EFFICACY OF FOUR HERBICIDE GROUPS ON WEED CONTROL, GROWTH AND YIELD OF MAIZE (*Zea Mays L.*)

BY

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DECLARATION

This thesis is the result of research work undertaken by me for the award of M.phil degree in the Department of Crop Science, University of Ghana. Apart from the references to other works which have been duly cited, this work has never been submitted elsewhere for the award of another degree.

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ABSTRACT

Two field studies were carried out from July 2012 to February 2013 to determine the efficacy of four groups of herbicide on weed control, growth and yield of maize (*Zea mays* L.) and to investigate the influence of their residual effect on weed succession, rotation crop, soil nutrient status and microbial population at the University Farm, Legon. The experiments, laid out in randomized complete block design, consisted of four replications of eight herbicide treatments from four herbicide groups (Glyphosate: Glyphader, Nwura Wura; Paraquat: Conti-quat, Kwatriqua; Atrazine: Sun-Atrazine, Atranex; 2, 4-D: Sun-2, 4-D, Bextra 2,4-D) applied at two concentrations (lower and higher recommended rates). Glyphader and Nwura Wura, which are glyphosates were applied pre-plant at 1.5 and 3.0L/ha and 2.5 and 4.0L/ha, respectively. Conti-quat and Kwatriqua (derivatives of paraquat) were applied pre-plant at 1.0 and 2.0L/ha and 1.5 and 2.0L/ha, respectively. Sun-Atrazine and Atranex are atrazines and were applied pre-emergence at 3.0 and 4.0L/ha and 1.25 and 2.5L/ha, respectively, whilst Sun-2, 4-D and Bextra 2, 4-D, derivatives of 2, 4-D, were also applied pre-emergence at 2.0 and 4.0L/ha and 1.5 and 2.5L/ha, respectively. The control plots were weeded manually only. Results showed that all herbicides applied increased weed mortality, most especially in the pre-emergence applications. The results also indicated that plants in the control plots had higher crop growth rate and net assimilation rate for low application rate. All herbicide treated plots positively influenced growth and yield of the maize. The highest maize yield per hectare (9779.0kgha^{-1}) was obtained in Sun-Atrazine treated plots, followed by Nwura Wura treated plots (9700.0kgha^{-1}) and Sun-2, 4-D treated plots (9770.0kgha^{-1}). Use of the herbicides positively influenced crop growth and increased biomass yield of both maize and cowpea

used as second crop. Results of soil analyses revealed that residual herbicides did not have any negative influence on nutrients status and microbial population of the soil.

DEDICATION

This thesis is dedicated to my mother, Kou Y. Mienwipia, father, Saye M. Mienwipia, brother, S. Emmanuel Mienwipia, fiancée, Krubo Sumo, all of whom have predeceased me for making me who I am today and to my children, Irena Z. Mienwipia, Chris C. Mienwipia, Hawah B. Mienwipia, Faith M. Mienwipia, Job N. Mienwipia for waiting on the Lord while I was on study leave.

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TABLE OF CONTENTS

TITLE **PAGE**

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS AND ACRONYMNS

%:	Percent
BMD:	Biomass duration
CGR:	Crop growth rate
Cm:	Centimeter
Fig:	Figure
G:	Grammes
H. dose:	Higher dose
L. dose:	Lower dose
L:	Leaf
LAD:	Leaf area duration
LAI:	Leaf area index
LSD:	Least Significant Difference
NAR:	Net assimilation rate
No:	Number
NS:	No Significant difference
RGR:	Relative growth rate
RLAGR:	Relative leaf area growth rate
WAS:	Week after sowing

CHAPTER ONE

INTRODUCTION

One of the oldest food grains is Maize (*Zea Mays* L.) and the only cultivated species in its genus. It is from the grass family poaceae (Gramineae). It is known by various common names but the most popular name is maize or corn (Paliwal, 2000). Maize is a fully domesticated plant which has lived with man and evolved since ancient times. It is completely dependent on human husbandry, does not grow in the wild and cannot survive in nature (Paliwal, 2000).

Maize is the third most important cereal crop in terms of production of cereals of the world (Ochse *et al*., 1996).

Maize is produced on more than 96.5 million hectares in the developing world (FAOSTAT-Agric, 2004), and millions of people worldwide are dependent on it as a staple food. It occupies less land area than either wheat or rice but has a greater average yield per unit area of about 5.5 tonnes per hectare (Ofori *et al.*, 2004). According to Paliwal (2000) the grain of maize is the most important component for which maize is cultivated, though every part, leaves, stalk, tassel, husk and cob is employed for different purposes.

Maize is used in several ways more than other cereals, its principal use include human feed, both home cooked and industrial; fodder, feed for animal, fermentation and various industrial products (Paliwal, 2000). The grain is very nourishing, with about 70-72% assimilable carbohydrates, 4 - 4.5% fats and oils and 9.5-11% proteins (Larger & Hill, 1991).

Maize is one of the most crucial and strategic cereal crops in Africa. It is cultivated in different parts of the continent under diverse climatic and ecological conditions. Owing to its

increasing importance, it has become a staple and cash crop for smallholder farmers (CIMMYT & IITA, 2010). As a result of the nutrient nature of maize, it is a preferred diet for several million poor consumers as well as one third of all undernourished children. Maize demand in developing countries will double and become the crop with the greatest production globally by 2050 according to CIMMYT & IITA (2010) estimate. In Africa maize supplies at least 20% of total daily calories consumed and accounts for 17 – 60% of peoples' total daily protein supplies (Krivanek *et al*., 2007). Maize is first on the list in terms of total production and consumption among cereal crops (Twumasi-Afriyie *et al*., 1992) in Ghana. According to Pingali & Pandey, (2001), maize is an important source of carbohydrate in the tropics and is a major staple food in Ghana for a large segment of the population in addition to being an important poultry feed and is used for industrial uses.

Nonetheless, maize has immense potential in the tropics and yield of up to 7.5 t / ha can be obtained if the crop is properly managed. Unfortunately, yields are still generally below 5 t / ha (FAO, 2007) and this low yield in tropical areas has been attributed to low nutrient status of tropical soils especially nitrogen, phosphorus and potassium resulting from the practice of slash and burn farming system associated with bush cultivated land and with excessive leaching of the soil nutrients. The low fertility status of most tropical soils hinders maize production as the crop is a heavy feeder (Steiner, 1991).

Maize although a robust growing plant in nature, is very sensitive to weed competition during the early stages of growth (Mabasa *et al*, 1995; Kumar & Sundari, 2002). As a result the weeds cause low yields in maize by competing with the crop for nutrients, water, sunlight and space, the most critical resources for crop productivity. Sometimes, wide spacing and slow initial growth of maize favours the growth of weeds even before crop emergence. However,

presence of weeds reduces the photosynthetic efficiency, dry matter production and distribution to economical parts and there by reduces sink capacity of crop resulting in poor grain yield. Thus yield losses due to season long weed infestation range from 30% to complete crop failure (Pandey *et al*., 2001). Uncontrolled weed growth may reduce maize yield as much as 90% (Ratta *et al.*, 1991). The critical period of crop weed competition is 3 to 6 weeks after sowing in case of maize. Hence managing weeds during this period is most critical for higher yields.

Weeds also pose severe problems for crop husbandry and infest fallow land, reduce soil fertility and moisture conditions and develop a potential threat to the succeeding crops (Khan *et al*., 2003). Thus, attention must be focused on weed control measures so as to maintain the competitive ability of the threatened crop by minimizing weed interference during the growth phases of crop. Accordingly, the nature of weed interference influences strongly the choice of weed control measures.

The methods of weed control include cultural, biological, chemical means among others. According to Singh *et al* (1996), weeds control methods are divided into two: non-chemical and chemical methods. However, the conventional method of weed control such as hand weeding tends to be expensive especially where labor is not available during the peak workload (Khan *et al.*, 2000). Admittedly, chemical weed control in maize is the best method being used in Ghana and other developing countries, as it is an effective and relatively inexpensive means for managing weeds in cereals (GGDP, 1991).

In many developing countries, farmers are faced with the problems of various herbicide groups recommended for weed control on the market and do no know how to make sound decision with regards to their efficacy. In view of this, there was a need to evaluate some selected herbicide groups which will provide an informed back ground for herbicides selection and recommendation for use in similar ecologies. In many developing countries weeding is left mostly to women and their daughters, resulting in high dropout rates by girls from school, hence attention to manage weed control must be pursued.

Following the return of Liberia to normality, returnees from various countries have learnt to consume foods made from maize, hence increased production of the crop is likely to occur and a need therefore to maximize production.

1.2 Objectives

In view of the foregoing, the objectives of the research were to:

- ascertain the efficacy of four herbicide groups on weed control.
- determine the impact of the herbicides on the growth and yield of maize.
- determine the residual impact of the herbicide groups on the agro-ecological zone using black eyed cowpea bioassay.

CHAPTER TWO

Literature Review

2.1 Biology of maize

Maize or corn (*Zea mays*) is a plant belonging to the family of grasses (*Poaceae*). It is a typical tropical plant with a tall, leafy structure having a fibrous root system, supporting a single culm with as many as 30 leaves. It is susceptible to invasion by weeds (Paliwal, 2000). The leaf axils in the upper part of the plant develop more prominently one or two lateral branches (Paliwal, 2000).These are terminated by a female inflorescence, a silk which develops into an ear well covered by the husk leaves which served as the storage part of the plant. In addition, the plant is terminated by a male inflorescence, the tassel with prominent central spike and many lateral branches with male flowers, all of which produce abundant pollen grains (Paliwal, 2000).

Maize is a monoecious plant that develops inflorescences with unisexual flowers that are always borne in separate parts of the plant. The female inflorescence, the ear arises from the axillary bud apices and the male inflorescence, tassel, develops from the apical growing point at the top of the plant. Paliwal (2000) however pointed out that maize, like any other plant, tends to maintain a homeostasis balance between the roots mass and shoot mass. If a soil-acquired resource, such as water or nutrients is inadequate, more assimilate moves to the root system, and root growth is favoured over shoot growth. Similarly, if radiation is inadequate for growth as a result of shading or cloudy conditions, more assimilate will be dedicated to shoot growth and the root: shoot ratio will declines.

2.2 Ecology of maize

Maize is adapted to a wide range of climates. In most areas it is sown at the onset of the rain, but due to its wide adaptation, it flowers at different times depending on the cultivar selected. Some will mature as early as 60 days after emergence while others require over 40 weeks. Maize will do well on most textural soils, especially a nutrient rich soil with adequate drainage to allow for the maintenance of sufficient oxygen for good root growth and activity, and enough water-holding capacity to provide adequate moisture throughout the growing season with a pH ($CaCl_2$) between 5.5 and 7.0 (Farrell & O'Keeffe, 2007).

In addition, Maize is a versatile crop grown over a range of agro climatic zones. In fact the suitability of maize to diverse environments is unmatched by any other crop (Dowswell *et.al.*, 1996). Also, it can be grown on a wide variety of soils, but performs best on well-drained, well-aerated, deep warm loams and silt loams containing adequate organic matter and well supplied with available nutrients.

Although it grows on a wide range of soils, it does not yield well on poor sandy soils, except with heavy application of fertilizers. On heavy clay soils, deep cultivation and ridging is necessary to improve drainage. Maize is suited for off-season cropping in swamps provided drainage is adequate (though planting in swamps is not always recommended for environmental reasons). It does not tolerate water logging; it can be killed if it stands in water for a period of two days (Dowswell *et.al.*, 1996).

2.3 Growth stages of maize

Maize like any other plant has what is referred to as growth stages during which the physiological, anatomical and morphological processes are noted. Maize has eleven growth stages and of the eleven, germination and emergence are stage zero while stages 6 to 10 occur after silking. In terms of crop management the stages are narrowed down to six incorporating, dry-down and grain harvesting (Colless, 1992). Notwithstanding, the vegetative growth stages are described by Paliwal (2001f) as Germination and emergence. The stages are as follows:

Stage 1: approximately from zero to fourteen days after sowing depending on factors such as soil temperature and moisture, sowing depth and surface hardness. During this stage the radical emerges and one to two days after that the plumule breaks the seed coat. The plant develops seminal roots, a temporary root system until about the three leaf stage of the seedling. Six to ten days after planting the coleoptiles emerges from the soil, splitting the tip to allow the growth of the first foliage leaves and the shoot meristem remains below the soil surface.

Stage 2: Early vegetative phase, about fourteen to forty two days after planting and this is marked by secondary or adventitious roots development from the first node below the soil surface. This develops into a thick, permanent fibrous root system reaching down to 1-2cm where some adventitious roots may also emerge from the above ground. The number of leaves that will develop on the plant, up to about 30, is determined (Irish & Jegla, 1997). The tassel begins to differentiate when about 5 leaves have emerged. The shoot meristem and the tassel primordium emerge above the soil surface by the six leaf stage and when eight leaves have

fully emerged, the shoot meristem will be about 15cm above the soil. The lower leaves may start to senesce by the end of the stage.

Stage 3: Late vegetative, about 42 to 60 days after sowing. This is the stage of rapid growth development, linear dry matter accumulation of both roots and leaves. During this stage there is a basic repeating unit structure comprising leaf blade, leaf sheath, node and internodes that make up the entire vegetative shoot. Internodes elongation produces a new leaf every 3-4 days. Eventually, the elongation of the lower internodes contributes to the formation of a stalk like structure that rises up through the leaf sheaths. By the end of stage 3, the 16^{th} leaf will have reached full size, although it will not have fully emerged and the ears within the husks will be a few centimeters long. The first 5-6 lower leaves may senesce and cease to be functional.

The brace roots usually emerge from the lower, above ground nodes. The extent of brace root production is cultivar dependent as well as influenced by the planting and nutrition. Also, there is a correlation between the final number of leaves produced on a plant and the time between sowing and silking. The length of vegetative development is linked to the thermal interval between the appearances of successive leaf tips and differs according to the temperature found in latitudinal zones, being higher in tropical than temperate areas (Tojo Soler *et al.* 2005).

The first reproductive stage is the anthesis or male flowering stage when pollen shed begins while the last reproductive stage is referred to as physiological maturity which is identified by a black layer visible at the base of the grain.

According to He *et al* (2010) based on the cultivar the maize plant can develop up to 20 to 21 total leaves, silks about 65 days after emergence, and mature around 120 days after emergence. The specific time interval, however, can vary among hybrids, environments, planting date, and location. The length of time between each growth stage, therefore, is dependent upon these circumstances. For example, an early maturing hybrid may produce fewer leaves or progress through the different growth stages at a faster rate. In contrast, a late-maturity hybrid may develop more leaves and progress through each growth stage at a slower pace. This means that the application of herbicides, fertilizer and other pesticides must be completed within the first two months of maize development.

2.4 Weeds as pest in crop production

There are many factors which cause low yields of maize, and of these weed growth, competing with the crop for nutrients, water, sunlight and space is most critical. The presence of weeds in maize field reduces the photosynthetic efficiency, dry matter production and distribution to economical parts there by reducing sink capacity of crop resulting in poor grain yield. However, yield losses due to weed infestation range from 30% to complete crop failure (Pandey *et al*., 2001). Weeds cause enormous damage to the maize crop, the magnitude of loss varies depending upon the growth and persistence of weed population in standing crop (Rout & Satapathy, 1996).

Aldrich & Kremer (1997) defined weed as a plant that originated in a natural environment and in response to impose or natural environments, evolved and continues to do so as interfering associate with our crops and activities. Furthermore, Zimdahl, (2007) indicated that weeds are plants with some particular, and perhaps unique, adaptations that enable them to survive and prosper in disturbed environments.

More so Navas (1991) as cited by Zimdhal (2007) demonstrated that weeds as a plant forms populations that are able to enter habitats cultivated, markedly disturbed or occupied by man and potentially depress or displace the resident plant populations which are advisedly cropped or one of ecological and or aesthetic interest.

Weeds are the oldest problem in agriculture and represent one of the main limiting factors in profitable crop production (Avery, 1997). They are also considered the most complex and serious problem in natural resource management. Zimdahl (2007) further noted that weeds have the following characteristics:

- Weeds grow well in gardens, cropped field and in places disturbed by man
- They have rapid seedling growth and the ability to reproduce when young
- Quick maturing in a short period of time when in the vegetative stage
- Dual modes of reproduction i.e. by seed and vegetative
- Environmental plasticity i.e. capable of tolerating and growing under wide range of climatic and edaphic conditions
- Weeds are often self-compatible yet self –pollination is not obligatory
- When a weed is cross-pollinated, the pollination is accomplished by no specialized flower visitors or by winds

- Weeds have the ability to resist detrimental environmental factors, unlike most crop seeds
- Weeds seeds exhibit several kinds of dormancy or dispersal in time to escape rigors of the environment and germinate when conditions are most favorable for survival
- weeds have the ability to compete inter -specifically by special means such as rosette, choking growth and allelochemicals
- High reproductive output.

For a plant to consistently be considered a weed, it must have those characteristics that set it apart from other plants and allow success in invading, becoming established and persisting in an agricultural setting (Monaco *et al.*,2002).

Weeds may be classified as annual, biennual or perennial. An annual weed completes the life cycle from seed to seed in less than one year in one growing season. Also, a biennial weed lives more than one year but not more than two years. In addition, perennial weed is usually divided into simple and creeping perennials. Simple is spread by seed and vegetative but the normal mode of reproduction is seed and creeping perennial also reproduce by seed and vegetative (Monaco *et al.*, 2002).

There are several methods and strategies that weeds use to compete with crops and these are bimodal reproduction, adaptability, earliness, allelopathy and dispersal among others. Bimodal reproduction involves more than one way to reproduce and dispersal indicates that weeds must be able to colonize and invade; adaptability denotes that weeds must be able to survive unexpected events; earliness also implies that weeds germinate early and grow faster and taller than the desired crops, thus capturing resources needed by the crops (Zimdahl,

2007). Allelopathy is defined as the effect of one plant on another through the release of chemical compound into the environment (Bhowmik & Inderjit, 2003) to inhibit the survival of the opponent plants.

According to Ziska & Dukes (2011) many crops originated from weeds species and are similar both genetically and ecologically and as such some weeds function as crops depending on location. In like of this (Rao & Rao, 2000) stated that weeds can serve as alternative hosts to several crop insect pests such as nematodes, aphids, thrips, weevils, flies and etc. by harbouring these pests and pathogens, inflict attack on the crops, thus resulting in increased cost of their control.

2.5 Losses caused by weeds

Weeds are considered notorious yield reducers that are, in many situations, economically more important than insects, fungi or other pest organisms (Savary *et al.*, 2000). Nevertheless, on the large spacial and secular scales it is difficult to estimate the yield loss caused by weeds singly from unevenness caused by weather, soil type or geographic location, and other pests (Oerke *et al.*, 1994). In like of this, it is not easy to evaluate the relative importance of different weed species which cause yield loss for producers.

Weed accounts for an approximated 4.1 million tonnes in lost cereal yields each year, and is considered by many experts to be the greatest obstacle to food production in Africa (Watson *et al.*, 1998). Weed damage to maize accounts for over US$7 billion in yield losses in sub-Saharan Africa, affecting the welfare and livelihood of over 100 million people (Kanampiu & Friesen, 2004).

Weeds have become an increasing problem in maize production as they are widespread all over the arable land cultivated for maize crop (Mehmeti *et al.,* 2011). Weeds cause high losses of maize yield and these losses due to weeds have been reported up to 35 % (Dangwal *et al.,* 2010). Thus, in maize production, it is necessary to undertake control of weeds which cause losses of maize grain yield. According to Anderson (1996), weeds compete with the crop mainly for water, light, nutrients and carbon dioxide. Valverde *et al* (1995) reported that 16-40 % yield losses in the maize fields were due to the weeds. Weeds differ from other plants in being more aggressive, having peculiar characteristics that make them more competitive and able to suppress the activity of all other plant communities around them and establish a kingdom of their own within a short period of time. These weeds are generally associated with commercially important crops of export potential, thus not only lower the quality but also the quantity of the crop produce resulting in heavy economic losses to the farmer. It is important to understand the yield loss associated with different weed species if we use weed thresholds to optimize the economics of weed management.

Corn yield loss is often varying among weed species. At a density of 2 weeds per foot of row, corn yield can be reduced up to 10 % (Lindquist *et al.,* 1996). Yield loss is also uneven among locations and years even at the same weed density (Jasieniuk *et al.,* 1999). Yield loss due to weeds in maize varies from 28-93%, depending on the type of weed flora, weed intensity and duration of crop-weed competition (Sharma & Thakur, 1998). Weeds are perceived by many farmers as being the greatest cause of yield loss in agricultural crops (Owen, 1998).

Weeds are the most persistent of all crop pests. One of the main reasons for low yield is high infestation of weeds and poor weed management practices. Researches indicate that maize plants are very susceptible to weed competition and yield losses are forecast at 35% to 80% complete crop failure (Sharma *et al.*, 1998; Zaciragic & Grabo, 2003) due to weeds. Weeds cause significant losses each year in the agriculture and a host of other human enterprises. They are different from the other pests that pose problems in crop production because the presence of weeds is relatively constant, while outbreaks of insects and disease pathogens are sporadic (Gianessi & Sankula, 2003).

Despite suitable production environment and high yielding diversities of maize, the yield per hectare in maize is still very low. Considering factors responsible for low yield, weed infestation is of prime importance. Weeds compete with the crop plants for space, light, moisture, nutrients and carbon dioxide, which reduced not only the yield, grain quality and hinder harvest operations but also increase the cost of production (Retta *et al.*, 1991). Presence of weeds in crops reduces the photosynthetic efficiency, dry matter production and distribution to economical parts and there by reduces sink capacity of crop resulting in poor grain yield. The yield of maize crops is directly proportional to water stress and weed density Rahnema & Bakhshandeh (2006); Panda *et al* (2004) as a result, the presence of weeds cause severe losses to our crops.

According to Zimdahl (2004) studies have been conducted in many crops in several environments under different conditions and found out that the critical period for weed control in maize has been determined with varying results obtained and Suggested that from 3 to 6

weeks after seeding is the critical period for weed control in maize. Knezevic *et al* (2002) and Rajcan & Swanton (2001) indicated that in developing a valuable management technique for weed control in maize it was useful to determine the appropriate timing of weed control. Zimdahl (2004) also mentioned that the critical period of weeds control has been the subject of extensive research in agronomic crops and it was expedient to quantify the critical period of weeds control as a common approach in such research and he added that it is a phase of the crop growth cycle when weed interference results in unacceptable yield losses.

2.6 Weeds management in crop production

A good start to crops results in vigorous growth owing to timely irrigation application before flowering of weeds, irrigation channels and alternative sources of water should be kept weed free by slashing or suitable herbicides (Singh *et al.*, 1996).

Weeds which are growing on the sides are the sources of seeds which are disseminated by water to different areas and fields. A Successful establishment of weeds which are especially effectual against crop can be prevented by the adoption of a proper cropping sequence. Periodic tilting in the crops rotation prevents progressing up of a particular weed seed reservoir in the soil. Such is a good method to prevent infestation of the weeds which are morphologically like that of the crops. A rigorous alertness to notice the weeds spreading and immediate action at appropriate level to check it should be the concern of everyone to avoid insertion and spread of any weed in the region or field. The weeds which cannot be prevented from infecting our economical crops need to be controlled (Singh *et al.*, 1996).

