CONTROL OF KIKUYU GRASS

A Thesis

Submitted to the Faculty

of

Graduate Studies

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by

Margaret Kamidi

In Partial Fulfillment of the

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of

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ABSTRACT

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Control of Kikuyu Grass

Major Professor: Dr. E.H. Stobbe, Department of Plant Science.

Tillage and glyphosate/tillage regimes were evaluated for control of Kikuyu grass in wheat under Kenyan conditions.

On sod, control of Kikuyu grass was better where the mouldboard plow was used than where the other tillage implements were used. On wheat stubble, there were no significant differences in control of Kikuyu grass bwetween the mouldboard plow, the disc plow and the chisel plow.

Kikuyu grass control and wheat yields were better when tillage was performed in November than when tillage was performed later, with or without glyphosate.

Control of Kikuyu grass and gain yield were higher when tillage followed glyphosate application within 21 days than when glyphosate was applied in November and tillage delayed until May.

Kikuyu grass control and grain yield were better when glyphosate was applied in November and January than when glyphosate was applied in February and May. Kikuyu grass control was better at 4 l/ha than at 2 and 3 l/ha of glyphosate.

Twelve nodes of one stolon branch of a Kikuyu grass plant were treated with glyphosate. Two days after treatment glyphosate had

translocated to the rhizomes. Four days after treatment glyphosate had translocated to untreated stolons of the same plant. Translocation of glyphosate to rhizomes appeared to be better than to untreated stolons of the same plant.

Kikuyu grass plants were established from single node cuttings of stolons and rhizomes. Plants from stolons were always bigger than plants from rhizomes.

EPTC and fluazifop-butyl were evaluated for control of Kikuyu grass in sunflower. Fluazifop-butyl gave good control of Kikuyu grass. EPTC did not control Kikuyu grass.

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INTRODUCTION

Kikuyu grass (Pennisetum clandestinum, Hochst ex Chiov) is a creeping mat-forming perennial grass with stout rhizomes below the soil surface and long stolons above ground. It is a forage grass of a high nutritional value and is widely grown on slopes and waterways for control of soil erosion.

The grass is an aggressive weed which competes with wheat by reducing the crop stand, and is difficult to control because of the presence of rhizomes. The rhizome buds stay dormant for a long time and start growing once conditions become favourable.

Kikuyu grass requires an annual rainfall of 1,000 mm and above, and a mean temperature varying between 13 - 18 C. The grass is found in the Kenyan highlands above 1,900 m, with a cool and wet climate. These are the same areas suitable for growing wheat. The latter is a poor competitor with Kikuyu grass. When wheat is infested with Kikuyu grass, a farmer incurs grain yield reductions.

In Kenya, Kikuyu grass is controlled by tillage during the dry season. Glyphosate is used for control of this grass in tea and coffee crops.

This study was initiated to determine:

1. a tillage regime most suitable for control of Kikuyu grass,
2. a glyphosate/tillage regime that achieves Kikuyu grass control and high wheat yields,

3. the rate and time of glyphosate application that gives maximum Kikuyu grass control and highest wheat yield,

4. the duration required between glyphosate application and tillage, and

5. herbicides that are effective against Kikuyu grass in sunflower.

LITERATURE REVIEW

2.1. Introduction

Kikuyu grass, a native of East Africa, has been recorded a serious weed in tea, coffee and pyrethrum (Ivens, 1975). In California, Kikuyu grass has been reported by Zimmerman (1970) as an aggressive weed in citrus and avocado seedlings, and it has been known to kill the seedling trees. Kikuyu grass was introduced to California in the 1920's for experimental erosion control, and is now well established as a weed pest in turf. Zimmerman cautioned that if the rate of Kikuyu grass spread was not checked, Kikuyu grass would become the predominant turfgrass throughout Southern California.

Kikuyu grass is a desirable plant for erosion control and as a forage grass. In Australia, Kikuyu grass has been used to choke out braken fern, converting unusable land into good pasture (Zimmerman, 1970).

2.2. Description of Kikuyu Grass

Kikuyu grass is a creeping plant. The grass spreads by stolons and rhizomes. The stolons of Kikuyu grass are stout-branched surface runners, which root readily at the nodes (Edwards, 1935). An abundance of leaf is produced which, when ungrazed may reach 30-40 cm in length. The stolons can grow more than 3 m in a single year (Zimmerman, 1970). The leaves of Kikuyu grass are loosely hairy and up to 6 mm wide.

Kikuyu grass only flowers when the plants are under stress,such as grazing, cutting, or when moisture is limiting (Edwards, 1937; Zimmerman, 1970). The spikes are usually in clusters of two to four, the normal number being three. They are born on short side-shoots growing from the stolons. The spikelets are almost entirely enclosed by the uppermost leaf-sheath.

No conspicous flowering stems appear. The only visable evidence of flowering is a bluish-white tinge over the surface of the sward, produced by the exsertion of anthers. The anthers are borne on filaments up to 25 mm long, the upper flower is perfect and the lower one has only the stigma (Edwards, 1937).

It has been observed (Edwards, 1937; Zimmerman, 1970) that the perfect flowers bear the short purple stigmas 1-3 days in advance of the stamens. The stigma withers and often disappears before the 3 stamens are exserted (Edwards, 1937). Both the stigma and anthers are exserted during the night, and by noon the following day have been shrivelled by the sun. The stigma may persist longer than the stamens since it is covered by the glumes.

After flowering, the inflorescence bearing leaf sheath becomes a short laterial dying branch in which the seeds mature (Zimmerman, 1970). The seeds are dark, shiny brown, flat, ovoid and about 2 mm long.

2.3. Distribution of Kikuyu Grass in Kenya

Edwards (1935) has described the Kikuyu grass zone as situated between the altitudes of 6,300 and 9,970 ft. (about 1,920 and 3,040 m). Kikuyu grass requires an annual rainfall of not less than 1000 mm and a mean temperature varying between 13-18 C. Edwards estimated the potential Kikuyu grass area in Kenya as 1,813,000 - 2,072,000 hectares. Kikuyu grass exists in six main areas in Kenya (Figure 1.). They are:

(1). an area from Molo, in the south to north of Sergoit,

(2.) the ridge of highlands extending from Kikuyu through the Kinangopplateau,

(3.) a region around Mt. Kenya, to the south and east of the mountain,

(4.) an area south-east of Mt. Elgon,

(5.) an area about Kericho towards the West, and

(6.) the upper Gilgil district.

2.4. Ecology of Kikuyu Grass

Kikuyu grass forms a well-defined phase in a succession of vegetation, in the cool and moist highlands of East Africa (Edwards, 1935). The grass occupies the land for a period following clearing of the forest climax and if the return of forest is prevented, remains until the soil fertility falls below a level that can support Kikuyu grass. The plant-succession consists of the following stages:

(1.) cool forest,

(2.) *Pennisetum clandestinum* - *Trifolium johnstonii*,

(3.) *Pennisetum schiperi* - *Eleusine jaeqari*, and

(4.) *Themeda triandra*, from high to low fertility, respectively.

The *Pennisetum clandestinum* stage of the plant succession is associated with conditions of high soil fertility such as are produced under forest (Edwards, 1935). The other stages can be explained by a gradual fall in fertility, particularly with regard to organic matter. Cultivation or any stirring of the soil, temporarily produces higher

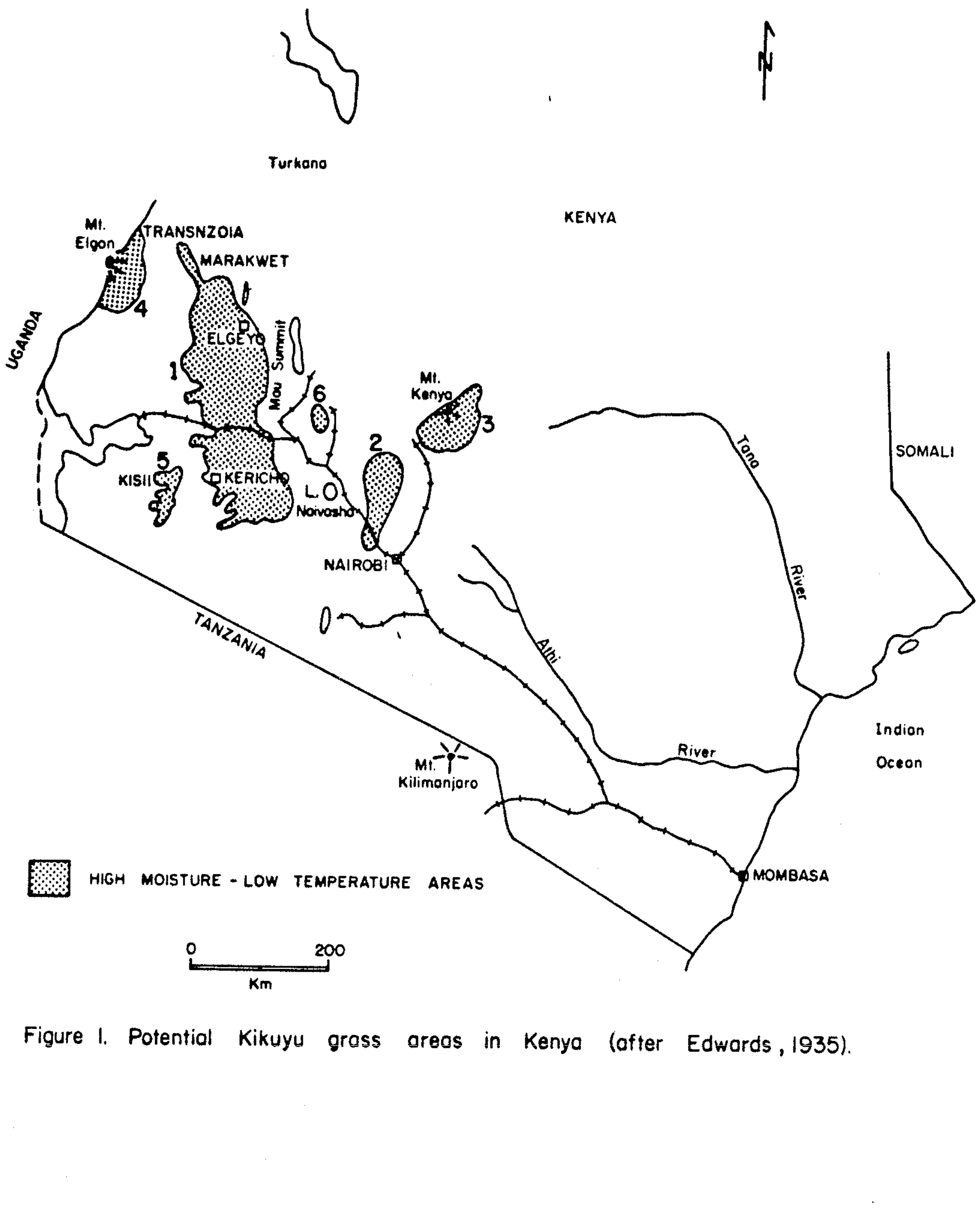

Figure 1. Potential Kikuyu grass areas in Kenya (after Edwards, 1935).

fertility and usually results in an increase of species belonging to higher stages in the succession.

2.5. Ecotypes of Kikuyu Grass

Edwards (1937) identified 3 types of Kikuyu grass showing distinct characteristics. These three types were named according to the areas of origin, Kabete, Molo and Rongai (Table 1). Besides the characteristics in Table 1, Edwards observed marked differences in habit of flowering between the three types. Molo and Kabete types were fertile while Rongai type was male sterile. Youngner *et al*. (1971) identified male sterile and fully fertile types in California.

Immediately after cutting, the Kabete type produced an abundance of anthers over the surface of the sward (Edwards, 1937). About 5

TABLE 1. Vegetative features of Kikuyu grass ecotypes. (From Edwards 1937)

Characteristic	Kikuyu Grass Type		
	Molo	Kabete	Rongai
leaf colour	light green	light green	dark green
leaf width	narrow	intermediate	broad
herbage appearance	fine	intermediate	coarse
thickness of creeping stem	slender	intermediate	thick
occurance of maximum growth stems	near the centre of the plant (domed shape)	even growth over the whole surface	ends of creeping stems (scooped out) appearance

days later stigmas appeared sparingly. The stigmas increased in proportion until they were approximately equal in number to anthers, and then anthers again became predominant about 22 days after cutting. In the Molo type scattered florets exserted anthers in the first few hours after cutting and some days later stigmas appeared in about equal quantities. By the fourteenth day stigmas predominated. Later, the proportion of florets showing anthers and stigmas became approximately equal. In the Rongai type, stigmas were exerted about 5 days after cutting.

As observed by Edwards (1937) the mode of recovery after cutting was different for the 3 types. The Rongai and Molo types could withstand more frequent cutting than the Kabete type.

2.6. Spread of Kikuyu Grass

Kikuyu grass spreads by seed and vegetative parts (Zimmerman, 1970). In pastures where Kikuyu grass is grazed the seeds are spread in cattle manure. In California, stem sections and seed have been shown to move in waterways. Kikuyu grass seed or single nodes are easily transmitted from one area to another in the mud on shoes as well as on farm equipment (Zimmerman, 1970).

2.7. Control of Kikuyu Grass

Tillage regimes, herbicides and a combination of tillage/ herbicide regimes have been used to achieve successful control of Kikuyu grass and other perennial grasses (Kolbe, 1961; Zimmerman,1970; Weed Research Organization, 1969-1970; Ivens, 1975; Bortland, 1973;

McMaugh, 1971; Youngner et al., 1971; Magambo et al., 1983).

2.7.1. Tillage

For tillage to be successful in the control of Kikuyu grass the weather conditions have to be dry for a prolonged period (Ivens, 1975; Youngner et al., 1971; Zimmerman, 1970; Kolbe, 1961). Kolbe (1961) suggested the following sequence of events to break up land which has formed a Kikuyu grass mat:

1. Two pre-discings with a harrow in January.
2. Leaving for two weeks to weather.
3. Following with a 2nd unit or rotovator.
4. Plow under with a mouldboard plow.
5. Leaving to weather for 1 month.
6. Finally breaking down with a disc harrow.

He advised the small farmers to plant Rose Coco or Canadian Wonder beans (*Phaseolus vulgaris*) and large scale farmers to plant oats (*Avena sativa*) as a smother crop.

For eradication of Kikuyu grass by cultivation, Youngner et al. (1971) proposed that a clean cultivation approach during the dry season would be successful, if sufficent time was available. The procedure was as follows: Cultivate or disc several times allowing the soil to dry out thoroughly. Irrigate to bring up seedlings and new growth of dormant rhizomes. Repeat the discing-drying and irrigation process until no live Kikuyu grass is noted for several weeks after irrigation.

By comparison, the key role of cultivation for the control of quackgrass (*Agropyron repens* L. Beauv) is the fragmentation of the rhizomes to stimulate their dormant buds into an active, and therefore, vulnerable state (Weed Research Organization, 1969-1971). In the wet autumn of 1968, a single rotary cultivation set to give a coarse chop and followed after an interval by plowing was reported to have reduced shoot emergence of quackgrass by an average of 80 percent. The disc cultivator gave good results by disrupting the rhizome system when it was operated at high speed and at shallow depth.

2.7.2. Herbicides

Researchers have used different herbicides for the control of Kikuyu grass and other perennial weeds and obtained various levels of success (Bortland, 1973; Magambo et al., 1983; McMaugh, 1971; Weed Research Organization, 1969-1971; Youngner et al., 1971; Zimmerman, 1970).

Bortland (1973) working in Zimbabwe described the following herbicide regime for control of perennial grasses, such as Kikuyu grass, couch grass and paspalum species in established orchard or plantations:

1. Apply paraquat at 1.0 - 1.5 l/ha in late autumn.
2. Apply dalapon at 5.0 kg/ha on vigorous regrowth.
3. Apply dalapon at 5.0 kg/ha approximately 6 weeks later or paraquat at 1.0 - 1.5 l/ha 10 - 14 days later.

Subsequent regrowth should be treated in a similar way. Repeated applications of dalapon at 5 kg/ha have been reported to achieve good control of Kikuyu grass (Youngner et al., 1971). Thus by a process of progressive exhaustion perennial grasses should be eradicated. However, Magambo et el. (1983) did not achieve satisfactory control of

Kikuyu grass with dalapon at 5 kg/ha in a single application. They found fluazifop-butyl ineffective against Kikuyu grass but reported excellent control with glyphosate at 2 kg/ha.

McMaugh (1971) achieved 100 percent kill of Cynodon, Pennisetum and Digitaria with siduron at 40 kg/ha applied in late summer. By comparison, dalapon, TCA and amino triazode have been used for control of quackgrass for many years with varying success (Weed Research Organization, 1969-1971). Best control of quackgrass was obtained using a combination of cultivation and TCA. The technique of quackgrass control by repeated applications of paraquat at low dose was a useful techique in a variety of farming conditions, particularly, when the weather was too wet to permit cultivations. Sodium 2,2,3,3, -tetrafluoro-propionate (Orga 3045) was found to give good control of quackgrass at 2 - 4 kg/ha either pre or post-emergence.

