EFFICACY OF HERBICIDES FOR WEED CONTROL IN SOYBEAN (GLYCINE MAX) UNDER A NO- TILLAGE CULTIVATION SYSTEM IN ZAMBIA

BY

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DECLARATION

I SILVEST SAMALI NJAU hereby declare that this dissertation represents my own work and that it has not previously been submitted for a degree at this or another university.

Signature..............

APPROVAL

This dissertation of **SYLVESTER NJAU** is approved as fulfilling part of the requirements for the award of the degree of Master of Science in Crop Science by the University of Zambia.

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DEDICATION

Dedicated to my mother Koleta, my wife Edilitruda and my son Ludovick, Stanslaus, Costancia, Rita, Juliana and the whole family.

ABSTRACT

A study was conducted at Lilayi farm in a no-tillage crop production system. The objective of the study was to assess the efficacy of new herbicides in a no-tillage soybean cultivation system in Zambia. Eleven treatments were used in this study. These include four preemergence, five postemergence and combinations of these herbicides. They were compared with hand hoe weeding (14 and 28 days after planting) and no weeding.

The seedbed was prepared by two applications of 0.6 kg a.i/ha paraquat before planting and this effectively controlled the first and second flush of weeds respectively. However, Euphorbia heterophylla recovered from the application of paraquat whereby the new shoots emerged from the lower nodes. All preemergence herbicides gave a season-long control of Nicandra physalodes. The infestation of other weeds was very low that their presence was considered to be negligible. The ability of Euphorbia heterophylla to recover from the application of paraquat made postemergence herbicides unable to control this weed effectively.

Weed cover relative to crop cover was low throughout the season. Whereas the no weeding treatment had significantly the highest weed biomass, other treatments did not differ significantly from each other in weed biomass.

Preemergence application of oxadiazon resulted in highest soybean seed yield and the no weeding treatment gave the lowest seed yield.

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TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

WAP	weeks after planting
DAP	days after planting
WCE	weed control efficiency
PRE	preemergence
POE	postemergence
Eh	*Euphorbia heterophylla*
Cb	*Commelina benghalensis*
Gp	*Galinsoga parviflora*
Ah	*Amaranthus hybridus*
Np	*Nicandra physalodes*
Tz	*Trichodesma zeylanicum*
Ds	*Datura stramonium*
me+mt	metribuzin+metolachlor
ox	oxadiazon
ox+mt	oxadiazon+metolachlor
imaz	imazethapyr
fo+fl	fomesafen+fluazifop-butyl
be+fl	bentazon+fluazifop-butyl
be+ac	bentazon+acifluorfen
ac+fl	acifluorfen+fluazifop-butyl
be+fe	bentazon+fenoxaprop-ethyl
HHW	hand hoe weeding
NW	no weeding
SED	standard error of difference
CV	coefficient of variation

1.0. INTRODUCTION

The soybean (Glycine max (L.) Merr. also known as soya bean, Chinese pea and Manchuria bean is a native of East Asia (Njuguna, 1985). The name soya according to Njuguna (1985), is said to have come from the Chinese " Chiang-Yiu" meaning soy sauce.

The production of soybean in Zambia has been increasing annually. Its production has increased from 15,905 tons in 1985/86 to 26,791 tons in 1989/90 harvested from 13,854 hectares and 29,814 hectares respectively (FAO, 1990). According to Javaheri (1990), about fifty five percent of the children under four years old in Zambia are malnourished. Soybean which possess about 40 percent high quality protein, 30 percent carbohydrates, 20 percent oil, some minerals and vitamins has the potential to combat malnutrition. This calls for more production of this valuable crop. However, reductions in soybean yields is one of the major problems facing production of the crop as a result of weed infestations (Caldwell et al., 1973). In Zambia, soybean yield reduction of up to 40 percent due to mainly broadleaf weed infestations has been reported (Akobundu, 1987). If soybean yield loss due to weed infestation is to be reduced, then weed control measures are inevitable (Johnson, 1971).

The use of herbicides is one of the methods recommended for soybean weed control. Extensive herbicide trials conducted in Zambia led to the recommendations by Vernon (1983) on some herbicides for weed control in soybeans. Some of these herbicides include metolachlor and metribuzin applied as preemergence. He also recommended the use of paraquat for late weeds as postemergence directed spray. Since then, other herbicides such as acifluorfen, fluazifop-butyl, oxadiazon and fomesafen have been developed and proved to be effective in weed control in soybean in other parts of the world. Mbamba (1991) worked on these herbicides under Zambian conditions for one season. However, more research work is needed in order to come up with recommendations for effective herbicide use. This study was done as the continuation of the work which was started by Mbamba with an addition of more herbicides and weed parameters. Additional literature was also consulted.

The objective of this study was to further assess the efficacy of these new herbicides in Zambia in a no-tillage soybean cultivation system. The main focus was on the needs of large-scale farmers on a no-tillage soybean cultivation system.

2.0. LITERATURE REVIEW

Soybean is one of the world's most important legume crop cultivated for its protein and oil, for livestock, and for its rotational value (Purseglove, 1968; Wellving, 1984). Due to its importance, soybean is called "The Golden Bean" or "The Gold that Grows" and is emerging as a major component in the solution of the world's protein deficit (Javaheri, 1990).

Soybean is a relatively new crop in Zambia and as a result of agronomic research and plant selection, soybean production has become a reliable venture (Wellving, 1984). It is grown by commercial and small scale farmers. Soybean rotates well with irrigated wheat, maize and other cereals. As a legume, it can fix nitrogen from the air and the crop which rotates with it can make use of the residual effect of the fixed nitrogen.

Apart from many other constraints in soybean production, infestation by weeds is one of the major problems in achieving higher yields (Kurchania et al, 1989). Weeds compete with soybeans for moisture, light, nutrients and reduce quantity and quality of the harvested product (Webber et al., 1987). Weeds also hamper the operation of equipment, harbour insects and diseases. The effect of weed competition on crop yields however varies with location, species, duration of infestation, moisture and weed density (Wax, 1977). In Zambia, commercial farmers control weeds in soybeans by mechanical, chemical control, or by a combination of methods. On the other hand, small scale farmers control weeds by hand weeding which is not practical on large scale farms and with a no-tillage soybean cultivation system, the use of herbicides for weed control becomes inevitable.

According to Wax (1977), uncontrolled weeds cause average annual losses of about 17 percent of the potential value of this crop in USA. Bozsa and Oliver (1990) reported yield reductions ranging from 10-80 percent in USA due to full season Xanthium strumarium interference with soybean depending on densities and duration. According to Harger and Nester (1981), when Euphorbia heterophylla was planted in soybeans at a rate of 2.5 plants per 30.5 cm row and allowed to compete for 8 weeks, 12 weeks or full season in the USA, yields were reduced by 18, 22, and 33 percent respectively. E. heterophylla is reported to be a major weed in Fiji, Ghana, Mexico, Philippines, Indonesia, Nigeria and Thailand (O'Makinwa and Akinyemiju, 1990). In Nigeria it is a principal weed of cowpeas and soybeans.

Uncontrolled weed growth reduced soybean yields by about 40 percent in Zambia (Akobundu, 1987). Average soybean yield reduction due to uncontrolled weed growth as reported from other countries indicate 53 percent in Ghana, 24 percent in India, 52 percent in Jamaica, 60 percent in Nigeria and 72 percent in Philippines (Akobundu, 1986).

All crops have a stage during their life cycle when they are particularly sensitive to weed competition. Early weed competition usually reduces crop yields far more than late-season weed growth hence effective early-season weed control is more important than late-season weed control (Klingman and Ashton, 1982). Klingman and Ashton (1982) also pointed out that if weeds are controlled until the crop forms a canopy on top of the weeds, the crop has a considerable competitive advantage. According to Friesen and Wall (1986), soybeans are poor competitors with weeds particularly early in the growing season, and control of weeds is essential for successful soybean production. A dense weed canopy on soybeans during the early reproductive stage might decrease pod setting and be a major factor responsible for yield reduction (Knake and Slife, 1969). Akobundu and Poku (1987) pointed out that soybean usually develop a full canopy cover at 8 weeks after emergence and can then compete with weeds until maturity. Little or no reduction in yield occurs if the soybeans are kept weed free for the first 4 weeks (Akobundu and Poku, 1987; Vernon, 1983). Akobundu and Poku (1987) reported no yield loss from weeds that germinated 20-40 days later than soybean in Nigeria, while those that germinated at the same time as the crop significantly reduced soybean yield. Similar results were reported by Tjitrosemito (1990) in India.

A good stand of soybean in narrow (50 cm) rows assists in the suppression of weeds. Wax and Pendlenton (1968), in USA, found that as row spacing was reduced, soybean yield increased while weed biomass decreased. This was due to the fact that soybeans in narrow rows provided more shade between the rows obscuring weeds from direct sunlight for photosynthesis and resulting in low weed dry matter.

