STUDIES ON INTEGRATING WEED MANAGEMENT STRATEGIES IN CARROT *(Daucus carota* L.) PRODUCTION

A RESEARCH THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE IN CROP PROTECTION.

DANIEL OJOWI

B.Sc. Crop Protection (J.K.U.A.T)

DEPARTMENT OF PLANT SCIENCE AND CROP PROTECTION

FACULTY OF AGRICULTURE

COLLEGE OF AGRICULTURE AND VETERINARY SCIENCES

UNIVERSITY OF NAIROBI

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Declaration

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

Signature.............. Date 8/MAY/2013

Daniel Ojowi

Department of Plant Sciences and Crop Protection

Supervisors:-

Signature .... Date 7/5/2013

Dr. Emmanuel Ariga

Department of Plant Sciences and Crop Protection

Signature.............. Date May, 8, 2013.

Prof. Ratemo Michieka

Department of Plant Sciences and Crop Protection

Signature .... Date 8/5/13

Prof. John Kimenju

Department of Plant Sciences and Crop Protection

Dedication

To my parents who have helped me a great deal to complete the study.
GOD BLESS THEM

Acknowledgement

My gratitude goes to the Almighty God for enabling me to complete the course, amidst the many challenges that I faced during the study period.

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MAY GOD BLESS YOU ALL ABUNDANTLY

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ABSTRACT

Weed control constitutes one of the main cost items and a constraint to carrot production. The current study was conducted with the aim of developing an integrated cost-effective strategy of managing weeds and increasing the competitive ability of the crop against weeds. The weed control strategies tested in RCBD and replicated three times; were black plastic mulch, grass mulch, herbicides (Linuron and Oxyfluorfen), and grass mulch with herbicide combinations. Crop competitive ability through application of foliar feed fertilizer with one hand weeding combinations, foliar feed fertilizer with grass mulch combination, hand weeding every two weeks, famers practice (two hand weeding), and control (unweeded check) were tested. Data was collected on weed species, weed density, weed control efficiency, yield attributes, yield and economic cost benefits were subjected to ANOVA and means separated by Duncan's multiple range test at $P \leq 0.005$. Efficacy of weed control and carrot yield were significantly higher among the treatments with black polythene achieving 99.6%, linuron 78.1% and famers practice 19.0 % weed control resulting in yield of 34,205.5 kg/ha, 30,356.7Kg/ha, 19,850 kg/ha respectively. The finding suggest that spraying linuron @ 2.0 kg/ha as a pre-emergence is the best for weed control to get higher yield and economic return than oxyfluorfen @ 1.0 L kg/ha. It was concluded that plastic mulch is an effective strategy of reducing weed growth in carrots.

Foliar feed application imparted competitive ability in carrot against weeds. However, the foliar feed levels and timing were not significant in imparting competitive ability in carrots i.e. choosing between 41, 48 and 55 days after sowing

or their combinations. All the treatments increased marketable yield substantially compared to unweeded check although yield varied marginally among the levels and timings. However, there was a significant difference ($P \leq 0.05$) in marketable yield by Foliar feed application at 41, 48 and 55 days after sowing in combination with hand weeding with yield of 24249 kg /ha compared to Foliar feed application at41, 48 and 55 days in combination with grass mulch yielding 21821 kg/ha. Application of foliar feed increased tolerance in carrot against the effect of weed completion. For example plots treated with foliar feed application 41, 48 and 55 days after sowing plus hand weeding once achieved 78.7 % weed control compared to unweeded check which registered no weed control at all (0%).

Overall, plastic mulch treatment gave the best weed control, the highest plant weight and marketable yield and yield attributes, resulting in the highest economic benefits. The rest of the treatments had potential of weed control at various level of effectiveness. It is, therefore, clear carrot production cannot be achieved without successful weed management that involve technology that is affordable and profitable to small scale farmers at the same time safeguarding the environment. The carrot producers presumably will benefit from the best, economical and efficient strategy in controlling weeds if the integrated weed management strategies are adopted.

CHAPTER ONE

1.0 INTRODUCTION

Integrated weed management is an approach of assembling a weed management plan that incorporates a number of tools consistent with farm goals (Swanton and Weise 1991; Akobundu, 1996; Vereijken and Kropff, 1996). This includes sanitation procedures, crop rotations, mulching, specialized tillage scheme, cover crops and herbicide. Integrated weed management combines preventive and curative weed control methods, based on ecological principles, to address environmental and economic concerns (Vereijken and Kropff, 1996). The best integrated approaches have been developed by the farmers themselves. This technique utilizes all suitable methods in as compatible manner as possible (Cardina *et al.*, 1999).

Carrots are a particularly difficult crop to manage in terms of weed control (Litterick, 1999). The crop is sensitive to poor seedbed conditions, slow to germinate and only reaches canopy closure towards the end of the season (Peacock, 1991; Tamet *et al*., 1996; Baumann, 2001). Carrots form an important component of organic crop rotations as a high value cash crop and are promoted as a healthy dietary component (Radics *et al*., 2002). Weed control in carrots is very important due to slow crop growth and lack of competitiveness with weeds early in the season (Luo, 2004). Weed competition can have significant impacts on both quality and yield. Typical impacts, as well as yield reductions, are uneven root size and problems caused to harvesting operations resulting in slower work rate, higher costs and harvest losses (Banga, 1963).The choice depends on soil type, moisture levels and crop growth level. Most of these are for early post emergence, before the five leaf stages. These techniques are, however, unsuitable for baby carrots that are grown on a close row bed system (Gál *et al,* 2008). The aim of integrated weed management is to reduce the need for control and this may involve both direct and indirect methods for dealing with weeds, and all stages of crop production (Cussans, 1995; Cardina *et al.*, 1999). Manipulation of the crop-weed relationship to favour the crop at the expense of the weeds is the basis of integrated weed management.

1.1 Constrains to Carrot Production in Kenya

Production problems experienced in growing carrots includes pests and diseases, high cost of inputs, poor quality seed, poor soil and adverse weather conditions. Unorganized marketing and poor production planning are the other problems leading to oversupply in some periods and hence very low prices (MOA, 2010).

A variety of pest reduces both the yield and market value of the roots, wherever carrots are grown (Lipari, 1976; Rubatzky *et al.*, 1999; Davis, 2007). Many pathogens of carrots are seed borne, the distribution of diseases, including some of serious maladies is worldwide .for example, Alternaria leaf blight and bacteria leaf blight, both of which can affect 100% of the acreage in a particular region, are seed borne and are found wherever are grown (Davis, 2007).

Bunching carrots damages free tops as well as roots, healthy tops are critical for harvest since in many areas the undercut carrots are mechanically picked up by the leaves, thus week tops results in efficient harvesting. Control of insect pest and disease are important for optimum carrot culture (Lipari, 1996). The root knot nematode *(Melodoigyne spp)* is a serious pest of carrot. Carrots affected by nematodes often exhibit forking of the taproot, stubbing of the roots, and unsightly galls. Complete crop losses in carrots have been reported, other nematodes causes' local loses, but overall. Losses are minimal (Davis, 2007). Pig weed (*Amaranthus hybridus L.*), nutsedges (*Cyperus spp*) and nightshade *(Solanum nigrum L.)*, are weeds that are difficult to control in carrots (Rubatzky *et al.*, 1999).

1.2 Problem Statement and Justification of the Research

Weed control for carrots production posse's particular difficulties. The crop is sensitive to poor seed bed conditions, slow to germinate and only reaches canopy closure towards the end of the season (Shaw, 1982; Bond, 1991). Weed control is very important in carrots due to slow crop growth and lack of competiveness with weeds early in the season, and in the absence of control, yields are often reduced by more than 90% (Bond, 1991). As well, weeds host important pests of carrots and at harvest reduce crop quality and harvesting efficiency (Davis, 2007). Weed competition has significant negative impacts on both quality and yield. Typical impacts, results in slower work rate, higher costs and harvest losses. Carrot yield can be increased through proper weed management. Herbicidal weed control is well established in Kenya but farmers mainly depend on manual hand weeding (MOA, 2009). Weed management option are aimed to increase yield, better quality production and reduced weed pressures. The degree of management is dependent on the characteristic of the weeds involved and the effectiveness of the method used (Smith, 1968; Ascard, 1990).

An integrated weed management program is essential in carrot production because of the short coming associated with single methods. Most of the registered herbicides do not control most of weeds in carrots and also famers are hindered by the high cost of the herbicides. Mechanical cultivation and hand-hoeing are laborius because of the high plant densities and the fact that carrots are not competitive against weeds. However, the limited number of herbicides available and the diversity of weeds that grow in carrot fields make it difficult to maintain adequate control throughout the growing season (Akobundu, 1996). Integrated weed management therefore can be incorporated as an approach that incorporates a number of tools consistent with farm goals and can be developed on farms by the farmers themselves. These methods are quite appropriate to improve crop performance and quality hence improving productivity, which leads to increase of farmer's income hence reduction of poverty (Tamet *et al.*, 1996; Peacock, 1991).

1.3 OBJECTIVES

1.3.1 Broad objective

To develop an integrated method of managing weeds, for optimum yields and profitability in carrot production.

1.3.2 Specific objectives

i. To determine the efficacy of mulching alone and in combination with, herbicides on weed control in carrots.

ii. To assess the potential of increasing weed suppression and tolerance to weed competition through application of foliar fertilizers in carrots.

iii. To assess the cost and yield of different strategies of weed control in carrots.

1.4 HYPOTHESIS TESTED

1) There is no significant difference between mulch, herbicides and mulch/ herbicide combinations in control of weeds in carrots.

2) Foliar feed does not increase growth rate and leaf canopy of carrots resulting in no suppression of weeds.

3) Integrated weed management is a cheaper and does not result in higher yield of carrots than the farmers practice.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Origin and use of carrot

Carrot (*Daucus carota* L.) is an important member of the family Umbelliferae, which produce an edible taproot (Sulaeman *et al*., 2001a). Native of Afghanistan and neighbouring land, carrots were cultivated in the Mediterranean region before the Christian era and in china (Rose and O'Relly, 2006; Mabey 1997). They are now extensively grown throughout the temperate zones. Early varieties had anthocyanin pigments in them giving the carrot a red, purple or black colour. A yellow variety without anthocyanin a rose in the 16^{th} century and became popular. In the 17^{th} century in Holland the familiar orange variety was produced (Dalby, 1997).

The modified root of carrot is the most widely used part of the plantas food but all parts of carrot plant are equally valuable. Nowadays the most commonly cultivated varieties have an orange root, and were developed from earlier yellow versions. In comparison, the wild carrot commonly called Queen Anne's lace is often white while other varieties of carrots can be purple. In addition to different colours, carrots also have many varieties that differ in shapes (Norwick, 2007). Long and tapering shape is the common versions that we see today, but other varieties are more round and bulbous or thick and cylindrical. In its second year the plant will flower, a process called bolting at which point the main stalk grows and the many umbels form, displaying small white flowers (Kjellenberg, 2007).

Carrots are valuable for their taste, good digestibility, and high contents of pro-vitamin A, and fibers. Both epidemiological and nutritional studies have pointed out its positive impact on human health (Sulaeman *et al.,* 2001a; Bender and Bender, 2005; Kjellenberg, 2007). In early use, carrots were grown for their aromatic leaves and seeds, not their roots. Some relatives of carrot are still grown for these, such as parsley, dill and cumin (Dalby, 2003). As the name implies, carrots are brimming with beta carotene which has been used as powerful antioxidant effective in fighting against some forms of cancer, especially lung cancer. Carrots seed are considered carminative, stimulant and very useful in cases of dysentery and chronic coughs. Like the rest of the vegetables, is valued as food because of its rich source of the fat soluble hydrocarbon, carotene ($C_{40}H_{56}$) the precursor of vitamin A (Bender and Bender, 2005).