The basic principles and practices whereby the crop's ability is increased to compete and suppress the growth of weeds (Ampong-Nyarko & De Datta, 1991) is referred to as cultural control. A robust crop contends more effectively with weeds than does a less robust crop. The cultural practices include weeds growth retardation, land preparation, crop rotation, cultivar selection, time of seedlings, planting method, plant population, and fertilizer and water management.

According to Singh *et al (*1996) and Ampong-Nyarko & De Datta (1991) a single approach established to keep crop-weed competition below threshold level is ineffective and undesirable. However, one method may be effective and economical in a situation but not in all agro-economical situations. No single herbicide is effective in controlling a wide range of weed flora. Although, the uninterrupted use of such herbicide produces resistance in escaped weed flora. Furthermore, uninterrupted use of one practice may yield to some undesirable consequences such as one crop rotation over years can result in the build- up of certain weed species, or the over use of one control method can increased the population of a particular weed species. However, it is advisable and advantageous to use combination of two or more control methods to acquire a desired result of control.

Further, the combination of methods can destroy all weed seeds and vegetative growth in soil as well as control the growing weed species which can result in highest economic returns and prevent the ecosystem from weed infestation beyond certain degree (Singh *et al.*, 1996).

In addition, certain hand tools are used by every developing country for weeding in the crops and these tools have flat iron blades, attached to a wooden handle to weed out the weeds which cannot be hand pulled. The efficiency of this hand weeding is slow, need between 200-400 men hour per hectare of each weeding. When the intensity of weed is high two such

weeding is necessary in most crops and as a result the output of hand weeding is very low compare to the herbicides treatment (FAO, 1982). Henceforth, between 20-30% hands weeding is inferior to weed free condition or herbicides. Also, since the farmers are ignorant of the fact that crop yield reduces appreciably even if hand weeding has been done, they must be relieved from the common belief that there is no loss of yield if two or more hand weeding is done. In addition FAO (1982) indicated that the planting time of some crops coincides with or just precedes periods of rain and such wet soil conditions do not permit efficient hand weeding when the time is due for weeding. In this situation, only herbicides, most especially pre-emergence herbicides which ensure season long weed control in maize is acceptable. Besides, hand weeding is not an effective method of control, although it gives some relief to the crop yet it still allows a sizable part of the potential yield to be lost through competition by weeds. In addition, competition is most intense when weed and crops are of similar morphology, similar water, soil and nutrients requirements then losses in grain yield can be as high as 50% or more. Also, there is more competition within the crop row than between the rows since the weeds are positioned within the immediate vicinity of the crops and as such the weeds reduce the general vigour of the crops with sequent decline in yield.

Subsequently, there is no hand tool or implement so far developed which can remove weed within row when they are very similar in morphology to the crop then chemical weed control. It is indicated by Marshall (1992) that the timing and frequency of hand weeding is critical but can lower weed numbers considerably. Tewari *et al* (2003) and Singh & Angiras (2004) indicated that the yield output from the plots kept free of weed during its entire growth period is compare to hand weeding done twice at 30 and 60 days after sowing in maize crop.

According to Makanganise *et al* (2001) the main method used to control weed by the majority of African smallholder farmers is hand weeding which is time consuming and labor intensive with up to 300 man hours per hectare required to weed maize fields with weed (Vogel, 1994). According to Haggblade & Tembo (2003b) the labour demand for hand weeding an entire crop field is about three times that of chemical control. Since labour is scarce especially during the early stage of the crop, untimely weeding in field can lead to more than 30% loss of potential yield of crops (Riches *et al.*, 1997).

The use of herbicides can eliminate early crop-weed competition and cut down the time farmers spend on weeding (Gatsi *et al*., 2001).

Waddington & Karigwindi (1996) indicated that as a result of labour shortages first weeding in maize is delayed and competition is increased.

Ineffectiveness of hand weeding under wet condition cause most farmers to frequently weed their crops in order to attain high yields. Some farmers may abandon their crops with heavy weed infestation as such resources and inputs previously invested to these deserted crops are therefore lost (Mashingaidze & Chivinge, 1998).

2.6.1 Chemical weed control

The property of the chemicals selectivity has been found to be extremely useful to kill specifically targeted species in spite of the presence of economic crops. Also, the use of herbicides to control weeds have a number of merits over other methods and these are: herbicides control the weeds between rows as well as within rows; herbicides applied before sowing or early pre-emergence provide weed free condition to the crop from the beginning

and give boost to the crop growth enabling it to suppress the weeds at later stages; herbicides control weeds when the soil is not workable owing to incessant rains (Singh *et al.,* 1996). Weeds which are difficult to control using hand weeding are easily done with herbicides; herbicides in some cases help in reducing the need for pre planting tillage; herbicides have the ability to cover a large area in a particular growth stage whereas more labour and time are required to do similar coverage in hand weeding among several advantages (Singh *et al.,* 1996).

Like any other control methods, herbicides have their own drawbacks which can be overcome if application methods are well understood. There is no automatic signal to stop a farmer who may be applying the chemical inaccurately until he visualizes negative results in the crops sprayed or in the rotation crops that come after. Herbicides drift, wash off and run off can cause substantial harm to neighbouring desirable organisms. A variety of herbicides can be stocked on a farm to control weeds in different crops depending on the diversity in farming but low income farmer may possess only one or two kinds of herbicides and continuous use of same herbicides can cause weed resistance to that herbicides. Weed identity and knowledge about the herbicides and its proper usages should be the hallmark as error in the use of herbicides can be costly (Singh *et al.,* 1996).

Poor weed management is one of the major causes for low yield in maize. The hand weeding which is referred to as conventional method of weed control is costly and non available at critical stages of crops growth. Herbicide treatment is a competitive and promising way to control weeds in the first few weeks of crop growth (Baker & Terry, 1991).

Akobundu (1998) and Forcella (1998) indicated that with herbicides, one single weed species is not generally controlled but rather more than one. Successful weed management should match the specific problems in a field and some basic knowledge on weed and crop ecology and biology such as weed-crop growth characteristics and the dynamics of weeds emergence are important aspects as many farmers in the developing countries are unaware of weeds interference and the best time for its removal (Akobundu, 1998; Labrada, 1998).

Several of the herbicides used to protect crops are grouped into chemical families: organochlirines, organophosphates and carbamates. Others are the phenoxy and benzoic acids (2, 4-D), tyriazines (atrazine), paraquat and glyphosate (Miller, 2002).

2.6.1.1 Atrazine

Atrazine, chlorotriazine herbicides, introduced in the 1950s as a broad spectrum herbicides to control annual grasses and broadleaf weeds (Eldridge *et al.,* 1999; USEPA, 2003). Atrazine remains one of the most widely used herbicides worldwide (Stevens & Sumner, 1991) and 75% is used to control weeds in corn. The mode of action of atrazine is to inhibit photosynthesis by preventing electron transfer leading to the destruction of chlorophyll at the reducing site of photosynthesis complex II in the chloroplasts. Atrazine is a selective pre- and post-emergence herbicide used widely on maize and other crops. It can be used as non-selective under higher concentrated conditions. Atrazine is absorbed through roots of weed, but some foliage absorption can occurs depending on the weed species and time of application (Burken & Schnoor, 1997). The most common and extensively used herbicide on maize is atrazine and is mobile in the soils according to (Battaglin *et al.*, 2003).

2.6.1.2 2, 4-D

2, 4-D is one of the oldest herbicides used to control broadleaf weeds globally and it is still in use as one of the most common herbicides. 2, 4-D is selective herbicides which kill dicots or broadleaf weeds only by mimicking the growth hormone auxin, to cause uncontrolled growth for susceptible weeds which eventually lead to their death. 2, 4-D inhibits the growth of roots and shoots (Cox, 1999; Grabinska-sota *et al.*, 2003).

When 2, 4-D is applied as pre-emergence herbicide for weed control it induces the process of cell de-differentiation in the susceptible species which affects the weeds by accelerating foliage senescence, chloroplast damage and chlorosis leading to disruption of the vascular systems (Davies, 1995). According to Grossmann (2000) 2, 4-D causes aberrations in RNA synthesis, alterations in cellular membrane which cause phytotoxic effect in weeds resulting in cell death. He also indicated that 2, 4-D induces the production of hydrogen peroxide or some reactive oxygen that contribute to cell death. The accumulation of the reactive oxygen could be the result of the decrease in photosynthesis because of stomata closure due to over production of ABA.

2.6.1.3 Glyphosate

Glyphosate is a non-selective systemic herbicide that is applied directly to plant through foliage and can also act as growth regulator when applied in small quantities (Tomlin, 2006.) It is one of the most widely used herbicides to control weeds in maize (*RED*, 1993). When glyphosate is taken up by weeds, it disrupts the shikimic acid which is vital for protein synthesis (Tomlin, 2006). The absorption of glyphosate across the leaves and stems are trans-located throughout the weeds by phloem. Its point of concentration is in the meristematic

tissue (Franz *et al.*, 1997) leading to stunted growth, loss of green coloration, leaf wrinkling or malformation and death of weeds. The absorption of glyphosate across the cuticle is moderate, and its transport across the cell membrane is slower than for most herbicides. Plant uptake of glyphosate from soil is negligible because glyphosate binds itself to the soil (Roberts, 1998) and accumulates in meristem, immature leaves, and underground tissues.

2.6.1.4 Paraquat

Paraquat is an important member of bipyridylium family of non-selective herbicide developed to protect crops from weeds invasion. It is an herbicide widely used for all spectrums of weeds. It is a fast acting, non-selective herbicides and can destroy tissues of weeds on contact and by translocation within the weeds (Suntres, 2002). The use of paraquat had brought substantial benefits to maize production globally. According to Bromilow (2003) Paraquat is foliar-applied, non selective herbicides used to control weeds in corn and other crops. To completely kill the weeds, it must be capable of accessing the entire weeds, as growing leaves and newly emerging roots. This often means that the herbicide not only needs to damage at the point of its absorption, but must also be trans-located to parts of the plant not contacted by the herbicide during application.

The concentrate may also contain an aliphatic detergent to assist entry into plant cells and hence enhance its toxicity (Dinis-Oliveira *et al.*, 2006). Paraquat is fast-acting, non-selective contact herbicide that is absorbed by the foliage. It destroys plant tissue by disrupting photosynthesis and rupturing cell membranes, which allows water to escape leading to rapid desiccation of foliage (Dinis-Olivera *et al* 2006). It can also be translocated within the plant, increasing the likelihood of residues.

2.7 Weed succession

According to Booth & Swanton (2002) herbicide application is among several factors which are responsible for weed succession or shift in weed flora. They noted that the removal of one weed species create a condition for another species to be established. Swanton *et a* (1993) indicated that agriculture has a general goal to reduce weeds competition with crops and in pursuance of this goal can determine which weeds flora is able to colonize and persist in cropland. However, they mentioned that a repeated used of herbicides to control broadleaf weeds can cause a shift to grass weeds as a result of herbicide efficacy against broadleaf weed. According to Kandasamy (1997) the inherent selectivity of herbicides to manage weeds can result in a shift in the weed flora from annuals to perennials or vice versa which are sometimes difficult to manage.

2.8 Herbicides and weeds interaction

The action of herbicides when it comes into contact with weeds is influenced by morphology and anatomy as well as several physiological and biochemical processes within the weeds such as absorption, translocation, and penetration (Monaco *et al*., 2002). In addition, upon the contact of herbicides unto the surface of weeds, several things happened to the active ingredient: it is volatilized and lost to the atmosphere; remains on the outer surface in a viscous liquid; penetrate the cuticle but remain absorbed in the wax components of the cuticle; penetrate the cuticle, enter the cell walls and then translocate before entry into the symplasm; penetrate the cuticle, enter the cell walls, and then move into the internal cellular system for symplastic translocation. Once the herbicides come into contact with the weeds it must be absorbed and translocated to the target site (Rao & Rao, 2000). They also added that entry through stomata is possible when the stomata are opened at the time of application and

hence, absorption is greater at the lower than the upper leaf surface. Penetration via the stem is as effective as the leaf. Moreover, as the herbicide is absorbed into weed system, translocation is done either apoplastically or symplastically along with assimilates to the target site of weeds. For soil applied herbicide, it is absorbed by the roots or root hairs penetrate the xylem and move upward apoplastically in the transpiration stream to the target sites (Rao & Rao, 2000). Herbicide translocation is a dynamic process that occurs in both xylem and phloem over an extended period as long as the herbicides are available. In spite of the site of entry into weed all herbicides can enter the symplast for phloem transport.

2.8.1 Effect of herbicides on weeds seed germination and early seedling growth

According to (Rao & Rao, 2000), when herbicide is applied to the soil at pre-plant or pre-emergence, it is absorbed by the roots or root hairs of the emerging seedlings into the xylem, and then translocated to the target sites. For the seeds, it is absorbed into the solution by diffusion, which is a physical process, independent of water uptake. This process is dependent on the concentration of herbicide and its solubility in water as well as the size, shape, seed coat hardness and permeability of the seed.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Experimental site

The experiment was conducted at the University of Ghana Farm, Legon, located (05^{o} $39^{'}$ N, 0^{0} $11^{'}$ W) in the Greater Accra Region, situated within the coastal savannah ecological zone of Ghana (Fuackie-Sobreh, 2010). The soil type on the farm is classified as the Adenta series, a savannah Acrisol (FAO/UNESCO, 1999). According to USDA classification the soil is 150 cm deep, moderately well-drained and occurring on the middle slope of Legon hill where it is gentle to medium (2%-3%).

The soil profile consist of about 23 cm dark brown to reddish brown sandy clay loam topsoil slightly sticky with a weak, fine granular structure with few to common fine, medium root distribution and below this is about 17 cm thick yellowish red sandy clay containing few fine roots and few fine quartz and ironstone concretions (Brammer, 1967).

3.2 Climatic condition during the experimental period

During the experimental period, minimum and maximum temperatures ranged from 23.1-24.6^{o}C and 28.8-32.4^{o}C, rainfall distribution ranged between 173.2-11.5 mm while relative humidity ranged between 69-89%.

Table 3. 1: Mean monthly temperature (°C), rainfall (mm) and relative humidity (%).

Month	Temperature (°C)		Rainfall	Relative humidity (%)	
	Minimum	Maximum	(mm)	Minimum	Maximum
June	23.7	30.3	173.2	78	89
July	23.1	28.8	20.9	68	86
August	22.4	28.2	11.5	67	86
September	23.2	30.0	42.5	67	86
October	23.8	31.2	88.3	67	89
November	24.6	32.4	14.0	63	88

Source: Ghana Meteorological Agency, Mempasem, Legon, 201

3.3 Experimental design

The design used in the experiment was a randomized complete block design (RCBD) with four replications containing nine treatments as shown in Table 3.2.

Table 3.2: Treatment, rate of application and time of application of herbicides

Treatment	Active ingredient	Rate of application ha^{-1}	Time of application
ATRAZINE			
Sun-Atrazine	500g/l Atrazine	3-4 litres	Pre-emergence
Atranex 50sc	500g/l Atrazine	1.25-2.5litres	Pre-emergence
2,4-D			
Sun-2, 4-D	720g/l Amine salt	2-4 litres	Pre-emergence
Bextra 2,4-D	720g/l Amine salt	1.5-2.5 litres	Pre-emergence
GLYPHOSATE			
Glyphader 480sl	480g/l Isopropylamine salt of Glyphosate	1.5-3 litres	Pre-plant
Nwura Wura	360g/l of glyphosate	2.5-4 litres	Pre-plant
PARAQUAT			
Conti-Quat 24sl	24g/l paraquate Dichloride	1-2 litres	Pre-plant
Kwatriqua	27.6g/l of paraquat	1.5-2 litres	Pre-plant
Control (no treatment)			

3.4 Field layout

Maize variety, Obatanpa was used and seeds were obtained from the Department of Crop Science, University of Ghana.

The experiment which was set up in a randomized complete block design (RCBD) had four replications. Each experimental unit comprised five maize rows, with plot size 4m long x 1.6m wide and 1m between plots. Distance between and within rows were 80cm x 40cm respectively. Three seeds were sown per hill and seedlings were thinned at two weeks after emergence leaving two plants per hill.

3.5 Cultivation patterns

The experiment commenced on July 9th 2012 and ended on February 15th 2013. There were two phases of the experiment. For the first phase, the maize crops were treated with the upper rate of herbicides in the initial planting and then with the lower rate of herbicides in the second planting. The second phase was in the rotation crop where black eyed cowpea was used to access the residual level of herbicides in the soil.

Prior to the experiment, the land cultivated had been left to fallow for one year. A reconnaissance survey was conducted to identify weed species. A 16 litre knapsack sprayer with flat-fan nozzles, calibrated was used to apply all herbicides. Paraquat and Glyphosate were applied seven days prior to sowing during the initial land preparation while Atrazine was applied three days after sowing and 2, 4-D was also applied three days after sowing of crops.

Two weeks after sowing, complete fertilizer(NPK) 15-15-15 was applied at the rate of 125kg/ha as side dressing and top dressed with sulphate of ammonia at the rate of 125kg/ha six weeks after emergence, respectively.

At 107 days after sowing the crops were harvested, dehusked and solar dried for seven days to the minimum moisture contents of 14% before data collection.

3.6 Data collection

Six record plants from the three central rows bordered on all plots were selected for data recording. The following data were collected during the experiment:

3.6.1 Weed species present on plot prior to experiment

A weed reconnaissance survey was carried out prior to sowing of crops and then at six weeks after sowing and at harvest to determine the weed density under each weed control alternative by using a 50cm x 50cm quadrat. The numbers of weeds in each quadrate were counted by placing the quadrat at three points selected at random in each plot and weed biomass taken to be dried and weighed.

3.6.2 Growth parameters

3.6.2.1 Days to emergence, tasseling and silking

The 50% plants emergence, 50% tasseling and 50% silking of the record plants were determined by recording from the date of sowing to the day the plants emerged, tasseled and silked respectively.

3.6.2.2 Plant height

Plant height was measured from the base of record plant at soil level to the crest of the uppermost leaf at 2,4,6,8, 10 and 12 weeks after sowing. Plant height was measured using a meter rule.

3.6.2.3 Shoot and root dry weights

At four (4) and eight (8) weeks respectively after sowing, a representative record plant from each plot was uprooted and root separated from shoot. The shoots were then chopped into pieces and the two plant parts placed in separate envelope and then placed in an oven to dry at 70^{o} C for 72 hours to obtain the dry weight.

3.6.2.4 Height of ear

The height of ear above ground from the collar of the stem to the node that had the first ear was measured using a meter rule.

3.6.3 Growth analysis

For each treatment plot, six maize plants were selected and identified for data collection. The plants height was measured from the base at soil level to the crest of the uppermost leaf at fourteen days intervals *in situ*. The mean value was calculated for the determination of the growth rate. The relative growth rate (RGR), the net assimilation rate (NAR), relative leaf area growth rate (R_w), crop growth rate (CGR), leaf area duration(LAD) and biomass duration(BMD) of each treatment plant was calculated using the formulae below:

- Relative growth rate $=(\ln W_2-\ln W_1)/\Delta T$
- Relative leaf area growth rate $=(\ln A_2-\ln A_1)/\Delta T$
- Net assimilation rate $=(W_2-W_1)/(A_2-A_1)*(\ln A_2-\ln A_1)/T_2-T_1$
- Crop growth rate =NAR*LAI
- Leaf area duration $=(A_2-A_1)/(\ln A_2-\ln A_1)*(T_2-T_1)$
- Biomass duration $=(W_2-W_1)/(\ln W_2-\ln W_1)*(T_2-T_1)$

Where ΔT is changed in time, T_2, T_1=time in days, W_2, W_1 =dry weight of crops and A_2, A_1 are leaf areas corresponding to T_2 and $T_1$and *In* is the natural logarithm of the number (Hunt, 1979).

3.6.3.1 Leaf area per plant and leaf area index

The length and width of all green leaves of record plants were measured using a meter rule at two weekly intervals. The product of the length and width of each leaf was multiplied by 0.75 to give the area for each leaf (Fageria *et al.*, 2006). Then the total number of leaves per plant was established after the flag leaf. The total leaf area per plant was obtained by summing up the leaf area of the record plants and then the mean leaf area of a plant was determined for each treatment.

Leaf Area Index was determined using the relation:

Leaf Area Index = Total leaf area of plant / inter row spacing x intra row spacing (cm), (Maddonni & Otegui, 1996).

3.6.4 Yield parameters

3.6.4.1 Ear length (cm)

The mean ear length was taken for six record plants selected at random from each plot and each ear was dehusked and measured from the base to the tip using a ruler.

3.6.4.2 Ear diameter (cm)

The ear diameter was computed from the circumference of the six ears from the record plants per plot and then it was taken at the mid-section of the dehusked ears by using the NAE Vernier caliper.

3.6.4.3 Number of rows of kernel per ear

The kernel row per ear of the six record plants per treatment plot was counted and recorded.

3.6.4.4 Number of kernels per row

The mean number of kernels per row of the six record plants per treatment plot was counted and recorded.

3.6.4.5 Number of kernels per ear

The total number of kernels per ear of the six record plants was ascertained by multiplying the number of kernel rows by number of kernels per row.

3.6.4.6 100 Seed weight (g)

The hundred seed weight was obtained by the random selection from the bulk of kernels shelled from the six record plants from each treatment plot.

3.6.4.7 Yield per plot (kg)

Grain yield per plot was obtained by multiplying the plant stand at maturity by the total dry weight of kernels from the six chosen ears per plot and then divided by six.

3.6.4.8 Yield per hectare (t/ha)

The yield per hectare was computed by converting the yield per plant to yield per hectare by using the relation:

Yield per hectare = mean grain yield per plant x $10000m^2$ ÷ Inter row spacing x intra row spacing (m^2).

Harvest index =Economical Yield (seed yield per plant/Biological Yield (shoot dry weight) X 100

3.6.5 Data analysis

Data collected were statistically analyzed using Genstat 9^{th} edition to ascertain the efficacy of each herbicide used for weed control, as well as their individual effects on growth performances and yield of the maize test plants. Where the analysis of variance indicated significant difference among treatment means, means were separated using Least Significant Difference test at 5% level of significance.

EXPERIMENT II: Influenced of residual herbicides on black eye cowpea and shift in weeds succession/population

The data regarding the cowpea crop followed the same pattern as that of the maize crop in experiment I except the data concerning the shift in weed succession and the detection of residue by the plant bioassay.

3.6.6 Weed succession/ shift in population

The weed succession (shift) in population was determined by observing the re-growth of weeds in each plot after each hand weeding.

3.6.7 Residual effect of herbicide groups using black eyed cowpea

The residual detection on black eyed cowpea was determined by visually and critically observing the growth pattern of the crop from emergence up to the 20 days after sowing.

3.6.8 Soil physical and chemical properties

Soil physical and chemical properties were determined using the standard procedures. Before experiment I and after experiment II, soil composite samples 0-20cm depths were randomly collected from the experimental field and brought to the Department of Soil Science laboratory for analysis for the determination of residual effects of herbicides on soil physical and chemical properties. Soil samples were air dried and sieved with the 2mm sieve.

3.6.9 Soil chemical properties

The soil chemical properties were done to determine the status of soil nutrients and microbial count.

- Total Nitrogen: Nitrogen was determined by the Kjeldahl method (Bremner, 1960)
- Organic Carbon: determined by the wet combustion method (Walkley & Black, 1934)
- Available phosphorus: determined by Bray and Kurtz method (Bray & Kurtz, 1945)
- Soil pH: Soil pH measurement was made with a 1:1.25 soil: water ratio with a 15 minutes standing time.
- Soil texture: Soil texture is the relative proportions of sand, silt and clay in the soil (method of soil particle distribution analysis)
- Exchangeable K, T.P, Na, Ca, Mg
- Microbial count: Serial dilution and pour plate technique in nutrient agar medium (Allen, 1953).

