KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY
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COLLEGE OF SCIENCE

DEPARTMENT OF THEORETICAL AND APPLIED BIOLOGY

THE EFFECT OF GLYPHOSATE AND PARAQUAT HERBICIDES APPLICATION ON GROWTH AND DEVELOPMENT OF *CEDRELA ODORATA* SEEDLINGS

A Thesis Submitted to the Department of Theoretical and Applied Biology, Faculty of Biological Science, Kwame Nkrumah University of Science and Technology, Kumasi in Partial Fulfillment of Requirement for the Degree of Master of Science in Environmental Science

By

RAYMOND MBIAH

BSc. (Hons). Natural Resources Management

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DECLARATION

I hereby declare that this is the original work I did with the help of my supervisor except for references to other people's work which has been duly acknowledged and that this work has neither been presented in whole or in part for the award of any degree elsewhere.

…………………………………………

RAYMOND MBIAH

STUDENT

…………………………………………

REV. STEPHEN AKYEAMPONG

ACADEMIC SUPERVISOR

DEPARTMENT OF THEORITICAL AND APPLIED BIOLOGY

…………………………………………

REV. STEPHEN AKYEAMPONG

HEAD OF DEPARTMENT

DEPARTMENT OF THEORITICAL AND APPLIED BIOLOGY

DEDICATION

I dedicate this work to my lovely wife Mrs. Portia Mbiah and my children Gad Kojo Mbiah and Roberta Aba Mbiah.

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My first thanks goes to the almighty God for his love guidance and inspiration given me throughout my studies.

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ABSTRACT

Timber production in Ghana has been rapidly dwindling over the years for various reasons including over exploitation with little attention to reforestation. Several attempts have been made to forestall the declining state of the nation's timber resources. This includes the establishment of plantations of both exotic and indigenous timber species by the Forestry commission and other private plantation developers. Several challenges have bedeviled the successes of plantation programs in Ghana. These include general plantation management with weed control problems taking the centre stage. Many farmers have resulted to the use of chemicals in the control of weeds with little regard to their effect in the growth and development of their untargeted plants species. It is for this reason that in this study growth effect of chemical weed control were compared with that of manual weed control in *Cedrela odorata* plantation. The effects of the weed control methods on the survival rates of *C. odorata* were also studied. Seedlings of *C. odorata* with an initial shoot height of 21.16cm and basal diameter of 0.46cm planted in a grid spacing of 2.00m by 2.00m in plantation were subjected to three different weed control treatment namely glyphosate treatment, paraquat treatment at a dose of 50 millitres per 5 litres of water applied by the use of pressure sprayer and manual weed control treatment by the use of machete. Four Growth parameters namely seedlings shoot height, basal diameter, bi-pinnate leave length and numbers of bi-pinnate leaves of the seedlings were studied for twenty six weeks after planting. The result showed that *C. odorata* seedlings were not tolerant of chemical weed control method. This was because, for all the parameters studied, manual weed control treated plots recorded a significantly high value than glyphosate and paraquat treated plots. Between glyphosate and paraquat treated plots, paraquat treated plots recorded a higher mean value than glyphosate treated plots for all the parameters tested. However, the analysis of variance showed no significant difference between the mean values of glyphosate and paraquat treated plot at $P \leq 0.05$ for all the parameters studied with the exception of seedling shoot height. In terms of seedling survival rate, manual weed control treatment recorded the highest survival rate of 88% whilst glyphosate and paraquat treated plots recorded 44% and 43% respectively. Though manual weed control is more expensive and labour intensive than chemical weed control, the study recommend application of manual weed control in the management of plantations where there are young seedlings involved and also recommend the application of paraquat or glyphosate herbicide only in situations where there are no non target plant species in their seedling stage to protect.

CHAPTER ONE

1.0 INTRODUCTION

The establishment of large scale plantations in recent years has become necessary as a result of the increasing awareness of the fast degradation of the forest cover, the consciousness of the immense contribution of the forest in environmental management, and the rising effect of climate change as a result of deforestation. For example, Houghton *et al.* (1987) concluded that 40% of the carbon released in Africa comes from clearing of closed forest, 35% from clearing of open forest or woodlands and the remaining 27% from conversion of fallow land to permanent agriculture. Forests are a major component of the global carbon cycle. There has been a heightened interest in the potential for using forest as a means of reducing climate change. This could be achieved by conserving existing stock of carbon in forest that are currently being lost and creating new stock of carbon in growing trees (Tipper, 1998). The contribution of forest plantations to socio-economic development is also very important as it generates income in the production of timber and fuel wood and the creation of employment. Weed management is among factors that need to be considered to ensure effective plantation development. Due to its fast-growing, light demanding nature, early clearing of weeds in *C. odorata* plantation is essential. Under natural conditions, *C. odorata* is a long-lived pioneer that tolerates shade only temporarily (World Agroforestry Centre, 2012).

Weeds are unwanted plants that compete with cultivated plants for space, nutrients, water and light (Monks and Bass, 1999). Weed management decisions varies according to plant life cycles, infestation size, environmental parameters and management objectives. Methods of weed management include cultural control, biological control, mechanical control and chemical control (Larimer County, 1995). Each of these methods has its own merits and demerits and a prudent plantation developer can make use of one means or a combination of them to control weeds efficiently and economically. With the gradual industrialization of our country, coupled with the rising standard of living and literacy rate, manual labour is becoming scarce. Chemical weed control which involves the use of herbicides is economical and less laborious in application as compared to laborious, tedious, time consuming and expensive manual weed management method. Due to their economic advantage over other weed control measures, herbicides are now extensively used in Ghana by many farmers and plantation developers with no or little regards to its effect on cultivated plants, animals and the environment as a whole. In Ghana several of these chemicals have been introduced and used extensively to control different kinds of weeds. Among these chemicals are glyphosate and paraquat which are commonly used due to their broad spectrum nature and economic advantage. The objective of this study was to investigate the effect of different weed control methods specifically chemical method (glyphosate and paraquat herbicides) and Manual weed control methods on the early growth and development of *C. odorata* seedlings in a plantation development.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Weeds

According to the Weed Science Society of America, a weed (invasive plants and weeds of natural areas) is any plant that is objectionable or interferes with the activities or welfare of man (Anonymous, 1994). The Merriam-Webster Online Dictionary (2013) defines a weed as 'a plant that is not valued where it is growing and is usually of vigorous growth, especially one that tends to overgrow or choke out more desirable plants'. The Oxford Dictionary of Current English (2006) also states that "a weed is a wild plant growing where it is not wanted" The term *weed* is a subjective one, without any classification value, since a plant that *is* a weed in one context is *not* a weed when growing where it belongs or is wanted. Indeed, a number of plants that many consider "weeds'' are often intentionally grown by people in gardens or other cultivated-plant settings. Therefore, a weed is a plant that is considered by the user of the term to be a nuisance. The word commonly is applied to unwanted plants in human-controlled settings, especially farm fields and gardens, but also lawns, parks, woods, and other areas. More vaguely, "weed" is applied to any plants that grow and reproduce aggressively and invasively (Janick, 1979).

2.1.1 Effect of Weeds on Crops

It was reported in 1967 that 9.7% of the world's crop production was lost to weeds. This doesn't account for other crop losses due to insects, animals, disease, drought, weather and other methods (Bokan, 2009). Also in 1967 8% of the potential U.S. crop production was lost to weeds. Over the last 30 years the estimates for total losses due to weeds range from $6 to 18 billion per year. Currently in the United States there are 100 million acres of land infested with noxious weeds and this is growing by at least 8% each year. In 1993, $3.6 to 5.4 billion was lost in direct costs (chemical costs, labor, equipment wear and tear) with an additional $1 billion in indirect costs to control the weeds. This cost includes yield reduction, chemical control, equipment and labor, animal losses or health care (Bokan, 2009).

According to Wikipedia (2012), weeds have effects on other plants. Some of these effects are discussed below:

Weeds can compete with productive crops or pasture, or convert productive land into unusable scrub. Weeds are also often poisonous, distasteful, produce thorns or other damaging body parts or otherwise interfere with the use and management of desirable plants by contaminating harvests or excluding livestock.

Also weeds tend to thrive at the expense of the more refined edible or ornamental crops. They provide competition for space, nutrients, water and light, although how seriously they will affect a crop depends on a number of factors. Some crops have greater resistance than others. Smaller, slower growing seedlings are more likely to be overwhelmed than those that are larger and more vigorous.

The presence of weeds does not necessarily mean that they are competing with a crop, especially during the early stages of growth when each plant can find the resources it requires without interfering with the others. However, as the seedlings' size increases, their root systems will spread as they each begin to require greater amounts of water and nutrients. Estimates suggest that weed and crop can co-exist harmoniously for around three weeks, therefore it is important that weeds be removed early in order to prevent competition occurring. Weed competition can have quite dramatic effects on crop growth.

Furthermore weeds can also host pests and diseases that can spread to cultivated crops. Charlock and Shepherd's purse may carry clubroot, eelworm can be harboured by chickweed, fat hen and shepherd's purse, while the cucumber mosaic virus, which can devastate the cucurbit family, is carried by a range of different weeds including chickweed and groundsel.

2.2 Weed control practices

Vegetation management practices can be grouped in two basic categories i.e. nonchemical and chemical. Nonchemical methods include cultural controls, mechanical controls, and biological controls. Chemical method involves the use of chemical substances mostly referred to as herbicide to kill or suppress the growth of all kinds of plants especially noxious weeds (Bill, 2009). Weed management is often most successful when it involves all of these methods in an integrated approach (Barry *et al.,* 2007). The necessary condition for any successful weed control is the promotion of growth of the crop species (Howell and Martens, 2000).

2.2.1 Cultural control

Cultural weed control creates conditions that inhibit the growth of weeds and promote growth of preferred plants. For instance Plants cannot grow without adequate sunlight therefore Placing a barrier such as mulches of organic materials (e.g. wood chips) and inorganic materials (e.g. crushed coral or gravel) over the ground to exclude light inhibits weed growth (Barry *et al.,* 2007). Howell and Martens (2000) have further discussed in the following section some common cultural weed control practices.

2.2.1.1 Soil Fertility and Condition

In the 1930s, it was noted that heavy use of newly introduced chemical fertilizers in Germany brought about a very perceptible alteration in the proportion of different types of weed species. Some species which had formerly been very common as field weeds were rapidly disappearing, while other types of weeds were becoming much more prominent. We continue to see today that the type of fertility amendments one uses has a powerful effect on weed pressure, in both the number and species present (Howell and Martens, 2000).

2.2.1.2 Crop Competition

Since a vigorously growing crop is less likely to be adversely affected by weed competition, any practice that promotes the health and vigor of the crop plants will reduce weed pressure. It is essential to create conditions where the intended crop can establish dominance quickly. Even in conventional systems, where chemicals are used, crop competition and vigor are really the primary means of effective weed control. That is because many sprays are effective only for a relatively short time before they break down, are diluted by rainfall, or leach out of the weed germination zone altogether. The crop itself must be able to out compete with the weeds; otherwise the weeds will rapidly dominate (Howell and Martens, 2000).

2.2.1.3 Variety Selection

Careful selection of crop varieties is essential to limit weeds and pathogen problems and to satisfy market needs (Howell and Martens, 2000).

2.2.1.4 Crop Rotation

Continuous monoculture of any species, including well-managed organic grains, effectively selects for populations of weeds, pathogens and insects that are very well adapted to those conditions. Every year that such an environment is created, all adapted pests that escape control measures will reproduce prolifically. In a proper crop rotation, the environment changes each year and will deny pest populations in the previous year's favorable conditions (Howell and Martens, 2000).

2.2.1.5 Sanitation

It is possible to prevent many new weeds from being introduced onto the farm and to prevent existing weeds from producing large quantities of seed. The use of clean seed, mowing weeds around the edges of fields or after harvest to prevent weeds from developing seeds, and thoroughly composting manure before application can greatly reduce the introduction of weed seeds and difficult weed species. It is even possible to selectively hand-eradicate isolated outbreaks of new weeds, effectively avoiding future infestations. Planting clean, high-quality seed is essential to crop success (Howell and Martens, 2000).

2.2.1.6 Deep Shading Crops

A deep shading crop is one that intercepts most of the sunlight that strikes a field, keeping the ground dark enough to smother any weed seedling soon after emergence. Ideally, such a crop should provide complete shading early in the season and maintain it as late as possible. It is desirable for the crop to be tall and give heavy shade that is high enough to prevent weeds from breaking through the canopy and growing above the crop (Howell and Martens, 2000).

2.2.1.7 Allelopathy

One way that plants compete with each other is by releasing chemical substances that inhibit the growth of other plants. This is called "allelopathy" and should be viewed as one of nature's most effective ways that plants deal with competition (Howell and Martens, 2000).

2.2.2 Mechanical weed control

Mechanical weed control can be defined as any physical activity that inhibits unwanted plant growth (Bell and Dean, 2005). Mechanical, or manual, weed control techniques manage weed populations through physical methods that remove, injure, kill, or make the growing conditions unfavorable. Some of these methods cause direct damage to the weeds through complete removal or causing a lethal injury. Other techniques may alter the growing environment by eliminating light, increasing the temperature of the soil, or depriving the plant of carbon dioxide or oxygen (Tu *et al.,* 2001). Mechanical control techniques can be either selective or non-selective. A selective method has very little impact on non-target plants where as a non-selective method affects the entire area that is being treated. If mechanical control methods are applied at the optimal time and intensity, some weed species may be controlled or even eradicated (USFW, 2012). Examples of mechanical weed control methods are discussed below.

2.2.2.1 Weed Pulling

Pulling methods uproot and remove the weed from the soil. Weed pulling can be used to control some shrubs, tree saplings, and herbaceous plants. Annuals and tap-rooted weeds tend to be very susceptible to pulling. The effectiveness of this method is dependent on the removal of as much of the root system as possible (Tu *et al.,* 2001). Well established perennial weeds are much less effectively controlled because of the difficulty of removing all of the root system and perennating plant parts. Small herbaceous weeds may be pulled by hand but larger plants may require the use of puller tools like the Weed Wrench or the Root Talon (USFW, 2012) This technique has a little to no impact on neighbouring non-target plants and has a minimal effect on the growing environment (Bell and Dean, 2005).

2.2.2.2 Mowing

Mowing methods cut or shred the above ground of the weed and can prevent and reduce seed populations as well as restrict the growth of weeds (USFW, 2012). Mowing can be a very successful control method for many annual weeds. Mowing is most effective when it is performed before the weeds are able to set seed because it can reduce the number of flower stalks and prevent the spread of more seed. However, the biology of the weed must be considered before mowing (Craft, 1975). Brush cutting and weed eating are also mowing techniques that reduce the biomass of the weeds. This method is usually used in combination with other control methods such as burning or herbicide treatments (Tu *et al.,* 2001).

2.2.2.3 Mulching

Mulch is a layer of material that is spread on the ground. Compared with some other methods of weed control, mulch is relatively simple and inexpensive. Mulching smothers the weeds by excluding light and providing a physical barrier to impede their emergence (Tu *et al.,* 2001). Mulches may be organic or synthetic. Organic mulches consist of plant by products such as:

pine straw, wood chips, green waste, compost, leaves, and grass clippings. Synthetic mulches, also known as ground cover fabric, can be made from materials like polyethylene, polypropylene, or polyester. Organic and synthetic mulches may be used in combination with each other to increase the amount of weeds controlled (Rao, 2000).

2.2.2.4 Tillage

Tillage, also known as cultivation, is the turning over of the soil. This method is more often used in agricultural crops (Rao, 2000). Tillage can be performed on a small scale with tools such as small, hand pushed rotary tillers or on a large scale with tractor mounted plows (USFW, 2012). Tillage is able to control weeds because when the soil is overturned, the vegetative parts of the plants are damaged and the root systems are exposed causing desiccation. Generally, the younger the weed is, the more readily it can be controlled with tillage (Rao, 2000). To control mature perennial weeds, repeated tillage is necessary. By continually destroying new growth and damaging the root system, the weed's food stores are depleted until it can no longer re-sprout (Rao, 2000). Also, when the soil is overturned, the soil seed bank is disrupted which can cause dormant weed seeds to germinate in the absence of the previous competitors. These new weeds can also be controlled by continued tillage until the soil seed bank is depleted (Craft, 1975).

2.2.2.5 Soil Solarization

Soil solarization is a simple method of weed control that is accomplished by covering the soil with a layer of clear or black plastic. The plastic that covers the ground, traps heat energy from the sun and raises the temperature of the soil (Craft, 1975). Many weed seeds and vegetative propagules are not able to withstand the temperatures and are killed. For this method to be most effective it should be implemented during the summer months and the soil should be moist (Haynes, 1995). Also, cool season weeds are more susceptible to soil solarization than are warm season weeds (Craft, 1975). Using black plastic as a cover excludes light which can help to control plants that are growing whereas clear plastic has been shown to produce higher soil temperatures (Rao, 2000).

2.2.2.6 Fire

Burning and flaming can be economical and practical methods of weed control if used carefully. For most plants, fire causes the cell walls to rupture when they reach a temperature of 45°C to 55°C (Rao, 2000). Burning can be used to remove accumulated vegetation by destroying the dry, matured plant matter as well as killing the green new growth. Buried weed seeds and plant propagules may also be destroyed during burning, however, dry seeds are much less susceptible to the increased temperature (Rao, 2000). Flaming is used on a smaller scale and includes the use of a propane torch with a fan tip. Flaming may be used to control weeds along fences and paved areas or places where the soil may be too wet to hoe, dig, or till. Flaming is most effective on young weeds that are less than two inches tall but repeated treatments may control tougher perennial weeds (Haynes, 1995).

