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Comparison of the Effectiveness of Zero Tillage and Intercropping on Weed Management in Maize (*Zea mays* L.)

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Abstract
Maize is an important cereal worldwide and weeds are a major constraint to production. A trial was conducted in Kigumo, Murang'a County, Central Province of Kenya in 2010 to compare the effects of glyphosate and intercropping maize with *Dolicos lablab* on weed and maize yield. Treatments comprised of DUMA SC41 and DK8031 maize varieties, glyphosate, intercropping and weedy arranged in a randomized complete block design in 5x3 m plots replicated three times and data collected in 3x1.5m area in each plot. Weed scores, biomass and maize yield were recorded. Data was analysed using Gen Stat software package, treatments effects compared using ANOVA and the means separated by Student New man Keuls**.** No significant differences in weed scores, biomass weight and maize yield in both seasons between glyphosate and intercropping at $P < 0.05$. Intercropping and glyphosate had similar effects on weeds and maize yield, the former can substitute herbicide use.
Key words:,,Maize, grain yield, small scale farmers, tillage methods

1. Introduction

Maize is one of the most important and popular cereals in the world and as in any other crop its productivity is genetically controlled but other factors like climate and agronomic practices such as weed management are crucial in determining its output (Bryan *et al*, 2011; FAO,2010; Mansoor,2007; Rattler *et al*, 2007; Dyer,1995). Half of the world maize is produced in the developing countries where maize flour is the staple food for the poor people while the maize stalk provide feed to their animals (Ofori *et al;* 2004). In the industrialized world maize is mainly used for livestock feed and raw material for industrial products.

In Sub-Sahara Africa maize is the staple food for an estimated 50% of the population providing 50% of carolies. In these countries the yields are low around 1.0t/ha, while in USA, Southern Ontario and Canada maize yields are more than 12.5t/ha (Ofori *et al;* 2004). According to Ofori *et al*, (2004) maize yields currently average 1.5t/ha in Africa, slightly more than 3t/ha in Latin America, 1.7t/ha in India and 5.5-6.3t/ha in Yugoslavia.

Weeds pose a great challenge especially to the poor resource farmers not only in reducing crop productivity as a result of competition with the crop but also in lowering profitability due to costs associated with the management (Bremer, 2008; Plessis, 2003; Ntege *at el*, 1997). The weed management practices used in maize production vary from hand weeding using simple tools such as panga and hoe, to use of draught animals, tractors, crop rotation, intercropping and herbicides. Among these weed management practices hand weeding, crop rotation and intercropping are most commonly used by the peasant farmers due to resource limitation like money to pay for labour, draught animals, tractor or buy herbicide (Lavabre,1991). The objective of this study was to compare glyphosate with intercropping of maize and *Dolicos lablab* in weed management.

2. Materials and methods

2.1Geographical and climatic characteristics of the study area

The experiment was conducted in Kigumo, Murang'a County, Central province of Kenya during the long and short rain seasons in 2010. The district covers an area of approximately 293km^2 with a total population of 123,766 people (KNBS, 2009) and average family and farm size of 4.4 and 0.81 ha respectively, (MOA, 2010). The average annual rainfall and temperature range between 1200 -2400mm and 14-24^{0}C respectively (MOA, 2010), the soils are humic nitosols, (Jaetzold, *et al*, 2006). The experimental site was located in the Upper midland agro ecological zone (UM1) formerly Upper midland zone (UM2) (Jaetzold, *et al*, 1983), which lies at 1800m above sea level and traversed by longitude 36^0 59'E and latitude 0^0 41.5'S.

2.2Experimental design and layout

The experiment was a 2 x 3 factorial, the treatments comprised of DK8031 and DUMA SC41 maize varieties and three weed management practices namely glyphosate, intercropping with *Dolicos lablab* and weedy (control). The experiment was laid out in a randomized complete block design (RCBD) with plots of 5x3m in three replications.

