.00	12.00	5.30	8.70
Mowing + weed removal	8.30	28.00	18.20	24.00	5.30	14.70
Herbicide + hoeing	14.70	2.70	8.70	22.70	5.30	14.00
Herbicide + mowing	22.70	41.30	32.00	10.70	18.70	14.70
Hoeing+incorporation	16.00	19.00	17.50	8.00	22.70	15.30
Hoeing + weed removal	13.30	5.30	9.30	9.30	2.70	6.00
Mean	15.83	22.05		14.45	10.00	
$LSD_{(P\leq 0.05)}$ (W)	20.00			NS		
$LSD_{(P\leq 0.05)}$ (N)	NS			NS		
$LSD_{(P\leq 0.05)}$ (WXN)	NS			NS		
CV%	52.90			39.00		

In the long rains, herbicide plus mowing treatments had significantly higher number of black jack plants than all the other treatments. During the short rains, herbicide plus hoeing and hoeing plus weed removal treatments had significantly the lowest number of black jack plants than all the other treatments (Table 24; Appendices 48 and 49). In the long rains, mulching had significantly higher number of coach grass plants than all the other treatments. Hoeing with weed removal and herbicide application plus hoeing had significantly lower number of blackjack plants than all the other treatments. In the short rains, there was no significant effect of weed management practice on the number of coach grass plants (Table 25; Appendices 50 and 51). In the long rains, hoeing plus weed removal and herbicide with hoeing treatments had significantly lower number of devils horsewhip plants than mowing with weed removal and herbicide with mowing treatments. There were no significant differences among mulching, mowing plus weed removal, herbicide plus mowing and hoeing plus weed incorporation into the soil treatments in the number of devils horsewhip plants. During the short rains, herbicide plus mowing treatments had significantly higher number of devils horsewhip plants than all the other treatments (Table 26; Appendices 52 and 53). During both seasons, hoeing plus weed removal treatment had significantly lower number of nutgrass plants than all the other treatments except hoeing plus weed incorporation into the soil treatment (Table 27; Appendices 54 and 55).

Table 24: Mean number/m^2 of blackjack (*Bidens pilosa*) plants in bean plots subjected to different weed management practices and nitrogen fertilizer during the long rain season (March to May) and short rain season (October to December) in 2009.

	Long rains			Short rains		
	Nitrogen level (N)			Nitrogen level (N)		
Weed control (W)	0 kgN/ha	30 kgN/ha	Mean	0 kgN/ha	30 kgN/ha	Mean
Mulching	21.30	38.90	30.00	22.70	52.00	37.30
Mowing + weed removal	49.30	20.00	34.70	58.70	21.30	40.00
Herbicide + hoeing	24.00	10.70	17.30	21.30	0.00	10.70
Herbicide + mowing	58.70	41.30	50.00	37.30	24.00	30.70
Hoeing+incorporation	20.00	50.70	35.30	12.00	37.30	24.70
Hoeing + weed removal	10.70	18.70	14.70	8.00	16.00	12.00
Mean	30.70	30.00		26.66	25.1	
$LSD_{(P\leq 0.05)}$ (W)	13.90			9.73		
$LSD_{(P\leq 0.05)}$ (N)	NS			NS		
$LSD_{(P\leq 0.05)}$ (WXN)	NS			NS		
CV%	15.80			31.2		

Table 25: Mean number/m^2 of couch grass (*Cynodon dactylon*) plants in bean plots subjected to different weed management practices and nitrogen fertilizer during the long rain season (March to May) and short rain season (October to December) in 2009.

	Long rains			Short rains		
	Nitrogen level (N)			Nitrogen level (N)		
Weed control (W)	0 kgN/ha	30 kgN/ha	Mean	0 kgN/ha	30 kgN/ha	Mean
Mulching	20.00	0.00	10.00	0.00	0.00	0.00
Mow + weed removal	2.67	0.00	1.33	2.70	10.70	6.70
Herbicide + hoeing	6.67	0.00	3.33	20.00	6.70	13.30
Herbicide + mowing	0.00	0.00	0.00	2.70	9.30	6.00
Hoeing+incorporation	1.33	0.00	0.67	4.00	9.30	6.70
Hoeing + weed removal	2.67	0.00	1.33	2.70	0.00	1.30
Mean	5.56	0.00		6.00	5.30	
LSD$_{(P\leq 0.05)}$ (W)	6.80			13.70		
LSD$_{(P\leq 0.05)}$ (N)	NS			NS		
LSD$_{(P\leq 0.05)}$ (WXN)	NS			NS		
CV%	61.60			56.00		

Table 26: Mean number/m^2 of devils horsewhip (*Achyranthes aspera*) plants in bean plots subjected to different weed management practices and nitrogen fertilizer during the long rain season (March to May) and short rain season (October to December) in 2009.

	Long rains			Short rains		
	Nitrogen level (N)			Nitrogen level (N)		
Weed control (W)	0 kgN/ha	30 kgN/ha	Mean	0 kgN/ha	30 kgN/ha	Mean
Mulching	24.00	17.30	20.70	17.30	8.00	12.70
Mowing + weed removal	28.00	28.00	28.00	18.70	6.70	12.70
Herbicide + hoeing	13.30	13.30	13.30	20.00	13.30	16.70
Herbicide + mowing	18.70	37.30	28.00	40.00	22.70	31.30
Hoeing+incorporation	2.70	29.30	16.00	8.00	20.00	14.00
Hoeing + weed removal	4.00	2.70	3.30	5.30	2.70	4.00
Mean	15.10	21.30		18.21	12.23	
LSD$_{(P\leq 0.05)}$ (W)	14.82			13.00		
LSD$_{(P\leq 0.05)}$ (N)	NS			NS		
LSD$_{(P\leq 0.05)}$ (WXN)	NS			NS		
CV%	67.50			72.00		

Table 27: Mean number/m^2 of nutgrass (*Cyperus rotundus*) plants in bean plots subjected to different weed management practices and nitrogen fertilizer during the long rain season (March to May) and short rain season (October to December) in 2009.

	Long rains			Short rains		
	Nitrogen level (N)			Nitrogen level (N)		
Weed control (W)	0 kgN/ha	30 kgN/ha	Mean	0 kgN/ha	30 kgN/ha	Mean
Mulching	32.00	46.70	39.30	12.30	44.00	28.20
Mowing + weed removal	61.30	29.30	45.30	33.30	16.00	24.70
Herbicide + hoeing	56.00	13.30	34.70	41.30	8.00	24.70
Herbicide + mowing	36.00	34.70	35.30	38.70	12.00	25.30
Hoeing+incorporation	6.70	48.00	27.30	8.00	40.00	24.00
Hoeing + weed removal	10.70	6.70	8.70	0.00	6.70	3.30
Mean	33.80	29.80		22.30	21.10	
$LSD_{(P\leq 0.05)}$ (W)	19.42			13.08		
$LSD_{(P\leq 0.05)}$ (N)	NS			NS		
$LSD_{(P\leq 0.05)}$ (WXN)	NS			NS		
CV%	50.80			50.00		

Table 28: Mean number/m^2 of star grass (*Heteranthera zosterifolia*) plants in bean plots subjected to different weed management practices and nitrogen fertilizer during the long rain season (March to May) and short rain season (October to December) in 2009.