2.2.2.7 Flooding

Flooding is a method of control that requires the area being treated to be saturated at a depth of 15 to 30 cm for a period of 3 to 8 weeks. The saturation of the soil reduces the availability of oxygen to the plant roots thereby killing the weed (Rao, 2000). This method has been shown to be highly effective in controlling established perennial weeds and may also suppress annual weeds by reducing the weed seed populations (Craft, 1975).

2.2.3 Biological control

Biological control of weeds is the deliberate use of natural enemies to reduce the density of a particular weed to a tolerable level. The objective of biological weed control is not eradication but simply the reduction of the weed population to an economically low level. In fact for biological control to be continuously successful, small numbers of the weed host must always be present to assure the survival of the natural enemy (Watson, 1977). Insects have been most frequently used as biological control agents of weeds and this will likely continue. The reasons are that there have been major successes using phytophagous insects and almost all of the scientists working in biocontrol of weeds are entomologists. However, recent research has demonstrated the potential of other organisms, including plant pathogens, nematodes, and fish. An example of biological weed control is the moth borer from Argentina used to destroy prickly pear cactus in Hawaii and Australia. Currently, the Hawaii Department of Agriculture is testing insects to control ivy gourd (*Coccinea grandis*) in urban and forest areas (Barry *et al.,* 2007). Biological weed control has recently received renewed interest because it is an environmentally compatible method of weed control without residue and pollution problems. However, it is critical that the biological control agents do not become pests themselves. Considerable host-specificity testing is done prior to the release of biological control agents to ensure they will not pose a threat to non-target species such as native and agricultural plants (CSIRO, 2011).

2.2.4 Chemical weed control

Chemical weed control is a method of controlling weeds by the application of chemicals mainly herbicides. Further detail of chemical weed control and herbicides are given in the subsequent sections.

2.2.5 Integrated weed management

A key aspect to weed management is to integrate control methods into a management system. A good weed-management plan integrates two or more control measures into a management system (Beck, 2008). Integrated weed management implies utilizing all methods of weed control in such a manner as to achieve optimum control with the least negative impact on non-target organisms and the environment (Bell and Dean, 2005).

2.3 Herbicides

Herbicides also commonly known as weedicides are chemical substances that are used for killing all types of plants especially noxious weeds. In the US herbicides use account for 70% of all agricultural pesticides used each year and many of today's herbicides were introduced in the 60s and the 70s (Bill, 2009).

2.3.1 How herbicides work

Herbicides kill plants by causing a buildup of toxic substance, where the toxic substance stays at reasonably low levels. By inhabiting the target site (enzymes), herbicides cause substance to build up and damage the plant. This is how glyphosate herbicide works. In some other cases, the death of the target plants seems to occur from de-regulation of very carefully controlled process of cell growth. This is how herbicides such as 2-4-D are effective. The plant essentially grows itself to death (Martin, 2004). Herbicides offer the most effective, economical and practical way of weed management. Islam *et al.* (2000) compared hand weeding with different herbicides and found Pretilachlor (500 g. a.i. ha^{-1}) the most successful herbicide with higher yield and cost benefit ratio.

2.3.2 Global herbicide use

Herbicides are widely used as an important alternative to prevent excessive growth of weeds in agricultural crop land, particularly where conservation tillage is adopted. Herbicide use has increased dramatically around the world over the past 6 decades (Gianessi and Reigner, 2007). Few herbicides were in use in the 1950s. However, by 2001 approximately 1.14 billion kilograms of herbicides were applied globally for the control of undesirable vegetation in agricultural, silvicultural, lawn care, aquacultural, and irrigation/recreational water management activities (Kiely *et al.,* 2009). Twenty-eight percent of1992 the total mass of herbicides is applied in the United States, with the remaining 72 percent being applied elsewhere around the globe (Kiely *et al.,* 2009). Herbicides represent 36% of global pesticide use, followed by insecticides (25%), fungicides (10%) and other chemical classes (Kiely *et al.,* 2009).

2.4 Factors affecting the choice of chemical control

Many chemical control methods are available. Several factors should be considered when deciding which is best. Goals, funding limitations, proximity to sensitive areas, types of weeds, and stage of weed growth influence the choice of herbicide. It is also necessary to understand how various herbicides kill weeds, how to handle them safely, and what hazards they present. This understanding allows applicators to select products that provide the desired control while limiting health risks to themselves and others (Barry *et al.,* 2007).

2.4.1 Stages of weed growth

When assessing the effect of herbicide on plants, it is important to know the stage of development, state of health, nutritional status and the genetic make-up of the plant as well as cultivation practices and the climate. Barry *et al.* (2007) identified four main growth stages that grasses and broadleaf weeds go through and relate each stage with their control strategies. The stages are seedling, vegetative, flowering (reproduction) and maturity stage.

2.4.1.1 Seedling

Plants in the germination and early-seedling stage are likely to be severely damaged by herbicides. This applies to both weeds and crops, and therefore the timing of application is crucial for the effect of many herbicides (Streibig, 2003). In respect to control strategy, the seedling stage of growth is the same for all types of weeds. Because seedlings are small and tender, less effort is required for control at this stage of growth than at any other. This is true whether nonchemical or chemical control is used. Herbicides with either foliar contact or residual soil activity are usually very effective against seedlings (Barry *et al.,* 2007).

2.4.1.2 Vegetative—annuals

Generally, we get the best effect of herbicides if they are applied when plants are either rapidly growing or are weakened by rapid growth, which temporarily depletes or exhausts their reserves (Streibig, 2003) During the vegetative stage of growth, energy produced by the plant goes into the production of stems, leaves, and roots. Control at this stage is still possible but sometimes more difficult than at the seedling stage. Cultivation, mowing, and post emergence herbicides are effective controls (Barry *et al.,* 2007).

2.4.1.3 Vegetative—perennials

When the plant is small, part of the energy used to produce stems and leaves comes from underground roots and stems. As the plant grows, more energy is produced in the plant's leaves. Some of this is moved to the underground parts for growth and storage. Translocated herbicides provide some control at this stage (Barry *et al.,* 2007). For many perennial weeds, the most sensitive stage is when new shoots are still in a young stage and their development has depleted the reserves of nutrients of the root system (Streibig, 2003).

2.4.1.4 Flowering—annuals

When a plant changes from the vegetative to the flowering stage of growth, most of its energy goes into the production of seed. As plants reach this mature stage, they usually are much harder to control by either mechanical or chemical methods than at earlier growth stages (Barry *et al.,* 2007).

2.4.1.5 Flowering—perennials

At this stage the plant's energy goes into the production of flowers and seeds. Food storage in the roots begins during these stages and continues through maturity. Chemical control is more effective at the flower-bud stage just before flowering (Barry *et al.,* 2007).

2.4.1.6 Maturity—annuals

Maturity and seed set complete the life cycle of annuals. Chemical control is usually not effective at this stage, because there is little or no movement of materials in the plant. Once the seeds are mature, mechanical and chemical controls are ineffective (Barry *et al.,* 2007).

2.4.1.7 Maturity—perennials

Mature perennial plants are more difficult to control, in some cases because of their size. Only the above-ground parts are affected when they are sprayed with contact herbicide. The underground roots and stems remain alive and send up new plant growth. Control with translocated herbicide is less effective when mature perennials are not in a growth flush. Woody plants go through the same four growth stages as other perennial plants. They do not die back to the ground but may lose their foliage during cooler months. Woody plants can be controlled with herbicides at any time, but control is easiest when the plants are small. Foliar treatments can be used at any time woody plants are actively producing leaves. They usually work best when the leaves are young (Barry *et al.,* 2007).

2.5 Environmental Effects of Herbicides

Nearly all herbicides are potentially dangerous in one way or another, but they are not likely to cause injury if used properly and if recommended precautions are observed. Because several kinds of danger are associated with handling and applying herbicides, and possible injury is not limited to the operator, the potential effects on all of the following should be considered: operator and handler, livestock, desirable plants, fish and wildlife, water quality, and equipment (NAVFAC MO-314 (1989).

2.5.1 Effects on operators and Handlers

The person who hauls, mixes, and applies the herbicidal spray, or spreads the dry product, could be poisoned from swallowing the herbicide, by skin absorption, or by inhalation. In each case, there is greater danger from the concentrated material than from the diluted spray solution or suspension (NAVFAC MO-314 (1989).

2.5.2 Effects on Desirable Plants.

Herbicides inevitably will impact on non-target species due to limitations in selectivity. Herbicide persistence and reapplication intervals are key factors determining the demographic impacts of herbicides on native plants (Crone *et al*., 2009). Certain precautions in the use of herbicides are necessary to prevent damage to nearby desirable plants. This damage may result from spray drift, washing, or leaching. Drift hazards are greatest when herbicides are sprayed on foliage. Danger is decreased with granular applications of nonvolatile herbicides. Spray drift occurs not only with volatile herbicides, i.e. high-volatile esters of 2, 4-D, but also with sprays that are atomized into a mist by high pressure and a small nozzle opening (NAVFAC MO-314, 1989). Wash-off migration of herbicides can be an important hazard on slopes, bare ground, and pavements. The herbicide may be carried by surface runoff water to valuable plants down slope. Problems often occur when water runs across an area treated with soil sterilant herbicides onto lawns or ornamental beds or among trees. Leaching moves chemicals downward through the soil. If the herbicides are readily absorbed by roots, plants whose roots extend under the treated area are likely to be injured. Desirable trees growing adjacent to areas treated with soil sterilants, or near ponds treated with some aquatic herbicides, are often injured (NAVFAC MO-314, 1989). According to Locke *et al.* (1995), Sublethal treatment of cotton with Roundup "severely affects seed germination, vigor and stand establishment under field conditions." At the lowest glyphosate rate tested, seed germination was reduced between 24 and 85 percent and seedling weight was reduced between 19 and 83 percent.

Glyphosate treatment has been found to increase the susceptibility of crop plants to a number of diseases. For example, glyphosate increased the susceptibility of tomatoes to crown and root disease (Brammal and Higgins, 1988); reduced the ability of bean plants to defend themselves against the disease anthracnose(Johal and Rahe, 1988); increased the growth of take-all disease in soil from a wheat field and decreased the proportion of soil fungi which was antagonistic to the take-all fungus (Mekwatanakarn and Sivassithamparam, 1987); and increased soil populations of two important root pathogens of peas (Kawate, 1997). In addition, Roundup injection of lodgepole pine inhibited the defensive response of the tree to blue stain fungus (Bergvinson and Borden, 1992).

2.5.3 Effect on Fish and other Wildlife

Applications of herbicides may have primary and secondary effects on wildlife. Primary effects are from direct poisoning. There are a few herbicides, such as the dinitros, that can directly poison animals; and copper sulphate can poison fish and fish food organisms, A few herbicides are very toxic to fish; but some, such as 2,4-D, can be used safely to control aquatic weeds. In general, most injury results from excessive application rates and spillage. Effects of herbicides on wildlife include animal poisoning due to changes in chemical composition of plants, and effects on organisms in the food chain (NAVFAC MO-314, 1989).

2.5.4 Contamination of Ground Water

The wide-spread use of herbicides in agriculture has resulted in frequent chemical detections in surface and ground waters (Gilliom, 2007). Examples include farm ponds in Ontario, Canada, contaminated by runoff from an agricultural treatment and a spill (Frank, 1990); the runoff from a watersheds treated with Roundup during production of no-till corn and fescue (Edward *et al.,* 1980); contaminated surface water in the Netherlands'; seven U.S. wells, one in Texas, six in Virginia contaminated with glyphosate (U.S EPA, 1992); contaminated forest streams in Oregon and Washington (Rashin and Grader, 1993); contaminated streams near Puget Sound, Washington (Bortleson and Davies, 1997); and contaminated wells under electrical substations treated with glyphosate (Smith *et al.,* 1996). The majority of herbicides used is highly water soluble and are therefore prone to runoff from terrestrial environments. In addition, spray drift and atmospheric deposition can contribute to herbicide contamination of aquatic environments. Lastly, selected herbicides are deliberately applied to aquatic environments for controlling nuisance aquatic vegetation. Although aquatic herbicide exposure by organisms has been widely documented, these exposures are not necessarily related to adverse non-target ecological effects on natural communities in aquatic environments (Gilliom, 2007).

2.5.5 Managing the effects of herbicides on non target organism

Herbicides are basically applied to suppress or control certain weeds. However, plant species may vary with respect to their ability to metabolize the herbicide. Such ability to metabolize or detoxify the herbicide contributes to the basis for the selectivity shown by tolerant versus susceptible plant species. Herbicide drift is of major concern if it reaches non-target areas or if humans, pets, or domestic livestock are inadvertently exposed to it. Generally, herbicides will have low toxicity to animal species and pose negligible risk for mammals, birds and fish when used as instructed by the label.

2.5.5.1 Drift management

Pesticide drift is defined as the physical movement of pesticide particles and vapor, blown during or soon after application to any site other than that intended. When pesticide solutions are sprayed, droplets are produced. Many of these droplets are so small that they stay suspended in the air to be carried by wind until they evaporate, contact something, or drop to the ground (Barry *et al.,* 2007). The most common pesticide drift is movement of spray droplets or, in the case of dry formulations, dust particles. Spray drift is directly influenced by the weather conditions, topography, crop or area being sprayed, application equipment and methods, and precision of the applicator. Drift of a chemical with low vapor pressure is called vapor drift. Vapors or gases can drift in harmful concentrations, even in the absence of wind. Some pesticide products are volatile or capable of vaporizing from soil and leaf surfaces in potentially harmful concentrations after application. Vapour of some herbicides can severely damage and even kill desirable plants (Barry *et al.,* 2007).

2.5.5.2 Managing the effect on Human and other Animals

Herbicide label may contain instructions to protect susceptible non-target species such as recommendations to minimize drift or avoid run-off. In view of this, it is relevant to read and follow all label directions and precautions to minimize potential exposure to non-target species. People and animals should be kept away from the area during herbicide application. They should also be kept from the area of potential drift and runoff until the spray has dried or the dust has settled. Some pesticides, other than herbicides, are potentially hazardous for a long time. Therefore, label directions concerning reentry into the sprayed area should be followed. The effects of herbicides on non-target organisms such as fish, birds, and beneficial insects must be considered. In studies of people (mostly farmers) exposed to glyphosate herbicides, exposure is associated with an increased risk of miscarriages, premature birth, and the cancer, non-Hodgkin's lymphoma (Cox, 2000). Barry *et al.* (2007), advised pesticide applicators to read the precautionary statements on the pesticide label before applying the product.

2.5.5.3 Degradation of herbicides

Once herbicides are released into the environment, to affect mainly weeds as their primary targets, they have to be degraded and eliminated during time to avoid long-lasting negative effects on soil microbiology or groundwater safety. Since a large number of herbicides have been introduced during the past four decades, the fate of these compounds is becoming increasingly important.

2.6 Classification of Herbicides

Fedtke (1982) classified herbicides into five major categories namely degree of selectivity, time of application, methods of application, translocation in plants and mechanism of action. These categories are by no means rigidly distinct. Many foliage-applied herbicides have significant soil activity, and the balance between activities can often be shifted by the size of the dose, formulations and adjuvant. For contact herbicides, however, transport is not directly related to long distance transport in xylem and or phloem from the site of uptake. Some herbicides, for example paraquat and diquat, are easily translocated in the absence of light under controlled conditions and sometimes in the field (Fedtke, 1982). The criteria of classification do not mean that these criteria themselves are independent. For example the degree of selectivity is very much dependent upon the time and method of application. Again categories are not rigidly distinct; many alleged foliage-applied herbicides have significant soil activity, and the balance between activities can often be shifted by dose rates, formulations and adjuvants (Streibig, 2003).

2.6.1 Degree of selectivity

For practical use in crops, we usually differentiate between selective and non-selective herbicides. The selectivity is not absolute, but is governed by the amount of the chemical applied, the way it is applied, the degree of wetting of the foliage, the amount of rainfall following the application, the tolerance of different plants to a specific chemical and the differences in the growth habits of the crops and the weeds (Martin, 2004).

2.6.1.1 Selective herbicides

Selective herbicides are used in dose rates which adequately control the weeds without seriously affecting the crop (Streibig, 2003). Some selective herbicides can be "nonselective" and kill untargeted plants when improperly applied at levels in excess of those specified on the product label (Barry *et al.,* 2007). The selective nature of some herbicides allows applicators to use them to eliminate weeds without damaging desirable plants in the same location. To properly use selective herbicides, applicators need to know whether the weed is a grass, broadleaf, sedge, or woody plant and whether it is an annual, biennial, or perennial. An example of a selective herbicide is 2-methyl-4-chlorophenoxyacetic acid (MCPA), which is used to control broadleaf weeds but leaves grasses unaffected. To be selective, the herbicides must first affect the target weed, not the crop. Then it must be metabolized, or broken down by the crop plant and not by the weed itself (Martin, 2004).

2.6.1.2 Nonselective herbicides

Nonselective herbicides kill vegetation without regard to type or species. Paraquat, glyphosate, dinoseb, and bromacil are examples of nonselective herbicides. Non selective herbicides may be "selective" when applied at low rates, in that they will kill sensitive plants but leave other plants only damaged, stunted, or unaffected, depending on the plant and the application rate. In general, application of herbicide at rates other than those specified on the label may constitute a misuse of the product and may result in reduced efficacy (Barry *et al.*, 2007). The non selective ones include glyphosate and they affect most plants both grasses and broad leaved (Martin, 2004).