Selective control of Kikuyu grass in turf using MSMA has been reported by Youngner et al. (1971). Control was achieved by repeated application of MSMA at 4 kg/ha approximated three weeks apart.

For rapid control of Kikuyu grass, Youngner et al. (1971) recommended methyl bromide fumigation under a plastic tarpaulin. This method would be suitable for very small infestations in either open ground or in turf. Cultivation to break up thatch and loosen the surface soil prior to fumigation would assure better penetration of the gas and consequently better kill of the plants.

One of the most difficult aspects of Kikuyu grass control is the destruction of seeds buried in the soil (Youngner et al., (1971). The seed has an extremely hard coat, and is highly resistant to imbibing water. Germination is very eratic and seeds may lie in the soil for years before germination. The dormant seed is not killed by most of the herbicides. Pre-emergence herbicides generally affect seed only when they are in the stages of germination or early seedling growth. The dormant seeds may not germinate until long after the herbicide has been degraded in the soil. If some chemical or practice could be found that would stimulate all the seeds to germinate at once, a great advancement in Kikuyu grass control would have been made.

2.7.3. Combination of Tillage and Herbicides

Prior to establishment of new orchards and plantations of coffee and tea, Bortland (1973) working in Zimbabwe, recommended for control of perennials such as, Kikuyu, couch and paspalum, the following tillage/herbicide regime:

1. Winter plow at least 12 months before planting.

2. Apply dalapon at 15 kg/ha the following spring to any patches of grass that survived. Split application of dalapon i.e. 7.5 kg/ha followed by 7.5 kg/ha 10 - 14 days later was reported to give better results.

3. Further regrowth should be treated with paraquat 1.0 - 1.5 l/ha.

2.8. Glyphosate for Control of Perennial Weeds

Glyphoste (N-phosphonomethyl glycine) is a water-soluble formulation of the isopropylamine salt of glyphosate. Glyphosate is a broad-spectrum, foliage-active herbicide commonly used to control weeds prior to planting a crop (Salazar and Appleby, 1982). Glyphosate is slowly translocated throughout the plant system giving destruction of underground roots and rhizomes, thereby controlling many deep rooted perennial species (Spurrier, 1973). Soil persistence of the herbicide is negligible.

Bingham et al. (1980) obtained 100 percent control of perennial ryegrass (Lolium perenne), orchard grass (Dactylis glomerata L), Kentucky blue grass (Poa pratensis L), red fescue (Festuca rubra L) and bent grass (Agrostis tenuis sibth) with glyphosate at 2.24 kg/ha. Glyphosate has been shown to be effective in controlling common milk weed (Asclepias syriaca L) (Wyrill and Burnside, 1976). The effectiveness of glyphosate against yellow nutsedge (Cyperus esculentus L), field bindweed (Convolvulus arvensis L) and Canada thistle (Cirsium arvense) (L) (Scop) has been reported by Sprankle et al. 1975.

Chawdhry (1975) obtained excellent control of sedges (Cyperus sp), couch grass (Digitaria scalarum Scweinf), and Bermudagrass (Cynodon dactylon) with glyphosate at 6 kg/ha sprayed at 3 month intervals. Control of couch grass with glyphosate at 2 kg/ha has been reported by Terry (1974). Zandstra and Nishimoto have reported successful control of purple nutsedge (Cyperus rotundus L) with glyphosate. McWhorter et al. (1980) and Lolas and Coble (1980) have reported glyphosate as one of the effective herbicides available for control of Johnsongrass (Sorghum halepense). At 3.4 and 4.5 kg/ha of glyphosate, Banks and Santelmann (1977) obtained maxium control of Johsongrass when the treated plants were at least 60 cm in height. Glyphosate has been reported to be very effective against Bermudagrass and horsenettle (Solanum carolinense L) (Whitwell et al., 1980). Effective control of Bermudagrass with glyphosate has also been reported by Fernadez and Bayer (1977) and Jordan (1981). Weed Research Organization (1972-1973) obtained good control of quackgrass with glyphosate at 1-2 kg/ha. Quackgrass control with glyphosate has been reported as good to excellent (Wyse, 1980; Ivany, 1981; Rioux et al., 1974; Westra et al., 1981; Davis et al., 1979; MacIntyre and Hsiao, 1982; Claus and Behrens, 1976).

2.9. Glyphosate Absorption

Glyphosate enters the plant through the aerial, chlorophyll containing parts (Caseley and Coupland, 1983). Diffusion is the most likely process for transport of solutes across the cuticle. A polar water soluble compound such as glyphosate probably penetrates the cuticle via the hydrophilic pathway (Caseley and Coupland, 1983). Cutin and carbohydrate fibres provide a polar route among the non-polar waxy portions of the cuticle.

Glyphosate penetration is characterized by an initial fast entry, followed by a longer phase of slower penetration (Caseley and Coupland, 1983). Brecke and Duke (1980), working with bean leaves, found rapid cuticular penetration over 4 hours, but very slow uptake of glyphosate by mesophyll cells. Gougler and Geiger (1981) studied glyphosate entry into the mesophyll of isolated sugar beet (*Beta vulgaris*) leaf discs and concluded that the concentration depedence of uptake and slow exodiffusion from the tissue was indicative of a passive mechanism. Richard and Slife (1979) demonstrated that glyphosate uptake by mesophyll cells of hemp dogbane (*Apocynum cannabinum* L) was concentration depedent and that glyphosate was not tightly bound to cellular components. They suggested that the negative charges of the cell wall and plasmalemma repel the strongly anionic glyphosate. This lack of strong binding would contribute to the movement of glyphosate in the apoplast. Slow penetration of the symplast could be a major barrier to the continued foliar absorption of glyphosate.

2.9.1. Processes Affecting Glyphosate in the Leaf

Caseley and Coupland (1983) reported that reducing the stomatal operture led to a reduction in transpiration. Reduced transpiration resulted in less removal of glyphosate in the apoplast and, therefore, the concentration gradient across the cuticle was reduced, thus limiting glyphosate uptake. Increase in water potential increased glyphosate entry as a hydrated cuticle favours uptake. A reduction in carbon dioxide fixation led to a reduction in glyphosate removal in the phloem, which in turn reduced the concentration gradient across the cuticle.

2.10. Factors Affecting Glyphosate Absorption

2.10.1. Concentration

Merritt (1982) applied the same dose per plant at 3 concentrations to garden radish (*Raphanus sativa*) and wild oats (*Avena fatua*) and the most concentrated glyphosate formulation was always the most toxic.

2.10.2. Droplet Size

Merritt (1982) reported that applying the same dose in drops of 200 or 400 mm diameter had no effect on glyphosate phytotoxicity on garden radish and wild oats.

2.10.3. Pre-spraying with Glyphosate

Schultz and Burnside (1980) found no difference in glyphosate entry and movement in hemp dogbane with or without a previous overall spray of formulated glyphosate. McAllister and Haderlie (1980) found that pre-spraying soybeans led to decreased glyphosate entry.

2.10.4. Site of Applications

Coupland et al. (1978) found that application of glyphosate to the adaxial surface of the lamina tip of quackgrass resulted in less damage than application to the lamina base. Coupland (1983) found that most phytotoxicity resulted from deposition of glyphosate on the adaxial surface of the leaf sheath. This is a smooth area free of epicuticular wax, compared with the lamina which is covered with dense wax platelets. In garden radish, Merritt (1982) observed the greatest activity when glyphosate was applied to the interveinal areas of true leaves. Glyphosate was less active when applied on cotyledons.

2.11. Other Routes Through which Glyphosate Enters the Plant

Turner and Loader (1974) demonstrated that solubilized oil formulations enable glyphosate to penetrate the bark of woody species. Roots of plants in nutrient solution containing glyphosate absorb the herbicide which moves throughout the plant (Haderlie et al., 1978; Penn and Lynch, 1982). Haderlie et al. (1978) reported that uptake of glyphosate, from sterile quartz sand, by germinating maize (Zea Mays) or soybean (Glycine max) seeds was minimal on weight basis until when the radicle became functional. Uptake in soybean seedlings was 10 times greater, on weight basis, than in maize. Germination of either species was not affected by glyphosate concentration upto 10^{-3}M, but seedling axis elongation was inhibited in soybeans at 15^{-4}M and in maize at 10^{-3}M. In both species major accumulation occurred in the radicle, with movement into the tip and some into the mesocotyl and coleoptile.

Penn and Lynch (1982) found that exposure of barley roots to glyphosate for 45 minutes had no apparent effect at 32 mg/l or less, but at 321 and 3210 mg/l it caused some wilting and chlorosis. The plants were not killed, later healthy leaves emerged. When the roots of wheat and barley were exposed to glyphosate for 24 hours, 18 days later, all the plants had died except those at concentrations of 3.2 and 6.4 mg/l, where emerging third leaves of some plants appeared healthy.

Salazar and Appleby (1982) found that seedlings of bent grass were damaged following the placement of seed on organic soil previously sprayed with 3.4 kg/ha of glyphosate. Baird et al. (1971) found that 30 kg/ha of glyphosate did not affect maize or soybean plants sown soon after treatment.

2.12. Translocation of Glyphosate

Successful control of perennial weeds with foliar-applied herbicides depends on absorption and basipetal translocation of the biologically active compound into the underground storage organs (Sprankle et al., 1975). Adsorption and translocation should be rapid to allow underground storage organs to accumulate sufficient quantities of the compound, to kill the entire plant before metabolism can degrade the compound.

Glyphosate has been observed to move to the leaf tip and the rapidly growing rhizomes, roots and untreated shoots of quackgrass (Sprankle et al., 1975). The movement of glyphosate was primarily in the phloem with the photoassimilates following the source to sink relationships. Claus and Behrens (1976) reported measurable amounts of glyphosate in all quackgrass rhizome node segments 3 days after treatment. They observed a definite pattern of glyphosate accumulation. The greatest accumulation was observed in segments near the rhizome tips while the lowest accumulation was observed in segments near the mother shoots. Weed Research Organization (1972-1973) also observed a similar pattern of glyphosate accumulation in quackgrass rhizome buds. In yellow nutsedge, glyphosate was reported by Sprankle et al. (1975) to have moved acropetally in the treated shoot and basipetally into the untreated shoots and developing tillers. They observed similar movements of glyphosate in Canada thistle.

In common milk weed and hemp dogbane glyphosate has been found to translocate in the phloem and accumulate in greater concentrations in new roots and shoots (Whitwell et al., 1980). They observed that glyphosate accumulation was greater in the roots and rhizomes than in the foliage of Bermudagrass. The greatest accumulation was observed in new roots, some acropetal translocation was reported in the treated sprig and into the leaves of the remainder of the plant. Sandberg et al. (1980) observed significant basipetal translocation of glyphosate in Canada thistle and wild buckwheat (Polygonum convolvulus L) between 3 and 14 days after treatment. No evident translocation of glyphosate was reported in field bindweed, hedge bindweed (Convolvulus sepium L) and morning glory (Ipomea purpures L. Roth).

In Johnsongrass, McWhorter et al. (1980) reported that most of glyphosate translocation was acropetal. In the rhizomes, they reported glyphosate translocation into actively growing buds and into adjacent plants growing from the same rhizome.

Glyphosate translocation into rhizomes and underground portions of perennial weeds has been reported to be very rapid (Spurrier, 1973). He reported that within 24 hours after foliar application, a major portion of the absorbed glyphosate would be translocated into the rhizomes. Zandstra and Nishimoto (1977) working with purple nutsedge, found the translocation of glyphosate from the treated leaf to other plant parts to increase from 5 percent of the amount applied at 1 day to 19 percent at 4 days and then decrease to 15 percent at 8 days. They attributed the reduction in amount translocated at 8 days to metabolism of glyphosate to carbon dioxide.

2.13. Factors Affecting Translocation of Glyphosate

2.13.1. Temperature

Effect of temperature on glyphosate has been reported to be dependent on species (McWhorter et al., 1980). In Johnsongrass the amount of glyphosate that translocated out of the treated area increased as the air temperature was increased from 24 to 35 C. In soybean plants they reported greater translocation at 24 C than at 29.5 C and 35 C.

The effect of temperature on translocation of glyphosate has been reported to be overcome at high relative humidities (Jordan, 1977). In Bermudagrass, more glyphosate translocation was observed at 32 C than at 22 C at 40 percent relative humidity. At 100 percent relative humidity no difference in the amount of glyphosate translocated was observed at the two temperatures.

Pre-treatment at -4 C has been reported to increase glyphosate translocation in quackgrass (Davis et al., 1979), but reduced glyphosate translocation in alfalfa plants (Medicago sativa). Weed Research Organization (1972) has recommended that the soil should be left undisturbed for longer periods after glyphosate application, as temperature drops. They found that at an air temperature of 8 C and soil temperature of 10 C it took 24 hours for all the 16 - 20 buds on glyphosate treated quackgrass plants to accumulate a lethal amount of the herbicide. At an air temperature 20 C they found it took 9 hours.

2.13.2. Relative Humidity

Whitwell et al. (1980) showed that relative humidity was important in the distribution of glyphosate in plants. High relative humidity enhanced the movements of glyphosate in Bermudagrass, Canada thistle and leafy spurge (Euphorbia esula L). Greater glyphosate translocation in Bermudagrass at 85 than at 35 percent relative humidity was observed. In the same species Jordan (1977) obtained greater glyphosate translocation at 100 than at 40 percent relative humidity. In Johnsongrass, McWhorter et al. (1980) observed more translocation of glyphosate at 100 than at 45 percent relative humidity. They found the effect of relative humidity on glyphosate translocation to be less distinct to soybeans than to Johnsongrass.

2.13.3. Soil Moisture

Soil moisture has been reported to have an effect on translocation of glyphosate (McWhorter et al., 1978; McIntyre and Hsiao, 1982). McIntyre and Hsiao have recommended that the use of glyphosate for quackgrass control should be restricted to periods when there is sufficient soil moisture to promote the active growth of the rhizomes. McWhorter et al. (1978) have reported greater glyphosate translocation at 20 than at 12 percent w/w soil moisture in a sandy loam soil.

2.13.4. Stage of Growth

It has been reported that various perennial weeds exhibit different sensitivities to glyphosate depending on their growth stage at the time of treatment (Whitwell et al., 1980). Very early treatment of perennial vegetation is usually less effective as many plants will not have emerged sufficiently to receive glyphosate (Spurrier, 1973). Perennial weeds must have adequate leaf area, 6 - 8 leaves, to permit absorption and translocation of glyphosate into the plant tissue and root system.

In quackgrass, Rioux et al. (1974) reported glyphosate translocation to the roots when applied to shoots at the 3 and 4-leaf stage but not at the 2-leaf stage. Whitwell et al. (1980) reported best control when glyphosate was applied to fully matured and fruiting horsenettle plants and flowering Canada thistle. They obtained greater rhizome bud kill when glyphosate was applied to quackgrass from jointing to early heading stage than with treatments applied during early vegetative growth stages. Ivany (1975) reported better control of quackgrass with glyphosate at 4 - 6 leaf stage than at 3 - 4 leaf stage. In glass house studies, Sprankle et al. (1975) reported more glyphosate translocation in quackgrass at 1 - 2 leaf stage than at 3 - 4 leaf stage. In purple nutsedge Zandstra and Nishimoto (1977) reported no effect of growth stage on translocation of glyphosate to the tubers. The purple nutsedge plants 2 to 6 weeks of age translocated the same amount of glyphosate. As the plants developed the tubers accumulated a larger portion of the herbicide than the shoots.

2.13.5. Tillage

Tillage too soon after glyphosate application resulted in a reduction in quackgrass control (Sprankle et al., 1975). Plowing disrupts the rhizome system thus interupting further translocation. Greater quackgrass control was observed when plowing was done one day after glyphosate application than when plowing was done the same day after glyphosate application. They did not achieve better control with longer periods between glyphosate application and plowing. Spurrier (1973) recommended that tillage could take place 1 to 4 days after the application of glyphosate to quackgrass without affecting the control. The performance of glyphosate was not affected by plowing 8 days after treatment (Weed Research Organization, 1969 - 1971).

Chase and Appleby (1979) reported 90 percent control of purple nutsedge with an interval of three days between application of glyphosate and tillage while 11 - 23 days intervals gave less control. Parochetti et al. (1975) found plowing from 4 - 21 days following glyphosate application to have no effect on Johnsongrass control.

2.13.6. Clipping

Clipping or mowing of vegetation just prior to application has been reported to reduce glyphosate effectiveness (Spurrier, 1973). He recommended that after clipping, the species should be allowed to regenerate sufficient new growth for absorption of the herbicide.

Rioux et al. (1974) found that cutting the foliage too soon after glyphosate application resulted in poor control of quackgrass. They did not obtain any quackgrass control when foliage was cut immediately after application. They obtained better control when foliage was cut 1 day after application.

2.14. E.P.T.C. For Control of Perennial Grasses

EPTC (ethyl NN-dipropylthiolcarbamate) is widely used for control of grass weeds (Rahman et al., 1979), both annual and perennial, such as, quackgrass (Wyse, 1980). Initially EPTC was applied on the soil surface for control of germinating weed seeds (Danielson, 1961). Studies conducted in 1958 showed that the activity of EPTC could be greatly increased by soil-incorporation immediately after application. Since then EPTC is used as a soil incorporated herbicide. Two formulations are available, Eptam which is EPTC alone and Eradicane which is EPTC plus an antidote, which protects the maize crop from herbicide injury (Rahman et al.).