	Long rains			Short rains		
	Nitrogen level (N)			Nitrogen level (N)		
Weed control (W)	0 kgN/ha	30 kgN/ha	Mean	0 kgN/ha	30 kgN/ha	Mean
Mulching	16.00	14.70	15.30	5.30	16.00	10.70
Mowing + weed removal	8.00	6.70	7.30	6.70	6.70	6.70
Herbicide + hoeing	17.30	5.30	11.30	9.30	8.00	8.70
Herbicide + mowing	6.70	18.70	12.70	5.30	10.70	8.00
Hoeing+incorporation	1.30	9.30	5.30	8.00	2.70	5.30
Hoeing + weed removal	4.00	14.70	9.30	1.30	12.00	6.70
Mean	8.30	11.60		6.00	9.30	
$LSD_{(P\leq 0.05)}$ (W)	NS			NS		
$LSD_{(P\leq 0.05)}$ (N)	NS			NS		
$LSD_{(P\leq 0.05)}$ (WXN)	NS			NS		
CV%	50.80			68.00		

Table 29: Mean number/m^2 of wondering jew (*Commelina benghalensis*) plants in bean plots subjected to different weed management practices and nitrogen fertilizer during the long rain season (March to May) and short rain season (October to December) in 2009.

	Long rains			Short rains		
	Nitrogen level (N)			Nitrogen level (N)		
Weed control (W)	0 kgN/ha	30 kgN/ha	Mean	0 kgN/ha	30 kgN/ha	Mean
Mulching	9.30	2.70	6.00	1.30	8.00	4.70
Mowing + weed removal	5.30	6.70	6.00	13.30	4.70	9.00
Herbicide + hoeing	2.70	5.30	4.00	14.70	2.70	8.70
Herbicide + mowing	2.70	16.00	9.30	12.00	5.30	8.70
Hoeing+incorporation	1.30	13.30	7.30	12.00	28.00	20.00
Hoeing + weed removal	8.70	2.70	5.30	1.30	5.30	3.30
Mean	4.90	7.80		9.10	9.00	
$LSD_{(P\leq 0.05)}$ (W)	NS			NS		
$LSD_{(P\leq 0.05)}$ (N)	NS			NS		
$LSD_{(P\leq 0.05)}$ (WXN)	NS			NS		
CV%	60.60			56.80		

In the long rains, mulching treatments had significantly lower number of *Oxalis latifolia* plants than all the other treatments. Hoeing plus weed removal treatment had significant fewer number of oxalis plants than the other treatments. During the short rains, weed management practice did not have a significant effect on the number of *oxalis latifolia* plants (Table 30; Appendices 60 and 61). During the short rains, hoeing plus weed incorporation into the soil and hoeing plus weed removal treatments had significantly lower total number of weed plants than herbicide plus mowing. However, there was no significant difference in the number of weed plants in all the other treatments. In the short rains, hoeing plus weed removal treatment had significantly lower number of total weeds than all the other treatments (Table 31; Appendices 62 and 63). Nitrogen application did not have a significant ($p\leq0.05$) effect on the number of each weed species and the total number of weeds during both seasons. Similarly, the effect of the interaction between weed management practice and N application on total number of weeds and number of each weed species during both seasons was not significant ($p \leq 0.05$) (Tables 23-30; Appendices 46-61).

Table 30: Mean number/m^2 of oxalis (*Oxalis latifolia*) plants in bean plots subjected to different weed management practices and nitrogen fertilizer during the long rain season (March to May) and short rain season (October to December) in 2009.

	Long rains			Short rains		
	Nitrogen level (N)			Nitrogen level (N)		
Weed control (W)	0 kgN/ha	30 kgN/ha	Mean	0 kgN/ha	30 kgN/ha	Mean
Mulching	41.30	74.70	8.00	37.30	52.00	4.70
Mowing + weed removal	86.70	53.30	70.00	57.30	13.30	9.00
Herbicide + hoeing	109.30	24.00	66.70	61.30	20.00	8.70
Herbicide + mowing	81.30	65.30	73.30	54.70	33.33	8.70
Hoeing+incorporation	34.70	24.00	50.00	20.00	24.00	20.00
Hoeing + weed removal	28.00	42.70	35.30	13.30	28.00	3.30
Mean	63.60	54.20		40.70	28.40	
$LSD_{(P \leq 0.05)}$ (W)	24.62			NS		
$LSD_{(P \leq 0.05)}$ (N)	NS			NS		
$LSD_{(P \leq 0.05)}$ (WXN)	NS			NS		
CV%	34.70			56.80		

Table 31: Mean number/m^2 of total weed number of all species in bean plots subjected to different weed management practices and nitrogen fertilizer during the long rain season (March to May) and short rain season (October to December) in 2009.

	Long rains			Short rains		
	Nitrogen level (N)			Nitrogen level (N)		
Weed control (W)	0 kgN/ha	30 kgN/ha	Mean	0 kgN/ha	30 kgN/ha	Mean
Mulching	184.00	175.00	179.00	105.30	189.30	147.30
Mowing + weed removal	251.00	172.00	211.00	210.70	85.30	148.00
Herbicide + hoeing	261.00	75.00	168.00	210.70	64.00	137.30
Herbicide + mowing	224.00	205.00	215.00	188.00	145.30	166.70
Hoeing+incorporation	85.00	187.00	136.00	76.00	182.70	129.30
Hoeing + weed removal	81.00	152.00	117.00	41.30	73.30	57.30
Mean	181.00	161.00		138.70	123.30	
$LSD_{(P \leq 0.05)}$ (W)	79.00			45.40		
$LSD_{(P \leq 0.05)}$ (N)	NS			NS		
$LSD_{(P \leq 0.05)}$ (WXN)	NS			NS		
CV%	38.50			28.80		

CHAPTER 5: DISCUSSION

5.1 Effect of weed management practices and nitrogen application on emergence and flowering of bean plants

Weed management practices significantly affected emergence of bean plants. This could be attributed to the differences in soil temperatures under different weed management practices. The delay in emergence in the mulched plots could be attributed to low soil temperatures. Mulching slows down emergence due to coldness and wetness in the soil (Sandoval- Avilla *et al.*, 2001). The delay in emergence could also have been contributed by inhibition by the surface cover as seedlings would require some force to penetrate through the mulch. In the treatments where the plots were hoed, soil temperatures may have been higher. Donahne (2003) reported that mulching is known to slow down seed emergence due to diurnal temperature changes. Higher number of plants emerged in the plots with hoeing plus weed removal and hoeing plus weed incorporation into the soil treatments than in herbicide and mowing plus weed removal treatments. This could have been contributed by the fine tilth and smaller clods created during hoeing. Haag *et al.*, (1999) showed that bean germination, emergence and early growth are improved by seedbed composed of smaller and finer tilth in conventional tillage. These results are also in agreement with those presented by Karlen et *al.*, (2003) and Morse (1999) reported that the most rapid germination was obtained with the tilled land and slowest germination in mulched and non tilled land. In contrast, Mannering and Fenster (2003) reported that directly drilled soil had a significantly greater plant emergence count than conventionally cultivated soil.