2.3 Procedure

Zero tillage plots were sprayed with glyphosate 36% EC a.i at 20ml/litre, that is (4 litres of glyphosate in 200 litres of water for a hectare) five days before planting. Maize was spaced at 75 x 30 cm and paths of 1.5 m and 1.0 m were used to separate blocks and plots respectively. In intercropping plots, a row of *Dolicos lablab* was factored between every two rows of maize (35cm from each maize row) and the plants spaced at 30cm apart. Maize and *Dolicos* holes 5cm and 3cm deep respectively were prepared and fertilizer NPK (23:23:0) applied at the rate of 20g per planting hole (200kg/ha). In each plot an area of 3 x 1.5m was marked for both weed and crops' data collection.

The number of emerged seedlings of both maize and *Dolicos* was counted twice at 3rd, and 5th, week after planting and the average percentage germination of the crops determined. Weed scoring was done at 3WAP, 7WAP, 11WAP, 15WAP and 19WAP by identification of individual species and their numbers in the sampling area of each plot by use of weed identification manuals and herbarium specimens.

After each of the first three weed counts (3WAP, 7WAP and 11WAP), zero tillage plots were sprayed with glyphosate using a hood to protect the maize crop from herbicide injury, while the intercropped plots were hand weeded using hoes but no weeding or spraying was done in weedy (control) plots until crop maturity. Top dressing of maize was done with CAN 26% (200kg/ha) after second weeding while insect pests and diseases were monitored and controlled accordingly. Weed biomass weight was taken once after the last weed scoring (19WAP) by cutting at the ground level all weeds species inside the sampling area of each plot. All broad leaved weeds from the marked area for sampling in each plot were put together and weighed when fresh, same was done for all gramineae and all the sedges. They were in turn dried in an oven at 60^{0}C for 72 hrs and their dry weight recorded. At maturity the height of each maize plant in the sampling area was measured in meters using a tape.

Yield was assessed by harvesting and counting the number of cobs per plant and weighing them. Maize cobs for each plot were dried separately, shelled and weighed at a moisture content of 14% which was ascertained by a moisture meter. Mean maize grain weight for each treatment was determined and used for translation of the maize grain yield to 90 kilogram bags and tons per hectare. The number of *Dolicos* branches per plant for 23 plants in the sampling area was counted 19 weeks after planting, yield of *Dolicos* was determined by counting and harvesting all the mature and dry pods from each plant in the sampling area of the plot. The number of seeds in each pod was counted, weighed and the mean for all plots was used to translate yield to kilograms per hectare.

All the collected data was analysed using Gen Stat computer software package (Discovery edition 12.1 PC/Windows XP Copyright 2009 by VSN International Ltd), analysis of variance (ANOVA) was used to assess the effects of intercropping and glyphosate on weed population and maize yield by comparing their means. Difference between the means was separated using Student New man Keuls and the statistical difference determined at $p < 0.05$.

3. Results and Discussion

3.1Results

3.1.1 Maize and *Dolicos* percentage germination

In both seasons there were no significant differences in percentage germination and interactions between the two maize varieties and the two tillage practices at $p < 0.05$. The percentage germination of the two maize varieties for the two seasons ranged from 55.6 to 70% for intercrop and 53.9 to 65% for glyphosate (Table 1). During the same period percentage germination of *Dolicos lablab* under both maize varieties ranged between 53.5% and 60.2% (Table 2).

3.1.2 Weed population

A total of forty one weed species were identified while another eight species could not be identified by either common or scientific names except by local names. For the weed counts during the long rain season, there were no significant differences between the two tillage practices in the mean number of weed species. From first to fourth weed counts, each of the two tillage practices significantly differed with the weedy (control) in the number of weed species but in the fifth weed count there was no significant difference between each of them and the weedy in the number of weed species (Tables 3). For the short rain season there were no significant differences between the two tillage practices in the mean number of weed species. For the first weed count there was no significant difference between each of the two tillage practices respectively and the weedy in the number of weed species but from the second to fifth weed counts each significantly differed with the weedy (Table 4).