Roeth (1973) found EPTC effective against seedborne Johnsongrass but ineffective against rhizome buds. He reported that EPTC suppressed germination and growth of purple nutsedge tubers in the soil. Holly (1976) has reported EPTC as one of the few herbicides giving useful control of purple nutsedge in cotton. Subsurface application of EPTC has been reported to give good control of yellow nutsedge (Hauser et al., 1966).

Above the concentration of 2 ppm, EPTC was reported to have killed all barnyardgrass seedlings (Echinoculoa crusigalii) (Dawson, 1963). He found that seed germination was not affected by EPTC. No injury was found when he exposed the seed and primary root to EPTC, whereas when he exposed the shoot or the coleoptile injury occured. Cartwright (1976) reported EPTC to injure the coleoptile of barnyard grass thus reducing its ability to penetrate the soil.

Johnson (1974) obtained 88 percent control of common Bermudagrass using EPTC as a foliar spray at 6.7 kg/ha in 2 applications at 6 - 7 week intervals. However, regrowth occurred. Elliot and Purnell (1976) reported that EPTC at 4.6 kg/ha gave excellent control of quackgrass and annual weeds. Brockman et al. (1973) found that EPTC at 4.5 kg/ha incorporated before seeding lucerne improved control of quackgrass by glyphosate at 1.14 - 2.27 kg/ha.

2.15. Factors Affecting the Efficiency and Persistence of EPTC the Soil

2.15.1. Depth of Incorporation

Gray and Weierich (1965) found that incorporation to at least 5 to 7.5 cm was necessary to prevent large losses of EPTC when light rain or sprinkle irrigation followed application. They reported very little loss of EPTC vapor when it was applied and incorporated in a loamy sand soil containing 10 percent (W/W) moisture. However, at moisture levels of 14.6 percent and greater, they reported large amounts of EPTC loss in just 2 hours.

Hauser et al. (1966) obtained better control of yellow nutsedge with placement at 3.75 cm below soil surface, than with placement at 16.75 cm. He obtained better control when EPTC was incorporated into the soil by a power driven rotary hoe than with a disc harrow. Roeth (1973) reported better control of purple nutsedge when EPTC was incorporated with a rototiller or tandem disc harrow than with a mulch treader or spike tooth harrow.

2.15.2. Soil Moisture

Gray and Weierich (1965) found the rate of loss of EPTC to increase as soil moisture increased. On dry soil the rate of loss of EPTC was found to be greatest during the first 15 minutes. Little more loss occurred during the following first few hours. They suggested that loss in the first 15 minutes occurred while the spray was drying. After the spray had dried, EPTC might have been adsorbed strongly to the dry soil.

EPTC has been reported to be strongly adsorbed on dry clays and organic molecules from which it is released in the presence of water (Hartley, 1976). Koren et al. (1969) and Fang et al. (1961) have reported a stronger and more rapid adsorption of EPTC by dry soils than by moist or wet soils. They suggested that the longer persistence of EPTC in dry soils was probably due to the ability of soil particles to adsorb EPTC and thus lessen the loss by vaporization.

2.15.3. Temperature

The persistence of volatile herbicides has been reported to decrease as temperature increases (Danielson and Gentner, 1964). Gray and Weierich (1965) found that increasing the soil temperature from 0 C to 19 C increased the rate of EPTC vaporization from moist soil but did not have any effect on the loss of EPTC from dry soil. They observed a faster rate of EPTC loss on sunny days than on cloudy days. Koren et al. (1969) found high temperatures and sunny days to increase the vapor loss of EPTC. They reported that EPTC has a negative heat of solution, and therefore high adsorption rates and high solubilites at low temperatures.

2.15.4. Soil Type

Soil type has been reported by several workers as having an influence on the performance and persistence of EPTC (Danielson et al., 1961; Fang et al., 1961; Koren et al., 1969). Koren et al. (1969) reported a negative correlation between toxicity of EPTC and percent organic matter. They also reported an inverse relationship between oat injury and soil adsorption of EPTC in various soil type. They showed that oat injury was also related to the cation exchange capacity which correlated closely with the clay and organic matter content.

EPTC was found to be more persistent in soil with high organic matter (Danielson et al., 1961). Fang et al. (1961) found loss of EPTC by evaporation to be greatest in light textured soils, less in heavy soils and least in peat. They observed a close relationship between the loss of EPTC and the amount of organic matter, clay content or the summation of both.

2.15.5. Previous Use of EPTC

The reduction of EPTC efficiency with continued use was first reported in New Zealand (Rahman et al., 1979). They obtained poor control of rough bristle grass (Setaria verticillata) with EPTC on blocks where EPTC had been used previously, but excellent control on the blocks which had previously received alachlor. They attributed the reduced activity to a faster rate of microbial breakdown in soils which had received EPTC in previous years. Obrigawitch et al. (1981) observed more rapid degradation of EPTC in soils that had prior exposure to EPTC. They found that one application of EPTC the previous year was sufficient to enhance the breakdown rate of EPTC.

EPTC inactivation in autoclaved soil was found to be one third of that in a corresponding unautoclaved soil (Fang et al., 1961). From this observation, they suggested that microbial breakdown was the major pathway of inactivation when EPTC was incorporated in the soil.

O, O-diethyl-O-phenol phosphorothioate (R-33865) when added to EPTC was found to extend EPTC persistence in soils with previous EPTC use, and provided increased shattercane (Sorghum bicolar (L) Moech) control (Obrigawitch et al., 1982). Addition of R-33865 to EPTC on soils with no prior EPTC treatment did not extend persistence of EPTC in soil.

2.15.6. Air Movement and Formulation of EPTC

Persistence of EPTC applied to soil surface has been reported to be inversely related to wind velocity (Obrigawitch et al., 1981; Danielson and Gentner, 1964).

Granular formulation was found to have advantages over sprays of EPTC on dry soils, but not on moist soils (Gray and Weierich, 1965). Little loss of EPTC was oberved when after 24 hours when granules were applied to the surface of dry soil, but a considerable amount was lost after 3 days. EPTC was lost quite rapidly the first 2 hours after applying the granules to moist and wet soil.

2.16. Fluazifop-butyl for Control of Perennial Grasses

Fluazifop-butyl (butyl 2-[4-{5-(trifluoromethyl)-2-pyridinyl)oxy} phenoxy]propanoate)is a selective post-emergence grass killer (Weed Science Society of America, 1983). Fluazifop-butyl controls both annual and perennial grasses in broadleaf crops.

Fluazifop-butyl translocates throughout the grass plant, moving from the foliage into the roots, rhizomes, stolons and growing points, and the entire plant is killed (Anderson, 1983). The phytotoxic action of fluazifop-butyl is slow. Even though growth ceases soon after fluazifop-butyl application, the process of killing the entire grass plant may take several weeks (Anderson, 1983).

Fluazifop-butyl is rapidly foliar absorbed and rain falling 1 hour after application results in little loss of its activity (Anderson, 1983). It is recommended that either a nonionic surfactant or an oil concentrate be added to the spray mixture at a concentration of 0.1 to 0.25 percent by volme to enhance foliar absorption.

Fluazifop-butyl should be applied to annual grasses when they are 5 - 15 cm tall, but best results are achieved when they are 5 - 7.5 cm tall (Anderson, 1983). Dosage for annual grass control range from 0.28 - 0.56 kg ai/ha. Perennial grass control may require 2 applications spaced 1 - 3 weeks apart at the rate range of 0.14 - 1.14 kg ai/ha.

MacQuarrie et al. (1983) applied fluazifop-butyl as a single application at 3 - 4 leaf stage of quackgrass at the rate of 0.5 kg/ha, at 5 - 6 leaf stage at the rate of 0.6 kg/ha and as split applications at the 2 stages at the rate of 0.3/0.4 kg/ha. All the above treatments were effective in controlling quackgrass during the first season. Drought conditions during the second season decreased the efficacy of fluazifop-butyl.

Dale (1983) evaluated the control of goose grass (Eleusine indica) using fluazifop-butyl in tung oil which was applied to soybean seed at the rates of 0.5 - 6.4 g ai/kg of seed. Soybean seeds pre-treated with fluazifop-butyl at 2.2 - 4.4 g ai/kg seed gave 100 percent control of goose grass, at the sowing rate of 4 seeds/pot. Eighty to ninety percent control of goose grass was obtained when soybean plants were sown at 1 seed/pot.

Cotton seeds, pre-treated with fluazifop-butyl at 2.2 g ai/kg seed and sown 4 cm apart in a row across a 20 by 20 cm tray of soil, containing barnyard grass seed, produced a weed free band 12 cm wide, centred on the row of cotton.

Harrison et al. (1983) conducted field studies to determine the optimum application date of fluazifop-butyl applied at 0.28 kg/ha plus one percent v/v crop oil concentrate, for the control of giant foxtail (Seteria faberi Herm). When fluazifop-butyl was applied early in the growing season, excellent early season giant foxtail control was observed. However, giant foxtail was able to reinfest before soybeans were able to canopy and thus reduced soybean yields. Late season applicatons of fluazifop-butyl provided good giant foxtail control, although the competitive effect exerted by giant foxtail before application of fluazifop-butyl resulted in reduced soybean yields.

Stewart et al. (1982) reported that fluazifop-butyl applied at 0.25 kg/ha gave excellent control of wild oats and goose grass.

Fluazifop-butyl applied at 0.5 - 0.75 kg/ha was required to give excellent control of perennial rye grass, dallis grass (Paspalum dilatatum), Bermudagrass, barnyard grass, green foxtail, quackgrass and canary grass (Phalaris canarviensis).

Harger et al. (1982) achieved 88 - 90 percent control of itchgrass (Rottoboellia exultata L) with fluazifop-butyl at 0.5 kg/ha. Renner and Harvey (1983) reported excellent control of wild proso millet (Panicum miliaceum L) and acceptable control of giant foxtail when fluazifop-butyl was applied.

MATERIALS AND METHODS

Field experiments were conducted at National Plant Breeding Station, Njoro in 1981 - 1984, on well drained, deep, dark reddish brown, friable clay with humic topsoil.

In 1981 - 1982 the experiments were conducted on Kikuyu grass sod. In 1982 - 1983, the experiments were conducted on wheat stubble. The stubble was treated with herbicides Buctril-M and Banvel Combi (for details on herbicides see Appendix 1) for control of broad-leaved weeds in late October 1982.

3.1 Tillage Equipment Used

The mouldboard plow had 3 bottoms and was 1.60 m wide. The disc plow had 3 discs with a diameter of 61.25 cm and was 1 m wide. The chisel plow had 9 blades arranged in 3 rows, 6.25 cm wide and 32.5 cm long, and was 2.4 m wide. The heavy disc harrow had 24 serated discs with a diameter of 53.75 cm, arranged in two rows, and was 2.7 m wide. The light disc harrow had 20 discs with a diameter of 55 cm, arranged in two rows, with the rear ones serated. The light disc harrow was 2.0 m wide. The Triple "K", which was staggered, had spring loaded tines, and was 2 m wide.

3.2. Wheat

3.2.1. Seedbed Preparation

In 1981 - 1982 unless otherwise stated, the sod was plowed with a mouldboard plow. The plowing was followed by a light disc harrow two weeks later.

In 1982 - 1983 three experiments were sown with wheat. Tillage operations are described under each experiment. Before seeding, the whole experimental area under wheat was harrowed with a heavy disc harrow on May 27. This tillage was done to level out the seedbed.

3.2.2. Spraying

Individual plots were sprayed with a bicycle mounted 4 nozzle sprayer. In 1981 - 1982 hollow cone nozzles with an output of 126 l/ha, were used to apply glyphosate, at a pressure of 2.2 bars.

In 1982 - 1983 flat-fan nozzles, Tee jet 80015 with an output of 170 l/ha, were used to apply glyphosate, at a pressure of 2.67 bars.

When herbicides were applied as a blanket treatment on the whole experiment area, a commercial sprayer was used.

3.2.3. Seeding and Fertilization

In 1982, Kenya Paa wheat was seeded using the Agronomy plot seeder (double disc) on May 29, at a rate of 100 kg/ha. Di-ammonium phosphate fertilizer at the rate of 100 kg/ha was applied with the seed.

In 1983, Kenya Tembo wheat was seeded using a commercial wheat seeder (International double disc drill) on May 30, at the rate of 160 kg/ha. Mono-ammonium fertilizer at the rate of 180 kg/ha was applied.

In both years wheat seed was dressed with copper oxychloride at the rate of 1 kg/100 kg seed.

3.2.4. General Weed Control

In 1982 Maytril at 2 l/ha was applied using a commercial sprayer on June 23 for control of broad-leaved weeds. Illoxan at 3 l/ha was applied on June 17 for control of annual setaria.

In 1983 Buctril-M at 1.4 l/ha was applied using a commercial sprayer on June 22 for control of broad-leaved weeds.

In both years copper oxychloride was applied together with the herbicide at the rate of 1 kg/ha.

3.2.5. Harvesting

Wheat was harvested using a Hege small plot combine harvester with a cutting width of 1.5 m.

Moisture content was determined and the weights adjusted to 12.5 percent moisture.

3.2.6. Plot Size

The treated and seeded area in 1982 was 15 m by 6 m of which an area of 15 m by 1.5 m was harvested from each plot. In 1983, the treated and seeded area was 10 m by 6 m of which an area of 10 m by 1.5 m was harvested.

3.3. Sunflower

3.3.1. Spraying

Eradicane and Eptam were applied with flat fan nozzles Teejet 6502 with an output of 226 l/ha in 1982 and flat fan nozzles Teejet SS6503 with an output of 317 l/ha in 1983, respectively. In 1982 the spraying pressure was 2.2 bars, and in 1983, 2.67 bars. Fluazifop-butyl was applied with flat fan nozzles, Teejet 80015 with an output of 170 l/ha.

3.3.2. Seeding and Fertilization

Kensun variety was grown in 1982 and Hybrid 307A in 1983. In both years seeding was done using a commercial maize seeder at a spacing of 70 cm by 35 cm. In 1982, di-ammonium phosphate fertilizer was placed with the seed at the rate of 100 kg/ha. In 1983, mono-ammonium phosphate fertilizer, at the rate of 100 kg/ha, was used for first seeding. Due to drought, the sunflowers did not germinate. Di-ammonium phosphate fertilizer, at the rate of 100 kg/ha, was used for the second seeding.

3.3.3. General Weed Control

When the sunflower were small broad-leaved weeds were pulled out of the plots by hand. Later, when the sunflowers were tall, bromoxynil at 2 l/ha was used as a directed spray for control of broad-leaved weeds.

3.3.4. Harvesting

In each plot 10 random 3-meter row subplots were harvested. Sunflower heads were cut by hand and threshed with sticks to remove the seeds. The seeds from each plot were bulked and weighed.

Depredation of the crop by birds was severe,particularly around the outside edges of the experimental area.

3.3.5. Plot Size

In 1982, sunflower plots were 20 m by 6 m. In 1983 the plots were 15 m by 6 m.

3.4. Kikuyu Grass Cover Assessments

A one square meter quandrant was thrown at random in the plots. The area covered by Kikuyu grass was recorded as a percent of the area in the quandrant. Kikuyu grass cover was taken 6 - 7 times in each plot. Average cover was determined excluding the greatest and the smallest values.

3.5. Data Collected

In addition, regrowth from stolons and rhizomes was determined.

3.6. Experimental Design

Unless otherwise noted, all experiments were conducted using a completely randomized block design with four replicates. All data was statistically analysed, and differences were determined using Turkey's W procedure. Only differences at 5 percent level were considered meaningful.

3.7. Experiment 1: Control of Kikuyu grass in wheat using tillage and glyphosate in combination with tillage, 1981 - 1982, 1982 - 1983.

3.7.1. 1981 - 1982

The treatments in experiment 1 were as described in Table 2. The chisel plow clogged repeatedly and resulted in a rough seedbed.

TABLE 2. Tillage and glyphosate treatments and date of operations performed in Experiment 1, 1981 - 1982.

Treatment Number	Operation	Passes	Date Performed
1.	Mouldboard plow	1	Nov.13.1981
	Light disc harrow	2	May 11.1982
2.	Chisel plow	2	Nov.17.1981
	Disc plow	1	Nov.17.1981
	Disc harrow	1	May 11.1982
3.	Chisel plow	3	Nov.17.1981
	Chisel plow	2	May 13.1982
4.	Disc harrow	3	May 12.1982
5.	Chisel plow	3	May 13.1982
6.	Mouldboard plow	1	Nov.13.1984
	Chisel plow	2	May 13.1982
7.	Glyphosate at 21/ha		Oct.30.1981
	Glyphosate at 21/ha		May 4.1982
	Disc harrow	1	May 12.1982
	Chisel plow	2	May 13.1982
8.	Glyphosate at 31/ha		Oct.30.1981
	Disc harrow	1	May 12.1982
	Chisel plow	2	May 13.1982
9.	Glyphosate at41/ha		Oct.30.1981
	Disc harrow	1	May 12.1982
	Chisel plow	2	May 12.1982
10.	Glyphosate at 31/ha		May 4.1982
	Disc harrow	1	May 12.1982
	Chisel plow	2	May 13.1982
11.	Glyphosate at 41/ha		May 5.1982
	Disc harrow	1	May 12.1982
	Chisel plow	2	May 13.1984

The experiment was not seeded The plots were evaluated for Kikuyu grass control on the 0 - 9 scale on June 17,1982 where 0 means no control and 9 means 100 percent control.