ns grown in hoeing plus weed removal and hoeing plus weed incorporation into the soil ments plots recorded the shortest time to achieve 50% flowering compared to mowing plus d removal, hoeing plus weed incorporation into the soil and mulching treatments. The early wering in the former treatments could be attributed to the fact that beans in these plots were earliest to emerge since there were no barriers in these treatments. This could also be ributed to water stress in these treatments as water content in the soil was low compared to the her treatments. Perreira and Jones (1999) reported that bean plants from tilled plots flowered rly compared to plants from untilled plots. Teasdale *et al*., (1999) also reported that water ress in bean plots with conventional tillage contributed to early flowering as compared to ntilled and mulched plots.

5.2 Effect of weed management practices and nitrogen application on plant height and dry matter accumulation

Plants from the mulched plots grew taller than those from plots with other treatments. Plants from herbicide treated and mowing with weed removal treatments plots were shorter in comparison to those from the mulching and hoeing with the weeds incorporated into the soil treatments. Mulching treatments had taller plants than other treatments possibly due to more water conserved in these plots. Haag *et al*., (1999) reported that mulch could aid in crop growth and cause an increase in yield due to increased water availability. Peterson *et al*., (2006) reported that mulch increased crop growth and yields compared to unmulched plots apparently from an increase in available water and reduction of soil temperatures.

During the growing season of the bean, it was observed that nitrogen treated plots had taller plants compared to the nitrogen untreated plots. Addition of nitrogen increased soil nitrogen levels and hence an increased crop growth. Smith and Barber (2000) found that bean plant height was increased by application of nitrogen. Ssali and Keya (2002) found that bean vegetative growth was increased by application of nitrogen at rates more than 20 kg/ha. Smith and Barber (2000) reported that bean plants need adequate supply of water and nitrogen to improve vegetative growth and to increase yield.

The results showed that dry matter production in mulching, hoeing with weed incorporation into the soil and hoeing plus weed removal treatments were significantly high as compared to mowing plus weed removal and herbicide treatments. This could have been attributed to more water conserved in these plots and water stress in the other plots. Hakim *et al.*, (1999) reported that residual mulch can increase growth and yield of beans through increased water availability and nutrient uptake in course textured soils. The mulching and hoeing plus weeds incorporation into the soil treatments could also have produced more dry matter as a result of added nutrients from the decomposition of the mulched material. The tilled plots could also have produced more dry matter as tilling aerates and improves root penetration in the soil hence increasing the surface area for nutrients and water absorption from the soil. In a study conducted in Kenya, it was found out that dry matter yield of beans was higher in mulched plots and no till plots than in the conventionally tilled plots (Laing *et al.*, 2004). White and Morris (1999) reported that mulching increased dry matter production and crop yield markedly.

The results also showed that application of nitrogen at a rate of 30 kg/ha did not increase bean dry matter production. Molina (2005) found that dry matter production of 6 bean cultivars increased with N application from 40 kg/ha but there was no significant yield difference at rates lower than 30kg/ha. Molina (2005) reported a significant increase of N levels in the leaves with increased soil nitrogen and obtained a positive correlation between yield and nitrogen levels, leaf area, dry weight and % of nitrogen in the leaves. Candisch and Clark (2005) found significant increases in dry matter in beans from N application at 40 kgN/ha although N fertilization consistently depressed N fixation.

5.3 Effect of weed management practice and nitrogen application on bean nodulation

Application of nitrogen resulted in a significant decrease in bean nodulation. This was due to the availability of N in the soil which may have depressed bean nodulation. Ssali and Keya (2002) also found that application of 20 kgN/ha had little effect on nodulation for all the bean cultivars and did not increase yield in all cases. However, application of 40 kgN/ha severely decreased nodulation and increased yield in all cases. In a study to determine the suppressive effect of N on nodulation, N_2 fixation was evaluated in an unfertile soil under greenhouse conditions with different levels of soil fertility (Eghball *et al.*, 1993). The overall average nodule number and weight increased under high fertility levels. At low N applications, nitrogen had a synergistic effect on N_2 fixation, by stimulating nodule formation, nitrogenase activity and plant growth, contrary to the findings of this study. These results indicated that a suitable balance of soil nutrients is essential to obtain high N_2 fixation rates and yield in common beans (Brown and

Amon, 2000). Candish and Clark, (2005) found that N fixation in beans decreased with increasing increments of nitrates in the soil.

5.4 Effect of weed management practices and nitrogen application on grain yield and yield components of common bean

Mulching and hoeing with weed incorporation into the soil treatments produced plants with the significantly high number of pods than the mowing with weed removal and herbicide treatments. Hoeing with weed removal treatments had significantly higher number of pods per plant than the mowing with weed removal and herbicide treatments but not significantly higher than the mulched treatments. This could be explained by the presence of conserved moisture and added nutrients in the mulching and hoeing with weeds incorporation into the soil treatments which may have resulted in vigorous vegetative growth and hence an increase in the number of pods per plant. Bean plants planted in the hoeing plus weed removal, mowing plus weed removal and herbicide treatments plots did not benefit from the conserved water as most of it was lost through evaporation. This may have resulting to reduced growth and hence low vegetative growth which reduced the number of pods per plant. Donald *et al.*, (2006) reported that bean plants that were under moisture stress produced fewer pods than those that were not under water stress. They also noted that bean plants that were subjected to high moisture stress during the flowering period had less vigorous growth and fewer pods per plant than those that were not. Smith and Barber (2002) also found that stress during flowering period was detrimental to final yield of pods and seeds and that adequate supply of water was necessary during pod filling to ensure adequate nutrient absorption and seed protein content. This may explain why the mulched plots had higher number of pods per plant as moisture was sufficient throughout the growth period.

The results also showed that mulching and hoeing plus weed incorporation into the soil treatments produced higher yield than hoeing plus weed removal, herbicide and mowing plus weed removal treatments. This could also be explained by water availability and added nutrients due to mulch decomposition releasing nutrients into the soil. Experiments conducted in Nigeria on various tillage systems showed that zero tillage with mulch had higher yield than conventionally tilled of one ploughing and harrowing (Othieno *et al*., 2000). Morris and White (1993) reported that mulching increased yields markedly and these higher yields on mulched treatments apparently resulted from an increase in available water and nutrients relative to the unmulched plots. Skarphol and Corey, (2001) also found that mulching can increase growth and yields of beans through increased water availability and nutrient uptake. Haag *et al*., (1999) and Karlen *et al*., (2002) reported that the lowest yield of beans crop responding to different tillage treatments was observed under a no tillage system. Mascianica *et al*., (2000) reported that there was no significant yield difference between the no till and mulched plots. Liebman *et al*., (1995) reported that beans responded significantly to minimum tillage yielding more seeds and pods than the average of the conventional tillage.