Chemical weed control in soybeans is a regular practice on large-scale mechanised farms (Halwankar et al., 1986). Traditional methods of weed control such as hand weeding are not practical and time consuming. The use of herbicides however, has some drawbacks. The quickest and most drastic changes in weed diversity have occurred as a result of prolonged herbicide use (Johnson and Coble, 1986). The prolonged use of the same or chemically similar herbicide or group of herbicides can potentially allow the establishment of tolerant species. On the other hand, Hinkle (1983) pointed out that weed resistance can be delayed by herbicide rotation , herbicide combinations, and use of rapid-acting herbicides. Hinkle (1983) cited crop rotation as a successful strategy to control weeds while delaying resistance. According to

Ball and Miller (1990), crops in rotation normally use different herbicides. A rotation of these crops including a rotation of herbicides of different modes of action is an effective way of preventing problems arising from changes in weed flora that occur from continuous use of the same herbicides.

Several investigators have shown that the efficacy and performance of soil applied herbicides is related to the two most important factors namely soil texture and soil organic matter (Wax, 1977; Weber et al., 1987; Caseley and Walker, 1990). Beside soil factors, environmental factors such as temperature and moisture, can influence herbicide performance (Weber et al., 1987; Caseley and Walker, 1990). Whereas weed populations, soil type, and crop dictate which herbicide to use, the chemical characteristics of the herbicide itself determines how it responds to all of the above factors (Blumhorst et al., 1990).

For soil-applied herbicides to be effective, moisture in the form of rainfall or irrigation is important soon after herbicide application to carry it through the top few centimetres of soil where most weed seeds germinate (Caseley and Walker, 1990). They also pointed out that the movement of water through the soil and the extent to which this results in redistribution of herbicide is controlled to a large extent by soil texture i.e the relative proportions of sand, silt and clay in the soil. Light-textured sandy soils are generally structureless and the particles are not aggregated together to form larger crumbs. These soils have low water holding capacities, are freely drained, and water plus dissolved herbicide move in them rapidly. On the other hand, heavy textured soils tend to hold more water, water infiltration and movement occur more slowly. Herbicide availability to weed seedlings in these soils may therefore be restricted.

Caseley and Walker (1990) also described organic matter as a factor playing an important role in controlling the availability of herbicides to weed seedlings in soils. Organic matter effectively removes herbicide from the soil solution by adsorption and hence reduces the amount which is available for movement and subsequent uptake by the weeds.

No-tillage production systems involve planting crops into undisturbed soil and crop residue (Carey and Defelice, 1991) and many problems of modern agriculture such as soil erosion are reduced. As compared to conventional tillage, the no-tillage system reduces moisture loss (Worsham, 1974). Near complete weed control is important for successful crop production and with no-tillage, reliance is placed on herbicides which are part and parcel of the system used in place of mechanical cultivation to control weeds (Triplett, 1978; Matthews, 1979; Kapusta, 1986).

Carey and Defelice (1991) reported that herbicides applied prior to planting (early preplant) may provide several advantages over preemergence herbicides for weed control in no-tillage soybean production. Early preplant herbicides provided excellent weed control and increased soybean yield when weed infestations were light (Stougaard et al., 1984; Werling and Buhler, 1988; Buhler and Werling, 1989). However, early preplant herbicides did not control weeds for the entire growing season under conditions favourable for herbicide degradation and when weed infestations were dense.

Robinson et al., (1984), in Georgia, USA, found that under a no-tillage soybean, preemergence application of metribuzin at 4.2 kg a.i/ha or an early postemergence application of 0.84 kg a.i/ha acifluorfen giving excellent control of broadleaf weeds. In Romania, Shoham et al., (1984), found postemergence application of 0.375 kg a.i/ha fomesafen + 0.75 kg a.i/ha fluazifop-butyl to be effective against Amaranthus spp and Solanum nigrum under a no-tillage soybean cultivation system. In another trial conducted in Argentina under the same tillage system, Shoham et al., (1984) found 0.25 kg a.i/ha fomesafen + 0.25 kg a.i/ha fluazifop-butyl giving adequate postemergence control of Amaranthus spp. In Brazil, Shoham et al., (1984), also under a no-tillage soybean cultivation system, found postemergence application of 0.5 kg a.i/ha fomesafen well controlling E. heterophylla. In addition, Jowers et al., (1986), in USA under the same tillage system, found successive germinations and regrowth of E. heterophylla following paraquat treatment making control difficult especially late in the growing season. Uncontrolled seedlings and later germination made application of postemergence herbicides necessary. On the other hand, under a conventional tillage system, Moore et al., (1990), in USA, found severe E. heterophylla infestation being controlled and peanut yield reduction being avoided with timely postemergence herbicide applications that included diphenyl ether herbicides such as acifluorfen. Other diphenyl ether herbicides also showed similar activity on E. heterophylla in soybeans (Griffin, 1986).

Under a conventional tillage system, Harger and Nester (1981), in USA, found metribuzin being the most effective soil-herbicide giving good control of E. heterophylla, whereas bentazon with 5 percent surfactant/ac was found to be effective as postemergence herbicide when applied before the weed seedlings were 10 cm tall. In Brazil, under a conventional tillage system, Cerdeira and Voll (1986a) found effective control of E. heterophylla being achieved by postemergence application of 0.36 kg a.i/ha acifluorfen. In another trial under the same tillage system, Cerdeira and Voll (1986b) found postemergence application of 0.76 kg a.i/ha bentazon giving satisfactory control of Commelina spp.

The work done by Mbamba (1991) at Lilayi/Lusaka, Zambia in a no-tillage soybean cultivation system, found preemergence herbicides giving poor control of weeds. However, the seedbed was not clean at the time of application of preemergence herbicides due to failure of paraquat to control weeds initially. On the other hand, postemergence application of fomesafen at 0.4 kg a.i/ha and acifluorfen 0.25 kg a.i/ha gave good and fair control of E. heterophylla, respectively.

3.0. MATERIALS AND METHODS

An on-farm trial was conducted during the 1991/92 cropping season. Crop husbandry practices followed by the farmer were the ones practised in this study.

3.1. CROP HUSBANDRY PRACTICES FOR THE TRIAL

Location	Lilayi farm, 17 km south of Lusaka, Zambia.
Tillage system	No-tillage
Crop rotation	Wheat/soybean
Variety	Kaleya
Planting	
-seed rate	100 kg/ha
-procedure	Furrows made by hand hoe and 30 seeds/meter row drilled by hand.
-date	28th December, 1991.
Emergence (50 percent)	6th January, 1992.
Weeding	14 and 28 days after planting (DAP)
-preplant	Two applications of 0.6 kg a.i/ha paraquat to control first and second flush of weeds respectively.
-preemergence	Applied 2 DAP.
-postemergence	Applied 22 DAP. Sequential application of fluazifop-butyl was done 29 DAP.
Fertilizer	No fertilizer was applied.
Insecticide	Thiodan 50 WP at 2 kg a.i/ha sprayed 60 DAP to control *Xanthodes graellsii.*
Fungicide	Brestan 60 WP at 1 kg a.i/ha sprayed 80 DAP to control red leaf blotch (*Pyrenochaeta glycines*).
Harvesting	Mechanical harvesting was done 128 DAP on 7th, May 1992.

3.2. EXPERIMENTAL DESIGN

A randomised complete block design replicated six times was used. The blocks were 32.0 m long and 10.0 m wide each with a path of 1.5 m between blocks. The plots within each block were 10.0 m long and were separated from each other on both sides by alleys 1.0 m wide. Gross plot size was 10.0 m x 2.0 m = 20.0 sq.m while harvest area was 6.0 m x 1.0 m= 6.0 sq.m.

3.3. TREATMENTS:

Eleven treatments were used in this study. These were:

1. No weeding (NW)
2. Hand hoe weeding (HHW)
3. 0.3 kg a.i/ha metribuzin + 1.4 kg a.i/ha metolachlor (tank mixed), (PRE)
4. 0.4 kg a.i/ha fomesafen + 0.3 kg a.i/ha fluazifop-butyl (applied sequentially), (POE)
5. 0.96 kg a.i/ha bentazon + 0.3 kg a.i/ha fluazifop-butyl (applied sequentially), (POE)
6. 0.96 kg a.i/ha bentazon + 0.25 kg a.i/ha acifluorfen (tank mixed), (POE)
7. 0.25 kg a.i/ha acifluorfen + 0.3 kg a.i/ha fluazifop-butyl (applied sequentially), (POE)
8. 0.96 kg a.i/ha bentazon + 0.18 kg a.i/ha fenoxaprop-ethyl (tank mixed), (POE)
9. 0.75 kg a.i/ha oxadiazon,(PRE)
10. 0.75 kg a.i/ha oxadiazon + 1.4 kg a.i/ha metolachlor (tank mixed), (PRE)
11. 0.1 kg a.i/ha imazethapyr, (PRE)

The rates of herbicides used in this study were the ones recommended for weed control in soybeans in Zambia while for the herbicides which are still under *evaluation, manufacturer's rates were used. All these herbicides were applied* using a plot sprayer fitted with five flat fan nozzles 50 cm apart, covering a width of 2 m and delivering a spray mixture of 600 l/ha at 3 bars.

