UNIVERSITY OF ZAMBIA
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DEPARTMENT OF CROP SCIENCE

WEED FLORA AND WEED MANAGEMENT UNDER DIFFERENT SOIL TILLAGE SYSTEMS IN SMALL SCALE SORGHUM (*Sorghum bicolor* (L) Moench) PRODUCTION IN CHIAWA.

by

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DECLARATION

I, **FRANK PHILLIP CHISAMANGA,** hereby do declare that this dissertation represents my own work and it has not previously been submitted for a degree at this or another university.

Signature

10TH DECEMBER, 95.

Date

APPROVAL

This dissertation of FRANK PHILLIP CHISAMANGA, is approved as fulfilling part of the requirements for the award of the degree of Master of Science in Agronomy (Crop science) by the University of Zambia.

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DEDICATION

I dedicate this work to my dearest parents, particularly to my late father Mr **TITUS T. CHISAMANGA**, who inspired me very much but could not live to see me to this end.

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ABSTRACT:

A research study on sorghum (*Sorghum bicolor* (L) Moench) production under small scale farming was conducted in Chiawa, during the 1993/94 cropping season. It consisted of three components, namely the weed flora survey, the socio-economic weed management survey and a field trial. The main objective of the research study was to determine the weed flora and weeding requirements on two different tillage systems practised in the area i.e., conventional and conservation tillage. The weed flora survey covered 30 sorghum fields, while the socio-economic survey involved 30 farmers from 17 villages across Chiawa. A two factorial split-plot design was used on the field trial, with tillage systems and weeding frequencies arranged on the main and sub-plots, respectively. Weeding frequencies comprised zero, one, two, three and clean weedings. The field trial was replicated 4 times. Data on soil moisture, weed cover, sorghum cover and sorghum height were collected a day before any weeding treatment was applied, while sorghum yields were recorded at harvesting time.

Paspalum scrobiculatum was the most dominant weed in Chiawa, while *Commelina benghalensis, Cyperus esculentus* and *Digitaria milanjiana* were considered the most difficult weeds to be controlled by hand hoeing. Yields under conventional tillage of 989 Kg/ha were significantly higher ($p < 0.05$) than those realised under conservation tillage of 733 Kg/ha. There was a significant negative correlation ($p < 0.05$) between weed

infestation and sorghum yield (r = - 0.90), while sorghum cover and height were positively correlated with sorghum yield across tillage systems. There was no interaction between tillage systems and weeding frequencies. Three timely weedings at 2, 4 and 6 WAP was more economical, practical and resulted in crop performance and yields which didn't differ from that of clean and two weedings. These observations however, need to be investigated further over several seasons in order to obtain tangible conclusions.

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Last but not least, I would like also to thank the **people of Chiawa** and particularly **Mr A. Zulu** the agricultural extension officer, who all made my research work a reality. I hope that this piece of work would in one way or another assist in improving their farming practices and enhance sorghum production.

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LIST OF ABBREVIATIONS AND ACRONYMS

ARPT	Adaptive Research Planning Team.
A.S.L.	Above Sea Level
Conserv.	Conservation
Conv.	Conventional
Cov.	Cover.
C.V.	Coefficient of Variation.
DBLP	Day Before Land Preparations
Freq.	Frequency.
ht.	Height
LSD	Least Significant Difference.
Matoro	River bank fields.
no	Number.
ns	Not significant.
Trt.	Treatment.
T	Tillage.
T_1	Conventional tillage.
T_2	Conservation tillage.
W	Weeding frequency.
W_0	Zero weeding.
W_1	One weeding at 3 WAP.
W_2	Two weedings at 3 and 6 WAP.
W_3	Three weedings at 2, 4 and 6 WAP.
W_C	Clean weeding (throughout).
WALP	Weeks After Land Preparations
WAP	Weeks After Planting.

1.0 INTRODUCTION

Sorghum (*Sorghum bicolor* (L.) Moench) is an indigenous cereal of Africa. It is an important grain cereal crop in the semi-arid regions of Africa. In Zambia, it is the staple food for many people in the hot and drought prone areas underlying in region 1 of Zambia's agro-ecological zones. These areas receive very erratic rainfall of less than 800 mm annually with high temperatures which usually result in high evapotranspiration. It is in this region that Chiawa is situated.

Agricultural activities in the area are dominated by small scale farmers who practice subsistence farming. The area is infested with Tsetse fly (*Glossina spp.*), hence the restriction of livestock keeping. Two field cropping systems are prevalent,i.e., upland fields which are mostly situated near the homestead and river bank fields referred to as *matoro*.

Sorghum is the major crop grown in these areas and others are millet, cotton and maize; the latter is mostly grown on the *matoro*. Being a warm season crop, sorghum is planted under conditions that are favourable for germination and luxuriant growth of weeds.

Land preparation is an extremely important weed control practice that is frequently over looked. Depending on the time of land preparation and rainfall onset, different tillage practices are used by farmers in Chiawa,i.e., conventional and conservation

tillage systems. With either tillage practice, farmers cultivate three to four weeks after the crop has emerged to remove the first flush of weeds. However, Masi (1989) observed that this did not meet the recommended agronomic practices of keeping sorghum weed free in the first four weeks.

Vernon and Fischer (1983) recommended that research be carried out on weed management in reduced tillage systems in the semi-arid areas. This has not been done so far (Anonymous, 1991). Sorghum yields are low, such that any appropriate weed management practice, among other agronomic factors, should have a positive effect on production. For an effective weed control programme and appropriate farming practices, correct weed identification is very important. Knowledge of the weed flora of a specific area may lead to adaptive technologies for improved sorghum production.

Based on sorghum production under small scale farming in the semi-arid regions and Chiawa in particular, the objectives of this study were;

(i) To determine the effect of weeding frequency on sorghum yield.

(ii) To assess the effects of conventional and conservation tillage systems on weeding requirements and sorghum yields.

(iii) To determine the weed flora in Chiawa sorghum fields.

(iv) To assess weed management practices and their impact on the socio-economy of small scale farming in Chiawa.

2.0 LITERATURE REVIEW

2.1 Sorghum production.

Sorghum is the fifth most important cereal in the world after wheat, rice, maize and barley (Doggett, 1987). In 1986, it was grown on some 47 million ha, mainly in the semi-arid areas of the tropics and subtropics. In sub-saharan Africa, sorghum accounted for 43 % of all major food staples produced from 1973 to 1977 (IFPRI, 1983). In Chiawa, subsistence agriculture is still the major form of food production practised, with sorghum being the main crop (Broeke, 1993). Chanda (1991) observed that sorghum was grown in Chiawa under hot and dry conditions compounded with erratic rains season after season.

Traditional sorghum cultivars, which are photo-sensitive, late maturing and low yielding, are widely grown (Anonymous, 1989). In recent years, improved cultivars, that are early maturing, higher yielding, responsive to improved management and more tolerant to drought, are becoming more and more popular. According to the local agricultural extension workers and ARPT (1991), farmers pay more attention to maize in the *matoro* than to sorghum, which results in untimely planting and weeding.

Masi (1991) reported average sorghum yields of an improved cultivar (Kuyuma) of 2500 kg/ha, while traditional cultivars planted by the small scale farmers in Chiawa yielded 500 kg/ha, only.

Sorghum is very vulnerable to attack by the red-billed weaver bird (*Quelea quelea*) and the armoured cricket (*Acanthoplus aspeiseri*) (Sithole, 1990). Sithole (1990) further stressed that armoured cricket should be deprived of food by keeping the fields and surroundings weed free.

2.2 A weed defined.

Weeds, just like insects and diseases are also classified as agricultural pests (Aldrich, 1984). Akobundu (1987) defined a weed as a plant growing where it is not needed and which interferes with human activities and welfare. Weeds encompass all types of undesirable woody plants, broadleaf plants, grasses, sedges, aquatic plants and parasitic flowering plants. Akobundu (1986) noted, that weeds were the most underestimated pests in tropical agriculture.

2.3 Weed flora.

Vernon (1983a) noted the importance of correct weed identification. Weeds differ from one species to another in their response to control measures, such that the best selection of the latter depends on correct identification of weed species present.

Weed problems in sorghum are similar to those of other food crops in the tropical savanna. While annual and perennial weeds are common problems, sorghum is particularly vulnerable to damage by the parasitic weeds *Striga asiatica* and *S. hermonthica* (Abalone, 1979). In tropical Africa, other major weeds of sorghum are *Andropogon spp., Brachiaria spp., Cynodon dactylon, Cyperus*

rotundus, Digitaria spp., Portulaca oleracea, Echinochloa colona, Euphorbia spp., Eleusine indica and Trichodesma spp. (Ogborn, 1980).

Vernon (1983a) reported more than 400 plant species found as weeds in arable land in Zambia, but only some are regarded as important. These include *Nicandra physalodes, Amaranthus spp., Galinsonga parviflora, Bidens pilosa, Datura stramonium, Acanthospermum spp., Commelina spp., Cyperus spp, Cynodon dactylon, Eleusine indica, Digitaria milanjiana, Rottboellia cochinchinensis, etc.* (Vernon, 1983a). For Chiawa, which is within a specific zone (region 1), the weed flora, specific for the area, has not been described and reported so far.

2.4 Weed competition and weed control in sorghum.

Small scale farmers have received increasing attention from agricultural researchers in recent years. It has been recognised that weed control stands as one of the most important factors affecting their crop yields (Campton, 1981). In small scale farming, Phillips *et al.* (1970, as cited by Zimdahl, 1980) estimated the annual sorghum grain loss due to weed competition reaching up to 40 percent.

Weeds interfere with crops by competing for moisture, carbon dioxide, nutrients and light, which reduces yield quantity and quality (Vernon, 1983b). Competition is greatest between plants that are similar in their growth habits, such as root growth and foliage characteristics, because they have nearly the

same demands upon the environment (Moody, 1983).

Water is the main ingredient in plant metabolism and is required for transportation of substances within plants. Water deficiency results in poor metabolism leading to poor crop yields (Mengel and Kirkby, 1987). Water deficiency is especially critical at flowering and grain formation stages of plants.