The results also showed that application of nitrogen resulted in a higher grain yield of beans and more pods per plant. This could be explained by an increase in vegetative growth as a result of availability of N. Similar results have been observed by other researchers. Scarisbrick *et al*., (2001) found that application of nitrogen fertilizer to beans resulted to higher seeds yield due to increased number of pods per plant. Edge *et al*., (2000) also found that mean seed yield of beans were increased by application of N fertilizer at rates higher than 40 kg/ha but not rates lower than this, contrary to the findings of this study. Haag *et al.*, (1999) found significant difference among 124 genotypes of beans in response to N levels. Overall, the high N levels significantly increased seed yield per plant, pod per plant and single seed weight. They observed that whereas genotypes responded differently to added fertilizer for all the above components, pods per plant exerted a predominant influence on bean yield at all the fertility levels. Smith and Barber (2000) found that shortage of N during the pod and seed development stages resulted in pod abortion, lower yields and poor quality seeds. However too much N caused excessive vegetative growth and proneness to lodging and diseases.

The results also showed that there was no significant effect of weed management practices and nitrogen application on the number of seeds per pod. These results indicate that the amount of seeds per pod could be determined by the genetic factors but not treatments. The seed weight did not differ between the weed management practices treatments except in the mulching treatments. This could also be explained by the presence of high moisture content in the soil and added nutrients due to mulch decomposition which resulted in plants with bigger and heavier seeds. The weight of the seeds did not differ significantly between the N treated and untreated plots. Robinsons *et al*., (2003) reported 20% reduction in bean seed yields under visible water stress.

They noted that the yield reduction was due to the reduction in the number of pods per plant before blooming and the number of beans seeds per pod during blooming and reduction in bean weight during maturation process.In different experiments, Tapia and Camacho (2000) reported that beans with mulch had fewer pods per plant than beans under chemical weed control, while beans in mechanical weed control resulted in lighter seeds than those under other weed control strategies.

5.5 Effect of weed management practices on soil moisture content and soil carbon

The results of the present study demonstrated that covering the soil with mulch significantly improved the water availability in the soil. This could be attributed to the fact that mulching reduces the amount of direct heat from the sun that reaches the soil thereby reducing evaporative water losses. Mulching may also have increased infiltration of water into the soil relative to the bare soil in the hoed plus weed removal and hoed plus weed incorporation into the soil plots.

Lal (2000) reported that mulches increased the water holding capacity of the soil through reduction of surface run off and evaporation. Stobble *et al.*, (2000) also reported that the rate of water loss through mulches is generally lower in comparison to the one from a bare surface. Hoeing the field and removing the weeds from the field increases the amount of direct sunlight that reaches the soil, thereby increasing evaporative water losses. Hoeing also degrades soil physical properties thereby decreasing infiltration and soil moisture storage and increases soil temperature (Unger, 1999). The results also demonstrated that plots that mowing plus weed removal and herbicide treated plots had significantly higher soil moisture content than hoeing plus weed removal treatments. This could be attributed to the fact that soil in these plots was not exposed to direct sunlight hence reducing evaporative water losses.

Mulching and hoeing plus weed incorporation into the soil treatments recorded the highest level of carbon in the soil. This could be explained by the fact that the incorporated mulch may have decomposed releasing organic carbon into the soil. Rodriguez, (2000) reported that organic mulch add organic matter in the soil which brings about aggregation of the soil particles and hence forming a stable soil.

5.6 Effect of weed management practices and nitrogen application on weed population

There was no significant effect of weed management practices on the number of weed plants in both seasons. This may be attributed to the fact that it may require several years rather than one season as was the case in this study for tillage practice to have an effect on composition of weed species. Swanton *et al.*, (1993) stated that shifts toward grass, perennial weeds, and volunteer crop plants had been observed under conservation tillage after three years of study. Teasdale *et al.*, (1999) showed that weed density increased after one year of no tillage and after two years of conventional tillage in a four year experiment with application of treatments to the same plot. Hooker *et al.*, (1997) did not find an influence of tillage on the relative proportion of annual broadleaf weed species, however there was a difference in total weed population between treatments.

Hoeing plus weed removal treatment recorded significantly lower total weed population than all the plots with other treatments. This may be attributed to the fact that hoeing the field and collecting the weeds and throwing them away removes a lot of weed seeds from the soil and hence reducing the weed population. In mowing with weed removal and herbicide treated plots, weed seeds remain dormant in the soil and quickly germinate when rained on. Donalhne (2003) reported reduced weed population on tilled plots than on untilled ones. This was attributed to weed seeds being abundant in the untilled plots. Mulching treatments recorded a higher number of weed population than the hoed plus weed removal treatments as a result of moisture availability in the soil, more organic carbon and higher soil N levels. Mulching reduced the number of oxalis plants but not the number of other weeds meaning that the effect of weed management practice depends on the weed species. Buhler (1998) reported that changing the tillage system changes the distribution and density of weed seeds in agricultural soils.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

This study has shown that mulching a bean crop is more effective in conserving soil moisture and hence having a good crop performance and yield than hoeing with weed removal and hoeing with weed incorporation into the soil and herbicide treatments. The evidence from the crop performance in terms of yield, height, flowering, and nodulation and seed weight suggests that mulching is the most promising weed management practice followed by hoeing plus weed incorporation into the soil. Small holder bean farmer may therefore be advised to adopt these two weed management options.

Hoeing the field should be done as a means of reducing weed population in the bean plots, but the ground should remain covered to retain the soil moisture and add nutrient to the soil as a result of decomposition of the mulched material. From the results of emergence, it may be necessary to apply mulch after emergence to enhance bean seedling emergence. Starter nitrogen at the rate of 30icides kgN/ha did not improve grain yield of beans. In general, the order of performance of the weed management practices was: mulching>hoeing plus weed incorporation into the soil>hoeing plus weed removal>spraying plus hoeing>spraying plus mowing>mowing. Hence it may not be advisable for small holder farmers to control weeds by spraying herbicides and mowing.

6.2. Recommendations for further research

(i) Studies to be conducted to determine the best mulching materials for a bean crop and related cost implications, especially to a small holder farmer.

(ii) Studies to be conducted to determine the weeds that leave a lot of weed seeds in the soil so that farmers can avoid using them as mulch.

(iii) Studies to be conducted to determine the effect of various rates of N application on bean performance grown under reduced tillage practices.

(iv) Studies to be conducted to determine temperature changes, evaporation rates, release of K and P under different weed management practices.