3.4. EVALUATIONS

Percent crop cover, percent weed cover and weed frequency were recorded after every 21 days from planting to harvesting time. Frequency of occurrence of weeds according to Klingman (1977) refers to the presence or absence of species within a sampling unit (subsample) without reference to the number of individuals that may be present expressed in percentage. Weed frequency was worked out as the number of quadrats in which a weed occured; expressed as a percentage of the total number of quadrats. A 0.5 sq.m. quadrat was used and the harvest area for each plot was divided into 0.5 sq.m squares and two subsamples were randomly taken from each plot and maintained for subsequent assessments. Visual score on a scale rating of 0-100 (0= no cover, 100= complete cover) was used for crop and weed cover assessment.

Weed control and crop injury assessments were recorded 7 and 14 days after herbicide application using ratings based on a visual score on a scale of 0-9 [0= no weed control or complete kill of crop, 9= complete weed control or 0complete crop tolerance] (appendix i, ii and iii). The other parameter measured was soybean seed yield (kg/ha) on the basis of 13 percent moisture.

The weeds were cut at ground level from the harvest area two days before harvesting and oven-dried at 90 degrees celcius for 16 hours and weed biomass was recorded. Then, weed control efficiency (WCE) was worked out by following formula as suggested by Halwankar et al., (1986).

$$WCE = \frac{W1 - W2}{W1} \times 100$$

where, W1= Dry matter of weeds in control plots

W2= Dry matter of weeds in treated plots

Soil analysis was carried out according to Brady (1974) (appendix iv). Rainfall data were collected from Mt. Makulu Research Station (Appendix v).

Data collected were statistically analyzed using analysis of variance (Appendix vi, vii and viii). Means of factors with significant F-values were further compared for all possible comparisons by Duncan's Multiple Range Test (DMRT) as suggested by Steel and Torrie, (1980).

4.0. RESULTS

The weed species present at the experimental area were Commelina benghalensis, Datura stramonium, Eleusine indica, Euphorbia heterophylla, Galinsoga parviflora, Nicandra physalodes, Spermacose senensis, Tegetes minuta and volunteer wheat (Triticum aestivum) (Table 1). These were the second flush of weeds after earlier application of 0.6 kg a.i/ha paraquat to control the first flush. These weeds which had at least 2-5 leaves and were actively growing were later effectively controlled by the application of 0.6 kg a.i/ha paraquat two days before planting. Whereas paraquat controlled the aboveground parts of E. heterophylla, new shoots subsequently developed from the lower nodes and competed with the crop.

4.1. EFFECT OF DIFFERENT WEED CONTROL TREATMENTS ON THE DEVELOPMENT OF THE WEED COVER (percent).

Weed cover relative to crop cover was low throughout the season (Figures 1 and 2). Weed cover at 6 WAP was highest in the no weeding treatment (9.5 percent) and lowest in the hand weeded treatment (0.0 percent) (Table 2). Weed cover for bentazon plus acifluorfen treatment declined between 3 WAP and 6 WAP whereas in other herbicide treatments it increased. Between 6 WAP and 9 WAP most of the herbicide treatments recorded a decline in weed cover except for oxadiazon. Over the whole growing season, the no weeding treatment recorded the highest mean weed cover (8.1 percent) and the hand weeded treatment had the lowest cover (0.8 percent). Among the weed species present at the no weeding treatment at 3 WAP, E. heterophylla had the highest cover (3.6 percent) and frequency (83.3 percent) (Table 3, Figure 3). Its cover continued to increase and attained a maximum at 9 WAP (5.1 percent) but its frequency declined to 58.3 percent.

Table 1. Weed species present at the experimental area, Lilayi Farm.

Name	Family
Commelina benghalensis (L)	Commelinaceae
Datura stramonium (L)	Solanaceae
Eleusine indica (L)	Poaceae
Euphorbia heterophylla (L)	Euphorbiaceae
Galinsoga parviflora (L)	Asteraceae
Nicandra physalodes (L)	Solanaceae
Spermacose senensis (L)	Rubiaceae
Tegetes minuta (L)	Asteraceae
Triticum aestivum (L) (volunteer wheat)	Poaceae

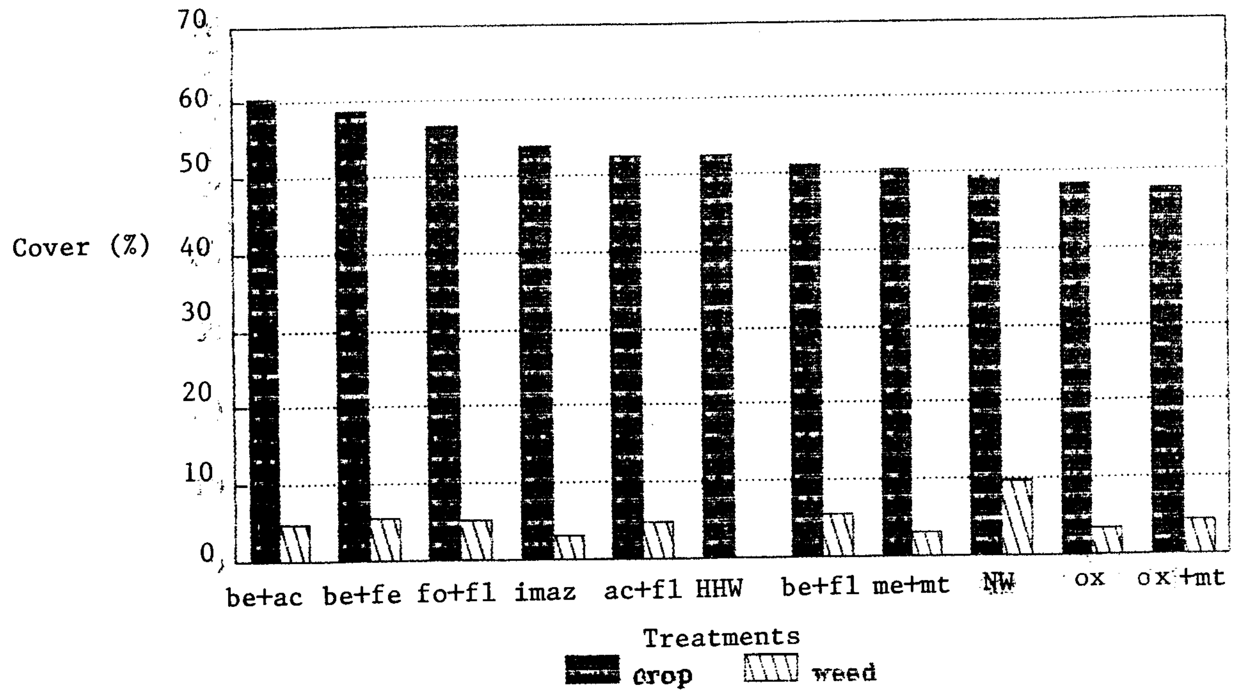

Figure 1. Effect of different weed control treatments on soybean cover and weed cover 6 WAP at Lilayi Farm.

Key:

be + ac = bentazon + acifluorfen
be + fe = bentazon + fenoxaprop-ethyl
fo + fl = fomesafen + fluazifop-butyl
imaz = imazethapyr
ac + fl = acifluorfen + fluazifop-butyl
HHW = Hand hoe weeding
be + fl = bentazon + fluazifop-butyl
me + mt = metribuzin + metolachlor
NW = No weeding
ox = oxadiazon
ox + mt = oxadiazon + metolachlor