3.7.2. 1982 - 1983

The treatments in Experiment 1, are described in Table 3. Assessment of Kikuyu grass cover were made on July 26, August 24 and November 11,1983. The wheat was harvested on November 3,1983.

3.8. Experiment 2: Effect of time of tillage following glyphosate application on Kikuyu grass cover, regrowth of stolon and rhizome pieces and wheat yield, 1981 - 1982, 1982 - 1983.

3.8.1. 1981 - 1982

Glyphosate was applied at 3 l/ha. At the designated time (Table 4) each plot was plowed with mouldboard plow then harrowed with a light disc harrow two weeks later. Just prior to seeding, the whole experimental area was harrowed with a light disc harrow once, and followed with a Triple "K".

Between June 3 and 12, stolons and rhizomes were dug out from 4 randomly selected 1 m^2 areas in each plot. The stolons and rhizomes were thoroughly mixed and divided into 4 equal parts. One part was cut into 10 cm pieces. These pieces were planted in wooden flats (0.75 m by 0.5 m by 0.1 m). On July 7 the pieces that had sprouted were counted. No attempt was made to group the stolons and rhizomes separately, since it was difficult to distinguish them.

The assessment of Kikuyu grass cover was made on June 27. The wheat was harvested in October. The data was analysed as a factorial

TABLE 3. Tillage and glyphosate treatments and date of operations performed in Experiment 1, 1982 - 1983.

Treatment Number	Operation	Passes	Date Performed
1.	Mouldboard plow	1	Nov.05.1982
	Disc harrow	2	Mar. 1983
	Disc harrow	1	May 18.1983
2.	Disc plow	1	Nov.05.1982
	Disc harrow	2	Mar. 1983
	Disc harrow	1	May 18.1983
3.	Chisel plow	2	Nov.05.1982
	Chisel plow	1	Mar. 1983
	Disc harrow	1	May 18.1983
4.	Disc harrow	2	Mar. 1983
	Disc harrow	2	May 18.1983
5.	Chisel plow	3	Mar. 1983
	Disc Harrow	1	May 18.1983
6.	Mouldboard plow	1	Nov.05.1982
	Chisel plow	1	Mar. 1983
	Disc harrow	1	May 18.1983
7.	Glyphosate 2 l/ha		Nov.05.1982
	Glyphosate 2 l/ha		May 14.1983
	Disc harrow	2	May 18.1983
8.	Glyphosate 3 l/ha		Nov.05.1982
	Disc harrow	2	May 18.1983
9.	Glyphosate 4 l/ha		Nov.05.1982
	Disc harrow	2	May 18.1983
10.	Glyphosate 3 l/ha		May 11.1983
	Disc harrow	2	May 18.1983
11.	Glyphosate 4 l/ha		May 11.1983
	Disc harrow	2	May 11.1983

TABLE 4. Date of glyphosate application and tillage operation in Experiment 2, 1981 - 1982.

Date of Glyphosate Application	Date of Tillage	Days to Tillage
Nov.06.1981	May 14.1982	194
Nov.06.1981	Nov.12.1981	6
Nov.06.1981	Nov.16.1981	10
Nov.06.1981	Nov.21.1981	15
Nov.06.1981	Nov.27.1981	21
May 5.1982	May 14.1982	9
May 5.1982	May 10.1982	5
May 6.1982	May 14.1982	8
May 6.1982	May 18.1982	12
May 6.1982	May 22.1982	16

1. Number of days from glyphosate application to the initial tillage.

TABLE 5. Date of glyphosate and tillage operations in Experiment 2, 1982 - 1983.

Treatment Number	Treatment Date of Glyphosate application	Date of Tillage	Days to Tillage
1.	Nov.05.1982	May 27.1983	200
2.	Nov.05.1982	Nov.08.1982	3
3.	Nov.05.1982	Nov.13.1982	6
4.	Nov.05.1982	Nov.17.1982	12
5.	Nov.05.1982	Nov.20.1982	15
6.	No spray	Nov.05.1982	-
7.	May 9.1983	May 27.1983	18
8.	May 9.1983	May 12.1983	3
9.	May 9.1983	May 16.1983	7
10.	May 9.1983	May 20.1983	11
11.	May 9.1983	May 24.1983	15
12.	No spray	May 20.1983	-

experiment.

3.8.2. 1982 - 1983

Glyphosate was applied at 3 l/ha (Table 5). Treatment 6 received no glyphosate but was plowed with a mouldboard plow on November 5,1982 and harrowed with a light disc harrow in March 1983. Treatment 12 received no glyphosate and was plowed with a mouldboard plow on May 20 and harrowed with a heavy disc harrow on May 24. Treatments 2 - 5 were harrowed with a heavy disc harrow two times at the designated dates. Treatments 8 - 11 were plowed with a mouldboard plow on the designated date and harrowed with a heavy disc harrow on May 24. Treatments 1 and 7 were harrowed on May 27 together with the other treatments.

The assessment of Kikuyu grass cover was made on July 26, August 25 and November 11,1983. The wheat was harvested on November 3,1983. The data was analysed as a factorial experiment.

3.9. Experiment 3: Effect of time of application and rate of glyphosate on Kikuyu grass cover and wheat yield.

Glyphosate was applied at 3 rates on 4 dates (Table 6). All the plots were plowed with a mouldboard plow on May,12,1983 and harrowed with a heavy disc harrow on May 18.

The assessment of Kikuyu grass cover was made on July 27, August 24 and November 9,1983. The wheat was harvested on November 3.

3.10. Experiment 4: Control of Kikuyu grass in sunflower using fluazifop-butyl, EPTC and a combination of both, 1982, 1983.

The formulation of EPTC in 1982 was Eradicane and in 1983 Eptam. EPTC was incorporated into the soil by harrowing with a light disc harrow across the plots once. Before seeding the whole plot area was harrowed with a light disc harrow perpendicular to the first harrowing. The treatments used in this experiments are described in Table 7.

3.10.1. 1982

Sunflowers were seeded on May 28. Broad-leaved weeds were removed by hand from the plots between August 2 - 10. Bromoxynil at 2 l/ha was applied as a directed spray in mid September.

Assessment of Kikuyu grass cover was made on July 24,August 12 and November 25. The sunflower seed was harvested in early November.

3.10.2. 1983

The field had been under wheat the previous year. The field was plowed with a mouldboard plow in March and harrowed two times with a heavy disc harrow on May 17. The field was seeded to sunflowers on May 25.

The sunflowers did not germinate due to drought. The field was harrowed once with a light disc harrow on June 10, and sunflowers seeded on June 20.

Broad-leaved weeds were pulled out of the plots on August 11 and 12. Bromoxynil at 2 l/ha was applied as a directed spray on October 4. Assessment of Kikuyu grass cover was made on August 17, October 17 and December 22. The sunflower seed was harvested on December 15.

TABLE 6. Date and rate of glyphosate application in Experiment 3.

Time of glyphosate application	Rate of glyphosate application in l/ha
Control	-
Nov.05.1982	2
Nov.05.1982	3
Nov.05.1983	4
Jan.03.1983	2
Jan.03.1983	3
Jan.03.1983	4
Feb.04.1983	2
Feb.04.1983	3
Feb.04.1983	4
May 5.1983	2
May 5.1983	3
May 5.1983	4

TABLE 7. Herbicide, rates and dates of application for Experiment 4, 1982, 1983.

Treatment	Rate kg ai/ha	Date of Application 1982	1983
Control	-	-	-
Fluazifop-butyl	0.5	June 23	July 25
Fluazifop-butyl	1.0	June 23	July 25
EPTC	3.0	May 25	May 19
EPTC	4.5	May 25	May 19
EPTC	6.0	May 25	May 19
EPTC +	3.0	May 25	May 19
Fluazifop-butyl	0.5	June 23	July 25
EPTC +	4.5	May 25	May 19
Fluazifop-butyl	1.0	June 23	July 25

3.11. Experiment 5: Establishment of Kikuyu grass from stolon and rhizome cuttings, 1983, 1983 - 1984

On July 4 and November 8, 1983, one hundred plants were established from single node cuttings of stolons, and the same number of plants were established from single node cuttings of rhizomes.

At 4,6,8,10,12 and 14 weeks after planting, 10 plants were harvested at random from those established from stolons and those established from rhizomes. All the soil was removed from the plants. The plants were air dried for 3 - 4 days. They were then dried in an oven at 65 C for 24 hours and weighed.

Comparison between weights of plants established from stolons and rhizomes was made using the unpaired "t" test.

3.12. Experiment 6: Translocation of glyphosate in Kikuyu grass, 1983, 1983 - 1984.

Fifty Kikuyu grass plants were established from single node cuttings of stolons. These plants were left to grow for 14 - 16 weeks. The first 12 nodes of one branch from each plant were completely covered with a glyphosate solution of 1 part glyphosate in 10 parts of water.

The plants were grouped into blocks according to their sizes prior to harvesting.

The plants were sampled 1,2,4,8 and 16 days after treatment. In 1983 the sixth and fourteenth nodes and in 1983 - 1984 the sixth and twelth nodes of the treated branch were cut and planted in tins containing soil (Figure 2). Every successive sixth node was cut and planted.

The branches were labelled starting with the branch closest to the treated branch in a clock wise direction. The sixth node and every successive sixth node of the other branches were planted. Rhizomes were planted as whole pieces.

On each day of sampling plants were selected from all the blocks.

In 1983 - 1984 untreated plants were sampled similarly to the treated plants.

Three weeks after the last sampling date, the buds of the planted nodes were examined to determine the viability of the buds.

3.12.1. 1983

The cuttings were planted on July 7, 1983. The plants were treated with glyphosate on October 4. Sampling was done on October 5,6,8,12 and 20. The buds were examined on November 22.

3.12.2. 1983 - 1984

The cuttings were planted on November 8, 1983. The plants were treated with glyphosate on February 13, 1984. Sampling was done on February 14,15,16,21 and 29. The control was sampled on March 7. The buds were examined on March 22 - 26.

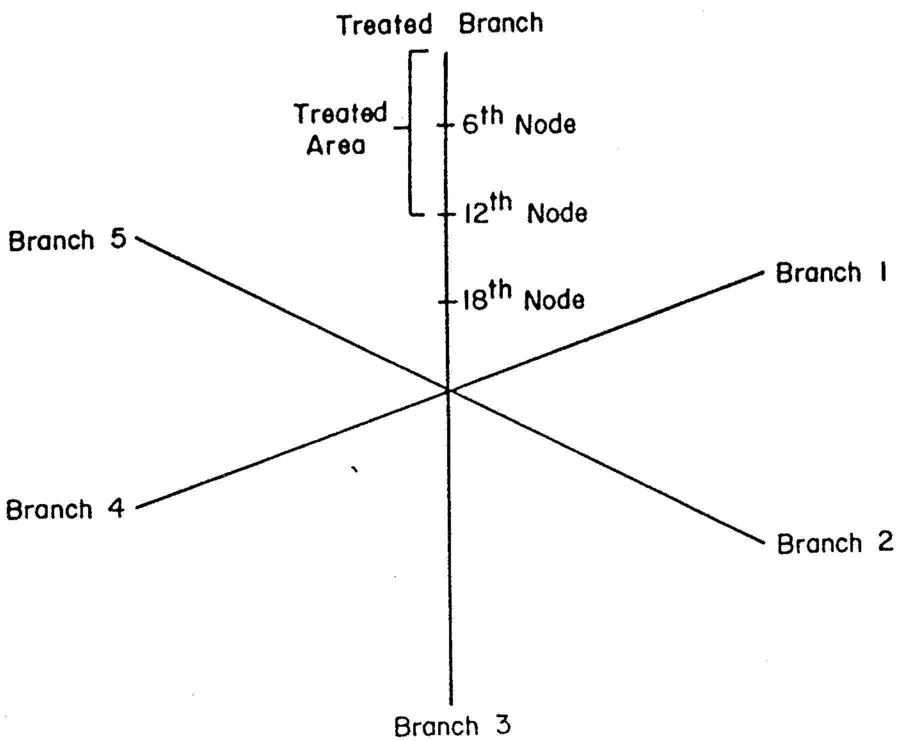

Figure 2. Schematic diagram showing how the plants were harvested.

RESULTS AND DISCUSSION

4.1 Experiment 1: Control of Kikuyu grass using tillage, and glyhosate in combination with tillage, 1981 -1982, 1982 - 1983.

4.1.1. 1981 - 1982

This trial was initiated on an area that had been under Kikuyu grass for several years. The land was sloping and soil surface uneven. Field conditions did not allow the tillage implements to perform adequately. Of the tillage equipment used, the mouldboard plow performed the best. The disc plow was not able to penetrate the sod and required a primary tillage operation.

The chisel plow gave adequate penetration of the sod, but clogged frequently and bunched the Kikuyu grass plants in a raking action. Under the conditions of this experiment, none of the tillage regimes utilized provided a suitable seedbed for a cereal crop.

4.1.1.1. Kikuyu Grass Cover

Plowing the field in November using a mouldboard plow, followed by either disc harrow (Treatment 1) or a chisel plow (Treatment 6) in May gave better control of Kikuyu grass than the other tillage regimes (Table 8). Using the chisel plow gave poor control of Kikuyu grass regardless of the time of use (Treatments 3 and 5), or whether it was followed with a disc plow (Treatment 2). Tilling with a disc harrow 3 times in May gave poor control of Kikuyu grass (Treatment 4).

TABLE 8. Effect of Tillage and Glyphosate in Combination with Tillage on Contol of Kikuyu Grass 1981 - 1982

	Treatment Operation	Passes	Date Performed	Kikuyu Grass Control 0 - 9 Scale
1.	Mouldboard	1	Nov.13.1981	
	Disc Harrow	2	May 11.1982	7
2.	Chisel Plow	2	Nov.17.1981	
	Disc Plow	1	Nov.17.1981	
	Disc Harrow	2	May 11.1982	4
3.	Chisel Plow	3	Nov.17.1981	
	Chisel Plow	2	May 13.1982	3
4.	Disc Harrow	3	May 12.1982	3
5.	Chisel Plow	3	May 13.1982	4
6.	Mouldboard Plow	1	Nov.13.1981	6
	Chisel Plow	2	May 13.1982	
7.	Glyphosate 2 l/ha		Oct.30.1981	
	Glyphosate 2 l/ha		May 4.1982	
	Disc Harrow	1	May 12.1982	
	Chisel Plow	2	May 13.1982	8
8.	Glyphosate 3 l/ha		Oct.30.1981	
	Disc Harrow	1	May 12.1982	
	Chisel Plow	2	May 13.1982	3
9.	Glyphosate 4 l/ha		Oct.30.1981	
	Disc Harrow	1	May 12.1982	
	Chisel Plow	2	May 13.1982	4
10.	Glyphosate 3 l/ha		May 4.1982	
	Disc Harrow	1	May 12.1982	
	Chisel Plow	2	May 13.1982	8
11.	Glyphosate 4 l/ha		May 4.1982	
	Disc Harrow	1	May 12.1982	
	Chisel Plow	2	May 13.1982	8

Split application of glyhosate, 2 l/ha in November and 2 l/ha in May (Treatment 7), and glyphosate at 3 and 4 l/ha applied in May gave good control of Kikuyu grass (Treatments 10 and 11). Glyphosate at 3 and 4 l/ha applied in November and tillage delayed up to May gave poor control of Kikuyu grass (Treatments 8 and 9) This poor control of Kikuyu grass by glyphosate at 3 and 4 l/ha in November was caused by a delay in tilling the plots following glyhosate application.

4.1.2. 1982 - 1983

This area had been in sod in 1981 and had been plowed and disc harrowed and seeded to wheat in 1982, but Kikuyu grass control was poor. By the end of the season, Kikuyu grass cover was high.

All the 3 primary tillage implements were able to penetrate through Kikuyu grass. Tillage regimes were adequate to allow seeding of a cereal crop (except where tillage treatments were initiated in March).

Where primary tillage operation was delayed until March (except where glyphosate was used in November), Kikuyu grass had formed a dense sod and a tillage regime did not prepare an adequate seebed.