CHAPTER FOUR

RESULTS

4.1 Weed density

Weeds density ($gm^{-2)}$ for experiment one is shown in Table 4.1. The data results indicated that weeds density at 6 WAS showed significant ($P \leq 0.05$) difference in all treatments including the control (no treatment) and up to 12 WAS. Sun-2, 4 –D ($2.70gm^{-2}$) had the lowest weeds biomass for high rate whereas Control had the maximum ($25.90gm^{-2}$). For the low rate, Bextra 2, 4-D ($2.80gm^{-2}$), Sun-2, 4-D ($3.30gm^{-2}$) had the lowest values and Control had the maximum ($20.98gm^{-2}$). Meanwhile at 12 WAS Nwura Wura ($4.75gm^{-2}$) had the lowest biomass value for high rate (200mls, 150mls, 80mls) of herbicides application and Control ($42.32gm^{-2}$) had the maximum biomass. Whereas for low rate Conti-quat ($14.7gm^{-2}$) had the minimum biomass and Control ($53.6gm^{-2}$) had the maximum biomass.

Table 4.1: Weed biomass per plot as influenced by different weeds control treatments six weeks after sowing and at 12 WAS (high & low rate)

Treatment	6 WAS (g/m^2)		12 WAS (g/m^2)	
	High rate	**Low rate**	**High rate**	**Low rate**
Sun-Atrazine	4.73	3.80	10.80	16.6
Atranex	4.88	4.57	9.13	19.0
Sun-2,4-D	2.70	3.30	8.45	14.5
Bextra 2, 4-D	3.80	2.80	9.90	16.6
Glyphader	3.05	6.45	9.08	23.8
Nwura Wuras	2.93	5.27	4.75	23.7
Conti-quat	4.03	3.45	9.38	14.7
Kwatriqua	4.00	3.62	9.48	14.4
Control	25.90	20.98	42.32	53.6
LSD (P ≤0.05)	**1.87**	**3.78**	**4.06**	**12.95**

4.2 Days to emergence, tasseling and silking

Table 4.2 shows the results of various herbicides and their application rate on days to 50% emergence, tasseling and silking. Days to 50% crop emergence showed significant (P ≤0.05) differences among all the treatments at low rate. However, days to 50% emergence for high rate, days to tasseling and silking showed no significant (P ≤0.05) differences among the treatments for both high and low rates.

At the high application rate for all the treatments, 50% emergence of seedlings ranged from four days after sowing to five days after sowing. In the plots treated with low rate of herbicides, days to 50% emergence differed significantly (P ≤0.05) with herbicides type. In the Triazine and Paraquat groups seedlings emergence was five days after sowing; seedlings

in the control plot emerged six days after sowing, while the rest of the treatments showed 50% of emergence four days after sowing.

Days to 50% tasseling was not significantly (P ≤0.05) influenced by herbicide treatments and it ranged from 53 to 56 DAS.

Differences in the number of days to 50% silking was also not significantly (P ≤0.05) influenced by herbicides application. At high application rate, silking occurred between 57 to 60 DAS, and in plots treated with low application rate, 50% of the plants silked between 56 to 58 DAS.

Table 4.2: Plant emergence and flowering behavior as influenced by different weed control treatment

Treatment	**Days to 50% emergence**		**Days to 50% tasseling**		**Days to 50% silking**	
	H. rate	**L. rate**	**H. rate**	**L. rate**	**H. rate**	**L. rate**
Sun-Atrazine	4	5	55	55	60	56.
Atranex	4	5	55	55	60	56
Sun-2,4-D	4	4	54	55	58	56
Bextra 2, 4-D	5	4	54	56	59	58
Glyphader	4	4	54	55	57	56
Nwura Wura	4	4	54	54	60	56
Conti-quat	4	5	54	54	58	56
Kwatriqua	4	4	53	54	58	56
Control	4	6	55	56	60	58
LSD (P ≤ 0.05)	**NS**	**1**	**NS**	**NS**	**NS**	**NS**

4.2.1 Plant height at 2-12 WAS and ear height 14 WAS

Figure 4.1 shows maize plant heights at biweekly intervals and ear height as influenced by different herbicides treatments applied at high rate. At seedling (2 WAS) and reproductive (8-12 WAS) growth stages, plants were significantly taller (P ≤0.05) in herbicides treated plots than those in the control plots. Whereas at 4 and 6 WAS the ear height and height of plant did not show any differences between control and herbicides treated plots. However, at 8 -10 WAS plants grown in plots treated with Paraquat were significantly higher (P≤0.05) than those grown in herbicides free plots. The plants heights at 12 WAS were significantly taller (P≤0.05) than those grown in herbicides free plots. Particularly in plots treated with Paraquat.

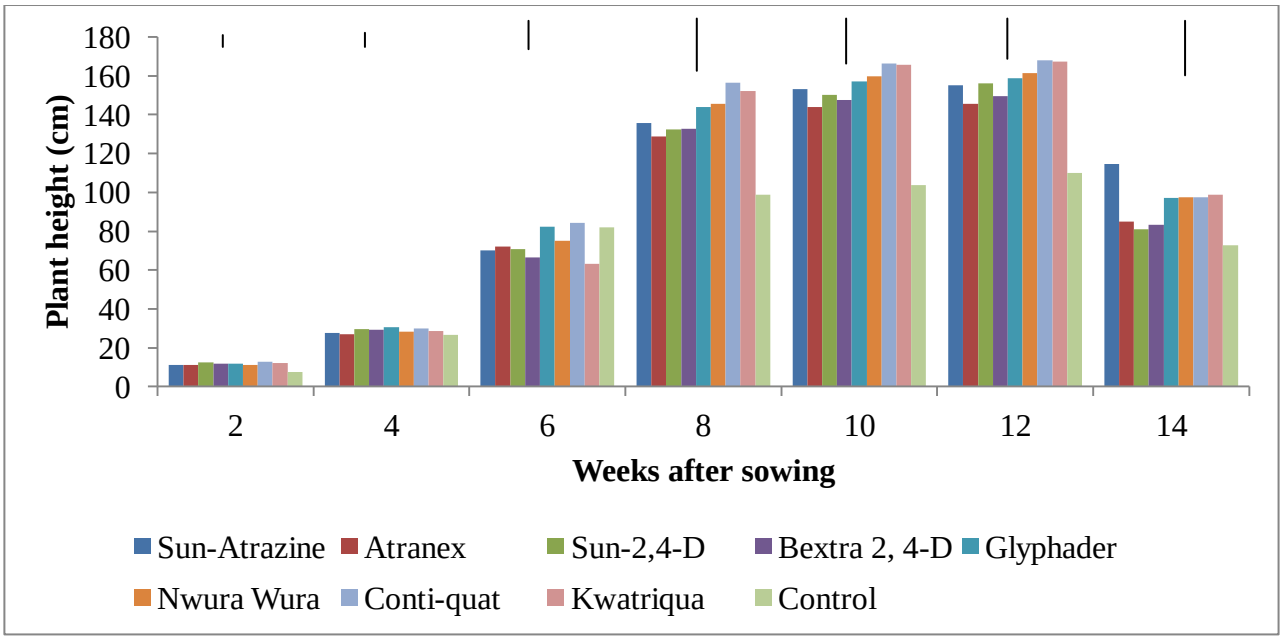

Fig.4. 1: Shows maize plant height at 2, 4, 6, 8, 10, and 12 WAS & ear height (14) as influenced by different weeds control treatments at high rate.

4.2.2 Plant height at 2-12 WAS and ear height at 14 WAS

Figure 4.2 indicates maize plant heights at biweekly intervals from 2-12 WAS and ear height at 14 WAS as influenced by different herbicides treatments. At seedling (2 WAS) through vegetative and reproductive (8-12 WAS) growth stages, plants were significantly taller ($P \leq 0.05$) in herbicides treated plots than the control. In particular, plants grown in plots treated with Paraquat were significantly higher ($P \leq 0.05$) than all herbicides treated plots. While plots treated with 2, 4-D were significantly shorter ($P \leq 0.05$) compared with those from all herbicides treated plots.

For ear height, the plots treated with Kwatriqua and Nwura Wura were significantly higher ($P \leq 0.05$) than all herbicides treated plots.

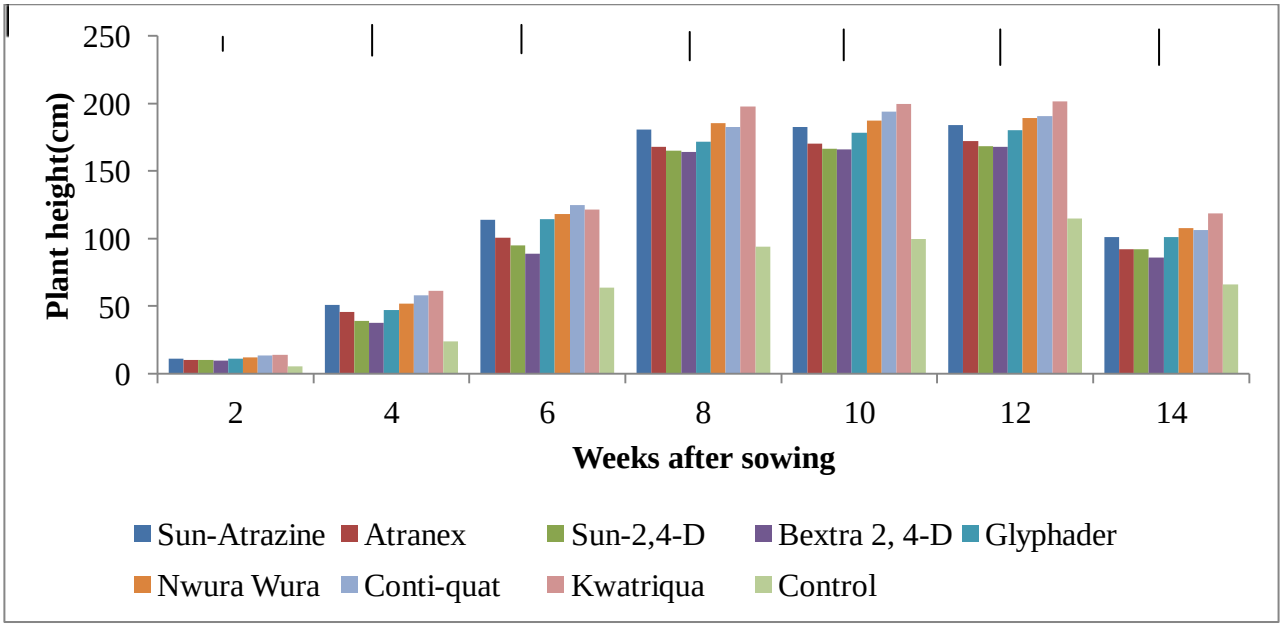

Fig. 4. 2: Shows maize plant height at 2, 4, 6, 8, 10 and 12 WAS & ear height at 14 WAS as influenced by different weeds control treatments at low rate.

4.2.3 Plant leaf number at 2-10 WAS

At 4, 6, and10 WAS plant leaf number showed statistically significant ($P \leq 0.05$) differences among the treatments at high application rate (Table 4.3). However, at 2, and 8 WAS showed no statistical significant differences among the treatments. There might be some differences in the values but are not shown statistically.

All herbicides treated plots had significantly ($P \leq 0.05$) higher number of leaves than control plots for the high application rates. Particularly in Glyphosate (9 leaves), Paraquat (9, 14, 19 leaves) and 2, 4-D (19 leaves) at 4, 6 and 10 WAS, respectively.

At low application rate, from seedling to reproductive growth stages (Table 4.3) revealed that there were statistically significant ($P \leq 0.05$) differences among the treatments. All the herbicides treated plots showed significantly higher number of leaves than control plots at the various growth stages except at 2 and 4 WAS where 2, 4-D was on par with control plots. However, triazine (13, 17, 19 leaves), Glyphosate (13 leaves), Paraquat (13 leaves) and 2, 4-D (19 leaves) had higher number of leaves among all herbicides treated plots at 6, 8 and 10 WAS. Values in parentheses are transformed values.

Table 4.3: Maize leaf number at 2, 4, 6, 8, and 10 WAS as influenced by different weeds control treatments

Rate	Treatment	2 WAS	4 WAS	6 WAS	8 WAS	10 WAS
High	Sun-Atrazine	5(1)	8(1)	13(1)	18(1)	20(1)
	Atranex	5(1)	8(1)	13(1)	18(1)	20(1)
	Sun-2, 4-D	5(1)	8(1)	13(1)	19(1)	20(1)
	Bextra 2, 4-D	5(1)	8(1)	12(1)	18(1)	19(1)
	Glyphader	5(1)	8(1)	13(1)	19(1)	20(1)
	Nwura Wura	4(1)	9(1)	13(1)	18(1)	20(1)
	Conti-quat	5(1)	9(1)	14(1)	16(1)	20(1)
	Kwatriqua	5(1)	8(1)	13(1)	19(1)	19(1)
	Control	4(1)	7(1)	10(1)	14(1)	16(1)
Rate	**LSD (P ≤0.05)**	**NS**	**1(.05)**	**1(.04)**	**NS**	**0.4(0.01)**
Low	Sun-Atrazine	5(1)	7(1)	13(1)	16(1)	18(1)
	Atranex	5(1)	7(1)	13(1)	17(1)	19(1)
	Sun- 2, 4-D	5(1)	6(1)	12(1)	16(1)	17(1)
	Bextra 2, 4-D	4(1)	7(1)	12(1)	16(1)	19(1)
	Glyphader	5(1)	7(1)	13(1)	16(1)	17(1)
	Nwura Wura	5(1)	7(1)	12(1)	16(1)	17(1)
	Conti-quat	5(1)	7(1)	12(1)	16(1)	17(1)
	Kwatriqua	5(1)	7(1)	13(1)	16(1)	17(1)
	Control	4(1)	5(1)	9(1)	12(1)	13(1)
	LSD (P ≤0.05)	**1(0.1)**	**1(0.1)**	**1(0.04)**	**1(0.02)**	**1(0.02)**

4.2.4 Plant leaf area at 2-10 WAS

Figure 4.3 shows maize plant leaf area over time as influenced by different weeds control treatments at high rate. At 2, 4, 8, and 10 WAS leaf area showed significant ($P \leq 0.05$) differences among the treatments.

At 2, 4, 8 and 10 WAS, respectively all herbicides treated plots showed significantly higher leaf area than control plots.

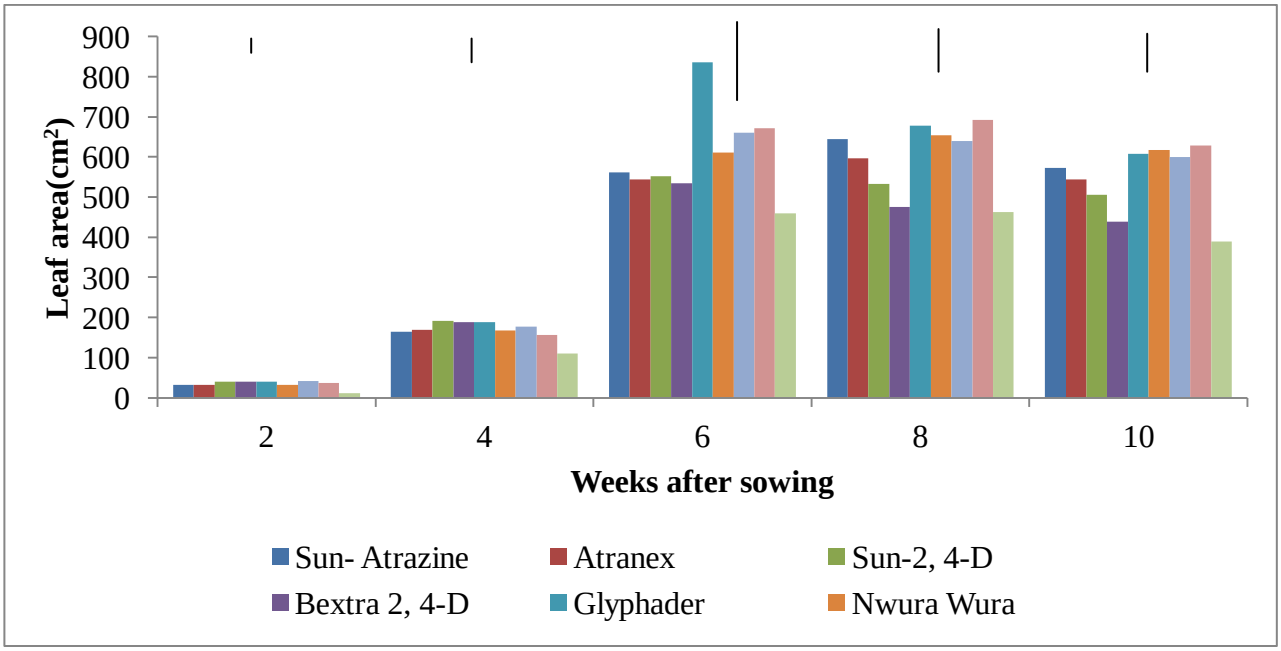

Fig. 4. 3: Maize leaf area over time, influenced by different weeds control treatments (high rate)

4.2.5 Plant leaf area at 2-10 WAS

Figure 4.4 shows maize plant leaf area over time as influenced by different weeds control treatments at low rate. Significant ($P \leq 0.05$) differences among the treatments were observed only at 2 and 10 WAS. However, all the herbicides treated plots showed higher leaf area than control plots. In particular, Paraquat ($57.3cm^2$) and Glyphosate ($50.10cm^2$, $584.0cm^2$) for 2 and 10 WAS.

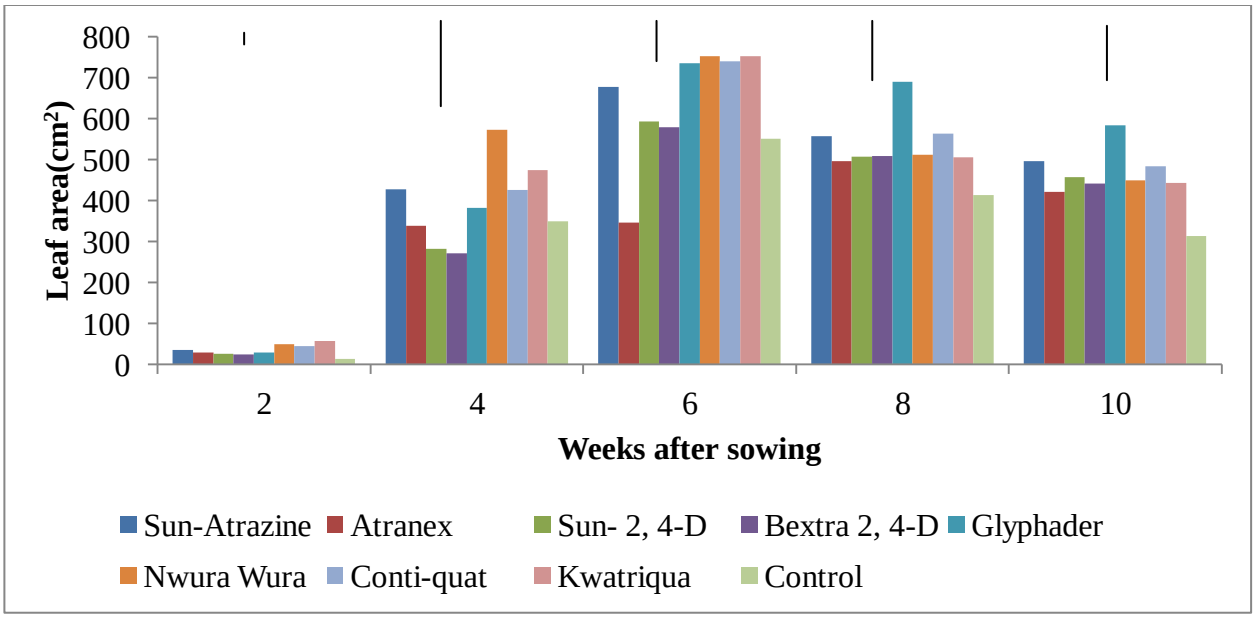

Fig. 4. 4: Maize leaf area over time, as influenced by different weeds control treatments (low rate)

4.2.6 Plant leaf area index at 2-10 WAS

Figure 4.5 shows leaf area index of maize plant over time as influenced by different weed control treatments at high rate. Siginicant ($P \leq 0.05$) differences among the treatments were observed at 2, 4, 8 and 10 WAS.

However, all the herbicides treated plots showed significantly higher LAI than the control plots, particularly in Paraquat (2161.0cm^2, 1963.0cm^2), Glyphosate (125.9cm^2, 2114.0cm^2).

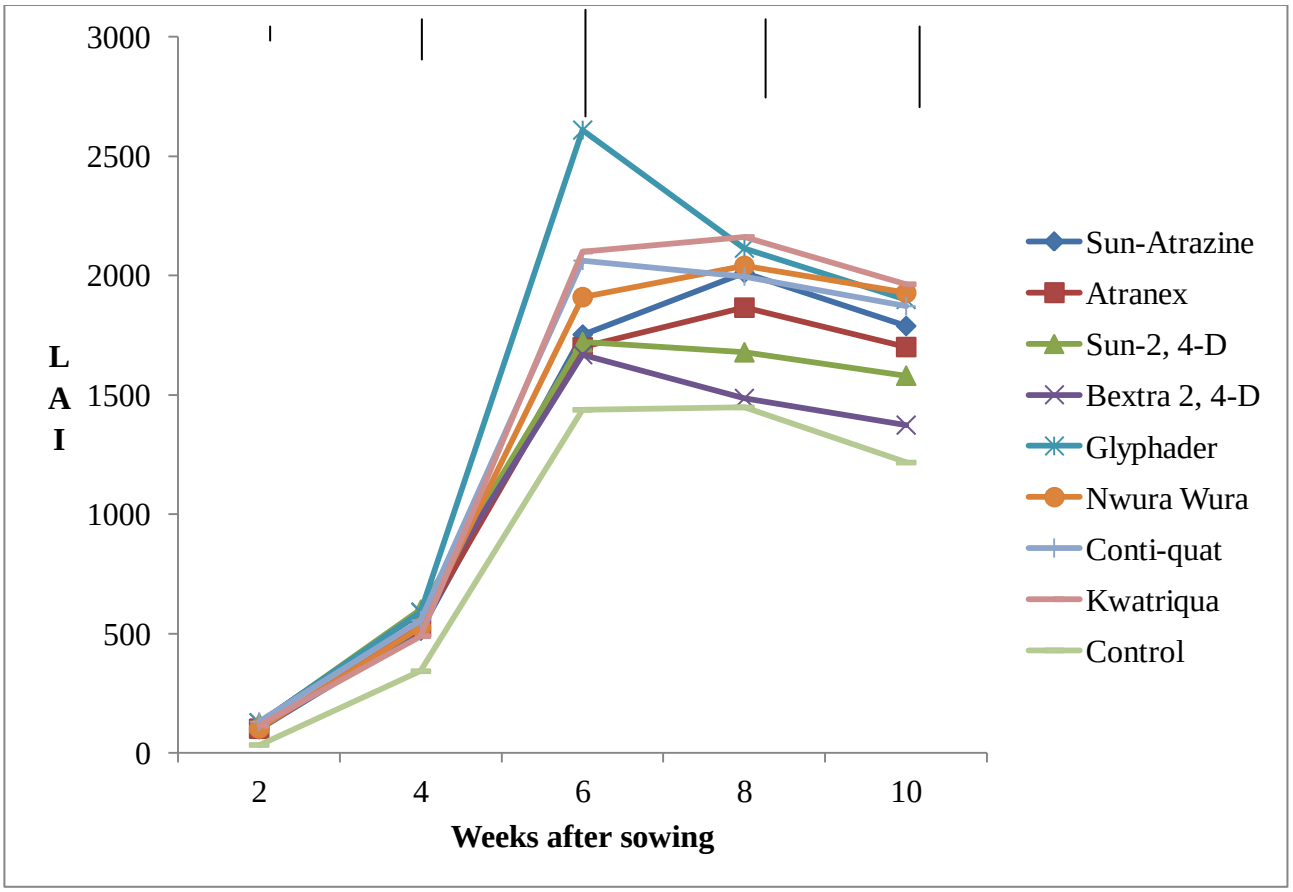

Fig. 4. 5: Maize leaf area index over time, influenced by different weed control treatments (high rate)

4.2.7 Plant leaf area index at 2-10 WAS

Figure 4.6 shows maize plant LAI at 2-10 WAS. Significant ($P \leq 0.05$) differences among the treatments were observed only at 2, 4 and 10 WAS.