2.2 Cultural Aspects of Carrot Production

Carrot seeds are small and are sown directly in the field after a good preparation of the soil (Anon, 1983; Ascard, 1990). Deep ploughing or working to loosen the soil to a depth of at least 30 cm is important to allow good root development. Sub-soiling can be advantageous in breaking compacted soil layers. As in other crops, over-working the soil should be guarded against, because the resulting compaction and possible surface capping can seriously affect emergence and root development of plants (Banga, 1963).

Carrot seeds are small and tend to germinate irregularly. The seedlings are delicate and cannot push through a tight or deep covering of soil. The seed should be covered to a uniform depth of 10 to 25 mm, and should be kept moist until the plants are well established. In loose, lights and, seeds could be planted 40 mm deep (Ascard, 1990). Thinning out of plants is not practical in large commercial plantings, so attention must be given to ensuring that the correct seeding rate is used at planting. Carrots are often planted on top of ridges or raised beds. This is especially important on heavier soils, shallow soils or those less well-drained, as it gives added soil depth, better drainage and the looser structured soils favoured by this crop (Bose and Som, 1990).

With the advent of herbicides, tillage for weed control is not an essential practice. However, tillage may be necessary should the soil cap after heavy rains. With wide row spacing it may also be a good practice to loosen heavy, compacted soil by running a tine to a depth of about 200 mm between the rows, when the roots are about 15 mm in diameter, to allow better roots and give smoother, better shaped roots. When the upper part of the root is exposed to sunlight, chlorophyll is formed, resulting in undesirable green shoulders. Keeping the shoulders covered with soil will prevent this condition; the cultivator sweeps should be adjusted to throw soil towards the row, lightly covering the exposed tops of the roots (Ashton, 1973).

(Bose and Som, 1990) noted that carrots require a fertile soil which allows rapid, uninterrupted growth. Heavy fertilizer dressings may then be necessary, but the use of compost or organic manures is not recommended, as they often cause unattractive, hairy roots, with a coarser texture. Carrots are sensitive to soil acidity. Soils of low pH often contain high levels of available aluminum and soluble manganese, both of which may adversely affect growth and yield. The aluminum will tend to immobilize soil phosphorus, rendering it unavailable to the plant. The pH (KCl) should be raised to over 5.5. A pH of 6.0 to 6.5 is regarded as optimum for carrot production (George, 1999). Dry conditions when the roots start bulking up can severely reduce yields and quality. Under dry conditions long, thin roots are produced, while excess moisture will result to a larger diameter but excessively short roots (Bose and Som, 1990).

Many authors (Lipari, 1976; Rubatzky *et al*., 1999; and George *et al.* 1999), reported that the amount of fertilizer applied to carrot varies considerably depending upon many factors such as time of the year, source of nutrients, soil fertility and stress conditions. According to George *et al.* (1999), he revealed that yield increased in carrots with N fertilization but the effect of N rate depended in planting date and also carrot root carotenoid concentration was maximized at 55 $mg.kg^{-1}$ fresh root tissue with 160 $kg.ha^{-1}$ N. Excessive fertilization is usually practiced to compensate for loses of nutrients from leaching and because some carrot producers believe that high rates of fertilization improves carrot quality (Lipari, 1976). Turker (1974) reported that big sizes carrots are more prone to damage during harvesting compared to small carrots, and high damage due to lifting may occur in heavy soil. Harvesting at optimum stage of maturity improves quality and storability of carrots.

2.3 Carrot Production in Kenya

Carrot is the most important and widely grown member of the family Apiaceae (Sulaeman *et al*., 2001a). Carrots are grown for the edible taproot, which contains high levels of carotene, the precumor of vitamin A, which is essential for human health and nutrition (Bender and Bender, 2005). Carrots are among the top 10 most important vegetable crops in terms of area devoted to its production and tonnage of crop production (Simon and Goldman, 2007).

Carrot as a produce is consumed fresh or processed and are largely grown for domestic market in Kenya (MOA, 2007). Central province is a major producer of carrots in Kenya (Table 1). Production of carrots is largely under rain fed and in cool areas of the country. Considerable decrease in area, production and value have been reported in Nyanza and Rift Valley provinces leading to an overall 9.1% and 7.7% decline in area and total volume produced respectively (MOA, 2010).

Carrot is directed seeded after a good preparation of the soil. Several plough are made before sowing in order to prepare a fine seed bed for seeds. The interval between rows is if of 25cm and the distance between the plants is 7-15cm. In general, to sow one hectare, 4-5 kg of seeded are needed, depending on the varieties (Anon, 1998). In Kenya, carrot is mostly cultivated as a cool season crop in areas with an average daily temperature 20°C -30°C. Soil temperatures above 30°C may reduce root quality and root colour. High temperatures can cause burning of young seedlings. Soils should be slightly acidic, pH 6.0-6.5. If the soil has 5% or more organic matter a pH of 5.2-5.7 generally gives a better result. For economic yields, carrots are grown in tropical regions at altitudes above 700 m. Early-maturing carrot cultivars may grow in the lowlands, but yields are low and the roots have a poor colour (FAO, 1999). Carrot grows best in a well-drained friable loam free of stones and hard soil clods. Maturation period in carrot depend on the variety. It takes 2- 3 months with the potential of high yields for family, food security and fresh market sales. It does well in areas under both rain fed and irrigated conditions, yield varies between 28-35ton/ha. Storage temperature between 3 and 5°C is usually recommended (MOA, 2010).

Table 1. Carrot production in Kenya between 2005-2009.

Province	Hectarage (Ha)					Production (MT)				
	2005	2006	2007	2008	2009	2005	2006	2007	2008	2009
Central	1,299	1,968	2,769	1669	1,900	18,186	27,552	38,766	41,725	57,000
Coast	14	15	23	23	28	196	210	322	414	504
Eastern	281	180	355	455	503	3,934	2,520	4,970	11375	10,060
Western	29	50	36	86	112	406	700	504	1,720	2,245
Nyanza	175	240	316	363	142.5	2,450	3,360	4,424	7,260	2850
Rift/Valley	920	1,062	981	886	474	12,880	14,868	13,734	26,580	9,480
Nairobi	19	20	5	3	5.9	266	280	70	60	118
North/ Eastern	0	0	0	0	0	0	0	0	0	0
Total	**2,737**	**3,535**	**4,462**	**3485**	**3,165**	**38,318**	**49,490**	**62,790**	**89,134**	**82,257**

Source: *Ministry of Agriculture, Kenya (2010).*

2.4 Effects of Weed on Carrot Quality

Carrots are increasingly consumed due to their quality characteristic such as flavor, sugar dry matter contents and their perceived health benefits (Rodriquez *et al.*, 1999; Rubatzky *et al.,* 1999). Carrots are truly one of nature's wonder foods. Not only are they universally relished for their delicious flavor and satisfying crunch but they also provide a wide range of health and benefits. Quality of carrot is partly determined by its sugar content which contributes to its sweetness, the total sugar content range from 3.5 to 10.7% in fresh carrots (Mabrouck, 1973). Sucrose is a major sugar representing 56.9% of total sugars, followed by glucose 24.6% and fructose 18.5 %, up to 70%of dry matter content consist of soluble sugars (Rodriquez *et al.*, 1999). These qualities of carrots are negatively affected by weeds during production.

The critical period of weed control is an important principal of an integrated weed management program (Nieto *et al*., 1968; Knezevic *et al.,* 2002). It is a period in the crop growth cycle during which weeds must be controlled to prevent quality and yield losses (Knezevic *et al.,* 2002). Many studies have been conducted to determine the critical period for weed control in various crops under various environmental conditions (Evans et al., 2003; Knezevic *et al.,* 2003; Van Acker *et al.,* 1993). Critical period for weed control is usually performed by measuring the affect of early season weed competition and late-season weed competition. Carrot is a relatively open crop, beside to avoid competition. Weeds are not tolerated in this crop because it is able to produce a lot of seeds in this open crop. Therefore, a threshold density is not used. In general, it's important to control weeds from emergence till around 80% crop closures (Clarence *et al.,* 2010).

Many authors (Dawson, 1970; Martin *et al.*, 2001; Knezevic *et al.,* 2002) have shown that weeds greatly reduce the yield, quality and marketable size of the crop. The main factors influencing the weed composition in carrots are soil type, climate of each growing season, the sowing period, and the cropping system (Clarence *et al.,* 2010). Competition between weed seedling and direct seeded carrot usually begin as completion for light. The effect of shading on carrot greatly is most severe during seedling stage. Weeds are the most competitive at the beginning of growing period. When the crop is not cultivated for 15 days the yield loss is up to 26%. When the weeds are in the competition from emergence up to harvesting about 90% of losses is expected (Martin *et al.,* 2001). Early-season weed competition is achieved by allowing weeds to emerge and grow with the crop for certain predetermined times, after which all weeds are removed in timely manner until harvest. For late-season weed competition, the crop is kept free from weeds until certain predetermined times, after which weeds are allowed to emerge and compete with the crop for the remainder of the growing season (Nieto *et al.,* 1968 ; Evans *et al.,* 2003). Manipulation of soil nutrient supply and soil available water are believed to influence the crop–weed interference relationships (Weaver *et al.,* 1992). Carrot should be free of weeds at least half of vegetation period and the critical period depends on cultivars, time of sowing and cultivation method involved (Martin *et al.*, 2001).

2.5 Weed Control in Carrots

Weeds reduce yields of carrots by reducing the size of carrot root by direct competition for nutrients, space and water. Weeds also cause deformation of carrots and therefore unmarketable (Carl *et al*., 2000). Weeds control is by far the most labour demanding field operation in carrot production. Many weeds including annuals and perennials are pests of carrots. Hand weeding is probably the oldest method of weed control and consist of hand pulling, hand slashing and hoeing which has consistently proved to be inefficient and costly (Kerkhoven, 2003). Yellow nutsedges *(Cyperus esculentus* L.) and purple nutsedges *(C. rotundus* L.), are the worst weed pests in carrots (Rubatzky *et al*., 1999). Post emergence herbicides control yellow nut sedge, but no herbicide is registered for purple nut sedge control in carrots (Litterick, 1999). Cultivation and pre plant chemical treatments offer some control of nut sedges, and fallow summer treatments can also be effective. Pre emergence or post emergence herbicides are available for control of grass, cereal, and broadleaved weeds (Gal, 2003).

2.5.1 Herbicides

Carrots do not compete well against weeds, due to its slow growth that suffers severe yield loss from weed competition and herbicides are important tools for weed management and for the production of high yield and quality carrots (Litterick, 1999). Majority of farmers follow herbicides application by one, or two applications. The two mostly frequently used herbicides in Kenya for carrot control are linuron and oxyfluorfen (MOA, 2007). The herbicides were registered after a series of test verifying the efficacy in weed control and compatibility with the environment.

2.5.1.1 Linuron for weed control in carrot

This is a selective pre and post emergence herbicide for controlling numerous broad leaved weeds in, common bean, carrot, maize and potato. The substituted urea linuron has been used as extensively in carrot production since the 1960s for control of annual weeds (Windholz, 1983). Linuron is registered in Kenya for use in carrot as either pre emergence 1.5 -2.0 kg a.i/ha or as post emergence 1.5-2.0kg a.i/ha (Balah, 1985). The weed communities are very rich in species both grasses and broad leaved species. Most growers use a several times a low dosage of linuron with additive on just emerged weeds. Currently, linuron is approved for use against weeds in carrots. Linuron is susceptible to garminean and annual dicot which include *Amaranthus spp, Chenopodium album, Digitaria sanguinalis, Stellaria media* and resistance to *Cynodon dactylon, Cyperus esculentus, Cyperus rotundus, Datura stramonium, Solanum nigram and Vicia sativa* (Carl *et al.*, 2000).