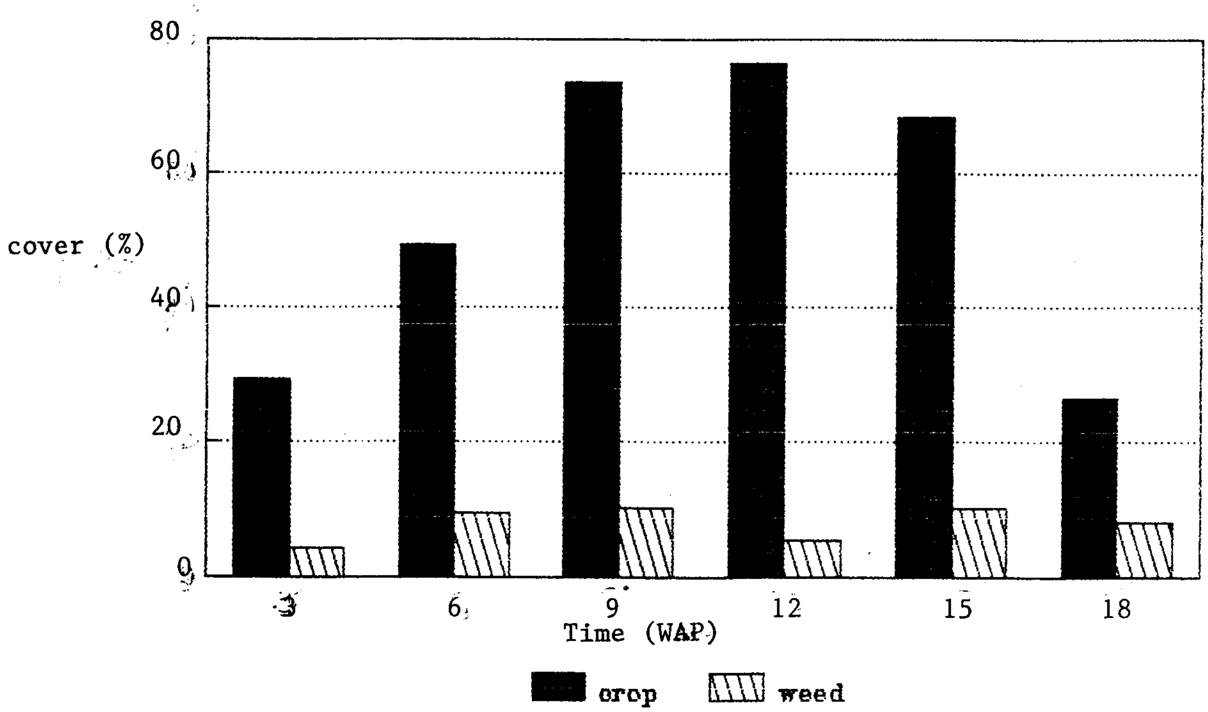

Figure 2. Crop and weed cover in the no -weeding treatment in soybeans at Lilayi Farm.

Table 2. Development of weed cover (percent) under different weed control treatments at Lilayi Farm

	Weeks after planting*							
Treatment.	3	6	9	12	15	18	Mean	SED
NW	4.4a	9.5a	10.4a	5.5a	10.4a	8.4a	8.1	1.1
be+fe	5.0a	5.5ab	5.1bc	3.3ab	3.6b	4.4ab	4.5	0.4
be+fl	5.2a	5.6ab	2.8bc	3.0ab	5.5b	4.3ab	4.4	0.5
ac+fl	3.7a	4.7ab	4.3bc	4.7ab	4.2b	4.2ab	4.3	0.2
ox	1.2a	3.3ab	6.3ab	5.4a	4.3b	3.9ab	4.1	0.7
be+ac	5.3a	4.7ab	2.6bc	3.0ab	3.8b	4.6ab	4.0	0.4
fo+fl	4.6a	5.2ab	3.1bc	2.6ab	2.2b	1.8b	3.2	0.6
ox+mt	1.3a	4.4ab	2.1bc	1.3ab	0.8b	2.1b	2.0	0.5
imaz	1.4a	3.1ab	0.9c	1.4ab	1.7b	0.5b	1.5	0.4
me+mt	1.5a	3.2ab	1.5bc	1.0b	1.0b	0.3b	1.4	0.4
HHW	1.3a	0.0b	0.5c	0.5b	0.8b	1.4b	0.8	0.2
Mean	3.2	4.5	3.6	2.9	3.5	3.3		
SED	0.5	0.7	0.5	0.9	0.9	0.7		
CV (%)	128.5	121.5	105.8	112.6	112.5	120.0		

* Means in the same week followed by the same letter are not significantly different at 0.05 level according to Duncan's multiple range test.

Key:

NW=	No weeding
be+fe=	bentazon+fenoxaprop-ethyl
be+fl=	bentazon+fluazifop-butyl
ac+fl=	acifluorfen+fluazifop-butyl
be+ac=	bentazon+acifluorfen
ox=	oxadiazon
fo+fl=	fomesafen+fluazifop-butyl
ox+mt=	oxadiazon+metolachlor
imaz=	imazethapyr
me+mt=	metribuzin+metolachlor
HHW=	Hand hoe weeding
SED=	Standard error of difference

Table 3. Weeds present in soybean (no-weeding) at Lilayi Farm

	3 WAP		6 WAP		9 WAP		12 WAP	
Treatment	% cover	% freq.	% cover	% freq.	% cover	% freq.	% cover	% freq.
Eh.	3.6	83.3	5.0	83.3	5.1	58.3	1.3	41.7
Cb.	0.5	33.3	2.4	33.3	3.0	41.7	1.8	41.7
Gp.	0.0	0.0	0.0	0.0	0.5	8.3	0.5	8.3
Ah.	0.5	33.3	0.5	16.7	0.5	25.0	0.5	8.3
Np.	0.5	0.0	1.7	50.0	1.6	50.0	1.5	25.0
Tz.	0.0	0.0	0.0	0.0	0.0	0.0	0.5	8.3
Ds.	0.0	0.0	0.0	0.0	0.0	0.0	0.5	8.3
Total	5.1		9.6		10.7		6.6	
Crop cover	29.2		49.2		73.3		76.3	

Key

WAP= Weeks after planting
Eh= Euphorbia heterophylla
Cb= Commelina benghalensis
Gp= Galinsoga parviflora
Ah= Amaranthus hybridus
Np= Nicandra physalodes
Tz= Trichodesma zeylanicum
Ds= Datura stramonium
freq= frequency

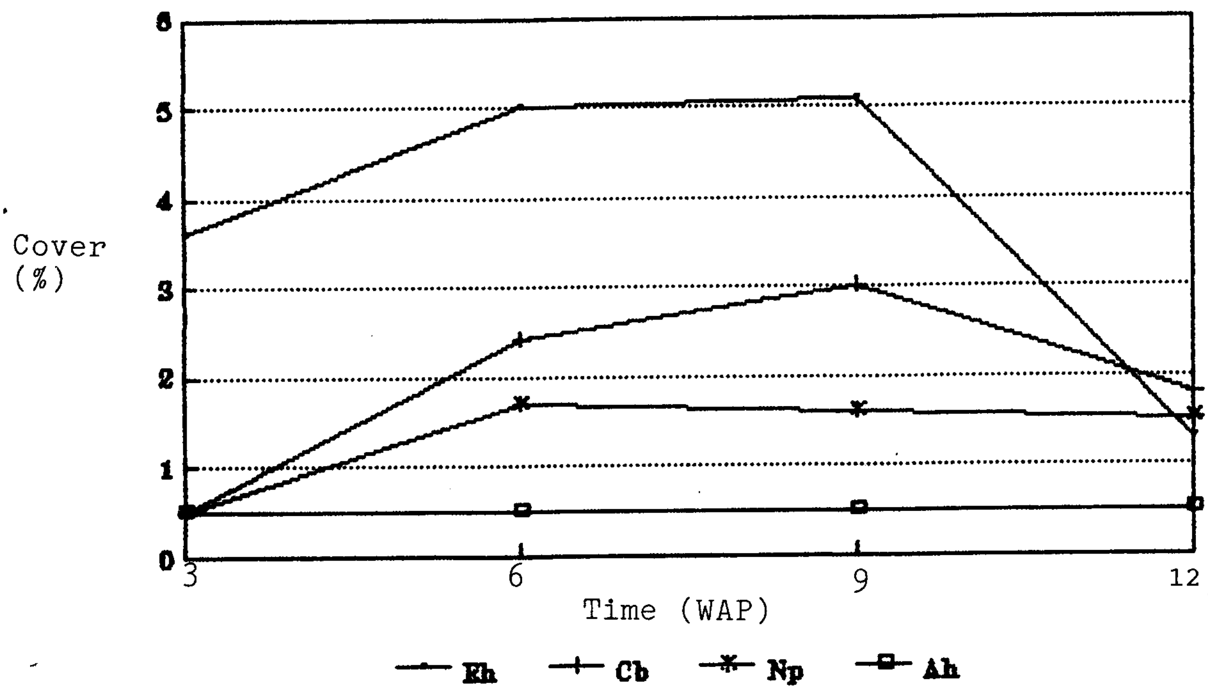

Figure 3. Development of uncontrolled weeds (percent cover i
the no weeding treatment) in soybeans at Lilayi Fa

Key:

Eh = *Euphorbia heterophylla*

Cb = *Commelina benghalensis*

Np = *Nicandra physalodes*

Ah = *Amaranthus hybridus*

Weed control with preemergence herbicides was satisfactory for all other weeds except E. heterophylla which recovered from the application of paraquat and thus continued to have a higher cover from 3 WAP (Table 4). All preemergence herbicides gave a season-long control of N. physalodes. Imazethapyr, and metribuzin plus metolachlor suppressed C. benghalensis effectively throughout the season. Preemergence application of oxadiazon and oxadiazon plus metolachlor caused slight crop injury (Appendix iii) in the form of abnormal seedlings. The crop however recovered completely within two weeks.