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Appendix 1: Weather data for 2009 long and short rains season in Kabete Field Station experimental site.

Month	Mean daily temperatures °C	(Rainfall mm)	Number of rainy days
March	20.7	76.9	6
April	19.9	75.7	11
May	19.0	146.6	16
October	17.67	56	13
November	18.8	122.6	11
December	19.4	95.8	9
Mean	19.2	95.6	11

Appendix 2: Means of nitrogen, carbon and soil moisture content in the experimental plots prior to planting during the long rains 2009.

	Nitrogen (g/kg) soil	Carbon (g/kg) soil	Soil water (%)
Mulching	2.44	22.00	10.50
Mowing +weed removal	2.43	24.00	9.21
Herbicide+ hoeing	2.49	23.00	9.31
Herbicide+mowing	2.46	22.00	10.20
Hoeing +Incorporation	2.44	22.00	9.70
Hoeing+weed removal	2.43	23.22	9.80

Appendix 3: Means of nitrogen, carbon and soil moisture content in the experimental plots prior to planting during the short rains 2009.

	Nitrogen (g/kg) soil	Carbon (g/kg) soil	Soil water (%)
Mulching	2.31	21.20	9.87
Mowing +weed removal	2.22	21.03	10.21
Herbicide+ hoeing	2.56	22.32.	14.32
Herbicide+mowing	2.46	23.34	13.22
Hoeing +Incorporation	2.33	21.42	10.61
Hoeing+weed removal	2.47	20.21	10.11

Appendix 7: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on plant height four weeks after planting during short rains (October to December) in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	28.38	14.19	4.22	
Nitrogen (N)	1	0.028	0.028	0.01	0.036 **
Weed managent(W)	5	362.139	72.42	12.76	<0.01***
N XW	5	11.47	2.29	0.04	0.84 *
Residual	22	113.55	5.67		
Total	35	522.306			

* Not significant at p≤ 0.05 ** Significant at p≤0.05 *** Significant at p≤ 0.01

Appendix 8: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on plant height six weeks after planting during long rains (March to May) in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	11.2268	5.613	39.6	
Nitrogen (N)	1	0.5014	0.501	3.45	0.201 *
Weed managent(W)	5	55.0023	11.00	15.32	<0.01 **
N XW	5	0.2023	0.04	6.67	0.998 *
Residual	22	14.3591	0.71		
Total	35	179			

* Not significant at p≤ 0.05 ** Significant at p≤0.01 *** Significant at p≤ 0.01

Appendix 9: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on plant height six weeks after planting during short rains (October to December) in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	0.32078	0.160	2.22	
Nitrogen (N)	1	1.74050	1.740	24.1	0.539 *
Weed managent(W)	5	49.661	9.993	61.6	<0.01 **
N XW	5	0.6664	0.13	0.82	0.549 *
Residual	22	3.2234	0.161		
Total	35	64.44728			

* Not significant at p≤ 0.05 ** Significant at p≤0.01

Appendix 10: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on plant height eight weeks after planting during long rains (March to May) in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	0.514	0.25	4.76	
Nitrogen (N)	1	8.668	8.668	160.3	0.236 *
Weed managent(W)	5	598.064	119.6	127.4	<0.01 **
N XW	5	2.797	0.55	0.53	0.704 *
Residual	22	18.778	0.939		
Total	35	885.545			

* Not significant at p≤ 0.05 ** Significant at p≤0.01

Appendix 11: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on plant height eight weeks after planting during short rains (October to December) in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	5.883	2.94	24.1	
Nitrogen (N)	1	45.904	45.904	376.2	0.03 *
Weed managent(W)	5	330.6096	66.12	43.82	<0.01 **
N XW	5	6.337	1.267	0.83	0.037 *
Residual	22	30.176	1.508		
Total	35	555.4433			

* Significant at p≤ 0.05 ** Significant at p≤0.01

Appendix 12: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on plant height ten weeks after planting during long rain season (March to May) in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	5.883	2.94	24.1	
Nitrogen (N)	1	65.904	45.904	276.2	0.23 *
Weed managent(W)	5	130.6096	66.12	63.82	<0.01 **
N XW	5	6.337	1.267	0.83	0.13 *
Residual	22	30.176	1.508		
Total	35	555.4433			

* Not significant at p≤ 0.05 * Significant at p≤ 0.05 ** Significant at p≤0.01

Appendix 13: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on plant height ten weeks after planting during short rain (October to December) s in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	46.762	23.381	21.45	
Nitrogen (N)	1	38.272	38.272	35.11	0.027 **
Weed managent(W)	5	543.576	108.71	54.99	<0.01 **
N XW	5	12.386	2.477	1.25	0.322 *
Residual	22	39.540	1.977	1.88	
Total	35	834.308			

* Not significant at p≤ 0.05   ** Significant at p≤0.05   *** Significant at p≤ 0.01

Appendix 14: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on flowering during long rain season (March to May) in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	0.389	0.194	0.08	
Nitrogen (N)	1	0.028	0.028	0.01	0.127 *
Weed managent(W)	5	65.472	13.094	10.38	<0.01 **
N XW	5	4.086	0.961	0.76	0.322 *
Residual	22	25.222	1.261	1.88	
Total	35	100.972			

* Not significant at p≤ 0.05   ** Significant at p≤0.01

Appendix 15: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on flowering during short rain season (October to December) in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	0.389	0.194	0.08	
Nitrogen (N)	1	0.028	0.028	0.01	0.926 *
Weed managent(W)	5	27.472	5.494	2.23	<0.01 **
N XW	5	10.139	2.028	0.82	0.547 *
Residual	22	49.222	2.461		
Total	35	92.306			

* Not significant at p≤ 0.05   ** Significant at p≤0.01

Appendix 16: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on root dry matter production during long rain season (March to May) in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	2.430	1.21	6.37	
Nitrogen (N)	1	3.8547	3.854	20.19	0.046 **
Weed managent(W)	5	32.6259	6.525	8.82	<0.01 ***
N XW	5	0.651	0.130	0.18	0.969 *
Residual	22	14.797	0.739		
Total	35	54.74			

* Not significant at p≤ 0.05 ** Significant at p≤0.05 *** Significant at p≤ 0.01

Appendix 17: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on root dry matter production during short rain season (October to December) in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	1.888	0.944	9.88	
Nitrogen (N)	1	4.537	4.537	47.47	0.020 **
Weed managent(W)	5	57.867	11.576	7.06	<0.01 ***
N XW	5	9.428	1.886	1.15	0.017 **
Residual	22	32.778	1.639		
Total	35	106.699			

** Significant at p≤0.05 *** Significant at p≤ 0.01

Appendix 18: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on shoot dry matter production during long rain season (March to May) in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	1.03	0.51	0.44	
Nitrogen (N)	1	61.13	61.13	52.83	0.018 **
Weed managent(W)	5	3120.25	624.05	10.49	<0.01 **
N XW	5	17.73	17.17	0.06	0.999 *
Residual	22	1189.50	59.47		
Total	35	4391.95			