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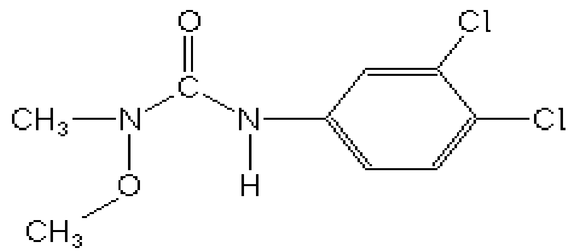

Figure 1.Chemical structure of linuron.

As a 3-(3, 4-Dichlorophenyl)-1-methoxy -1-methylurea, it works by inhibiting photosynthesis by binding to the Q_a-binding niche on the D1 protein of photosystem II complex in the chloroplast thylakoid membrane in target weed plants (Windholz, 1983). In a recent study, Carl *et al.* (2000) compared the application of linuron with hand weeding and non treated for weed control and found out linuron applied as pre- or post emergence was slightly less effective than 100% weed control obtained by hand weeding. Henne and Quest (1973) compared linuron treatment to hand weeding and non weeded check. Yield in the weedy check were 10 % of those in the hand weeded plots and 15% those following linuron treatment.

2.5.1.2 Oxyfluorfen for weed control in carrot

Weeds are problem since the seeds of carrot germinate late. In condition weeds become more competitive. The protection of carrots from weeds, combines herbicides, agronomic technique and sometimes supplement hand weeding. Oxyfluorfen is registered in Kenya for the control of weeds in onions, cabbage, tomato and onion (Balah, 1985). 1.0L a.i /ha is being recommended as both pre emergence and post emergence It has also a potential to control weeds in Garlic, Maize, Sugarcane, Cotton and ornamental crops. As contact herbicide and light is required for it to affect target plants .It is available in emulsifiable concentrate and granular formulations (Meister, 1992).

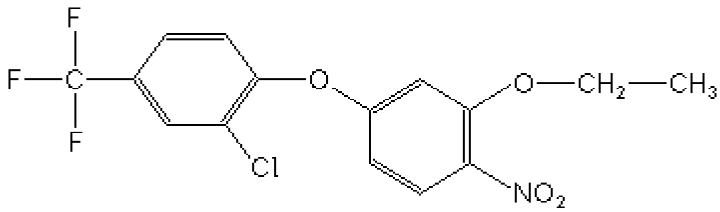

Figure 2: Chemical structure of Oxyfluorfen.

Oxyfluorfen as a surface acting herbicide and active on young weeds, it has a prolonged residue activity lasting up to three months (Rohm and Haas, 1981) therefore the re-growth of many annual weeds are controlled by prolonged oxyfluorfen. Many authors (Singh *et al.*, 1990; Khokhar *et al.*, 2006; Qasem, 2007; Gilreath *et al.*, 2008) have reported satisfactory result of weed control from oxyfluorfen. Kamal (1988) observed that oxyfluorfen at 0.20 kg ha^{-1} as pre-emergence reduced the weed population by 85 per cent over weedy check; he further noted that an increase in herbicidal dose caused burning effect on emerging sprouts. Singh *et al.*, 1990 and Babiker and Ahmed (1986), reported that oxyfluorfen at 0.25 and 0.34 kg/ ha^{-1} respectively gave maximum yield and highest weed control efficiency in onions. According to Gilreath *et al.* (2008), oxyfluorfen was one of the herbicides, which guaranteed the longest weed control in leek crop. In cauliflower crop Oxyfluorfen decreased weed dry weight by 65.5 % (Qasem, 2007). Qasem (2006) state that many weeds, which are difficultly destroyed, were very sensitive to

Oxyfluorfen, for example white goosefoot (*Chenopodium* L.). Some carrot producer in the region have resorted to using oxyfluorfen at 1.0 L a.i/ha as a pre emergence herbicide in carrot and yet it is not registered in Kenya for use in carrot production (MOA, 2007).

2.5.2 Plastic mulch for weed control

Polyethylene plastic mulch was generated for commercial use in 1939 and has been used extensively in commercial vegetable production since the early 1960s (Mohler and Teasdale, 1993; Ham and Kluitenburg, 1994; Egley, 1996; Mohler and Teasdale, 1993; Mohler, 1996). Polyethylene plastic is made from polyethylene resin which is in the form of pellets. The pellets are heated and processed into bendable sheets of plastic film (Clarke, 1987). Throughout the succeeding years, plastic mulch has been used as one component of a complete intensive vegetable production system. Carrot has been grown successfully using plastic mulches (Bond and Burch, 1989). Crops have shown significant increases in earliness, total yield, and quality (Mohler and Di Tommaso, 2008).The most commonly selected mulch films include low density polyethylene, linear density polyethylene, high density polyethylene, and metallocene (Ham and Kluitenburg, 1994).

Black plastic mulch contributes to weed management in carrot by reducing weed seed germination, blocking weed growth, and favoring the crop by conserving soil moisture and sometimes by moderating soil temperature (Waggoner *et al.,* 1960; Bond and Burch, 1989). Black plastic provide an effective barrier to most weeds and are able to mechanized application. Covering the soil surface with black plastic mulch reduces weed seed germination, shade and physically hinders emerging weeds; enhance crop growth and competitiveness by conserving soil moisture and sometimes by modifying soil temperature (Teasdale and Mohler, 2000). An ideal plastic mulch film should be flexible and rigid enough for easy of removal from various growing environments (Ham and Kluitenburg, 1994). Black polythene mulches are widely used widely for weed control in organic and conventional system (Majek and Nearly, 1991; Russo *et al.,* 1997). Russo *et al.,* (1997) concluded that clear mulches are better than black for warming the soil but do not control weeds. Plastic mulch is virtually impermeable to water and water vapour. Synthetic mulches like black polyethylene film are laid on a prepared seedbed just before sowing carrot through slits cut into the mulch (Mohler and Di Tommaso, 2008). Black plastic effectively block weed emergence, and promote soil warming and early crop growth. Weeds emerging through planting holes may require manual removal, and alleys between mulched beds generally need cultivation or other weed control measures (Waggoner *et al.,* 1960).

2.5.2.1 Plastic Mulch Primary Effects

Plastic mulch was first noted for its ability to increase soil temperature in the 1950's (Emmert, 1957). It is beneficial to adjust the soil's microclimate to prolong the growing season and increase plant growth (Russo *et al.,* 1997 and Tarara, 2000). Heating properties of plastic such as reflectivity, absorptive, and transmittance and their interaction with the sun's radiation will have a direct effect on the soil temperatures beneath the plastic mulch (Schales and Sheldrake, 1963). Plant growth requires radiation as a source of energy for photosynthesis, the means by which the radiation from the sun is converted to chemical energy (Stevenset *et al.,* 1991). Net radiation is defined as the sum of absorbed shortwave and long wave radiation minus emitted long wave radiation (Ham and Kluitenburg, 1994). Munguia *et al.*, (1999) found that net radiation is higher in the plastic mulch than in non plastic mulch environment. This is important because it relates to the spectral properties of the plastic mulch to surrounding environment. There are three basic non-radioactive components to radiant energy at the soil surface: conduction of heat into the ground; flux of latent heat in connection with evaporation from the soil; and convection of sensible heat into the layer of air between the soil surface and the mulch. The rate at which a soil increases or decreases heat over a period of twenty-four hours is closely associated with the diurnal cycle of surface temperature (Stevenset *et al.*, 1991). Black plastic mulch usually produces the highest soil temperature compared to other colored mulches (Diaz-Perez and Batal, 2002). The black plastic mulch, the predominant color used in crop production, is an opaque black body absorber and radiator (Schales, 1963).

2.5.2.2 Secondary Effects of Plastic Mulch

The use of color plastic mulch has resulted in enhanced growth and earlier yields than that of bare soil (Kasperbauer and Hunt, 1998; Rangarajan and Ingall, 2001; Loughrin and Kasperbauer, 2004; Seyfi and Rashidi, 2007). A grower’s ability to produce an early crop is not only beneficial in outperforming competitors but it gives the crop a chance to develop before the onset of disease. This in effect provides a premium for early maturity and improved quality (Loughrin and Kasperbauer, 2004). Rangarajan and Ingall (2001) found that the use of red, silver, and blue plastic mulches increased earliness of radicchio lettuce head formation compared to bare soil. Early crop yield advantage of red mulch was evident in tomato yields compared to yields produced on bare soil.

Soil temperature under raised plastic mulch covered beds typically, heats faster in the spring and excess water will drain from bed into row middles. Keeping the plants drier and preventing deterioration in product quality from contact between harvestable portions of the plants and wet soil or standing water (Lamont, 2004). There are other benefits to using plastic mulch for vegetable crop production such as increased efficient use of fertilizer inputs through fertigation technology, reduced leaching of fertilizers, reduced soil erosion, decrease incidence of disease, improved management of insect pest, reduced weed populations, reduced soil compaction, and maximum efficiency through double or triple cropping (Lamont, 2004).

2.5.3 Organic mulch for weed control in carrot

Organic mulches includes of straw, straw dust, bark, and composted green waste (Agele *et al.*, 2000). Organic mulches that have a darker, more multifaceted surface tend to reflect less light. Grass mulch is more popular in cropping systems, they suppress weeds at the same time reducing soil tillage for weed control, under any tillage implemented (Mohler, 1993; Bilalis *et al.*, 2003). Grass mulch on the soil surface is known to suppress weed emergence (Stevens *et al.*, 199; Agele *et al.*, 2000; Tu *et al.*, 2001). Seed germination of weeds is affected by soil moisture and temperature. Mulch not only suppresses weeds but also maintains the soil moisture compared with unmulched soil. It is important to ensure, mulch is not affected by weeds seed (Forcella, 1998). Mulch prevents sunlight from reaching the top layers of the soil, which slows down the germination of weed seeds Grass mulch suppresses annual weed seedlings, conserve moisture, and add organic matter as they break down, but they are more labour intensive to apply (Tu *et al.*, 2001.). Mulching reduces weed competition against carrot and save labour costs for weed control (Stevens *et al.*, 1991). The success of emergence through mulches relates to the capacity of seedling to grow around obstructing mulch element under limiting light condition (Teasdale and Mohler, 1993). Grass mulch areas have been found to keep moisture in plant root zones and reduce the rate of evaporation. As a result, mulched areas need less water. In addition, mulched areas that do not include landscape plants will not require any water at all. Grass also mulch increases yield of crop and water keeping capacity of the soil (Moitra *et al.,* 1996). According to Tu *et al.* (2001.) mulch is not serviceable for controlling of perennial weeds, because these plants accumulate much nutrient and break through the covered surface easily. Agele *et al.*, 2000 noted clipping mulch improve yield of tomato and water keeping capacity of the soil according to uncovered control. It increased the amount of water in the top 5 cm of the soil and decreased soil temperature in the top 5 cm. Moitra *et al.* (1996) reported that straw mulch 15 cm thick has been used to control weeds better in rhubarb and was the most effective than herbicides or hand weeding treatments. However, at initial stages the mulch suppressed the crop growth.