4.1.2.1. Kikuyu Grass Cover

No differences were detected in Kikuyu grass cover between the use of the three primary tillage implements, mouldboard, disc and chisel plows, (Table 9, Treatment 1 - 3). However, the mouldboard plow used in November followed by a disc harrow in March and May appeared to give the best control of Kikuyu grass (Treatment 1). When a mouldboard plow was used in November followed with a chisel plow in March, control of

TABLE 9. Effect of several glyphosate applications and tillage practices on Kikuyu grass cover and wheat yield 1982 - 1983

Treatment[1] Nov.05.1982	March.1983 and #passes	May.11.1983	Cost Kshs/ha	Kikuyu Grass Cover (%) Jul.26.1983[2]	Aug.24.1983[2]	Nov.11.1983[2]	Grain Yield T/ha
1. Mouldboard Plow	disc Harrow 2		1,275	5.00 abc[3]	7 abc[3]	23 ab[3]	2.77 a[3]
2. Disc Plow	Disc Harrow 2		1,325	16 ab	19 abcd	37 abc	3.04 a
3. Chisel Plow	Chisel Plow 2		1,300	15.00 ab	27 bcde	34 abc	3.04 a
4. -	Disc Harrow 2		1,100	56 c	64 e	78 d	1.64 b
5. -	Chisel Plow 3		1,700	17 abc	36 cde	52 bcd	2.49 ab
6. Mouldboard Plow	Chisel Plow 1		1,300	37 bc	49 de	71 cd	1.69 b
7. Glyphosate 2 l/ha	-	Glyphosate 2 l/ha	1,670	3 a	3 ab	16 ab	2.46 ab
8. Glyphosate 3 l/ha	-		1,390	12 ab	12 abcd	29 ab	2.31 ab
9. Glyphosate 4 l/ha	-		1,670	4 ab	5 abc	14 a	2.67 a
10. -	-	Glyphosate 3 l/ha	1,390	3 a	1 a	11 a	2.96 a
11. -	-	Glyphosate 4 l/ha	1,670	4 ab	6 abc	19 ab	2.54 ab

1. All the plots were disc harrowed on May.18.1983.
2. Data was transformed by Arcsine. Percentage Transformation before analysis.
3. Numbers followed by the same letter in the same column are not significantly different.

Kikuyu grass was not as good as when the mouldboard plow was followed by a disc harrow in March (Treatments 6 and 1). The chisel plow clogged and did not give good exposure of the rhizomes for dessication.

Using a disc harrow 2 times in March followed by a disc harrow 2 times in May gave very poor control of Kikuyu grass (Treatment 4). Using a chisel plough 3 times in March followed by a disc harrow 2 times in May appeared to give less control of Kikuyu grass at the end of the season than using a chisel plow in November followed by a chisel plow in March (Treatments 5 and 3).

Glyphosate (Treatment 7 - 11) gave good control of Kikuyu grass and no differences in Kikuyu grass cover between the glyphosate treatments could be detected.

4.1.2.2. Grain Yield

Treatments that had the lowest Kikuyu grass cover appeared to have the highest grain yields. Plots that were tilled in November tended to have higher yields than plots that were tilled in May with or without glyphosate. When Kikuyu grass was killed in November, the yields were higher than when Kikuyu grass was killed in March. The low yield in March tilled plots may have been due to competition by the high Kikuyu grass cover observed in these plots.

4.2. Experiment 2: Effect of time of tillage following glyhosate application on Kikuyu grass cover, regrowth of stolon and rhizome pieces and wheat yield, 1981 - 1982, 1982 - 1983.

4.2.1. 1981 - 1982

4.2.1.1. Kikuyu Grass Cover

Time of tillage following glyphosate application did not affect Kikuyu grass cover, except when glyphosate was applied in November and tillage delayed until May (Table 10). When glyphosate was applied in November, there was significantly less Kikuyu grass cover than when glyphosate was applied in May. Tillage 6 - 21 days after glyphosate application enhanced the performance of glyphosate on Kikuyu grass control.

4.2.1.2. Regrowth of Stolon and Rhizome Pieces

The treatment with glyphosate application in November and tillage in May (Treatment 1) had a higher amount of regrowth than when tillage followed glyphosate application within 6 - 21 days. The assessment of the stolon and rhizome regrowth confirmed that tillage 6 - 21 days after glyphosate applicaton enhanced the control of Kikuyu grass. There were fewer stolon and rhizome pieces which sprouted when glyphosate was applied in November than when glyphosate was applied in May.

4.2.1.3. Grain Yield

Grain yield was significantly higher for the plots sprayed and tilled in November (Treatments 2 - 5) than for plots sprayed and tilled in May (Treatments 6 - 10). More moisture may have been stored in plots that were sprayed and tilled in November. It would appear that that to obtain the highest grain yields, glyphosate should be applied in November and tillage should follow within 6 - 21 days after application.

TABLE 10. Effect of time on tillage following glyphosate application on Kikuyu grass cover, regrowth of stolon and rhizome pieces, and wheat grain yield 1981 - 1982.

	Time of Glyphosate Application	Date of Tillage	Days to Initial Tillage	Kikuyu Grass Cover (%)	Sprouted Stolons and Rhizome Pieces (Sprouts/m²)	Grain Yield T/ha
1.	Nov.06.1981	May 14.1982	194	22 b[1,2]	20. b[2,3]	0.87 bc[2]
2.	Nov.06.1981	Nov.12.1981	6	4 a	2 a	1.01 ab
3.	Nov.06.1981	Nov.16.1981	10	4 a	3 a	1.05 a
4.	Nov.06.1981	Nov.21.1981	15	4 a	4 a	1.01 ab
5.	Nov.06.1981	Nov.27.1981	21	5 a	6 ab	1.00 ab
6.	May 5.1982	May 14.1982	9	6 a	7 ab	0.72 cd
7.	May 5.1982	May 10.1982	5	8 a	7 ab	0.71 cd
8.	May 6.1982	May 14.1982	8	6 a	7 ab	0.69 d
9.	May 6.1982	May 18.1982	12	8 a	5 ab	0.66 d
10.	May 6.1982	May 22.1982	16	9 a	3 a	0.69 d
	November applied Glyphosate[4]			4 a	4 a	1.02 a
	May applied Glyphosate			7 b	6 b	0.69 b
	Days to Tillage		5-6	6 a	4 a	0.86 a
			8-10	5 a	5 a	0.87 a
			12-15	6 a	4 a	0.84 a
			16-21	7 a	4 a	0.84 a

1. Data was transformed by square root transformation before analysis.
2. Number followed by the same letter in the same column are not significantly different.
3. Data was transformed by x + 1/2 before analysis.
4. The treatment in which glyphosate was applied in November and tillage was done in May was not included in the mean.

The plots sprayed in November and tilled in May (Treatment 7) had significantly higher yields than plots sprayed and tilled in November. This finding demonstrates that for the highest grain yield, glyphosate should be applied in November. Although the plots sprayed in November and tilled in May (Treatment 1) had higher Kikuyu grass cover than the May treated and tilled plots, this was not reflected in the yield. The decaying Kikuyu grass may have produced chemicals that were toxic to wheat, thereby reducing the grain yield.

4.2.2. 1982 - 1983

4.2.2.1. Kikuyu Grass Cover

The plots that were not treated with glyphosate (Treatment 6 and 12) had significantly higher Kikuyu grass cover than the plots that were treated with glyphosate (Table 11). No differences in Kikuyu grass cover were detected when glyphosate was applied in November or May.

The plots that were treated with glyphosate in November and tilled in May (Treatment 1) appeared to have more Kikuyu grass cover than those plots tilled 3 - 18 days after spraying with glyphosate. Treatment 7 as opposed to Treatment 8 - 11 was not plowed with a mouldboard plow, but only received a disc harrowing after glyphosate treatment. This method of tillage would seem ineffective on a Kikuyu grass mat even after treatment with glyphosate.

4.2.2.2. Grain Yields

Plots treated with glyphosate in May appeared to have higher

TABLE 11. Effect of time of tillage following glyphosate application on Kikuyu grass cover and wheat yield 1982 - 1983

	Time of Glyphosate Application at 1.08 kg/ha	Date of Tillage	Days to tillage	Kikuyu Grass Cover (%) Jul.26.1983	Aug.25.1983	Nov.11.1983	Grain Yield T/ha
1.	Nov.05.1982	May 27.1983	200	12 a[1,2]	22 ab[1,2]	54 abc[1,2]	1.51 ab[2]
2.	Nov.05.1982	Nov.08.1982	3	5 a	4 a	16 a	1.97 ab
3.	Nov.05.1982	Nov.13.1982	6	10 a	7 ab	36 a	1.90 ab
4.	Nov.05.1982	Nov.17.1982	12	14 a	14 ab	34 a	2.14 ab
5.	Nov.05.1982	Nov.20.1982	15	14 a	11 ab	29 a	2.18 ab
6.	No spraying	Nov.05.1982	-	81 c	93 c	90 c	0.57 c
7.	May 9.1982	May 27.1983	18	32 ab	36 b	50 abc	2.06 ab
8.	May 9.1982	May 12.1983	3	8 a	12 ab	29 a	2.65 a
9.	May 9.1982	May 16.1983	7	9 a	13 ab	30 a	2.64 a
10.	May 9.1982	May 20.1983	11	11 a	14 ab	37 a	2.66 a
11.	May 9.1982	May 21.1983	15	12 a	19 ab	43 ab	1.78 ab
12.	No spraying	May 20.1983	-	60 bc	82 c	86 bc	1.28 b
	Glyphosate applied in November[3]			10 a	8 a	29 a	2.05 b
	Glyphosate applied in May[4]			10 a	16 a	35 a	2.42 a
	Days to Tillage		3	6 a	8 a	22 a	2.31 a
			6-7	10 a	10 a	33 a	2.27 a
			11-12	12 a	14 a	35 a	2.40 a
			15	13 a	15 a	36 ab	1.98 a
			no spraying	70 b	88 b	88 b	0.92 b

1. Data was transformed by Arcsine Percentage Transformation before analysis.
2. Number followed by the same letter in the same column are not significantly different.
3. Treatment 1 is not included in the mean.
4. Treatment 7 is not included in the mean.

yields than plots treated in November. The tillage operations described were performed on individual plots. To achieve a level seedbed the whole experimental area was disc harrowed with a light disc harrow. To level the whole area of the three wheat experiments (Experiments 1,2,and 3) the area was disc harrowed with a heavy disc harrow. The soil in the plots that had been tilled in November become more pulverized than the soil in the plots tilled in May. The finely worked soil may have lost more soil moisture by evaporation than the coarse soils. The poor grain yields in plots tilled in November may have been caused by water stress. The last half of May 1983 was very dry. Excessive tillage should not occur on a large farm since an optimum tillage regime could be established.

Treatments that had the highest Kikuyu grass cover (Treatments 6 and 12) had the lowest yields. Higher yields were obtained when glyphosate was used to control the Kikuyu grass than when tillage alone was used.

4.3. Experiment 3: Effect of time of application and rate of glyphosate on Kikuyu grass cover and wheat yield.

4.3.1. Kikuyu Grass Cover

The plots that were not treated with glyphosate (Treatment 1) had the highest Kikuyu grass cover (Table 12). All the treated plots had significantly lower Kikuyu grass cover than the control. The plots treated with glyphosate in November and January had lower Kikuyu grass cover than the plots sprayed in February and May. There appeared to be a progressive increase in Kikuyu grass cover as treatment with glyphosate was delayed from January to May. It would appear that early glyphosate application results in better Kikuyu grass control than late glyphosate application. Kikuyu grass cover decreased when the rate of glyphosate was increased from 2 to 4 l/ha.

4.3.2. Grain Yield

The plots treated with glyphosate had higher grain yields (Table 12) than the plots that were not treated by glyphosate. The plots that were not treated with glyphosate had greater Kikuyu grass cover. The low yield in the control plots may have been caused by Kikuyu grass competition.

The plots sprayed in November and January had higher grain yields than plots sprayed in February and May. There was a tendency for yield to decrease with increase in delay in applying glyphosate between January and May.

There was a significant correlation between Kikuyu grass cover taken on November 9, 1983 and grain yield. The November and January treated plots had lower Kikuyu grass cover and higher grain yields than February and May treated plots.

4.4. Experiment 4: Control of Kikuyu grass in sunflower using fluazifop-butyl, EPTC and a combination of both, 1982, 1983.

4.4.1. 1982

4.4.1.1. Kikuyu Grass Cover

The experimental area was thoroughly tilled prior to seeding. The sunflower plants developed a canopy before the Kikuyu grass was

TABLE 12. Effect of time of application and rate of glyphosate on Kikuyu grass cover and wheat yield 1982 - 1983.

	Date of Glyphosate Application	Rate l/ha	Kikuyu Grass Cover (%) Jul.27.1983	Aug.24.1983	Nov.09.1983	Grain Yield T/ha
1.	Control	-	55 e[1,2]	67 b[1,2]	75 c[1,2]	1.42 c[2]
2.	Nov.05.1982	2	6 a	16 a	29 ab	2.65 ab
3.	Nov.05.1982	3	5 a	10 a	29 ab	2.77 ab
4.	Nov.05.1982	4	4 a	9 a	27 ab	2.60 ab
5.	Jan.03.1983	2	8 ab	9 a	33 ab	2.85 ab
6.	Jan.03.1983	3	5 a	6 a	18 a	3.10 a
7.	Jan.03.1983	4	6 a	10 a	25 ab	3.14 a
8.	Feb.04.1983	2	17 cd	34 ab	48 abc	2.54 ab
9.	Feb.04.1983	3	8 abc	14 a	37 ab	2.49 ab
10.	Feb.04.1983	4	5 a	11 a	32 ab	2.83 ab
11.	May 5.1983	2	23 d	28 a	59 bc	2.12 bc
12.	May 5.1983	3	10 bcd	26 a	38 ab	2.14 bc
13.	May 5.1983	4	10 abc	10 a	28 ab	2.40 ab
	Glyphosate applied in November		5 a	12 a	28 a	2.67 ab
	Glyhposate applied in January		6 a	8 a	26 a	3.03 a
	Glyphosate applied in February		10 ab	20 a	39 ab	2.62 b
	Glyphosate applied in May		17 b	21 a	42 b	2.2 c
Rate of Glyphosate Application l/ha		2	14 a	22 b	42 b	2.51 a
		3	9 a	14 a	30 ab	2.62 a
		4	6 a	10 a	28 a	2.74 a

1. Data was transformed by the Arcsin. Percentage Transformation before Analysis.
2. Numbers followed by the same letter in the same column are not significantly different.

established. Even in the control plots, Kikuyu grass cover was low until after harvest (Table 13).

All the treated plots had lower Kikuyu grass cover than the untreated plots. Plots treated with fluazifop-butyl alone (Treatments 2 and 3) or in combination with EPTC (Treatments 7 and 8) appeared to have the lowest Kikuyu grass cover. Kikuyu grass cover, in plots treated with EPTC (Treatment 4, 5, and 6) appeared to be suppressed early in the season, but at the end of the season, the Kikuyu grass appeared to outgrow the early season growth suppression. The plots treated with fluazifop-butly alone (Treatment 2 and 3) were as clean as the plots treated with EPTC and fluazifop-butyl (Treatments 7 and 8). It would appear that EPTC had little benefical effect when used in combination with fluazifop-butyl.

At the end of the season fluazifop-butyl appeared to give better control of Kikuyu grass at 1 kg/ha than at 0.5 kg/ha. EPTC at the rate of 6 kg/ha appeared to suppress Kikuyu grass more than at the rates of 3 and 4.5 kg/ha.

4.4.1.2. Seed Yield

No differences were observed in the seed yield of sunflowers between the various treatments. It would appear that Kikuyu grass infestation was too low to cause severe competition with the sunflower. The sunflower is a large plant and shaded the Kikuyu grass thus suppressing its growth. There was great variability in the seed yield of sunflower due to bird damage. Bird damage may have masked the difference between the various treatments due to Kikuyu grass cover.

TABLE 13. Effect of fluazifop-butyl, EPTC and a combination of both on Kikuyu grass cover and sunflower seed yield, 1982.

	Treatment	Rate Kg/ha	Kikuyu Grass Cover (%) July.24	August.12	November.25	Grain Yield T/ha
1.	Control	-	14 c[1,2]	24 c[1,2]	68 b[2,3]	2.25 a[2]
2.	Fluazifop-butyl	0.5	2 ab	2 ab	24 a	2.40 a
3.	Fluazifop-butyl	1.0	2 ab	1 ab	12 a	2.37 a
4.	EPTC	3.0	4 ab	16 c	42 a	2.60 a
5.	EPTC	4.5	3 ab	8 bc	43 a	2.56 a
6.	EPTC	6.0	3 ab	6 ab	28 a	2.51 a
7.	EPTC + fluazifop-butyl	3.0 0.5	1 ab	1 ab	11 a	2.71 a
8.	EPTC + fluazifop-butyl	1.0	0 a	0 a	9 a	2.65 a

1. Data was transformed using x + 1/2 Transformation before analysis.
2. Numbers followed by the same letter in the same column are not sifnificantly differnt.
3. Data was transformed by Arcsine. Percentage transformation before analysis.

