International Journal of Farming and Allied Sciences
Available online at www.ijfas.com
©2013 IJFAS Journal-2013-2-4/78-82
ISSN 2322-4134 ©2013 IJFAS

Farmer-Friendly Strategies of Managing Weeds in Carrot (*Daucus carota* L.) Production

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ABSTRACT: Weed control constitutes one of the main cost items in carrot production. The current study was conducted at the field station farm, University of Nairobi in 2011 with the aim of developing a cost-effective strategy of managing weeds and increasing the competitive ability of the crop against weeds. The weed control strategies tested in RCBD were replicated three times; black plastic mulch, grass mulch, herbicides (Linuron and oxyfluorfen), mulch / herbicide combinations, foliar feed fertilizer/ one hand weeding combinations, foliar feed fertilizer / 1.5 cm grass mulch combination, hand weeding every two weeks, famers practice (two hand weeding), and control (no weeding). Data on weeds and crop were collected and subjected to analysis of variance (ANOVA), using Genstat (Dicovery edition 3 by VSN international), statistical program. Means were separated using Duncan multiple range tests at P<0.0.5, using Genstart Computer package. Pigweed (*Amaranthus hybridus* L), black jack (*Bidens pilosa* L) and oxalis *(Oxalis latifolia* L) were the most common weeds in the experimental plots. Efficacy of weed control and carrot yields significantly differed. Black polythene achieved (99.2% weed control and 33,984 kg/ha yield; Linuron (78%; 26,544 Kg/ha) and two hand weeding (19%; 14168 kg/ha). It was concluded that mulching is an effective strategy of reducing weed growth in carrots. Foliar feed application imparts competitive ability in the crop against weeds.

***Keywords*:** Herbicide, mulching materials, foliar feed fertilizer, weed control efficiency, yield components

INTRODUCTION

Integrated weed management is an approach of assembling a weed management plan that incorporates a number of tools consistent with farm goals. These include cultural, mechanical, biological, and chemical control (Shaw, 1982). The degree of management is dependent on the characteristic of the weeds involved and the effectiveness of the method used (Tamet *et al.*, 1996; Peacock, 1991). Carrot is an important crop for healthy diet and so it's needed to be available in high quality (Radics *et al*., 2002). 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% (Grundy *et al.*, 2004). Weed competition can have 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 (Grundy *et al.*, 2004).Weed management option are aimed to increase yield, better quality production and reduced weed pressures (Smith, 1968). In consideration from the above factors the objective of the study was to determine integrated methods of weed control that can result in optimal yield of carrots (*Daucas carota* L.) and in respect to economic benefits.

MATERIAL AND METHODS

A Field experiment was conducted at the Field Station, College of Agriculture and Veterinary Science, University of Nairobi during 2011. The elevation of this

site is 1400 meters above sea level and lies at latitude 1o 15' 5 and longitude 36° 44'E. The soil type is nitosol (Nyandat and Michieka, 1970), soil pH ranges from 5.2 to 7.2 in the top layer and 5.2 to 7.7 in subsoil layer.

Weather pattern: The mean monthly temperature, rainfall and evaporation rate of the research site during the months of study are given in Fig 1.

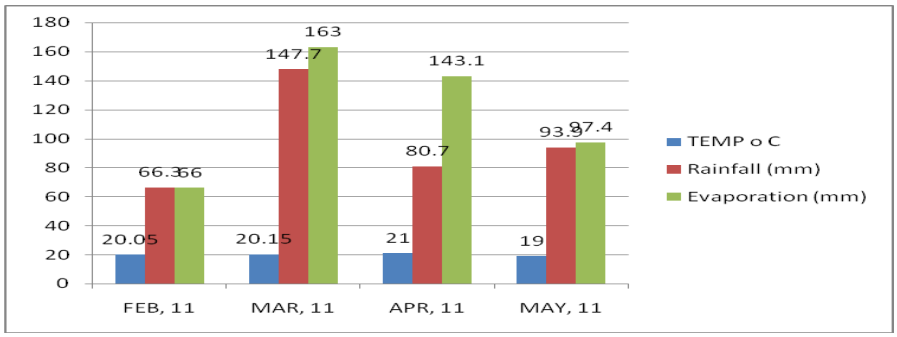

Figure 1. Mean monthly temperature, rainfall and evaporation period during the growing season