2.5.4 Foliar Fertilizer and competitive ability of carrots on weeds

Carrot fertilization is one of the most critical components of successful production. Carrots have a medium requirement for nitrogen, potassium and phosphorous, however, timing of applications is just as critical as amount of fertilizer used (Weaver *et al.,* 1992; Knezevic *et al.,* 2002; Evanset *et al.* 2003). Foliar fertilization entails the application of essential plant nutrients to above ground plant parts. More recently, foliar feeding fertilizer has been widely used and accepted as an essential part of crop production, especially in horticultural crops (Jamal *et al.,* 2006). Weed competition is especially dramatic when carrot is direct seeded. The critical period of weed competition is usually longer in direct-seeded than in transplanted crops. The competitive ability of crops and weeds can be significantly influenced by the amount of fertilizer applied, its location, and the time of application (Tollenaar *et al*., 1994; Di Tomaso 1995; Evans, 2001). Carrot grows slowly and may not fully occupy the space even at maturity, however optimal crop management makes the crop more weed tolerant and weed competition (Callaway, 1992). Most vegetable that emerge, establish, and grow rapidly get through their critical weed free period early in the season, and those quickly form a closed canopy (Evans, 2001). Foliar feeding has been used as a means of supplying supplemental doses of minor and major nutrients, plant hormones, stimulants, and other beneficial substances. The effects of foliar fertilization include yield increase, resistance to diseases and insect pests, improved drought tolerance, and enhanced crop quality (Trejo-Tellez *et al.,* 2007). Damages inflicted by weeds in carrot include reduced yields, improper root formation, and interference with harvest operations (Bell *et al.,* 2000 and Bellinder *et al.,* 1997). Crop competition is one of the cheapest and most useful methods. However, the competitive relationship between crop and weeds is highly dependent on many factors including the characteristics of the crop and the weeds, cultural practices (Knezevic *et al.,* 2002), supply and availability of nutrients (Di Tomaso, 1995; Evans *et al.,* 2003).

Several management practices contributes significant to crop competition and this includes, choosing locally adapted crop varieties, use of high quality seed, optimized crop nutrition and maintaining optimum crop growing condition. Crop cultivars vary in their ability to suppress weed and tolerance weed interference (Mohler, 1993; Mohler, 2001). Understanding basic mechanisms and timing of nutrient uptake in weeds and crops can lead to fertilization strategies which will enhance the competitive ability of crops while reducing interference from weeds. The availability of nutrients influences the timeliness and extent of early season competition from weeds (Weaver *et al.*, 1992). Evanset *et al.* (2003) reported that the addition of nitrogen fertilizer delayed the beginning and hastened the end of the critical period of weed control in corn. Weed density appears to be more important in the determination of the beginning of the weed competition, whereas it has a less notable effect on its end (Martin *et al.*, 2001). The timing of fertilizer applications can take advantage of maximal rates of nutrient uptake into crop roots at specific developmental stages. In addition, nutrient use efficiency can be enhanced by choosing appropriate crop cultivars, maintaining effective weed control practices, or altering row spacing or seeding rate to increase accumulation of nitrogen, phosphorus, and potassium in crops. Canopy as a host characteristic contribute to cultivar effective on weeds (Callaway, 1992). Vegetable producers often use row width that accommodate cultivation equipment, but if row width can be narrowed and crop sown in a more equidisatant manner, weed suppression can be enhance: this is especially true if crop densities can be increased concomitantly (Mohler, 2001). At very low weed densities there may be no critical period for weed competition. This was observed by Martin *et al.* (2001) in canola (*Brassica napus* L.) and Van Acker *et al.* (1993) in soybean.

Callaway (1992) reported evidence of significant varietal differences in weed tolerance and competiveness in all 21 crops investigated including potatoes, squash, beans and carrots, as well as cereal grains. Hill (2006) recommended looking for the traits when choosing varieties for competitiveness this includes: rapid emergence, quick canopy closure, efficient nutrient scavenging, and growth habit and drought tolerance. In horticultural practice, foliar fertilization is also recommended as the most effective method of supplying plants with nutrients under deficiency conditions (Trejo-Téllez *et al.,* 2007). Moreover, in their studies Mazur (1992), Kołota and Biesiada (2000), indicated the possibility of limiting mineral fertilizer use by means of application of foliar fertilization. It has been established that foliar feed fertilizers are effective and affordable on increasing the yield and fruit quality in vegetable (Osińska and Kołota, 2002; Kowalska *et al.,* 2006; Anna *et al.,* 2007).

CHAPTER THREE

3.0 Materials and Methods

3.1 Study area

A Field study was carried out at Field Station, College of Agriculture and Veterinary Science, University of Nairobi during 2011 and 2012. The elevation of this site is 1400 meters above sea level and lies at latitude 1o 15' 5 and longitude 36^{o} 44'E. The site received a mean rainfall of 108mm in a bimodal pattern, long rain from mid December to late Feb and short rains from early March to May 2012. The mean annual maximum and minimum temperature were 21.6 ^{o}c and 15.1 ^{o}c respectively. The soil type is nitosol (Nyandat and Michieka, 1970). The first season was planted in December 2011-February 2012 while the second season was carried out in March 2012-May 2012.

3.2 Experimental design and Treatments

Completely randomized block design (CRBD), was laid in this experiment with three replication, during 2010-2011 and repeated during 2011-2012. Two sets of experiment were conducted for two seasons; experiment **I** constituted of nine treatments which was laid in the field, with three replicates bringing a total of 27 plots. Experiment **II** constituted of nine treatments, with each treatment replicated three times bringing a total of 27 plots. The plot size was 38m by 33m with 54 experimental plots each measuring 3 m by 3m. Each experiment occupied a total of $627m^2$. Plots were divided by weed-free roads of 0.5 m and combinations were administered in table 2.

Table 2a: Treatments for experiment I

T1	Grass mulch (3cm thick)
T2	Black plastic mulch (0.25mm)
T3	Linuron (1.0 L a.i /ha)
T4	Oxyfluorfen (1.5 Kg a.i /ha)
T5	Linuron (0.5 L a.i /ha) + Grass mulch (3cm thick)
T6	Oxyfluorfen (0.75 Kg a.i /ha) + Grass mulch (3cm thick)
T7	Unweeded check
T8	Hand weeding every 2 weeks
T9	Hand weeding 35 and 65 DAS

Table 3b: Treatments for experiment II

T1	Foliar 41DAS+ hand weeding once
T2	Foliar 41, 48 DAS+ hand weeding once
T3	Foliar 41, 48, 55 DAS+ hand weeding once
T4	Foliar 41 DAS+ grass mulch (1.5 cm thick)
T5	Foliar 41, 48 DAS+ grass mulch (1.5 cm thick)
T6	Foliar 41, 48, 55 DAS+ grass mulch (1.5 cm thick)
T7	Unweeded check
T8	Hand weeding after every 2 weeks
T9	Hand weeding 35 and 65 DAS

3.2.1 Description of the treatments applied

3.2.1.1 Plastic mulch

Plastic mulch of 0.25 mm thick was laid with slits spaced at 25 cm. This was to help to reduce the amount of radiation and weeds had rough time to push the plastic paper hence it discouraged weed from emerging (Emmert, 1957).

3.2.1.2 Organic mulch

Once young carrots were large enough to show substantial foliage (2-3 true leaves), organic mulch were spread of about a 3cm layer on the soil around and among them in the bed. This was helpfully for the soil to retain moisture and discourage weeds as they grow. For the half rate organic mulch treatments, 1.5 cm was used to lay it on the soil as per recommendation of (Mohler, 1993; Sarker, 1999; Bilalis *et al.*, 2003).

3.2.1.3 Herbicides and Fertilizer

Linuron (Femuron®) as pre-emergence herbicides was applied in accordance to label directions at the rate of 1.0 L a.i /ha. It was applied on carrots soon after planting, when the soil was moist through, flat fan spray tips by a knapsack sprayer with swath width 1.8 m at kPha 220 pressure. Oxyfluorfen (Galigan 240 E ®) as a pre-emergence was applied in accordance to label directions at the rate of 1.5 Kg a.i /ha (Windholz, 1983).

Foliar fertilizer (Farmphoska plus Vegetative ® 12:10:7+0.4 MgO).Which acts quickly via the leaves and is well tolerated by large variety of field. The chemical was applied in accordance to label directions at the rate of 1.0L a.i/ha using a knapsack sprayer delivering 189 L/ha with 220 kPa pressure through a cone spray tip with swath width of 0.75m. Foliar feed fertilizer treatment was applied in 3 stages; 41, 48, and 54 days after carrots were sown.

3.2.2 Carrot variety studied

Certified Nantes variety of carrots seeds obtained from Kenya seed company (Nairobi, Kenya) and were sown directly in the fine raised seed beds, into holes measuring 1cm deep, 30 cm apart between lines mixed with sand. Fertilizer application were manually broadcast over the plants at the rate of 40 kg N/ha, 80 kg P205 / ha and 80 kg k /ha, and ranked in before seedling. After sowing, the 2cm of soil was used to cover the seeds. Carrots were irrigated uniformly in consideration of the need basis. Carrots were topped dressed 56 days after sowing with 35kg N/ha., thinning was done to limit soil borne diseases. Seed requirements was at 200 plants/m^2 and 80% germination (Bose and Som, 1990).

3.3 Data Collection

Records were undertaken before, during and after thinning of the carrots have taken place (30 cm between the lines, 8cm apart from one crop to another). This was necessary to establish any phytoxic effect on carrots. Observation was done 2 times a week after daily recording. The parameters that were under investigation include those listed below.

3.3.1 Effect of treatments on carrot emergence

The days of emergence of the carrots was established after 75% germination rate. This was necessary parameter because emergence may be delayed due to the effect of a treatment applied. This parameter was important to measure the population germinated over expected population per plot.

3.3.2 Percentage weeds control.

The percentage weed control was rated weekly on the scale of zero to 100; with zero equal no control and 100 equal perfect weed control or total kill. This rating was done at all weed species in the plots. The weed count was done by species within a 2m by 2m quadrat at the center of the treated plot at an interval of every 2 weeks after crop emergence till harvesting.

Weed control efficiency was calculated as:

$$WCE\ (\%) = \frac{A-B}{A} \times 100$$

.

Where, A and B are the dry matter weight (g/m^2) of weed of control and treated plots respectively. This parameter was important when interpreting both visual evaluation and yield data. The unknown weeds species were identified using illustration from the common weeds of East Africa (Terry and Michieka, 1987).

3.4.3 Effect of treatments on dry matter of weeds

Different weed species were clipped at the ground surface, identified and oven dried separately at 70 ^oc for 72 hours, then thereafter weighed into an aluminum weighing pan which was previously weighed (tare weight). Weighing pan was cooled to room temperature and then weighed again for dry mass determination. This parameter was important as it reflected differences between too large and many small (Terry and Michieka, 1987).

3.3.4 Effect of treatments on marketable carrots

The carrots were clipped at the ground surface, put in a clear labeled polythene bags transported in the plant pathology laboratory, university of Nairobi. Ten carrot plants were randomly harvested from each plot 14 weeks after sowing which was the first harvest; selected plants per plot were used to determine mean root length and diameter. Root length was measured from the tip to the top of each root and the diameter of root was measured at the largest portion in the shoulder of each crop. This parameter was much important because some treatments might possible damage the carrots, thus failing to attain the expected marketable sizes.

3.3.5 Effect of treatments on marketable yield of carrots.

Carrots were harvested after the maturity period of 14 weeks from sowing. The area sample was on a marked area of 2m by 2m from the center of each plot. The carrots were then clipped at the ground surface, and then washed off adhering soil debris, put in a clear labeled polythene bags and taken to the laboratory at the university, thereafter mean weight was taken and then recorded, this aided in getting harvest.. Yield data was extrapolated to kg/ha for each treatment as follows:

[Weight of carrots (kg)/Net plot area (m2)] * 10000

3.3.6 Economics of different weed control strategies.

The cost of the different strategies in weed control per plot was calculated, and then compared. The economic returns were mainly dependent on the plot yields; this was helpful in bringing the total cost of production per different strategies. These included: costs of hand-weeding, herbicides, foliar fertilizers and their application, polythene sheet, and grass mulch acquisition and application. Prevailing carrot prices were obtained from the market information Ministry of Agriculture which reflected the prices when the time of harvesting took place. The test for the profitability of each weed control option, economic benefit was calculated using the method described by Reichelderfer *et al*. (1984). Economic benefits were estimated as the difference between yield gain value and the cost for the weed management.