2.6.2 Time of application

Herbicides are also classified in terms of the time of application. These are pre-emergence herbicide and post emergence herbicides. As the name implies, pre-emergence herbicides must be applied before the weeds emerge and they control weeds as they germinate. Pre-emergent herbicides work in a number of ways. In short, they are applied to the soil and either taken up by the emerging root, shoot, or a combination of both. The specific site of 'root' or 'shoot' uptake varies between each herbicide and mode of action, giving each herbicide group its unique weed control attributes. All pre-emergent herbicides however need at least some soil moisture or ideally rainfall following application to become 'activated' and available to weed seeds. Until this occurs, uptake may be limited and weed control may be poor. Some are sensitive to sunlight and need to be mixed into the soil to minimize losses. Some are volatile and can be lost to evaporation, especially from wet soil (Haskins, 2012). Most have residual activity that provides season-long control, with some carrying over to the following year. They are broad-spectrum (non-selective) but will not control established perennial weeds.

Post-emergence herbicides on the other hand control weeds after they emerge. They can be classified in different ways. They can either be labeled as contact or systemic herbicides. Contact herbicides kill "only the green tissues contacted by the spray" whereas systemic herbicides "move within the plant from the point of application to other plant parts" effectively killing the root. Post-emergent herbicide can also be categorized as selective and non-selective herbicides (Johns, 2010). To be most effective, post- emergence herbicides may require a surfactant or other additive. They exhibit no residual activity, and must be re-applied as needed. Post-emergence herbicides have the tendency of causing injury to the untargeted crop.

2.6.3 Method of application

The major groups of herbicides are further classified into three groups with respect to their mode of application. They are soil applied herbicides, foliar applied herbicides, and aquatic herbicides.

2.6.4 Soil-Applied Herbicides

The soil applied herbicides are grouped into two. These are root inhibitors and shoot inhibitor herbicides. Root inhibitors have little or no foliar activity and are mostly applied pre-emergence for control of seedling grasses and some broadleaf plants in certain crops. These herbicides inhibit the steps in plant cell division responsible for chromosome separation and cell wall formation (Ross and Childs 1996). Roots appear club-shaped. Examples of root inhibitors include trifluralin and pendithalin. Shoot inhibitor herbicides are commonly applied at the pre-emergence stage for control of seedling grasses, some broadleaf plants, and some perennials from tubers and rhizomes (Ross and Childs 1996). Injury appears as malformed, dark-green shoots and leaves on injured young plants (Ross and Childs 1996). Shoot inhibitor herbicides are generally used in crops. Examples of shoot inhibitors include alachlor and butylate.

The persistence of herbicide in the soil depends on the product's characteristics and rate of application, the soil's texture and organic matter content, the weather (precipitation and temperature), and the terrain as it affects surface flow. The herbicide effect can be lost when it remains concentrated at the soil surface, partially leaches (diluting it) and is flushed downward through the soil in a band, allowing new weeds to grow above (Barry *et al.,* 2007). Three factors affect the movement of herbicide applied to soil: soil texture-how much sand, silt, and clay it contains, soil organic matter level and slope (Barry *et al.,* 2007).

2.6.5 Foliar- Applied Herbicides

Foliar applied herbicides are targeted to the leaves of growing plants, usually as sprays, but in a few cases as dust applications (Ross and Childs, 1996). The foliar-applied herbicides have been divided into three categories according to how they move through a plant. These are; downwardly mobile (symplastically translocated) herbicides, upwardly mobile herbicides (apoplastically translocated) herbicides and contact (non-translocated) herbicides (Ross and Childs, 1996).

2.6.6 Downwardly Mobile Herbicides (Symplastically Translocated)

These herbicides are designed to move from the source of sugar production (leaves) to the actively growing parts of the plant (points of energy use). These herbicides interfere or completely eliminate plant growth. Downwardly mobile herbicides can be divided into four different chemistry groups:

2.6.6.1 Auxin Growth Regulators

Auxin growth regulators are used for control of annual and perennial broadleaf plants in grass crops and non-crop situations. Bending and twisting of leaves and stems is evident almost immediately after application (Ross and Childs, 1996). Delayed symptoms include misshapen leaves, stems, flowers, and abnormal roots (Ross and Childs, 1996). These herbicides are highly non-specific and injury to non-target plants can be a problem. Examples of common auxin growth regulators include picloram, dicamba, and 2, 4-D.

2.6.6.2 Amino Acid Inhibitors (Aromatic)

Amino acid inhibitors are used to control annual grasses, cool-season grasses and certain broadleaf plants. Glyphosate and sulfosate are the two main compounds with this mode of action. These herbicides are effective only when applied to foliage, as they are rapidly deactivated in the soil. They are relatively non-selective herbicides, but several glyphosate tolerant crops are currently being marketed or tested.

2.6.6.3 Amino Acid Inhibitors (Branched-chain)

This second type of amino acid inhibitor includes several different chemistry groups. These herbicides stunt root growth, which in time starves the plant. Complete symptom development is very slow and may take over three weeks (Ross and Childs, 1996). These herbicides are used at the pre- and post-emergence stage on broadleaf weeds and annual grasses in crop and non-crop situations. Examples of branched-chain amino acid inhibitors include imazapyr, chlorsulfuron, nicosulfuron, and metsulfuron.

2.6.6.4 Grass Meristem Destroyers

Grass meristem destroyers are used for the selective removal of most grass species from the stands of any non-grass crop. There is also some selectivity of the herbicides in killing grass species grass species. These herbicides cause the discoloration and the disintegration of meristematic tissue at and above the nodes of plants. Leaves turn, yellow, reddish, and sometimes wilt (Ross and Childs, 1996). Examples of grass meristem destroyers include fluazifop, quizalofop, and sethoxydim. Grass meristem destroyers should be used early post-emergence on annual grasses and at post-emergence but before the boot stage (the stage just prior to inflorescence emergence) of established perennial grasses (Ross and Childs, 1996).

2.6.7 Upwardly Mobile Herbicides (Apoplastically Translocated)

Upwardly mobile herbicides move upward through the transpiration stream of the plant. These herbicides are photosynthetic inhibitors and they move upward through the transpiration stream of the plant. Symptoms develop from the bottom to the top on plant shoots (Ross and Childs, 1996). Chlorosis first appears between leaf veins and along the margins which is later followed by death of the tissue (Ross and Childs, 1996). Any potential control of established perennials must come from continued soil uptake and not movement downward through the plant from the shoots (Ross and Childs, 1996). These herbicides typically have excellent soil activity and are used at pre and post-emergence stages in certain annual and established perennial crops. They are also used in non-crop vegetation for general weed control. Examples of photosynthetic inhibitors include atrazine, metribuzin, and tebithuron.

2.6.8 Contact Herbicides (Non-Translocated)

Contact herbicides only damage the tissue they are applied to, killing plants by desiccating leaf and stem tissue (Bell and Dean, 2005). Contact herbicides are cell membrane destroyers. This group results in the rapid disruption of cell membranes and very rapid kill of plants. The compounds penetrate the cytoplasm, and destroy the cell membranes almost immediately. The rapid disruption of the cell membranes prevents translocation to other region of the plant (Ross and Childs, 1996). Severe injury is evident hours after application and maximum kill is attained in a week or less. Partial coverage of a plant with spray results in spotting or partial shoot kill (Ross and Childs, 1996). These herbicides are non-selective and damage to non-target species is a common problem. Examples of cell membrane destroyers include paraquat and glufosinate.

2.7 Herbicides Used For the Experiment

2.7.1 Glyphosate

Glyphosate, N-(phosphonomethyl) glycine, is a systemic and nonselective herbicide used to kill broadleaved, grass, and sedge species (WHO, 1994). It has been registered in the U.S. since 1974 and is used to control weeds in a wide variety of agricultural, urban, lawn and garden, aquatic, and forestry ecosystems (US EPA, 1986). Most glyphosate herbicides contain the isopropylamine salt of glyphosate (US EPA, 1993). Considerable research has established that glyphosate inhibits an enzyme pathway, the shikimic acid pathway, preventing plants from synthesizing three aromatic amino acids (phenylalanine, tyrosine and tryptophan). These amino acids are essential for growth and survival of most plants. The key enzyme inhibited by glyphosate is called EPSP synthase (Franz *et al.,* 1997). Glyphosate also "may inhibit or repress" two other enzymes, involved in the synthesis of the same amino acids (US EPA, 1986). These enzymes are present in higher plants and microorganisms but not in animals (Franz *et al.,* 1997). Glyphosate can affect plant enzymes not connected with the shikimic acid pathway. In sugar cane, it reduces the activity of one of the enzymes involved in sugar metabolism (Su, 1992). It also inhibits a major detoxification enzyme in plants (Lamb, 1998). Glyphosate has been called "extremely persistent" by the U.S. Environmental Protection Agency, and half lives of over 100 days have been measured in field tests in Iowa and New York. Glyphosate has been found in streams following agricultural, urban, and forestry applications (Cox, 2000). As a broad-spectrum herbicide, glyphosate has potent acutely toxic effects on most plant species. There are also other kinds of serious effects. These include effects on endangered species, reduced seed quality, reduction in the ability to fix nitrogen, increased susceptibility to plant diseases, and reduction in the activity of mycorrhizal fungi (Cox, 2000). Plants that are resistant to glyphosate are able to tolerate treatment without showing signs of toxicity. Although many weed scientists argue that "it is nearly impossible for glyphosate resistance to evolve in weeds (Gressel, 1996)." Others argue that "there are few constraints to weeds evolving resistance." The second group of scientists appears to be correct. In 1996 an Australian researcher reported that a population of annual ryegrass had developed resistance and tolerated five times the recommended field application rate (Sindel, 1996).

2.7.2 Paraquat

Paraquat is nonselective contact herbicide that binds strongly to soil, where it is highly persistent (Mergel, 2010). The compound's most common presentation is in the form of salts, which are both colorless and odorless, although certain technical formulations may present as white or pale yellow, as well as emit an ammonia-like smell. Paraquat also goes by the more technical name, paraquat dichloride (Mergel, 2010). Paraquat is quaternary ammonium herbicides. The site of action for quaternary ammonium herbicides such as paraquat and diquat is in the chloroplast. Paraquat is known to act on the photosystems I (PSI) within the photosynthetic membrane. The free electrons from the PSI react with the paraquat ion to give a free radical form that interferes with oxygen leading to superoxides. The production of Reactive Oxygen Species (ROS) in turn results in lipid peroxidation and photo bleaching (Duke *et al.*, 2006). Thus, paraquat acts in the presence of light and the herbicidal activity increases with increased light intensity. Paraquat is highly persistent in the soil environment, with reported field half-lives of greater than 1000 days (Wauchope *et al.,* 1992). The reported half-life for paraquat in one study ranged from 16 months (aerobic laboratory conditions) to 13 years (field study) (Rao and Davidson, 1980). Ultraviolet light, sunlight, and soil microorganisms can degrade paraquat to products which are less toxic than the parent compound. The strong affinity for adsorption by soil particles and organic matter may limit the bioavailability of paraquat to plants, earthworms, and microorganisms (Wauchope *et al.*, 1992). The bound residues may persist indefinitely and can be transported in runoff with the sediment. Paraquat is not significantly mobile in most soils. That which does not become associated with soil particles can be decomposed to a nontoxic end product by soil bacteria (Wagner, 1981). Thus, paraquat does not present a high risk of groundwater contamination. Of 721 groundwater samples analyzed, only one contained paraquat at a concentration of 20 mg/L (US EPA, 1987). Paraquat is a highly toxic compound in EPA toxicity class I. this makes paraquat a Restricted Use Pesticide (RUP). RUPs may be purchased and used only by certified applicators (EXTOXNET, 1996). Although paraquat is now rarely used in the United States, it is still widely applied in developing countries (Mergel, 2010).

2.8 *C. odorata*

2.8.1 Botanical Description of *Cedrela odorata*

Cedro hembra (*C. odorata)* also known as Spanish-cedar in English commerce, is the most widely distributed and commercially important species in the genus *Cedrela.* The genus cedrela has undergone two major systematic revisions since 1960. The most recent revision reduced the number of species to seven (Styles, 1981). The common cedro, *Cedrela odorata* L., embraces 28 other named species, including *C. mexicana C. odorata* is a monoecious, deciduous, and medium-sized to large tree. According to Orwa *et al.,* (2009), *C. odorata* can grow up to 40m tall and even 60m in South America. Its bole is straight, cylindrical and branchless for up to 25-120cm (max. 300cm) diameter. Buttresses are absent or small and up to 2 m high; bark surface rough and fissured, reddish brown especially near the base of the bole and greyish higher up; inner bark pink or purplish-red. Branchlets are finely to conspicuously lenticellate, Leaves alternate, paripinnate with (min. 5) 6-12 (max. 15) pairs of leaflets; leaflets opposite to alternate, ovate to oblong-lanceolate, 5-16 cm long, usually glabrous, base oblique; apex acute to shortly acuminate. Inflorescence in terminal panicles with flowers being unisexual, but with well developed vestiges of the opposite sex, actinomorphic, pentamerous, greenish-white, subsessile, 6-9 mm long and possesses a garlic smell. Calyx cup shaped, split on one side, shallowly to deeply toothed; petals free, imbricate and adnate for 1/3 of their length, forming into a long, columnar androgynophore by a medium carina (therefore preventing their spreading in open flowers), white or cream tinged red near the margin. Stamens 5, free, but adnate to the androgynophore below; anthers dorsifixed, opening by longitudinal slits; ovary 5-locular, pubescent; each locule with 10-14ovules; style short, stigma discoid. Fruit a pendulous, reddish-brown capsule with 5 thin, woody valves, oblong-ellipsoid, to obovoid (min. 1.5) 2-3.5 (max. 4) cm long. Seed a sharply angled or winged columella Seedling with epigeal germination; cotyledons leaf-like; first leaves opposite, 3-foliolate with entire leaflets (Lemmens, 2008).

2.8.2 Ecology of *C. odorata*

In its natural area of distribution, *C. odorata* is found in both primary and secondary evergreen to semi-deciduous lowland or lower montane rainforest. It demands light and does not tolerate water logging or flooding. Widely distributed in wet forests of low elevations in Tropical America. Native apparently throughout West Indies in Greater Antilles and Lesser Antilles to Trinidad and Tobago, the range spread by cultivation. The plant is also native in continental tropical America from Mexico to Ecuador, Peru, Brazil and French Guyana. Trees are best planted in regions with very fertile soils and with perfect drainage that results in the good aeration of the soil required by the root system. Drought for part of the year does not adversely affect the health of the tree. In its natural habitat, removing trees around the seed tree and gradually opening up the canopy in the forest can encourage regeneration. In research plots in Papua New Guinea, the latter method has been shown to encourage growth; however, it increases the risk of insect attack. Because of the valuable wood, the native trees of this species are now found only in scattered, remote areas in Puerto Rico, chiefly in the moist limestone and lower cordillera forest regions (Orwa *et al*., 2009).

2.8.3 Biophysical Limits of *C. odorata*

C. odorata requires an altitude of 0-1900 m, Mean annual temperature of 22-26°C. In Uganda, *C. odorata* grows well in the warm and moist climate near the Lake Victoria (Lemmens, 2008). The Mean annual rainfall ranges between 1000mm and 3700 mm. (Orwa *et al*., 2009). It tolerates some drought once the tree is well established. *C. odorata* is not demanding of soil nutrients but tolerate soils high in calcium. Lemmens (2008) has further indicated that, *C. odorata* prefers well drained sites on a variety of soils, but is usually more common on limestone derived soil. It also grows on well drained sites over weakly acidic soils derived from volcanic rock (ultisols) and tolerates heavy soil (Orwa *et al*., 2009).

2.8.4 Reproduction and Early Growth of *C. odorata*

2.8.4.1 Flowering and Fruiting

C. odorata's reproductive cycle is synchronized with the growing season of the site; throughout its range it flowers at the beginning of the rainy season. Flowering begins when new leaves are expanding. The large and much-branched inflorescences bear numerous small, five-part, symmetrical greenish-white flower. Fruit development takes about 9 or 10 months and fruits ripen during the next dry season. Trees fruit at an age of 10 to 12 years.

2.8.4.2 Seed Production and Dissemination

Fruits open from the top downward to release 40 to 50 winged seeds when ripe. Seed weight is about 8 to 10 percent of dry fruit weight. One kilogram (2.2 lb) contains 20,000 to 50,000 seeds (9,100 to 22,700/lb, approximately). Seeds are 20 to 25 mm (0.75 to 1.0 in) long, wing included, and are wind dispersed. Heavy seed crops are produced annually in some areas and biennially or irregularly in others (Miller *et al.,* 1957). Seeds are shed during the dry season.

They lose viability quickly if not stored very dry at reduced temperatures (Chaplin, 1980). Germination begins with the onset of the rainy season and is epigeous. Vigorous germination is the rule, with seed viability reportedly up to 90 percent (Mas and Luyano, 1974). Germination is rapid, usually completed within 2 to 4 weeks.

2.8.4.3 Seedling growth and Development

Early development of the seedling is rapid as long as moisture and light are adequate (Whitmore, 1971). Seedlings may attain a height of 40-50cm after 3 month and 130-150cm after 12 months. Early mean annual growth may be up to 2.3m in height and 4.8cm in diameter under favourable site conditions (Lemmens, 2008). In a plantation in Ghana, mean annual height and diameter increments decreased from 4.8 m and 5.4 cm, respectively, in the 2nd year to 1.4 m and 2.1 cm in the 15th year. In Côte d'Ivoire the best provenances reach a mean diameter of 23–27 cm after 14 years and of 45–51 cm after 24 years. A tree planted in Uganda reached 35 m tall after 20 years. In the east Usambara mountains (Tanzania) 50-year-old trees were 26–34 m tall, with a bole 14–21 m long and 40–50 cm in diameter. The root system is superficial. First flowering can be expected after 10–15 years. Flowering is annual, but good seed production occurs every 1–2 years. The flowers are pollinated by insects such as bees and moths. Fruits ripen about 3 months after flowering (Lemmens, 2008). Shade-grown seedlings saturate photosynthetically at low intensities and are shade tolerant, but sun-grown seedlings require high light intensities for best growth (Inoue, 1980). Shade-grown seedlings are susceptible to sunscald and subsequent insect attack when moved to sun (Omoyiola, 1972). Early growth is vigorous under partial shade, when the shoot borer attack is not severe (Whitmore, 1971). In natural forest, high seedling densities are common near fruiting trees shortly after the beginning of the rainy season, but most of these seedlings disappear by the middle of the rains or a little later; this high natural mortality may be due to shade or competition but is thought to be partly due to damping off or other root problems (Mas and Luyano, 1974).