Vernon (1983b) reports, that elsewhere research had shown that weeds in sorghum compete particularly for moisture. Zimdahl (1980) noted, that water supply exerted a tremendous influence on all sorghum/weed competition. Akobundu (1987) recorded, that the effect of weed competition was more severe under conditions of adequate soil moisture, particularly at the time of sorghum seedling emergence and establishment, than when moisture was scarce. In times of inadequate moisture, however, weeds were more adversely affected than sorghum. There is also evidence, that weeds are harmful during the early weeks of sorghum growth, as concluded by Shetty (1978) from a trial in the drought prone region in Ukiriguru (Tanzania).

At planting time both, weeds and sorghum seedlings emerge almost at the same time. Akobundu (1987) explained, that sorghum seedlings, being relatively small and weak and their water uptake lower than that of most weeds, were not able to compete well with the more vigorous weed seedlings. Research has also shown, that in dry conditions it is important to keep sorghum fields weed free until grain formation, in order to avoid excessive loss of

moisture from the soil through the weeds (Hamaamba, 1989).

Weeding at the right time has a direct effect on crop yield. Burnside (1966) stated, that in sorghum, initial weed control should be carried out within four weeks after planting. He showed that in the semi-arid West Africa, when fields were weeded at 2, 3, 4, 5, 6 and 8 weeks after planting and kept weed free thereafter, yields decreased by 2, 5, 16, 24, 38, and 57 percent, respectively. Enyi (1973) analyzed the effects of weed interference in sorghum in a low rainfall area in Tanzania and reported, that three weedings at 2, 4 and 8 weeks after planting gave the best yield, and increased leaf area index, ear length, and grain weight per unit ear length.

2.5 Soil tillage.

The role of soil tillage, i.e., ploughing, seedbed preparation or crop cultivation, as a weed control method is well accepted and documented, notes Zimdahl (1980). Lal (1977) defined tillage as a physical, chemical or biological manipulation of the soil to optimize conditions for seed germination, emergence and seedling establishment. Keen and Russel (1937, as cited by Alexandre, 1984) could not find any justification for tillage operations beyond the minimum needed to provide a proper seedbed, and to control weeds until the crop is well established.

In traditional farming, a wide range of land preparation methods are used in different agro-ecological regions. Two distinct methods include conventional and conservation tillage.

Conventional tillage refers to a method of seed bed preparation that involves physical soil manipulation by commonly used equipment such as a plough or the hand hoe (Lal, 1977).

Conservation tillage (otherwise known as mulch farming) is by definition quite independent of the degree of soil tillage carried out (Oliver, 1989). It is broadly defined to include any tillage practice which leaves at least 30 to 50 percent crop residue cover on the soil surface after planting (Vowles, 1989. Crosson, 1981). Wittmus *et al*. (1973, as cited by Akobundu, 1987) described conservation tillage as including tillage systems that create as good an environment as possible for the growing of the crop, and that optimizes conservation of soil and water resources.

Massee (1983) observed, that conservation tillage is synonymous with optimum retention of residue on the soil surface and the utilization of herbicide to control weeds, where tillage is not or cannot be performed. In Chiawa, where moisture is a limiting factor in crop production, conservation tillage is practised to retain and conserve soil moisture, particularly at the beginning of the rainy season (Anonymous, 1989). However, while conservation tillage is recommended for the lowland humid tropics, conventional tillage appears to be better than conservation tillage for the semi-arid tropics (Nicou and Chopart, 1979, as cited by Akobundu, 1987). In the semi-arid tropics, crop residue cover is generally sparse and inadequate for an effective cover. Where inadequate mulch is present under

conservation tillage, more water is lost through run off, and there is a great problem of crop stand establishment (Robinson, 1984, as cited by Akobundu, 1987).

Sanford *et al*. (1982) compared conventional and conservation tillage systems in Sudan and found, that from a two year average yield, conventional tillage resulted in a 19 percent higher yield than that of conservation tillage.

Conservation tillage does not stir soil so much to bring seeds from the depth, where they are dormant, to the surface where some would germinate. It, however, increases the population of perennial weeds. Conventional tillage increases the rate at which the soil seed bank is activated, hence increasing weed germination (Akobundu, 1987).

3.0 MATERIALS AND METHODS

3.1 Location.

The research was conducted in Chiawa during the 1993/94 cropping season. It covered three major components, namely the weed flora survey, field trial and the socio-economic weed management survey (Fig 1).

Chiawa, which is a chiefdom, is actually situated in the Zambezi and Kafue river valleys, about 150 km south east of Lusaka and is part of the Kafue district in Lusaka Province. It lies between latitude 15^0 45' and 16^0 00' south and longitude 28^0 30' and 29^0 13' east. The altitude ranges between 370 m and 540 m above sea level. Goba, a derivative of the Shona language spoken in Zimbabwe, is the language used locally. In Chiawa, farming is dominated by small scale farmers[1].

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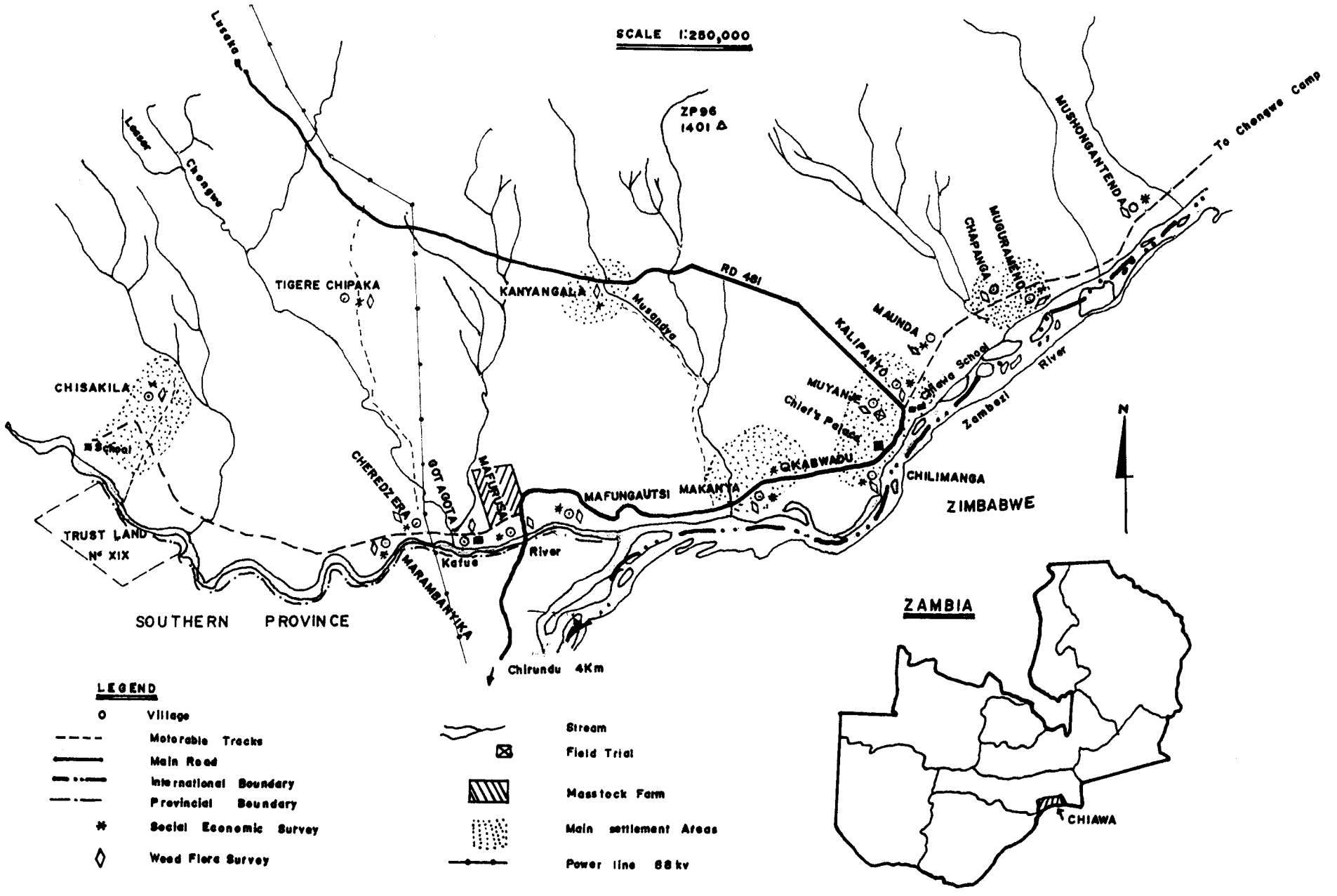
[1] In this text, a small scale farmer is one who cultivates an average of 5 ha or less, using mainly the hand hoe or oxen (either owned or hired) and produces for home consumption (Anonymous, 1994).

FIG I. VILLAGE SETTLEMENTS IN CHIAWA 1993/94



3.2 Weed flora survey.

The weed flora survey covered thirty sorghum fields in 17 villages across Chiawa (Fig 1). Farmers' fields, both from the upland and *matoro*, were randomly selected from each village, using the random number technique. The selected fields had to be at least 0.5 km apart within the same village, while villages were 3 to 5 km apart.

Two surveys were planned, but because of the drought, only one was carried out. There was no meaningful weed cover after the first weeding. The only survey was done just before the first weeding in late January, when most sorghum fields were in their 3rd and 4th week after replanting in late December.

Depending on the farmers' field size, two to three samples were taken using a 0.5 square metre quadrant with the stratified random sampling techniques. Weed cover (species by species) and crop cover were assessed by visual observation and expressed in percent. In addition, other noticeable weeds in the fields were recorded as "present weeds." This was done by recording any weed species noticed at least more than twice in the field.

The collected data were analyzed by getting the averages of data from weeds and the crop. These were then rated according to their average cover and frequency of occurrence.

3.3 Field trial.

3.3.1 Site.

The field trial was an on-farm experiment located in Chiawa centre, on a selected small scale farmer's field in Muyanje village on the upland (Table 1). It was a relatively old field, which had been in use for the past three years on a monocultural practice of sorghum.

Table 1: SITE DESCRIPTION OF THE FIELD TRIAL; MUYANJE-CHIAWA, 1993/94.