However, all the herbicides treated plots showed significantly higher LAI than control plots, especially in Paraquat (178.9cm^2); Glyphosate (1825.0cm^2).

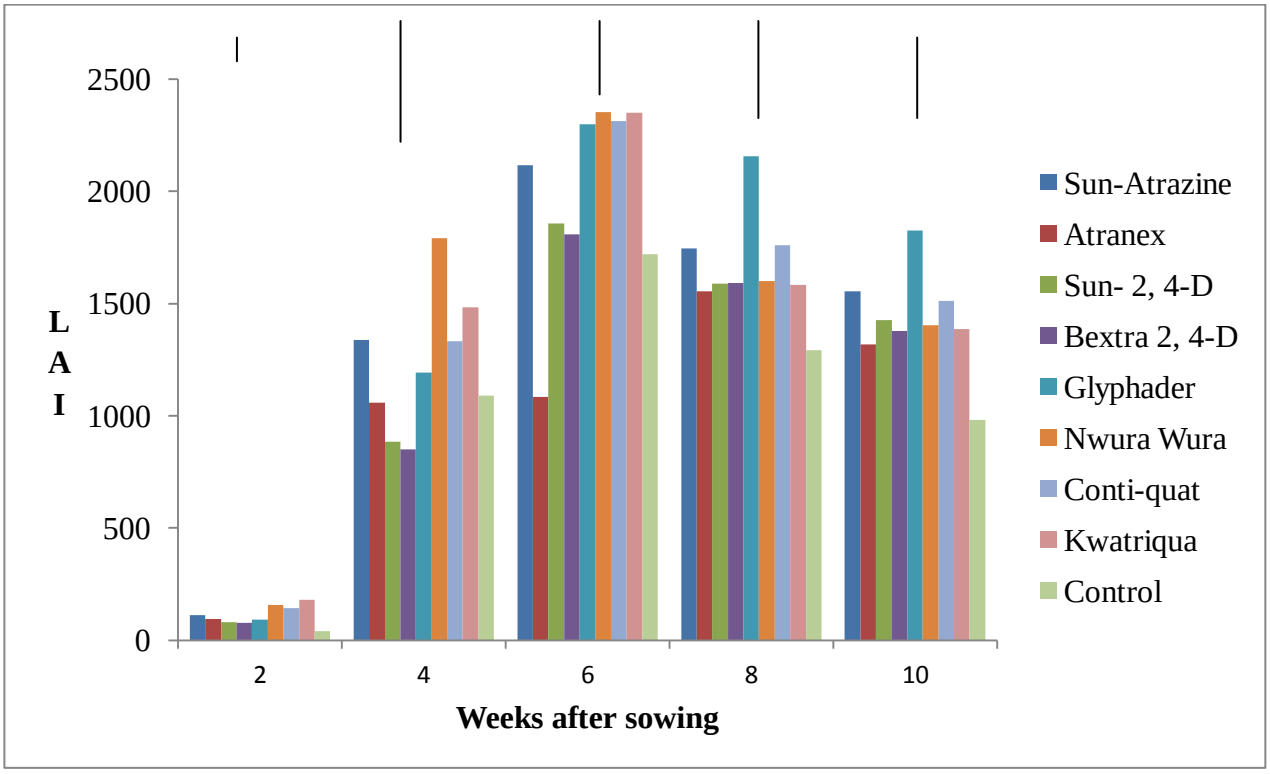

Fig. 4. 6: Maize leaf area index over time, influenced by different weed control treatments (low rate)

4.2.8 Plant belowground and aboveground biomasses

Table 4.4 shows below ground biomass and the above ground biomass of maize plant over time as influenced by different weeds control treatments (high and low rate). Statistically significant ($P \leq 0.05$) differences among the treatnents were observed on the below ground biomass at 4, 6 and aboveground biomass at 6 WAS. The belowground biomass at 4 and 6 WAS showed higher values in all herbicides treated plots than control plots except at 4 WAS where control (19.56gm^{-2}) was slightly higher than Paraquat (14.33gm^{-2}), Triazine (16.15gm^{-2}), Glyphosate (17.83gm^{-2}). However, 2, 4-D (31.00gm^{-2}, 25.38gm^{-2}) showed the maximum below ground biomass at 4 WAS. Paraquat (110.30gm^{-2}) showed the maximum below ground

biomass at 6 WAS. Similarly, at 6 WAS all herbicides treated plots showed higher aboveground biomass than control plots.

At low application rate (Table 4.4) significant ($P \leq 0.05$) differences among the treatments for both belowground and aboveground biomasses were observed. However, all herbicides treated plots showed higher belowground biomass than control plots. Meanwhile, for the aboveground biomass all herbicides treated plots showed higher biomass than control plots except at 6 WAS where control (140.60gm^{-2}) is higher than 2, 4-D (109.70gm^{-2})

Table 4.4: Maize root and stem biomass as influenced by different weed control treatments (high & low rate)

Rate	Treatment	Crop root biomass at 4 WAS(g)	Crop root biomass at 6 WAS(g)	Crop stem biomass at 4 WAS	Crop stem biomass at 6 WAS
High	Sun-Atrazine	24.80	95.5	47.0	194.9
	Atranex	16.15	91.6	41.8	157.6
	Sun-2,4-D	31.00	62.0	49.6	123.4
	Bextra 2, 4-D	25.38	50.3	41.5	108.3
	Glyphader	17.83	60.5	42.2	127.3
	Nwura Wura	21.50	55.7	39.2	136.3
	Conti-quat	14.33	110.3	28.9	172.1
	Kwatriqua	24.23	80.7	45.7	147.1
	Control	19.56	13.4	23.7	73.9
Rate	**LSD (P ≤0.05)**	**8.58**	**40.13**	**NS**	**46.37**
Low	Sun-Atrazine	24.50	97.0	50.2	199.9
	Atranex	22.93	91.7	42.7	171.0
	Sun-2,4-D	12.18	60.7	42.9	150.7
	Bextra 2, 4-D	15.58	72.3	29.9	109.7
	Glyphader	14.90	58.5	42.4	168.3
	Nwura Wura	11.83	47.3	37.1	147.2
	Conti-quat	22.38	99.4	43.5	173.5
	Kwatriqua	14.43	67.8	49.4	177.6
	Control	7.94	39.3	11.3	140.6
	LSD (P ≤0.05)	**8.74**	**38.32**	**11.83**	**47.31**

4.3 Ear length (cm)

The values of the ear length at high application rate (Table 4.5) ranged from 6.99 t0 17.53cm. The maximum length was observed in Triazine (17.53cm), followed by Paraquat (17.48cm) and Glyphosate (17.14cm) compared to the minimum length in control (6.99cm). It showed statistical significant ($P \leq 0.05$) among the treatments. For the low application rate, values ranged from 12.84 to 17.41cm. The maximum length was observed in plots treated with Paraquat (17.41cm), followed by 2, 4-D (17.41cm) compared to the minimum in control (12.84cm). Differences were significant ($P \leq 0.05$).

4.3.1 Ear diameter (cm)

The values ranged from 3.74 to 5.10cm. The maximum diameter was obtained in Triazine (5.10cm) among the treatments and the minimum was noted in control (3.74cm). For the low application rate (Table 4.5) values showed a similar trend. The results showed Statistical significant ($P \leq 0.05$) differences among the treatments for both high and low application rates in the table.

4.3.2 Number of kernels per row

The values ranged from 15 to 35 numbers of kernels per row. The maximum number of kernels was observed in Triazine (35) and Glyphosate (35) among the treatment compared to the minimum in 2, 4-D (29cm) and control (15cm). Also, at low application rate (Table 4.5) the values ranged from 17 to 36 kernels per row. The maximum number of kernels per row was noted in 2, 4-D (36) among the treatments compared to the minimum in control (17). Statistically, both high and low applications were significant ($P \leq 0.05$).

4.3.3 Number of rows of kernels per ear

The number of rows of kernels per ear at high application rate (Table 4.5) ranged from 13 to 15. The minimum number of rows of kernels per ear was noted in Paraquat (14), 2, 4-D (13) and control (13). All the other treatments had (15) rows of kernels per ear respectively. Differences were statistically significant ($P \leq 0.05$). Results at low application rate (Table 4.5) showed no statistical significance ($P \leq 0.05$).

4.3.4 Number of kernels per ear

The number of kernels per ear showed statistically significant ($P \leq 0.05$) differences among the treatments at both high and low application rates (Table 4.5). At high application rate all herbicide treated plots had higher number of kernels per ear than the control plots, with Triazine (507) treated plots showing the highest. For low application rates 2, 4-D (483) had the highest number of kernels per ear.

4.3.5 Grain weight per ear (g)

The grain weight per ear (Table 4.5) showed statistically significant ($P \leq 0.05$) differences among the treatments at both high and low application rates. All herbicide treated plots had higher grain weight per ear than the control plots with Triazine (156.5g) and 2, 4-D (156.3g) having the highest grain weight per ear for high and low application rates.

4.3.6 100 seed weight (g)

The 100 seed weight (Table 4.5) showed statistically significant ($P \leq 0.05$) differences among the treatments at both high and low application rates. All herbicide treated plots showed higher 100 seed weight than the control plots with Triazine (40.75g) and Glyphosate (37.60g) treated plots showing highest 100 seed weight. Meanwhile values in parentheses are transformed values.

Table 4.5: Maize yield and yield components as influenced by different weed control treatments (high & low rate)

Rate	Treatment	Ear length (cm)	Ear diameter (cm)	No. of kernels /row	No. of rows of kernels/ear	No. of kernel/ear	Grain weight/ ear(g)	100 seed weight (g)
High	Sun-Atrazine	17.53	5.10	35(2)	15(1)	507(3)	156.5	40.75
	Atranex	16.95	4.71	32(2)	15(1)	468(3)	128.8	33.88
	Sun- 2, 4-D	16.74	4.68	31(2)	13(1)	400(3)	129.8	37.35
	Bextra 2, 4-D	15.83	4.67	29(2)	14(1)	403(3)	120.8	36.42
	Glyphader	17.14	4.63	31(2)	15(1)	452(3)	132.1	34.15
	Nwura Wura	16.94	4.97	35(2)	15(1)	502(3)	155.2	35.17
	Conti-quat	17.48	4.79	33(2)	14(1)	475(3)	143.6	36.05
	Kwatriqua	16.52	4.78	32(2)	15(1)	467(3)	137.4	35.40
	Control	6.99	3.74	15(2)	13(1)	181(2)	40.4	18.63
Rate	**LSD (P ≤0.05)**	**1.34**	**0.35**	**2(0.04)**	**1(0.01)**	**38(0.03)**	**24.43**	**5.76**
Low	Sun-Atrazine	16.28	4.54	33(2)	14(1)	456(3)	111.8	30.28
	Atranex	15.87	4.49	33(2)	14(1)	458(3)	117.2	32.13
	Sun- 2, 4-D	17.41	4.72	36(2)	15(1)	521(3)	156.3	36.10
	Bextra 2, 4-D	16.50	4.59	34(2)	14(1)	483(3)	122.8	34.53
	Glyphader	16.84	4.59	34(2)	14(1)	475(3)	130.4	37.60
	Nwura Wura	16.07	4.76	33(2)	15(1)	481(3)	133.6	31.55
	Conti-quat	15.72	4.66	32(2)	14(1)	446(3)	116.7	34.53
	Kwatriqua	17.41	4.60	34(2)	14(1)	482(3)	119.9	32.45
	Control	12.84	4.12	17(1)	15(1)	255(2)	37.4	19.51
	LSD (P ≤0.05)	**1.38**	**0.24**	**4(0.1)**	**NS**	**65**	**22.79**	**5.49**

4.3.7 Yield per plot (kg)

The syield per plot at high application rate (Table 4.6) ranged from 1.62 to 6.26kg. The maximum yield per plot was noted in Trirazine (6.26kg) followed by plots treated with Glyphosate (6.21kg) among all the treatments compared to the minimum yield per plot note in control (1.62kg). At low application rate (Table 4.6) ranged from 1.50 to 6.25kg. The maximum yield per plot was noted in 2, 4-D (6.25kg), followed by Glyphosate (5.34kg,5.21kg) among the treatments compared to the minimum yield per plot noted in control (1.50kg).

4.3.8 Yield per hectare ($kgha^{-1}$)

The values ranged from 2524 to 9779$kgha^{-1}$ at high application rate (Table 4.6). The maximum yield per hectare was noted in Triazine (9779.0$kgha^{-1}$), followed by Glyphosate (9700.0$kgha^{-1}$) compared to the minimum yield noted in Control (2524.0$kgha^{-1}$). At low application (Table 4.6) values ranged from 2340 to 9770$kgha^{-1}$. The maximum yield was noted in 2, 4-D (9770.0$kgha^{-1}$), followed by Glyphosate (8348.0$kgha^{-1}$, 8148.0$kgha^{-1}$) compared to the minimum yield in Control (2340.0$kgha^{-1}$).

Table 4.6: Maize yield and yield components as influenced by different weed control treatments (high & low rate)

Treatment	Yield per plot(kg)-high	Yield per hectare(kg)-high	Yield per plot(kg)-low	Yield per hectare(kg)-low
Sun-Atrazine	6.26	9779.0	4.47	6989.0
Atranex	5.15	8051.0	4.69	7324.0
Sun-2, 4-D	5.19	8114.0	6.25	9770.0
Bextra 2, 4-D	4.83	7551.0	4.91	7672.0
Glyphader	5.29	8259.0	5.21	8148.0
Nwura Wura	6.21	9700.0	5.34	8348.0
Conti-quat	5.74	8976.0	4.67	7296.0
Kwatriqua	5.50	8586.0	4.79	7491.0
Control	1.62	2524.0	1.50	2340.0
LSD ($P \leq 0.05$)	**0.98**	**1527.00**	**0.91**	**1424.20**

4.3.9 Relative growth rate (g/g day)

The RGR values at high application (Table 4.7) ranged from 0.0578 to 0.1053g/g day. The maximum was noted in Control (0.1053g/gday) compared to those of the herbicides treated plots.

4.3.10 Relative leaf area growth rate (cm^2/cm^2day)

The RLAGR values at high application rate (Table 4.7) ranged from 0.861 to1.219 cm^2/cm^2day. The maximum value was noted in plots treated with Paraquat (1.219 cm^2/cm^2day) among all the treatments compared to Control (1.150 cm^2/cm^2day).

4.3.11 Net assimilation rate (g/cm^{2}day)

The NAR at high application rate (Table 4.7) ranged from 1.56 to 3.74g/cm^{2}day. The maximum value was noted in Triazine (3.74g/cm^{2}day), followed by Paraquat (3.32g /cm^{2}day) among all treatments including control. At low application rate (Table 4.7), NAR values ranged from 0.00984 to 0.02764g/cm^2 day. The results revealed that control had the maximum (0.02764g/cm^2 day).

4.3.12 Crop growth rate (g/cm^2 day)

The CGR at high application rate (Table 4.7) ranged from 55.5 to198.2g/cm^2 days. All herbicide treated plots had higher CGR over the control plots, with Triazine (198.2g/cm^2 day) treated plots showing the highest CGR. At low application rate (Table 4.7) control (3.015g/cm^{2}day) showed the highest CGR.

4.3.13 Leaf area duration (cm2 day)

The values of LAD at both high and low application rates (Table 4.7) showed no statistically significant ($P \leq 0.05$) differences among the treatments.

4.3.14 Biomass duration (g day)

The BMD at high and low application rates (Table 4.7) showed statistically significant ($P \leq 0.05$) differences among the treatments. All herbicide treated plots had higher BMD than the control plots at both high and low application rates with Triazine (1239g day) and Paraquat (1034.0 g days) showing the highest BMD.

Table 4.7: Plant growth analysis of maize as influenced by different weed control treatments (high & low rate)

Rate	Treatment	RGR (g/g day)	RLAGR (cm^2/cm^2day)	NAR (g/cm^2day)	CGR (g/cm^2day)	LAD (cm^2day)	BMD (g day)
High	Sun-Atrazine	0.1151	1.018	3.74	198.2	3830.0	1239.0
	Atranex	0.1124	0.987	3.10	160.4	3800.0	1045.0
	Sun-2, 4-D	0.0788	0.861	1.81	108.0	4130.0	969.0
	Bextra 2, 4-D	0.0783	0.886	1.61	102.2	3960.0	823.0
	Glyphader	0.0953	1.043	1.56	93.5	6230.0	916.0
	Nwura Wura	0.0997	1.109	2.41	128.4	4050.0	925.0
	Conti-quat	0.1522	1.111	3.32	181.5	4350.0	959.0
	Kwatriqua	0.0947	1.219	2.41	114.1	4250.0	1034.0
	Control	0.0843	1.150	1.59	55.5	2990.0	518.0
Rate	**LSD (P ≤ 0.05)**	**NS**	**0.15**	**1.08**	**65.22**	**NS**	**195.80**
Low	Sun-Atrazine	0.0628	0.285	0.01391	1.719	10540.0	2384.0
	Atranex	0.0630	0.402	0.01095	1.099	53740.0	2035.0
	Sun- 2, 4-D	0.0578	0.346	0.01423	1.247	9010.0	1882.0
	Bextra 2, 4-D	0.0582	0.390	0.01543	1.233	8710.0	1347.0
	Glyphader	0.0628	0.315	0.01215	1.429	11460.0	2008.0
	Nwura Wura	0.0627	0.287	0.01169	1.488	12150.0	1757.0
	Conti-quat	0.0629	0.303	0.01305	1.570	11810.0	2068.0
	Kwatriqua	0.0578	0.216	0.00984	1.430	13060.0	2198.0
	Control	0.1053	0.152	0.02764	3.015	7760.0	1172.0
	LSD (P ≤0.05)	**0.01**	**NS**	**0.01**	**0.43**	**NS**	**536.80**

EXPERIMENT II: PLANT BIOASSAY FOR RESIDUAL HERBICIDES

4.4 Weed succession

The results (Table 4.8) shows initial weed species before Experiment I. Atrazine treated plots had 52.6% broad leaf, 36.8% grasses and 10.5% sedges, 2, 4-D treated plots had 57.1% broad leaf, 33.3% grasses and 9.5% sedges. Also, Glyphosate treated plots had 52.9% broad leaf, 35.2% grasses and 11.8% sedges wheareas Paraquat treated had 50% broad leaf, 41.6% grasses and 8.3% sedges.

Table 4.8: Shows initial weed species before Experiment I

Eleusine indica(g),*Brachiaria lata*(g),*Cyperus rotundus*(s),*Cyperus esculantus*(s),*Euphorbia heterophylla*(b),*Celosia laxa*(b),*Panicum maximum*(g),*Croton lobatus*(b),*Indigofera hirsuta*(b),*Phyllanthus amarus*(b),*Sesamum indicum*(b),*Sida spp*(b),*Commelina benghalensis*(b), *Paspalium orbicularu*(g),*Digitaria horizontalis*(g),*Trianthem a portulacastrum*(b), *Macroptilium lathyroides*(b),*Mimosa pudica*(g),*Rottboellia cochinchinensis*(g),	*Brachiaria lata*(g),*Cyperus rotundus*(s),*Cyperus esculentus*(s),*Celosia laxa*(b),*Panicum maximum*(g),*Croton lobatus*(b),*Mimosa pudica*(g),*Commelina benghalensis*(b), *Indigofera hirsuta*(b),*Phyllanthus amarus*(b),*Digitaria horizontalis*(g), *Paspalium orbicularu*(g),*Sesamu m indicum*(b),*Sida spp*(b),*Rottboella cochinchinesis*(g), *Senna obtusifolia*(b), *Euphorbia heterophylla*(b), *Dactyloctenium aegyptium*(g), *Trianthema portulacastrum*(b), *Amaranthus caudatus*(b), *Phyllanthus amarus*(b),	*Celosia laxa*(b),*Brachiaria lata*(g),*Panicum maximum*(g), *Phyllanthus amarus*(b),*Commelina benghalensis*(b), *Senna obtusifolia*(b), *Digitaria horizontalis*(g), *Amaranthus spinosus*(b), *Dactyloctenium aegyptilium*(g), *Paspalium orbicularu*(g),*Cyperus esculentus*(s),*Cyperus rotundus*(s),*Sesamum indicum*(b),*Trianthem a portulacastrum*(b), *Rottboella cochinchinesis*(g), *Croton lobatus*(b),*Sida spp*(b)	*Panicum maximum*(g), *Croton lobatus*(b), *Phyllanthus amarus*(b), *Sesamum indicum*(b), *Digitaria horizontalis*(g), *Celosia laxa*(b),*Brachiaria lata*(g),*Rottboella cochinchinesis*(g), *Cynodon nlemfuensis*(g), *Cyperus rotundus*(s), *Trianthema portulacastrum*(b) ,*senna occidentalis*(b)

NB: b means broadleaf , g means grass and s means sedges.

The results of (Table 4.9) shows weed species after Experiment I. Atrazine treated plots had 55.6% broad leaf, 33.3% grasses and 11.1% sedges. The 2, 4-D treated plots had 28.6% broad leaf, 57.1% grasses and 14.3% sedges. The Glyphosate treated plots had 42. 8% broad leaf, 42.8% grasses and 14.3% sedges whereas in the Paraquat treated plots were 50% broad leaf, 37.5% grasses and 12.5% sedges.

Table 4.9: shows weed species after Experiment I

Triazine	2, 4-D	Glyphosate	Paraquat
Cyperus rotundus(s), *Trianthema portulacastrum*(b), *Mimosa pudica*(g), *Brachiaria lata*(g), *Sesamum indicum*(b),*Cleome viscose*(b),*Digitaria horizontalis*(g),*Euphorbia heterophylla*(b),*Phyllanthus amarus*(b)	*Cyperus rotundus*(s), *Mimosa pudica*(g), *Brachiaria lata*(g), *Panicum maximum*(g), *Digitaria horizontalis* (g), *Euphorbia heterophylla*(b),*Cleome viscose*(b)	*Cyperus rotundus*(s), *Trianthema portulacastrum*(b), *Brachiaria lata*(g), *Panicum maximum*(g), *Cleome viscose* (b), *Digitaria horizontalis*(g), *Phyllanthus amarus*(b),	*Trianthema portulacastrum*(b), *Cyperus rotundus*(s), *Phyllanthus amarus*(b),*Panicum maximum*(g), *Digitaria horizontalis*(g), *Brachiaria lata*(g), *Cleome viscose*(b), *Croton lobatus*(b),

NB: b means broadleaf, g means grass and s means sedges.