RESULTS AND DISCUSSION

The experiment was laid out in a randomized complete block design (RCBD) with each treatment replicated three times. The size of each plot was 3.0 by 3.0 meters. Experiment one comprised of two mulch levels, i.e. (black plastic mulch; 0.25mm) and (grass mulch; 3cm), two herbicides, i.e. (Linuron; 1.0 L/ha) and Oxyfluorfen; 1.5 Kg/ha), herbicides/ mulching combinations, i.e. (Linuron; 0.5 L/ha + grass mulch; 3cm) and (Oxyfluorfen; 0.75 Kg /ha + grass mulch; 3cm), weeding i.e. (No weeding), (one hand weeding after two weeks), and (two hand weeding; after 35 and 65 days). Experiment two comprised of foliar feed fertilizer 1.0 L/ha and hand weeding combinations i.e.(foliar feed application after 41 days + one hand weeding after 35 days), (foliar feed foliar application after 41 and 48 days + one hand weeding after 35 days), and (foliar feed application after 41 , 48 and 55 days + one hand weeding after 35 days), foliar feed fertilizer / 1.5 cm grass mulch, i.e.(foliar feed application after 41 days + grass mulch; 1.5 cm), (foliar feed foliar application after 41 and 48 + grass mulch; 1.5 cm), (foliar feed application after 41 , 48 and 55 days + grass mulch; 1.5 cm), weeding i.e. (No weeding), (one hand weeding after two weeks), and (two hand weeding after 35 and 65 days). A buffer zone of 0.5 m spacing was provided between plots.

Certified Nantes variety of carrots seeds were drilled 30cm apart directly in the fine raised seed beds. Fertilizer were applied at the rate of 40 kg N/ha and 80 kg $P_2 0_5$ / ha. Carrots were topped dressed 56 days after sowing with 35kg N/ha. Seedlings were thinned to 5-8 cm within the rows (Bose and Som, 1990). Black plastic mulch (0.25mm thick) was spread and held down with forked sticks to prevent it from been blown by wind (Emmert, 1957). Grass mulch was spread at required depth, when carrots had formed 2-3 true leaves. This was to help the soil retain moisture and discourage weeds as they grow (Sarker, 1999). All other recommended agronomic practices were followed uniformly across the treatments. The area sample weed and crop samples were harvested from a marked area of 2m by 2m at the center of each plot. Different weed species were clipped at the ground surface, identified and oven dried at 70 °c for 72 hours. Carrots were harvested, in replicates, 90 days after germination. Carrot weights (CW), carrot diameter (DM) and carrot length (CL) were determined from 20 samples taken randomly from harvested carrots of each plot. The cost and benefit of the different weed control strategies were computed and compared.

Data on weeds and crop were collected and subjected to analysis of variance (ANOVA), using Genstat (discovery edition 3 by VSN international), statistical program. Means were separated using Duncan's multiple range tests at $P < 0.05$.

Effect of weed management technologies on weeds

The weed management strategies significantly affected carrot growth, development and yield through their ability to suppress weed population, composition and growth.Pigweed (*Amaranthus hybridus* L.*)*, black jack (*Biden pilosa* L.*)*, oxalis (*Oxalis latifolia* L.*)*, chick weed (*Stellaria medi* L) and yellow nutsedge (*Cyperus esculentus* L.*)* were the five major weed infesting in the field (Tables 1and 2). Tamate *et al*, (1996) reported occurrence of the same weed species in carrots fields. *Amaranthus hybridus* (66.5%) and *Oxalis latifolia* (16.2%) were found dominant in almost all plots. Density of weed population in the first experiment after application of treatments were (224 per area) and the second experimented recorded a (313 per area). This resulted in difference in the effect of herbicide treatments and their consequent effects on crop growth and yield). foliar feed application after 41 , 48 and 55 days recorded a high the dry mater weight of weeds (18.43g) compared to foliar

feed application after 41 days (15.4g), this was due to competitive ability of weeds for space and nutrients uptake (Callaway, 1992).

Weed population were significantly influenced by different treatments and times of application. All components of mulching materials, weeding, and mulching/herbicides combination reduced weed significantly. Black plastic mulch was 99.2% effective in controlling weeds; plastic mulch is non-perforated and contains ultra violet inhibitor. It is considered as a one time expense that offer significant returns over the long run, in addition the soil moisture loss due to surface evaporation is greatly reduced (Lamont, 2004). Linuron and oxyfluorfen resulted in significant weed reduction by 83% and 60 % respectively. Both herbicides were found effective in killing the different weed species and reducing their dry matter production. The lowest number of weeds/m^2 and high marketable yield were recorded in black plastic mulch (3, 306 kg/m^2) followed by 1.0 L/ha Linuron and 3cm grass mulch (7, 252kg/ m^2). Linuron achieved 78.8 % weed control compared to Oxyfluorfen which registered only 32.9 % weed control. The second highest effective method was recorded in one hand weeding after every two weeks (99.1. %), one hand weeding after 35 and 65 days reduced the weed population over the unweeded check. However, it was not as effective as one hand weeding after every two weeks. *Cyperus esculentus* was the most difficult weed to control in nearly all plots probably due to its reproduction structure. This is due to plant having a stratified and layered root system, with tubers and roots being interconnected to depth of 50 cm or more (Daniel, 2000) The high moisture content recorded during the experiment also encourages weed growth. On the other hand, there was an increase in weed population on treatments with foliar fertilizer application. There was a significant difference ($P \leq 0.05$) between foliar feed application after 41 days + one hand weeding after 35 days, and foliar feed application after 41 days + 1.5 cm grass mulch in terms of weed population. Application of foliar feed increased tolerance of carrot crop to the effect of weed competition. For example plots treated with foliar feed application after 41, 48 and 55 days + 1.5 cm 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 (Callaway, 1992).