Postemergence application of fomesafen, acifluorfen and bentazon gave an effective control of N. physalodes (Table 5, Appendix ii). Postemergence application of fomesafen also gave satisfactory control of C. benghalensis. The effect of fomesafen on E. heterophylla did not last long before the new shoots emerged from the lower nodes resulting in higher weed cover when compared to other weed species. Acifluorfen did not give satisfactory control of E. heterophylla and bentazon did not give any visible effect on it (Appendix ii). However, bentazon gave good control of C. benghalensis seedlings. Generally, weed control and in particular control of E. heterophylla in the postemergence herbicides was lower than that in the preemergence herbicides (Table 4 and 5). Of the postemergence herbicides, fomesafen and acifluorfen caused slight crop injury (Appendix iii) in terms of chlorosis but the crop recovered completely.

4.2. EFFECT OF DIFFERENT WEED CONTROL TREATMENTS ON THE WEED BIOMASS.

The no weeding treatment had the highest weed biomass (169 kg/ha) (Table 6; Figures 4 and 5). Although herbicide treatments did not differ significantly from each other in weed biomass, preemergence application of imazethapyr resulted in the lowest weed biomass (6 kg/ha) with the highest weed control

Table 4. Effect of preemergence herbicides on weed cover in soybeans at Lilayi Farm

		Weed cover (percent)			
		Weed species			
Treatment	WAP	Eh	Cb	Np	Total
	3	1.5	0.0	0.0	1.5
me+mt	6	3.1	0.5	0.0	3.6
	9	1.4	0.5	0.0	1.9
	3	0.5	0.5	0.0	1.0
ox.	6	2.0	1.3	0.0	3.3
	9	2.1	3.8	0.0	5.9
	3	0.5	0.5	0.0	1.0
ox+mt.	6	1.9	0.5	0.0	2.4
	9	0.5	1.9	0.0	2.4
	3	1.4	0.5	0.0	1.9
imaz.	6	3.0	0.5	0.0	3.5
	9	0.5	0.5	0.0	1.0
	3	0.5	0.5	0.0	1.0
HHW.	6	0.0	0.0	0.0	0.0
	9	0.0	0.0	0.0	0.0
	3	3.6	0.5	0.5	4.6
NW.	6	5.0	2.4	1.7	9.1
	9	5.1	3.0	1.6	9.7

Key:
- me+mt= metribuzin+metolachlor
- ox= oxadiazon
- ox+mt= oxadiazon+metolachlor
- imaz= imazethapyr
- HHW= Hand hoe weeding
- NW= No weeding
- Eh= *Euphorbia heterophylla*
- Cb= *Commelina benghalensis*
- Np= *Nicandra physalodes*

Table 5. Effect of postemergence herbicides on weed cover in soybeans at Lilayi Farm

		Weed cover (percent)			
		Weed species			
Treatment	WAP	Eh	Cb	Np	Total
	3	4.6	0.5	0.0	5.1
fo+fl	6	4.8	0.5	0.0	5.3
	9	3.0	0.5	0.0	3.5
	3	4.1	1.0	0.0	5.1
be+fl.	6	5.6	0.5	0.0	6.1
	9	1.5	1.4	0.5	3.4
	3	3.7	1.4	0.0	5.1
be+ac.	6	3.9	0.5	0.0	4.4
	9	2.2	0.5	0.0	2.7
	3	2.0	1.1	0.5	3.6
ac+fl.	6	3.0	1.8	0.0	4.8
	9	1.7	2.2	0.0	3.9
	3	4.5	0.5	0.0	5.0
be+fe.	6	4.5	0.5	0.0	5.0
	9	3.3	1.8	0.0	5.1
	3	0.5	0.5	0.0	1.0
HHW.	6	0.0	0.0	0.0	0.0
	9	0.5	0.0	0.0	0.0
	3	3.6	0.5	0.5	4.6
NW.	6	5.0	2.4	1.7	9.1
	9	5.1	3.0	1.6	9.7

Key: fo+fl= fomesafen+fluazifop-butyl
be+fl= bentazon+fluazifop-butyl
be+ac= bentazon+acifluorfen
ac+fl= acifluorfen+fluazifop-butyl
be+fe= bentazon+fenoxaprop-ethyl
HHW= Hand hoe weeding
NW= No weeding
Eh= *Euphorbia heterophylla*
Cb= *Commelina benghalensis*
Np= *Nicandra physalodes*

Table 6. Effect of different weed control treatments on weed biomass 125 DAP and weed control efficiency (WCE) in soybean at Lilayi Farm

Treatment	Weed biomass kg/ha	Weed control efficiency (percent)
No weeding	169a*	–
bentazon+fluazifop-butyl	53b	69
bentazon+acifluorfen	50b	70
acifluorfen+fluazifop-butyl	45b	74
bentazon+fenoxaprop-ethyl	38b	78
oxadiazon	34b	80
fomesafen+fluazifop-butyl	31b	82
metribuzin+metolachlor	27b	84
oxadiazon+metolachlor	19b	89
Hand hoe weeding	17b	90
imazethapyr	6b	97
CV (percent)	96.6	

* Means followed by the same letter are not significantly different at 0.05 level according to Duncan's multiple range test

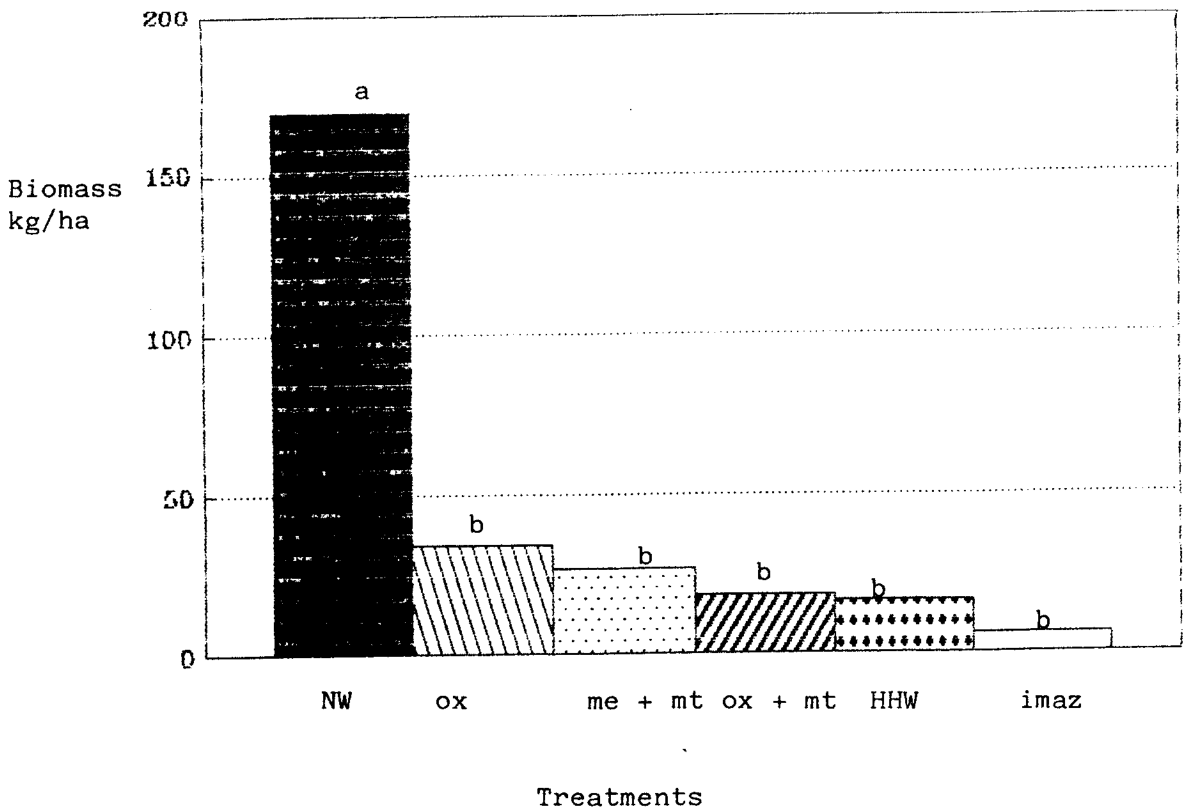

Figure 4. Effect of preemergence treatments on weed biomass in soybeans 125 DAP at Lilayi Farm. Bars followed by the same letter are not significantly different at 0.05 level according to Duncan's multiple range test.