2.8.5 Damaging Agents of *C. odorata*

C. odorata can tolerate some crown damage by hurricanes and will often resprout. Shade-grown seedlings are sensitive to sunscald after which they become more vulnerable to insect attack. *C. odorata* from tropical provenances is not likely to be frost tolerant. Provenances showing frost resistance grow more slowly than tropical provenances (Malimbwi, 1978, Omoyiola, 1973). Plantations of *C. odorata* have suffered snail damage in Malaysia and Africa. Slugs killed some nursery stock of an exotic provenance in the Virgin Islands. Beetle damage is a problem in some plantations in Africa, but evidently not in the New World (Malimbwi, 1978, Omoyiola, 1973). The most serious insect pest of *C. odorata* is the mahogany shootborer *Hypsipyla grandella* (Holdridge, 1976).

2.8.6 *C. odorata* Plantation Management

Trial timber plantations of *C. odorata* have been established in Côte d'Ivoire, Ghana, Congo, Uganda, Tanzania, Madagascar and South Africa. Tests in Ghana showed that application of 200 ml of 15:15:15 NPK fertilizer solution to seedlings in pots filled with sandy loam once in every 1–2 weeks increased stem height and diameter growth significantly; the optimum concentration was 1.2–1.6 g/l. Adding compost to the pots also had a positive effect on seedling growth. *C. odorata* cannot be managed by coppicing. As the root system is superficial, there is some risk of wind damage and therefore thinning should be executed carefully. In Fiji, *C. odorata* proved to be vulnerable to being blown over by wind (Orwa *et al.,* 2009). Pruning is not required when *C. odorata* is grown as a stand, but trees affected by Hypsipyla attack may need pruning to remove multiple leaders formed. In mixed stands, it is realistic to raise only 10-20 high-quality trees/ha. Well-formed, straight stems are usual except in trees grown in open places. The tree does not coppice. During the 1st 9 years in trial plantations of *C. odorata* in Java, the mean annual increment was 17 cubic m/ha at 650 m altitude and 28 cubic m/ha at 800 m altitude. A 40-year-old plantation in Nigeria yielded a timber volume of 445 cubic m/ha. *C. odorata* shows potential for plantations, as it is fast growing and produces multipurpose timber. Weeding during the first year is necessary. *C. odorata* is a fast growing, light demanding species and in natural conditions it is long lived pioneer that tolerates shade only temporarily (Orwa *et al.,* 2009). In enrichment planting it is important to ensure sufficient overhead light. Although tolerant of weeds during the seedling stage (Whitmore, 1976), *C. odorata* is classed as intolerant of weeds and shade at the sapling stage and beyond (Malimbwi, 1978). Its thin and spreading crown of light green leaves suggests the habit of a light demanding species as does its potential for fast growth and its appearance after fire (Malimbwi, 1978), in hedgerows (Mas and Luyano, 1974) and on ruins (Raunio, 1973). It is best described as late successional, as it has a moderately long life span.

CHAPTER THREE

3.0 MATERIALS AND METHOD

3.1 Study Area

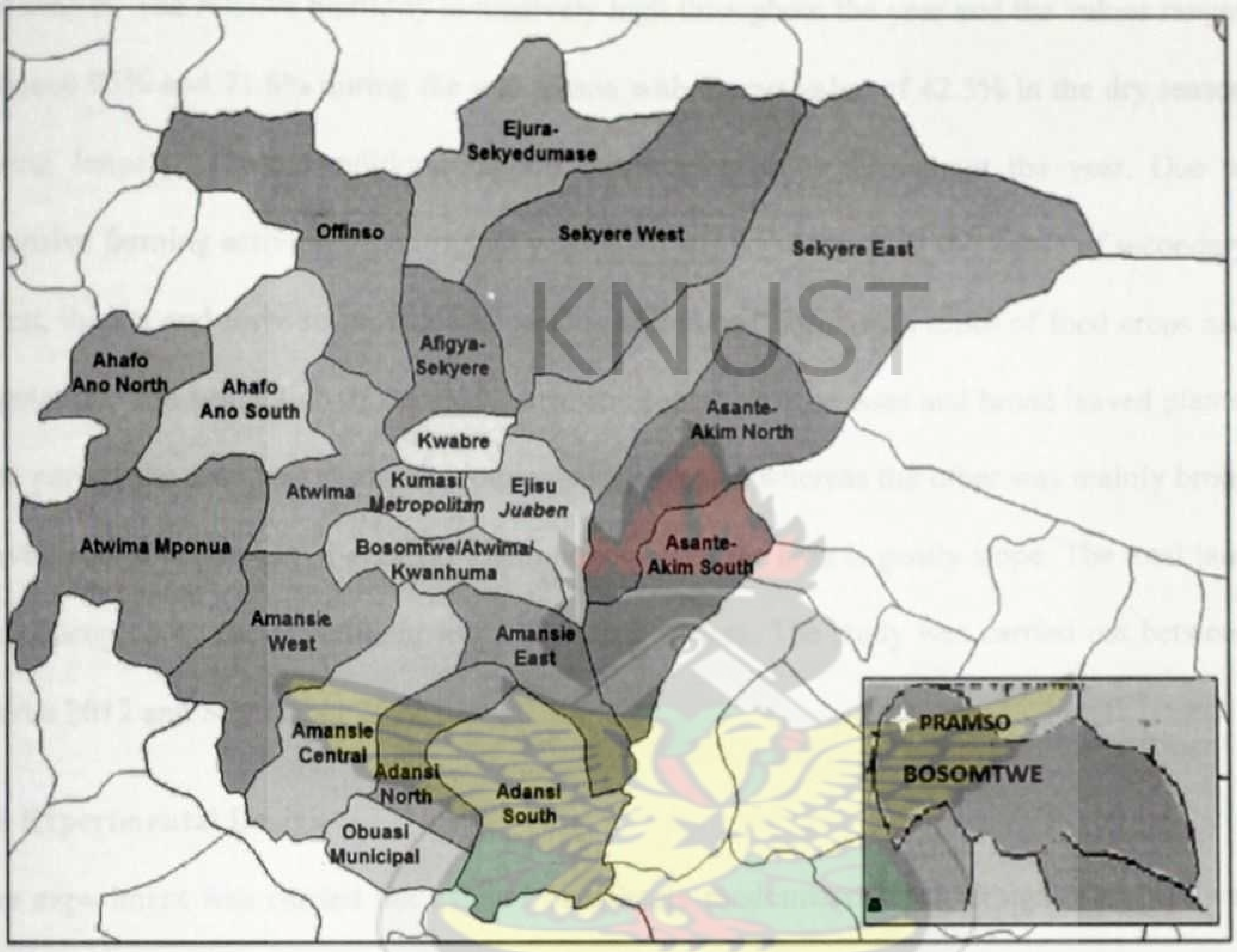

Figure 1. Map of Ashanti Region. Inset, Bosomtwe District Showing Pramso

The research was carried out by conducting a field experiment on plot 15 at Kokobiriko near Pramso in the Bosomtwe district (Figure 1) which is located in the central portion of Ashanti Region of Ghana on latitude 6^0 32^1N and longitude 1^0 29^1W. The Bosomtwe district where the study was conducted falls within the forest belt of the Ashanti Region and it is within the West Semi-equatorial climate region with a rainfall regime typical of the moist semi-deciduous forest zone of the country. There are two well-defined rainfall seasons; the major season occurs from March to July with a peak fall in June. The minor season starts from September to November with a peak fall in October. August is generally cool and dry. The dry season begins in December and ends in February. The mean annual rainfall is approximately 166cm. Temperature are generally uniformly-high throughout the year with an annual mean of 24°C. The highest mean (27.8 °C) occurs just before the major season in February as observed in Kumasi. The mean minimum temperature occurs during the minor wet season. The relative humidity is relatively high throughout the year and the values ranges between 95% and 71.6% during the wet season with lowest value of 42.5% in the dry season during January. These conditions support farming activities throughout the year. Due to extensive farming activities, the original vegetation has been degraded to mosaic of secondary forest, thicket and forbs re-growth and various abandoned farms with relics of food crops and vegetation. The vegetation of the study area was a mixture of grasses and broad leaved plants. One part of the area was distinctly dominated by grasses whereas the other was mainly broad leaves with few patches of grasses. The topography of the area is gently slope. The total land area occupied by the experiment was 900 square meters. The study was carried out between March 2012 and September 2012.

3.2 Experimental Design

The experiment was carried out using a completely randomized block design. The plot was divided into two blocks of the same size based on the types of weed in the area. Block A was dominated by broad leaved weeds with few patches of grasses, and a well drained soil whereas Block B consisted of mainly grasses and the soil being more clayey than block A . Each block was further divided into three sub-plots (treatment units) of 9.00m x15.00m namely plots 1A, 2A and 3A for glyphosate, paraquat and manual treatment respectively in block A and 1B, 2B and 3B for glyphosate, paraquat and manual treatment respectively in block B. Each treatment unit was planted with at least 20 seedlings of *C. odorata* in a grid spacing of 2.00m x 2.00m. A row of buffer weeds of 2.00m was included to separate contiguous treatment units. *C. odorata* seedlings were obtained from Forestry Research

Institute of Ghana (FORIG) nursery at Fumesua. The Seedlings at the time of planting had an average basal diameter and shoot height of 0.46 cm and 21.16 cm respectively. They were planted in March 2012. In each block, three weed control treatments were randomly allocated with each treatment appearing once in a block. The three weed control treatment consisted of two different herbicides i.e. glyphosate (T1) and paraquat (T2) and the other weed control treatment being manual weed control (T3). The study relied solely on natural weather condition for the entire study period. Also no pest control methods were undertaken during the study period.

3.3 Weed Control

The three weed control treatments methods were used in the preparation of the respective plots three weeks before planting of seedlings. The next treatment was done on the fourth week after planting and subsequently at eight weeks interval when weeds have fully emerged on the plots. The herbicides namely glyphosate and paraquat commonly used in Ghana were applied at a dose of 50 millitres per 5 litres of water for each treatment unit using pressure sprayer at a low pressure to minimize spray drift by wind action. The manual weed control treatment was also carried out using cutlasses. To ensure consistency, the same person was engaged in the weed control treatment application throughout the study period.

3.4 Data collection

The effects of treatment and plots on growth performance of the seedlings were assessed by taking data on growth parameters such as, seedling shoot height, basal diameter, average leaf length and number of bi-pinnate leaves per seedling. The first growth assessment was done on the second week after planting. This was repeated at four week interval until the twenty sixth week after planting. Seedling shoot heights were taken from 10 mm above ground level to the point of emergence of a new leaves using a tape measure. The lengths of at least two bi-pinnate leaves were also taken for each seedling using a tape measure and their means recorded. The basal diameters of the seedling were also taken at 10 mm above ground level by means of a veneer caliper. The total number of bi-pinnate leaves of each seedling were also counted and recorded.

3.5 Statistical Analysis

Microsoft Office Excel 2007 analysis tool pack was used to perform the analysis of variance (ANOVA), bar graph and the descriptive statistics of the effects of weed control treatment on the growth performance of seedlings.

CHAPTER FOUR

4.0 RESULTS

4.1 Basal Diameter Growth

4.1.1 Effects of plots on Basal Diameter Growth

Figure 2 shows the mean basal diameter growth of the seedlings against the six treatment units. The seedlings recorded the highest mean basal diameter growth of 0.23 cm in plot 3A and the least basal diameter of 0.07 cm in plot 1B. The same mean value (0.11 cm) was recorded for plots 1A, 2A and 2B. The analysis of variance of the mean basal diameter (Table 1) indicate a significant difference among all the plots at $P \leq 0.05$. However there was no significant difference between the mean basal diameter for plot 1A and 2A as well as plot 1B and 2B at $P \leq 0.05$. Also there were significant differences between plot 3A and any of the other plots in block A. Again the ANOVA also shows significant differences between plot 3B and any of the other plots in block B. The mean basal diameter growth for block A and block B were 0.15cm and 0.11cm respectively. The ANOVA indicates a significant difference between block A and block B at $P \leq 0.05$.

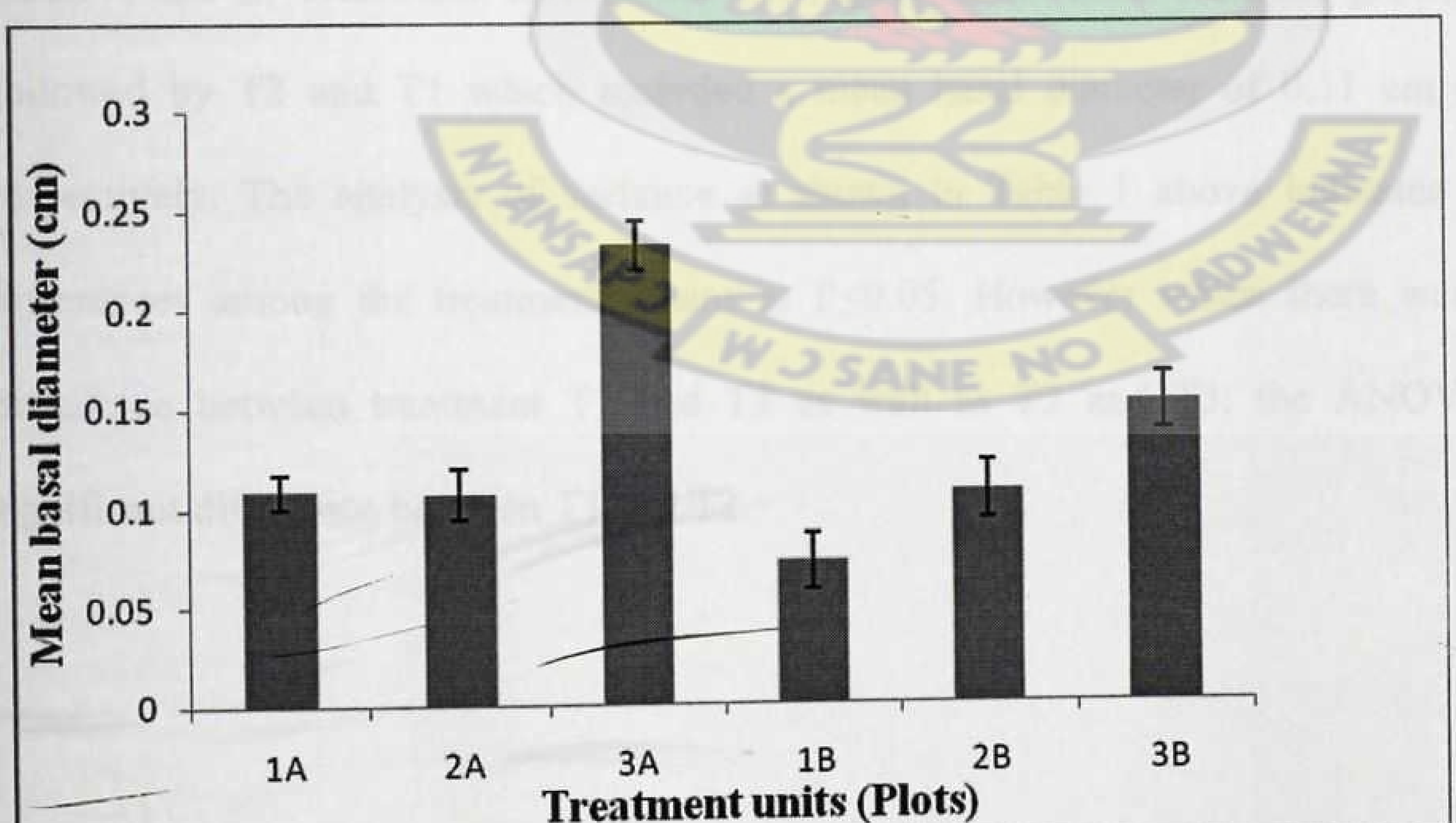

Figure 2. Effect of treatmnent units (Plots) on mean basal diameter (cm)

Table 1: Analysis of variance of the mean basal diameter (cm) growth of seedlings

Sources of variation	*F*	*F crit*	*df*
Plots			
1A,2A,3A,1B,2B,3B	19.31*	2.22	5,954
1A, 2A,3A	39.55*	3.01	2, 519
1A, 2A	0.01^{ns}	3.87	1,340
1A,3A	64.07*	3.87	1,358
2A,3A	48.07*	3.87	1,340
1B,2B,3B	7.66*	3.02	2,435
1B,2B	3.01^{ns}	3.88	1,262
2B,3B	4.69*	3.87	1,316
1B,3B	14.97*	3.87	1,292
Blocks			
BLK A, BLK B	9.75*	3.85	1,958
Treatments			
T1, T2, T3	35.36*	3.01	2,957
T1, T2	1.19^{ns}	3.86	1,604
T1,T3	59.96*	3.86	1,652
T2,T3	38.43*	3.86	1,658
Months of observation			
APRIL-SEPT	7.20*	2.22	5,954

* Significant at $P \leq 0.05$; **ns** not significant at $P \leq 0.05$

4.1.2 Effects Of weed control treatment on the basal diameter growth of seedlings

Figure 3 shows the mean basal diameter growth for the three weed control treatment for both block A and B. Treatment T3 recorded the highest mean basal diameter growth of 0.19 cm followed by T2 and T1 which recorded a mean basal diameter of 0.11 cm and 0.09 cm respectively. The analysis of variance as shown in Table 1 above indicates a significant differences among the treatment means at $P \leq 0.05$. However whilst there were significant difference between treatment T1 and T3 as well as T2 and T3, the ANOVA shows no significant difference between T1 and T2.