Item:	Description
ALTITUDE	395 m ASL
TOTAL SEASONAL RAINFALL (1993/94)	407 mm
AVERAGE MONTHLY TEMPERATURE	28.6 ^{0}C
CROPPING SYSTEM	Mono cropping, sorghum.
SOIL TYPE	Loamy Sand
SOIL COLOUR	Brown (7.5 YR 4/4)
pH ($CaCl_2$)	5.2
NITROGEN (N) (%)	0.06
PHOSPHORUS (P) (mg/kg soil)	8.3
ORGANIC MATTER (OM) (%)	0.9
FERTILIZATION	None, since 1990.

3.3.2 Experimental design and field layout.

A split-plot design with two factors was used. Tillage system (T) was assigned to the main plot and weeding frequency (W) to sub plots. The two factors had the following treatment levels;

a) Tillage system (T);

1. Conventional tillage (T_1).

2. Conservation tillage (T_2).

b) Weeding frequency (W);

1. Zero weeding (W_0).
2. One weeding (W_1) at 3 WAP.
3. Two weedings (W_2) at 3 and 6 WAP (Recommended).
4. Three weedings (W_3) at 2, 4 and 6 WAP.
5. Clean weeding (W_C) throughout.

The field trial was replicated four times (Appendix F). All treatments were randomly apportioned, giving a total of forty (40) plots. Each main plot (T) covered an area of 22.75 x 5 m, while each sub plot (W) covered an area of 5 x 3.75 m, giving a total area of 22.75 x 49.0 m (1114.75 m^2) including path ways.

3.3.3 Treatment application.

All treatments were applied in accordance with the small scale farmers' practices using the hand hoe. Land preparation was carried out with the first good rains in mid December. Land was prepared in accordance with the conventional and conservation tillage practices.

Conventional tillage consisted of hand hoe ploughing to a depth of 10 to 15 cm. Under conservation tillage, land preparation consisted of only removing unwanted woody plants. Apart from this, the soil, crop residues and other vegetation remained undisturbed. Crop residues were maintained to act as a mulch. Planting in both tillage systems was carried out on the third day after land preparation.

Weeding treatments (W) were applied using the hand hoe. Under the zero weeding treatment (W_0), weeds were allowed to grow throughout the season. In the clean weeding treatment (W_C), plots were kept weed free throughout by weekly checks and weeding.

3.3.4 Agronomic practices.

With respect to agronomic practices, the sorghum standard recommendations, as from the Department of Agriculture, were followed (Table 2). Due to the erratic onset of the rains, however, the crop had to be replanted in early January, as the first planting completely failed to emerge.

As crop emergence was sparse under the conservation tillage, gap filling was done by transplanting thinned out plants from conventional tillage plots, a common practice by local farmers.

The red-billed weaver bird *(Quelea quelea)* was a nuisance, and scarring had to be carried out. The armoured cricket *(Acanthoplus aspeiseri)* heavily attacked the crop during the grain dough stage, and an insecticide (Cypermethrin) was used to control the insects. The control of birds, however, was not very efficient due to a heavy infestation.

Table 2: AGRONOMIC PRACTICES, FIELD TRIAL; MUYANJE-CHIAWA, 1993/94.

Practice;	Application *
Land preparation: Conventional tillage Conservation tillage	11/12/1993 Soil tillage to 10 cm. No tillage/crop residue maintained.
Variety	Kuyuma (Hybrid)
Germination test	95 %
1st Planting date	14/12/1993
Replanting date	6/01/1994
Seed rate	8 kg/ha
Row spacing	75 cm
Inter row spacing	50 cm
50 % crop emergence date	14/01/1994
Gap filling (transplanting)	27/01/94, (conservation tillage only)
1st Weeding at 2 WAP[1]	20/01/94
2nd Weeding at 3 WAP	27/01/94
3rd Weeding at 4 WAP	03/02/94
4th Weeding at 6 WAP	17/02/94
Fertilization: Basal dressing (comp. D) Top dressing (urea)	 100 kg/ha (at planting time) 100 kg/ha (at 6 WAP)
Insect pest control**	Cypermethrin EC (350ml/ha)
Bird scaring	From early dough stage to harvesting.
Harvesting	Manually, 20-21 April 1994.

[1] Weeks After Planting.
* Where NOT indicated, agronomic practices were the same in both conventional and conservation tillage systems.
** *Armoured cricket (Acanthoplus aspeiseri).*

3.3.5 Data collection.

a) Crop performance.

When 50 percent of sorghum seedlings had reached the three leaf stage, crop emergence was recorded as percentage of planted stations. Thereafter, crop height data were collected every two weeks, a day before any weeding treatment was applied. Data were collected until the 10^{th} week after planting.

b) Weed/crop assessment.

The weed and crop cover percentages were assessed using a 0.5 square metre quadrant. A visual score on a scale rating from 0 to 100 (0 = no cover; 100 = complete cover) was used for crop and weed cover assessment.

The weed frequency was worked out from the number of sampling units with the specific weed species, divided by the total number of samples and expressed in percent. The weed/crop assessment data were taken at the same time as crop height.

c) Yields.

Sorghum harvesting was carried out from a 3 x 1.6 metre area, from each treatment. The harvested heads were sun dried for two weeks and weighed at 17 percent grain moisture, which is within the harvesting limits of 16 percent. Thereafter, it was threshed and 1000 grains were randomly picked and weighed.

d) Soil moisture.

Soil moisture content was taken using the thermo-gravimetric

method. Soil samples were taken from each treatment a day after land preparation (tillage), and thereafter every 7 days, for a period of four weeks.

The samples were weighed immediately and later taken to the laboratory for oven drying at 105 ^{0}C until zero soil moisture for 24 hours. The oven dried soil samples were reweighed and the soil moisture determined by using the following equation;

$$W_S = \frac{M_{S+W} - M_S \times 100}{M_S}$$

where; W_S = soil moisture

M_{S+W} = mass of wet soil (mass of solids + H_2O)

M_S = mass of dry soil (mass of solids only)

3.3.6 Data analysis.

The collected data were analyzed by means of analysis of variance. A mean separation, using the LSD test, was carried out to quantify the least significant difference among different means of treatments. Correlation analysis was done to find out, how the yield of sorghum was correlated with crop and weed cover, crop emergence, crop height and 1000 grain weight. All these analysis were done using the MSTAT computer programme.

3.4 Socio-economic weed management survey.

The socio-economic weed management survey was carried out to assess how the small scale farmer treats and manages his/her weeds in sorghum fields. A questionnaire with 33 questions, covering the farmer, farming practices, weeds, weeding

frequencies etc. was used (Appendix D).

A total of 30 respondents (farmers) from across Chiawa were randomly selected from 17 villages, using the random number method (Fig 1). The survey was done in late March, when farmers had finished all their weedings. The interviews were deliberately conducted on farmers' fields to facilitate adequate questioning and explanation. The collected information (responses) from the questionnaire were summed up and then averaged.

4.0 RESULTS

4.1 The weather.

During the season, the rains started late in November. Good planting rains, however, only started in late December. In early February, Chiawa area experienced a long dry spell (Appendix A). The total seasonal rainfall was 407 mm, which was poorly distributed. This was below the 10 year mean annual rainfall of 650 mm. The average monthly temperature was 28.6 ^{0}C. The late rains and the prolonged drought adversely affected the emergence and development of the crop and weeds.

4.2 Weed flora of Chiawa.

A total of 31 weed species were noticed in both, upland and *matoro* sorghum fields (Table 3 and Appendix C). Among the grasses and sedges, the most dominant weeds in the area were *Paspalum scrobiculatum* (L), *Panicum maximum* (Jacq), *Digitaria milanjiana* (Steud) and *Cyperus esculentus* (L). *Commelina benghalensis* (L), *Ceratotheca sesamoides* (Endl), *Boerhavia diffusa* (L), *Celosia trigyna* (L) and *Ocimum canum* (Sims) were common among the broadleaf weeds.

With most farmers using conventional tillage, the first flush of weeds, mainly compraising grasses, emerged before the crop and later developed along side with the crop. This resulted in 46 % weed cover, as compared to a 19 % sorghum cover just before the first weeding three to four weeks after planting.

4.2.1 Upland and *matoro* weed flora.

A total of 77 % of the sorghum fields were on the uplands, situated around respective homesteads (Table 4). Only 23 % of the fields were situated near the river banks (*matoro*). *Matoro* fields are largely used for growing maize, because of the inundating rivers. Plant development (Table 4) is generally faster in the *matoro* as compared to the upland fields. *P. scrobiculatum* was the most prevalent weed in both, *matoro* and upland fields.

B. diffusa was a widely distributed weed on the upland, particular on fields near the homestead. *Cyperus rotundus* (L), *Rottboellia cochinchinensis* (L) and *Sorghum verticilliflorum* (Stapf) were found and observed in the *matoro* fields only.

C.sesamoides, *Corchorus olitorius* (L) and *Amaranthus hybridus* (L) were tolerated to some extent. They are used as relish, particularly at the beginning of the rainy season.

4.3 Field trial.

4.3.1 Weed flora.

A total of 20 weed species were recorded in the field trial (Table 5). Of these, nine were most prevalent, as observed in the zero weeding (W_0) plots of both, conventional and conservation tillage systems. These included *P. scrobiculatum and P. maximum,* among the grasses and *C. sesamoides, C. trigyna B. diffusa, C. olitorius, O. canum* and *T. zeylanicum*, among the broadleaf weeds.

Table 3: WEED INCIDENCE IN THIRTY SORGHUM FIELDS; CHIAWA, 1993/94.*

No of weed species/quadrant (0.5 m^2)	7
No of weed species/field	10
Average weed cover (%)	46
Average sorghum cover (%)	19

Weed species	Average cover (%)	Site freq.[1] (%)
Paspalum scrobiculatum	15.0	100
Boerhavia diffusa	4.7	77
Panicum maximum	3.1	62
Ceratotheca sesamoides **	4.3	58
Corchorus olitorius **	1.8	50
Commelina benghalensis	2.7	46
Celosia trigyna	1.9	39
Cyperus esculentus	2.4	31
Phyllanthus spp.	0.5	27
Amaranthus hybridus **	0.7	19
Digitaria milanjiana	0.5	19
Ocimum canum ***	0.5	15
Rottboellia cochinchinensis	1.3	15
Portulaca oleracea	0.4	15
Launaea cornuta	0.1	12
Spermacoce senensis	0.3	12
Trichodesma zeylanicum	1.2	12
Echinochloa colona	0.1	10
Cassia obtusifolia	0.3	8
Setaria homonyma	0.2	8
Oldenlandia herbacea	0.1	8
Ipomoea dichroa	0.1	8
Gisekia pharnaceoides	0.1	8
Cynodon dactylon	0.3	8
Cyperus rotundus	0.2	4
Euphorbia hirta	0.1	4
Bidens pilosa	0.6	4
Eleusine indica	0.6	4
Tridax procumbens	0.1	4
Sorghum verticilliflorum	0.1	4
Asparagus spp.	0.1	4

[1] Frequency.
* Surveyed just before the first weedings.
** Weed species used as relish.
*** Weed species used as medicine.