* Not significant at p≤ 0.05 ** Significant at p≤0.01

Appendix 19: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on shoot dry matter production during short rain season (October to December) in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	22.43	11.22	0.66	
Nitrogen (N)	1	305.84	305.84	1.54	0.023 **
Weed managent(W)	5	2600.98	520.20	8.60	<0.01 ***
N XW	5	159.89	31.95	0.53	0.999 *
Residual	22	1209.83	60.49		
Total	35	4695.18			

* Not significant at p≤ 0.05 ** Significant at p≤0.05 *** Significant at p≤ 0.01

Appendix 20: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on number of active nodules during long rain season (March to May) in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	6.05	3.02	0.13	
Nitrogen (N)	1	478.403	478.4	20.36	0.026 *
Weed managent(W)	5	102.697	20.53	4.14	0.01 **
N XW	5	121.514	24.30	4.90	0.003 **
Residual	22	99.211	4.961		
Total	35	1982.37			

* Significant at p≤ 0.05 ** Significant at p≤0.01

Appendix 21: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on number of active nodules during short rain season (October to December) in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	6.05	3.02	0.13	
Nitrogen (N)	1	478.403	478.4	20.36	0.021 *
Weed managent(W)	5	102.697	20.53	4.14	0.001 **
N XW	5	121.514	24.30	4.90	0.002 **
Residual	22	99.211	4.961		
Total	35	1982.37			

* Significant at p≤ 0.05 ** Significant at p≤0.01

Appendix 22: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on number of total nodules during long rain season (March to May) in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	532.117	266.058	0.36	
Nitrogen (N)	1	0.025	0.025	0.00	0.019 **
Weed managent(W)	5	289.625	57.925	3.83	0.014 **
N XW	5	3.358	0.672	o.04	0.999 *
Residual	22	302.833	15.142		
Total	35	4785.775			

* Not significant at p≤ 0.05 ** Significant at p≤0.05

Appendix 23: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on number of total nodules during short rain season (October to December) in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	1386.45	693.23	10.38	
Nitrogen (N)	1	205.51	205.51	3.08	0.022 **
Weed managent(W)	5	285.57	57.11	2.06	0.013 **
N XW	5	93.72	18.74	0.68	0.646 *
Residual	22	554.44	20.78		
Total	35	9392.00			

* Not significant at p≤ 0.05 ** Significant at p≤0.05

Appendix 24: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on active nodule weight during long rain season (March to May) in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	3910	1955	0.07	
Nitrogen (N)	1	633085	633085	21.38	0.044 **
Weed managent(W)	5	112529	22506	1.97	0.028 **
N XW	5	156190	31238	2.73	0.0496 **
Residual	22	228976	11449		
Total	35	1193903			

** Significant at p≤0.05

Appendix 25: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on active nodule weight during short rain season (October to December) in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	6024	3012	0.13	
Nitrogen (N)	1	510748	510748	22.51	0.042 **
Weed managent(W)	5	99040	19808	3.29	0.025 **
N XW	5	96521	19304	3.21	0.027 **
Residual	22	120346	6017		
Total	35	878050			

** Significant at p≤0.05

Appendix 26: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on total nodule weight during long rain season (March to May) in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	346562	173281	5.32	
Nitrogen (N)	1	43939	43939	1.55	0.035 **
Weed managent(W)	5	259386	51877	2.40	0.022 **
N XW	5	252172	50434	1.95	0.131 *
Residual	22	518095	25905		
Total	35	1485275			

* Not significant at p≤ 0.05 ** Significant at p≤0.05

Appendix 27: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on total nodule weight during short rain season (October to December) in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	7513	3757	0.08	
Nitrogen (N)	1	456525	456525	10.90	0.046 **
Weed managent(W)	5	232974	46595	2.15	0.015 **
N XW	5	37914	7583	0.33	0.887 *
Residual	22	454906	22745		
Total	35	1279310			

* Not significant at p≤ 0.05 ** Significant at p≤0.05

Appendix 28: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on number of pods per bean plant during long rain season (March to May) in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	156.839	78.419	39.71	
Nitrogen (N)	1	90.00	90.00	85.57	0.221 *
Weed managent(W)	5	1295.38	659.078	59.19	≤0.0015 **
N XW	5	37.800	7.560	1.73	0.1494 *
Residual	22	87.544	4.377		
Total	35	3438.122			

* Not significant at p≤ 0.05 ** Significant at p≤ 0.01

Appendix 29: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on number of pods per bean plant during short rain season (October to December) in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	73.145	36.572	10.88	
Nitrogen (N)	1	117.992	117.992	35.09	0.123 *
Weed managent(W)	5	1676.905	6.250	41.58	≤0.001 **
N XW	5	31.248	8.066	0.77	0.1494 *
Residual	22	161.325	5.456		
Total	35	3835.708			

* Not significant at p≤ 0.05 ** Significant at p≤ 0.01

Appendix 30: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on number of seeds per pod during long rain season (March to May) in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	2.852	1.4271	5.94	
Nitrogen (N)	1	0.1480	0.1480	0.62	0.515 *
Weed managent(W)	5	11.0501	2.2100	3.78	0.231 *
N XW	5	1.6221	0.3244	0.56	0.733 *
Residual	22	11.6822	0.5841		
Total	35	129.4700			

* Not significant at p≤ 0.05

Appendix 31: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on number of seeds per pod during short rain season (October to December) in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	1.4972	0.7486	1.91	
Nitrogen (N)	1	0.0401	0.0401	0.10	0.779 *
Weed managent(W)	5	6.1077	1.2215	5.14	0.371 *
N XW	5	0.3039	0.0608	0.26	0.932 *
Residual	22	4.7561	0.2378		
Total	35	97.9790			

* Not significant at p≤ 0.05

Appendix 32: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on 100 seeds weight during long rain season (March to May) in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	0.0834	0.0417	1.91	
Nitrogen (N)	1	0.3062	0.3062	1.37	0.779 *
Weed managent(W)	5	6.0964	1.3193	3.04	0.0451 **
N XW	5	1.64470	0.3294	0.55	0.932 *
Residual	22	11.9310	0.5965		
Total	35	20.5126			

* Not significant at p≤ 0.05 ** Significant at p≤0.01

Appendix 33: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on 100 seeds weight during short rain season (October to December) in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	0.4403	0.2201	0.30	
Nitrogen (N)	1	1.3806	1.3806	1.88	0.304 *
Weed managent(W)	5	7.4291	0.7357	3.17	0.048 **
N XW	5	0.5951	1.4858	0.17	0.969 *
Residual	22	13.6797	0.6840		
Total	35	24.9962			