<u>Key:</u>

NW = No weeding
ox = oxadiazon
me + mt = metribuzin + metolachlor
HHW = Hand hoe weeding
imaz = imazethapyr
ox + mt = oxadiazon + metolachlor

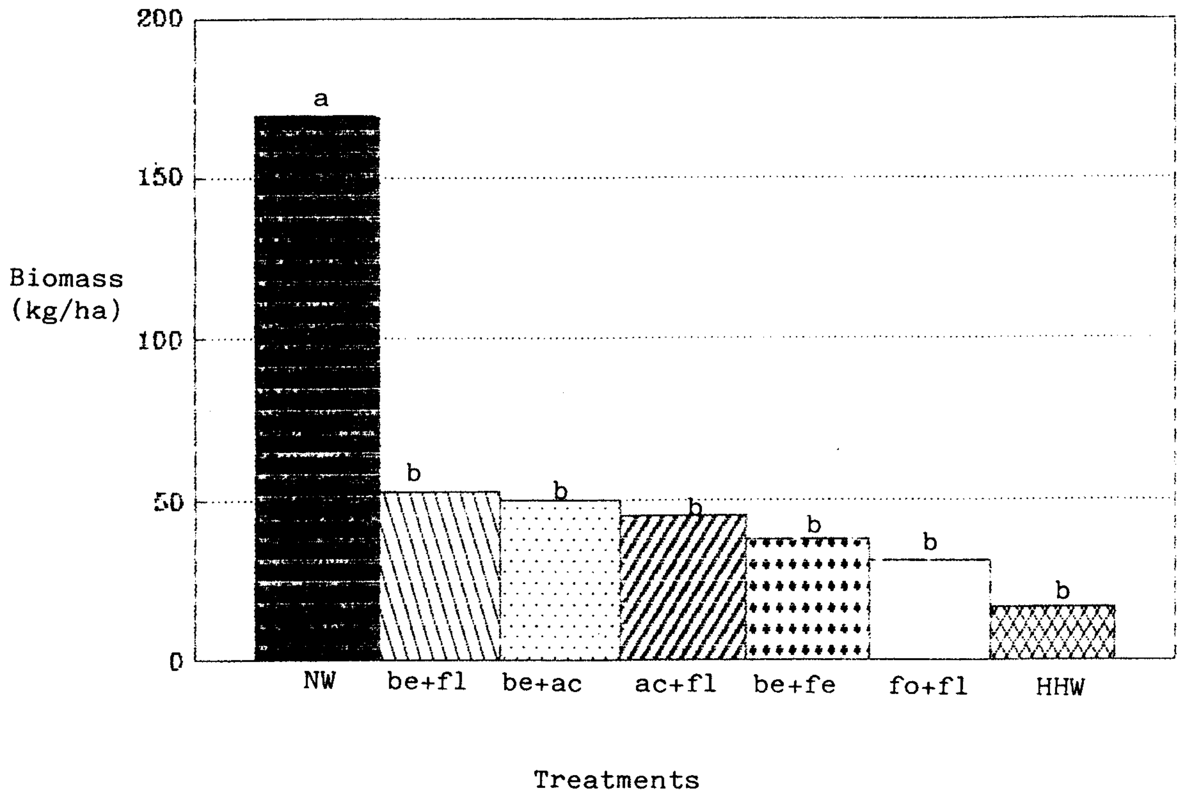

Figure 5. Effect of postemergence treatments on weed biomass in soybeans 125 DAP at Lilayi Farm. Bars followed by the same letter are not significantly different at 0.05 level according to Duncan's multiple range test.

Key:

NW = No weeding
be+fl = bentazon + fluazifop-butyl
be+ac = bentazon + acifluorfen
ac+fl = acifluorfen + fluazifop-butyl
be+fe = bentazon + fenoxaprop-butyl
fo+fl = fomesafen + fluazifop-butyl
HHW - Hand hoe weeding

efficiency (97 percent).

4.3. EFFECT OF DIFFERENT WEED CONTROL TREATMENTS ON THE DEVELOPMENT OF CROP COVER (percent).

Crop cover for all treatments increased significantly over time and attained maximum cover at 12 WAP. Thereafter it declined (Table 7). Crop cover at 12 WAP was highest (90.0 percent) in the oxadiazon treatment and lowest in the acifluorfen plus fluazifop-butyl (75.0 percent) treatment. Over the whole growing season, the bentazon plus fenoxaprop-ethyl treatment recorded the highest average crop cover (63.0 percent) whereas acifluorfen plus fluazifop-butyl recorded the lowest cover (53.7 percent).

4.4. EFFECT OF DIFFERENT WEED CONTROL TREATMENTS ON SOYBEAN SEED YIELD.

Preemergence application of oxadiazon resulted in the highest soybean seed yield (2782 kg/ha) followed by imazethapyr (2704 kg/ha) (Table 8, Figures 6 and 7). The no weeding treatment had the lowest seed yield (1980 kg/ha). Although the hand weeded treatment yielded higher than postemergence herbicide treatments, the differences were not significant. Oxadiazon plots yielded 17 percent more than hand weeded ones whereas the no weeding treatment yielded 17 percent less. Generally, herbicides applied preemergence performed better than those applied postemergence in terms of soybean seed yield although the differences were not significant (Figures 6 and 7). All preemergence treatments out-yielded the hand weeded treatment but all postemergence treatments yielded less than hand weeded plots. Crop cover at 12 WAP across treatments was positively correlated to soybean seed yield (r= 0.740).

Table 7. Development of soybean crop cover (percent) under different weed control treatments at Lilayi Farm

	Weeks after planting*							
Treatment.	3	6	9	12	15	18	Mean	SED
be+fe	40.3a	58.8ab	79.2a	87.9a	81.2ab	30.4ab	63.0	9.7
fo+fl	30.8a	56.7ab	70.8ab	84.2ab	77.9abc	35.8abc	59.4	9.1
be+fl	29.9a	50.9ab	67.5b	87.5a	85.4a	35.0a	59.4	10.1
imaz	33.0a	54.0ab	75.8ab	86.3ab	82.1ab	20.8b	58.7	11.1
HHW	30.8a	52.5ab	77.5ab	87.5a	75.4abc	27.5ab	58.5	10.4
me+mt	30.8a	50.4ab	69.6ab	85.0abc	78.8abc	35.8a	58.4	9.3
be+ac	31.6a	60.4a	69.2ab	79.6abc	74.2abc	29.6ab	57.4	8.9
ox	32.0a	48.3ab	69.6ab	90.0a	75.8abc	23.3b	56.5	10.7
ox+mt	28.7a	47.5b	67.5b	86.3ab	80.9ab	22.5b	55.6	11.0
NW	29.2a	49.2ab	73.3ab	76.3bc	68.3c	26.7ab	53.8	9.1
ac+fl	30.8a	52.5ab	69.2ab	75.0c	72.4bc	22.5b	53.7	9.2
Mean	31.6	52.8	71.7	84.1	77.5	28.2		
SED	0.9	1.3	1.2	1.5	1.5	1.7		
CV (%)	27.6	17.5	11.0	9.3	11.8	27.8		

* Means in the same week followed by the same letter are not significantly different at 0.05 level according to Duncan's multiple range test.

Key

be+fe= bentazon+fenoxoprop-ethyl
be+fl= bentazon+fluazifop-butyl
fo+fl= fomesafen+fluazifop-butyl
imaz= imazethapyr
HHW= Hand hoe weeding
me+mt= metribuzin+metolachlor
be+ac= bentazon+acifluorfen
ox= oxadiazon
ox+mt= oxadiazon+metolachlor
NW= No weeding
ac+fl= acifluorfen+fluazifop-butyl
SED= standard error of difference

Table 8. Effect of different weed control treatments on soybean seed yield at Lilayi Farm

Treatment	Seed yield kg/ha	Percentage of hand weeded
oxadiazon	2782a*	117
imazethapyr	2704ab	114
oxadiazon+metolachlor	2424abc	102
metribuzin+metolachlor	2405abc	101
Hand hoe weeding	2374abc	100
bentazon+fluazifop-butyl	2360abc	99
fomesafen+fluazifop-butyl	2352abc	99
bentazon+fenoxaprop-ethyl	2344abc	99
acifluorfen+fluazifop-butyl	2228abc	94
bentazon+acifluorfen	2120bc	89
No weeding	1980c	83
CV (percent)	19.9	

* Means followed by the same letter are not significantly different at 0.05 level according to Duncan's multiple range test.