Table 4: WEED INCIDENCE IN UPLAND AND *MATORO* SORGHUM FIELDS; CHIAWA, 1993/94.*

	Upland	Matoro
Distribution of fields (%).	77	23
Average weed cover (%)	43	51
Average sorghum cover (%)	17	20

	Upland		Matoro	
Weed species	Cov.[1] (%)	Freq.[2] (%)	Cov.(%)	Freq.(%)
Paspalum scrobiculatum	16.2	100	11.0	100
Boerhavia diffusa	5.8	90	0.8	17
Panicum maximum	3.8	70	0.9	33
Ceratotheca sesamoides **	4.4	70	3.8	25
Corchorus olitorius **	2.3	65	-	-
Commelina benghalensis	1.0	35	8.9	83
Celosia trigyna	2.3	40	0.7	33
Cyperus esculentus	0.2	10	7.8	70
Phyllanthus spp.	0.6	30	0.4	11
Amaranthus hybridus **	0.9	25	-	-
Digitaria milanjiana	0.6	20	0.2	15
Ocimum canum ***	0.4	15	0.8	17
Rottboellia cochinchinensis	-	-	5.7	67
Portulaca oleracea	0.5	15	-	-
Launaea cornuta	0.2	5	-	-
Spermacoce senensis	0.3	15	-	-
Trichodesma zeylanicum	0.5	15	5.0	50
Echinochloa colona	0.1	5	0.4	10
Cassia obtusifolia	0.3	5	0.3	9
Setaria homonyma	0.3	10	-	-
Oldenlandia herbacea	0.1	10	-	-
Ipomoea dichroa	0.1	5	0.3	8
Gisekia pharnaceoides	0.2	5	0.2	5
Cynodon dactylon	0.2	5	0.7	20
Cyperus rotundus	-	-	0.8	21
Euphorbia hirta	-	-	0.2	13
Bidens pilosa	0.1	5	0.3	17
Eleusine indica	0.1	5	0.2	4
Sorghum verticilliflorum	-	-	0.2	33
Asparagus spp.	0.2	5	-	-

[1] Cover.
[2] (site) frequency.
* Surveyed just before the first weedings.
** Weed species used as relish.
*** Weed species used as medicine.

P. scrobiculatum was the most common in all plots, and at 2 WAP it covered 26 % of the soil. It reached its maximum cover at 4 WAP. *C. sesamoides* and *C. olitorius* showed increasing coverage and occurrence (frequency) with time. At 6 WAP, *T. zeylanicum* emerged wide spread with a 5 % cover and 75 % site occurrence.

4.3.2 Effect of tillage system (conventional and conservation).

4.3.2.1 Effect of tillage on soil moisture and sorghum emergence.

A day before land preparation (1 DBLP), there was no difference in soil moisture between conventional and conservation tillage systems (Table 6). After tillage treatments were applied, 2 and 3 weeks after land preparation (WALP), the soil under conventional tillage had more residual moisture than that under conservation tillage. Thereafter, 4 weeks after land preparations, there were no differences.

Conventional tillage, with a higher soil moisture during the period 2 and 3 WALP, resulted in a significant higher sorghum emergence as compared to conservation tillage (Table 6).

4.3.2.2 Effect of tillage system on weed cover.

Weed incidence under conservation tillage was higher than that under conventional tillage, with 40 % and 36 % mean cover, respectively (Table 7).

Table 5: WEED FLORA DEVELOPMENT IN ZERO WEEDED SORGHUM; CHIAWA, 1993/94.

Weed	Weed cover(%) & frequency (%)							
	2 WAP		4 WAP		6 WAP		Mean	
spp	Cov.	Freq.	Cov.	Freq.	Cov.	Freq.	Cov.	Freq.
Ps	26	100	34	100	32	95	31	98
Cs	9	51	15	64	19	95	14	60
Pm	10	59	13	62	9	57	11	59
Bd	4	55	2	50	5	70	4	58
Ct	5	40	5	42	4	35	5	39
Co	1	30	4	38	5	40	3	36
Cb	3	45	2	30	1	30	2	35
Tz	0	0	0	0	5	75	1	25
Oc	3	8	5	12	9	18	6	13
Dt	3	15	0	0	0	0	1	5
Cd	1	6	2	10	0	0	1	5
As	0	0	1	5	0	0	0.3	2
Bp	0	0	0.5	2	0	0	0.2	0.7

Legend:

Ps = *Paspalum scrobiculatum*
Pm = *Panicum maximum*
Cs = *Ceratotheca sesamoides*
Bd = *Boerhavia diffusa*
Co = *Corchorus olitorius*
Cb = *Commelina benghalensis*
Tz = *Trichodesma zeylanicum*
Oc = *Ocimum canum*
Dt = *Digitaria milanjiana*
Ct = *Celosia trigyna*
Cd = *Cynodon dactylon*
As = *Asparagus spp.*
Bp = *Bidens pilosa*
WAP = Weeks after planting
Cov. = Cover
Freq. = Frequency

Table 6: EFFECT OF TILLAGE SYSTEM ON SOIL MOISTURE AND SORGHUM EMERGENCE; CHIAWA, 1993/94.

	Tillage				
	Conv.	Conserv.	Mean	LSD	CV (%)
a) S/moisture (%)					
1 DBLP	15.2 ns	14.9 ns	15.1	1.5	5.6
2 WALP	14.3 *	12.6 *	13.5	0.6	3.4
3 WALP	13.6 *	12.2 *	12.9	0.7	5.7
4 WALP	11.3 ns	12.7 ns	12.0	1.7	6.5
b) Emergence (%)	65 *	33 *	49	18.7	18.1

* Values in the same row are significantly different from each other at 5 % probability level according to the LSD test.

Legend:

1 DBLP A day before land preparations.
2 WALP Two weeks after land preparations.
3 WALP Three weeks after land preparations.
4 WALP Four weeks after land preparations.
Conv. = conventional.
Conserv. = conservation.

Table 7: EFFECT OF TILLAGE SYSTEM ON WEED COVER; CHIAWA, 1993/94.

	Weed cover (%)			
WAP[1]:	Conventional tillage	Conservation tillage	Mean	CV (%)
2	43 *	53 *	48	25.2
3	44 *	50 *	47	20.5
4	29	31	30	26.5
6	31	30	30	21.6
8	33 *	37 *	35	11.1
Mean	36 *	40 *	38	20.9

[1] Weeks after planting.
* Values in the same row are significantly different from each other at 5 % probability level.

4.3.2.3 Effect of tillage system on sorghum development.

Sorghum development, in terms of height and crop cover, progressed with time (Table 8 and Fig 2). The crop under conventional tillage developed faster than that under conservation tillage, particularly in height. The influence of tillage on sorghum cover was only noticed at 2 and 8 WAP, with conventional tillage having a significantly higher cover than conservation tillage.

Table 8: EFFECT OF TILLAGE SYSTEM ON SORGHUM DEVELOPMENT; CHIAWA, 1993/94.

	Conventional tillage		Conservation tillage		Mean		CV (%)	
WAP:	Cov.(%)	ht.(cm)	Cov.(%)	ht.(cm)	Cov.	ht.	Cov.	ht.
2	23**	10*	17**	7*	20	9	12.2	8.2
3	26	19*	22	12*	24	16	17.2	11.1
4	33	35*	27	29*	30	32	10.0	3.8
6	37	50*	34	44*	36	47	10.2	2.6
8	42**	71	39**	51	41	61	6.7	29.2
Mean	32	37*	28	29*	30	33	11.3	11.0

*/** Values in the same row are significantly different from each other at 5 % probability level.

Legend

WAP = Weeks After Planting.
Cov. = Cover.
ht. = Height

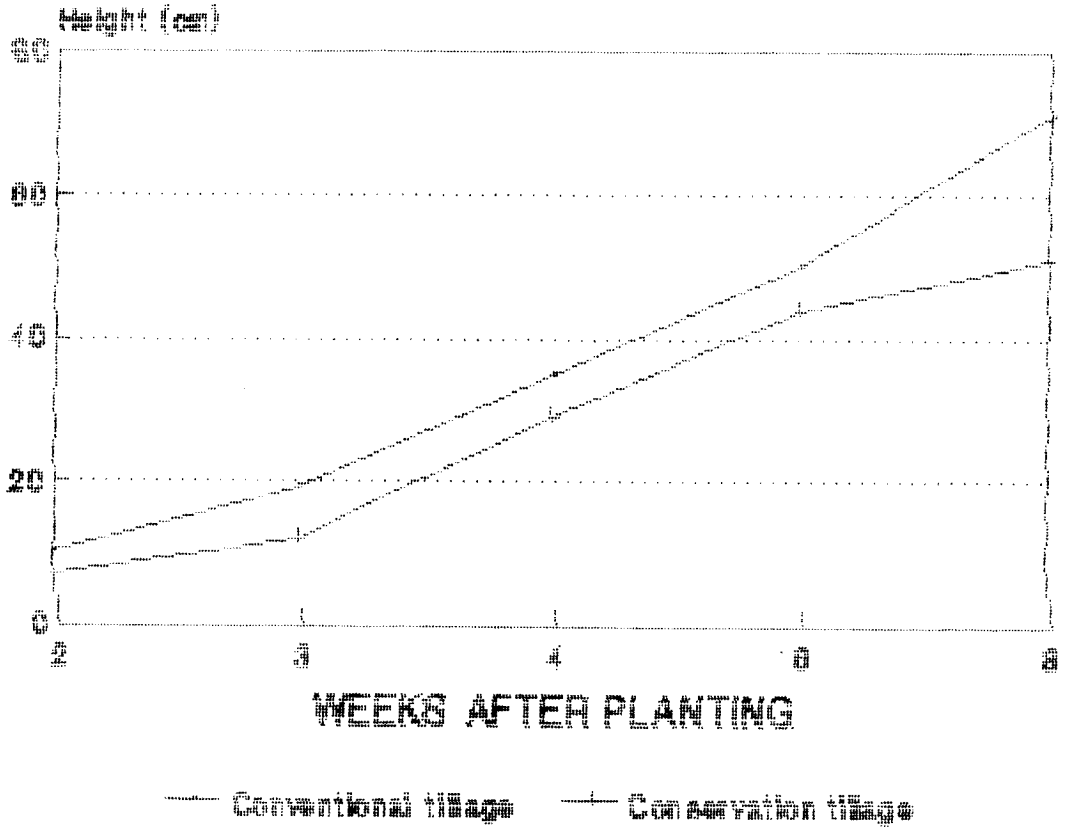


Fig 2: EFFECT OF TILLAGE ON SORGHUM DEVELOPMENT (HEIGHT): CHIAWA, 1993/94

4.3.2.4 Effect of tillage system on sorghum 1000 grain weight and yield.

The yield of 989 kg/ha, attained under conventional tillage, was significantly higher than that under conservation tillage, yielding 733 kg/ha (Table 9). The tillage system, however, did not show any significant effect on the 1000 grain weight.