4.5 Residual detection on black eyed cowpea (bioassay)

From the date of sowing up to emergence through maturity of black eyed cowpea there was no sign or symptom shown by the bio-detectors (leaves or roots) such as yellowing of leaves, purplish appearing of cotyledon, malformation of plants, etc. These crops were cared for from the date of sowing up to harvest as indicated by subsequent sections.

4.6 Days to 50% emergence and flowering

Days to 50% emergence and 50% flowering of the black eyed cowpea for high and low rates showed no statistically significant ($p \leq 0.05$) differences among the treatments. At both high and low application rates, 50% emergence were attained from 3 to 4 DAS. Days to 50% flowering for high and low application rates were attained from 22- 24 DAS.

4.6.1 Plant height at 2-6 WAS

Plant height of black eyed cowpea at 2 and 4 WAS were not significant. Plant height at 6 WAS showed significantly taller (P ≤0.05) for all herbicides treated than control, particular in Paraquat treated plots (Figure 4.7).

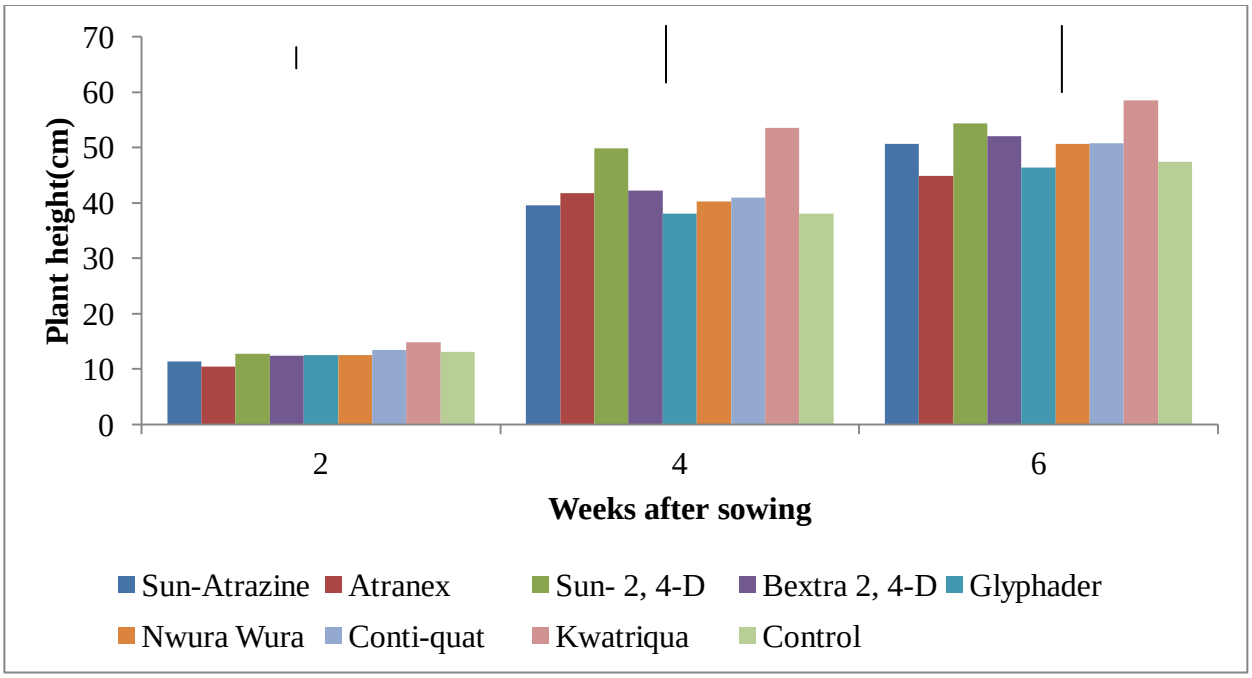

Fig. 4. 7: Plant heights of black eyed cowpea at 2, 4, and 6 WAS as influenced by different weeds control treatments (high rate)

4.6.2 Plant height at 2- 6 WAS

Plant height at 2 and 4 WAS were not significant. However, at 6 WAS all herbicides treated plots showed significantly taller (P ≤0.05) than Control, particularly Paraquat treated plots (Figure 4.8).

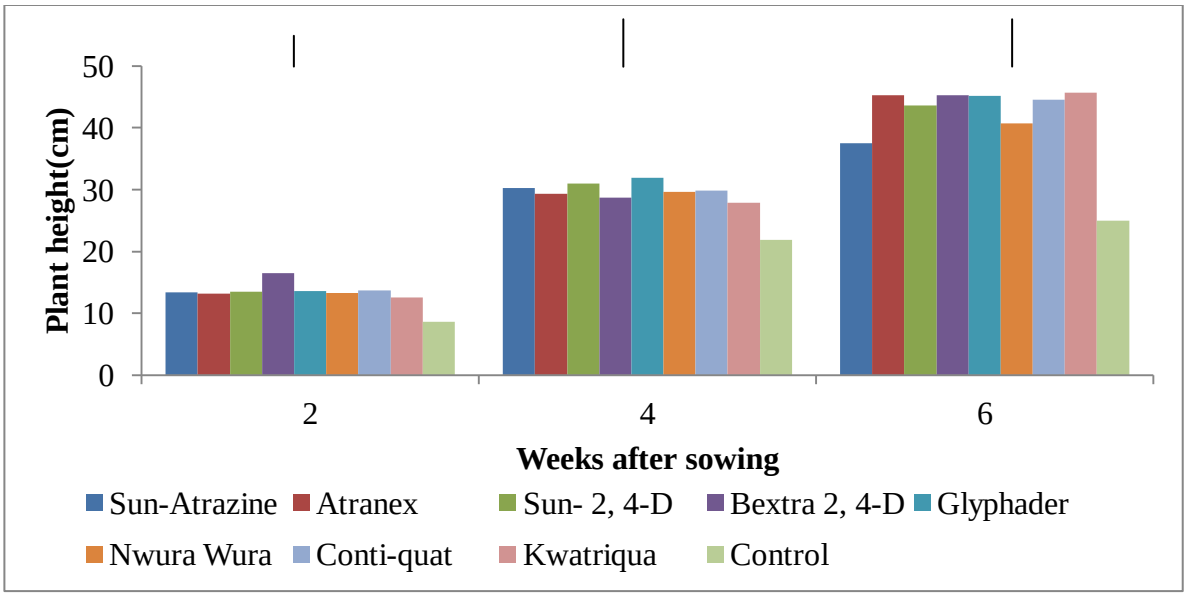

Fig. 4. 8: Plant heights of black eyed cowpea at 2, 4, and 6 WAS as influenced by different weeds control treatments (low rate)

4.6.3 Plant leaf number at 2-6 WAS

Plant leaf number at 2 WAS at high application rate (Table 4.10) showed statistically significant (P ≤0.05) differences among the treatments. All the herbicide treated plots showed significantly more leaves than Control plot. For the low rate Control showed significantly (P ≤0.05) more leaves than herbicides treated plots.

The leaf number at 4 WAS at high rate (Table 4.10) showed that control had significantly (P ≤0.05) more leaves than all herbicide treated plots. For low rate all herbicide treated plots showed significantly (P ≤0.05) higher leaf number than control with Glyphosate showing the higher leaves among all herbicide treated plots.

At 6 WAS the leaf number was not significant at high rate. For low rate all herbicide treated plots showed significantly (P ≤0.05) higher leaf number than control with Paraquat showing the higher leaf number. Values in parentheses are transformed values.

Table 4.10: Black eyed cowpea leaf number (2-6 WAS) over time influenced by different weeds control treatments

Rate	Treatment	2 WAS	4 WAS	6 WAS
High	Sun-Atrazine	4(1)	20(1)	45(2)
	Atranex	4(1)	20(1)	45(2)
	Sun- 2, 4-D	4(1)	27(1)	47(2)
	Bextra 2, 4-D	4(1	23(1)	45(2)
	Glyphader	4(1)	24(1)	45(2)
	Nwura Wura	4(1)	22(1)	50(2)
	Conti-quat	4(1)	23(1)	46(2)
	Kwatriqua	4(1)	23(1)	46(2)
	Control	3(0.4)	32(2)	40(2)
Rate	**LSD (P ≤0.05)**	**1(0.01)**	**1(0.01)**	**NS**
Low	Sun-Atrazine	3(0.4)	9(1)	23(1)
	Atranex	3(0.4)	9(1)	28(1)
	Sun- 2, 4-D	3(1)	9(1)	31(2)
	Bextra 2, 4-D	3(0.4)	10(1)	28(1)
	Glyphader	4(1)	12(1)	31(2)
	Nwura Wura	3(0.4)	9(1)	24(1)
	Conti-quat	3((1)	10(1)	30(2)
	Kwatriqua	4(1)	9(1)	31(2)
	Control	5(1)	9(1)	26(1)
	LSD (P ≤0.05)	**1(0.2)**	**2(0.1)**	**5(0.1)**

4.6.4 Plant leaf area at 2-6 WAS

At 2-6 WAS plant leaf area was not significant (P ≤0.05) at high application rate. For low rate 2 and 6 WAS not significant. At 4 WAS all herbicide treated plots showed significantly (P ≤0.05) wider leaf area than control plot with Triazine showing wider leaf area (Table 4.11).

4.6.5 Plant leaf area index at 2-6 WAS

At 2-6 WAS plant leaf area index was not significant (P ≤0.05) at high rate. For low application rate the trend was similar except at 4 WAS where all herbicide treated showed statistically significant (P ≤0.05) LAI over the control (Table 4.11).

Table 4.11: Black eyed cowpea leaf area and leaf area index over time influenced by different weeds control treatments (high & low)

Rate	Treatment	L. area 2 (cm^2)	L. area 4 (cm^2)	L. area 6 (cm^2)	LAI at 2 (cm^2)	LAI at 4 (cm^2)	LAI at 6 (cm^2)
High	Sun-Atrazine	22.40	48.78	57.47	70.0	152.4	179.6
	Atranex	23.44	48.95	54.68	73.3	153.0	170.9
	Sun- 2, 4-D	23.52	47.24	58.44	73.5	147.6	182.6
	Bextra 2, 4-D	22.60	46.78	57.79	70.6	146.2	180.6
	Glyphader	24.93	49.03	61.41	77.9	153.2	191.9
	Nwura Wura	20.63	46.67	58.71	64.5	145.8	183.5
	Conti-quat	23.31	49.00	61.52	72.8	153.1	192.3
	Kwatriqua	27.76	49.92	56.17	86.7	156.0	175.5
	Control	17.18	45.64	53.59	53.7	142.6	167.5
Rate	**LSD (P ≤0.05)**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Low	Sun-Atrazine	26.76	41.14	46.14	83.6	128.6	144.2
	Atranex	25.20	37.06	43.39	78.7	115.8	135.6
	Sun- 2, 4-D	19.35	34.63	41.16	91.7	108.2	128.6
	Bextra 2, 4-D	24.91	35.40	40.62	77.8	110.6	126.9
	Glyphader	27.46	37.08	42.92	85.8	115.9	134.1
	Nwura Wura	28.29	35.61	40.71	88.4	111.3	127.2
	Conti-quat	26.36	38.28	45.96	82.4	119.6	143.6
	Kwatriqua	23.77	39.14	46.31	74.3	122.3	144.7
	Control	17.32	22.96	38.87	54.1	71.8	121.5
	LSD (P ≤0.05)	**NS**	**6.42**	**NS**	**NS**	**20.08**	**NS**

4.6.6 Plant relative growth rate (g/gday)

The plant RGR at high application rate (Table 4.12) showed no statistical significant (P≤0.05) differences among the treatments. For low application rate control (0.03681g/g day) showed significant (P≤0.05) higher RGR over all herbicides treated plots.

4.6.7 Plant relative leaf area growth rate (cm^2/cm^2day)

Plant RLAGR was not significant (P≤0.05) at high application rate (Table 4.12).

4.6.8 Plant net assimilation rate (g/cm^2day)

The plant NAR at high and low application rates (Table 4.12) showed no statistical significant (P≤0.05) differences among the treatments.

4.6.9 Plant crop growth rate (g/cm^2day)

Plant CGR at high and low application rates (Table 4.12) showed no statistical significant (P≤0.05) differences among the treatments.

4.6.10 Plant leaf area duration (cm^2day)

The plant LAD at high application rate (Table 4.12) showed no statistical significant (P≤0.05) differences among the treatments. For low application rate Control (16.15cm^2day) showed statistically significant (P≤0.05) higher LAD over all the treatments.

4.6.11 Plant biomass duration (gday)

The plant BMD at high and low application rates (Table 4.12) showed statistically significant (P≤0.05) differences among the treatments. Irrespective of application rate, all herbicides treated plots showed significantly (P≤0.05) higher BMD than control plots.

Table 4.12: Plant growth analysis of black eyed cowpea as influenced by different weeds control treatments

Rate	Treatment	RGR (g/g day)	RLAGR (cm^2/cm^2day)	NAR (g/cm^2day)	CGR (g/cm^2day)	LAD (cm^2day)	BMD (g day)
High	Sun-Atrazine	0.0432	0.0115	0.493	7.57	68.1	516.0
	Atranex	0.0369	0.0109	0.341	5.18	55.2	535.0
	Sun- 2, 4-D	0.0269	0.0171	0.225	3.44	61.6	479.0
	Bextra 2, 4-D	0.0302	0.0122	0.121	1.80	112.0	482.0
	Glyphader	0.0398	0.0178	0.292	4.44	69.7	441.0
	Nwura Wura	0.0374	0.0146	0.206	3.14	106.2	533.0
	Conti-quat	0.0381	0.0160	0.281	4.33	111.3	499.0
	Kwatriqua	0.0546	0.0063	0.238	3.71	113.8	473.0
	Control	0.0410	0.0140	0.162	2.45	26.9	134.0
Rate	**LSD (P ≤0.05)**	**NS**	**NS**	**NS**	**NS**	**NS**	**135.90**
Low	Sun-Atrazine	0.00260	0.0114	0.114	1.36	7.02	115.4
	Atranex	0.00474	0.0131	0.126	1.36	6.55	117.4
	Sun- 2, 4-D	0.00476	0.0125	0.125	1.21	5.25	119.0
	Bextra 2, 4-D	0.00545	0.0122	0.119	1.18	3.73	117.9
	Glyphader	0.00318	0.0107	0.095	1.09	5.32	104.5
	Nwura Wura	0.00823	0.0107	0.104	1.10	3.17	114.4
	Conti-quat	0.00341	0.0162	0.130	1.51	10.10	89.6
	Kwatriqua	0.00274	0.0147	0.138	1.66	9.31	106.7
	Control	0.03681	0.0354	0.158	1.24	16.15	39.5
	LSD (P ≤0.05)	**0.01**	**0.01**	**NS**	**NS**	**7.54**	**27.86**

4.6.12 Plant leaf biomass at 2-6 WAS

Plant leaf biomass at 2 WAS showed statistically significant (P≤0.05) differences among the treatments at high application rate (Table 4.13). At high application rate, all herbicide treated plots showed significantly (P≤0.05) higher leaf biomass than control plots, with Triazine (12.02g) showing higher leaf biomass. At low application rate, all herbicide treated plots showed no significant differences in the leaf biomass.

Table 4.13: Plant biomass of black eyed cowpea leaf at 2, 4, and 6 WAS as influenced by different weeds control treatments

High rate				**Low rate**		
Treatment	**wt.(g) at 2**	**wt.(g) at 4**	**wt.(g) at 6**	**Wt.(g) at 2**	**Wt.(g) at 4**	**Wt.(g) at 6**
Sun-Atrazine	11.00	23.50	44.1	12.40	15.00	16.15
Atranex	12.02	25.05	36.6	12.32	15.63	17.65
Sun- 2, 4-D	11.19	25.90	30.1	12.32	15.88	16.55
Bextra 2, 4-D	11.39	27.70	34.7	12.95	16.07	17.30
Glyphader	10.87	23.42	31.9	13.80	14.95	16.55
Nwura Wura	11.25	25.37	32.1	12.00	14.50	15.35
Conti-quat	10.86	26.30	38.0	12.30	14.75	15.75
Kwatriquat	10.94	21.77	34.0	13.92	14.15	14.75
Control	9.45	17.82	20.6	12.75	14.63	14.70
LSD (P ≤0.05)	**0.73**	**NS**	**NS**	**NS**	**NS**	**NS**

4.6.13 Plant root biomass at 2-8 WAS

The plant root biomass at 2 WAS showed statistically significant (P≤0.05) differences among the treatments at high and low application rates (Table 4.14). Irrespective of application rate, all herbicide treated plots showed significantly (P≤0.05) higher root biomass than control plots.

The plant root biomass at 4 WAS showed no statistical significant (P≤0.05) differences among the treatments at high rate. For low rate all herbicide treated plots showed significantly (P≤0.05) higher root biomass than control plot.

Plant root biomass at 6 WAS showed statistically significant (P≤0.05) differences among the treatments at high rate (Table 4.14). All herbicide treated plots showed significantly (P≤0.05) higher root biomass than control plot with Triazine (3.75g) showing highest root biomass. At low application rate showed no significant differences among the treatments.

The plant root biomass at 8 WAS showed statistically significant (P≤0.05) differences among the treatments at high and low application rates (Table 4.14). Irrespective of application rate, all herbicide treated plots showed significantly (P≤0.05) higher root biomass over control with Paraquat (13.62g) and 2, 4-D (10.80g) showing highest root biomass at high and low rates.

Table 4.14: Plant biomass of black eyed cowpea root at 2, 4, 6 and 8 WAS as influenced by different weeds control treatments

	High rate				**Low rate**			
Treatment	**wt.(g) at 2**	**wt.(g) at 4**	**wt.(g) at 6**	**Wt.(g) at 8**	**wt.(g) at 2**	**wt.(g) at 4**	**wt.(g) at 6**	**Wt.(g) at 8**
Sun-Atrazine	0.38	1.35	2.93	12.70	0.47	0.75	1.12	10.00
Atranex	0.57	1.30	3.75	12.85	0.52	0.75	0.90	10.30
Sun- 2, 4-D	0.51	1.55	1.78	12.80	0.42	0.82	1.20	10.80
Bextra 2, 4-D	0.54	1.00	2.05	13.03	0.65	1.07	1.35	10.05
Glyphader	0.50	1.30	2.80	13.05	0.50	0.67	1.07	10.02
Nwura Wura	0.50	1.40	2.30	13.62	0.40	0.77	1.02	10.15
Conti-quat	0.64	0.97	3.22	13.62	0.42	0.65	0.95	10.05
Kwatriqua	0.55	1.12	3.23	12.47	0.55	0.67	0.92	9.90
Control	0.12	0.62	1.14	1.31	0.05	0.09	0.21	0.24
LSD (P ≤0.05)	**0.16**	**NS**	**1.28**	**1.66**	**0.26**	**0.51**	**NS**	**0.89**

4.6.14 Plant stems biomass at 2-8 WAS

The plant stem biomass at high application rate showed statistically significant (P≤0.05) differences among the treatments (Figure 4.9). All the herbicide treated plots showed significantly (P≤0.05) higher stem biomass than control plot. At 2 WAS Atranex (14.83g) showed the highest stem biomass among all herbicide treated plots. At 4 WAS Paraquat (31.72g) showed significantly higher biomass among the herbicide treated plots.

Plant stem biomass at 6 WAS showed statistically significant (P≤0.05) differences among the herbicide treated plots (Figure 4.9) with Triazine yielding the highest.

Plant biomass at 8 WAS showed statistically significant (P≤0.05) differences among the treatments. All herbicide treated plots yielded significantly higher then the control plots with Triazine (51.80g) giving the highest plant biomass.

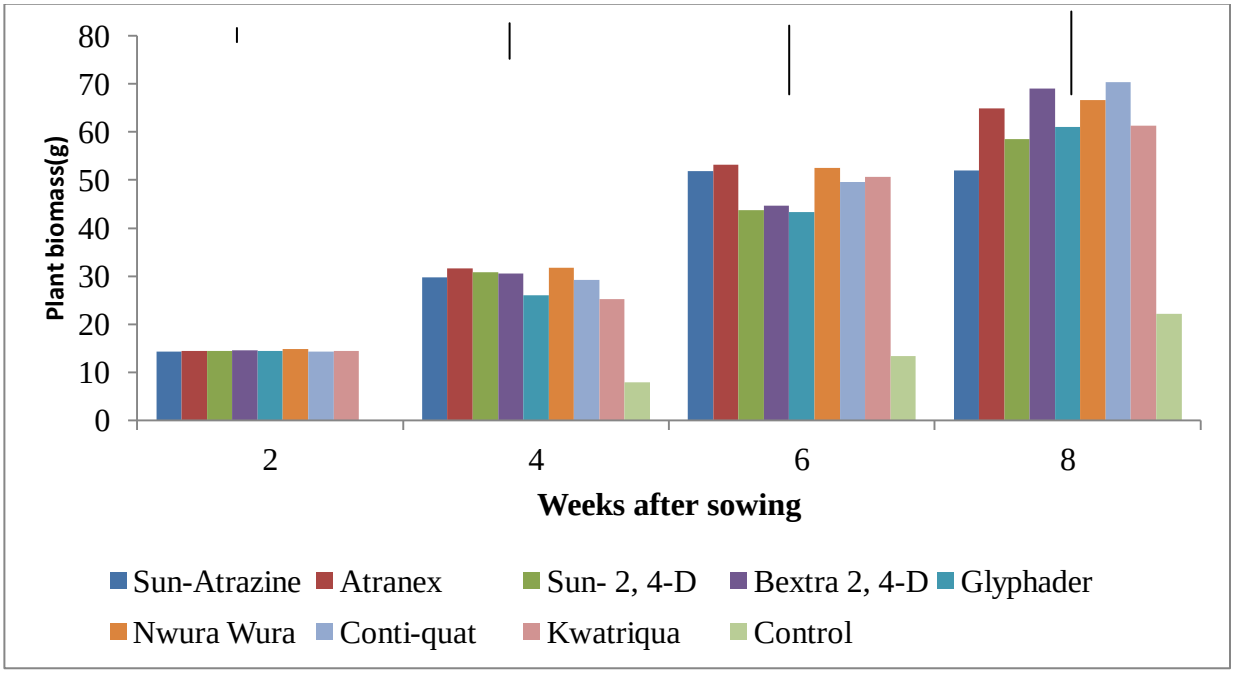

Fig. 4. 9: Plant biomass of black eyed cowpea stem over time as influenced by different weeds control treatments (high rate)

4.6.15 Plant stem biomass at 2-8 WAS

The plant stem biomass at 2 -8 WAS showed statistically significant (P≤0.05) differences among the treatments at low rate (Figure 4.10). All herbicides treated plots showed significantly (P≤0.05) higher plant biomass than control plots. At 2 and 4 WAS Triazine treated plots (19.08g, 17.05g) produced the highest plant biomass.

The plant stem biomass at low application rate (Figure 4.10) showed that 2, 4-D (17.77g) and Triazine (27.45g) treated plots produced the highest plant biomass at 6 and 8 WAS among all the herbicide treated plots.