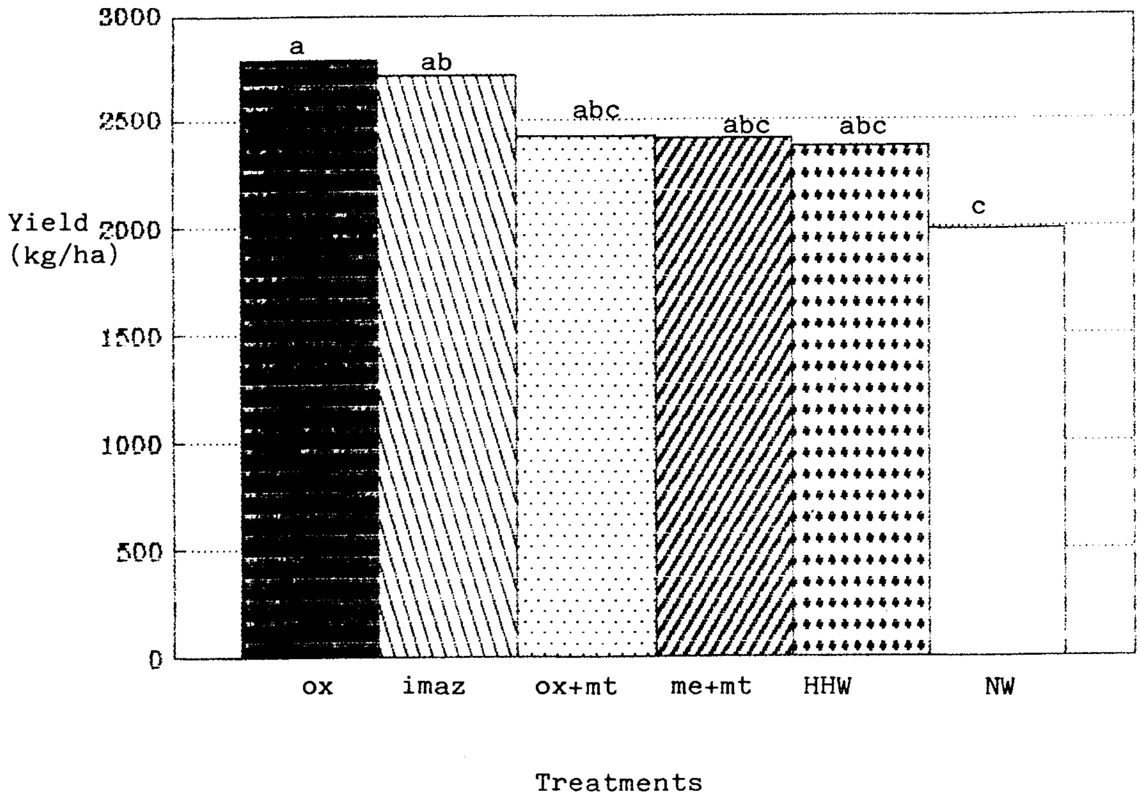

Figure 6. Effect of preemergence treatments on soybean seed yield at Lilayi Farm. Bars followed by the same letter not significantly different at 0.05 level according to Duncan's multiple range test.

Key

ox = oxadiazon
imaz = imazethapyr
ox+mt = oxadiazon + metolachlor
HHW = Hand hoe weeding
NW = No weeding
me + mt = metribuzin + metolachlor

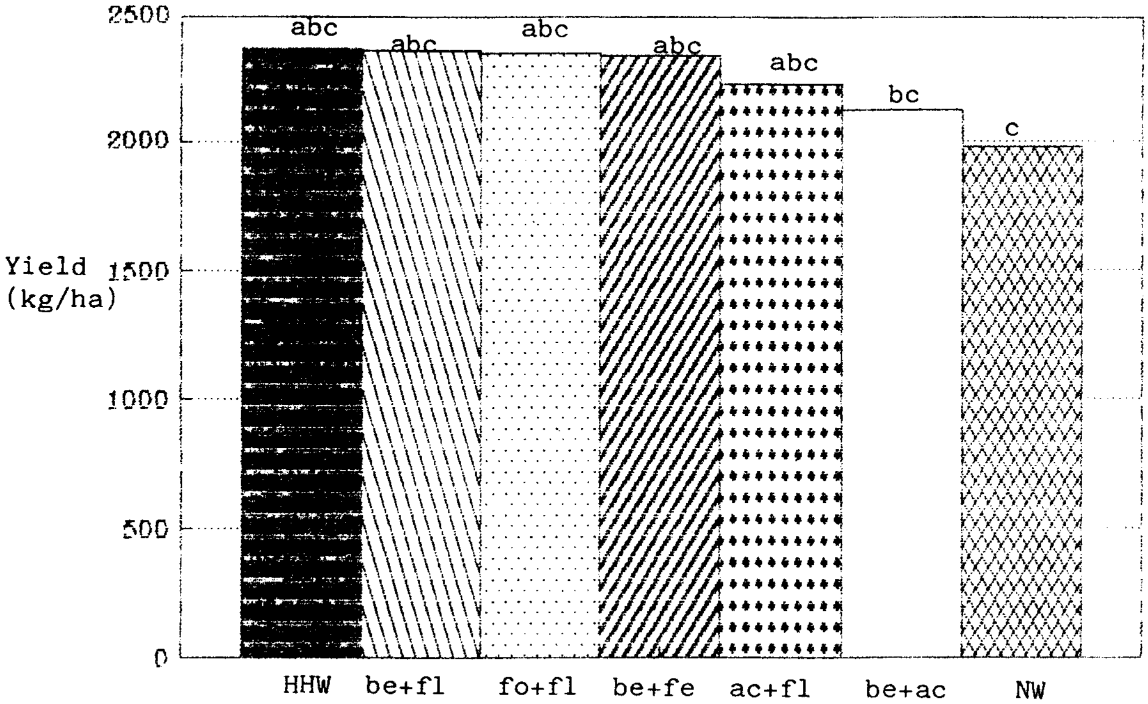

Figure 7. Effect of postemergence treatments on soybean seed yiel at Lilayi Farm. Bars followed by the same letter are not significantly different at 0.05 level accordi Duncan's multiple range test.

Key:

HHW = Hand hoe weeding
be+fl = bentazon + fluazifop-butyl
fo+fl = fomesafen + fluazifop-butyl
be+fe = bentazon + fenoxaprop-ethyl
ac+fl = acifluorfen + fluazifop-butyl
be+ac = bentazon + acifluorfen
NW = No weeding

5.0. DISCUSSION

The weed flora in the experimental area consisted of E. heterophylla and C. benghalensis among other weed species present (Table 1). The farm on which this study was conducted has been used intensively for the past nine years and this has systematically allowed the removal of easily controlled weeds while allowing E. heterophylla and C. benghalensis to become better established. The study conducted by Mbamba (1991) under two different tillage systems found the weed flora being different also. Whereas the weeds under conventional tillage such as N. physalodes were easily controlled by a number of herbicides, those under a no-tillage system such as E. heterophylla were difficult to control. Once established, the eradication of these weeds is difficult. Cultural practices such as irrigation also enhanced their persistence and have made them to become dominant in the area.

E. heterophylla has an ability to produce a large quantity of seeds which germinate rapidly and plants produce seeds at a very early stage so that dense infestations build up rapidly (O'Makinwa and Akinyemiju, 1990). According to O'Makinwa and Akinyemiju (1990), the seeds of this weed hardly show dormancy and reach a high percentage germination immediately after fruit dehiscence. Flowering of E. heterophylla begins about four weeks after emergence and its life cycle is between seven to eight weeks. On the other hand, C. benghalensis has fleshy stems with nodes which can regenerate after cultivation or herbicide application. It has also an ability to produce underground flowers which can produce viable seeds at different depths in the soil and these emerge at different times (Vernon, 1983).

Preplant weed control at the experimental area was achieved by the application of paraquat which was used in place of mechanical cultivation to control existing weeds (Table 1). Most of soil-applied herbicides are effective when applied on a clean seedbed, hence initial weed control before planting was necessary. Initial weed control was also aimed at ensuring that only the effect of soil activity of the preemergence herbicides was evaluated.

This study experienced a low weed infestation throughout the season (Figures 1 and 2). Effective control of the first and second flush of weeds by paraquat before planting coupled with dry weather conditions during the season (Appendix v) reduced subsequent weed emergence and growth. As was pointed out by Griffin et al.,(1989), water is one of the most limiting resources to plant growth. Lack of sufficient rainfall and soil water strongly influenced germination and growth of weeds.

The low weed infestation experienced in this study had a bearing on herbicide treatments resulting in relatively low herbicide effects on weed cover, weed biomass, soybean crop cover and soybean seed yield (Tables 2, 6, 7 and 8). On the other hand, the high variation (cv) in weed cover and weed biomass was due to the nonuniform nature of weed infestations that were observed.

None of the preemergence herbicides could effectively control E. heterophylla (Table 4). The E. heterophylla infestations from 3 WAP might have been mainly due to the weeds recovering from the application of paraquat. Because preemergence herbicides are effective on weed seeds and seedlings, they therefore, could not work on the weeds recovering from paraquat application which had grown too large with well established root systems. On the other hand, the presence of wheat straw in some plots might also have contributed to the ineffective control of the new emerging weed seedlings. Banks and Robinson (1986) found the activity of metolachlor being reduced by wheat straw through intercepting the herbicide applied, reducing the amount reaching the soil and altering its distribution.