4.4.2. 1983

4.4.2.1. Kikuyu Grass Cover

Kikuyu grass cover remained low in all plots until after the sunflower was harvested (Table 14). Plots treated with fluazifop-butyl alone (Treatments 2 and 3) or in combination with EPTC (Treatments 7 and 8) had lower Kikuyu grass cover than the plots treated with EPTC. Fluazifop-butyl may have killed some of the Kikuyu grass plants. Kikuyu grass in plots treated with EPTC appeared to be suppressed early in the season but at the end of the season, the Kikuyu grass appeared to outgrow the early season growth suppression. It would appear that EPTC suppressed Kikuyu grass early in the season, but that EPTC's effect on Kikuyu grass was reduced with time.

At the end of the season the plots treated with fluazifop-butyl alone (Treatment 2 and 3) had as little Kikuyu grass as plots treated with fluazifop-butyl in combination with EPTC. There was no additional benefit of EPTC when it was used in combination with fluazifop-butyl.

There was no difference in Kikuyu grass cover between fluazifop-butyl at 0.5 and 1 kg/ha. It would appear that fluazifop-butyl at 0.5 kg/ha gives acceptable control of Kikuyu grass. Rate of EPTC had no effect on the control of Kikuyu grass.

4.4.2.2. Seed Yield

There were no differences in yield of sunflower between the various treatments. It would appear that sunflower is a very competitive crop once established. There was great variability in yield due to bird damage. Bird damage may have masked the differences

TABLE 14. Effect of Fluazifop-butyl, EPTC and a combination of both on Kikuyu grass cover and sunflower seed yield, 1983.

	Treatment	Rate Kg/ha	Kikuyu Grass Cover (%) Aug.17.1983	Oct.17.1983	Dec.22.1983	Seed Yield T/ha
1.	Control	-	18 c[1,2]	19 c[1,2]	50 b[2,3]	2.61 a[2]
2.	Fluazifop-butyl	0.5	4 ab	3 ab	5 a	2.96 a
3.	Fluazifop-butyl	1.0	3 ab	1 ab	2 a	2.73 a
4.	EPTC	3.0	13 bc	23 c	52 b	2.96 a
5.	EPTC	4.5	8 abc	11 bc	26 ab	2.86 a
6.	EPTC	6.0	12 abc	24 c	59 b	2.64 a
7.	EPTC + fluazifop-butyl	3.0 0.5	3 ab	3 ab	5 a	2.64 a
8.	EPTC + fluazifop-butyl	1.0	3 ab	1 a	4 a	2.67 a

1. Data was transformed using square root transformation before analysis.
2. Numbers followed by the same letter in the same column are not significantly different.
3. Data was transformed using Arcsin Percentage Transformation before analysis.

in yield between the treatments.

4.5. Experiment 5: Establishment of Kikuyu grass from stolon and rhizome cuttings, 1983, 1983 - 1984.

4.5.1. 1983

Kikuyu grass plants grown from single node cuttings developed more stolons than rhizomes during the duration of this experiment. Dry matter accumulation in plants established from stolons was more rapid than in plants established from rhizomes (Table 15). Twelve weeks after planting, plants from stolon cuttings were more than two times as large as the plants from rhizome cuttings.

The logarithm of the weight of plants was determined and plotted against time (Figure 3). Regression analysis showed that there was no significant difference between the growth rate of plants from rhizomes and stolons.

4.5.2. 1983 - 1984

Kikuyu grass plants grown from single node cuttings developed more stolons than rhizomes during the duration of this experiment. Plants grown from stolons were much larger than plants from rhizomes (Table 16). Although establishment of Kikuyu grass was by both stolons and rhizomes, the rapid early growth of stolons resulted in larger plants than the slow early establishment from rhizomes. The growth rate of plants from stolons was not significantly different from that of plants from rhizomes (Figure 4).

Although the rate of growth of plants from stolons was not significantly different from that of plants from rhizomes, the shorter

TABLE 15. Weight of Kikuyu grass plants, established from single node cuttings of stolons and rhizomes, 1983.

	WEEKS AFTER PLANTING				
	Four Weeks	Six Weeks	Eight Weeks	Ten Weeks	Twelve Weeks
Weight of plants established from stolons (gms)	0.41	2.16	10.46	22.38	33.64
Weight of plants established from rhizomes (gms)	0.37	0.83	5.45	9.28	13.63
Unpaired "T" - Test at 5 %	NS	S	NS	S	S

TABLE 16. Weight of Kikuyu grass plants, established from single node cuttings of stolons and rhizomes, 1983 and 1984.

	WEEKS AFTER PLANTING					
	Four Weeks	Six Weeks	Eight Weeks	Ten Weeks	Twelve Weeks	Fourteen Weeks
Weight of plants established from stolons (gms)	1.05	4.99	9.74	24.25	88.46	71.20
Weight of plants established from rhizomes (gms)	1.38	2.84	7.48	15.34	24.58	46.36
Unpaired "T" - Test at 5 %	NS	S	NS	NS	S	NS

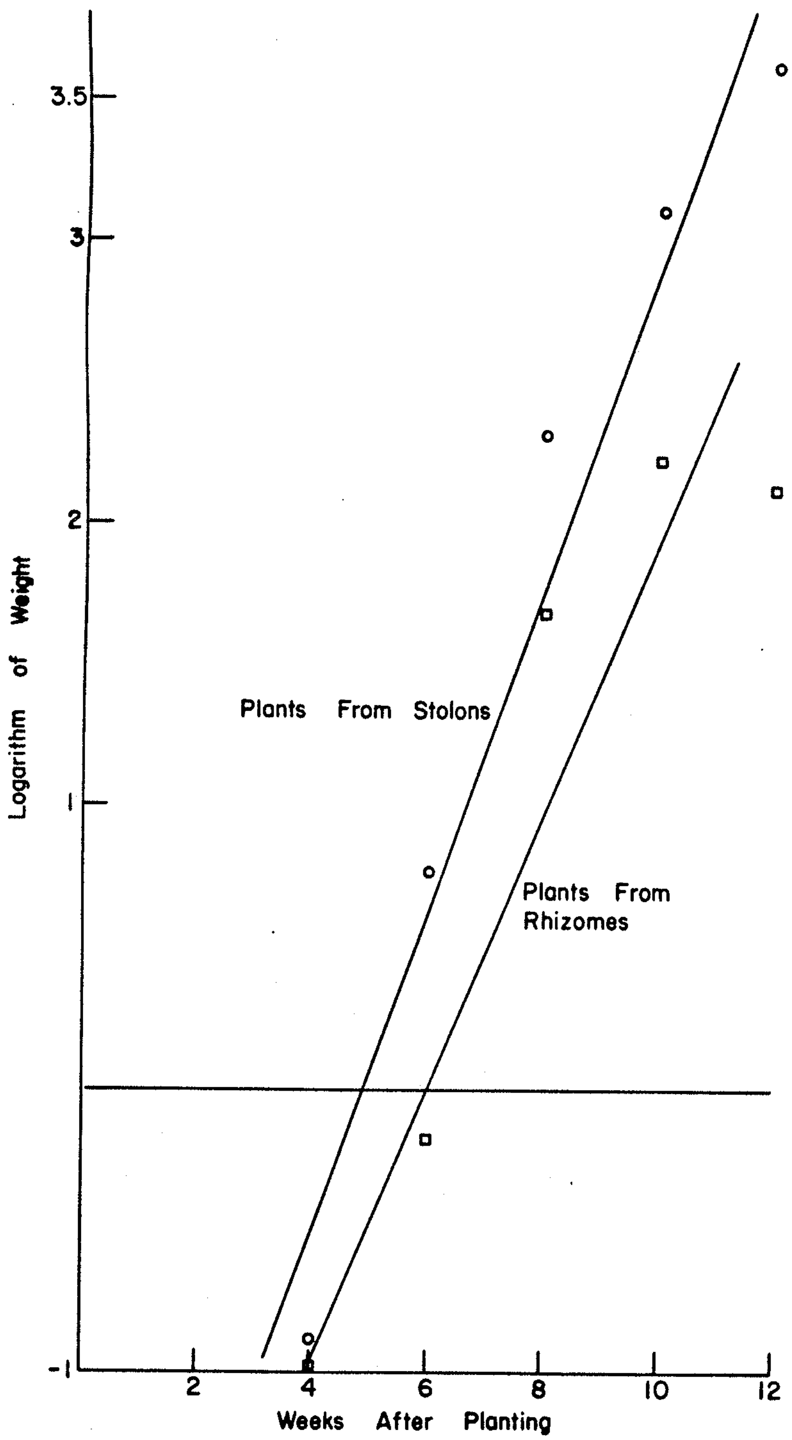

Figure 3. Logarithm of weight as a function of time of harvesting, 1983.

establishment period of stolon buds resulted in larger plants as compared to the longer establishment period of buds from rhizomes. During the duration of the experiment Kikuyu grass stolons had many branches, while the rhizomes did not have any branches. It would appear that there is greater apical dormacy in the rhizomes than in the stolons.

4.6. Experiment 6: Translocation of glyphosate in Kikuyu grass, 1983, 1983 - 1984.

Glyphosate was applied to single stolons of Kikuyu grass plants to determine the movement of the herbicide in the plant.

4.6.1. 1983

One day after glyphosate application two nodes per stolon branch were examined. Most of the herbicide activity remained in the treated stolons (Table 17a). Forty seven nodes were sampled outside of the treated area, five nodes (eleven percent) were dead. The nodes that were dead were at the 14th position on the treated branch. Six rhizomes pieces were sampled of which one sprouted.

Seventy-nine nodes were sampled outside of the treated area two days after glyphosate application (Table 17b). Ten of these nodes, (thirteen percent) were dead, six at the 14th position on the treated stolon, two at the 20th position on the treated stolon and two at the 6th position on an untreated stolon. Five pieces of rhizomes were sampled, two of which were dead.

Seventy-eight nodes were sampled outside of the treated area four days after glyphosate application (Table 17c). Only eight nodes (ten

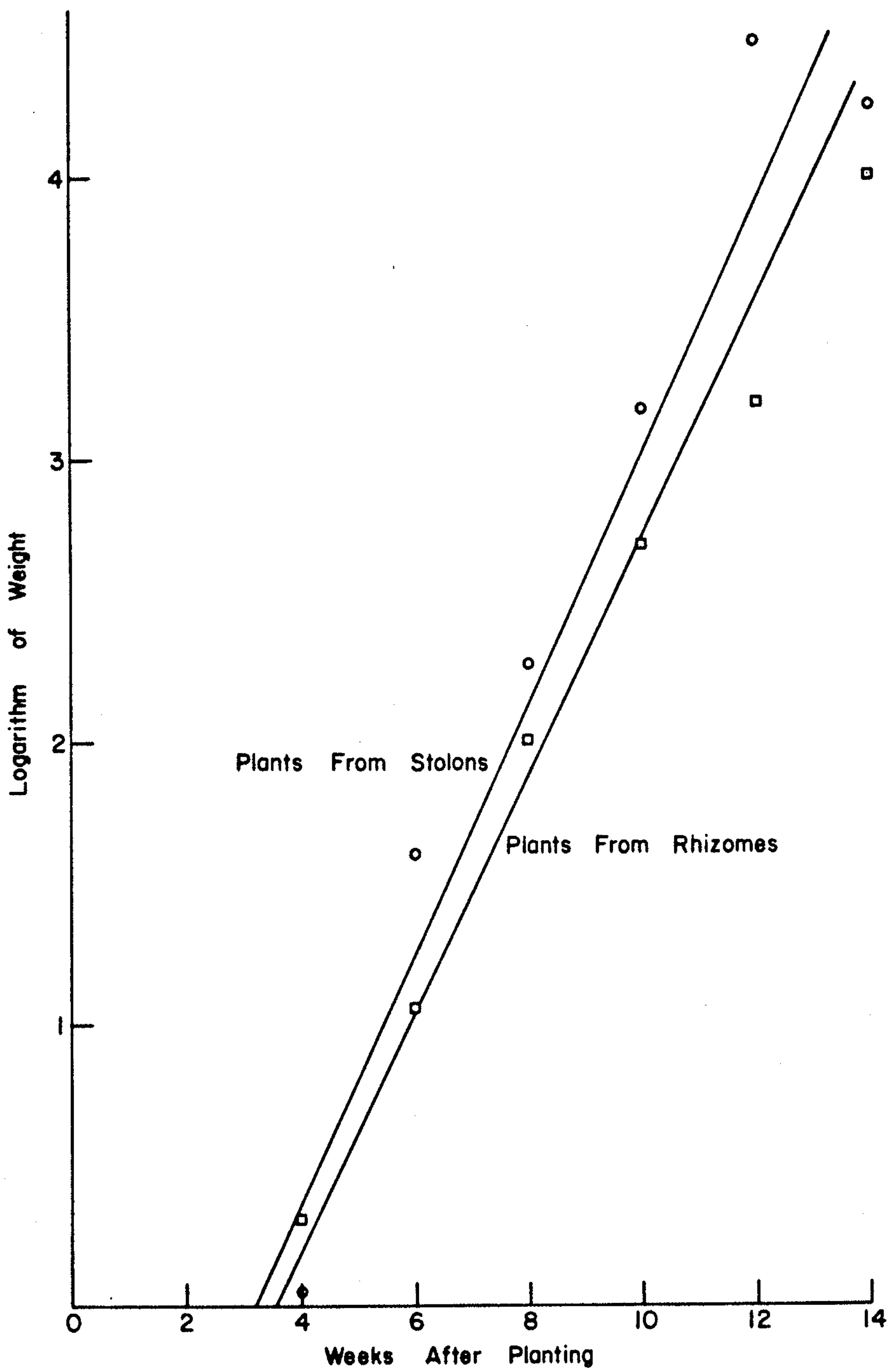

Figure 4. Logarithm of weight as a function of time of harvesting, 1983-4.

TABLE 17a. Sprouting of nodes in treated Kikuyu grass one day after treatent with glyphosate, 1983.

Block No.	1		2		3		4		5		6	
Node number[1]	6	12	6	12	6	12	6	12	6	12	6	12
Treated Branch[2]	x	x	x	x	x	x	x	x	x	x	x	x
Branch 1	0		0	0	0		0	0	0	0	0	
Branch 2	0	0	0		0	0	0		0	0	0	0
Branch 3	0		0	0	0		0	0	0		0	
Branch 4	0		0		0		0		0		0	0
Branch 5	0	0					0		0			
Branch 6	0											
Branch 7	0	0										
Rhizomes		2 x		1 x	10	2 x						

Key: 0 Sprouted
x Dead

1. Node number counted from tip to stolon.
2. Nodes 1 to 12 were treated with glyphosate. The viability of nodes 6 (in the treated area) and 14 were determined . Only two nodes per branch were examined.

percent) were dead, six at the 14th position on the treated stolon and two at the sixth position on an untreated stolon. Three pieces of rhizomes were sampled and all of them sprouted.

Ninety-six nodes were sampled outside of the treated area eight days after treatment (Table 17d). Sixteen (17 percent) of which were dead, six at the 14th position on the treated stolon, eight at the sixth position on an untreated stolon and two at the 12th position on an untreated stolon. Seven pieces of rhizomes were sampled, two of which were dead.

Seventy-five nodes were sampled outside of the treated area 16 days after treatment (Table 17e). Thirty-four nodes (45 percent) were dead, six at the 14th position, three at the 20th position and one at the 26th position on the treated stolon. Seventeen nodes were at the sixth position on an untreated stolons and seven at the 12th position on an untreated branch. Three pieces of rhizomes were sampled, two of which were dead.

Glyphosate translocated down the nodes of the treated branch without accumulating in all the buds. Glyphosate translocated to the tip of some untreated stolons and accumulated in lethal amounts starting from the tip of the branch towards the base. This pattern of glyphosate accumulation has been reported by Claus and Behrens (1976) and Weed Research Organization (1972 - 1973). Glyphosate translocates to the actively growing apical bud. After this bud is killed, the bud below is released from apical dormacy and starts to develop, becoming the main sink of glyphosate translocation.

Sixteen days after glyphosate application, there were still viable rhizomes. Translocation both to the untreated stolons and rhizomes was

Table 17b Sprouting of nodes in treated Kikuyu grass two days after treatment with glyphosate , 1983.

Block No.	1	2	3	4	5	6
Node number [1]	6,12,18,24,30	6,12,18,24,	6,12,18	6,12,18,24	6,12,18,24	6,12,18
Treated Branch[2]	x x 0 0 0	x x x 0	x x 0	x x 0 0	x x 0 0	x x x
Branch 1	0 0	0 0	0 0 0	0 0	0 0	0
Branch 2	0 0	0 0 0 0	0 0	0 0 0	0 0 0	x
Branch 3	0 0	0 0 0 0	0 0	0 0	0 0 0	0
Branch 4	0 0	0	0	0 0	0	0 0 0
Branch 5	0			0 0 0 0	0 0	0
Branch 6	0 0			x	0	
Branch 7						
Rhizomes	10		10	1 x	10	1 x

Key: 0 Sprouted
x Dead

1. Node Number counted from tip of stolon.
2. For the treated branch the 14th and subsequent 6th nodes were sampled in place of the 12th node.

TABLE 17c Sprouting of nodes in Kikuyu grass four days after treatment with glyphosate, 1983.