3.1.3 Weed biomass

There were no significant differences between intercrop and glyphosate in dry weight weed biomass for broad leaved, grasses and sedges at $P < 0.05$ for the two seasons (Table 5). Both tillage practices significantly differed from the weedy in broad leaf biomass weight in both the long and short rain seasons at $P < 0.05$. During the long rains season there were no significant differences between each of the two tillage practices and the weedy respectively in grasses biomass weight in DK8031. Each of the two tillage practices in DUMA SC41 significantly differed from the weedy in grasses biomass weight.

In the short rain season both tillage practices in the two maize varieties significantly differed from the weedy in grasses biomass weight (Table 5). During the long rains season there were no significant differences between each of the two tillage practices and the weedy in sedges weed biomass weight although weedy had higher biomass. During the short rains season significant differences were observed between each of the two tillage practices and the weedy in sedges weed biomass at $P < 0.05$ (Table 5). The weed biomass from the two maize varieties differed with regard to weed management, DUMA SC41 had significantly higher weed biomass than DK8031 in both glyphosate and intercrop (Table 5).

3.1.4 Maize yield

The maize grain yield results varied with varieties used and the seasons. In the long rain season, there was no significant difference in grain yield weight between glyphosate and intercrop for both DK8031 and DUMA SC41 maize varieties at $p < 0.05$ although intercrop had higher grain weight than glyphosate in both maize varieties (Table 6).

In both the long and short rain seasons there were no significant differences in grain yield between the weedy and both glyphosate and intercrop treatments respectively for DUMA SC41 variety at $p < 0.05$. During the long rains season weedy significantly differed in grain yield with both glyphosate and intercrop treatments respectively for DK8031 at $p<0.05$ but during the short rains season only the intercrop significantly differed in grain yield with the weedy for the same variety at $p<0.05$ (Table 6). Overall there was significant difference in yield between DUMA SC 41 and DK 8031 in both seasons at $p < 0.05$ (Table 6).

3.2. Discussion

The analysis of weed count showed that there was no significant difference between glyphosate and maize/*Dolicos* intercropping in the number of weed species at $p < 0.05$, although in most of weed counts glyphosate had higher number of weed species compared with maize/*Dolicos* intercrop indicating that intercropping was more effective than glyphosate in suppressing the weeds thereby reducing their population. This is in agreement with work done by Maina, (1997) who reported that use of herbicides and intercropping significantly controlled the weeds, the herbicide controlled the weeds at the early stage of crop growth. The author further reported that maize-bean and maize-potato intercrop each separately effectively suppressed weeds such that weeds did not have any significant effect on the yields. She also observed that intercropping using the right bean varieties and spacing replaced two weedings in one of the experimental sites and was cheaper than use of herbicide.

The analysis of weed biomass showed that there were no significant differences between glyphosate and maize/*Dolicos* intercropping in weed biomass dry weight in both seasons at $p< 0.05$. The ability of maize/*Dolicos* intercropping to suppress weeds equally or better than glyphosate means intercropping could be beneficial to the small scale farmers who practice it in weed management by not only reducing cost of herbicide but also maximizing on available land by enabling the farmers to obtain yield from two crops from the same piece of land in one season.

Intercropping can also be a useful tool in combating weed problem by eliminating drudgery associated with weeding especially if it can replace one or two weedings in a crop's growth period by reducing labour requirement and time for weeding. Due to reduced labour requirement by intercropping, the cost of maize production would be low thereby encouraging farmers to increase maize acreage leading to considerable increase in both maize yield and net returns for them as reported by Carlson, (2008). The ability of the *Dolicos lablab* to suppress the weeds emanates from its growth habit, since like most of leguminous plants it has a high leaf area index due to massive forage that precludes light from reaching the ground where weeds are growing (Beets,1990).

Maize and *Dolicos* overall germination percentages for both seasons were average (54.5% and 59.7%) respectively, the low percentage germination was due to unfavourable weather conditions set by intermittent rainfall during planting time in both seasons.