3.3.7 Incidence of pest and diseases on carrots.

The incidence of pest and disease was monitored, as a check of good husbandry so that prevention measures were taken to save the carrots as blanket application. The crop was not found to be infected by any pest or disease.

3.3.8 Statistical analysis.

An analysis of variance (ANOVA) was performed on data collected for each trait, using Genstat (discovery edition 3 by VSN international, 2008) statistical package. The results for both seasons were significant and data were pooled prior to statistical analysis. The Means were separated using Duncan's multiple range tests at $P < 0.05$. Nonparametric rank correlations were calculated for weed control within each of the experiments.

CHAPTER FOUR

4.0 RESULTS

4.1 The Efficacy of Mulching, Herbicides and Mulching/ Herbicides Combination on Weed Control in Carrots.

The results of the experiment was undertaken to determine the efficacy of mulching alone, herbicides alone, and mulching and herbicides combination strategies in carrots var. Nantes under field conditions at field station farm, University of Nairobi as presented here under.

4.1.1 Weed flora

Pigweed (*Amaranthus hybridus* L.*)*, black jack (*Biden pilosa* L.*)*, oxalis (*Oxalis latifolia* L.*)*, chickweed (*Stellaria media* L.*)*, and yellow nutsedge (*Cyperus esculentus* L.*)*, as the five major weed infesting the field (Table 3). *Amaranthus hybridus* and *Oxalis latifolia* were found dominating almost in all the plots expect the linuron treatment. Plots subjected to oxyfluorfen, hand weeding after every two weeks, and unweeded check were infested with weed flora mentioned above. The use of half rate of oxyfluorfen combined with 3 cm thick grass mulch had effect on *Biden pilosa*, *Cyperus esculentus*, and *Stellaria media*. In plots treated with black plastic mulch and half rate oxyfluorfen with combination of mulch, black jack (*Biden pilosa* L.*)* and chickweed (*Stellaria media* L.*)* were effectively suppressed.

4.1.2 Weed count

Observation recorded on weed count by species of crop growth is presented in (Table 3) indicated significant difference ($P \geq 0.05$). Weed count ranged from 5-42; with oxyfluorfen and unweeded check producing the highest weed count, and the least being recorded in other treatments. The few weeds that were observed on mulching treatments were during the late stages of carrot development. However, there was no statistically difference between grass mulch, black plastic mulch, linuron alone, linuron with combination of grass mulch, oxyfluorfen with combination of grass mulch and hand weeding after every 2 weeks.

Table 4. Effect of weed control methods on number and species on five main weeds/ m^2. during 2011/2012 seasons

Treatments	*Amaranthus hybridus*	*Biden pilosa*	*Cyperus esculentus*	*Oxalis latifolia*	*Stellaria media*	No. of weeds	Dry weight (g)
Grass mulch (3cm thick)	4	1	1	2	0	8b	1.11a
Black plastic mulch (0.25mm)	2	0	2	1	0	5b	0.32a
Linuron (1.0 L a.i /ha)	2	3	3	0	0	8b	13.2ac
Oxyfluorfen (1.5 Kg a.i /ha)	12	8	1	14	1	36a	33.53b
Linuron(0.5 L a.i /ha) + Grass mulch (3cm thick)	4	1	0	1	1	7b	1.45a
Oxyfluorfen(0.75 Kg a.i /ha) + Grass mulch (3cm thick)	2	0	0	4	0	6b	1.60a
Unweeded check	31	1	1	4	5	42a	60.83c
Hand weeding every 2 weeks	7	1	4	1	1	14b	0.22a
Hand weeding 35 and 65 DAS	23	2	2	2	0	29a	39.50b
Lsd @ 0.005						12.0	2.345
C.V %						19.67	9.86

*Means within the same column with different letters significantly differ at 0.05 probability level.

DAS= Days after sowing

a.i= active ingredient

4.1.3 Dry weight of weeds

Total dry matter of weeds were significantly higher in treatment tested however; there was no significant difference (P≥0.05) in mulching option, linuron alone, linuron with mulch combination, oxyfluorfen with mulch combination and hand weeding after every two weeks. The significant differences were compared to the other treatments which include herbicide application oxyfluorfen, hand weeding check and unweeded check. Dry weight of weeds ranged from 0.22g-60.83g (Table 3). Plots treated with oxyfluorfen, hand weeding after 35 and 65 days and unweeded check had significantly higher weed density than other treated plots. For the weeds pigweed, black jack, oxalis, chickweed and yellow nutsedge, plots treated with oxyfluorfen, hand weeding twice and unweeded check gave the highest dry weight than those under grass mulch, black plastic mulch, linuron alone, half rate linuron with grass mulch, half rate oxyfluorfen with grass mulch and hand weeding after every 2 weeks.

4.1.4 Weed control percentage

The data on weed control efficiency indicated significant difference (P≥0.05) due to various treatments applied (Table 4). Among mulching treatment; black plastic mulch was found to be significant higher 99.6% followed by grass mulch 97.3% However, the herbicidal treatments oxyfluorfen recorded the lowest value 72.95% compared to linuron 98.1%. Plots treated with either half rate linuron or oxyfluorfen combined with grass mulch did not show any significance difference (96.1% and 91.8% respectively) compared to each other. In weeding check, hand weeding after every 2 weeks gave 98.1% followed by hand weeding after 35 and 65 days after sowing. In contrast, to unweeded check 0.00%.

Table 5. Efficacy of weed management methods diversity on percentage weed control during 2011/2012 seasons

Treatment	Weed control (%)
Grass mulch (3cm thick)	97.3a
Black plastic mulch (0.255mm)	99.6a
Linuron (1.0 L a.i /ha)	78.1b
Oxyfluorfen (1.5 Kg a.i /ha)	72.95c
Linuron(0.5 L a.i /ha)+ Grass mulch (3cm thick)	96.1a
Oxyfluorfen(0.75 Kg a.i /ha) + Grass mulch (3cm thick)	95.8a
Unweeded check	00.0d
Hand weeding every 2 weeks	98.1a
Hand weeding 35 and 65 DAS	22.0c
Lsd @ 0.05	11.43
CV (%)	19.3

*Means within the same column with different letters significantly differ at 0.05 probability level.

4.1.5 Effect of treatments on yield, yield components and economic value of carrots.

There were significant differences (P≥0.05) in three parameters of yield, and yield components; this include carrot length, carrot diameter and carrot marketable yield. Variables of marketable carrot length ranged from 9.73cm-16.67cm (Table 5). Significance difference (P≥0.05) was observed on this parameter. Plots treated with grass mulch alone, black plastic mulch were not statistically different from each other and this was compared to linuron alone, oxyfluorfen alone, grass mulch with either half rate linuron or oxyfluorfen and weedy check. Plot treated with grass mulch and plastic mulch had the greatest carrot length of 16.18 cm and 16.67 cm respectively, which were at par with linuron combined with grass mulch at 14.50 cm. The herbicidal treatment linuron gave the best with 13.62 cm as compared to oxyfluorfen 11.17cm. The least carrot marketable length was recorded from unweeded check which gave 0.00 cm.

Carrot diameter was significance difference in all plots ($P \geq 0.05$). It ranged from 2.83cm-3.44cm (Table 5). Plot subjected to grass mulch had carrot diameter that was significantly higher than all the treatment plots mentioned. Half rate linuron and oxyfluorfen with grass mulch plots produced carrot that were significantly thicker than those in the weedy plot but significantly thinner than black plastic mulch. However, the herbicidal plot oxyfluorfen recorded significantly thinner diameter than linuron. It gave a carrot diameter of 2.85cm compared to 3.25 cm linuron. In weedy check, hand weeding after every two weeks gave a significant difference compared to two hand weeding and unwedded plots respectively.

Carrot yield differed significantly among the weed management options. Plot treated with black plastic mulch had the greatest marketable yield 34,205.5 kg/ha which was significant higher followed by 30,785.67 kg/ha compared to hand weeding after every 35 and 65 days after sowing. Carrot marketable yield from grass mulch, linuron alone, were similar to half rate oxyfluorfen with grass mulch plot. The lowest carrot yield was obtained in plots treated with oxyfluorfen alone, hand weeding after every 2 weeks and hand weeding after 35 and 65 days respectively. There were no marketable carrots from unweeded check in all seasons.

Table 6. Effect of weed management strategies on yield (kg), yield components (cm) and economic analysis of carrots on weed management strategies during 2011/2012 seasons

Treatment	Yield (kg/ha)	Value (KES)	CL (cm)	CD (cm)	WMC(KES)	Economic benefits (KES)
Grass mulch (3cm thick)	30785.67df	1,341,800	16.18f	3.48def	7,000	1,334,800
Black plastic mulch (0.255mm)	34205.50h	1,699,200	16.67f	3.42cf	64,000	1,635,200
Linuron (1.0 L a.i /ha)	32356.67efgh	1,327,200	13.62d	3.25c	13,000	1,314,200
Oxyfluorfen (1.5 Kg a.i /ha)	26949.50c	1,077,350	11.17c	2.85b	10,900	1, 066,450
Linuron (0.5 L a.i /ha) + Grass mulch (3cm thick)	31034.00dg	1,397,950	14.50e	3.37cd	16,100	1,381,850
Oxyfluorfen (0.75 Kg a.i /ha) + Grass mulch (3cm thick)	30489.50de	1,346,850	14.10de	3.30c	15,050	1,331,800
Unweeded check	0.00a	0	0.00a	0.00a	0	0
Hand weeding every 2 weeks	28479.00cd	1,574,750	13.78d	3.40ce	88,000	1,335,950
Hand weeding 35 and 65 DAS	19850.00b	708,400	9.73b	3.30c	21,000	687,400
Lsd @ 0.05	1.267	-	1.530	0.0064	-	-
CV (%)	16.34	-	7.86	5.31	-	-

*Means within the same column with different letters significantly differ at 0.05 probability level.

(WC: weed control; CL: carrot length; CD: carrot diameter; WN: weed number; WDM: weed dry matter; WMC: weed management cost; KES: Kenya shilling; DAS: days after sowing)

*Knapsack cost @ KES 9,000; Herbicide Linuron (Femuron®)/ha @ KES 5760; Herbicide Oxyfluorfen (Galigan®)/ha @KES 7,800; Protective clothing @ KES 3800; Herbicide spraying/ ha @ KES 1400, Polythene sheet @ KES 128,000: Price of carrots @ 50/ kg.

In (Table 5), the highest economic benefit was witnessed in black polythene mulch which gave KES 1,635,200 per ha, followed by half rate linuron with grass mulch KES 1,381,850, grass mulch KES 1,334,800, half rate oxyflourfen with grass mulch KES1,331,800 , linuron KES1,334,800 and hand weeding after 35 and 65 days being the lowest KES 687,400.

4.2 Weed Suppression and Tolerance to Weed Competition through Application of Foliar Fertilizers in Carrots.

The results of the experiment to assess the potential of increasing weed suppression and tolerance to weed competition through application of foliar fertilizers in carrots var. Nantes under field conditions in cropping season 2011-2012 at field station farm, University of Nairobi are presented below.

4.2.1 Weed flora

Pigweed (*Amaranthus hybridus* L.*)*, black jack (*Biden pilosa* L.*)*, oxalis (*Oxalis latifolia* L.*)*, chickweed (*Stellaria media* L.*)*, and yellow nutsedge (*Cyperus esculentus* L.*)*, were the five major weed infesting in the field (Table 6). *Amaranthus hybridus* and *Oxalis latifolia* were found dominating in plots treated with weedy check and weed free. In weedy check all weed flora mentioned was dominating. Yellow nutsedge (*Cyperus esculentus* L.*)* was found dominating in the plots treated with Foliar 41, 48, and 55 days after sowing plus hand weeding once, Foliar 41, 48, and 55 days after sowing plus grass mulch applied at depth 1.5cm and Unweeded check.