There was a significant positive correlation between sorghum emergence, sorghum height, sorghum cover at 4 and 8 WAP, 1000 grain weight and sorghum grain yield (Table 10). Weed cover at 4 and 8 WAP, on the other hand, was negatively correlated with sorghum yield.

Table 9: EFFECT OF TILLAGE SYSTEM ON SORGHUM 1000 GRAIN WEIGHT AND YIELD; CHIAWA, 1993/94.

	Tillage		Mean	LSD	CV (%)
	Conv.	Conserv.			
1000 grain wt (g)	16.2	13.1	14.7	5.3	28.1
Yield (kg/ha)	989 *	733 *	861	171.3	15.2

Conv. refers to conventional and Conserv. to conservation.
* Values in the same row are significantly different from each other at 5 % probability level.

Table 10: CORRELATION BETWEEN SORGHUM EMERGENCE, SORGHUM HEIGHT, WEED COVER, SORGHUM COVER, 1000 GRAIN WEIGHT AND SORGHUM GRAIN YIELD ACROSS TILLAGE SYSTEM; CHIAWA, 1993/94.

Component:	Correlation with sorghum yield (coefficient)*
Sorghum emergence	+ 0.73
Weed cover (4 WAP[1])	- 0.80
Weed cover (8 WAP)	- 0.90
Sorghum cover (4 WAP)	+ 0.86
Sorghum cover (8 WAP)	+ 0.86
Sorghum height	+ 0.92
1000 grain weight	+ 0.80

[1] Weeks after planting.
* All Significant at 5 % probability level.

4.3.3 Effect of weeding frequency:

4.3.3.1 Effect of weeding frequency on weed cover.

There was a reduction of weed cover with increasing weeding frequency (Table 11). Under zero weeding, the weed cover was highest reaching 81 %. Clean weeding had only 15 % cover, which was significantly different from that of the other weedings regimes.

4.3.3.2 Effect of weeding frequency on sorghum cover.

Weeding frequency affected the development of sorghum in terms of crop cover (Table 12). Zero weeding had the least mean crop cover of 8 %. Clean weeding had the highest, which did not differ from that of three weedings (W_3).

Table 11: *EFFECT OF WEEDING FREQUENCY ON WEED COVER; CHIAWA, 1993/94.*

	Weed cover (%)				
Treatment:	2 WAP	4 WAP	6 WAP	8 WAP	Mean
W_0	62 a	84 a	86 a	93 a	81 a
W_1	53 a	20 b	26 b	40 b	35 b
W_2	50 a	21 bc	20 b	22 c	28 b
W_3	55 a	24 b	11 c	13 d	26 b
W_C	24 b	13 c	10 c	12 d	15 c
LSD	14.8	9.6	8.0	4.7	9.3
CV (%)	25.2	26.2	21.6	11.1	21.0

Values in the same column with the same letter are NOT significantly different from each other at 5 % probability level, according to the LSD test.

Legend:

WAP= Weeks after planting.

W_0 = Zero weeding (throughout).

W_1 = One weeding (3 WAP).

W_2 = Two weedings (3 and 6 WAP).

W_3 = Three weedings (2, 4 and 6 WAP).

W_C = Clean weeding (throughout).

Table 12: EFFECT OF WEEDING FREQUENCY ON SORGHUM COVER; CHIAWA, 1993/94.

Treatment:	Sorghum cover (%) 2 WAP	4 WAP	6 WAP	8 WAP	Mean
W_0	16 c	10 c	3 d	1 c	8 d
W_1	20 b	30 b	38 c	45 b	33 c
W_2	20 b	36 a	42 bc	48 b	37 b
W_3	18 bc	36 a	46 ab	53 a	38 ab
W_C	23 a	38 a	47 a	55 a	41 a
LSD	3.1	3.6	4.4	3.3	3.6
CV (%)	12.6	10.0	10.2	6.7	9.9

Values in the same column with the same letter are NOT significantly different from each other at 5 % probability level according to the LSD test.

Legend:

WAP= Weeks after planting.
W_0 = Zero weeding (throughout).
W_1 = One weeding (3 WAP).
W_2 = Two weedings (3 and 6 WAP).
W_3 = Three weedings (2, 4 and 6 WAP).
W_C = Clean weeding (throughout).

4.3.3.3 Effect of weeding frequency on sorghum height.

There was an increase in sorghum height with more frequent weeding (Table 13). Zero weeding (W_0) had the lowest mean height of only 14 cm. Sorghum reached its greatest height under clean weeding (W_C), with 89 cm at 8 WAP, which did not differ from that of three weedings (W_3).

Table 13: EFFECT OF WEEDING FREQUENCY ON SORGHUM DEVELOPMENT (HEIGHT); CHIAWA, 1993/94.

Treatment:	Height (cm) 2 WAP	4 WAP	6 WAP	8 WAP	Mean
W_0	7 b	23 d	10 e	14 d	14 d
W_1	8 b	32 c	53 d	58 c	38 c
W_2	8 b	32 c	55 c	63 bc	40 bc
W_3	8 b	34 b	59 b	82 ab	46 ab
W_C	10 a	39 a	61 a	89 a	50 a
LSD	*0.8*	*1.5*	*1.5*	*21.8*	*6.4*
CV (%)	8.2	3.8	2.6	29.2	11.0

Values in the same column with the same letter are NOT significantly different from each other at 5 % probability level according to the LSD test.

Legend:

WAP= Weeks after planting.
W_0 = Zero weeding (throughout).
W_1 = One weeding (3 WAP).
W_2 = Two weedings (3 and 6 WAP).
W_3 = Three weedings (2, 4 and 6 WAP).
W_C = Clean weeding (throughout).

4.3.3.4 Effect of weeding frequency on sorghum 1000 grain weight and yield.

Weeding frequency had no effect on sorghum 1000 grain weight, except for the zero weeding (W_0) treatment (Table 14). There was, however, an increase in sorghum grain yield with more frequent weeding. There was a highly significant negative correlation between weed cover and sorghum yield ($r = -0.97$) (Table 15 and Fig 3). On the other hand, sorghum cover and sorghum height were positively correlated with sorghum yield, with coefficients of $r = + 0.93$ and $r = + 0.96$, respectively.

Table 14: EFFECT OF WEEDING FREQUENCY ON SORGHUM 1000 GRAIN WEIGHT AND YIELD; CHIAWA, 1993/94.

Treatment:	1000 grain wt (g)	Yield (kg/ha)	Yield (%)*
W_0	4.5 b	73 d	5
W_1	14.4 a	591 c	43
W_2	17.7 a	1060 b	81
W_3	18.1 a	1207 ab	88
W_C	18.8 a	1374 a	100
Means	14.7	861	-
LSD	5.1	209.9	-
CV (%)	28.2	16.3	-

Values in the same column with the same letter are NOT significantly different from each other at 5 % probability level, according to the LSD test.

* Percent grain yield as compared to clean weeding (W_C).

Legend:

W_0 = Zero weeding (throughout).
W_1 = One weeding (3 WAP).
W_2 = Two weedings (3 and 6 WAP).
W_3 = Three weedings (2, 4 and 6 WAP).
W_C = Clean weeding (throughout).

Table 15: CORRELATION BETWEEN WEED COVER, SORGHUM COVER, SORGHUM HEIGHT AND SORGHUM YIELD ACROSS WEEDING FREQUENCY; CHIAWA, 1993/94.

Component (mean values)	Correlation with sorghum yield (coefficient)*
Weed cover	- 0.97
Sorghum cover	+ 0.93
Sorghum height	+ 0.96

All significant at 5 % probability level.