On the other hand, preemergence application of imazethapyr has a potential to reduce weed problems in a no-till soybean production system (Tables 4, 6 and Figure 4). Although the control of E. heterophylla was not satisfactory, the E. heterophylla weed seedlings which emerged after the application of imazethapyr were slender and the leaves were reduced in size suggesting the reduction in cell division as it was pointed out by Caseley and Walker (1990).

There is also a potential for preemergence application of oxadiazon. However, the combination of oxadiazon plus metolachlor could offer better results (Table 4). Whereas oxadiazon alone could not effectively control E. heterophylla and C. benghalensis, a combination of oxadiazon plus metolachlor resulted in better control of these weeds.

None of the postemergence treatments could control E. heterophylla effectively (Table 5). Whereas fomesafen had a good initial effect on the weed leaves (Appendix ii), being a contact herbicide it had little or no residual activity. As a result new shoots emerged from the lower nodes and competed with the crop. Fomesafen which is registered for postemergence control of dicotyledonous weeds in soybeans has a potential to control E. heterophylla (Shoham et al., 1984). However, the larger weeds with thick stems which recovered from the application of paraquat made control unsatisfactory. The age of a plant determines its response to a particular herbicide; young plants are less tolerant than older ones. The younger the plant, the higher the percentage of the plant that is meristematic (growing) tissue, thus making it more vulnerable for herbicides (Klingman and Ashton, 1982).

In general, control of E. heterophylla in the postemergence treatments was lower than that achieved in the preemergence treatments (Tables 4 and 5). Normally, postemergence herbicides involve several problems including ineffectiveness on larger weeds and the treated weeds continuing to compete with the crop until they die. The new shoots of E. heterophylla which emerged from the lower nodes after the application of paraquat might have grown rapidly and attained the tolerant stage by the time when postemergence herbicides were applied resulting in the ineffective control of the weed.

Acifluorfen, which is one of the diphenyl ether herbicides recommended for the control of E. heterophylla in Nigeria, might give more satisfactory results (Table 5) if its application rate would be increased. Mbamba (1991) also obtained poor control of this weed with 0.25 kg a.i/ha acifluorfen which was used in this study. Cerdeira and Voll (1986a) in Brazil obtained satisfactory control of this weed with 0.36 kg a.i/ha acifluorfen and O'Makinwa and Akinyemiju (1990) in Nigeria obtained better results with postemergence application of 1-2 kg a.i/ha acifluorfen.

The highest crop cover recorded by preemergence application of oxadiazon at 12 WAP, did result in subsequent highest soybean seed yield (Tables 7 and 8), the overall correlation coefficient across treatments being r= 0.740 (significant at P= 0.05). This is in accordance with what Shibles and Weber (1965) found in soybeans. When dry matter production rate was plotted against percent light interception, a linear relationship was found, indicating that productivity depends on the leaf area and particularly on light interception by that leaf area. The findings by Willmot et al,. (1989) confirm further that soybean seed yield is highly dependent upon the level of light interception by the canopy during the seed filling period.

Generally, all preemergence treatments gave higher yields than the postemergence treatments although the differences were not significant (Table 8, Figures 6 and 7). This might be due to lower levels of control of E. heterophylla in the postemergence treatments compared to preemergence treatments (Tables 4 and 5). As it was pointed out by Carey and Defelice (1991) in Columbia on a no-tillage soybean cultivation system, earlier control of weeds before soybean emergence may provide a yield advantage during seasons with limited rainfall by reducing crop-weed competition for the limited soil moisture.

6.0. CONCLUSION AND RECOMMENDATIONS

Euphorbia heterophylla can be singled out as a troublesome weed to control, especially in no-tillage systems under Zambian condition. Problems related to its control were also encountered by Mbamba (1991) on the same tillage system. The ability of this weed to recover from herbicide treatments makes its control difficult. There is a need therefore to investigate further the efficacy of various herbicides on the control of this weed in no-tillage soybean cultivation systems.

There is a potential for the preemergence application of oxadiazon or imazethapyr for weed control in no-tillage soybean cultivation systems in Zambia. On the other hand, fomesafen can be used to control broadleaf weeds in soybeans when applied as a postemergence herbicide. However, the study is not conclusive due to dry weather condition which existed during the growing season and which was unfavourable for crop-weed competition. The study should be repeated and acifluorfen should be evaluated further by increasing the rate of application. A combination of oxadiazon plus metolachlor should be investigated more for its efficacy.

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8.0. APPENDICES

Appendix i. Weed control and crop injury assessment rating scale.

Weed control		Crop injury	
9*	complete control	9*	complete tolerance
8*	excellent control	8*	possible effect
7*	good control	7*	slight effect
6	fair control	6	definite effect
5	poor control	5	severe effect
4	moderate injury	4	severe effect
3	definite effect	3	severe effect
2	slight injury	2	severe effect
1	possible injury	1	severe effect
		0	complete kill

* commercially acceptable

Appendix ii. Effect of herbicide treatments on weed control rating in soybean at Lilayi Farm (7 days after treatment).

	Weed species						
Treat.	Eh	Cb	Np	Gp	Ah	Ss	Tm
	score						
be+fe	5	5	7	4	4	4	4
be+fl	5	7	7	4	7	4	7
ac+fl	6	6	8	4	8	6	6
be+ac	6	7	8	5	7	4	7
ox	7	7	8	6	7	6	7
fo+fl	7	7	8	7	8	8	7
ox+mt	7	7	8	7	8	6	7
imaz	7	7	8	8	9	9	8
me+mt	6	7	8	6	8	6	7

Key

be+fe= bentazon+fenoxaprop-ethyl
be+fl= bentazon+fluazifop-butyl
ac+fl= acifluorfen+fluazifop-butyl
be+ac= bentazon+acifluorfen
ox= oxadiazon
fo+fl= fomesafen+fluazifop-butyl
ox+mt= oxadiazon+metolachlor
imaz= imazethapyr
me+mt= metribuzin+metolachlor

Eh= Euphorbia heterophylla
Cb= Commelina benghalensis
Np= Nicandra physalodes
Gp= Galinsoga parviflora
Ah= Amaranthus hybridus
Ss= Spermacose senensis
Tm= Tegetes minuta

Appendix iii. Crop injury score (7 days after treatment).

Treatment	score
bentazon+fenoxaprop-ethyl	9
bentazon+fluazifop-butyl	9
acifluorfen+fluazifop-butyl	7
bentazon+acifluorfen	7
oxadiazon	7
fomesafen+fluazifop-butyl	7
oxadiazon+metolachlor	7
imazethapyr	9
metribuzin+metolachlor	8

Appendix iv. Soil analysis from the experimental area, Lilayi Farm

	0-5 cm depth	0-20 cm depth
pH	6.60	6.60
Organic matter (%)	3.92	2.59
Nitrogen (%)	0.03	0.04
Humic matter (%)	6.00	6.00
Phosphorus (ppm/kg soil)	56.70	54.60
Potassium (meq cation/100 g soil)	1.34	1.01
Sodium (meq cation/100 g soil)	0.74	0.91
Calcium (meq cation/100 g soil)	2.23	2.40
Magnesium (meq cation/100 g soil)	0.13	0.17
Soil texture	10 % clay	16 % clay
	60 % silt	46 % silt
	30 % sand	38 % sand
Textural name	silty loam	loam

Appendix v. Monthly rainfall data during the growing season, Mt. Makulu Research Station.

Month	1990/91	1991/92	1950-80 average
		mm	
December	246.0	60.7	219
January	230.9	168.5	203
February	152.8	44.9	177
March	104.4	166.4	84
April	4.4	5.0	25
May	1.3	6.0	12
Total	739.8	451.5	720

Appendix vi. Mean squares for analysis of variance for weed cover (percent) at Lilayi Farm.

Source of variation	Degree of freedom	Weeks after planting 3	6	9	12	15	18
Total	65						
Replication	5	51.25*	89.47*	26.92*	14.42*	11.09*	7.59*
Treatment	10	19.57 NS	31.84*	49.05*	18.16*	47.31*	33.21*
Error	50	16.64	29.45	14.40	10.52	15.15	15.32

NS, * indicates non significance and significance at P=0.05 respectively.

Appendix vii. Mean squares for analysis of variance for crop cover (percent) at Lilayi Farm.

Source of variation	Degrees of freedom	Weeks after planting 3	6	9	12	15	18
Total	65						
Replication	5	155.83*	205.38*	59.44*	27.14*	133.12*	59.55*
Treatment	10	58.94 NS	108.27*	100.04*	148.43*	143.04*	189.22*
Error	50	75.91	85.80	61.75	61.47	83.79	61.59

NS, * indicates non significance and significance at P=0.05 respectively.

Appendix viii. Mean squares for analysis of variance for weed biomass and soybean seed yield at Lilayi Farm.

Source of variation	Degrees of freedom	Weed biomass	Soybean seed yield
Total	65		
Replication	5	994.52*	743914.68*
Treatment	10	11537.41*	312790.35*
Error	50	1835.74	221764.31

* indicates significance at P=0.05