4.2.2 Weed count

Observations recorded on weed count by species of crop growth are presented in (Table 6). Weed count ranged from 17-50; Hand weeding after every 2 weeks being the least and unweeded check with the highest. Unweeded check produced a significant count followed by Hand weeding 35 and 65 days after sowing and Foliar 41 days after sowing plus application of 1.5cm thick grass mulch respectively.

4.2.3 Total number of weeds

The effect of foliar feed fertilizer and their combination on the number of weeds indicated significant difference ($P \geq 0.05$) (Table 6).In general, the number of weeds were significantly higher in unweeded check followed by hand weeding 35 and 65 days after sowing, with lowest population, hand weeding after every two weeks, and foliar feed at 41, 48, and 55 days after sowing plus hand weeding once respectively. There was no significance different in plots treated with Foliar 41 days after sowing plus hand weeding once, foliar at41, and 48 days after sowing plus hand weeding once, foliar at 41, 48, and 55 days after sowing plus hand weeding once, Foliar 41, 48 days after sowing plus application of 1.5cm thick grass mulch, and Hand weeding after every 2 weeks. However, significance difference was observed with the all treatment compared with Hand weeding 35 and 65 days after sowing , foliar at 41, 48, and 55 days after sowing plus application of 1.5 cm thick grass mulch, and foliar at 41 days after sowing plus application of 1.5cm thick grass mulch.

Table 7. Effect of weed control methods on number of five main weeds /m^2 during 2011/2012 seasons

Treatments	*Amaranthus hybridus*	*Biden pilosa*	*Cyperus esculentus*	*Oxalis latifolia*	*Stellaria media*	No. of weeds	Dry weight(g)
Foliar 41DAS+ hand weeding once	8	0	0	4	1	17c	15.4bc
Foliar 41, 48 DAS+ hand weeding once	6	1	0	6	0	15c	16.56bc
Foliar 41, 48, 55 DAS+ hand weeding once	10	2	3	2	0	14c	18.43bc
Foliar 41 DAS+ grass mulch (1.5 cm thick)	20	0	0	10	2	28b	12.78bc
Foliar 41, 48 DAS+ grass mulch (1.5 cm thick)	15	0	0	1	0	17c	17.53bc
Foliar 41, 48, 55 DAS+ grass mulch (1.5 cm thick)	26	0	3	7	0	34ab	16.7bc
Unweeded check	34	3	6	2	1	50a	57.66a
Hand weeding after every 2 weeks	12	0	0	0	0	16c	0.130c
Hand weeding 35 and 65 DAS	32	2	0	0	0	36a	26.86b
Lsd@ 0.05						13.32	2.75
CV (%)						22.01	18.01

*Means in the same column with different letters significantly at 0.05 probability level.

4.2.4 Total dry weight of weeds

Total dry matter of weeds differs significantly ($P \geq 0.05$) among the nine treatment tested. However, there were no significant difference in foliar feed applications and their combinations (Table 6). The significant differences were observed in unweeded check and hand weeding treatments. Dry weight of weeds ranged from 0.19g-53.3g; with unweeded check being the highest and hand weeding after every two weeks being the least. Unweeded check had a higher significance difference compared to Hand weeding after every 2 weeks, and Hand weeding 35 and 65 days after sowing

4.2.5 Weed control percentage

The data on weed control efficiency indicated significant difference ($P \geq 0.05$) due to various treatments applied (Table 7). Foliar feed application and their combination were compared and it had no significant difference ($P \geq 0.05$). Weed control was highest in hand weeding after every two weeks 98.1 % and unweeded check 0.0% being the least. In weedy check, Hand weeding every 2 weeks had a higher significant difference compared to hand weeding 35 and 65 days after sowing.

Table 8. Efficacy of weed management methods diversity on percentage weed control during 2011/2012 seasons

Treatment	Weed control (%)
Foliar 41DAS+ hand weeding once	73.05b
Foliar 41, 48 DAS+ hand weeding once	74.49b
Foliar 41, 48, 55 DAS+ hand weeding once	78.2b
Foliar 41 DAS+ grass mulch (1.5 cm thick)	77.8b
Foliar 41, 48 DAS+ grass mulch (1.5 cm thick)	74.5b
Foliar 41, 48, 55 DAS+ grass mulch (1.5 cm thick)	71.0b
Unweeded check	00.0d
Hand weeding every 2 weeks	98.1a
Hand weeding 35 and 65 DAS	53.0c
Lsd @ 0.05	0.56
CV (%)	18.56

*Means within the same column with different letters significantly differ at 0.05 probability level.

4.2.6 Effect of treatment on yield, yield components and economic analysis of carrots

There was significance different (P≥0.05) in three parameters of yield, and yield components, this include carrot length, carrot diameter and marketable carrot yield (Table 8). Marketable carrot length ranged from 10.50cm -16.37cm; with foliar feed with their combination being the highest and unweeded check being the least. Variables of marketable carrot diameter ranged from 2.10 - 3.25cm; with foliar feed with foliar with their combination being the highest and unweeded check being the least. The marketable yield also differed significantly (P≥0.05), with hand weeding after two weeks being the highest and unweeded check being the lowest.

Table 9. Effect of weed control strategies on yield, yield components and the economic analysis of carrots during 2011/2012 seasons.

Treatment	yield (kg/ha)	Yield value	CL (cm)	CD(cm)	WMC(KES)	Economic benefits(KES)
Foliar 41DAS+ hand weeding once	18480.67c	838,850	11.98d	1.64b	7, 600	831,250
Foliar 41, 48 DAS+ hand weeding once	19805.67c	939,300	15.23f	2.73df	8,200	931,100
Foliar 41, 48, 55 DAS+ hand weeding once	24239.33e	1,212,450	16.33g	3.21efg	8,900	1,203,550
Foliar 41 DAS+ grass mulch (1.5 cm thick)	18042.00b	911,650	10.33bc	2.23cd	4,400	907,250
Foliar 41, 48 DAS+ grass mulch (1.5 cm thick)	19628.17c	964,150	10.98c	1.96bc	6,000	958,150
Foliar 41, 48, 55 DAS+ grass mulch (1.5 cm thick)	21925.50d	1,091,000	12.27d	2.70de	6,800	1,083,200
Unweeded check	0.00a	0	0.00a	0.00a	0	0
Hand weeding every 2 weeks	28137.83f	1,364,700	13.90e	3.21efg	88,000	1,276,700
Hand weeding 35 and 65 DAS	19817.50c	960,450	10.18b	2.75dg	21,000	939,050
Lsd @ 0.05	13.14	-	0.314	1.22	-	-
CV (%)	21.23	-	5.64	7.65	-	-

*Means within the same column with different letters significantly differ at 0.05 probability level.

(WC: weed control; CL: carrot length; CD: carrot diameter; WN: weed number; WDM: weed dry matter; WMC: weed management cost; DAS: days after sowing; KES: Kenya shilings)

*knapsack cost @ KES 9,000; foliar feed fertilizer (farmaphoska plus®) @ KES 6, 000, hand weeding after two weeks @ 88,000, one hand weeding after 35 and 65 days @ KES 21,000, Foliar spraying @ KES 4,000, Price of carrots @ 50/ kg.

The highest economic benefit was witnessed in hand weeding after every 2 weeks KES 1,276,700, foliar feed application at 41, 48, and 55 days after sowing plus hand weeding once KES 1,203,550 and the lowest economic benefit was recorded on unweeded check (Table 9). Farmers practice produced KES 939,050 compared to hand weeding after every two weeks KES 1,276,700.

CHAPTER FIVE

5.0 DISCUSSION

Weed infestation is one of the limiting factors in successful crop production. Any plant competing with cultivated plants or that in some other way interfere with man's legitimate activities is considered to be a weed. Weeds are referred to as unwanted and undesirable plants, profile, persistent, competitive and harmful to the total environment. The weather condition in both two seasons favoured the crop over the weeds: initial moisture when sowing allowed the crop to germinate and establish followed by dry weather preventing a large flush of weed emergence.

5.1 Efficacy of Mulching, Herbicides and Mulching/ Herbicides Combination in Weed Control in Carrots.

5.1.1 Effect of weed management technologies on weeds

Annual weeds were the most dominant in the site where the experiment was conducted; this was consistent with expectation because the experiment was conducted in field that has been under cultivation for a long time. The highest weed growth was recorded on unweeded plots in all seasons where weed growth was dense. This was followed by hand weeding twice where black jack, amaranthus, cyperus were dominant. Plots treated with hand weeding after every two weeks resulted in decrease of the dominant weed species which includes; black jack, amaranthus, and cyperus at field station. Tamate *et al.*, (1996) reported occurrence of the same weed species in carrots fields. These findings are in agreement with the results of many authors who reported that farming practices influence the species composition of weed communities in arable fields (Akobundu, 1992; Leeson *et al.*, 2000). *Amaranthus hybridus* and *Oxalis latifolia* were found dominant in almost all plots. Weed population were significantly influenced by different treatments and times of application. All components of mulching materials, weeding after two weeks, and mulching/ herbicides combination reduced weed species population. Linuron and oxyfluorfen resulted in significant weed reduction but application of linuron was significant superior than oxyfluorfen ($p \leq 0.05$). The lowest number of weeds/m^2 were recorded under black plastic mulch 4/m^2. Teasdale and Mohler (1999) reported that the success of emergence through mulches was related to the capacity of seedling to grow around obstructing mulch elements under limiting light condition. Hand weeding at 35 and 65 days which was considered farmers practice also reduced the weed population over control but it was not effective as compared to hand weeding after every two weeks. However, no weed control strategies provided a 100% control.

Cyperus esculentus was the most difficult weed to control in nearly all plots probably due to its reproduction structure, where a single plant can produce several thousand tubers per season and high moisture content encourages the growth. Under field condition, nutsedge had high power of regeneration from sprouting of dormant tuber after application of herbicides. Anderson (1983), suggested proper timing of control measures for tuberous weeds such as nutsedges as extremely important because of tuberization process which must be stopped before new tuber start to form and develop. Therefore, timing of post emergence herbicides application relative to tuberization is crucial for overall control of yellow nut sedge. He further suggested yellow nutsedges foliage is desiccated quickly by application of oxyfluorfen but re-sprouting increased the number of shoots present 50 days after herbicides application. Cyperus was not controlled by both herbicidal treatments; this was due to the underground storage organs and the ability to regenerate fast. These results indicate that nut sedge plots can recover and produce large amount of tuber when they are treated alone with, herbicides alone, and mulching options as a control strategy. Conversely, hand weeding after every two weeks was most effective on nutsedges under field condition. This suggests that hand weeding after every two weeks is advantageous and could improve results under variable weather condition as per the results.

5.1.2 The effect of treatments on dry weight of weeds

Weeds dry weight is a good evidence of aggressiveness of weeds. The increased dry weight would reflect that weeds were healthy, vigorous and extracted a lot of growth. Weed dry matter is a factor to accumulate biomass number (Qasem, 2007; Gilreath *et al.*, 2008). In the present study, unweeded control recorded significantly higher weed dry matter at all the stages of crop growth due to unchecked growth of weeds. The advantage of grass mulch, black plastic mulch, linuron alone, half rate linuron with grass mulch and hand weeding after every two weeks was realized, because weed dry weight were lower. In herbicidal plots, effective of pre emergence application of linuron and oxyfluorfen was still visible in plots treated with half rate linuron with grass mulch and oxyfluorfen with grass mulch. This was due to the fact that weeds were killed before they produced seed and the power of regeneration was low. This agrees with Ashton (1973), who reported that the available soil applied herbicides are able to control weeds. Plots treated with hand weeding at every 35 and 65 days produced the weed dry weight similar to oxyfluorfen alone. In all other weed control strategies, dry weights of weeds were low.