* Not significant at p≤ 0.05 ** Significant at p≤0.05

Appendix 34: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on grain yield during long rain season (March to May) in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	6.05	3.02	0.13	
Nitrogen (N)	1	478.403	478.4	20.36	0.0646 *
Weed managent(W)	5	102.697	20.53	4.14	0.01 ***
N XW	5	121.514	24.30	4.90	0.004 **
Residual	22	99.211	4.961		
Total	35	1982.37			

* Not significant at p≤ 0.05 * Significant at p≤ 0.05 ** Significant at p≤0.01

Appendix 35: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on grain yield during short rain season (October to December) in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	9242	4621	0.11	
Nitrogen (N)	1	17454	17454	0.43	0.581 *
Weed managent(W)	5	319082	41038	4.14	≤0.01 ***
N XW	5	27235	63816	4.90	0.63 *
Residual	22	174021	8701		
Total	35	629109			

* Not significant at *p*≤ 0.05 * Significant at *p*≤ 0.05 *** Significant at *p*≤0.01

Appendix 36: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on soil moisture content at four weeks after planting during long rain season (March to May) in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	3.562	1.78	0.71	
Nitrogen (N)	1	1.588	1.588	0.63	0.510 *
Weed managent(W)	5	117.234	23.447	6.66	<0.01 ***
N XW	5	91.475	18.29	5.20	0.1002 *
Residual	22	70.368	3.518		
Total	35	289.254			

* Not significant at p≤ 0.05 ** Significant at p≤0.05 *** Significant at p≤ 0.01

Appendix 37: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on soil moisture content at four weeks after planting during short rain season (October to December) in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	1.562	1.78	0.14	
Nitrogen (N)	1	0.053	0.053	0.01	0.930 *
Weed managent(W)	5	10.816	11.77	10.38	<0.01 **
N XW	5	58.849	3.218	2.84	0.2002 *
Residual	22	22.677	1.134		
Total	35	110.048			

* Not significant at $p \leq 0.05$ ** Significant at $p \leq 0.01$

Appendix 38: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on soil moisture content at six weeks after planting during long rain season (March to May) in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	2.3074	1.15	0.87	
Nitrogen (N)	1	0.119	0.119	0.09	0.793 *
Weed managent(W)	5	2.6528	4.7681	5.21	0.003 **
N XW	5	97.072	19.41	21.21	0.231 *
Residual	22	18.311	0.915		
Total	35	144.3037			

* Not significant at $p \leq 0.05$ ** Significant at $p \leq 0.05$

Appendix 39: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on soil moisture content at six weeks after planting during short rain season (October to December) in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	10.521	5.261	1.30	
Nitrogen (N)	1	0.018	0.018	0.00	0.793 *
Weed managent(W)	5	129.370	25.874	10.24	0.003 **
N XW	5	7.212	1.444	0.57	0.231 *
Residual	22	50.547	2.527		
Total	35	205.754			

* Not significant at $p \leq 0.05$ ** Significant at $p \leq 0.05$

Appendix 40: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on soil moisture content at eight weeks after planting during long rain season (March to May) in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	0.7805	0.39	0.36	
Nitrogen (N)	1	1.5459	1.545	1.43	0.354 *
Weed managent(W)	5	27.411	5.4824	5.66	0.0032 **
N XW	5	29.0102	5.802	5.99	0.102 *
Residual	22	19.3831	0.969		
Total	35	80.2881			

* Not significant at p≤ 0.05 ** Significant at p≤0.05

Appendix 41: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on soil moisture content at eight weeks after planting during short rain season (October to December) in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	1.0878	0.5439	18.65	
Nitrogen (N)	1	0.1332	0.13322	4.57	0.166 *
Weed managent(W)	5	23.5102	4.7020	5.27	0.003 **
N XW	5	17.5468	3.5092	3.93	0.1012 *
Residual	22	17.8538	0.8927		
Total	35	60.1903			

* Not significant at p≤ 0.05 ** Significant at p≤0.01

Appendix 42: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on soil moisture content at ten weeks after planting during long rain season (March to May) in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	0.8559	0.42	0.66	
Nitrogen (N)	1	0.8867	0.886	1.37	0.354 *
Weed managent(W)	5	8.0031	1.6006	2.49	0.006 **
N XW	5	63.244	12.64	19.69	0.101 *
Residual	22	12.8451	0.642		
Total	35	87.1284			

* Not significant at p≤ 0.05 ** Significant at p≤0.01

Appendix 43: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on soil moisture content at ten weeks after planting during short rain season (October to December) in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	14.279	7.139	0.77	
Nitrogen (N)	1	17.375	17.377	1.88	0.354 *
Weed managent(W)	5	18.491	39.063	6.01	0.006 **
N XW	5	195.313	5.663	0.87	0.101 *
Residual	22	28.314	6.500		
Total	35	403.762			

* Not significant at p≤ 0.05 ** Significant at p≤0.01

Appendix 44: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on soil nitrogen content during long rain season (March to May) in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	0.02167	0.01083	0.52	
Nitrogen (N)	1	44.2222	44.222	1.40	<0.01 **
Weed managent(W)	5	3.51583	0.70317	47.40	<0.001 **
N XW	5	3.14917	0.62983	42.46	0.101 *
Residual	22	0.29669	0.01483		
Total	35	51.24750			

* Not significant at p≤ 0.05 ** Significant at p≤0.01

Appendix 45: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on soil nitrogen content during short rain season (October to December) in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	0.12389	0.06194	0.42	
Nitrogen (N)	1	29.52111	29.52111	200.90	0.0054 **
Weed managent(W)	5	0.4788	0.09578	1.650	0.016 **
N XW	5	2.73222	0.54644	9.40	0.207 *
Residual	22	1.16222	0.05811		
Total	35	34.31222			

Not significant at p≤ 0.05 ** Significant at p≤0.01

Appendix 46: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on soil carbon content during long rain season (March to May) in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	22.042	22.042	0.42	
Nitrogen (N)	1	0.042	0.042	200.90	0.951 *
Weed managent(W)	5	7.042	125.075	1.650	<0.001 **
N XW	5	625.375	6.742	9.40	0.268 *
Residual	22	33.708	4.442		
Total	35	732.625			

* Not significant at p≤ 0.05 ** Significant at p≤0.01

Appendix 47: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on soil carbon content during short rain season (October to December) in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	5.042	5.042	1.49	
Nitrogen (N)	1	9.375	9.375	2.78	0.344 *
Weed managent(W)	5	3.375	111.742	18.29	<0.001 **
N XW	5	558.708	3.675	0.60	0.701 *
Residual	22	18.375	6.108		
Total	35	655.958			

* Not significant at p≤ 0.05 ** Significant at p≤0.01

Appendix 48: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on soil number of amaranthus plants during long rain season (March to May) in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	126.06	63.03	7.25	
Nitrogen (N)	1	14.69	14.69	1.69	0.323 *
Weed managent(W)	5	138.47	27.69	1.74	0.001 **
N XW	5	203.81	40.76	2.56	0.213 *
Residual	22	317.89	15.89		
Total	35	818.31			