Block No.	1	2	3	4	5	6
Node number[1]	6,12,18,24	6,12,18,24,30	6,12,18,24	6,12,18,24	6,12,18,24	6,12,18,24
Treated Branch[2]	x x 0 0	x x 0 0 0	x x 0 0	x x	x x 0	x x 0 0
Branch 1	0	0 0 0	0 0	x 0 0	0 0	0 0
Branch 2	0 0 0	0 0 0	0 0	0 0 0 0	0 0	0
Branch 3	0 0	0 0	0 0 0	0 0	x 0 0 0	0 0 0
Branch 4	0 0	0 0 0	0 0 0	0 0 0	0	
Branch 5				0 0		
Branch 6				0 0 0 0		
Branch 7						
Rhizomes			20	10		

Key: 0 Sprouted
x Dead

1. Node Number counted from tip of stolon.
2. For the treated branch the 14th and subsequent 6th nodes were sampled in place of 12th nodes.

TABLE 17d Sprouting of nodes in Kikuyu grass eight days after treatment with glyphosate, 1983.

Block No.	1	2	3	4	5	6
Node number[1]	6,12,18,24	6,12,18	6,12,18	6,12,18,24	6,12,18,24	6,12,18
Treated Branch[2]	x x 0	x x 0	x x 0	x x 0 0	x x 0	x x
Branch 1	0 0 0	0	x 0	0 0 0	x x	0 0
Branch 2	0 0	0 0 0	x	0 0 0	x x	0 0
Branch 3	0 0	0 0 0	0 0	0 0	0 0 0 0	0
Branch 4	0 0 0 0	0	0	0 0 0	x 0	0 0 0
Branch 5	0 0		0	0 0 0	0	x
Branch 6	0 0 0		0 0	0 0 0	0	0
Branch 7	0 0		0 0		0	0 0
Branch 8					0	0 0
Branch 9						0 0
Rhizomes	10	30	2 x	10		

Key: 0 Sprouted
x Dead

1. Node Number counted from tip of stolon.
2. For the treated branch the 14th and subsequent 6th nodes were sampled in place of the 12th node.

TABLE 17e Sprouting of nodes in Kikuyu grass sixteen days after treatment with glyphosate, 1983.

Block No.	1	2	3	4	5	6
Node number [1]	6,12,18,24,30	6,12,18,24	6,12,18,24	6,12,18,24	6,12,18	6,12
Treated Branch [2]	x x	x x	x x x x	x x x	x x x	x x
Branch 1	x x	0	x 0	x 0 0 0	x x	x x
Branch 2	0 0 0 0 0	x 0 0	x x 0	0 0	x x	x x
Branch 3	0 0 0 0	x x 0 0	x 0 0	x 0 0 0	x	x
Branch 4	0 0	0	0 0	0 0		x 0
Branch 5	x	0	0 0	0 0 0		
Branch 6			x 0			
Branch 7						
Rhizomes	1 x		10 1 x			

Key: 0 Sprouted
x Dead

1. Node Number counted from tip of stolon.
2. For the treated branch the 14th and subsequent 6th nodes were sampled in place of the 12th node.

slow.

4.6.2. <u>1983 - 1984</u>

Untreated plants of Kikuyu grass were sampled indentically with plants treated with glyphosate. Ninety-eight nodes were sampled of which only four nodes (four percent) were dead (Table 18a). Of the 27 pieces of rhizomes sampled only six (22 percent) were dead.

Fifty- three nodes were sampled outside of the treated area one day after treatment (Table 18b). Eleven of these were dead, five at the 18th position on the treated stolon, four at the sixth position on an untreated stolon and two at the 12th position on an untreated stolon. Twenty-three pieces of rhizomes were sampled, eight (35 percent) of which were dead.

Eighty-two nodes were sampled outside of the treated area two days after treatment (Table 18c) seventeen nodes (21 percent) were dead, six at the 18th position and two at the 24th position on the treated branch, six at the sixth position on an untreated branch and three at the 12th position of an untreated branch. Twenty rhizome pieces were sampled, 16 (80 percent) of which were dead.

Eighty-five nodes were sampled outside of the treated area four days after treatment (Table 18d), twenty-six (30 percent) of which were dead, five at the 18th position and three at the 24th position on the treated branch. Eight were at the sixth position, seven at the 12th position and two at 18th position on an untreated branch. Thirty rhizome pieces were sampled of which twenty-seven (90 percent) were dead.

Eighty-nine nodes were sampled outside of the treated area eight

TABLE 18a Sprouting of nodes in untreated Kikuyu grass plants, 1983 - 1984.

Block No.	1	2	3	4	5	6	7
Node number[1]	6,12,18,24,30	6,12,18	6,12,18	6,12,18,24	6,12,18	6,12,18,24	6,12,18,24
Branch 1	0 0 0 0 0	0 0 0	0 0 0	0 0 0 0	0 0 0	0 0 0 0	0 0 0 0
Branch 2	0 x	0 0	0 0	0 x	0	0 0	0 0 0
Branch 3	0 0	0	0 0 0	0 0 0	0 x	0 x	0 0 0
Branch 4	0 0	0	0 0	0 0 0	0 0 0	0 0 0	0
Branch 5	0 0	0	0 0	0 0 0 0	0 0 0	0 0	
Branch 6		0 0	0 0	0	0 0 0	0 0	
Branch 7		0	0 0				
Rhizomes	40 1 x	30 1 x	20 1 x	40	20 1 x	20 2x	40

Key: 0 Sprouted
x Dead

1. Node Number counted from tip of stolon.

TABLE 18b Sprouting of nodes in Kikuyu grass plants one day after treatment with glyphosate, 1983 - 1984

Block No.	1	2	3	4	5	6	7
Node number[1]	6,12,18,24	6,12,18,24	6,12,18,24,30	6,12,18	6,12,18	6,12	6,12,18
Treated Branch	x x x 0	x x x	x x x 0 0	x x x	x x x	x x	x x 0
Branch 1	0 0	x 0 0 0	0 0 0	0 0 0	0	0 x	0
Branch 2	0 0	0 0	0 0 0	0 0	x	0 0	0 0
Branch 3	0 0 0	0 0		x x	x		
Branch 4		0			0 0	0	
Branch 5					0		
Branch 6					0		
Branch 7							
Rhizomes	40	10 1 x	20 2 x	10 3 x	20	20 1 x	30 1 x

Key: 0 Sprouted
x Dead

1. Node Number counted from tip of stolon.

days after treatment (Table 18e), twenty (22 percent) of which were dead, six at the 18th position on the treated branch, seven at the sixth position, five at the 12th poistion and one at the 18th position on an untreated branch. Thirty-five rhizome pieces were sampled of which nineteen (54 percent) were dead.

Sixteen days after treatment all the nodes that were sampled from the treated branch were dead (Table 18f). Seventy nodes were sampled outside the treated area, 24 (34 percent) of which were dead, 12 on the treated branch, seven at the sixth position, four at the 12th position and one at the 18th position on an untreated branch.

Translocation of glyphosate from the stolons to the rhizomes was very rapid. Two days after treatment more than half (80 percent) of the rhizomes sampled were dead (Table 18c). In the untreated plants only 22 percent of the rhizomes were dead (Table 18a). It would appear that a large fraction of the rhizomes had received a lethal dose of glyphosate two days after treatment. Movement of glyphosate from the treated stolon to the untreated stolon was slower than movement of glyphosate from the treated stolon to rhizomes. Two days after treatment with glyphosate only a few nodes, six at the sixth position of untreated branches had received lethal amounts of glyphosate (Table 18c). Sixteen days after treatment with glyphosate only one node at the 18th position on an untreated branch was dead. There were still many viable buds on the untreated branches. Possibly the reason for rapid translocation into the rhizomes was their size. The rhizomes were much smaller and fewer in number than the stolons. Whitwell _et al_. (1980) observed greater glyphosate accumulation in the roots and rhizomes than in the foliage of Berumdagrass.

TABLE 18c Sprouting of nodes in Kikuyu grass 2 days after treatment glyphosate, 1983 - 1984.

Block No.	1	2	3	4	5	6	7
Node number 1	6,12,18,24,30	6,12,18,24	6,12,18	6,12,18,24	6,12,18	6,12,18	6,12,18
Treated Branch	x x x x 0	x x x x	x x x	x x x	x x x	x x	x x x
Branch 1	0 0	x 0	0	x 0 0 0	0 0	x	x 0
Branch 2	0	0 0	0 0	0 0		0 0 0	0 0
Branch 3	0 0 0	0 x	0 0 0	0 0		0 0	0 0
Branch 4	0 0 0	x x	0 0	0 x		0	
Branch 5	0 0	0 0	0 0 0			0 0	
Branch 6	0 0	0 0 0	x 0			0 0	
Branch 7	0 0	0 0 0					
Rhizomes	30 1 x	5 x	3 x	3 x	2 x		10 2 x

Key: 0 Sprouted
x Dead

1. Node Number counted from tip of stolon.

TABLE 18d Sprouting of nodes in Kikuyu grass four days after treatment glyphosate, 1983 - 1984.

Block No.	1	2	3	4	5	6	7
Node number[1]	6,12,18,24	6,12,18,24	6,12,18,24	6,12,18	6,12,18,24	6,12,18	6,12
Treated Branch	x x x x	x x x	x x x x	x x x	x x x x	x x	x x
Branch 1	0 0 0	0 x	0 0 0	x	x 0	x x x	x
Branch 2	0 0	0 0 0 x	0 0	x	0	x x x	x x
Branch 3	0 0	0 0 0	0 0 0	x x	0		0 0
Branch 4	0 x	0 0 0	0 0	0 0	0 0		0 0
Branch 5	0 0 0	0 0	0	0 0	0 x		
Branch 6		0 0 0	0 0	0 0	0		
Branch 7		0	0 0				
Rhizomes	20 2 x	5 x	4 x	1 x	10 7 x	1 x	7 x

Key: 0 Sprouted
x Dead

1. Node Number counted from tip of stolon.

TABLE 18e Sprouting of nodes in Kikuyu grass eight days after treatment glyphosate, 1983 - 1984.

Block No.	1	2	3	4	5	6	7
Node number[1]	6,12,18,24	6,12,18,24	6,12,18,24	6,12,18	6,12,18	6,12,18	6,12,18
Treated Branch	x x x	x x x 0	x x x 0	x x x	x x x	x x	x x x
Branch 1	0	0 0	0	0 0	x x x	x x	0 0
Branch 2	0 0	0	0 0	x	0 0	0 0 0	0 0
Branch 3	0 x 0 0	0 0	x	0 0 0	0 0	0 0 0	0 0
Branch 4	0 0 0 0	0 0 0 0	0 x			0 0	0 0 0
Branch 5	0 0	0	0 0 0			x 0	x x
Branch 6	0 0	0 0 0	0 0 0			x 0	
Branch 7	0 0	0					
Rhizomes	90 4 x	30 7 x	2 x	2 x	5 x	10 2 x	

Key: 0 Sprouted
x Dead

1. Node Number counted from tip of stolon.

TABLE 18f Sprouting of nodes in Kikuyu grass sixteen days after treatment glyphosate, 1983 - 1984.

Block No.	1	2	3	4	5	6	7
7th Node	6,12,18,24,30	6,12,18,24,30	6,12,18,24	6,12,18,24	6,12,18,24	6,12,18	6,12,18
Treated Branch	x x x x x	x x x x x	x x x	x x x x	x x x x	x x	x x x
Branch 1	x x x 0 0	x 0 0 0	0 0 0 0	0 0	0 0	0 x	0
Branch 2	0 0 0	x 0	0 0	x x	x 0 0	0 0 0	0
Branch 3	0 0		0 0	0	0	0 0	0
Branch 4	0 0			0	0 0	0 0	0
Branch 5					x x	0 0	x
Branch 6							
Branch 7							
Rhizomes	5 x			1 x	2 x	3 x	2 x

Key: 0 Sprouted
x Dead

1. Node Number counted from tip of stolon.

GENERAL DISCUSSION

5.1. Tillage

Three primary tillage implements that farmers can use are the mouldboard plow, the disc plow and the chisel plow. The disc plow was included in this study because it is the most commonly used implement by farmers in Kenya. The mouldboard plow was included because it inverts the soil burying Kikuyu grass stolons and exposing the rhizomes. The aim was to determine the effect of soil inversion on control of Kikuyu grass. The chisel plow was included in this study because, it gives minimum distrubance of the soil. The soil is therefore not prone to erosion by wind or water. The chisel plow pulls out Kikuyu grass stolons and rhizomes without breaking them and exposes them for dessication as whole units.

5.1.1. Kikuyu Grass Control

In 1981 - 1982 the tillage experiment was initiated on an area that had been under Kikuyu grass for several years (pasture ley). The land was sloping and the soil surface uneven. Field conditions did not allow the tillage implements to perform adequately.

The mouldboard plow achieved good penetration on sod and adequate control of Kikuyu grass was obtained. Burying the stolons reduced their chances of reestablishment as they tended to rot. Since Kikuyu grass plants have more stolons than rhizomes, burying the stolons greatly reduced the potential buds that would have caused reinfestation. The few rhizomes that were exposed were dessicated in the sun during the long dry period that flowed after plowing, from end of November to beginning of April 1982.

The mouldboard plow achieved good penetration of the sod, and good control of Kikuyu grass, but it inverted the soil leaving it exposed to erosion by wind and water.

The disc plow could not penetrate the sod and required a primary tillage operation, such as a chisel plow. When the disc plow followed two operations with a chisel plow, an adequate seebed was prepared, but Kikuyu grass control was poor. When the stolons were not completely loosened from the soil and were not buried, they appeared to survive adverse conditions, such as drought, and established new growth when conditions became favourable. When the rhizomes were buried in the soil, they could survive drought and estblished new growth when the rains resumed.

The chisel plow gave adequate penetration of the sod, but clogged repeatedly and bunched the Kikuyu grass plants in a raking action. This raking action resulted in large heaps of Kikuyu grass plants which made the field uneven and difficult to seed. Kikuyu grass control was also poor. The rhizomes in the heaps were protected from the sun and were able to grow when the rains resumed in April. Not all Kikuyu grass plants were pulled out. Some plants were left standing in between the blades of the chisel plow.

Kikuyu grass control was not appreciably different when the chisel plow was used in November or May. The disc harrow was used as a primary tillage implement in May. Kikuyu grass control was poor as the disc harrow could not penetrate the sod.

In 1982 - 1983 the tillage trial was established on a field that was under wheat stubble. The Kikuyu grass was not matted and the four tillage implements used in this trial were able to penetrate the soil. In general, the control of Kikuyu grass by tillage was poorer than control by the use of the herbicide, glyphosate. Kikuyu grass cover was not significantly different for the various tillage treatments. November and December 1982 (Appendix 2) were wet. Therefore, the required long dry period to dessicate Kikuyu grass rhizomes was not available. In the absence of a long dry period, tillage alone did not adequately control the Kikuyu grass. Successful control of Kikuyu grass by tillage can only be achieved under a prolonged dry period as has been reported by Ivens (1945), Koble (1961, Youngner et al. (1971) and Zimmerman (1970).

Kikuyu grass cover was significantly higher when tillage was initiated in March than when tillage was initiated in November.

On sod, mouldboard plowing in November would appear to be an appropriate primary tillage operation. Harrowing with a disc harrow 1 - 2 weeks after plowing would expose loose stolon and rhizome pieces for dessication. Another two harrows in February and prior to seeding would ensure a fine tilth for seeding a cereal crop.

On wheat stubble, any of the three primary tillage implements (the mouldboard, disc plow and chisel plow) used in November would be adequate. Harrowing with a disc harrow 1 - 2 weeks after plowing would expose loose Kikuyu grass for dessication. Two other harrowings in February and prior to seeding would produce a fine seedbed for a cereal crop.

Removal of Kikuyu grass stolons by grazing or slashing and allowing to dessicate before tillage would enhance control by tillage. Kikuyu grass plants produce more stolons than rhizomes. By dessicating stolons before tillage potential buds that would develop into Kikuyu grass plants would be reduced.

A dry period for dessication of Kikuyu grass after tillage is essential if successful control of Kikuyu grass by tillage is to be achieved. Extensive tillage is required to expose the Kikuyu grass plants for dessication. Extensive tillage loosens up the soil exposing it to erosion by water and wind. Complete control of Kikuyu grass by tillage cannot be achieved in one season.

5.1.2. Grain Yield

No differences in yield were detected between the three primary tillage implements when used in November. The yield was lower when primary tillage was initiated in March than in November. The plots where primary tillage was initiated in March also had higher Kikuyu grass cover. It would appear that the competition from the high Kikuyu grass cover depressed the grain yield. Tillage in November may have stimulated nitrogen mineralization so that nitrogen was available in May when the crop was planted. Triplette et al. (1978) reported that plowing stimulated nitrogen mineralization. Kikuyu grass left growing up to March may have used up soil moisture, that could have been stored in the soil and used by the crop. The lower yields in plots tilled in March may have been caused by water stress.