The maize yield in both seasons for maize/*Dolicos* intercropping and glyphosate were not significantly different in grain yield at $p < 0.05$ although intercrop had slightly higher grain weight than glyphosate in two out of the four cases. This conforms to other results obtained by Chui, *et al,* (1996) who reported that herbicide application, intercropping maize with beans both effectively controlled weeds and their maize grain yields were not significantly different. Also Mureithi *et al*, (2005) working in Kisii and Kitale on intercropping maize with *Dolicos* reported increased maize yield and income per unit area for the farmers.

Chen *et al*,(2004) found that intercropping maize with legumes was beneficial in yield increment due to improved soil fertility, less competition for water and nutrients between maize and weeds as the latter are suppressed by the leguminous crop. Intercropping maize with leguminous crops was also found to be beneficial in improving maize yield due to reduced stem borer population when maize was intercropped with cow peas at Katumani and also maize/bean intercrop in Embu district resulted in low stem borer population as reported by Omlo, (1984).

The various factors that could have influenced the grain yield results were nitrogen fixation by the legume leading to higher yield, the legume cover inhibits weed growth eliminating weed competition for resources with the crop and minimizing soil moisture loss through evaporation reserving it for the crop**.** Use of intercrop would result into environmental conservation from pollution by the herbicide and avoid weed developing resistance due to repeated use of the same herbicide. Use of herbicide in terms of safe handling also requires technical knowhow which is low among the small scale farmers. The variation in maize grain yield between the two seasons was due to weather conditions that prevailed during the experimentation period. During the long rain season the area received a total of 971.6mm of rainfall spread over 81days compared with 398.8mm received during the short rain season spread over 28 days and hence higher yields for both varieties during the long rain season than during the short rain season.

4. Conclusions and recommendations

Glyphosate and maize/*Dolicos lablab* intercrop were not significantly different in weed suppression and maize grain yield and farmers should therefore be encouraged to intercrop maize with *Dolicos* or other leguminous crops as a way of managing weeds since it is cheap, requires low technical knowhow, it is environmentally friendly and has no chance of weed resistance build up

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Table 1: Percentage germination for DUMA SC41 and DK8031 maize varieties under intercropping, glyphosate and weedy/control during the long and short rain seasons 2010

Variety	Weed control	Germination percentage		Average
		Long rains	Short rains	
DUMA SC41	Intercropping	55.6[a]	56.3[a]	56.0
	Weedy/control	52.2 [a]	53.7 [a]	53.0
	Glyphosate	53.9[a]	55.0[a]	54.5
DK8031	Intercropping	70.0[a]	67.3[a]	68.7
	Weedy/control	62.0 [a]	65.0 [a]	63.5
	Glyphosate	65.0[a]	62.7[a]	63.9
Lsd		*13.4*	*5.8*	*9.6*
CV%		*31.1*	*17.4*	*24.3*

In the table means bearing the same letter along the columns are not significantly different

Table 2: Percentage germination for *Dolicos lablab* during the long and short rain seasons

Weed control	Percentage germination		
	Long rains season	Short rains season	Average
DUMA SC41-Intercropping	58.0[a]	59.0[a]	58.5
DK8031- Intercropping	53.5[a]	60.2[a]	60.3
Lsd	*4.3*	*1.4*	*2.9*
CV%	*5.6*	*4.2*	*4.9*

In the table means bearing the same letter along the columns are not significantly different

Table 3: Weed counts/m^2 for glyphosate, intercrop and weedy during the long rain season