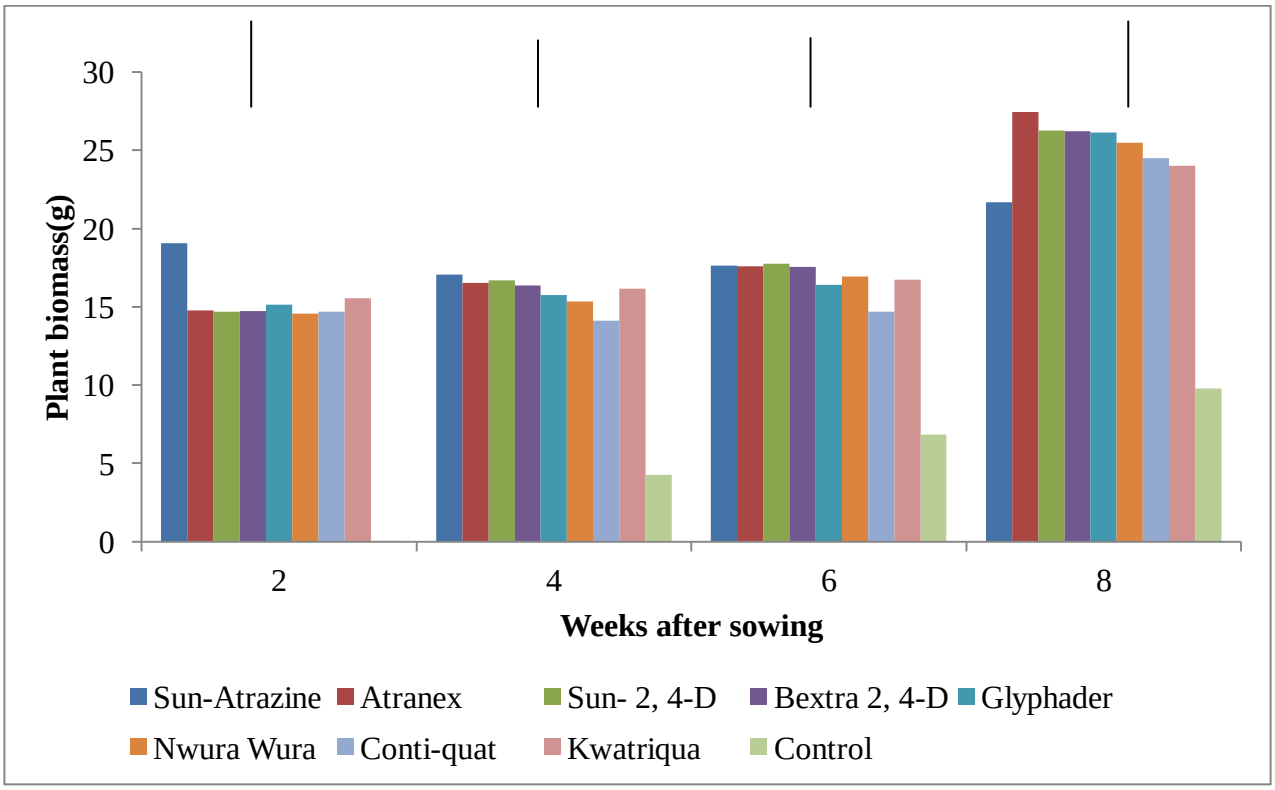

Fig. 4. 10: Plant biomass of black eyed cowpea stem over time as influenced by different weeds control treatments (low rate)

4.6.16 Number of nodes at 4 and 6 WAS

The number of nodes at 4 WAS (Table 4.15) showed significant (P≤0.05) differences among the treatments at both high and low application rates. The maximum number of nodes was obtained in the Control (31 nodes) plots whereas for low application rate Glyphosate treated plots yielded the highest.

At 6 WAS no significant (P≤0.05) differences among the treatments at high application rate was obtained (Table 4.15). At low application rate however, all herbicides treated plots showed significant higher (P≤0.05) node number than control plot with 2, 4-D (13 nodes) giving the highest node number among all herbicide treated plots.

4.7 Number of flowers at 4 and 6 WAS

The number of flowers at 4 WAS showed no significant (P≤0.05) differences among the treatments at high application (Table 4.15). For plots treated with low application rate all herbicide treated plots showed significantly higher (P≤0.05) flower number than control plots with Glyphosate (7 flowers) giving the highest flower number among all herbicide treated plots. At 6 WAS showed significant (P≤0.05) differences among the treatments for the plots treated with high application rate (Table 4.15) with Glyphosate (40 flowers) giving the highest flower numbers. No significant (P≤0.05) differences were among the treatments for low rate at 6 WAS.

4.7.1 Number of pods at 6 WAS

The number of pods at 6 WAS showed significant (P≤0.05) differences among the treatments at high application rate (Table 4.15). All herbicide treated plots showed significantly higher pods over the control plots with the 2, 4-D (32 pods) giving the highest pods. Values in parentheses are transformed values.

Table 4.15: Plant reproductive data of black eyed cowpea over time as influenced by different weeds control treatments

Rate	Treatment	No. of node at 4	No. of node at 6	No. of flower at 4	No. of flower at 6	No. of pod at 6
High	Sun-Atrazine	16(1)	44(2)	3(0.4)	34(2)	29(2)
	Atranex	17(1)	44(2)	3(0.4)	36(2)	30(2)
	Sun- 2, 4-D	20(1)	46(2)	4(0.4)	38(2)	32(2)
	Bextra 2, 4-D	16(1)	46(2)	3(0.4)	39(2)	30(2)
	Glyphader	18(1)	44(2)	3(1)	36(2)	29(2)
	Nwura Wura	17(1)	48(2)	4(1)	40(2)	28(1)
	Conti-quat	16(1)	45(2)	3(0.4)	36(2)	27(1)
	Kwatriqua	17(1)	45(2)	5(1)	37(2)	28(1)
	Control	31(2)	41(2)	3(0.4)	26(1)	10(1)
Rate	**LSD (P ≤0.05)**	**6(0.1)**	**NS**	**NS**	**5(0.1)**	**6(0.1)**
	Sun-Atrazine	8(1)	8(1)	5(1)	11(1)	10(1)
	Atranex	7(1)	9(1)	5(1)	10(1)	10(1)
	Sun- 2, 4-D	7(1)	13(1)	5(1)	11(1)	11(1)
	Bextra 2, 4-D	8(1)	11(1)	5(1)	10(1)	9(1)
	Glyphader	10(1)	10(1)	7(1)	10(1)	11(1)
	Nwura Wura	7(1)	9(1)	4(1)	10(1)	10(1)
	Conti-quat	8(1)	10(1)	5(1)	10(1)	11(1)
	Kwatriqua	7(1)	10(1)	4(1)	10(1)	11(1)
	Control	2(1)	6(1)	1(0.03)	10(1)	10(1)
	LSD (P ≤0.05)	**2(0.1)**	**4(0.1)**	**2(0.2)**	**NS**	**NS**

4.7.2 Number of pods at harvest

The number of pod at harvest showed statistically significant ($P \leq 0.05$) differences among the treatments for both high and low application rates (Table 4.16). All herbicide treated plots showed higher number of pods at harvest than the control plots, with Glyphosate yielding the highest number of pods at high rate and 2, 4-D yielding the highest number of pods at low rate.

4.7.3 Dry pod weight (g)

The dry pod weight showed statistically significant ($P \leq 0.05$) differences among the treatments at both high and low application rates (Table 4.16). All herbicide treated plots showed higher pod weight than the control plots with 2, 4-D yielding the highest pod weight for both high and low rates.

4.7.4 Number of seed per pod

The number of seed per pod showed no statistically significant ($P \leq 0.05$) differences among the treatments at high application rate (Table 4.16). For low application rate all herbicide treated plots showed significantly ($P \leq 0.05$) higher number of seed per pod than the control plot with 2, 4-D treated plots showing the highest number of seed per pod.

4.7.5 100 seed weight (g)

The 100 seed weight showed statistically significant ($P \leq 0.05$) differences among the treatments at both high and low rates (Table 4.16). All herbicide treated plots showed higher 100 seed weight than the control plots, with Triazine (21.03g) treated plots yielding the highest weight for high rate while Paraquat (19.02g) treated plots yielded the highest weight for low rate.

4.7.6 Harvest index (%)

The harvest index was statistically significant (P≤0.05) among the treatments for both high and low application rates (Table 4.16). All herbicide treated plots showed higher harvest index than the control plots, with Triazine (41.3%) and Paraquat (68.6%) showing the highest harvest indexes. Values in parentheses are transformed values.

Table 4.16: Yield and yield components of black eyed cowpea as influenced by different weeds control treatments

Rate	Treatment	No. of pod at harvest	Dry pod weight(g)	No. of seed per pod	100 seed weight(g)	Harvest index (%)
High	Sun-Atrazine	40(2)	51.8	10(1)	20.83	41.3
	Atranex	49(2)	63.0	10(1)	21.03	32.4
	Sun- 2, 4-D	51(2)	65.6	10(1)	20.10	36.3
	Bextra 2, 4-D	50(2)	66.5	10(1)	19.78	32.6
	Glyphader	53(2)	64.0	10(1)	20.38	33.6
	Nwura Wura	48(2)	61.7	10(1)	20.58	30.3
	Conti-quat	51(2)	60.3	10(1)	19.95	27.8
	Kwatriqua	43(2)	55.3	10(1)	20.90	34.7
	Control	15(1)	24.9	9(1)	18.95	30.1
Rate	**LSD (P ≤0.05)**	**12(0.1)**	**16.79**	**NS**	**1.09**	**11.86**
Low	Sun-Atrazine	21(1)	20.67	7(1)	18.40	66.9
	Atranex	21(1)	22.91	8(1)	18.75	56.7
	Sun- 2, 4-D	27(1)	26.66	9(1)	18.10	67.9
	Bextra 2, 4-D	23(1)	25.46	8(1)	18.40	57.5
	Glyphader	25(1)	24.82	7(1)	18.12	57.7
	Nwura Wura	25(1)	25.89	8(1)	18.15	60.2
	Conti-quat	23(1)	24.30	8(1)	18.65	68.6
	Kwatriqua	22(1)	23.00	8(1)	19.02	64.7
	Control	17(1	17.04	5(1)	16.55	50.6
	LSD (P ≤0.05)	**4(0.1)**	**4.66**	**1(0.1)**	**1.19**	**18.96**

4.7.7 Yield per plot (kg)

The yield per plot showed statistically significant ($P \leq 0.05$) differences among the treatments at both high and low rates (Table 4.17). All herbicide treated plots showed significantly higher ($P \leq 0.05$) yield than the control plots. The 2, 4-D treated plots accrued the highest yield per plot.

4.7.8 Yield per hectare (kgha-1)

The yield per hectare showed statistically significant ($P \leq 0.05$) differences among the treatments at both high and low rates (Table 4.17). All herbicide treated plots showed significantly higher ($P \leq 0.05$) yield than the control plots. The 2, 4-D treated plots gave the highest yield per hectare.

Table 4.17: Yield and yield component of black eyed cowpea as influenced by different weeds control treatments (high & low)

	High rate		Low rate	
Treatment	**Yield per plot(kg)**	**Yield per hectare(kg)**	**Yield per plot(kg)**	**Yield per hectare(kg)**
Sun-Atrazine	2.07	3239.0	0.83	1292.0
Atranex	2.52	3938.0	0.92	1432.0
Sun- 2, 4-D	2.62	4099.0	1.07	1666.0
Bextra 2, 4-D	2.66	4158.0	1.02	1591.0
Glyphader	2.56	4002.0	0.99	1551.0
Nwura	2.46	3858.0	1.04	1618.0
Conti-quat	2.41	3766.0	0.97	1519.0
Kwatriqua	2.21	3456.0	0.92	1437.0
Control	0.99	1556.0	0.68	1065.0
LSD (P ≤0.05)	**0.67**	**1049.30**	**0.18**	**291.70**

4.8 Soil physical and chemical properties

The results of soil analysis done on the physical and chemical properties of the soil sample taken from the experimental field before and after the two experiments showed (Table 4.18 and 4.19). The results revealed that the various herbicide groups applied did not negatively influence or affect soil fertility and microbial population.

Table 4.18: Soil physical & chemical properties from 0-20cm soil layer before experiment

Sample	pH	E. Cord	N	O.C	T.P	P	Na	K	Ca	Mg	sand	silt	clay
		uS^{cm-1}		%		Mg/kg		Cmol/kg		Percent particle size			
High	4.5	442	0.10	1.18	1423.8	79.8	0.52	0.60	5.2	2.2	72.43	15.07	12.5
Low	5.3	552	0.13	1.21	1042.7	40.75	0.68	1.06	7.8	3.6	73.04	14.46	12.5
Microbial population before Experiment I & II													
High					$1.3x10^5$								
Low					$1.7x10^5$								

Table 4.19: Soil physical & chemical properties from 0-20cm soil layer after experiment

Sample	pH	E. Cord	N	O.C	P	T.P	Na	k	Ca	Mg	Sand	Silt	Clay
		uS^{cm-1}	(%)		Mg/kg		Cmol/kg				Percent particle size		
High	4.3	104	0.06	1.01	47.8	846.0	0.48	0.37	2.4	0.8	74.05	13.45	12.5
Low	5.0	148	0.07	0.72	64.1	1218.6	0.52	0.49	3.2	0.8	74.18	13.32	12.5
Microbial population after Experiment I & II													
High rate				$3.4x\ 10^5$									
Low rate				$3.0x10^5$									

CHAPTER FIVE

DISCUSSION

5.1 Weed population dynamics under maize and rotation

The initial weed flora and density prior to herbicides application varied across the experimental plots. There were broad leaf weeds, sedges and other weeds which occurred at various densities. Among these weed types' *Panicum maximum* was most dominant. The data on weed mortality (gm^{-2}) indicated that all the herbicides applied at high and low rates significantly reduced weeds in the treated plots, compared with the control. Herbicides considerably increased weed mortality throughout the experiment. It is therefore evident that different herbicide treatments can keep weed population below harmful levels in the maize crop. The results also indicated that herbicides provided an enabling environment for the growth of maize. These results are in close confirmity with the results of Subhan *et al* (2007), who reported that herbicides can be used to effectively control weed growth. The results were also in agreement with Chikoye *et al* (2004) who indicated that there can be significant differences in various weed control treatments with regard to their effect on weed density. Nonetheless, herbicide, when correctly applied significantly suppresses weed density even up to crop harvest. Similar findings were reported by Abdullah, (2007) and Hassan *et al* (2010) who reported that herbicides significantly reduced weed density in maize crop.

5.2 Effect of herbicides on maize plant growth

5.2.1 Plant emergence

Days to 50% emergence of seeds following use of chemical weed control at high rate of different herbicides was not significant as all the treatments had the same emergence pattern,

except for those grown on plots treated with Bextra 2, 4-D. For low rates the days to 50% emergence ranged from 4 to 6 days. Similar observations were made by Maglhaes *et al* (2000) who found that besides providing good weed control, herbicides administration had no phytotoxic effect on maize crops.

5.2.2 Plant height

Increase in plant height is a function of genetics as well as environmental conditions. Differences among the treatments were observed throughout plant growth. However, plant height differed significantly at 2, 8 and 10 WAS. At 4 and 6 WAS plant height appeared similar in all treatments, basically implying an important level of growth. Lack of increases in plant height during the period may be attributed to the plant channeling resources for growth to reproductive organs.

The increase in the height of maize in treated plots may be due reduced competition from weeds thus making available sufficient nutrients and moisture to the crops. These results are in line with the findings of Nawab *et al* (1999) and Hassan *et al* (2010) which reported increased height of maize crop in plots treated with herbicides to control weeds than that without herbicides. Furthermore, Akma *et al* (2010) also mentioned that there was increased height of maize plants when nutrients were available to the maize crop.

5.2.3 Number of leaves, leaf area, LAI

All herbicides treated plots showed significantly higher ($P \leq 0.05$) number of leaves at 4, 6 and 10 WAS. However, at 2 and 8 WAS differences in number of leaves were not significantly different from the control plots only for the high rates.

In a similar manner, all herbicide treated plots showed significantly higher leaf area than control plots except at 6 WAS in which differences were not significant.

The LAI which plays a vital role during the growth period of maize dry matter accumulation is the function of sunlight absorption and henceforth a function of LAI (Tollenar & Aguider, 1991). The results of this study are in line with the finding of Wani *et al* (1995) which indicated that since the leaf of a plant is the area where food is manufactured it plays an important function in regulating plant growth and development. Henceforth, grain yield of maize can be predicted based on its leaf area. Also, the leaf area is useful for measuring the photosynthetic efficiency of the maize crop. Thus the wider the leaf area the better it is for the crop to capture energy. For the plots with smaller leaf areas it can be concluded that this could be due to weeds competition for the available resources which caused decrease in maize leaf area.

5.3 Effect of herbicides on maize reproductive parameters

5.3.1 Days to silking

The influence of herbicides on days to silking was not significant and ranged between 53 to 56 days after sowing. These results might be due to the fact that silking is controlled by the interactions of both genetics and environmental influences. This is in line with Subhan *et al* (2007) that reported that the application of herbicides had no significant effect on days to 50% silking in maize.

5.3.2 Ear length, Number of kernels ear^{-1}

The ear length was significantly higher in all herbicide treated plots than the control plots. Ali *et al* (2003) reported that ear length increases when adequate weed control treatments are applied and proper herbicides application is done in maize production.

The determination of the final yield of maize is predicated from the number of kernels per ear. This means that the number of kernels per ear plays a pivotal role in yield determination. The results revealed that at high and low application rates of herbicides with all treated plots showed significantly higher ($P \leq 0.05$) kernels per ear than control plots. This can be attributed to the weed free environment created as a result of timely and proper herbicides application which caused the crops to assimilate nutrients and moisture. The results are in confirmity with the finding of Salarzai (2001) which stated that significantly the number of kernels per ear increase with the appropriate herbicides application.

5.3.3 Yield per hectare (kgha^{-1})

The yield per hectare was significantly higher ($P \leq 0.05$) in all herbicide treated plots than control plots. Since the herbicides were able to create an enabling environment for the crop by controlling the weeds below harmful levels, most of the nutrients and assimilate might have been directly absorbed by the crop as a result of less competition from weeds owing to the effects of herbicides on the weeds. These results can be backed by the findings of Khan (2002) and Subhan *et al* (2007) which stated that kernel yield of maize crop can be increased when weeds are controlled by herbicides application.

5.4 Effect of herbicides on maize physiological parameters

5.4.1 Crop Growth Rate (CGR) (g/cm^{2}day)

All herbicide treated plots had significantly higher CGR than the control plots except for low rates whereby the Control plot had the highest CGR. This suggest the over flow of nutrients and its components to none targeted site. These results confirm that of Gardner *et al* (1985) who said that CGR is a reservoir of canopy photosynthesizing and denotes the rate of biological or dry matter accumulation.

5.4.2 Net assimilation rate (g/cm^{2}day)

The NAR is the amount of dry matter produced per leaf area per unit of time. It measures the photosynthetic efficiency of the maize crop. Increase in LAI as a result of increase in crop growth causes fewer leaves to get full sunlight and therefore causes a decrease in NAR (Gardner *et al.*, 1985)

The results of NAR for both high and low rates showed significantly differences among the treatments. The results showed a decrease in NAR with time which are in agreement with the findings of Rahman *et al* (2004).

5.4.3 Relative growth rate (g/g day)

The result of the relative growth rate at high application rates showed higher value for control plots than the herbicide treated plots, which suggest the changes that occur in plant development when it grows older. This result conformed to that of Radosevich (1997) which

stated that differences in the rate of assimilation of nutrients might cause variation in growth rate.

5.4.4 Relative leaf area growth rate (cm^2/cm^2day)

The results showed the highest RLAGR value for Paraquat treated plots, which implied that the plots had greater resource use than the other plots. This result is in agreement with that of Radosevich (1997) which stated that due to plant characteristics for favourable environment can cause higher RLAGR due to nutrient intake and Chiariello *et al* (1991) which stated it might be due to the partitioning of photosynthate and absorbed nutrients in the leaves.

5.4.5 Biomass duration (g day)

Biomass duration is the rate of carbon gain with reference to number of days over time i.e the outcome of CO_2 assimilation by leaves.The results showed highest BMD for Triazine and Paraquat treated plots which suggest that the plants had higher assimilate utilization and production efficiency. The result is in conformity with the finding of Radosevich (1997) which stated that higher BMD might be due to differences in distribution of assimilates to various parts of plant as a result of physiological response and Chiariello *et al* (1991) who stated that it might be due its capability to acquire maximum assimilates overtime.

EXPERIMENT II: PLANT BIOASSAY FOR RESIDUAL HERBICIDES

5.5 Weed succession (shift)

The weed flora recorded at the beginning of experiment I up to experiment II showed a shift of the weed flora from broadleaf to grasses to sedges and vice versa in all plots. However,

since the soil environment is so complex one cannot attribute existing condition therein to a single factor.These results are in confirmation with that of Legere & Samon (1999) which stated that a single variable cannot influenced weed shift rather multiple abiotic and biotic factors, Derksen *et al* (1993) also stated that agronomic and environmental factors, like crop rotation, soil type, moisture, herbicides etc. can affect weed succession.

5.6 Residual effects of herbicides on cowpea growth and yield

All herbicide treated plots performed significantly better than the control plots. There was no sign or symptom of phytotoxicity detected during the period of experiment II except stress due to water. The findings are in line with that of Vicari *et al* (1994) who reported that under field conditions, herbicides molecules which chemically bond with the soil colloid is constantly disturbed as a result of changes in temperature and moisture content of soil which affects their availability to crops. However, under advantageous condition as a result of climate and soil, a portion of herbicides active ingredient could be made available to crop to cause phytotoxic effect (Sadowski & Kucharski, 2003).

5.6.1 Days to 50% emergence and flowering of black eyed cowpea

The results were not significant for days to 50% emergence and flowering of the succeeding crop. Seedling emerged from 3-4 DAS and flowering occurred between 22-24 DAS. The results are contrary to the finding of Maglhaes *et al* (2000) which stated that apart from providing good weed control, herbicides application had no phytotoxic effect on the crop.

5.6.2 Number of pod at harvest

The numbers of pods per plant were higher in all herbicide treated plots compared to the control plots. Residual weed control might have minimized competition from infested plots.The result is associated with the findings of Townley & Wright (1994) which suggested that good weeds control is paramount in order to accrue high yield of crop.

5.6.3 Yield per hectare ($kgha^{-1}$)

All herbicide treated plots had significantly higher yield per hectare than the control plots at both high and low rates. This implied that the herbicides were effective in the control of weeds which resulted in the the higher yield. The results are in line with the findings of Miller & Libbey (1999) which stated that proper weed control treatments will provide better yield for the crops.

5.7 Influenced of different herbicides on the physical and chemical properties of soil at the experimental sites

The results of the soil physical and chemical properties showed that the herbicides did not negatively influence the nutrients or microbes. In fact, there was an increased in the microbial population after the experiment. The increase in population might be due to crops residues, which served as nutrients for the microbes.The more available nutrients the better it is for their population to increase.The results are in conformity with the findings of Barrett & Burke (2000) which stated that increase in nutrients causes increase in microbes and Akobundu, (1987) who suggested that the effects of herbicides in the soil are generally on the host plants but not on the microbes depending on the abiotic factors.