Successful control of Kikuyu grass by tillage can only be achieved when a long dry period follows after tillage to dessicate the Kikuyu grass plants. The beginning of the 1981 - 1982 season was drier than the beginning of the 1982 - 1983 season (Appendix 2). Kikuyu grass control where the mouldboard plow was used in the 1981 - 1982 season was better than in the 1982 - 1983 season. On sod the mouldboard plow gave better control of Kikuyu grass than the other implements. On wheat stubble there was no significant difference between the three primary tillage implements. Higher yields were obtained when primary tillage was initiated in November than when primary tillage was initiated in March.

5.2. Glyphosate

Glyphosate was used in this study because it has been found to effectively control many perennial grasses in Kenya. It has been successfully used for control of Kikuyu grass in tea and coffee (Magambo et al. 1983; Chawdhry, 1975).

5.2.1. Kikuyu Grass Control

Glyhphosate effectively controlled Kikuyu grass. Three rates of glyphosate were used in this study 2, 3, and 4 l/ha. No significant differences were detected between these rates. However, there was a tendence for Kikuyu grass cover to decrease as the rate of glyphosate increased from 2 - 4 l/ha. It would appear that with the economic rates used in this study, complete control of Kikuyu grass could not be obtained in one season.

To obtain good control of Kikuyu grass by glyphosate, complete coverage of the herbage is recommended. Glyhphosate translocation from one stolon to the rhizomes was very rapid. Two days after treatment with glyphosate 80 percent of the rhizome pieces sampled had received lethal amounts of glyphosate. Translocation from one stolon to another was very slow. Sixteen days after treatment there were several buds from untreated branches that were viable. It is therefore necessary to obtain good coverage of the herbage to ensure that all the buds on the stolons receive lethal amounts of glyphosate.

Two litres per hectacre of glyphosate on light infestation of Kikuyu grass would appear to give acceptable control of Kikuyu grass. Four litres per hectacre would be recommended for heavy infestation of Kikuyu grass. Higher rates of glyphosate would give better results, but would not be economical to use prior to seeding. Magambo et al. (1983) reported excellent control of Kikuyu grass with glyphosate at 2 kg/ha (5.6 l/ha). Such high rates would be justifiable in a crop such as tea.

Glyphosate cannot achieve complete control of Kikuyu grass for zero tillage on heavily infested areas. A farmer interested in zero tillage would first have to control Kikuyu grass with a combination of glyphosate and tillage.

Tillage 3 - 21 days after glyphosate application greatly enhanced the performance of the herbicide. When glyphosate was applied in November and tillage delayed until May, Kikuyu grass cover was higher than when glyphosate application was followed by tillage within 21 days. Kikuyu grass that was not controlled by glyposate in November became established and was not controlled by tillage in May. There was a tendency for Kikuyu grass cover to increase as the interval between glyphosate application and tillage increased from 3 - 15 days. Chase and Appleby (1979) reported 90 percent control of purple nutsedge with an interval of three days between application of glyphosate and tillage, but less control with intervals of 11 - 23 days. Parachetti et al. (1975) found plowing from 4 - 21 days following glyphosate application to have no effect on Johnsongrass control. One tillage operation may have been able to kill Kikuyu grass plants weakened by glyphosate.

Glyphosate is translocated to meristematic tissue (actively growing buds) of stolons and rhizomes. These would be the buds at the tip of stolons and rhizomes. The topmost bud would have to be dead before the bud below it began active growth and became a sink for glyphosate translocation. The process of killing one bud at a time, would take a long time and glyphosate would be degraded before the buds at the base of a long stolon became a sink. Fragmentation of stolons and rhizomes by tillage broke apical dormancy and all the buds started active growth becoming sinks of assimilates and glyphosate . As is reported by Weed Research Organization (1969 - 1971), the key role of cultivation is the fragmentation of the stolons and rhizomes to stimulate their dormant buds into active and therefore, vulnerable state.

The type of implement to use after glyphosate application would depend on the level of Kikuyu grass infestation. Kikuyu grass cover was significantly higher on plots tilled with a disc harrow after glyphosate application in May than on plots which were plowed with a mouldboard plow. There were no significant differences in Kikuyu grass cover between plots harrowed after glyphosate application in November and plots plowed after glyphosate application in May. In May Kikuyu grass had formed a dense mat as compared to November. Three to five days after glyphosate application, Kikuyu grasss plants were still as intact as before glyphosate application.

On light infestation of Kikuyu grass, two operations with a heavy disc harrow would be adequate tillage after glyphosate application. When Kikuyu grass has formed a mat then a mouldboard plow should be used.

Plots treated with glyphosate in November tended to have less Kikuyu grass cover than plots treated in May. When tillage was delayed until May, the amount of Kikuyu grass cover tended to increase with delay in glyphsoate application from November to May. For the best control of Kikuyu grass, tillage after glyphosate application was required. Tillage exposed Kikuyu grass that had not been controlled by glyphosate for dessication during the dry period that followed. When tillage did not follow glyphosate application until May, the Kikuyu grass not controlled by the glyphosate became well established and was not killed by tillage operation in May.

5.2.2. Grain Yield

No differences in grain yield was detected between tillage treatments initiated in November and treatments where glyphosate was applied. Although glyhposate treatments tended to give better control of Kikuyu grass, this was not reflected in grain yields. It would appear that early tillage of plots treated with glyphosate in November was required for higher yields to have been realized. Tillage in November stimulated nitrogen mineralization so that nitrogen was available in May when wheat was seeded. When Kikuyu grass was treated with glyphsoate in May, there was a delay between the onset of the rains and spraying of glyphosate to allow regrowth of Kikuyu grass. Regrowth of Kikuyu grass in May utilized a lot of moisture from the soil.

In 1981 - 1982, plots on which glyphosate was applied in November and tillage followed within 4 - 21 days had significantly higher yields than plots on which glyphosate was applied in May. All the treatments showed good Kikuyu grass control. Plots on which glyposate was applied in November and tillage delayed till May had lower yields than the plots on which glyphosate was applied in November and tillage followed within 3 - 21 days. Low yields on plots treated with glyphosate in November and tilled in May may have been caused by Kikuyu grass competetion due to high Kikuyu grass covers. Tillage in November might have stimulated nitrogen mineralization so that nitrogen was available in May when wheat was seeded. The low yields on plots on which glyphosate was applied in May may have been caused by lower availability of nitrogen due to temporary immobilization of nitrogen by decomposing Kikuyu grass and less soil moisture. High organic matter content in the soil has been reported to cause a high carbon/nitrogen ratio resulting in immobilization of nitrogen (Baeumer and Bakerman, 1974; Russell et al., 1975 and Triplett et al., 1979). Kikuyu grass left growing upto May may have used up soil moisture, that would otherwise be stored in the soil and used by the crop. Kikuyu grass used up a lot of soil moisture during the period of regrowth after the onset of the rains in April, depleting the soil of moisture that would have been used by the wheat crop.

Although it has not been reported, decomposing Kikuyu grass may have produced some chemicals that inhibited the development of wheat.

Toai and Linscott (1979) reported decaying quack grass rhizomes to contain toxins that inhibited alfalfa seedling development. Gabor and Veatch (1981) isolated a phytotoxin from quackgrass rhizomes that inhibited the seedling root growth of corn, oats, cucumber (Cucumis sativus L) and alfalfa.

In the 1982 - 1983 season, plots on which glyphosate was applied in May appeared to have higher yields than plots on which glyphosate was applied in November. These results are the reverse of the results of the previous season. Due to the plot design, the November treatments were harrowed four times compared to two harrowings after glyphosate application in May. The excessive tillage resulted in drying of the plots tilled in November which were more finely worked than the plots tilled in May. The last half of May 1983 was very dry. The crop on plots tilled in May had a better start with more soil moisture than the crop on plots tilled in November which was under water stress.

In general grain yield was higher when Kikuyu grass was controlled early (November and January) than when Kikuyu grass was controlled late (February, May). Early application of glyphosate will ensure better control of Kikuyu grass and higher grain yields.

5.3. Control of Kikuyu Grasss in Sunflowers

Selective control of Kikuyu grass in cereal crops is not possible. In order to grow cereals Kikuyu grass has to be controlled before the crop is seeded. In broad leaved crops such as sunflower, selective control of Kikuyu grass can be achieved by use of herbicides. Growing sunflower in rotation with wheat will enable a farmer to control Kikuyu grass the season before seeding the wheat crop.

5.3.1. Kikuyu Grass Cover

Throughout the growing season Kikuyu grass cover was low until towards the end of the season, even in control plots. Sunflower is a competitive crop, it suppressed Kikuyu grass. Suppression of Kikuyu grass may have been due to shading by sunflower leaves. Sunflower roots may have produced substances that suppressed Kikuyu grass development. Ivans and Burnside (1982) reported that fresh and dry weights of soybeans and sorghum were reduced when they were planted in soil in which sunflower had been previously grown.

Two herbicides were tested in this study. EPTC and fluazifop-butyl, separately and in combination. EPTC suppressed Kikuyu grass at the beginning of the season. At the end of the season, Kikuyu grass cover in plots treated with EPTC was as high as in untreated plots. Roeth (1973) found EPTC to delay emergence but failed to control rhizomatous Johnsongrass. He reported good seedling control. Kikuyu grass infestation in the plots was mainly by vegetative buds and not by seed. EPTC was not effective on plants established from stolon and rhizome pieces. Holly (1976) reported that many soil applied herbicides, particularly thiocarbomates, such as EPTC, are effective on young seedlings.

Fluazifop-butyl killed most of the Kikuyu grass plants. Kikuyu grass cover in plots treated with fluazifop-butyl was low, even after the sunflower had been harvested. EPTC had no additional benefits when it was applied in combination with fluazifop-butyl. Fluazifop-butyl gave good control of Kikuyu grass even at the rate of 0.5 kg/ha. Stewart et al. (1982) obtained excellent control of quackgrass at 0.5 - 0.75 kg/ha. However, Magambo et al. (1983) found fluazifop-butyl did not effectively control Kikuyu grass.

The low infestation levels of Kikuyu grass after treatment with fluazifop-butyl would be easy to control by low rates of glyphosate followed by light tillage.

5.3.2. Seed Yield

There were no significant differences in sunflower seed yield between the various treatments. Sunflower is a large plant and therefore out-competed the Kikuyu grass plants. The use of herbicides in sunflower for control of Kikuyu grass is not justified as there was no yield increase. However, the use of fluazifop-butyl would make subsequent control easier and cheaper. Low rate of glyphosate 2 l/ha followed by light tillage operation with the disc harrow 3 - 5 days later would give excellent control of Kikuyu grass before seeding of a cereal crop the following season.

5.4. Kikuyu Grass Establishment

Kikuyu grass was established from both stolon and rhizome single node cuttings. The rate of growth was not significantly different between the plants from stolons and plants from rhizomes. Plants from stolon cuttings developed into larger plants during the duration of the experiment. The initial establishment of stolon buds was faster than the establishment of rhizome buds. The rapid establishment of stolon buds resulted in larger plants as compared to the slow establishment of rhizome buds.

Destruction of stolons by grazing or cutting and burning before tillage would reduce the number of potential buds for reinfestation. Rhizome buds would be exposed for dessication by tillage. Kikuyu grass control by tillage would be enhanced by destruction of stolons before tillage. Kikuyu grass has more growth above ground than below the ground surface.

5.5. Translocation of Glyphosate in Kikuyu Grass Plants

This experiment was carried out two times from July - November 1983 and November 1983 to February 1984.

The first time, translocation from one stolon to the rhizomes was slow. Translocation to the rhizomes was not evident until eight days after treatment with glyphosate. Sixteen days after treatment some rhizomes had not received lethal amounts of glyphosate. Translocation from the treated stolon to the untreated stolons was evident eight days after treatment.

The second time the translocation experiment was carried out, translocation of glyphosate from the treated stolon to the rhizomes was very rapid. Two days after treatment 80 percent of the rhizomes were dead. Sixteen days after treatment, translocation to the untreated stolons was not complete. Many buds on the untreated stolons were still viable. Complete coverage is essential for faster translocation of glyphosate and therefore good control of Kikuyu grass. Fragmentation by tillage 3 - 7 days after treatment with glyphosate will stimulate rapid meristimatic activity in axillary buds making them more vunerable to glyphosate.

Plants grown in July were established under water stress conditions. They were watered every 3 - 4 days. Possibly the soil dried faster than it was watered. Plants grown in November were watered every two days and were established under wetter conditions. Absorption and translocation were therefore slower in the stressed plants. McIntyre and Hsiao (1982) have recommended that the use of glyphosate for quackgrass control should be restricted to periods when there is sufficient soil moisture to promote the active growth of the plants.

SUMMARY AND CONCLUSIONS

On a pasture ley, the mouldboard plow achieved good control penetration and control of Kikuyu grass. Control of Kikuyu grass when a disc plow and a chisel plow were used was poor. A mouldboard plow would be recommended as the primary tillage implement on a pasture ley in November. Three harrows, two weeks after plowing, in February and prior to seeding would be recommended as subsequent operations.

On wheat stubble, the three primary tillage implements achieved good penetration. Kikuyu grass cover was not significantly different, although where the mouldboard plow was used appeared to have less Kikuyu grass cover. On heavy infestations of Kikuyu a mouldboard plow should be used. On light infestations a disc plow or chisel plow could be used. In both cases a disc harrow two weeks later, in February and prior to seeding would enhance control and provide a suitable seedbed for wheat.

Tillage will be successful for control of Kikuyu grass if there is a prolonged dry period. In the absence of a prolonged dry period, control of Kikuyu grass by tillage would be poor.

Glyphosate effectively controlled Kikuyu grass. On light infestation 2 l/ha would obtain good control. On heavy infestation 4 l/ha would be recommended. Glyphosate at higher rates would give better control of Kikuyu grass, but this would only be justified on plantation crops, such as tea and coffee.

Tillage is recommended 3 - 5 days after glyphosate application; a heavy disc harrow on light infestation, a mouldboard plow on heavy infestation. A disc harrow should follow two weeks later where a plow is used as a primary tillage implement. Another harrow prior to seeding would loosen up the soil for seeding.

Glyphosate application followed by tillage should be as early as possible, after harvesting to allow Kikuyu grass that escaped glyphosate to be dessicated in the sun. Kikuyu grass should be well decomposed by the time wheat is seeded. Applying glyphosate in November will ensure that glyphosate is applied to actively growing Kikuyu grass plants for faster absorption and translocation and therefore better control.

Kikuyu grass may be controlled one season in advance before seeding when sunflower is grown in rotation with wheat. Fluazifop-butyl at 0.5 kg/ha applied 4 - 5 weeks after seeding of sunflower is recommended for good control of Kikuyu grass. Early tillage with a heavy disc harrow or chisel plow soon after harvesting the sunflower will expose Kikuyu grass for dessication. Glyphosate at 2 l/ha 3 - 5 days before tillage would give good control of Kikuyu grass left after use of fluazifop-butyl, even in the absence of a prolonged dry period.

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APPENDIX

APPENDIX 1. Trade, Common and Chemical Names, Formulations, Prices and Manufacturers of Herbicides used.

PRODUCT NAME	CHEMICAL NAME	ACTIVE INGREDIENT NAME	g/l	MANUFACTURER	PRICE Ksh/litre
EPTAM	E.P.T.C.	S-ethyl dipropylthiocarbamate	750	Stauffer	-
ERADICANE	E.P.T.C.	S-ethyl dipropylthiocarbamate	750	Stauffer	130
FUSILADE	FLUAZIFOP-BUTYL	(±)-butyl2-(4((5-(trifluoromethyl) -2-pyridinyl)oxy)phenoxy)propanette	250	I.C.I.	350(est.)
BANVEL COMBI	DICAMBA +	3,6-dichloro-o-anisk acid	200	Velsicol	76
	CMPP	2-(4-chlo-o-tolyl)oxy)propionic*	200		
BUCTRIL M	BROMOXYNIL+	3,5-dibromo-4-hydroxybenzonitrite	200	Rhone-Poulene Inc.	78
	MCPA	(4-chloro-o-toly)acetic acid	200		
PARDNER	BROMOXYNL	3,5-dibromo-4-hydroxybenzonitrite	250	Rhone-Poulene Inc.	135
ROUNDUP	GLYPHOSATE	N-(phosphonomethyl)glycine	360	Monsanto	280
ILLOXAN	DIC-LOFOP-METHYL	methyl 2-(4-(2,4-dichlorophenoxy) phenoxy) propanoate	360	Hoechst	203
MAYTRIL	IOXYYNIL	4-hydroxy-3,5-diiodobenzonitrile (4-cyano-2,6-diiodophenol)	68	May & Baker	120
	BROMOXYNIL	3,5-dibromo-4-hydroxybenzonitrite	68		
	CMPP	2-(4-chloro-o-tolyl)oxy)propionic acid	32.8		

APPENDIX 2. Monthly Precipitation 1981 - 1983

Month	Precipitation in mm		
	1981	1982	1983
January	0.8	7.0	24.2
February	22.1	21.1	27.9
March	112.8	4.9	14.4
April	212.2	144.1	119.1
May	106.9	131.8	97.9
June	37.6	40.3	37.5
July	85.0	42.8	70.4
August	156.8	247.9	170.0
September	118.4	28.6	123.5
October	22.9	94.5	62.3
November	29.7	139.9	81.7
December	34.9	62.2	118.1