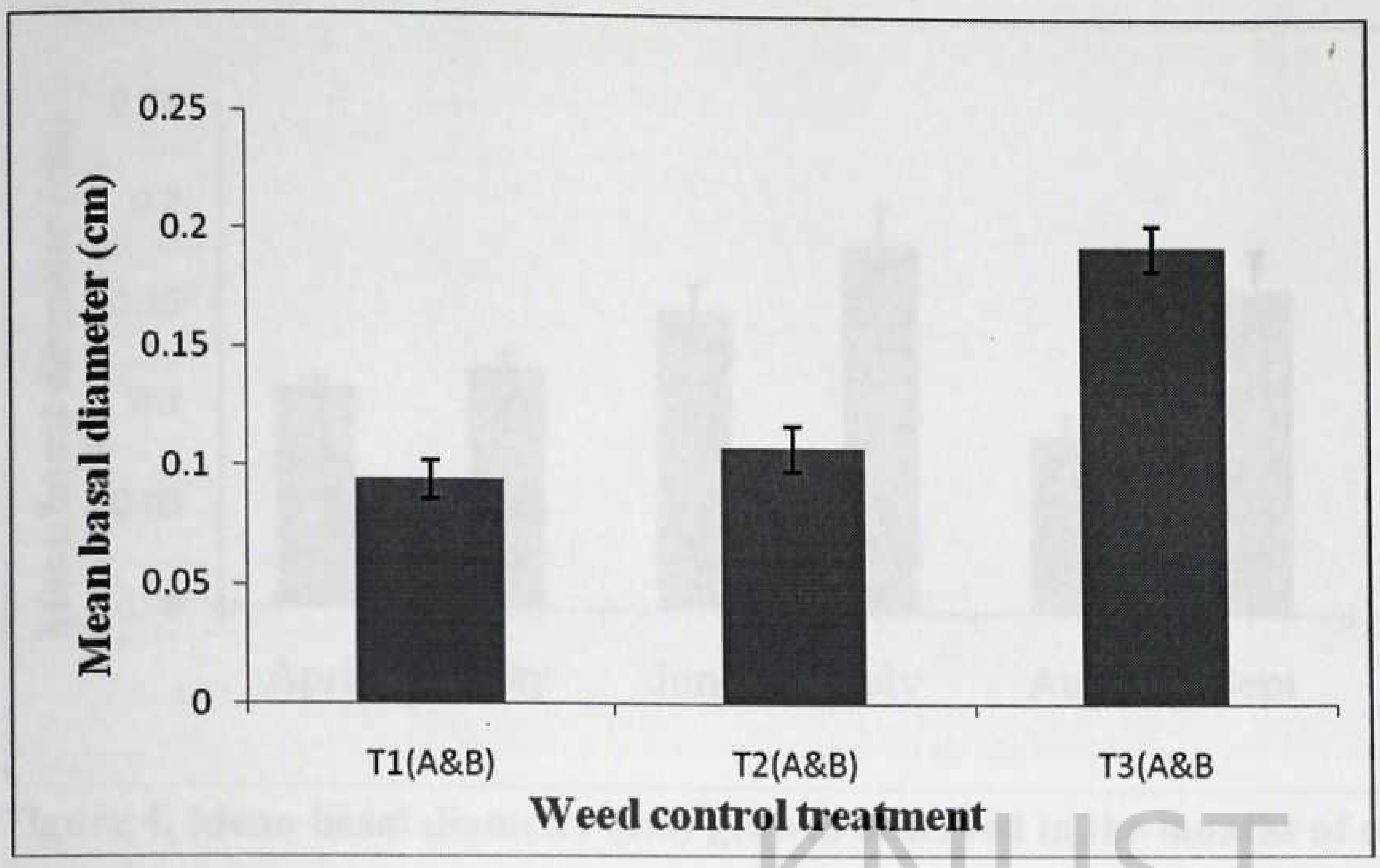

Figure 3. Effects of weed control treatments on mean basal diameter (cm) growth

4.1.3 Basal diameter growth changes as observed in the months of observation

Figure 4 shows the mean basal diameter growth recorded over the months of observation, from April to September 2012. From the result, the highest mean basal diameter (cm) growth of 0.18 cm was recorded in July 2012 and the least mean basal diameter of 0.09 cm was recorded in August 2012. Figure 4 also shows a steady increase of mean basal diameter from April 2012 to July 2012. There was a sharp drop of mean basal diameter growth value in August 2012. However the mean basal diameter growth increased in September 2012.

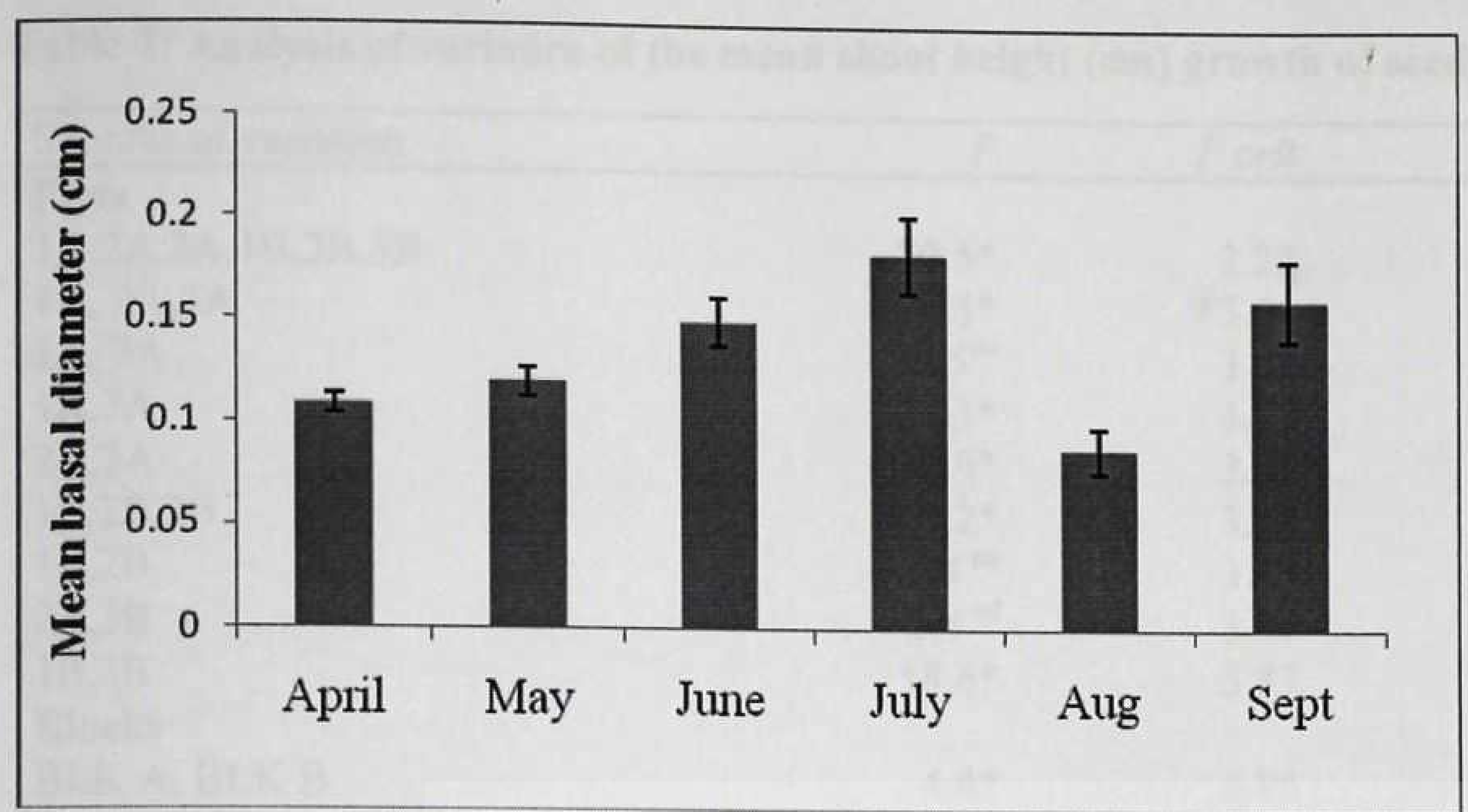

Figure 4. Mean basal diameter (cm) growth observed in the months of observation

4.2 Shoot Height Growth of Seedlings

4.2.1 Effects of plots on the seedling shoot height Growth

Figure 5 shows the mean shoot height (cm) growth of seedlings against the six treatment units. Plot 3A recorded the highest mean shoot height growth of 6.75cm. This was followed by plots 3B, 2B, 2A and 1A respectively with 1B recording the least mean shoot height growth of 1.79 cm. Analysis of variance of the mean shoot height growth as shown in Table 2 indicate a significant difference among all the plots at $P \leq 0.05$. However there were no significant difference between the mean shoot height growth of plots 1A and 2A as well as 1B and 2B at $P \leq 0.05$. Also there were significant differences between plot 3A and any of the other plots in block A. In block B, there was a significant difference between plot 3B and plot 1B. But no significant difference was observed between plot 3B and 2B. The mean shoot height growth for block A and block B were 4.06cm and 3.10cm respectively. The ANOVA indicates a significant difference between block A and block B at $P \leq 0.05$.

Table 2: Analysis of variance of the mean shoot height (cm) growth of seedlings

Sources of variation	*F*	*F crit*	*df*
Plots			
1A,2A,3A,1B,2B,3B	20.5*	2.22	5,954
1A, 2A,3A	39.5*	3.01	2,519
1A, 2A	2.5^{ns}	3.87	1,340
1A,3A	63*	3.87	1,358
2A,3A	37.9*	3.87	1,340
1B,2B,3B	8.2*	3.02	2,435
1B,2B	6.4^{ns}	3.88	1,262
2B,3B	2.4^{ns}	3.87	1,316
1B,3B	18.6*	3.87	1.292
Blocks			
BLK A, BLK B	4.4*	3.85	1,958
Treatments			
T1, T2, T3	38*	3.01	2,957
T1, T2	8.5*	3.86	1,604
T1,T3	70.7*	3.86	1,652
T2,T3	28.7*	3.86	1,658
Months of observation			
APRIL-SEPT	21.6*	2.22	5,954

* Significant at $P \leq 0.05$; **ns** not significant at $P \leq 0.05$

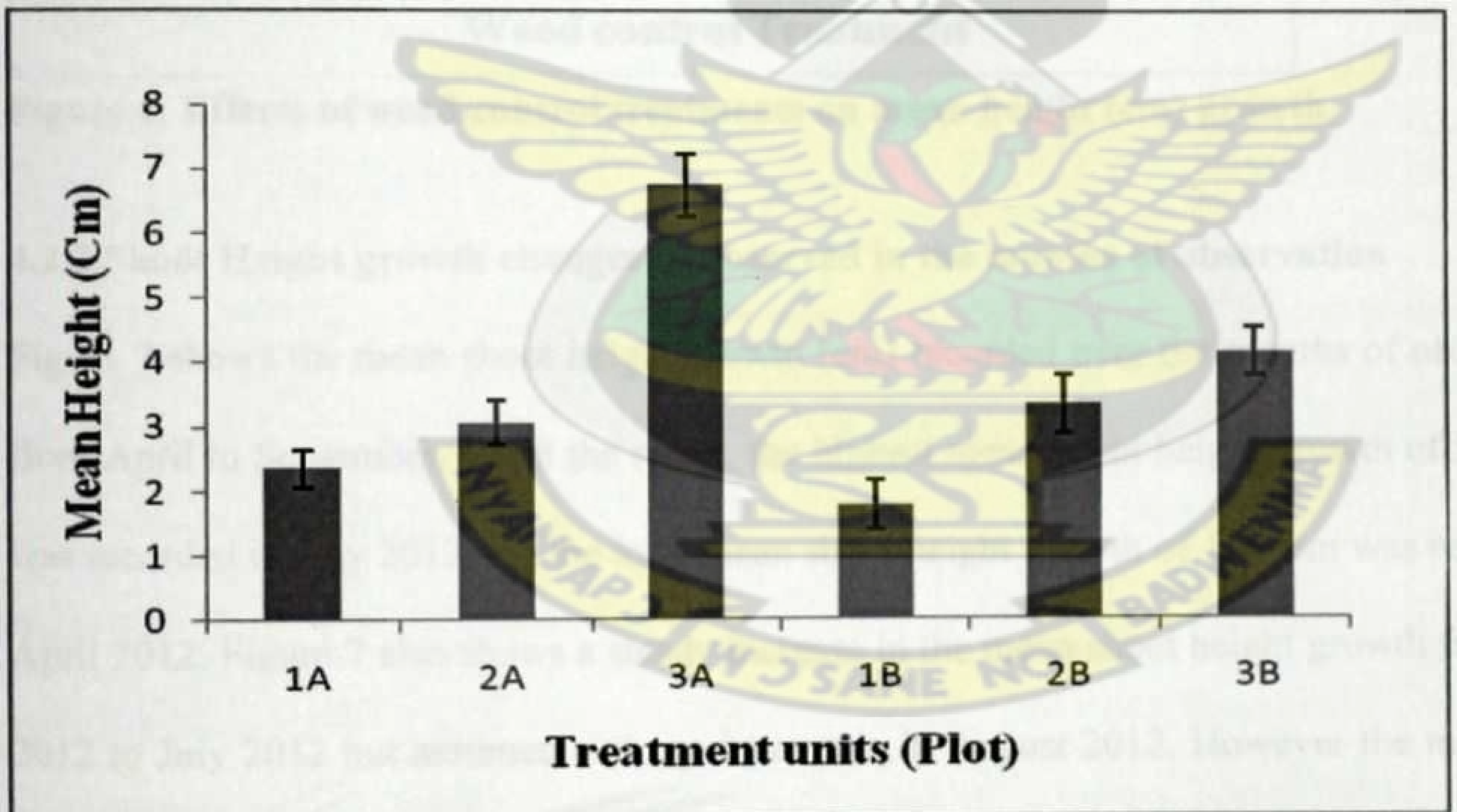

Figure 5. Effect of treatmnent units (Plots) on mean shoot height growth (cm)

4.2.2 Effects Of weed control treatment on the shoot height (cm) growth of seedlings

Figure 6 shows the mean shoot height growth for the three weed control treatment for both block A and B. Treatment T3 recorded the highest mean shoot height growth of 5.48cm followed by T2 and T1 with a mean shoot height growth of 3.21cm and 2.14cm respectively. The analysis of variance as shown in Table 2 above indicates a significant differences among the treatment means at P≤0.05. The ANOVA also shows a significant difference between T1 and T2, T1 and T3 as well as T2 and T3.

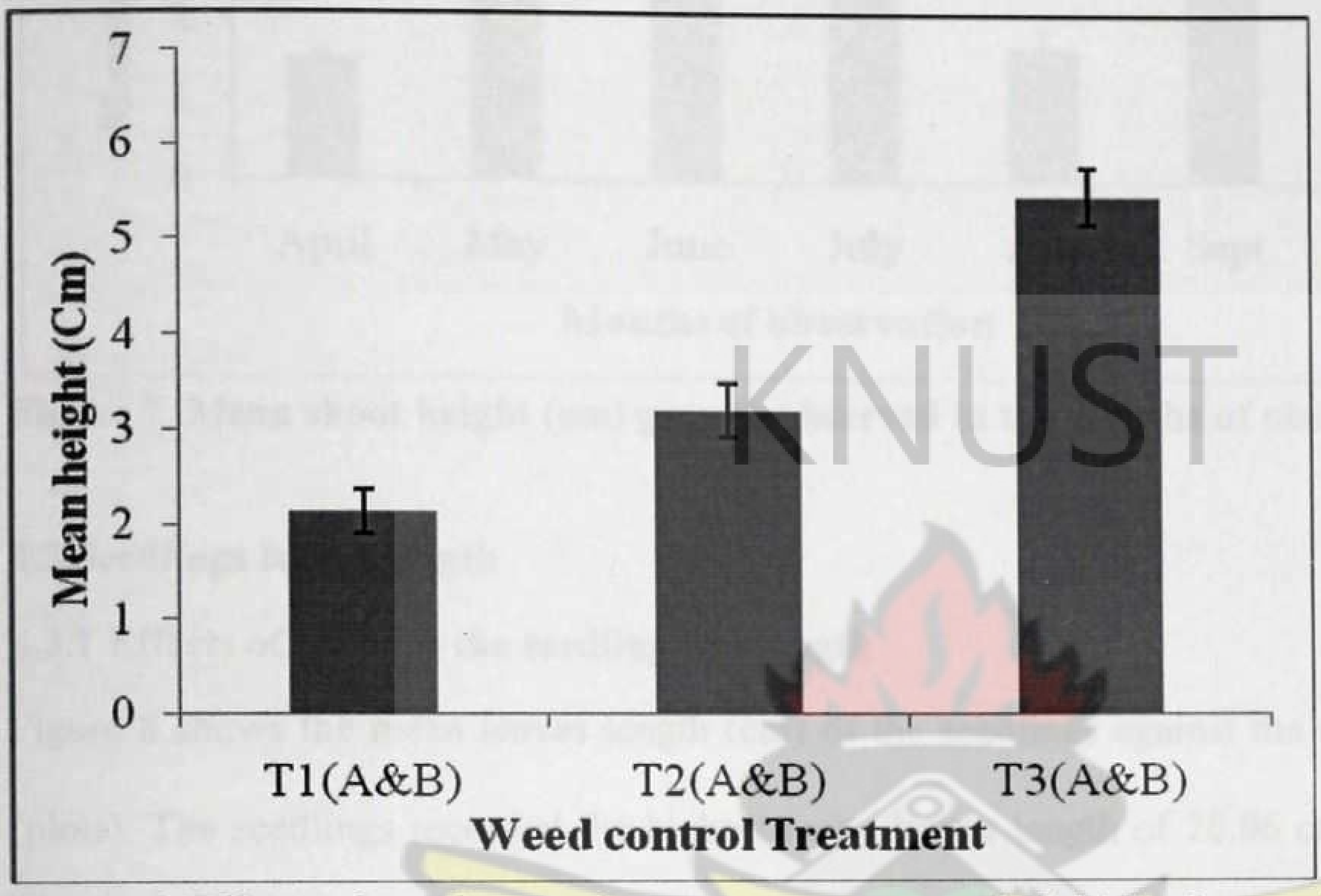

Figure 6. Effects of weed control treatments on mean height (cm) growth

4.2.3 Shoot Height growth changes as observed in the months of observation

Figure 7 shows the mean shoot height growth (cm) recorded over the months of observation, from April to September. From the result, the highest mean shoot height growth of 5.70 (cm) was recorded in July 2012 and the least mean shoot height growth of 1.51 cm was recorded in April 2012. Figure 7 also shows a steady increase in the mean shoot height growth from April 2012 to July 2012 but assumed a sharp down turn in August 2012. However the mean shoot height growth recovered in September 2012 after a sharp downturn in August 2012.