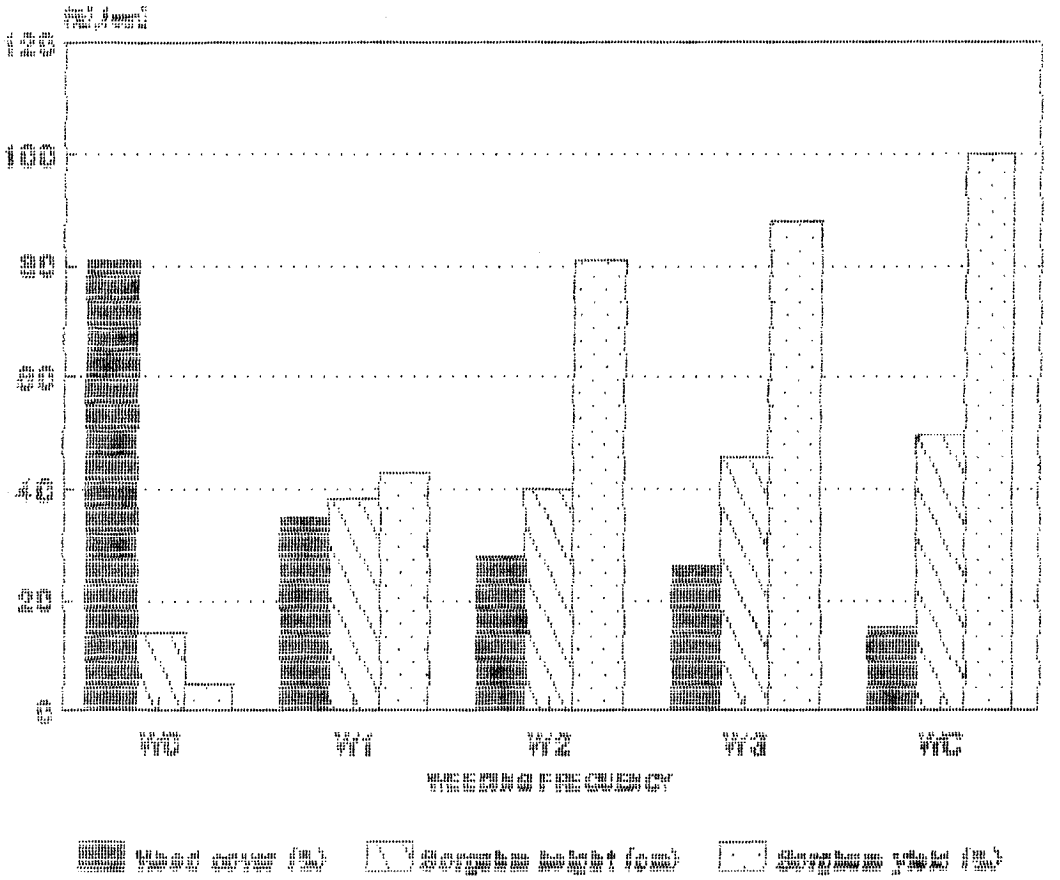


Fig 3: EFFECT OF WEEDING FREQUENCY ON WEED COVER, SORGHUM HEIGHT AND SORGHUM YIELD; CHIAWA, 1993/94.

* denotes percent grain yield as compared to clean weeding (W_c).

Legend;

W_0 = Zero weeding.
W_1 = One weeding at 3 WAP.
W_2 = Two weeding at 3 and 6 WAP.
W_3 = Three weedings at 2, 4 and 6 WAP.
W_c = Clean weeding throughout.

4.3.4 Interaction between tillage system and weeding frequency.

There was no interaction between tillage system and weeding frequency with respect to weed cover, sorghum cover, sorghum height development and sorghum yield (Appendix E).

4.4 Socio-economic weed management survey.

4.4.1 Socio-economy of small scale farming.

The agricultural set up is a mixed farming system with cropping as the dominant part. Livestock keeping comprising of chicken, goats and pigs is very low and insignificant. Because of the prevalence of tsetse fly in the area, cattle keeping is restricted.

Farming households are dominated by male heads, and females make up 40 % only (Table 16). A farming household has an average labour force of 5 persons, which includes children. 57 % of the farmers have their sorghum fields situated on the uplands, near their respective homestead. 33 % of the farmers have sorghum fields situated both on the uplands and *matoro*.

Rainfall, and particularly its poor distribution, is pointed out as the major constraint in farming, followed by weed infestation. Among the pests, 47 % of the farmers reported weeds as being the major pest. Only 27 % reported insect pests, which included the

armoured cricket and stem borer, as a major problem. 64 % of the farmers considered weeding as the most labour intensive cropping activity. Where labour is hired, 58 % of the farmers pay in kind by giving out essential commodities like salt, soap, beer, etc.

Table 16: SOCIO-ECONOMIC DATA OF SMALL SCALE FARMING IN CHIAWA; 1993/94.

Item:	Respondents mark:
Farmers' gender (%):	
Male	60
Female	40
Field location (%):	
Upland (around homestead)	57
Both (upland & *matoro*)	33
River bank (*matoro*)	10
Farming constraints (%):	
Rain	64
Weeds	53
Insects	51
Major pests (%):	
Weeds	47
Insect pests	27
Birds	23
Average family labour (no. of persons).	5.3
Peak period of labour requirement (%):	
Weeding	64
Harvesting	25
Birds/animal scaring	11
Casual labour payment (%):	
In kind	58
Cash	27

4.4.2 Sorghum based cropping system under small scale farming.

Sorghum is mainly grown on fields, which have been in use for over 2 years (Table 17). An average farm household cultivates 1.4 ha of sorghum. No systematic crop rotation is practised by farmers. Farmers, however, use a field for cropping for a period of 5 years, before leaving it fallow for 3 years. Most farmers (97 %) are using a hand hoe, and only 3 % hire oxen or a tractor for cultivation.

Depending on the onset of the rains, 55 % of the farmers prepare their fields in November. A total of 67 % of the farmers practice mono-cropping with sorghum and maize as the common crops grown. Generally, inter-cropping involves cucurbits grown along side sorghum as the main crop. 48 % of the farmers prefer to plant both the local (traditional) and improved (hybrids) cultivars for their food security. Only about 20 % of the farmers use chemical fertilizers, because of its non availability and high costs.

Sorghum is generally produced for subsistence purposes and in a good weeded season, farmers get an average yield of 800 kg/ha. In a year of surplus production, sorghum grain may be sold locally for brewing local beer. In a poor weeded season, yields may be as low as 20 kg/ha.

4.4.3 Weed management under small scale farming.

Most farmers (45 %) determine the time of weeding by looking at the crop stage (Table 18). 30 % of the farmers weed after considering time of emergence (2-3 WAE). Three weedings are

Table 17: CROPPING SYSTEM OF SMALL SCALE FARMERS; CHIAWA, 1993/94.

Item:	Respondents mark:
Average size of cultivated land (ha).	1.4 (range 0.5 - 5)
Land history (%):	
Virgin land	10
Used land (>2 years)	90 (range 2 - 6)
Crop rotation	90 (crop/fallow)
Fallow period (years)	3
Cropping period (years)	5
Cultivation method (%):	
Hand hoe	97
Ox/Tractor (hired)	3
Time of land preparation (%):	
November	55
December	25
October	15
Type of land preparation (%)	
Conventional tillage	62
Both (conv. & conserv.)	30
Conservation tillage	8
Cropping systems (%):	
Mono-cropping (> 1 crop)	67
Mono-cropping (1 crop)	27
Inter-cropping	6
Besides sorghum, other crops grown (%):	
Maize	70
Pearl millet	25
Cucurbits	5
Sorghum variety (%):	
Both (local & improved)	48
Local	36
Improved (hybrid)	18
Fertilizer Utilization (%).	20
Average sorghum yield (kg/ha):	
In a good weeded season *	800 (range 550 - 2000)
In a poor weeded season	< 20

* Season, when weeding has not been disturbed by other factors like too much rain and labour constraints.

Table 18: WEED CONTROL MANAGEMENT UNDER SMALL SCALE FARMING; CHIAWA, 1993/94.

Item:	Respondents mark:
Determination of weeding time (%):	
Crop stage	45
Weeks after emergence (WAE)	30
Weed infestation	20
Weeks after planting (WAP)	5
Weeding Frequency (%):	
3 weedings	60
2 weedings	27
4 weedings and more.	8
1 weeding	5
First weeding (%):	
4 weeks after planting	50
3 weeks after planting	40
Later than 4 weeks after planting	10
Weeding methods (%):	
Hand hoe	98
Ox-cultivations	2
Major constraints in weeding (%):	
Too much rains to weed	50
Labour shortage	23
Too dry to weed	20
Weeding strategy efficiency (%):	
Efficient	77
Not efficient	23
Dominant weeds (%):	
Paspalum scrobiculatum	90
Boerhavia diffusa	65
Ceratotheca sesamoides	50
Commelina benghalensis *	40
Cyperus esculentus *	30
Digitaria milanjiana *	20
Utilized weeds (%):	
Food purpose: *Amaranthus hybridus*	100
Ceratotheca sesamoides	95
Corchorus olitorius	75
Medicinal purpose: *Ocimum canum*	80

* Difficult weed species to control by hand hoe.

commonly carried out by 60 % of the farmers, while 8 % of them carry out 4 or more weedings, depending on the weed infestation. The first weeding is mostly carried out 3 to 4 weeks after planting (WAP). 10 % of the farmers do their first weeding even later than 4 weeks after planting. 98 % of the farmers use the hand hoe for weeding purposes.

Most farmers (77 %) take their weeding strategies as being efficient. 90 % of the farmers regarded *Paspalum scrobiculatum* as the most common and wide spread weed, while *Commelina benghalensis, Cyperus esculentus* and *Digitaria milanjiana* were considered to be difficult to control by hand hoe, because of their ability to regrow after cultivation. *Striga spp.* were reported to readily appear in very old sorghum fields of 6 years and above.

Some weeds are considered useful and are utilized for food and medicinal purposes, which means that farmers would tolerate them to some extent in their fields. These include *Ceratotheca sesamoides, Corchorus olitorius* and *Amaranthus hybridus* for food, and *Ocimum canum* as a medicine.

5.0 DISCUSSION

5.1 1993/94 weather.

Chiawa, where the research was conducted, is situated in region I of Zambia's agro-ecological zones. It receives rainfall of less than 800 mm annually. The rainy season generally runs from October to May, with very erratic rainfall. During the 1993/94 season, however, Chiawa received only 407 mm. It was poorly distributed, with January alone receiving 208 mm (Appendix A). This amount was less than that of 1992/93 season's rainfall of 511 mm and far below a 10 year average rainfall of 650 mm. The high average monthly temperature was 28.6 ^{0}C, resulting into high evapotranspiration.

This pattern of weather, compounded with the mainly loamy sand type of soils in the area, had an adverse effect on agricultural activities as evident from the research study itself. The field trial and many other farmers' fields had to be replanted in late December and early January, when there was adequate soil moisture. The drought, which set in early February, together with the poor water holding capacity of the soil, resulted in water deficiency at critical crop stages of head and grain formation. It also impaired further emergence and development of weeds. As a result only one weed flora survey was carried out in late January.

5.2 Weed flora.

The semi-arid type of climate in Chiawa, which is often

characterized by dry spells and high temperature, gives a peculiar weed flora. The one in sorghum fields comprised mainly of annual grasses, sedges and broadleaf weeds, with very few perennial weeds (Table 3). The top five common weeds in Chiawa, *Paspalum scobiculatum, Boerhavia diffusa, Panicum maximum, Ceratotheca sesamoides* and *Corchorus olitorius* are not among the ten most common weed species in Zambia, as compiled by Vernon (1983). *Paspalum scrobiculatum*, the most prevalent weed in Chiawa (Table 3 and Table 18) is neither reported among the common weeds of Zambia (Vernon, 1983), nor among the major weeds of sorghum in tropical Africa as listed by Ogborn (1980).