5.1.3 Efficacy of weed control treatments on weed species

Black plastic mulch provided adequate weed control as significantly lower weed density than in other weed control treatment. Plastic mulch is non-perforated, and contains UV inhibitor. It's considered as a onetime expense that offers significant returns over the long run. In addition the soil moisture loss due to surface evaporation is greatly reduced. This agrees with (Mohler, 1993; Bilalis *et al.,* 2003; Gilreath *et al.,* 2008). Similarly, the other weed control treatments enhanced weed control efficacy especially in those plots subjected to hand weeding after every two weeks, pre emergence application of linuron, grass mulch , half rate linuron with grass mulch, and half rate oxyfluorfen with grass mulch. This treatments effectively controlled weeds as reflected in low weed density .This also agree with by (Mohler, 1993; Bilalis *et al.,* 2003 Qasem, 2006), who reported a complete and good control of weeds. This treatment seems to show superiority over two hand weeding.

It is quite evident from the results that herbicides significantly reduced number of weeds over unweeded control. In case of herbicides applied alone, linuron which interferes with the photosynthetic process in susceptible plants resulted into 78.1% control compared to oxyfluorfen 72.95% applied alone. Sprinkler irrigation was within 10 days of application as recommended, without this moisture for incorporation, linuron effectiveness would have been reduced. This result suggests that application of either linuron or oxyfluorfen can efficiently control weed in carrots. The results corroborate with the results obtained by Carl and Bent (2000), who reported higher weed control efficiency with application of Linuron and oxyfluorfen herbicides. These results are also with conformity with Babiker and Ahmed (1986) and Singh *et al*. (1990), who obtained effective control of weed by oxyfluorfen. Qasem,(2006), state that many weeds, which are difficultly destroyed, such as white goosefoot (*Chenopodium* L.).

Moreover, herbicidal control plots treated with linuron alone and oxyfluorfen alone were not effective against certain weeds. Without any further examinations, the chemical strategy used cannot be regarded as effective alternative to mulching. Many authors (Anderson, 1983; Appleby and Paller, 1978), have suggested that only o chloracetamide herbicides such as alchlor [2-choloro-N-(2, 6-diethylphenyl) N-methoxymethyl) acetamide and metachlor have proven to be relatively effective in controlling nut sedge. This confirm the recommendation of Rohm and Haas (1981) that oxyfluorfen as a surface acting herbicide and active on young weeds, it has a prolonged residue activity lasting up to three months. This contributed negative to weed. The second highest effective method was witnessed in hand weeding 99.1%. Hand wedding was effective in removing troublesome weeds, but it’s costly, labourious and may dislodge carrots along the way. It was effective but it did not control the growth of yellow nutsedge (*Cyperus esculentus)*. The same trend was observed by Henson and Little, (1969) that nutsedges were capable to penetrate the mulch. Mulch was effective, but it did not control the growth of yellow nutsedge.

5.1.4 Effects of weed management treatments on marketable yield, yield attributes and economic returns

The carrot length and diameter are the parameters that are of importance to the farmer, and they influence the marketable size of the carrot crop. However, carrot length was better with grass mulch and black plastic mulch than all the weed control strategies used. The use of black plastic mulch and grass mulch showed the highest result probably due to maximum moisture available, which helped in rapid cell elongation leading to high root formation. Carrots root diameter was significantly influenced by the application of mulching options. The maximum root diameter was recorded from grass mulch followed by black plastic mulch which showed no significance difference between then but it had significance difference with other treatments. Mulching ensured better moisture availability that resulted in thicker carrots (Lamont, 2005). A similar trend was observed by Tarara (2000), who stated that it is beneficial to adjust the soil's microclimate to prolong the growing season and increase plant growth.

Mulch enables carrots to make better use of nutrients and water in the soil, encouraging healthy growing conditions and resisting their ability to resist attack from pest. The best way of to keep the moisture in the ground and the carrots from drying out is to use mulch. The marketable yield was significantly influenced by application of black plastic mulch, grass mulch, hand weeding after every 2 weeks, half rate application of linuron and oxyfluorfen with grass mulch. These treatment effectively controlled weeds as reflected in low weed density and this agrees with the report of Mohler and Di Tommaso, (2008). The highest marketable yield was recorded from black plastic mulch. Reason behind these is that polyethylene mulch raise the soil temperature, this effect is mostly derived from the suppression of latent loss through evaporation. Treatments without mulch showed a decline in yield as compared to mulching. Mulching prevents leaching of fertilizer, because its act as physical barrier to rainfall (Schales and Sheldrake, 1963). Clarke (1987) noted that black polyethylene gives effective weed control by cutting down solar radiation by 90% resulting in etiolated growth and eventual death of weeds under the film.

Grass mulch and black polythene mulch treatments had equivalent yields that were over two times as high as of hand weeding after 35 and 65 days after sowing. The higher yield was attributed to lower weed-crop competition, higher absorption of nutrients and sufficient interception of sunlight as well as air circulation. This is an agreement with Gal and Radics (2003), who reported that the use of mulching influenced the yield of vegetables. Convert *et al* (2003) also concluded that mulching especially black plastic mulch reduced leaching of nutrients, reduced evaporation of soil water, reduced weed problem and increased water use efficiency. Mulching as an option was the most effective treatments which are confirmed by literature sources under different crops. Unweeded check resulted in heavy weed cover; hence it's not adequate either for production or further farming practice because the crop is slow to germinate.

Returns were higher in mulching options both half recommended rate of linuron with grass mulch and plastic mulch returned the highest profit KES 1,387,050/ha and KES 1,635,200/ha respectively, hand weeding 35 and 65 days produced lower return KES

687,400 /ha this was because of low yield resulting from weed competion in all seasons as compared to herbicides application both linuron and oxyfluorfen application. Linuron as versatile, efficient and cost effective herbicides for weed control had a higher return compared to oxyfluorfen even though weed control was less than plastic mulch in this study; it was the best and cost effective herbicides compared to oxyfluorfen.

5.2 Weed Suppression and Tolerance To Weed Competition Through Application of Foliar Fertilizers in Carrots.

5.2.1 Effect of weed management technologies on weeds

Annual weeds were the most dominant in the site were experiment was conducted. This was with expectation because the experiment was conducted in field that was under cultivation for a long duration. The highest weed growth was recorded on unweeded plots, where weed growth was dense. This was followed by hand weeding twice where black jack, amaranthus, and yellow nutsedge were dominant. Amaranthus and oxalis were found dominant in almost all plots. Weed population were significantly influenced by different treatments and times of application. *Cyperus esculentus* was the most difficult to control in nearly all plots probably due to its reproduction structure, and high moisture content that encourages the growth

Weeds present were a naturally occurring infestation, *Amaranthus hybridus* was most abundant and evenly distributed weed in both years. Under field condition, nutsedge had high power of regeneration from sprouting of dormant tuber after application of herbicides application. Anderson (1983), suggested proper timing of control measures for such as nutsedges is extremely important because of tuberization process must be stopped before new tuber start to form and develop. Therefore, timing of post emergence herbicides applicants relative to tuberization is crucial for overall control of yellow nutsedge. Cyperus was not controlled by either treatments tested, this was due to the underground storage organs and the ability to regenerate fast. These results indicate that nut sedge plots can recover and produce large amount of tuber when they are treated alone with, herbicides, and mulching options as a control strategy. Conversely, hand weeding after every two weeks was more effective on nut edges under field condition. This suggests that hand weeding after every two weeks would be advantageous and could improve results under variable weather condition.

Moreover, there was a significant difference ($P \leq 0.05$) in foliar feed application at 41 days after sowing combinations with weedy check. Application of foliar feed increased tolerance to the crop against the effect of weed competition. For example, plots treated with foliar feed application at 41, 48 and 55 days plus hand weeding once had a percentage control of 78.7 %. This was due to competitive ability of weeds for space and nutrients. Dry matter weight was significantly ($P \leq 0.05$) reduced by weeding after every two weeks and gave 71.1% control. Based on this study's findings, it is clear that foliar feed application increases the dry matter of weeds as compared to the unweeded check.

5.2.2 The effect of treatments on dry weight of weeds

Foliar feed application at 41 , 48 and 55 days after sowing days recorded a high dry mater weight of weeds compared to foliar feed application at 41 days, this was due to competitive ability of weeds for space and nutrients uptake (Callaway, 1992). Plots treated with foliar feed application were not significantly from each other. However, dry weights of foliar feed application weeds were significantly higher than two hand weeding. Weedy check recorded a highly significance different in dry weight, this was to be expected, because the plots were dense and carrots grew long and thinner. Closure of the crop canopy is likely to have developed much earlier in treatments where hand weeding was incorporated with foliar feed application as part of integrated weed management tool, resulting in shading that reduced weed dry matter as recorded. On contrary, the effect of hand weeding on dry weight of weeds was not comparable. The low carrot population density in the farmers control did not develop a closed canopy and hence could not smoother weeds, as indicated by the high level of weed dry matter in this treatment. The size of the crop canopy has shown to play an important role in weed suppression (Seavers and Wright, 1999).

5.2.3 Effects of weed management technologies on marketable yield and yield attribute

The perusal of carrot length, diameter and yield mean in the results revealed that foliar application of 12:10:7+0.4 MgO at the rate of 1.0 L a.i/ha two times seem to be optimal for carrots plants with combination of hand wedding once. The liquid fertilizer stimulated the plant growth yield and growth quality. Sharangai and Paria (1996) found that the application of higher level of K produced longer, wider and heavier roots than the lower levels. However, none of the foliar feed application strategies resulted higher yield than hand weeding after every two weeks. This was with agreement with results from (Di Tomaso, 1995; Knezevic *et al.*, 2002; Evans *et* *al.,* 2003). Regarding total yield, foliar feed application treatments were no significantly to each other but highly significant to weedy check. The nutrient content was most favourable not only to the carrot but also for the weeds. The results revealed that foliar feed application with their combination significantly improved the quality of roots as indicated by the yield and yield parameters of carrots. Hassan *et al*, (1992) also revealed similar trends that there was an increase of average root weight, root length and yield with increasing the application of N.P.K fertilizers. The lower yield in unweeded check revealed the enhanced competition for space, light and nutrient between the weeds and carrots crop resulting in lower yield per unit area as compared to the plots under weeding after every two weeks. Carrot yield was significantly higher for treatments which foliar feed application + hand weeding after 35days after sowing and hand weeding after every two weeks. Other treatments had carrot marketable yield similar to farmer's practice ($P > 0.05$) except unweeded check.

The unweeded check had no marketable yield due to high weed competition, sharing of nutrients, air and sunlight. This was expected because of superiority of weeds over carrot and the crop is considered to be a slow growing crop (Di Tomaso, 1995; Evans *et al.,* 2003). Foliar feed application with mulching methods had marketable yield similar to hand weeding after every two weeks. Application of foliar feed increased tolerance of carrot crop to the effect of weed competition. For example plots treated with foliar feed application at 41, 48 and 55 days plus 1.5 cm thick grass mulch enhanced the canopy closure and therefore it reduces the amount of light that reaches the soil surface which some small seeded weed seeds need to initiate germination. The faster the canopy the more weeds its shut out (Seavers and Wright, 1999).