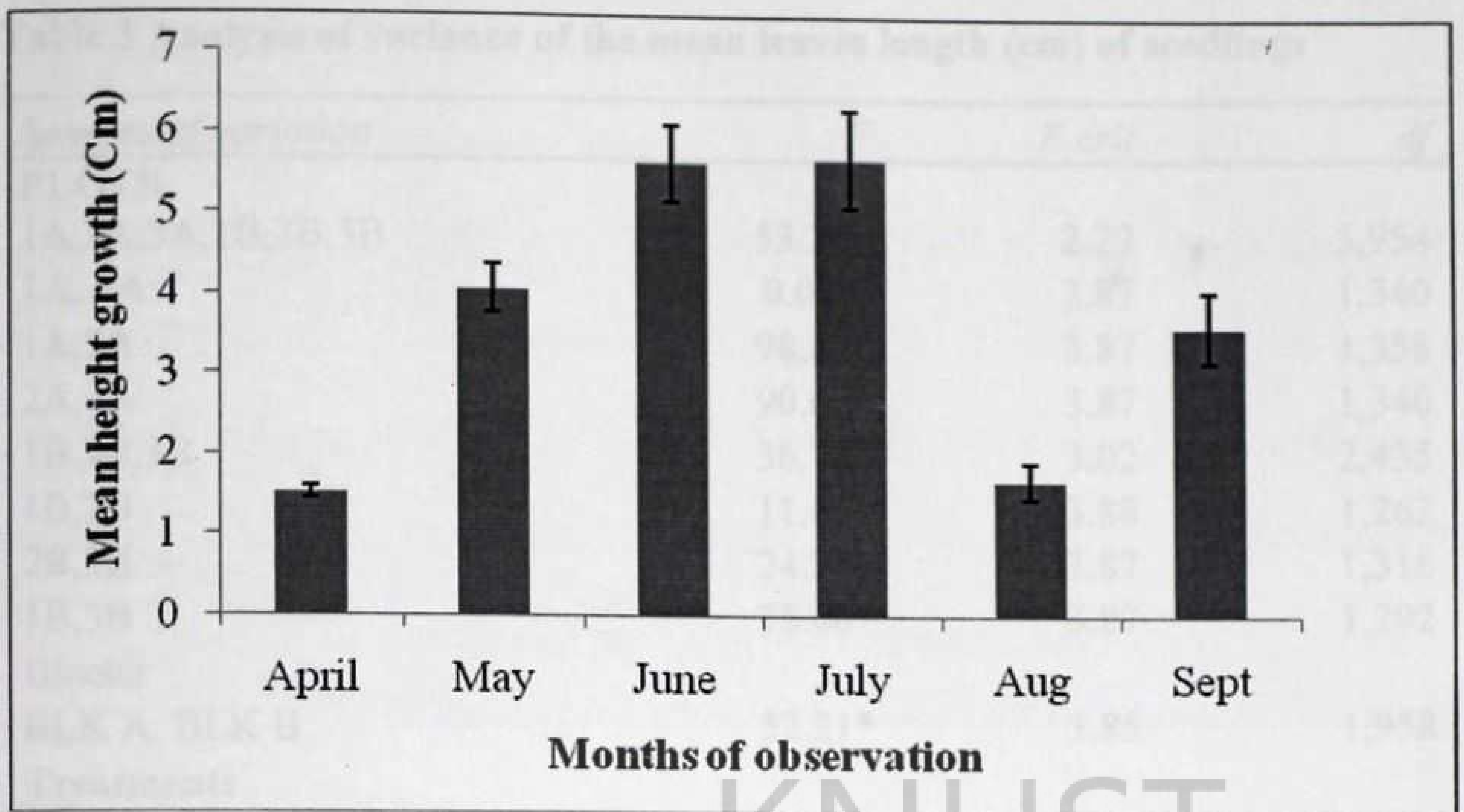

Figure 7. Mean shoot height (cm) growth observed in the months of observation

4.3 Seedlings leaves length

4.3.1 Effects of plots on the seedling leaf length

Figure 8 shows the mean leaves length (cm) of the seedlings against the six treatment units (plots). The seedlings recorded the highest mean leaves length of 26.06 cm in plot 3A. This was followed by plots 3B, 1A, 2A and 2B respectively with 1B recording the least mean leaves length of 7.23 cm. The Analysis of variance of the leaves length (cm) as shown in Table 3 indicate a significant difference among all the plots at $P \leq 0.05$. However there was no significant difference between the mean leaves length of plot 1A and 2A at $P \leq 0.05$. There was a significant difference between plots 1B and 2B. Also there were significant differences between plot 3A and any of the other plots in block A. Again there was significant difference between plot 3B and any of the other plots in block B. The mean leaves length for block A and block B were 18.41cm and 12.32cm respectively. The ANOVA (Table 3) also indicates a significant difference between block A and block B at $P \leq 0.05$.

Table 3 Analysis of variance of the mean leaves length (cm) of seedlings

Sources of variation	*F*	*F crit*	*df*
PLOTS			
1A,2A,3A,1B,2B,3B	53.26*	2.22	5,954
1A, 2A	0.08 ns	3.87	1,340
1A,3A	98.82*	3.87	1,358
2A,3A	90.66*	3.87	1,340
1B,2B,3B	36.78*	3.02	2,435
1B,2B	11.81*	3.88	1,262
2B,3B	24.26*	3.87	1,316
1B,3B	78.46*	3.87	1,292
Blocks			
BLK A, BLK B	52.21*	3.85	1,958
Treatments			
T1, T2, T3	80.87*	3.01	2,957
T1, T2	2.62 ns	3.86	1,604
T1,T3	137.28*	3.86	1,652
T2,T3	96.84*	3.86	1,658
Months of observation			
APRIL-SEPT	1.34 ns	2.22	5,954

* Significant at $P \leq 0.05$; **ns** not significant at $P \leq 0.05$

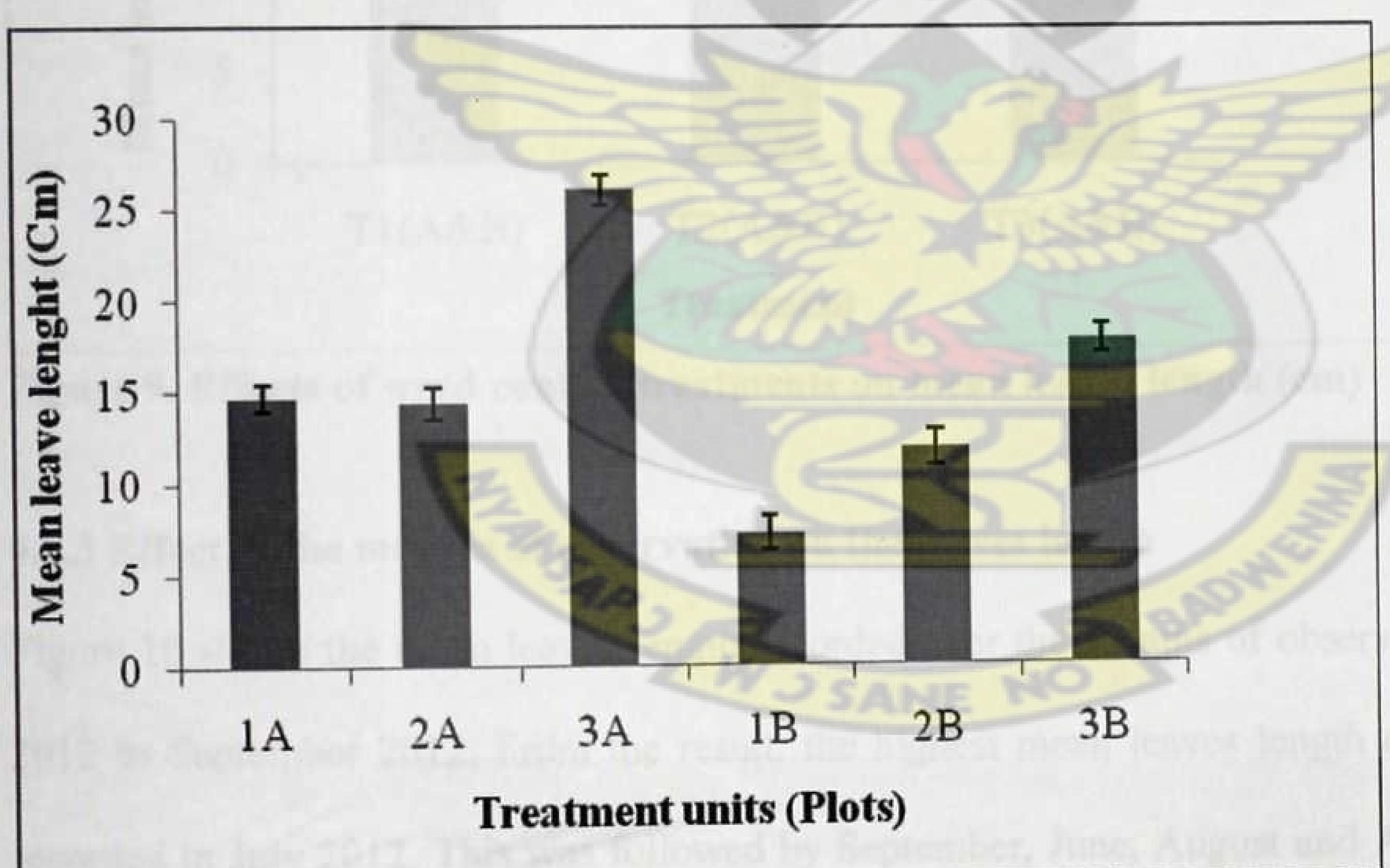

Figure 8. Effect of treatmnent units (Plots) on mean leaves length (cm)

4.3.2 Effects of weed control treatment on the leaves length

Figure 9 shows the mean leaves length (cm) for the three weed control treatment recorded in both block A and B. Treatment T3 recorded the highest mean leaves length of 22.03 cm followed by T2 and T1 with mean leaves length of 13.22 cm and 11.75 cm respectively. The analysis of variance as shown in Table 3 above indicates a significant differences among the three treatment means at $P \leq 0.05$. The ANOVA also shows significant difference between T1 and T3 as well as T2 and T3. But no significant difference was observed between T1 and T2.

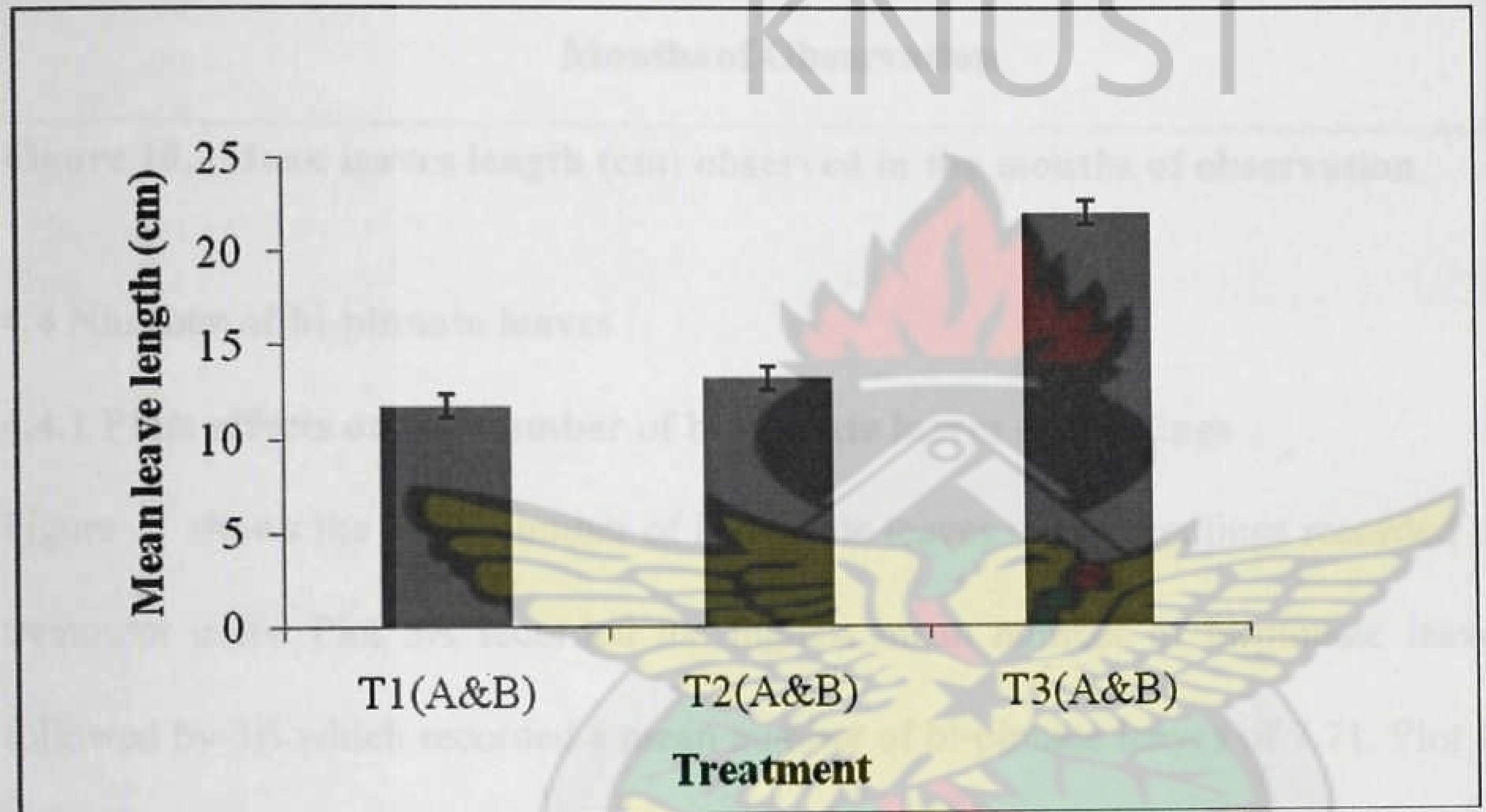

Figure 9. Effects of weed control treatments on mean leaves length (cm)

4.3.3 Effect of the months of observation on the leaves length

Figure 10 shows the mean leaves length recorded over the months of observation from April 2012 to September 2012. From the result, the highest mean leaves length of 17.60 cm was recorded in July 2012. This was followed by September, June, August and April respectively with May recording the least mean leaves length growth of 14.67cm.