The high incidence of grass weeds like *P. scrobiculatum, Panicum maximum* and *Digitaria milanjiana* exerted stiff competition on sorghum, especially during the seedling stage, due to similar requirements. This is in conformity with Moody (1983), who noted, that plants with similar growth habits exert similar demands on the environment. The similarities in appearance between sorghum seedlings and the grass weeds also makes identification and differentiation in the early stages difficult. This contributes to farmers carrying out their first weeding late (Table 18).

The prevalent cropping patterns of the uplands and *matoro* showed some differences in weed flora and its development. The upland cropping system entirely depends on rainfall, whereas the *matoro* system even survives by the inundating Kafue and Zambezi rivers. Because of this extra soil moisture, weed and crop cover development was faster on the *matoro* than that of the uplands

(Table 4). *Boerhavia diffusa*, a more drought tolerant weed, was prevalent on the uplands, especially on fields near the homesteads. *Rottboellia cochinchinensis*, which is a wide spread weed on the plateau in the high and medium rainfall areas of Zambia, was only found in the *matoro* (Table 4). *Striga spp.* which are very harmful parasitic weeds to sorghum (Abalone, 1979) were not noticed during the survey. Farmers, however, reported that *Striga spp.* may be found in very old sorghum fields (Appendix C). The rotation of cropping and fallow periods of 5 and 3 years, respectively (Table 17), reduces the risk of these parasitic weeds. During fallow periods, *Striga spp.* may not have an appropriate host plant (sorghum) to survive on.

Commelina benghalensis, Digitaria milanjiana and *Cyperus spp.* were considered difficult to control by hand hoe, because of their ability to regrow after cultivation (Table 18). *C. benghalensis* is able to regrow from pieces of its fleshy stem, while *Cyperus spp.* would sprout from its rhizomes and tubers. *D. milanjiana,* a perennial weed, is able to regenerate from its rhizomes after hand or ox cultivation.

Ceratotheca sesamoides, Corchorus olitorius and *Amaranthus hybridus*, from the first flush of weeds, are to some extent not considered as weeds (Table 18). They are used as relish, particularly at the beginning of the season, when food is very scarce. *Ocimum canum* is used as a medicine, mainly as a mosquito repellent.

5.3 Tillage system and weeding frequency.

The onset of rains determines the type of tillage system the farmers would use (Table 17). When the onset of rain is late (mid December), farmers opt to use conservation tillage due to lack of preparation time.

The field trial, situated on the upland, entirely depended on the rainfall. Since the amount of rainfall was little and poorly distributed, it adversely affected the performance of sorghum and weeds in terms of emergence, establishment and yields.

There was a higher soil moisture under conventional tillage than under conservation tillage, particularly at 2 and 3 WALP (Table 6). This was contrary to the expectation, that conservation tillage would conserve more soil moisture than conventional tillage. It can be attributed to the sparse and inadequate crop residue cover under conservation tillage, which impaired the conservation of soil moisture and allowed water losses through run offs. This agrees with Nicou and Chopart (1979, as cited by Akobundu, 1987) that in the semi-arid tropics, there is no adequate crop residue cover for an effective conservation tillage practice. Water penetration into the top soil profile under conventional tillage was better than that under conservation tillage. This is in conformity with Lal (1977), who stated, that conventional tillage optimizes the conditions for seed germination and emergence, hence seedling establishment. Also, the high weed incidence under conservation tillage most likely increased loss of water through transpiration in addition

to evaporation from the soil.

With a significant higher soil moisture during the period of germination and emergence (Date 2 and 3), conventional tillage had a higher rate of sorghum emergence than that under conservation tillage, rating 65 % and 33 %, respectively (Table 6). Moisture is the most important ingredient for germination, enhancing good emergence.

The high incidence of weeds at early stages under conservation tillage (Table 7), can be attributed to soil tillage. Under conventional tillage, early weeds were controlled by soil tillage, whereas they were not controlled under conservation tillage. This agrees with Zimdahl (1980), who noted that soil tillage also helps in controlling weeds. The low sorghum emergence and high weed incidence under conservation tillage further suppressed sorghum seedling establishment and necessitated gap filling (Table 2). The high weed infestations under conservation tillage affected sorghum development and yield by competing for moisture, nutrients and light, particularly in the early stages (Tables 7, 8, 9 and 10). The drought affected the overall sorghum height development further, as sorghum tends to head early under very severe moisture stress. Since most of the first flush of weeds (Table 3) were grasses (*P.scrobiculatum, P. maximum, D. milanjiana*), they exerted similar demands on the environment. This is in conformity with Akobundu (1987) and Moody (1983), who reported that sorghum seedlings are relatively small and weak, and are not able to compete well with the more vigorous

weed seedlings, particularly with the ones of similar growth characteristics.

Sorghum grain yields under conventional tillage were higher than those of conservation tillage (Table 9). This can be attributed to the overall higher sorghum emergence, higher sorghum cover, faster sorghum development and lower weed cover under conventional tillage (Tables 6, 7 and 8). Gap filling by transplanting from conventional to conservation tillage did not have any significant impact. This is as a result of the high weed infestation, hence the inability of the sorghum seedlings to pick up. These results are in agreement with those reported by Sanford *et al.* (1982) in sorghum trials in Sudan, comparing conventional and conservation tillage systems. Sanford *et al.* (1982) found, that from a two year average, conventional tillage resulted in a 19 % higher sorghum yield than that of conservation tillage.

The lower yields under conservation tillage were a result of high weed infestation, which reduced crop emergence and establishment. This aspect is supported by the significant negative correlation ($p < 0.05$) between weed cover at 4 and 8 WAP and sorghum yields, with coefficients of $r = -0.80$ and $r = -0.90$, respectively. This may explain why about 62 % of the farmers (Table 17) opt using conventional tillage rather than conservation tillage.

The yields of 989 kg/ha and 733 kg/ha under conventional and conservation tillage systems, respectively, were far below those

observed by Masi (1991). He reported yields of 2500 kg/ha in the same area. This can be attributed to the late onset and poor distribution of rains during the 1993/94 season (Appendix A). To some extent, the heavy infestation of the red-billed weaver birds further compounded yield losses, despite of control measures. Because of the drought, only few isolated sorghum fields managed to form heads and later matured. This made bird scaring not all that effective, due to high bird pressure.

The general trend showed, that there was an increasing sorghum performance with more frequent weedings (Tables 11, 12, 13 and 14). As a result, the higher the weed cover, the lower sorghum development and yield (Fig 3). Zero weeding had the highest weed incidence and this resulted in poor crop performance with extremely low grain yields. This was due to the stiff competition exerted by weeds from early seedling stage through to head formation. It explains, why Hamaamba (1989) stated, that in dry conditions, sorghum fields should be kept weed free until grain formation. This is to avoid excesses loss of water from the soil through weeds by transpiration. Less soil moisture also reduces the uptake of nutrients by the crop, hence affecting development.

Clean weeding throughout had the best crop performance and yield, which did not differ from that of three weedings at 2, 4 and 6 WAP (Tables 12, 13 and 14). This suggests, that it may not be necessary to devote labour to keep sorghum fields weed free throughout. It ties well with Enyi (1973), who reported, that 3 weedings gave high yields, increased leaf index and grain weight

per ear. It proved to be better and more economical than zero, one, two and more than three weedings. The overall effect of weeding frequency on weed cover is further supported by a high negative correlation between weed cover and sorghum grain yields of r= - 0.97.

When comparing these results with the weeding practice of farmers in Chiawa, 60 % of them are actually carrying out three weedings, but usually do them untimely (Table 18). For instance, the first weeding at 4 WAP, as carried out by 50 % of the farmers in the area, is too late to sustain healthy sorghum seedling establishment. By 4 WAP, there is a heavy weed infestation, which makes weed/crop competition very stiff, thereby adversely affecting the crop. This is also supported by the results of the field trial (Tables 12 and 13). It shows, that at four weeks after planting, early weeding (W_3) at 2 WAP had better crop stand (crop cover and height) than delayed weeding (W_1) at 3 WAP. This is why Shetty (1978) and Burnside (1966) called for early weed control (within 3 WAP), as weeds are harmful to sorghum seedlings.

5.4 Socio-economic weed management implications.

Farmers tend to pay more attention to maize grown in the *matoro* than to upland crops, despite of sorghum being the major crop in Chiawa. Farmers feel that maize needs closer agronomic attention than sorghum. As a result, planting and weeding schedules of sorghum are affected. This agrees well with ARPT (1991) findings in the area, pointing out that farmers spend more time on maize

in the *matoro* than on sorghum. Rainfall being the main farming constraint, farmers prefer to plant maize on the *matoro* where it can benefit from the inundated river banks, rather than depending entirely on rainfed sorghum for their food security (Tables 16 and 17).

With an average family labour force of five persons, which includes school going children, the poor apportioning of labour between sorghum and maize fields makes it difficult to cope with an average of 1.4 ha of sorghum fields (Table 16). First preference of labour is given to maize fields. As a result, low input management, particularly on weeding, is given to sorghum, hence low production. Low sorghum yields of about 800 kg/ha are further compounded by the use of low yielding local varieties and non application of chemical fertilizers. Hiring of labour in Chiawa is difficult, as almost everyone is involved in his or her own crop production.

6.0 CONCLUSIONS AND RECOMMENDATIONS

Within the limits and conditions under which this research study was conducted, conventional tillage showed better crop performance and grain yields as compared to conservation tillage. The benefits of conservation tillage were not observed. Three timely weedings at 2, 4 and 6 weeks after planting were more economical and practical for the local farmers. It however, gave crop performance and yields which didn't differ from that of two and clean weedings.

Paspalum scrobiculatum was the most prevalent weed in Chiawa small scale sorghum fields. *Commelina benghalensis, Cyperus esculentus* and *Digitaria milanjiana* are seen as being difficult to control by hand hoe weeding.