Maize variety	Weed control	Weed counts/m^2					Average
		3WAP*	7 WAP	11WAP	15WAP	19WAP	
DUMA SC 41	Glyphosate	2.2^a	8.2^a	4.2^a	2.0^a	4.2^a	4.2
	Weedy/control	8.7^b	25.1^b	18.2^b	7.1^b	6.2^a	13.1
	Intercrop	3.8^a	10.7^a	2.9^a	3.3^a	4.4^a	5.0
DK8031	Glyphosate	2.7^a	8.0^a	2.9^a	1.6^a	3.3^a	3.7
	Weedy/control	5.8^{ab}	14.4^{ab}	11.1^{ab}	5.1^b	4.2^a	8.1
	Intercrop	3.3^a	7.6^a	1.3^a	2.0^a	2.9^a	3.4
Lsd(0.05)		*3.5*	*15.6*	*12.6*	*2.4*	*NS*	
CV%		*48.3*	*59.5*	*114.7*	*39.3*	*33.5*	

WAP* = Weeks After Planting;
In the table means bearing the same letter along the columns are not significantly different.

Table 4: Weed counts/m^2 for glyphosate, intercrop and weedy during the short rain season

Maize variety	Weed control	Weed counts/m^2					Average
		3WAP*	7WAP	11WAP	15WAP	19WAP	
DUMA SC 41	Glyphosate	6.5^a	3.4^a	3.3^a	0.7^a	2.4^a	2.9
	Weedy/control	8.8^a	8.0^b	8.2^b	9.9^b	8.9^b	8.8
	Intercropping	5.3^a	1.6^a	0.8^a	2.7^a	2.4^a	2.6
DK8031	Glyphosate	5.2^a	2.5^a	0.6^a	1.4^a	1.6^a	2.2
	Weedy/control	8.5^a	6.2^{ab}	6.5^b	6.9^b	6.0^{ab}	6.8
	Intercropping	4.3^a	2.7^a	0.8^a	1.2^a	1.4^a	2.1
Lsd (0.05)		*NS*	*4.1*	*2.5*	*4.8*	*2.7*	
CV %		*59.6*	*61.9*	*62.3*	*77.0*	*39.4*	

WAP* = Weeks After Planting
In the table means bearing the same letter along the columns are not significantly different

Table 5: Weed biomass under glyphosate, weedy and intercrop treatments during the long and short rain seasons 2010

Variety	Weed control	Long rains season			Short rains season			Average
		Weed category			Weed category			
		Broad leaf	Grasses	Sedges	Broad leaf	Grasses	Sedges	
DUMA SC41	Glyphosate	687[ab]	174[a]	0.7[a]	41[a]	109[a]	0.1[a]	168.6
	Weedy/control	1,371[b]	2,504[b]	4.5[a]	1,262[b]	3,090[c]	9.8[ab]	1373.6
	Intercropping	432[ab]	431[a]	0.8[a]	24[a]	12[a]	3.0[a]	150.5
DK8031	Glyphosate	271[a]	62[a]	0.4[a]	34[a]	4[a]	0.6[a]	62
	Weedy/control	980[ab]	277[a]	6.3[a]	1,268[b]	1,890[b]	13.5[b]	739.1
	Intercropping	152[a]	126[a]	1.4[a]	8[a]	7[a]	0.3[a]	49.1
Lsd		*631.6*	*1011.5*	*9.3*	*675.6*	*619.7*	*10.1*	*591.6*
CV%		*39.0*	*103.2*	*139.5*	*105.2*	*54.7*	*133.2*	*115.0*

In the table means bearing the same letter along the columns are not significantly different

Table 6: DK8031 and DUMA SC41 grain yield (tons /ha) for long and short rain seasons 2010

Variety	Weed management	Yield tons/ha		
		Long rains season	Short rains season	Average
DUMA SC41	Glyphosate	1.01[a]	0.87[a]	0.94
	Weedy/control	0.40[a]	0.08[a]	0.24
	Intercropping	1.11[a]	0.95[a]	1.03
DK8031	Glyphosate	2.19[ab]	1.37[ab]	1.78
	Weedy/control	1.14a	0.36[a]	0.75
	Intercropping	3.32[b]	2.37[b]	2.85
Lsd		*1.78*	*1.39*	*1.59*
CV%		*62.4*	*77.4*	*69.9*

In the table means bearing the same letter along the columns are not significantly different