Table 1. Effect of weed control measures on number and dry weight of different weed species/ m^2 experiment one

Treatments	Rate of application	Amaranthus hybridus	Biden pilosa	Cyperus esculentus	Oxalis latifolia	Stellaria media	No. of weeds	Dry weight(g)
GM	3cm thick	3	1	0	2	0	6b	1.28a
BPM	0.25 mm thick	0	0	2	0	0	2b	0.34a
L	1.0 L a.i/ha	2	3	3	0	0	8b	10.07a
O	1.5 Kg a.i/ha	12	8	1	14	1	36a	32.4b
2LG	0.5 L a.i/ha,3 cm thick	4	1	0	1	1	7b	1.7a
2OG	0.75 Kg a.i /ha, 3cm thick	2	0	0	4	0	6b	1.87a
NW	unweeded check	31	1	1	4	5	42a	48.3b
1HW	weeding @ every 2 weeks	7	1	4	1	1	14b	0.39a
2HW	weeding@ 35 and 65 DAS (farmers practice)	23	2	2	2	0	29a	39b
TOTAL		84	16	13	28	8	150	135.4

(BPM: black plastic mulch; GM: grass mulch; L: Linuron; O: Oxyfluorfen; 2LG: half rate Linuron + grass mulch; 2OG: half rate Oxyfluorfen + grass mulch; NW: no weeding; 1HW: hand weeding after two weeks; 2HW: two hand weeding)

Table 2. Effect of weed control measures on number and dry weight of different weed species/ m2 experiment two

Treatments	Rate of application	Amaranthus hybridus	Biden pilosa	Cyperus esculentus	Oxalis latifolia	Stellaria media	No. of weeds	Dry weight(g)
FL1H	after 41 days, one hand weeding	8	0	0	4	1	13c	15.4bc
FL2H	After 41 and 48 days, one hand weeding	6	1	0	6	0	13c	16.56bc
FL3H	After 41,48 and 55days, one hand weeding	10	2	3	2	0	17c	18.43bc
FL1G	after 41 days, 1.5cm thick	20	0	0	10	2	32b	12.78bc
FL2G	After 41 and 48 days, 1.5cm thick	15	0	0	1	0	16c	17.53bc
FL3G	After 41,48 and 55days, 1.5 cm thick	26	0	3	7	0	33ab	16.7bc
NW	No weeding	34	3	6	2	1	46a	57.66a
1HW	One hand weeding after every two weeks	12	0	0	0	0	12c	0.130c
2HW	Two hand weeding after 35 and 65 days	32	2	0	0	0	34a	26.86b
Total		163	8	12	32	4	216	182.05

(FL1H: foliar feed level 1 + hand weeding; FL2H: foliar feed level 2 + hand weeding; FL3H: foliar feed level 3 + hand weeding; FL1G: foliar feed level 1 + 1.5 cm grass mulch; FL2G: foliar feed level 2 + 1.5 cm grass mulch; FL3G: foliar feed level 3 + 1.5 cm grass mulch; NW: no weeding; 1HW: hand weeding after two weeks; 2HW: two hand weeding)

Effects of weed management technologies on marketable yield and yield attribute

Results revealed that marketable yield of carrots were highly influenced by application of mulches. Black plastic mulch produced the highest carrot length (16.7 cm) and carrot diameter (3.44cm) with a resultant yield of 33,984 kg/ha, compared with one hand weeding after 35 and 65 days: carrot length; (9.36 cm) and carrot diameter; (3.26 cm) with a yield of 14,168 kg/ha. Schales and Sheldrake, (1963) reported that mulching contributes to lower weed competition, higher soil moisture content and sufficient interception of sunlight by the crop in the absence of server weed infestation. Mulching also ensured better moisture availability that resulted in thicker carrots (Lamont, 2005).Similar trends was observed by Tarara, (2000) who reported that it is beneficial to adjust the soil's microclimate to prolong the growing season and increase plant growth. The results from the second experiment revealed that foliar feed application after 41 days + 1.5 cm grass mulch was optimal for carrot crop, at the rate of 35g/l5 l as increasing the level more than this did not significantly improve any of the above parameters mentioned. There was no significance impact of timing. i.e. choosing between application of the foliar feed after 48 0r 35 days after emergence. Sharangi and Paria (1996) found that the application of this level produced the longer, wider and heavier than lower levels. Similar trends were observed by Shibairo *et al.,* (1998) who reported that increasing the level of potassium significantly improved carrot weight and shelf life as indicated by decreased post harvest moisture loss. There were no marketable carrots from the unweeded (control) plots.