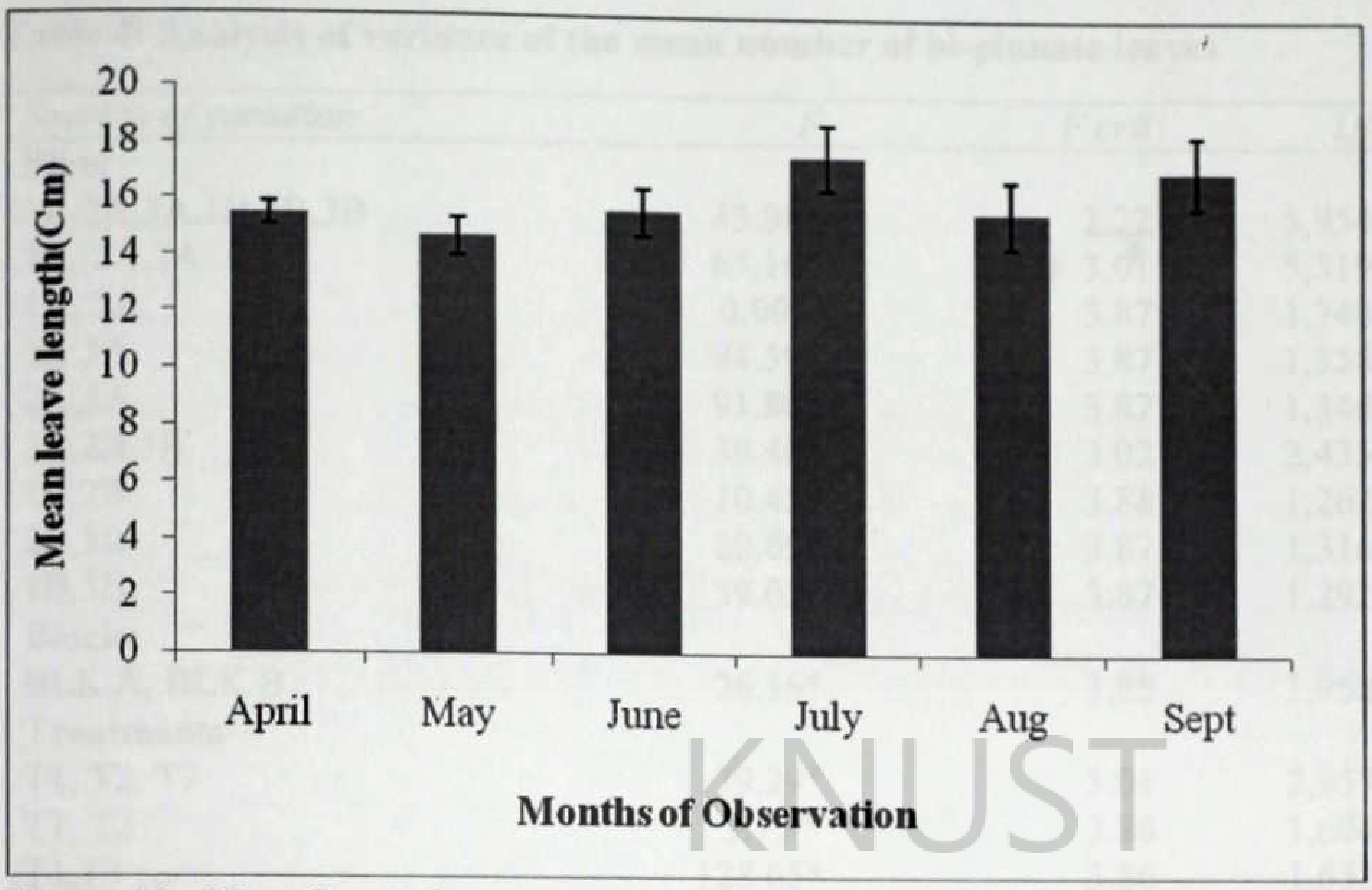

Figure 10. Mean leaves length (cm) observed in the months of observation

4.4 Number of bi-pinnate leaves

4.4.1 Plots effects on the number of bi-pinnate leaves of seedlings

Figure 11 shows the mean number of bi-pinnate leaves of the seedlings recorded in all the six treatment units. Plot 3A recorded the highest mean number of bi-pinnate leaves of 10.71 followed by 3B which recorded a mean number of bi-pinnate leaves of 7.71. Plot 1B recorded the least mean number of bi-pinnate leaves of 3.05. Plot 1A, 2A and 2B had a close mean number of bi-pinnate leaves of 5.63, 5.61 and 5.12 number of leaves respectively. The analysis of variance of the mean number of bi-pinnate leaves (Table 4) indicate a significant difference among all the plots at $P \leq 0.05$. However there were no significant difference between the mean number of bi-pinnate leaves for plot 1A and 2A. The mean number of bi-pinnate leaves counted for block A and B were 7.32 And 5.29 respectively. The ANOVA in Table 4 indicate a significant difference between the two blocks at $P \leq 0.05$.

Table 4: Analysis of variance of the mean number of bi-pinnate leaves

Sources of variation	*F*	*F crit*	*Df*
Plots			
1A,2A,3A,1B,2B,3B	43.88*	2.22	5,954
1A, 2A,3A	65.16*	3.01	5,519
1A, 2A	0.00 ns	3.87	1,340
1A,3A	94.59*	3.87	1,358
2A,3A	91.80*	3.87	1,340
1B,2B,3B	30.40*	3.02	2,435
1B,2B	10.45*	3.88	1,262
2B,3B	20.69*	3.87	1,316
1B,3B	59.05*	3.87	1,292
Blocks			
BLK A, BLK B	26.16*	3.85	1,958
Treatments			
T1, T2, T3	79.29*	3.01	2,957
T1, T2	3.75 ns	3.86	1,604
T1,T3	128.65*	3.86	1,652
T2,T3	93.87*	3.86	1,658
Months of observation			
APRIL-SEPT	3.89*	2.22	5,954

* Significant at $P \leq 0.05$; **ns** not significant at $P \leq 0.05$

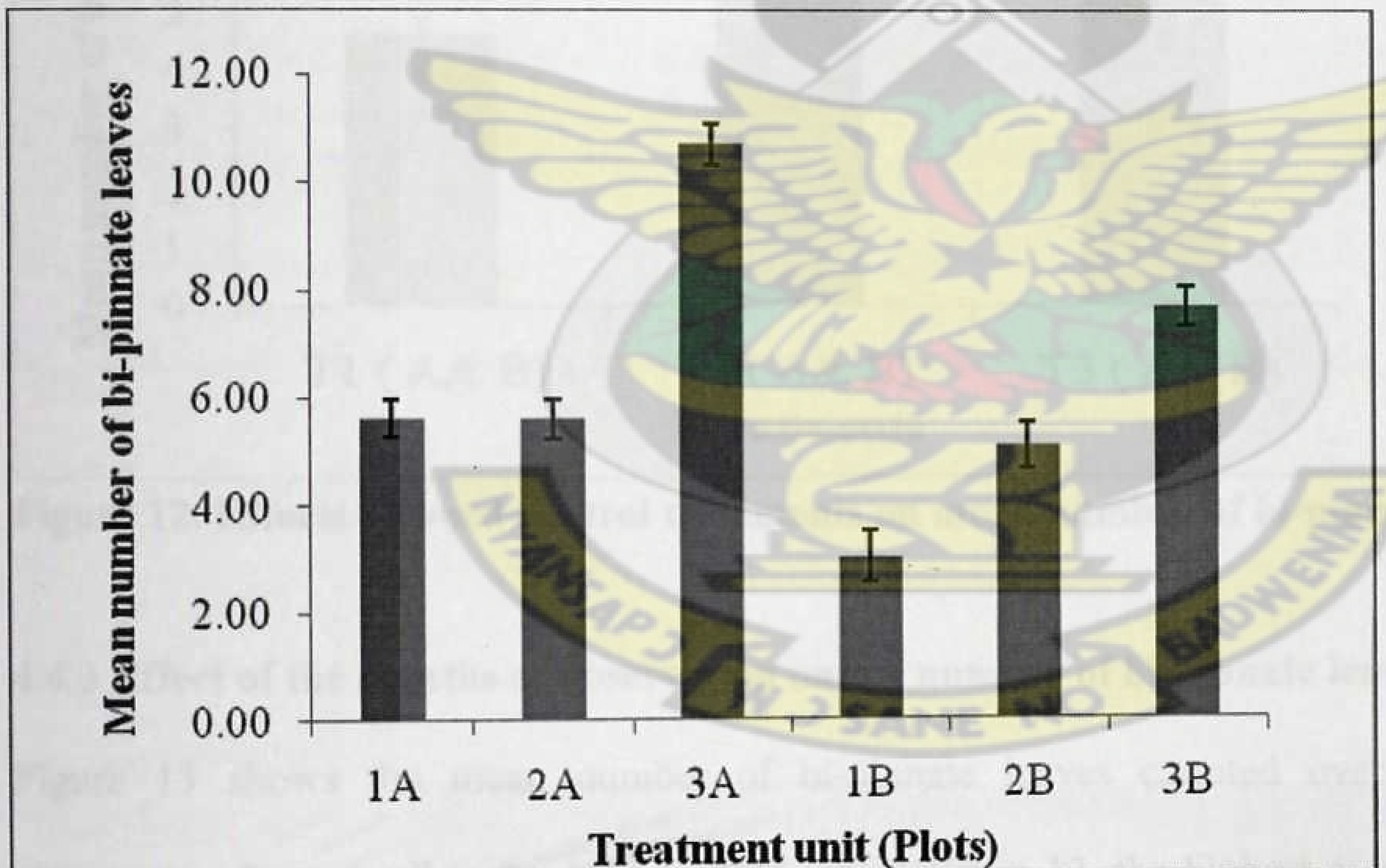

Figure 11. Effect of treatmnent units (Plots) on mean number of bi-pinnate leaves

4.4.2 Effects of weed control treatment on the number of bi-pinnate leaves

Figure 12 shows the mean number of bi-pinnate leaves of seedlings counted for the three weed control treatment for both block A and B. Treatment T3 according to figure 12, recorded the highest mean number of bi-pinnate leaves of 9.23 followed by T2 and T1 with a mean number of bi-pinnate leaves of 5.38 and 4.60 respectively. The analysis of variance as shown in Table 4 above indicates a significant differences among the three treatment means at $P \leq 0.05$. The ANOVA (Table 4) also shows significant difference between T1 and T3 as well as T2 and T3. But no significant difference was observed between T1 and T2.

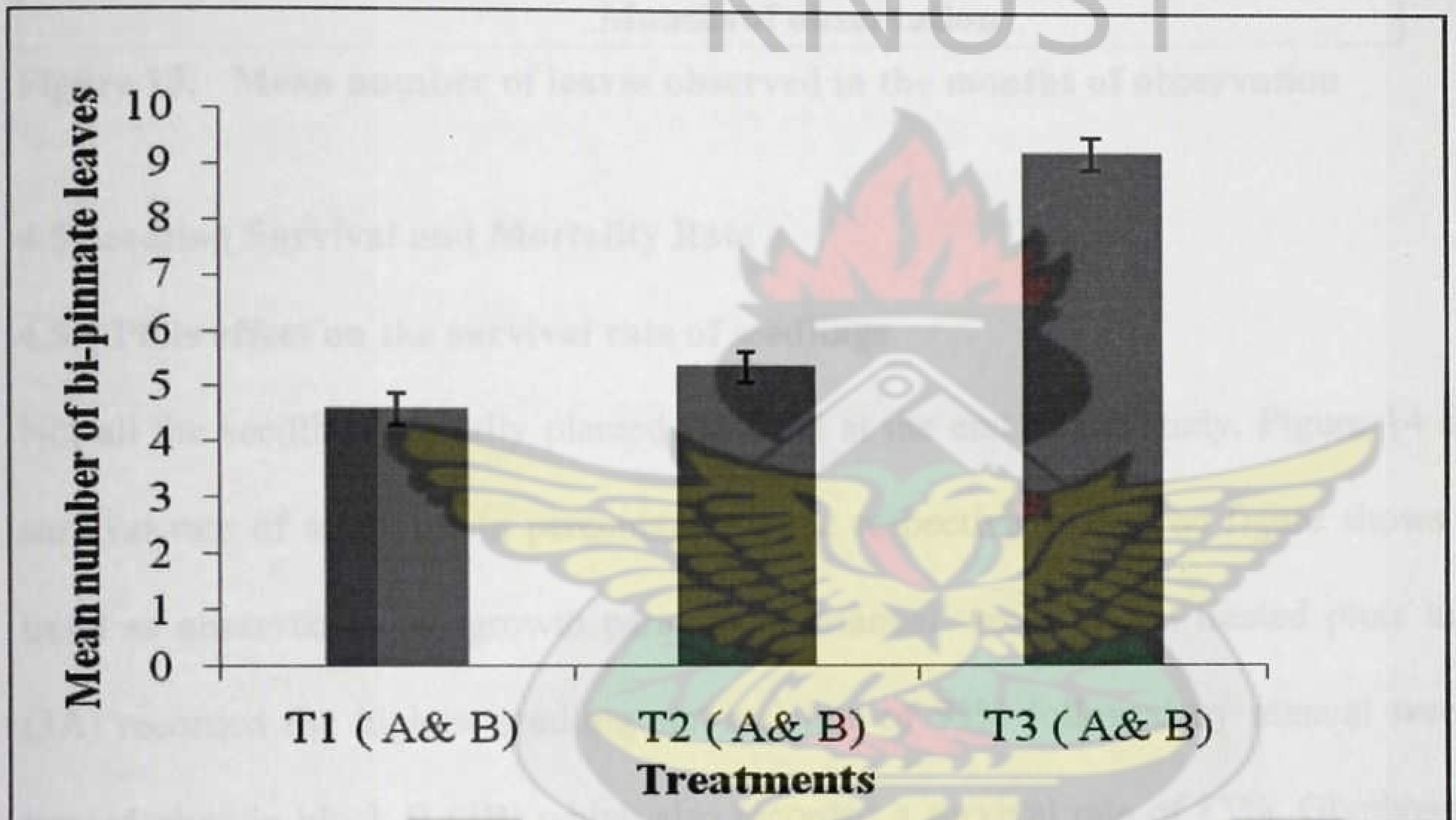

Figure 12. Effects of weed control treatments on mean number of bi-pinnate leaves

4.4.3 Effect of the months of observation on the number of bi-pinnate leaves

Figure 13 shows the mean number of bi-pinnate leaves counted over the months of observation from April to September 2012. From figure 13, the highest mean number of bi-pinnate leaves of 8.03 was recorded in September 2012 and the least value of 5.40 was also recorded in May, 2012. The figure also shows a marginal increase of mean number of bi-pinnate leaves from May 2012 to September 2012.

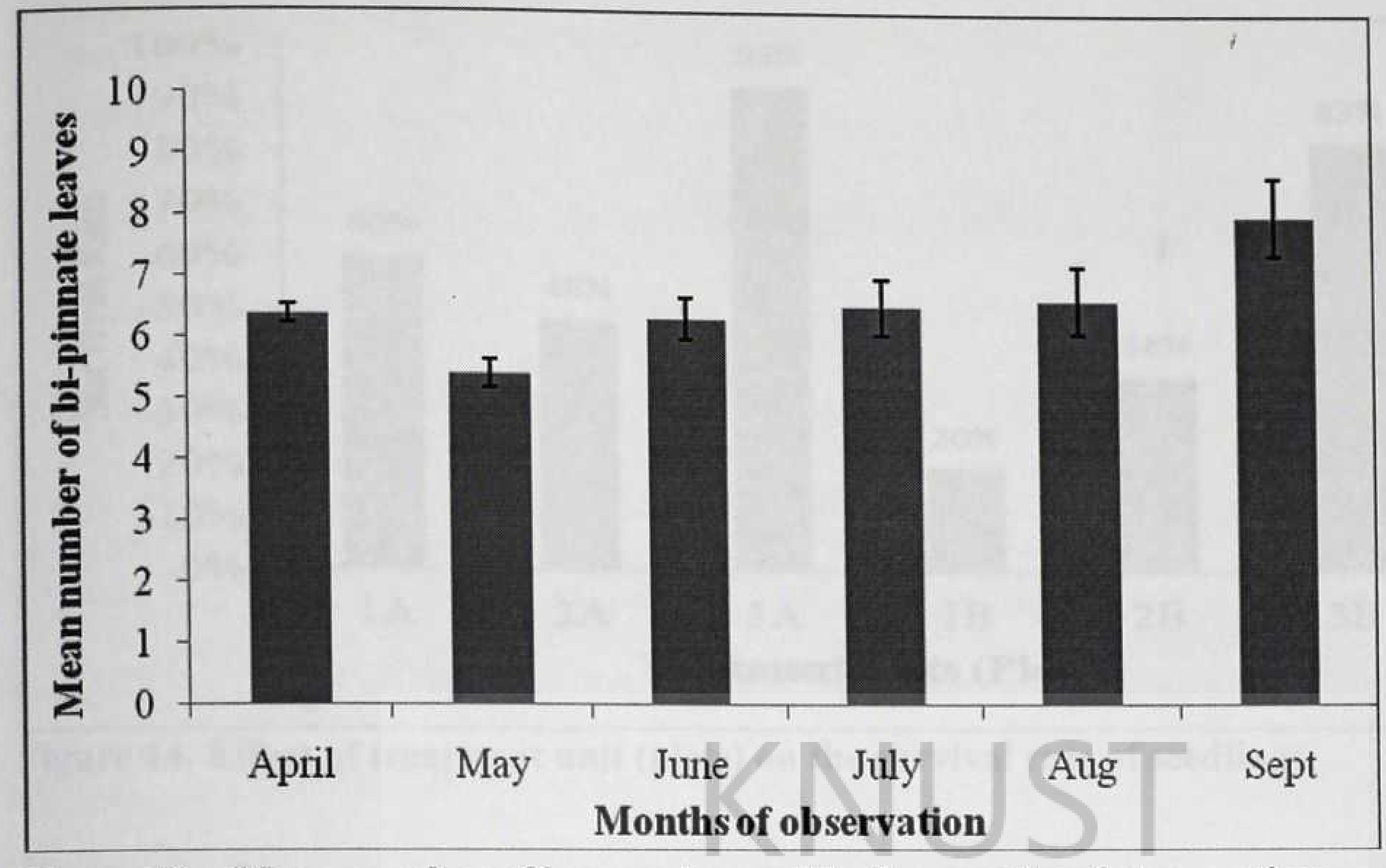

Figure 13. Mean number of leaves observed in the months of observation

4.5 Seedling Survival and Mortality Rate

4.5.1 Plots effect on the survival rate of seedlings

Not all the seedlings initially planted survived at the end of the study. Figure 14 shows the survival rate of seedlings in percentage for the respective plots. The figure shows a similar trend as observed in the growth parameters. Manual weed control treated plots in block A (3A) recorded the highest seedling survival rate of 93% followed by manual weed control treated plots in block B (3B) which also recorded a survival rate of 83%. Glyphosate treated plot in block B (1B) recorded the least rate of survival of 20% almost three times less than that recorded in glyphosate treated plot in block A.

Out of the total 160 seedlings planted, 96 seedlings, representing 60% survived at the end of the study. In Block A out of the initial 87 seedlings planted, 59 representing 68% of the seedlings survived at the end of the study whereas in block B 37 out of the initial 73 seedlings planted representing 51% survived at the end of the study.