There was no clear advantage of foliar feed application levels and there was no significant impact on timing i.e. choosing between 47, 48 and 55 days after soing for the application of foliar fertilizer. This was in line with Lipari (1997), who reported that although fertilizer significant affected root yield, the effect on the root quality was not significant. He further reported that the weight of individual root increased as the level of fertilizers increased but this finding contradicts his observation on the percentage of unmarketable roots as an increment. The difference in results would be attributed to different weed flora and agro ecological zones. Foliar feed application after 41, 48 plus hand weeding once was optimal for carrot crop, at the rate of 1.0L / ha as increasing the level more than this did not significantly improve any of the above parameters mentioned. Kanwar and Malik (1971) also reported carrot yield increased significantly in response to normal or high level of foliar feed fertilizer, but high level doses were less effective and caused bolting and root splitting.

The foliar fertilizers applied in this study significantly increased the number of marketable yield in comparison with the farmers practice. This finding is clear that using foliar feed fertilizer increases the marketable yield. While foliar fertilization is being used on a wide variety of crops, its economic value is generally deemed greater for horticultural than for agronomic crops. This is because horticultural crops are of higher value and their nutrient status is more carefully monitored (Williams, Greg and Williams, 1986). Callaway (1992), who highlighted the importance of foliar feed, it increased tolerance of carrot crop to the effect of weed competition and enhanced the canopy closure and therefore it reduced the amount of light that reaches the soil surface which some small seeded weed seeds need to initiate germination and therefore it shut down germination Additionally, because of the efficiency of nutrient use in foliar applications, growers can be confident they are maximizing their yield by foliar Application.

Carrot is a short duration crop and does not require a fixed cost not input expect land. Comparing the highest return was witnessed in four hand weeding which gave KES 1, 276,700 /ha, it at par with foliar feed application at 41, 48 and 55 days option plus hand weeding once KES 1,203,55 /ha. The use of foliar feed application at 41, 48 and 55 days plus additional of 1.5 cm thick grass mulch gave KES 1,083,200/ha. Farmers practice (hand weeding 35 and 65 days) produced lower return KES 987,050/ha. This was because of low yield in all seasons. Zero return from unweeded check was with expectation because there were no carrots to be harvested. The carrots grew thinner and smaller with time in the use of foliar feed application at 41 days plus hand weeding once achieving KES 831, 250/ha. This was with expectation in terms of the total yield produced. The use of four hand weeding as the most costly and laborious, this was followed by the use of two hand weeding. Foliar feed fertilizer seemed cheaper in weed management, but the returns were lower compared to hand weeding strategies.

6.0 CHAPTER SIX

6.1 CONCLUSIONS

6.1.2 The efficacy of mulching alone and in combination with, herbicides on weed control in carrots.

Weed population significantly reduced with mulching, four hand weeding and herbicide application. Black plastic mulch, grass mulch, linuron used in this study gave satisfactory weed control resulting in low weed number and no. per unit area. However, they failed to give control yellow nutsedge. There were statistically difference between mulching option and herbicides application concerning the weed control. However, better weed control strategies were obtained in plots where mulching option were applied, consequently, black plastic mulch gave the overall best weed control. Black plastic mulch is non-perforated, contains ultra violet inhibitor and it's an effective alternative to mechanical weed control and herbicides which have adverse effect due to their high persistence level at the expense of environment protection. The use of mulching alone, half rate recommended herbicide with grass mulch combination improved weed control as an option of integrated weed management method without causing any phytotoxic effects to the carrots. Whereas black plastic mulch gave the best weed control strategies, grass mulch alone, grass mulch with linuron at the rate of 0.5 l a.i/ha, grass mulch with oxyfluorfen at the rate of 0.75 a.i/ha and hand weeding performed well and were comparable to herbicides. Two pre-emergence herbicides, namely linuron and oxyfluorfen significantly decreased weed population and growth compared to unweeded check control. Linuron remains the best for weed control comparable to oxyfluorfen. Carrot famers can use linuron at the rate of 1.0 l a.i/ha to effectively control weeds.

6.1.2 Weed suppression and tolerance to weed competition through application of foliar fertilizers in carrots.

It was revealed that increasing root development and supplying nutrients directly to the plant, foliar feeding helped carrot to achieve maximum growth throughout. Foliar feed fertilizer increased tolerance of carrot crop to the effect of weed competition and enhanced the canopy closure. Therefore, it reduced the amount of light that reaches the soil surface which some small seeded weed seeds need to initiate germination and therefore it shut down germination. Additionally, because of the efficiency of nutrient use in foliar feed applications, carrot producer can be confident they are maximizing their yield by foliar application with a combination of good agriculture practice. It was evident that the use of hand weeding after every two weeks was the best practice comparable to foliar feed application and their combinations. The use of timing and rates of foliar feed fertilizer application were not significant, but choosing the timing to 41, 48 and 58 days after sowing gives the overall best. Based on this study finding, it is clear that foliar feed application, imparts the competitive ability in the crop against weeds. By increasing root development and supplying nutrients directly to the plant, foliar feeding helped carrot to achieved maximum growth throughout, have generated a revenue increase that is twice times greater than the input cost of the application. Such advantage increased the competitive flexibility in the timing of the operations.

6.1.3 Cost and yield of different strategies of weed control in carrots.

Growing carrot is a remunerative and successful agriculture enterprise. The final choice of the weed management method depends to greater extent on the cost of the strategies used and their relative efficiency. Black plastic mulch was expensive means of control compared to all strategies and it gave the best returns in terms of total marketable yield. Although chemical weed control seems to be cheaper and effective, the overall economics of this practice does not justify its general adoption by growers where the labour is costly and scarce to during period of farm operations. Hand weeding after every two weeks was costly and labour intensive compared to the use of foliar feed fertilizers. It was realized that it had the best in terms of economic benefit. Choosing between the use of hand weeding once and 1.5 cm thick mulch had no impact to weed management comparable to hand weeding after every two weeks. Carrot producer need a high investment in terms of weed management to maintain a highly marketable yield and profitable.

6.2 RECOMMENDATIONS

- Farmers should be sensitive not to plant carrots in the field heavily with weeds, especially perennial that are difficult to control

- Famers can use plastic mulch as a component of integrated weed management with combination of good agricultural practice.

- Promote the use of cultural practice such as sanitation, certified carrot seeds, irrigation and timely harvest to get the best harvest.
- Study the weed species around to develop appropriate management strategies.
- Linuron @ 1.0 kg/ha could be used for weed control whereas oxyflourfen should not be used in carrots field.
- Foliar feed application at three stages 41, 48, 56 days should be used with a combination of other strategies i.e grass mulch for better yield and weed management.
- Hand weedings methods are extremely tedious, time consuming and costly in weed management

Recommendation for future research

1. The efficacy of various herbicides in control of *Cyperus esculentus* in carrot.

2. Evaluation of the efficacy of different rates of foliar feed fertilizers on weed growth and yield of carrots.

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Appendices

APPENDIX 1: Qualitative scale of degree of weed control

<table>
<tr><td></td><td colspan="4">WEED SCORE SCALE</td></tr>
<tr><td rowspan="11">SCORE VALUES</td><td>Percentage</td><td>0-10</td><td>0-5</td><td>1-5</td></tr>
<tr><td>0-10</td><td>0-1</td><td>0</td><td rowspan="2">1</td></tr>
<tr><td>10-20</td><td>1-2</td><td rowspan="2">1</td></tr>
<tr><td>20-30</td><td>2-3</td><td rowspan="2">2</td></tr>
<tr><td>30-40</td><td>3-4</td><td rowspan="2">2</td></tr>
<tr><td>40-50</td><td>4-5</td><td rowspan="2">3</td></tr>
<tr><td>50-60</td><td>5-6</td><td rowspan="2">3</td></tr>
<tr><td>60-70</td><td>6-7</td><td rowspan="2">4</td></tr>
<tr><td>70-80</td><td>7-8</td><td rowspan="2">4</td></tr>
<tr><td>80-90</td><td>8-9</td><td rowspan="2">5</td></tr>
<tr><td>90-100</td><td>9-10</td><td>5</td></tr>
<tr><td colspan="5">Note:
0 percent signifies; NO control of weeds or No injury to the crops
100 percent signifies; Complete control of weeds or complete kill of the crops
0-5 and 1-5 scale; Each number represents level of commercial acceptability
1-3= no acceptable; 4 = minimum level of control; 5= excellent control</td></tr>
</table>

APPENDIX 2: European system of weed control and crop injury index

Scale	**Rating effect on weeds**	**Rating effect on crop**
1	Complete kill	No effect
2	Very good	Very light symptoms
3	Good	Light symptoms
4	Sufficient in practice	Symptoms not reflected
5	Medium	Medium
6	Fair	Fairly heavy damage
7	Poor	Heavy damage
8	Very poor	Very heavy damage
9	No effect	Complete kill
Note: Scale from 1-4= positive range Scale from 6-9= negative range		

APPENDIX 3: kabete soil profile analysis

Soil type	Rainfall intensity (mm/h)	Moisture state	pH
nitosol	150	wet	6.2

APPENDIX 4: ANOVA table for the marketable carrot yield experiment 1

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	5.008E9	8	6.261E8	97.639	.000
Within Groups	2.885E8	45	6411986.915		
Total	5.297E9	53			

Calculated F = 97.639

Tabulated F = 2.097

Conclusion:
The marketable carrot yield differs significantly [F (8, 45) = 97.639, p≤0.05] among the 9 treatments.

APPENDIX 5: ANOVA table for the marketable Carrot length (cm) experiment 1

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1092.606	8	136.576	368.165	.000
Within Groups	16.693	45	.371		
Total	1109.299	53			

Calculated F = 368.165
Tabulated F = 2.097

Conclusion:
Carrot length differs significantly [F (8, 45) = 368.17, p≤0.05] among the 9 treatments.

APPENDIX 6: ANOVA table for the marketable Carrot diameter (cm) experiment 1

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	30.533	8	3.817	176.451	.000
Within Groups	.973	45	.022		
Total	31.506	53			

Calculated F = 176.45
Tabulated F = 2.097

Conclusion:
Carrot diameter differs significantly [F (8, 45) = 176.45, p≤0.05] among the 9 treatments.

APPENDIX 7: ANOVA table for the dry matter weight of weeds (kg) experiment 1

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	25534.270	8	3191.784	60.649	.000
Within Groups	2368.225	45	52.627		
Total	27902.495	53			

Calculated F = 60.649
Tabulated F = 2.097

Conclusion:

The dry matter weight of weeds differs significantly [F (8, 45) = 60.65, p≤0.05] among the 9 treatments.

APPENDIX 8: ANOVA table for the marketable carrots yield (kg) experiment 2

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2.9009	8	3.6258	252.235	.000
Within Groups	6.4677	45	1437091.704		
Total	2.9659	53			

Calculated F = 252.235
Tabulated F = 2.097

Conclusion:
The marketable carrot yield differs significantly [F (8, 45) = 252.24, p≤0.05] among the 9 treatments.

APPENDIX 9 : ANOVA table for the Carrots length (cm) experiment 2

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	927.377	8	115.922	362.466	.000
Within Groups	14.392	45	.320		
Total	941.768	53			

Calculated F = 362.466
Tabulated F = 2.097

Conclusion:
Carrot length differs significantly [*F* (8, 45) = 362.47, $p \leq 0.05$] among the 9 treatments.

APPENDIX 10: Mean monthly temperature, rainfall and evaporation period during the growing season (2011-2012).

MONTHS	TEMP MEAN ^{o}C		RAINFALL KG/M2		PAN EVAPORATION KG/M2
	MAX	MIN	NO.OF DAYS IN A MONTH	TOTAL	
DEC 2011	24.8	17.7	6	67	176.3
JAN 2012	24.1	11.9	0	0.0	181.5
FEB 2012	26.4	16.0	2	16.0	172.5
MARCH 2012	26.6	13.9	2	5.0	198.5
APRIL 2012	23.9	15.0	21	352.6	114.0
MAY 2012	25.2	18.0	4	56	156.8