Table 3. Mean comparison of yield, yield components and economic analysis of carrots under weed management strategies, including mulching.

Treatment	Yield (kg/ha)	Value (KES)	WC(%)	CL(cm)	CD(cm)	WN	WDM(g)	WMC(KES)	Economic benefit (KES)
GM	26836e	1,341,800	97.3a	15.6a	3.43a	6b	1.28a	7,000	1,334,800
BPM	33984a	1,699,200	99.2a	16.7a	3.44a	3b	0.34a	23,333	1,675,867
L	26544f	1,327,200	78.1b	13.5a	3.23a	8b	10.07a	7,800	1,319,400
O	21547g	1,077,350	32.95c	10.9a	2.83a	36a	32.4b	5,700	1, 071,650
2LG	27959c	1,397,950	96.1a	13.6a	3.36a	7b	1.7a	10,900	1,387,050
2OG	26937e	1,346,850	95.8a	13.3a	3.26a	6b	1.87a	9850	1,337,000
NW	0i	0	00.0d	0a	0a	41a	48.3b	0	0
1HW	31495b	1,574,750	98.1a	13.4a	3.36a	14b	0.39a	44,000	1,530,750
2HW	14168h	708,400	19.0c	9.36a	3.26a	29a	39b	21,000	687,400

Means within the same column with different letters significantly differ at 0.05 probability level according to DMRT
(WC: weed control; CL: carrot length; CD: carrot diameter; WN: weed number; WDM: weed dry matter; WMC: weed management cost)*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 70,000: Price of carrots @ 50/ kg

Table 4. Mean comparison of yield, yield components and economic analysis of carrots under weed management strategies, including foliar application of fertilizer

Treatment	yield (kg/ha)	Yield value	WC(%)	CL (cm)	CD(cm)	WN	WDM(g)	WMC(KES)	Economic benefits
FL1H	16777h	838,850	73.05b	11.83a	1.64a	12c	15.4bc	7, 600	831,250
FL2H	18786f	939,300	71.49b	15.43a	2.72a	13c	16.56bc	8,200	931,100
FL3H	24249b	1,212,450	68.2b	16.3a	3.21a	18bc	18.43bc	8,900	1,203,550
FL1G	18233g	911,650	77.8b	9.96a	2.23a	32ab	12.78bc	4,400	907,250
FL2G	19283d	964,150	69.5b	10.3a	1.95a	16c	17.53bc	6,000	958,150
FL3G	21821c	1,091,000	71.0b	12.4a	2.7a	46a	16.7bc	6,800	1,083,200
NW	0i	0	00.0d	0a	0a	48a	57.66a	0	0
1HW	27294a	1,364,700	98.1a	13.9a	3.20a	12c	0.130c	44,000	1,32,700
2HW	19208e	960,450	53.0c	9.86a	2.74a	34a	26.86b	21,000	939,050

Means within the same column with different letters significantly differ at 0.05 probability level according to DMRT
*Knapsack cost @ KES 9,000; foliar feed fertilizer (farmaphoska®) @ KES 6, 000, one hand weeding after two weeks @ 44,000, one hand weeding after 35 and 65 days @ KES 21,000, Foliar spraying @ KES 4,000, Price of carrots @ 50/ kg

Economic benefit

The economic benefits of weed management technologies were calculated, keeping all other input costs constant. Data on table 3 and 4 reveals that the use of 0.25 mm thick black plastic mulch have gave the highest benefits (KES 1,675,867) followed by 0.5 L /ha Linuron + 3 cm grass mulch (KES 1,387,050), the lowest benefits was witnessed in one hand weeding after 35 and 65 days (KES 687,400), foliar feed application after 41 days + one hand weeding after 35 days (KES 831,250),and Although the black plastic mulch gave the highest yield and gross return, from the economic view it was the most of expensive weed management option.

CONLUSION

The results obtained from this study showed that the use of mulching, mulching/herbicide combination improved weed control as an option of integrated weed management method without causing any phytotoxic effects to the carrots. Application of foliar feed 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 (Callaway, 1992). Plastic mulch was more effective than any other treatments on weeds control and economical benefits. Plastic mulch is non-perforated, contains ultra violet inhibitor and its 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 (Takahasi *et al*, 1971).It's therefore clear that carrot production can not be achieved without successful weed management. The carrot producers presumably will benefit from the best, economical and efficient strategy in controlling weeds. Carrot producers are advised to use plastic mulch as an alternative method of weed control because of its availability at the farm level, cost and re-use.

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