The results and experience reported here are out of one season (1993/94), on which valid conclusions cannot be based. Therefore, further research should be initiated on tillage systems with emphasis on agro-climatology and soil types. Farmers, however, should be encouraged to weed their sorghum fields early enough, i.e., at 2 weeks after planting.

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8.0 APPENDICES

Appendix A: CLIMATOLOGICAL DATA; CHIAWA.

Month:	Rainfall (mm)* 1992/93	Rainfall (mm)* 1993/94	Rainy days 1993/94	Temp. °C 1993/94
Oct :	29.5	-	-	27.8
Nov :	30.0	80.0	4	30.2
Dec :	60.5	55.5	4	29.9
Jan :	250.5	208.0	18	27.3
Feb :	41.0	40.5	6	29.7
Mar :	88.5	22.5	3	27.8
Apr :	10.6	-	-	27.6
Total:	510.6	406.5	35 (average)	28.6

* Mean annual rainfall = 650 mm (10 years data; 1982-1992).

Source: Masstock Chiawa farms, Chiawa. 1994.

Appendix B: SOIL CHARACTERISTICS, FIELD TRIAL; MUYANJE-CHIAWA, 1993/94.

Item:	Classification:
Soil type:	Loamy sand
Soil colour:	Brown (7.5 YR 4/4)
Nitrogen (N) (%):	0.06
Phosphorus (P) (mg/kg soil):	8.3
Organic matter (%):	0.9
pH ($CaCl_2$):	5.2
Soil texture (%):	
Silt:	16
Sand:	71
Clay:	13

Appendix C: LOCAL NAMES OF COMMON WEED SPECIES IN CHIAWA.

Weed species:	Local name (Goba):
*Amaranthus spp.**	Bonongwe
Boerhavia diffusa *	Chiyangatila
Celosia trigyna	Gare
Ceratotheca sesamoides *	Katate
Commelina benghalensis	Nyakatete
Corchorus olitorius *	Nyai
Cynodon dactylon	Kapinga mbizi
Cyperus esculentus *	Nkokwe
Digitaria milanjiana *	Sangazi
Echinochloa colona	Mande
Ocimum canum *	Katanda nyunyu
Panicum maximum *	Nyavari
Paspalum scrobiculatum *	Nyakapanda
Rottboellia cochinchinensis	Chibayane ngombe
Sorghum verticilliflorum	Musonde
Striga spp.	Kaloyi
Trichodesma zeylanicum	Duyuyu

* Commonly known weed species.

Appendix D: SOCIO-ECONOMIC WEED MANAGEMENT SURVEY QUESTIONNAIRE; CHIAWA, 1993/94.

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1. Date:_____ Interviewer:_____

2. Camp:_____

3. Village:_____

4. Farmer:_____

5. Gender:_____

6. Family labour (workable):_____

7. Field locality:
   a) Around homestead
   b) Open area
   c) River banks (matoro)

8. Cultivated area:_____

9. Land history:
   a) Virgin
   b) Used,(Years)_____

10. Soil type:_____

11. Cultivation methods:
    a) Hand hoe
    b) Ox drawn
    c) Tractor

12. Land preparation:
    a) Conservation tillage
    b) Conventional tillage

13. Under what conditions do you prefer using:

	1) Conservation.	2) Conventional.
a) Early wet planting	_____	_____
b) Early dry planting	_____	_____
c) Late planting	_____	_____
d) Others	_____	_____

14. Time of land preparation:_____

15. Cropping pattern:
    a) Mono-cropping (1 crop)
    b) Mono-cropping (> 1 crops)
    c) Inter-cropping

16. Other crops grown:_____

17. Type of Sorghum grown:
    a) Local
    b) Improved
    c) Both

18. Date of (first) planting:_____

19. Date and times of replanting:_____

20. Do you use fertilizer?
    a) Yes, (what type?)_____
    b) No

21. Farming constraints (in priority order):
    * Insect pest
    * Disease pest
    * Weed pest
    * Rainfall
    * Capital
    * Labour
    * Inputs
    * Others

22. Which of the following is the major problem?
    a) Weeds
    b) Insect pests
    c) Birds
    d) Others_____

23. What are the most dominant weeds in your field:

    1)_____ 6)_____

    2)_____ 7)_____

    3)_____ 8)_____

    4)_____ 9)_____

    5)_____ 10)_____

24. What is the importance and usage of the common weeds:
    1._____

    2._____

    3._____

25. How do you determine when to weed:_____

    _____

    _____

26. How many times do you weed?

WHEN:

a) 1 times _____

b) 2 times _____

c) 3 times _____

d) Others _____

27. Methods of weeding:
    a) Hand hoe
    b) Ox-cultivation
    c) Others

28. Is your weeding strategy efficient?
    a) Yes
    b) No, (then why?) _____

29. What is your major constraint in weeding?
    a) Labour
    b) Too much rains
    c) Too dry
    d) Others_____

30. In cases where you hire labour, how do you pay them?

    _____

31. Which is the peak period of your labour requirements?
    * Land preparation
    * Planting
    * Weeding
    * Bird/animal scaring
    * Harvesting

32. What were your sorghum yields when you had a good weeding and NOT in the previous years?

	Year:	Actual yield:	Expected yield:
a)	_____	_____	_____
b)	_____	_____	_____
c)	_____	_____	_____

33. General comments on sorghum growing and weeds;

    _____

    _____

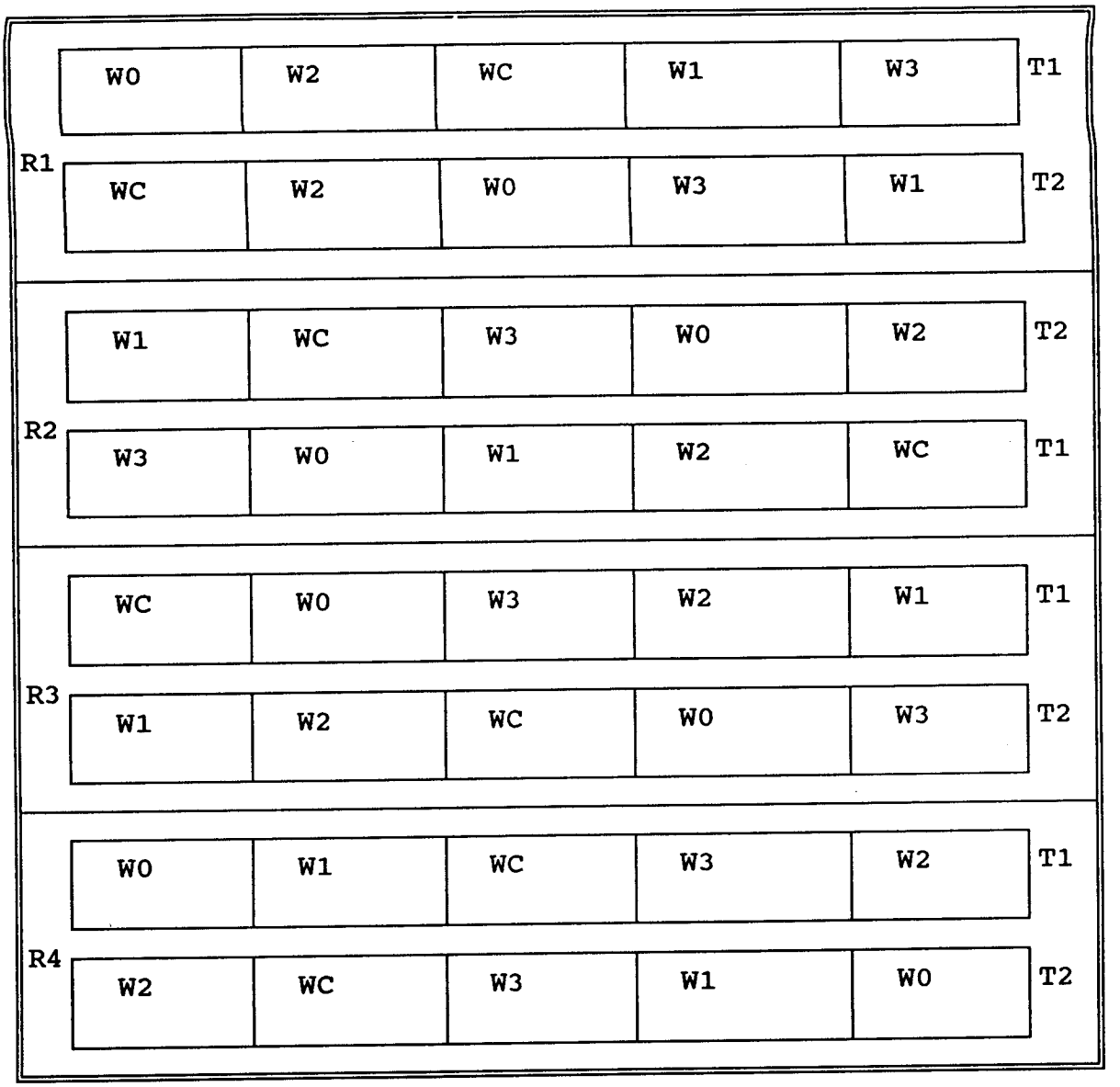
    _____

Appendix E: ANALYSIS OF VARIANCE (ANOVA) TABLE OF SORGHUM GRAIN YIELDS (SPLIT-PLOT). CHIAWA, 1993/94.

Source:	DF	SS	MS	F_C	$F_{T(0.05)}$
Rep.	2	12982.52	6491.26	0.67	
Tillage (A)	1	415598.64	415598.64	42.64 *	18.51
Error	2	19491.33	9745.66		
Weeding (B)	4	6834372.96	1708593.24	84.57 *	3.06
Interaction (AB)	4	48256.91	12064.23	0.60 ns	3.06
Error	15	303051.81	20203.45		

CV = 16.3 %
* Significant at 5 % probability level.
ns = Not significant.

Appendix F: FIELD TRIAL LAYOUT; MUYANJE-CHIAWA, 1993/94.



Legend:

R = Replication.
T_1 = Conventional tillage.
T_2 = Conservation tillage.
W_0 = Zero weeding (throughout).
W_1 = One weeding (3 WAP).
W_2 = Two weedings (3 and 6 WAP).
W_3 = Three weedings (2, 4 and 6 WAP).
W_C = Clean weeding (throughout).