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

In Experiment I, growth and yield of maize (*Zea mays* L.) were studied under different weed control alternatives. The results showed that the use of these alternatives to control weed in maize crops resulted in increased growth and yield of maize. All the herbicides applied increased weed mortality below harmful levels, most especially, in Pre-applied, 2, 4-D and pre- plant, Glyphosate.

In Experiment II, the results revealed that the use of herbicides to control weeds can lead to a shift in weed growth and significantly influence the growth of succeeding crops, with no negative influence on the crop, soil fertility status as well as microbial population in the soil.

6.2 Recommendations

The different herbicides used in this study had different levels of efficacy in controlling weeds below harmful levels. However, maize farners can use the low levels of the pre-applied, 2, 4-D and pre-plant, Glyphosate herbicides to control weeds in their maize crops since they proved superior over the other alternatives.

However, no analysis was carried out to determine the level of herbicide residue and individual population of microbes in the soil. Further studies are therefore suggested to conclusively determine the residual quantity of each herbicide and the population of each microbe in the soil in order to predict the ultimate effect of any detected level on flora and fauna on the soil.

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APPENDIX

1. Analysis of variance (ANOVA) for weed biomass at 6 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		9.819	3.273	2.03	
Rep.*Units* stratum						
Treatment	8		1761.260	220.157	136.80	<.001
Residual	21	(3)	33.795	1.609		
Total	32	(3)	575.659			

ANOVA for weed biomass at 12 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		13.793	4.598	0.60	
Rep.*Units* stratum						
Treatment	8		4069.058	508.632	66.80	<.001
Residual	21	(3)	159.899	7.614		
Total	32	(3)	1359.595			

2.ANOVA for maize plant 50% emergence at high rate

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		0.38607	0.12869	1.92	
Rep.*Units* stratum						
Treatment	8		0.96877	0.12110	1.81	0.132
Residual	21	(3)	1.40626	0.06696		
Total	32	(3)	2.72727			

3.ANOVA for maize plant 50% tasseling at high rate

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		1.983	0.661	0.47	
Rep.*Units* stratum						

Treatment	8		12.328	1.541	1.11	0.398
Residual	21	(3)	29.250	1.393		
Total	32	(3)	42.970			

4.ANOVA for maize plant 50% silking at high rate

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		2.937	0.979	0.19	
Rep.*Units* stratum						
Treatment	8		34.596	4.325	0.82	0.593
Residual	21	(3)	110.657	5.269		
Total	32	(3)	146.061			

5.ANOVA for maize plant height at 2 to 12 WAS at high rate
At 2 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		2.7600	0.9200	1.07	
Rep.*Units* stratum						
Treatment	8		77.9873	9.7484	11.38	<.001
Residual	21	(3)	17.9879	0.8566		
Total	32	(3)	50.3696			

At 4 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		53.238	17.746	2.49	
Rep.*Units* stratum						
Treatment	8		58.569	7.321	1.03	0.446
Residual	21	(3)	149.476	7.118		
Total	32	(3)	238.579			

At 6 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.

Rep stratum	3		1400.64	466.88	6.43	
Rep.*Units* stratum						
Treatment	8		1277.56	159.69	2.20	0.071
Residual	21	(3)	1523.87	72.57		
Total	32	(3)	3935.83			

At 8 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		4408.1	1469.4	4.53	
Rep.*Units* stratum						
Treatment	8		7004.0	875.5	2.70	0.033
Residual	21	(3)	6814.4	324.5		
Total	32	(3)	16177.4			

At 10 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		989.2	329.7	1.32	
Rep.*Units* stratum						
Treatment	8		11446.1	1430.8	5.71	<.001
Residual	21	(3)	5258.4	250.4		
Total	32	(3)	11011.0			

At 12 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		998.2	332.7	1.50	
Rep.*Units* stratum						
Treatment	8		9859.2	1232.4	5.54	<.001
Residual	21	(3)	4668.2	222.3		
Total	32	(3)	9891.7			

6.ANOVA for maize plant height at 2-12 at low rate
At 2 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		62.980	20.993	9.42	
Rep.*Units* stratum						
Treatment	8		196.124	24.515	11.00	<.001
Residual	21	(3)	46.810	2.229		
Total	32	(3)	192.196			

At 4 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		1548.32	516.11	8.65	
Rep.*Units* stratum						
Treatment	8		4173.35	521.67	8.74	<.001
Residual	21	(3)	1252.81	59.66		
Total	32	(3)	5001.36			

At 6 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		1862.97	620.99	9.24	
Rep.*Units* stratum						
Treatment	8		12413.98	1551.75	23.08	<.001
Residual	21	(3)	1411.74	67.23		
Total	32	(3)	9467.23			

At 8 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		2240.1	746.7	5.69	
Rep.*Units* stratum						
Treatment	8		28379.1	3547.4	27.04	<.001
Residual	21	(3)	2755.2	131.2		
Total	32	(3)	14722.0			

At 10 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		2784.4	928.1	8.76	
Rep.*Units* stratum						
Treatment	8		27599.9	3450.0	32.56	<.001
Residual	21	(3)	2225.3	106.0		
Total	32	(3)	14873.1			

At 12 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		2656.9	885.6	7.77	
Rep.*Units* stratum						
Treatment	8		19950.4	2493.8	21.89	<.001
Residual	21	(3)	2392.1	113.9		
Total	32	(3)	12867.2			

7.ANOVA for maize plant leaf number at 2-10 at high rate
At 2 WAS (untransformed)

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		0.45332	0.15111	1.63	
Rep.*Units* stratum						
Treatment	8		1.41270	0.17659	1.91	0.113
Residual	21	(3)	1.94446	0.09259		
Total	32	(3)	3.33838			

Transformed:

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		0.0040284	0.0013428	1.63	
Rep.*Units* stratum						
Treatment	8		0.0128290	0.0016036	1.95	0.105

Residual	21	(3)	0.0172655	0.0008222		
Total	32	(3)	0.0295450			

At 4 WAS (untransformed)

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		3.484E+00	1.161E+00	2.72	
Rep.*Units* stratum						
Treatment	8		8.786E+05	1.098E+05	2.576E+05	<.001
Residual	21	(3)	8.951E+00	4.263E-01		
Total	32	(3)	2.392E+05			

Transformed:

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		0.010600	0.003533	2.96	
Rep.*Units* stratum						
Treatment	8		0.134399	0.016800	14.09	<.001
Residual	21	(3)	0.025038	0.001192		
Total	32	(3)	0.085265			

At 6 WAS (untransformed)

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		16.2300	5.4100	9.18	
Rep.*Units* stratum						
Treatment	8		35.1743	4.3968	7.46	<.001
Residual	21	(3)	12.3724	0.5892		
Total	32	(3)	45.6566			

Transformed:

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.

Rep stratum	3		0.0177775	0.0059258	9.11	
Rep.*Units* stratum						
Treatment	8		0.0564302	0.0070538	10.84	<.001
Residual	21	(3)	0.0136660	0.0006508		
Total	32	(3)	0.0568778			

At 8WAS (untransformed)

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		76.37	25.46	0.93	
Rep.*Units* stratum						
Treatment	8		286.43	35.80	1.30	0.295
Residual	21	(3)	576.88	27.47		
Total	32	(3)	878.69			

Transformed:

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		0.015566	0.005189	0.89	
Rep.*Units* stratum						
Treatment	8		0.121282	0.015160	2.61	0.037
Residual	21	(3)	0.121931	0.005806		
Total	32	(3)	0.206451			

At 10 WAS (untransformed)

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		0.50197	0.16732	2.55	
Rep.*Units* stratum						
Treatment	8		130.27249	16.28406	247.92	<.001
Residual	21	(3)	1.37935	0.06568		
Total	32	(3)	36.44949			

Transformed:

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		0.00023352	0.00007784	2.53	
Rep.*Units* stratum						
Treatment	8		0.08478485	0.01059811	343.94	<.001
Residual	21	(3)	0.00064710	0.00003081		
Total	32	(3)	0.02344176			

8. ANOVA for maize plant leaf number at 2-10 at low rate

At 2 WAS (untransformed)

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		2.7409	0.9136	4.80	
Rep.*Units* stratum						
Treatment	8		7.2733	0.9092	4.78	0.002
Residual	21	(3)	3.9974	0.1904		
Total	32	(3)	9.0623			

Transformed:

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		0.022554	0.007518	4.72	
Rep.*Units* stratum						
Treatment	8		0.064399	0.008050	5.05	0.001
Residual	21	(3)	0.033472	0.001594		
Total	32	(3)	0.075868			

At 4 WAS (untransformed)

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		10.3779	3.4593	9.67	
Rep.*Units* stratum						

Treatment	8		12.4316	1.5540	4.34	0.003
Residual	21	(3)	7.5139	0.3578		
Total	32	(3)	20.9259			

Transformed:

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		0.045166	0.015055	9.72	
Rep.*Units* stratum						
Treatment	8		0.053088	0.006636	4.28	0.004
Residual	21	(3)	0.032532	0.001549		
Total	32	(3)	0.092251			

At 6 WAS (untransformed)

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		9.3017	3.1006	5.57	
Rep.*Units* stratum						
Treatment	8		48.4824	6.0603	10.89	<.001
Residual	21	(3)	11.6849	0.5564		
Total	32	(3)	30.4865			

Transformed:

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		0.0112256	0.0037419	5.38	
Rep.*Units* stratum						
Treatment	8		0.0698900	0.0087363	12.57	<.001
Residual	21	(3)	0.0146002	0.0006952		
Total	32	(3)	0.040094			

At 8 WAS (untransformed)

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.

Rep stratum	3		4.9666	1.6555	3.33	
Rep.*Units* stratum						
Treatment	8		50.5936	6.3242	12.70	<.001
Residual	21	(3)	10.4549	0.4979		
Total	32	(3)	29.6178			

Transformed:

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		0.0037383	0.0012461	3.32	
Rep.*Units* stratum						
Treatment	8		0.0447276	0.0055910	14.87	<.001
Residual	21	(3)	0.0078936	0.0003759		
Total	32	(3)	0.0240660			

At 10 WAS (untransformed)

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		14.6266	4.8755	11.62	
Rep.*Units* stratum						
Treatment	8		50.5770	6.3221	15.07	<.001
Residual	21	(3)	8.8091	0.4195		
Total	32	(3)	34.3350			

Transformed:

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		0.0101965	0.0033988	12.17	
Rep.*Units* stratum						
Treatment	8		0.0388389	0.0048549	17.39	<.001
Residual	21	(3)	0.0058636	0.0002792		
Total	32	(3)	0.0245181			

9. ANOVA for maize plant leaf area at 2-10 at high rate
At 2 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		1668.2	556.1	5.13	
Rep.*Units* stratum						
Treatment	8		2959.1	369.9	3.41	0.011
Residual	21	(3)	2274.9	108.3		
Total	32	(3)	4600.7			

At 4 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		2478.	826.	0.78	
Rep.*Units* stratum						
Treatment	8		20311.	2539.	2.41	0.051
Residual	21	(3)	22159.	1055.		
Total	32	(3)	33657.			

At 6 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		123046.	41015.	1.72	
Rep.*Units* stratum						
Treatment	8		380739.	47592.	1.99	0.098
Residual	21	(3)	501672.	23889.		
Total	32	(3)	962638.			

At 8 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		67417.	22472.	5.78	
Rep.*Units* stratum						
Treatment	8		237734.	29717.	7.64	<.001
Residual	21	(3)	81639.	3888.		
Total	32	(3)	345912.			

At 10 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		30415.	10138.	2.68	
Rep.*Units* stratum						
Treatment	8		226635.	28329.	7.48	<.001
Residual	21	(3)	79542.	3788.		
Total	32	(3)	267160.			

10. ANOVA for maize plant leaf area at 2-10 WAS at low rate

At 2 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		560.0	186.7	0.86	
Rep.*Units* stratum						
Treatment	8		6130.2	766.3	3.53	0.010
Residual	21	(3)	4564.9	217.4		
Total	32	(3)	9434.7			

At 4 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		234128.	78043.	5.12	
Rep.*Units* stratum						
Treatment	8		293274.	36659.	2.41	0.051
Residual	21	(3)	319805.	15229.		
Total	32	(3)	813884.			

At 6 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		53492.	17831.	4.32	
Rep.*Units* stratum						
Treatment	8		278705.	34838.	8.44	<.001
Residual	21	(3)	86635.	4125.		

Total	32	(3)	306466.			

At 8 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		64328.	21443.	2.14	
Rep.*Units* stratum						
Treatment	8		176002.	22000.	2.20	0.071
Residual	21	(3)	210393.	10019.		
Total	32	(3)	413256.			

At 10 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		3329.	1110.	0.19	
Rep.*Units* stratum						
Treatment	8		162815.	20352.	3.41	0.011
Residual	21	(3)	125259.	5965.		
Total	32	(3)	227596.			

11. ANOVA for maize plant leaf area index at 2-10 WAS at high rate
At 2 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		16291.	5430.	5.13	
Rep.*Units* stratum						
Treatment	8		28898.	3612.	3.41	0.011
Residual	21	(3)	22216.	1058.		
Total	32	(3)	44928.			

At 4 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		24195.	8065.	0.78	

Rep.*Units* stratum						
Treatment	8		198348.	24793.	2.41	0.051
Residual	21	(3)	216393.	10304.		
Total	32	(3)	328685.			

At 6 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		1201619.	400540.	1.72	
Rep.*Units* stratum						
Treatment	8		3718153.	464769.	1.99	0.098
Residual	21	(3)	4899137.	233292.		
Total	32	(3)	9400763.			

At 8 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		679338.	226446.	6.02	
Rep.*Units* stratum						
Treatment	8		2290278.	286285.	7.62	<.001
Residual	21	(3)	789383.	37590.		
Total	32	(3)	3360105.			

At 10 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		297018.	99006.	2.68	
Rep.*Units* stratum						
Treatment	8		2213233.	276654.	7.48	<.001
Residual	21	(3)	776781.	36990.		
Total	32	(3)	2608988.			

12. ANOVA for maize plant leaf area index at 2-10 WAS at low rate

At 2 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		5468.	1823.	0.86	
Rep.*Units* stratum						
Treatment	8		59865.	7483.	3.53	0.010
Residual	21	(3)	44579.	2123.		
Total	32	(3)	92136.			

At 4 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		2286411.	762137.	5.12	
Rep.*Units* stratum						
Treatment	8		2864000.	358000.	2.41	0.051
Residual	21	(3)	3123095.	148719.		
Total	32	(3)	7948085.			

At 6 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		522384.	174128.	4.32	
Rep.*Units* stratum						
Treatment	8		2721728.	340216.	8.44	<.001
Residual	21	(3)	846043.	40288.		
Total	32	(3)	2992829.			

At 8 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		628206.	209402.	2.14	
Rep.*Units* stratum						
Treatment	8		1718774.	214847.	2.20	0.071
Residual	21	(3)	2054620.	97839.		
Total	32	(3)	4035701.			

At 10 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		32505.	10835.	0.19	
Rep.*Units* stratum						
Treatment	8		1589993.	198749.	3.41	0.011
Residual	21	(3)	1223232.	58249.		
Total	32	(3)	2222620.			

13. ANOVA of of maize plant root dry weight at 4 & 6 WAS at high rate
At 4 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		284.61	94.87	2.79	
Rep.*Units* stratum						
Treatment	8		883.08	110.39	3.24	0.015
Residual	21	(3)	714.61	34.03		
Total	32	(3)	1839.89			

At 6 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		6749.9	2250.0	3.02	
Rep.*Units* stratum						
Treatment	8		27155.2	3394.4	4.56	0.002
Residual	21	(3)	15642.3	744.9		
Total	32	(3)	37925.3			

14. ANOVA for maize plant stem dry weight at 4 & 6 WAS at high rate
At 4 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		2013.50	671.17	9.11	
Rep.*Units* stratum						

Treatment	8		2295.02	286.88	3.89	0.006
Residual	21	(3)	1547.63	73.70		
Total	32	(3)	4666.62			

At 6 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		28408.6	9469.5	9.52	
Rep.*Units* stratum						
Treatment	8		40738.9	5092.4	5.12	0.001
Residual	21	(3)	20883.2	994.4		
Total	32	(3)	74784.6			

15. ANOVA for maize plant root dry weight at 4 & 6 WAS at Low rate
At 4 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		313.93	104.64	2.96	
Rep.*Units* stratum						
Treatment	8		1043.68	130.46	3.69	0.008
Residual	21	(3)	743.20	35.39		
Total	32	(3)	1819.66			

At 6 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		9998.0	3332.7	4.91	
Rep.*Units* stratum						
Treatment	8		14998.8	1874.9	2.76	0.030
Residual	21	(3)	14262.1	679.1		
Total	32	(3)	35146.1			

16. ANOVA for maize plant stem dry at 4 & 6 WAS at low rate
At 4 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		1577.33	525.78	8.13	
Rep.*Units* stratum						
Treatment	8		4593.91	574.24	8.88	<.001
Residual	21	(3)	1358.26	64.68		
Total	32	(3)	4673.76			

At 6 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		23488.	7829.	7.56	
Rep.*Units* stratum						
Treatment	8		21743.	2718.	2.63	0.036
Residual	21	(3)	21740.	1035.		
Total	32	(3)	63181.			

17. ANOVA for maize plant yield and yield component at high rate

ANOVA for Ear length

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		7.0203	2.3401	2.81	
Rep.*Units* stratum						
Treatment	8		356.6818	44.5852	53.57	<.001
Residual	21	(3)	17.4792	0.8323		
Total	32	(3)	114.6896			

ANOVA for Ear diameter

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		0.31523	0.10508	1.83	
Rep.*Units* stratum						
Treatment	8		4.62931	0.57866	10.06	<.001
Residual	21	(3)	1.20771	0.05751		
Total	32	(3)	3.12908			

ANOVA for number of kernels per row (untransformed)

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		42.367	14.122	6.95	
Rep.*Units* stratum						
Treatment	8		1171.797	146.475	72.06	<.001
Residual	21	(3)	42.688	2.033		
Total	32	(3)	455.118			

Transformed:

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		0.0017510	0.0005837	0.93	
Rep.*Units* stratum						
Treatment	8		0.0182214	0.0022777	3.62	0.008
Residual	21	(3)	0.0131993	0.0006285		
Total	32	(3)	0.0253415			

ANOVA for number of rows of kernels per ear (untransformed)

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		1.9547	0.6516	0.92	
Rep.*Units* stratum						
Treatment	8		18.3056	2.2882	3.22	0.015
Residual	21	(3)	14.9168	0.7103		
Total	32	(3)	27.5572			

Transformed:

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		0.0112291	0.0037430	6.57	
Rep.*Units* stratum						
Treatment	8		0.5640030	0.0705004	123.80	<.001
Residual	21	(3)	0.0119588	0.0005695		

Total	32	(3)	0.1959420			

ANOVA for number of kernels per ear (untransformed)

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		12560.7	4186.9	6.18	
Rep.*Units* stratum						
Treatment	8		319778.8	39972.3	58.99	<.001
Residual	21	(3)	14229.1	677.6		
Total	32	(3)	137765.8			

Transformed:

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		0.0080261	0.0026754	7.03	
Rep.*Units* stratum						
Treatment	8		0.3826892	0.0478361	125.63	<.001
Residual	21	(3)	0.0079963	0.0003808		
Total	32	(3)	0.1276926			

ANOVA for grain weight

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		1884.6	628.2	2.28	
Rep.*Units* stratum						
Treatment	8		38496.8	4812.1	17.43	<.001
Residual	21	(3)	5796.9	276.0		
Total	32	(3)	19354.4			

ANOVA for 100 seed weight

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		93.28	31.09	2.03	

Rep.*Units* stratum						
Treatment	8		1224.52	153.07	9.99	<.001
Residual	21	(3)	321.72	15.32		
Total	32	(3)	781.83			

18. ANOVA for maize plant yield and yield component at low rate

ANOVA for Ear length

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		12.4025	4.1342	4.70	
Rep.*Units* stratum						
Treatment	8		60.0772	7.5096	8.54	<.001
Residual	21	(3)	18.4696	0.8795		
Total	32	(3)	51.4042			

ANOVA for ear diameter

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		0.76603	0.25534	9.87	
Rep.*Units* stratum						
Treatment	8		1.09904	0.13738	5.31	<.001
Residual	21	(3)	0.54317	0.02587		
Total	32	(3)	1.65475			

ANOVA for number of kernels per row (untransformed)

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		26.634	8.878	1.52	
Rep.*Units* stratum						
Treatment	8		991.444	123.930	21.20	<.001
Residual	21	(3)	122.747	5.845		
Total	32	(3)	416.375			

Transformed:

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		0.004879	0.001626	1.58	
Rep.*Units* stratum						
Treatment	8		0.290649	0.036331	35.34	<.001
Residual	21	(3)	0.021588	0.001028		
Total	32	(3)	0.103595			

ANOVA for number of rows of kernels per ear (untransformed)

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		4.3114	1.4371	1.98	
Rep.*Units* stratum						
Treatment	8		4.5927	0.5741	0.79	0.615
Residual	21	(3)	15.2128	0.7244		
Total	32	(3)	22.4899			

Transformed:

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		0.004879	0.001626	1.58	
Rep.*Units* stratum						
Treatment	8		0.290649	0.036331	35.34	<.001
Residual	21	(3)	0.021588	0.001028		
Total	32	(3)	0.103595			

ANOVA for number of kernels per ear (untransformed)

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		12522.	4174.	2.11	
Rep.*Units* stratum						
Treatment	8		187848.	23481.	11.87	<.001
Residual	21	(3)	41525.	1977.		
Total	32	(3)	113022.			

Transformed:

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		0.010401	0.003467	2.16	
Rep.*Units* stratum						
Treatment	8		0.266048	0.033256	20.68	<.001
Residual	21	(3)	0.033774	0.001608		
Total	32	(3)	0.121980			

ANOVA for grain weight

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		6678.4	2226.1	9.27	
Rep.*Units* stratum						
Treatment	8		33564.8	4195.6	17.47	<.001
Residual	21	(3)	5043.0	240.1		
Total	32	(3)	21886.4			

ANOVA for 100 seed weight

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		318.22	106.07	7.60	
Rep.*Units* stratum						
Treatment	8		861.74	107.72	7.71	<.001
Residual	21	(3)	293.23	13.96		
Total	32	(3)	883.58			

19. ANOVA for maize yield per plot at high rate

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		3.0154	1.0051	2.28	
Rep.*Units* stratum						
Treatment	8		61.5949	7.6994	17.43	<.001
Residual	21	(3)	9.2750	0.4417		
Total	32	(3)	30.9671			

20. ANOVA for maize yield per hectare at high rate

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		7361780.	2453927.	2.28	
Rep.*Units* stratum						
Treatment	8		150378223.	18797278.	17.43	<.001
Residual	21	(3)	22644001.	1078286.		
Total	32	(3)	75603179.			

21. ANOVA for maize yield per plot at low rate

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		10.6855	3.5618	9.27	
Rep.*Units* stratum						
Treatment	8		53.7037	6.7130	17.47	<.001
Residual	21	(3)	8.0688	0.3842		
Total	32	(3)	35.0183			

22. ANOVA for maize yield per hectare at low rate

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		26087670.	8695890.	9.27	
Rep.*Units* stratum						
Treatment	8		131112647.	16389081.	17.47	<.001
Residual	21	(3)	19699181.	938056.		

Total	32	(3)	85493921.			