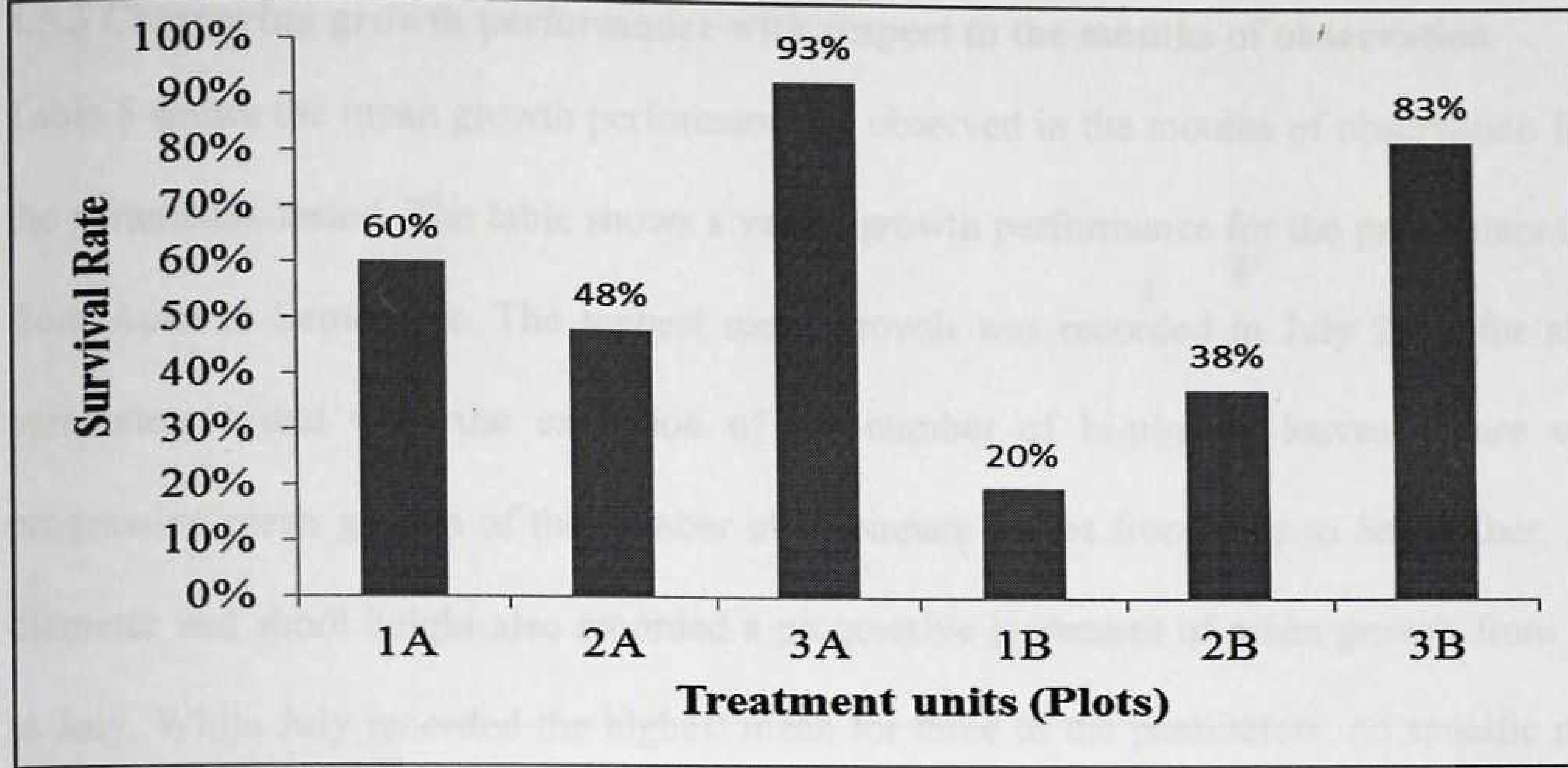

Figure 14. Effect of treatment unit (plots) on the survival rate of seedlings

4.5.2 Treatment effect on the survival rate of seedlings

Figure 15 shows the effect of the three weed control treatment on the rate of survival of the seedlings. The treatment effect also shows a similar trend as was observed for the treatment effect of almost all the growth parameters studied. Manual weed control treatment, T3 recorded the highest survival rate of 88% (52 out of 59 seedlings survived). Glyphosate treated plots, T1 and paraquat treated plots T2 had a 44% and 43% survival rate respectively.

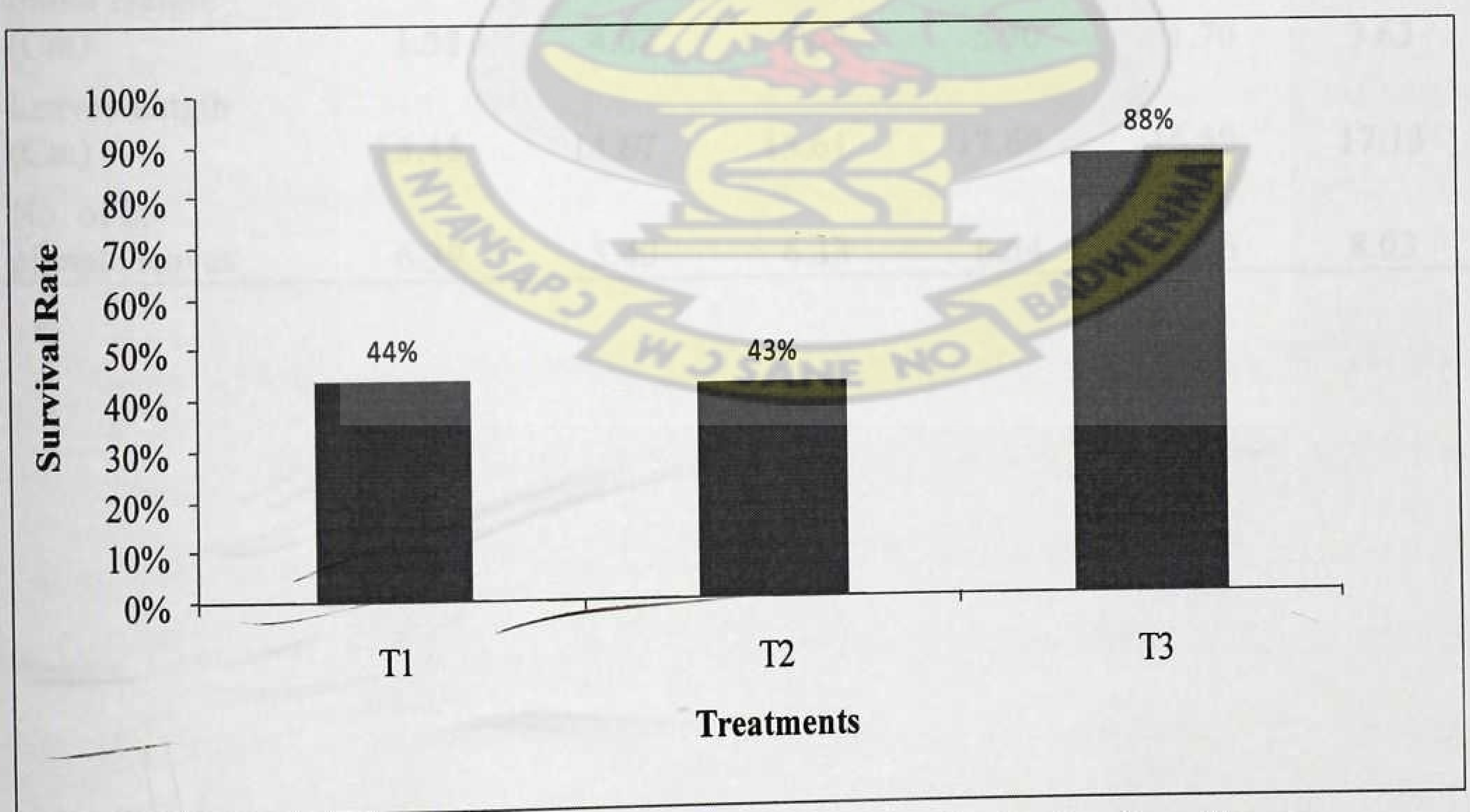

Figure 15. Effects of weed control treatment on the survival rate of seedlings

4.5.3 Comparing growth performance with respect to the months of observation

Table 5 shows the mean growth performance as observed in the months of observation for all the parameters tested. The table shows a varied growth performance for the parameters tested from April to September. The highest mean growth was recorded in July 2012 for all the parameters tested with the exception of the number of bi-pinnate leaves. There was a progressive mean growth of the number of bi-pinnate leaves from May to September. Basal diameter and shoot height also recorded a progressive increment of mean growth from April to July. While July recorded the highest mean for three of the parameters, no specific month recorded the least mean growth value for all the parameters tested. For instance whilst August recorded the least mean diameter growth, April recorded the least mean shoot height growth and May recorded the least mean leaves length and number of bi-pinnate leaves.

Table 5: Mean growth performance as observed in the months of observation

Growth Parameters	April	May	June	July	Aug	Sept
Basal diameter (Cm)	0.11	0.12	0.15	0.18	0.09	0.16
Shoot Height (Cm)	1.52	4.07	5.64	5.70	1.70	3.63
Leaves length (Cm)	15.45	14.67	15.61	17.60	15.59	17.13
No. of bi-pinnate leaves	6.39	5.40	6.33	6.54	6.66	8.03

CHAPTER FIVE

5.0 DISCUSSION

5.1 Effect of Weed Control Treatment on the growth of seedlings

The result of the study shows that manual weed control had the highest mean value for all the parameters tested. The analysis of variance indicates a significant difference among the three weed control treatment means for all the parameters tested. However with the exception of seedling shoot height, there was no significant difference between the treatment means for glyphosate treated plots (T1) and paraquat treated plots (T2) but there was a significant difference between T3 and any of the other treatment means (i.e.T1 and T2) at $P \leq 0.05$. This implies that, the difference comes up mainly as a result of the less adverse effects manual weed control had on the growth of the seedlings. This is shown by the high mean value that manual weed control recorded for all the parameters tested. This is an indication that the seedlings of *C. odorata* are less tolerant to herbicide treatment even at a very small dose. This small amount of herbicide might have affected the seedlings through gradual herbicide drift and uptake from the soil. According to Sutton (1978), rates of application may have inverse results and there is some evidence that lower concentrations of glyphosate may achieve a greater herbicidal effect than a higher concentration. If a translocatable herbicide (like glyphosate) is applied at a higher concentration, it may kill tissues on contact before is translocated to other tissues. Individual plants may respond to chemical treatment based on health, age, or other factors unrelated to species physiology. As well, plant vigour may determine ability to absorb and translocate chemicals. The herbicides had much impact on the seedlings because according to Streibig (2003), plants in the germination and early seedling stages are likely to be severely damaged by herbicides and this applies to both weeds and crops.

5.2 Effect of Chemical weed control treatment on the growth of seedlings

Comparing the effects of the two herbicide used for this study, for all the parameters tested, the result indicates that plots treated with paraquat resulted in a better seedling growth than plots treated with glyphosate. Glyphosate being a systemic herbicide (WHO, 1994), has the tendency of causing injury to seedlings and stunt their growth even at a small dose as compared to paraquat herbicides. Paraquat herbicides are quick acting, non selective contact herbicides (Mergel, 2010). Due to their nature of acting on contact and not systemic, most of the seedlings that were affected by the paraquat herbicide were able to recover after few days of injury. This is the reason why seedlings in plots treated with paraquat had a high mean value than seedlings in plots treated with glyphosate herbicides.

5.3 The effect of weed control treatment on the Seedling survival and mortality

The study established that *C. odorata* seedling was not tolerant to glyphosate and paraquat herbicide treatment. According to Faccini and Puricelli, (2007), herbicide tolerance is the inherent ability of a species to survive and reproduce after herbicide treatment, mainly at the recommended dose. Altogether 60% (i.e. 96 out of 160) of the original seedlings planted survived at the end of the study period. Block A had 68% survival whilst block B had 51% survival. Though the difference in percentage survival in block A and B could be attributed to several factors, in all herbicide application was very critical to the survival of the seedlings. The manually treated plots (T3) recorded a relatively high survival percentage in both block A and block B. T3 in Block A had 93% survival (i.e. 28 out of 30 seedlings) and 83% (i.e. 24 out of 29 seedlings) in block B giving an average of 88% survival (i.e. 52 out of 59 seedlings). On the other hand plots treated with herbicides recorded a very low percentage survival. Glyphosate treated plots (T1) and paraquat treated plots (T2) in both blocks had a low survival percentage of 44% (22 out of 50 seedlings) and 43% (22 out of 51 seedlings) respectively. Barry *et al.* (2007) established that because seedlings are small and tender, herbicides with foliar, contact or residual soil activity are usually effective against seedlings. This explains why there were low survival percentages of both glyphosate and paraquat treated plots. The high mortality recorded in block B may not be attributed to the effect of the herbicide application alone. There might be other factors which were not immediately known. This is because, in block A, plot 1A which is a glyphosate treated plot, recorded the second highest survival of 60% after manual weed control treated plot 3A. It was expected that in block B the glyphosate treated plot, 1B would have also recorded the second highest survival after manual treated plot 3B. Nevertheless, plot 1B recorded the least percentage survival of 20% and paraquat treated plot, 2A recorded the second survival percentage (38%) after manual weed control treated plot 3A. This inconsistency of survival percentage among the weed control treatment methods in block A and B suggest that there might be other factors aside herbicide treatment effect that contributed to the mortality of the seedlings.

5.4 Effect of months of observation on the seedling development

Growth and development for the seedlings may not be attributed to the effect of weed control treatment alone. Because weather conditions were not constant along the months of observation, it can be inferred that weather conditions may have influenced the development of the seedlings regardless of the weed control treatment. Also there is a relation between the weather and the efficacy of herbicide application. Armed *et al.* (2003), state that weather conditions, specifically precipitation amount and timing can significantly impact the efficacy of individual herbicides. In a research conducted, Stewart *et al.* (2012) concluded that, excessive precipitation may delay post herbicide application allowing weeds to grow beyond an optimal size. High amount of precipitation (i.e. greater than 25mm) especially immediately after application, can cause herbicide to leach through the soil profile consequently reduce efficacy (Ferrell *et al.,* 2004). Balfour (1989) also state that, the determination of the effects of herbicides is linked to their behavior in the environment. The degree to which the plants receive the herbicide has been related to amount (i.e. rate), phenology (i.e. season of application), method of application and individual plant characteristics (e.g. evergreen versus deciduous habit). Although weather conditions were not constant along the months of observation from April to September, the result indicated a progressive growth of seedlings for some of the parameters tested. For instance, basal diameter and shoot height recorded a progressive incremental growth from April to July. Number of bi-pinnate leave also recorded a progressive increase from May to September. This implies that Seedlings will naturally develop with time regardless of other management practices. July recording the highest mean growth for almost all the parameters tested may be attributed to the fact that there might be an optimum weather conditions i.e. precipitation, temperature, light and relative humidity creating a favourable condition for the growth and development of the seedlings regardless of the effect of weed control treatment application.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

The following conclusions can be deduced from the results of the studies

1. The seedlings of *C. odorata* are intolerant of glyphosate and paraquat herbicide and that the herbicide application has an adverse effect on the growth and development of *C. odorata* seedlings.
2. Among all the parameters tested with the exception of shoot height, there were no significant differences between the means of glyphosate treated plots and paraquat treated plots. It was observed that seedlings that were being injured by paraquat herbicide had a higher tendency to recover with time than seedlings being injured by glyphosate herbicide. This partly accounted for the high survival rate of seedlings in paraquat treated plots than glyphosate treated plots.
3. Growth and development of *C. odorata* seedlings in a plantation is better when Manual weed control is applied as compared to chemical weed control.
4. Manual weed control treatment yields a high survival rate of *C. odorata* seedlings at the end of the study as compared to chemical weed control treatment which had a very low survival rate.

Based upon the results of this study, the following recommendations are suggested:

1. Managers of plantations must evaluate the successes of different weed management practices in terms of investment and benefits. Clearly from the results of the experiment, manual weed control has proven to be more reliable in terms of its effect on the seedling of *C. odorata*. The mortality rate of *C. odorata* seedlings in manual weed control plots is far less than that of the chemical weed control plots. However in terms of practicability, chemical weed control application is less laborious and can be

applied to a very large area of land within a relatively shorter time period as compared to more laborious and time consuming manual weed control. Even though manual weed control has less impact on non target plants and the environment, it is far too expensive nowadays to apply in a large scale plantation.

2. The results of the study have clearly indicated that, paraquat and glyphosate are effective in the control of all kinds of weeds but their impact on the non-target plant, *C. odorata* in their seedling stage are adverse. For this reason, it is recommended that glyphosate or paraquat herbicides are used only in complete land clearing where there are no non-target plants in their seedling stage to protect.

3. According to Streibig (2003), plants in the germination and early-seedling stage are likely to be severely damaged by herbicides. This applies to both weeds and crops, and therefore the timing of application is crucial for the effect of many herbicides. In the control of weeds in *C. odorata* plantation were seedlings are young and tender, manual weed control is preferred to chemical weed control since the impact of herbicide on the growth and survival of the seedlings were severe. Because seedlings were small and tender, less effort is required for control at this stage of growth than at any other. This is true whether nonchemical or chemical control is used. Herbicides with either foliar contact or residual soil activity are usually very effective against seedlings (Barry *et al.,* 2007). Therefore in order to achieve an effective weed control with less impact on the preferred plants it is recommended that manual weed control is applied. Glyphosate or paraquat herbicides can be used only on a more matured non-target plant stands. It is therefore recommended that this experiment is repeated on a more matured stands of *C. odorata* plantation or any preferred non-target plant species.

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