* Not significant at p≤ 0.05 ** Significant at p≤0.01

Appendix 49: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on soil number of amaranthus plants during short rain (October to December) season in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	0.500	0.250	0.03	
Nitrogen (N)	1	4.694	4.694	1.65	0.504 *
Weed managent(W)	5	33.917	6.783	0.71	0.621 *
N XW	5	76.806	15.361	1.61	0.202 *
Residual	22	190.444	9.522		
Total	35	320.750			

* Not significant at p≤ 0.05

Appendix 50: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on soil number of blackjack plants during long rain seaso (March to May) n in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	84.722	42.361	4.94	
Nitrogen (N)	1	0.250	0.250	0.03	0.880 *
Weed managent(W)	5	329.472	65.894	7.63	<0.001 **
N XW	5	259.917	51.983	6.02	0.321 *
Residual	22	172.778	8.639		
Total	35	864.306			

* Not significant at p≤ 0.05 ** Significant at p≤0.01

Appendix 51: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on soil number of blackjack plants during short rain season (October to December) in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	69.389	34.694	1.47	
Nitrogen (N)	1	1.361	1.361	0.06	0.832 *
Weed managent(W)	5	47.056	58.428	1.433	<0.001 **
N XW	5	292.139	67.094	16.45	0.127 *
Residual	22	335.472	4.078		
Total	35	81.556			

* Not significant at p≤ 0.05 ** Significant at p≤0.01

Appendix 52: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on soil number of coachgrass plants during long rain season (March to May) in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	4.389	2.194	1.00	
Nitrogen (N)	1	17.361	17.361	7.91	0.107 *
Weed managent(W)	5	25.806	5.162	2.59	<0.05 **
N XW	5	25.806	5.161	2.59	0.158 *
Residual	22	39.889	1.994		
Total	35	117.639			

* Not significant at p≤ 0.05 ** Significant at p≤0.05

Appendix 53: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on soil number of coachgrass plants during short rain season (October to December) in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	15.500	7.750	0.20	
Nitrogen (N)	1	0.256	0.250	0.01	0.944 *
Weed managent(W)	5	41.917	8.383	1.04	<0.042 **
N XW	5	29.917	5.983	0.74	0.600 *
Residual	22	161.00	8.050		
Total	35	326.750			

* Not significant at p≤ 0.05 ** Significant at p≤0.05

Appendix 54: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on number of devils horsewhip plants during long rain season (March to May) in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	22.389	11.194	1.91	
Nitrogen (N)	1	21.778	21.778	3.72	0.194 *
Weed managent(W)	5	167.889	33.573	3.55	<0.019 **
N XW	5	81.889	16.378	1.73	0.174 *
Residual	22	189.222	9.461		
Total	35	494.889			

* Not significant at p≤ 0.05 ** Significant at p≤0.05

Appendix 55: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on number of devils horsewhip plants during short rain season (October to December) in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	15.056	7.528	1.20	
Nitrogen (N)	1	16.000	16.000	2.56	0.251 *
Weed managent(W)	5	148.222	6.250	3.77	0.014 **
N XW	5	46.667	29.644	1.93	0.350 *
Residual	22	157.111	9.333		
Total	35	395.556			

* Not significant at p≤ 0.05 ** Significant at p≤0.01

Appendix 56: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on number of nutgrass plants during long rain season (March to May) in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	38.22	19.11	1.29	
Nitrogen (N)	1	1.36	1.36	0.09	0.790 *
Weed managent(W)	5	312.14	62.43	4.00	0.014 **
N XW	5	530.14	106.03	6.79	0.1023 *
Residual	22	312.22	15.61		
Total	35	1223.64			

* Not significant at p≤ 0.05 ** Significant at p≤0.05

Appendix 57: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on number of nutgrass plants during short rain season (October to December) in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	16.167	8.083	1.12	
Nitrogen (N)	1	1.361	1.361	0.19	0.706 *
Weed managent(W)	5	156.250	31.450	4.05	0.011 **
N XW	5	378.139	75.623	9.73	0.231 *
Residual	22	155.444	7.773		
Total	35	722.750			

* Not significant at p≤ 0.05 ** Significant at p≤0.05

Appendix 58: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on number of stargrass plants during long rain season (March to May) in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	1.556	0.778	0.11	
Nitrogen (N)	1	4.00	4.00	0.57	0.529 *
Weed managent(W)	5	24.889	4.978	0.62	0.686 *
N XW	5	40.00	8.0023	1.00	0.445 *
Residual	22	160.444	8.0222		
Total	35	244.889			

* Not significant at p≤ 0.05

Appendix 59: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on number of stargrass plants during short rain season (October to December) in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	61.167	30.583	0.50	
Nitrogen (N)	1	12.250	12.250	0.20	0.699 *
Weed managent(W)	5	12.583	2.517	0.40	0.846 *
N XW	5	28.582	5.717	0.90	0.500 *
Residual	22	127.000	6.350		
Total	35	364.750			

* Not significant at p≤ 0.05

Appendix 60: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on number of wondering jew plants during long rain season (March to May) in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	2.672	1.33	0.02	
Nitrogen (N)	1	75.111	75.112	0.85	0.454 *
Weed managent(W)	5	176.89	20.00	0.41	0.838 *
N XW	5	100.00	106.04	2.16	0.100 *
Residual	22	530.00	49.16		
Total	35	1868.00			

* Not significant at p≤ 0.05 ** Significant at p≤0.05

Appendix 61: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on number of wondering jew plants during short rain season (October to December) in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	324.2	162.324	1.51	
Nitrogen (N)	1	0.1	0.1	0.00	0.977 *
Weed managent(W)	5	1032.60	206.521	0.89	0.505 *
N XW	5	869.99	174.01	0.75	0.594 *
Residual	22	4626.23	231.321		
Total	35	7067.96			

* Not significant at $p \leq 0.05$

Appendix 62: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on number of oxalis plants during long rain season (March to May) in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	1688.9	844.4	1.74	
Nitrogen (N)	1	784.00	784.0	1.62	0.332 *
Weed managent(W)	5	6163.66	1232.79	2.95	0.037 **
N XW	5	15589.3	3117.9	7.46	0.112 *
Residual	22	8359.09	418.00		
Total	35	33555.8			

* Not significant at $p \leq 0.05$ ** Significant at $p \leq 0.01$

Appendix 63: Analysis of variance (ANOVA) table for the effect of weed management practices and nitrogen application on number of oxalis plants during short rain season (October to December) in 2009.

Source of variation	d.f.	s.s.	m.s.	v.r.	F. pr
Block	2	2080.99	1040.4	10.22	
Nitrogen (N)	1	1344.43	1344.4	13.21	0.1068 *
Weed managent(W)	5	3479.62	695.99	1.81	0.158 *
N XW	5	5474.22	1094.8	2.84	0.143 *
Residual	22	7710.9	385.5		
Total	35	20292.9			

* Not significant at $p \leq 0.05$