23. ANOVA for plant growth analysis at high rate
ANOVA for RGR

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		0.001344	0.000448	0.45	
Rep.*Units* stratum						
Treatment	8		0.017261	0.002158	2.14	0.077
Residual	21	(3)	0.021136	0.001006		
Total	32	(3)	0.039107			

ANOVA for RLAGR

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		0.0017754	0.0005918	5.81	
Rep.*Units* stratum						
Treatment	8		0.0045261	0.0005658	5.55	<.001
Residual	21	(3)	0.0021392	0.0001019		
Total	32	(3)	0.0077281			

ANOVA for NAR

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		0.104156	0.034719	6.47	
Rep.*Units* stratum						
Treatment	8		0.218870	0.027359	5.10	0.001
Residual	21	(3)	0.112604	0.005362		
Total	32	(3)	0.403931			

ANOVA for CGR

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.

Rep stratum	3		349.58	116.53	5.92	
Rep.*Units* stratum						
Treatment	8		660.99	82.62	4.20	0.004
Residual	21	(3)	413.08	19.67		
Total	32	(3)	1224.29			

ANOVA for LAD

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		53508.	17836.	0.83	
Rep.*Units* stratum						
Treatment	8		239255.	29907.	1.39	0.257
Residual	21	(3)	451847.	21517.		
Total	32	(3)	707785.			

ANOVA for BMD
Variate: BMD_g_days

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		1201506.	400502.	22.58	
Rep.*Units* stratum						
Treatment	8		1211172.	151397.	8.54	<.001
Residual	21	(3)	372450.	17736.		
Total	32	(3)	2080275.			

24. ANOVA for plant growth analysis at low rate
ANOVA for RGR

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		0.00018746	0.00006249	1.72	
Rep.*Units* stratum						
Treatment	8		0.00714899	0.00089362	24.62	<.001
Residual	21	(3)	0.00076222	0.00003630		
Total	32	(3)	0.00272116			

ANOVA for RLAGR

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		0.0010386	0.0003462	2.33	
Rep.*Units* stratum						
Treatment	8		0.0020035	0.0002504	1.69	0.160
Residual	21	(3)	0.0031152	0.0001483		
Total	32	(3)	0.0053133			

ANOVA for NAR

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		1.519E-06	5.064E-07	3.98	
Rep.*Units* stratum						
Treatment	8		8.938E-06	1.117E-06	8.77	<.001
Residual	21	(3)	2.674E-06	1.273E-07		
Total	32	(3)	6.475E-06			

ANOVA for CGR

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		0.0041678	0.0013893	1.63	
Rep.*Units* stratum						
Treatment	8		0.1037823	0.0129728	15.21	<.001
Residual	21	(3)	0.0179076	0.0008527		
Total	32	(3)	0.0536113			

ANOVA for LAD

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		34854929.	11618310.	1.22	
Rep.*Units* stratum						
Treatment	8		85270924.	10658866.	1.12	0.388
Residual	21	(3)	199274787.	9489276.		

Total	32	(3)	295560954.			

ANOVA for BMD

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		3320021.	1106674.	8.30	
Rep.*Units* stratum						
Treatment	8		4919292.	614911.	4.61	0.002
Residual	21	(3)	2798344.	133254.		
Total	32	(3)	8985046.			

25. ANOVA for cowpea plant height at 2-6 WAS at high rate

ANOVA at 2 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		20.290	6.763	2.36	
Rep.*Units* stratum						
Treatment	8		49.511	6.189	2.16	0.076
Residual	21	(3)	60.229	2.868		
Total	32	(3)	126.590			

ANOVA at 4 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		423.00	141.00	2.15	
Rep.*Units* stratum						
Treatment	8		924.38	115.55	1.77	0.141
Residual	21	(3)	1374.16	65.44		
Total	32	(3)	2662.71			

ANOVA at 6 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.

Rep stratum	3		248.43	82.81	1.50	
Rep.*Units* stratum						
Treatment	8		1468.32	183.54	3.32	0.013
Residual	21	(3)	1161.23	55.30		
Total	32	(3)	2294.00			

26. ANOVA for cowpea plant height at 2-6 WAS at low rate
ANOVA at 2 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		52.50	17.50	1.56	
Rep.*Units* stratum						
Treatment	8		129.88	16.23	1.44	0.236
Residual	21	(3)	235.95	11.24		
Total	32	(3)	330.31			

ANOVA at 4 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		184.39	61.46	2.50	
Rep.*Units* stratum						
Treatment	8		272.61	34.08	1.39	0.259
Residual	21	(3)	516.01	24.57		
Total	32	(3)	754.71			

ANOVA at 6 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		263.56	87.85	3.39	
Rep.*Units* stratum						
Treatment	8		1450.59	181.32	7.00	<.001
Residual	21	(3)	543.99	25.90		
Total	32	(3)	1214.46			

27. ANOVA for cowpea plant number of leaf at 2-6 WAS at high rate

ANOVA at 2 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		3.7408	1.2469	10.73	
Rep.*Units* stratum						
Treatment	8		7.1127	0.8891	7.65	<.001
Residual	21	(3)	2.4415	0.1163		
Total	32	(3)	8.4311			

ANOVA at 4 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		15.87	5.29	0.41	
Rep.*Units* stratum						
Treatment	8		447.85	55.98	4.32	0.003
Residual	21	(3)	271.85	12.95		
Total	32	(3)	498.86			

ANOVA at 6 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		1269.68	423.23	17.03	
Rep.*Units* stratum						
Treatment	8		225.37	28.17	1.13	0.382
Residual	21	(3)	521.77	24.85		
Total	32	(3)	1937.76			

28. ANOVA for cowpea plant number of leaf at 2-6 WAS at low rate

ANOVA at 2 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		55.8364	18.6121	38.83	

Rep.*Units* stratum						
Treatment	8		22.8454	2.8557	5.96	<.001
Residual	21	(3)	10.0669	0.4794		
Total	32	(3)	65.8350			

ANOVA at 4 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		78.369	26.123	9.52	
Rep.*Units* stratum						
Treatment	8		120.363	15.045	5.48	<.001
Residual	21	(3)	57.609	2.743		
Total	32	(3)	167.663			

ANOVA at 6 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		997.84	332.61	32.19	
Rep.*Units* stratum						
Treatment	8		284.23	35.53	3.44	0.011
Residual	21	(3)	216.97	10.33		
Total	32	(3)	1497.00			

29. ANOVA for cowpea plant leaf area at 2-6 WAS at high rate

ANOVA at 2 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		65.71	21.90	1.29	
Rep.*Units* stratum						
Treatment	8		267.16	33.39	1.97	0.102
Residual	21	(3)	355.92	16.95		
Total	32	(3)	607.76			

ANOVA at 4 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		138.278	46.093	6.44	
Rep.*Units* stratum						
Treatment	8		66.691	8.336	1.16	0.365
Residual	21	(3)	150.369	7.160		
Total	32	(3)	317.820			

ANOVA at 6 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		596.39	198.80	6.18	
Rep.*Units* stratum						
Treatment	8		233.39	29.17	0.91	0.529
Residual	21	(3)	675.44	32.16		
Total	32	(3)	1407.17			

30. ANOVA for cowpea plant leaf area at 2-6 WAS at low rate

ANOVA at 2 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		1092.67	364.22	16.58	
Rep.*Units* stratum						
Treatment	8		396.33	49.54	2.25	0.065
Residual	21	(3)	461.40	21.97		
Total	32	(3)	1536.57			

ANOVA at 4 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		1162.06	387.35	20.28	
Rep.*Units* stratum						
Treatment	8		861.17	107.65	5.64	<.001

Residual	21	(3)	401.03	19.10		
Total 32 (3) 1656.85						

ANOVA at 6 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		878.61	292.87	15.07	
Rep.*Units* stratum						
Treatment	8		244.24	30.53	1.57	0.193
Residual	21	(3)	408.22	19.44		
Total 32 (3) 1362.62						

31. ANOVA for cowpea plant leaf area index at 2-6 WAS at high rate

ANOVA at 2 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		641.7	213.9	1.29	
Rep.*Units* stratum						
Treatment	8		2608.9	326.1	1.97	0.102
Residual	21	(3)	3475.8	165.5		
Total	32	(3)	5935.1			

ANOVA at 4 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		1350.37	450.12	6.44	
Rep.*Units* stratum						
Treatment	8		651.28	81.41	1.16	0.365
Residual	21	(3)	1468.45	69.93		
Total	32	(3)	3103.71			

ANOVA at 6 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.

Rep stratum	3		5824.2	1941.4	6.18	
Rep.*Units* stratum						
Treatment	8		2279.2	284.9	0.91	0.529
Residual	21	(3)	6596.1	314.1		
Total	32	(3)	13741.9			

32. ANOVA for cowpea plant leaf area index at 2-6 WAS at low rate

ANOVA at 2 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		10670.6	3556.9	16.58	
Rep.*Units* stratum						
Treatment	8		3870.4	483.8	2.25	0.065
Residual	21	(3)	4505.9	214.6		
Total	32	(3)	15005.6			

ANOVA at 4 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		11348.2	3782.7	20.28	
Rep.*Units* stratum						
Treatment	8		8409.9	1051.2	5.64	<.001
Residual	21	(3)	3916.4	186.5		
Total	32	(3)	16180.2			

ANOVA at 6 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		8580.2	2860.1	15.07	
Rep.*Units* stratum						
Treatment	8		2385.2	298.1	1.57	0.193
Residual	21	(3)	3986.5	189.8		
Total	32	(3)	13306.9			

33. ANOVA for plant growth analysis for cowpea plant at high rate

ANOVA for RGR

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		0.0048613	0.0016204	5.76	
Rep.*Units* stratum						
Treatment	8		0.0019792	0.0002474	0.88	0.549
Residual	21	(3)	0.0059069	0.0002813		
Total	32	(3)	0.0121929			

ANOVA for RLAGR

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		0.00077517	0.00025839	4.35	
Rep.*Units* stratum						
Treatment	8		0.00041336	0.00005167	0.87	0.557
Residual	21	(3)	0.00124882	0.00005947		
Total	32	(3)	0.00237536			

ANOVA for NAR

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		0.12174	0.04058	0.83	
Rep.*Units* stratum						
Treatment	8		0.38349	0.04794	0.98	0.480
Residual	21	(3)	1.02963	0.04903		
Total	32	(3)	1.51115			

ANOVA for CGR

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		31.93	10.64	0.90	
Rep.*Units* stratum						

Treatment	8		91.09	11.39	0.97	0.488
Residual	21	(3)	247.71	11.80		
Total	32	(3)	364.75			

ANOVA for LAD

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		13970.	4657.	2.51	
Rep.*Units* stratum						
Treatment	8		31401.	3925.	2.12	0.080
Residual	21	(3)	38907.	1853.		
Total	32	(3)	70646			

ANOVA for BMD

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		55143.	18381.	2.15	
Rep.*Units* stratum						
Treatment	8		492058.	61507.	7.21	<.001
Residual	21	(3)	179251.	8536.		
Total	32	(3)	394213.			

34. ANOVA for plant growth analysis for cowpea plant at low rate

ANOVA for RGR

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		0.00014974	0.00004991	1.84	
Rep.*Units* stratum						
Treatment	8		0.00383546	0.00047943	17.66	<.001
Residual	21	(3)	0.00057026	0.00002716		
Total	32	(3)	0.00204793			

ANOVA for RLAGR

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.

Rep stratum	3		0.00033166	0.00011055	2.63	
Rep.*Units* stratum						
Treatment	8		0.00194187	0.00024273	5.77	<.001
Residual	21	(3)	0.00088387	0.00004209		
Total 32 (3)	0.00163948					

ANOVA for NAR

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		0.026329	0.008776	1.92	
Rep.*Units* stratum						
Treatment	8		0.011078	0.001385	0.30	0.956
Residual	21	(3)	0.095860	0.004565		
Total 32 (3)	0.125104					

ANOVA for LAD

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		164.18	54.73	2.08	
Rep.*Units* stratum						
Treatment	8		514.65	64.33	2.45	0.048
Residual	21	(3)	551.58	26.27		
Total 32 (3)	962.96					

Variate: BMD

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		2970.6	990.2	2.76	
Rep.*Units* stratum						
Treatment	8		20772.0	2596.5	7.23	<.001
Residual	21	(3)	7536.7	358.9		
Total	32	(3)	15983.0			

35. ANOVA for leaf biomass at 2-6 WAS at high rate

ANOVA at 2 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		1.9508	0.6503	2.63	
Rep.*Units* stratum						
Treatment	8		14.8961	1.8620	7.53	<.001
Residual	21	(3)	5.1914	0.2472		
Total 32 (3) 13.2328						

ANOVA at 4 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		340.31	113.44	5.45	
Rep.*Units* stratum						
Treatment	8		276.94	34.62	1.66	0.167
Residual	21	(3)	437.01	20.81		
Total 32 (3) 878.80						

ANOVA at 6 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		206.8	68.9	0.53	
Rep.*Units* stratum						
Treatment	8		1305.1	163.1	1.26	0.315
Residual	21	(3)	2717.1	129.4		
Total 32 (3) 3666.2						

36. ANOVA for leaf biomass at 2-6 WAS at low rate

ANOVA at 2 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		20.954	6.985	3.88	

Rep.*Units* stratum						
Treatment	8		15.212	1.902	1.06	0.429
Residual	21	(3)	37.827	1.801		
Total	32	(3)	71.753			

ANOVA at 4 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		30.955	10.318	3.09	
Rep.*Units* stratum						
Treatment	8		13.796	1.725	0.52	0.831
Residual	21	(3)	70.187	3.342		
Total	32	(3)	111.176			

ANOVA at 6 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		50.188	16.729	4.76	
Rep.*Units* stratum						
Treatment	8		34.868	4.358	1.24	0.325
Residual	21	(3)	73.774	3.513		
Total	32	(3)	144.702			

37. ANOVA for root biomass at 2-8 WAS at high rate

ANOVA at 2 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		0.09283	0.03094	2.51	
Rep.*Units* stratum						
Treatment	8		0.72053	0.09007	7.30	<.001
Residual	21	(3)	0.25905	0.01234		
Total	32	(3)	0.67183			

ANOVA at 4 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		0.7952	0.2651	1.46	
Rep.*Units* stratum						
Treatment	8		2.4977	0.3122	1.72	0.152
Residual	21	(3)	3.8075	0.1813		
Total	32	(3)	5.9333			

ANOVA at 6 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		7.9099	2.6366	3.49	
Rep.*Units* stratum						
Treatment	8		21.7983	2.7248	3.61	0.009
Residual	21	(3)	15.8438	0.7545		
Total	32	(3)	38.7200			

ANOVA at 8 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		10.452	3.484	2.72	
Rep.*Units* stratum						
Treatment	8		492.555	61.569	48.14	<.001
Residual	21	(3)	26.856	1.279		
Total	32	(3)	171.893			

38. ANOVA for root biomass at 2-8 WAS at low rate

ANOVA at 2 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		0.08558	0.02853	0.86	
Rep.*Units* stratum						

Treatment	8		0.86404	0.10800	3.27	0.014
Residual	21	(3)	0.69375	0.03304		
Total 32 (3) 1.10909						

ANOVA at 4 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		1.1568	0.3856	3.17	
Rep.*Units* stratum						
Treatment	8		3.2165	0.4021	3.30	0.013
Residual	21	(3)	2.5566	0.1217		
Total	32	(3)	4.4218			

ANOVA at 6 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		1.1221	0.3740	1.58	
Rep.*Units* stratum						
Treatment	8		3.2704	0.4088	1.73	0.150
Residual	21	(3)	4.9688	0.2366		
Total 32 (3) 6.9424						

ANOVA at 8 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		0.9311	0.3104	0.84	
Rep.*Units* stratum						
Treatment	8		352.1564	44.0196	119.60	<.001
Residual	21	(3)	7.7291	0.3681		
Total	32	(3)	105.0788			

39. ANOVA for stem biomass at 2-8 WAS at high rate

ANOVA at 2 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		0.5762	0.1921	1.40	
Rep.*Units* stratum						
Treatment	8		734.3239	91.7905	667.05	<.001
Residual	21	(3)	2.8898	0.1376		
Total	32	(3)	199.1893			

ANOVA at 4 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		562.33	187.44	7.66	
Rep.*Units* stratum						
Treatment	8		1809.42	226.18	9.24	<.001
Residual	21	(3)	513.97	24.47		
Total	32	(3)	1675.25			

ANOVA at 6 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		750.5	250.2	1.68	
Rep.*Units* stratum						
Treatment	8		4916.0	614.5	4.12	0.004
Residual	21	(3)	3135.3	149.3		
Total	32	(3)	5594.8			

ANOVA at 8 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		2081.4	693.8	3.91	
Rep.*Units* stratum						

Treatment	8		6909.7	863.7	4.87	0.002
Residual	21	(3)	3721.6	177.2		
Total	32	(3)	8043.5			

40. ANOVA for stem biomass at 2-8 WAS at low rate

ANOVA at 2 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		61.05	20.35	1.84	
Rep.*Units* stratum						
Treatment	8		906.22	113.28	10.24	<.001
Residual	21	(3)	232.21	11.06		
Total	32	(3)	520.23			

ANOVA at 4 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		4.710	1.570	0.30	
Rep.*Units* stratum						
Treatment	8		515.548	64.443	12.30	<.001
Residual	21	(3)	109.992	5.238		
Total	32	(3)	260.213			

ANOVA at 6 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		20.335	6.778	1.58	
Rep.*Units* stratum						
Treatment	8		392.702	49.088	11.46	<.001
Residual	21	(3)	89.960	4.284		
Total	32	(3)	213.081			

ANOVA at 8 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		162.33	54.11	4.12	
Rep.*Units* stratum						
Treatment	8		939.96	117.49	8.95	<.001
Residual	21	(3)	275.77	13.13		
Total	32	(3)	657.98			

41. ANOVA for cowpea number of node at at 4 & 6 WAS at high rate

ANOVA at 4 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		199.65	66.55	4.68	
Rep.*Units* stratum						
Treatment	8		758.37	94.80	6.67	<.001
Residual	21	(3)	298.67	14.22		
Total	32	(3)	636.26			

ANOVA at 6 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		1327.70	442.57	23.65	
Rep.*Units* stratum						
Treatment	8		109.36	13.67	0.73	0.664
Residual	21	(3)	393.03	18.72		
Total	32	(3)	1767.23			

42. ANOVA for cowpea number of node at at 4 & 6 WAS at low rate

ANOVA at 4 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		115.995	38.665	14.82	

Rep.*Units* stratum						
Treatment	8		145.907	18.238	6.99	<.001
Residual	21	(3)	54.776	2.608		
Total 32 (3) 191.460						

ANOVA at 6 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		217.585	72.528	8.59	
Rep.*Units* stratum						
Treatment	8		286.155	35.769	4.24	0.004
Residual	21	(3)	177.227	8.439		
Total 32 (3) 445.340						

43. ANOVA for cowpea number of flower at at 4 & 6 WAS at high rate

ANOVA at 4 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		34.837	11.612	7.44	
Rep.*Units* stratum						
Treatment	8		17.016	2.127	1.36	0.269
Residual	21	(3)	32.788	1.561		
Total 32 (3) 83.320						

ANOVA at 6 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		858.62	286.21	22.87	
Rep.*Units* stratum						
Treatment	8		539.57	67.45	5.39	<.001
Residual	21	(3)	262.83	12.52		
Total 32 (3) 1465.66						

44. ANOVA for cowpea number of flower at at 4 & 6 WAS at low rate

ANOVA at 4 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		103.666	34.555	13.67	
Rep.*Units* stratum						
Treatment	8		159.466	19.933	7.88	<.001
Residual	21	(3)	53.102	2.529		
Total	32	(3)	177.101			

ANOVA at 6 WAS

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		4.657	1.552	1.49	
Rep.*Units* stratum						
Treatment	8		7.671	0.959	0.92	0.521
Residual	21	(3)	21.927	1.044		
Total	32	(3)	33.520			

45. ANOVA for cowpea number of pod at harvest at high rate

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		483.77	161.26	2.54	
Rep.*Units* stratum						
Treatment	8		4458.58	557.32	8.78	<.001
Residual	21	(3)	1333.40	63.50		
Total	32	(3)	3127.93			

46. ANOVA for cowpea number of pod at harvest at low rate

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		124.637	41.546	5.65	

Rep.*Units* stratum						
Treatment	8		239.936	29.992	4.08	0.005
Residual	21	(3)	154.411	7.353		
Total	32	(3)	384.414			

47. ANOVA for dry pod weight at high rate

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		665.1	221.7	1.70	
Rep.*Units* stratum						
Treatment	8		5375.6	672.0	5.15	0.001
Residual	21	(3)	2737.4	130.4		
Total	32	(3)	5051.2			

48. ANOVA for dry pod weight at low rate

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		157.84	52.61	5.22	
Rep.*Units* stratum						
Treatment	8		288.69	36.09	3.58	0.009
Residual	21	(3)	211.54	10.07		
Total	32	(3)	475.27			

49. ANOVA for number of seed per pod at high rate

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		4.6773	1.5591	2.58	
Rep.*Units* stratum						
Treatment	8		9.0489	1.1311	1.87	0.119
Residual	21	(3)	12.6919	0.6044		
Total	32	(3)	23.1684			

50. ANOVA for number of seed per pod at low rate

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.

Rep stratum	3		23.3739	7.7913	10.86	
Rep.*Units* stratum						
Treatment	8		37.7359	4.7170	6.58	<.001
Residual	21	(3)	15.0626	0.7173		
Total	32	(3)	45.3401			

51 ANOVA for 100 seed weight at high rate

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		4.7402	1.5801	2.88	
Rep.*Units* stratum						
Treatment	8		14.0249	1.7531	3.19	0.016
Residual	21	(3)	11.5291	0.5490		
Total	32	(3)	23.1406			

52. ANOVA for 100 seed weight at low rate

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		3.3219	1.1073	1.68	
Rep.*Units* stratum						
Treatment	8		16.0380	2.0048	3.04	0.020
Residual	21	(3)	13.8476	0.6594		
Total	32	(3)	22.5800			

53. ANOVA for harvest index at high rate

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		1077.24	359.08	5.52	
Rep.*Units* stratum						
Treatment	8		5095.75	636.97	9.80	<.001
Residual	21	(3)	1364.89	64.99		
Total	32	(3)	3806.49			

54. ANOVA for harvest index at low rate

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		131.4	43.8	0.26	
Rep.*Units* stratum						
Treatment	8		3304.9	413.1	2.49	0.045
Residual	21	(3)	3489.4	166.2		
Total	32	(3)	5068.5			

55. ANOVA for yield per plot at high rate

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		1.0641	0.3547	1.70	
Rep.*Units* stratum						
Treatment	8		8.6010	1.0751	5.15	0.001
Residual	21	(3)	4.3798	0.2086		
Total	32	(3)	8.0819			

56. ANOVA for yield per plot at low rate

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		0.25255	0.08418	5.22	
Rep.*Units* stratum						
Treatment	8		0.46190	0.05774	3.58	0.009
Residual	21	(3)	0.33847	0.01612		
Total	32	(3)	0.76043			

57. ANOVA for yield per hectare at high rate

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		2597863.	865954.	1.70	
Rep.*Units* stratum						
Treatment	8		20998608.	2624826.	5.15	0.001
Residual	21	(3)	10692836.	509183.		

Total 32 (3) 19731156.

58. ANOVA for yield per hectare at low rate

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3		616571.	205524.	5.22	
Rep.*Units* stratum						
Treatment	8		1127684.	140960.	3.58	0.009
Residual	21	(3)	826347.	39350.		
Total	32	(3)	1856514.			