UNIVERSITY OF CAPE COAST

WEED CONTROL STUDIES ON SOYBEAN IN THE COASTAL SHRUB AND THICKET VEGETATION BELT OF CENTRAL REGION

BY

FRIMPONG KODUA
B.Sc. (AGRIC.) HONS,; DIP.ED. (CAPE COAST)

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SUGGESTED SHORT TITLE

Weed Control studies on Soybean (*Glycine max* L.).

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DECLARATION

It is hereby affirmed that this research work was carried out entirely by me in the Department of Crop Science, School of Agriculture, University of Cape Coast, Ghana and that this work has neither been wholly nor partially presented for any degree work anywhere else.

....CANDIDATE
(FRIMPONG KODUA)

DATE: 15TH JULY 1998

....PRINCIPAL SUPERVISOR
(PROF. A.G. CARSON)

DATE: 15TH JULY, 1998

....HEAD OF DEPARTMENT
(PROF. A.G. CARSON)

DATE: 15TH JULY, 1998

DEDICATION

To Jehovah El-Shaddai,

my beloved wife Jemima Frimpong Kodua

and my two children

Nana Kodua and Betty

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ABSTRACT

Protein malnutrition, major dietary problem in developing countries, Ghana included, requires greater attention today than ever before. Soybean, a high protein legume has recently been accepted by Ghanaians as an alternative to groundnuts and cowpea in their diet. On weight for weight basis, the yield of this crop is approximately twice that of meat, cowpea, beans and four times that of cereals. Besides soybean has less pest and disease problems as compared to other well established legumes. However, weed competition is one of the major constraints in the production of the crop. Thus the experiment was to determine:-

(a) the critical competition period so as to establish the most economical weeding regime for the crop.

(b) the most practical and cost effective weed management practice in soybean fields and

(c) residual action of two pre-emergence herbicides, Galex and Stomp, on the field by bioassay techniques.

The studies were carried out at the Teaching and Research Farm of the School of Agriculture, University of Cape Coast, during the 1994 Major and the 1995 major seasons. The field experiments were set up as RCBD with four replicates at a spacing of 75cm x 5 cm. Ten weeding regimes were tried in the 1st experiment while the second experiment consisted of 12 treatments which included varying rates of Stomp, Galex, hoeing periods and their combinations. The third experiment employed a bioassay technique using sorghum and millet as test plants to determine residual levels of the two pre-emergence herbicides.

The studies showed 67% and 81% yield reduction as a result of unchecked weed growth in 1994 and 1995 respectively. At 70% attainable yields, the critical periods of competition were found to be 23-35 and 20-32 days after emergence in the 1994 and 1995 seasons respectively. Also, soybean grain yield and its parameters and plant growth deceased significantly as duration of weed competition increased from 10 to 40 days after crop emergence. The herbicides studied gave a relatively higher percentage weed control in the 1994 minor season than in the 1995 major season. This was attributed to the dominance of *Cyperus rotundus* L. and *Trianthema postulacastrum* L. which are known to be efficient plants and therefore better competitors than soybean, in the 1995 major season weed population.

The studies showed that both herbicides proved effective against weeds at 2.0 kg/ha except on *Cyperus rotundus*. In both seasons of study, manual weed control resulted in a financial advantage and no level of residual, concentration, likely to prove injurious, phytotoxic or detrimental to subsequent crop growth and development was detected.

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CHAPTER ONE

INTRODUCTION

Protein malnutrition is a major problem in the developing world, even though the developing countries are endowed with high potentials in terms of agricultural land and animal numbers (Nestel, 1974). According to FAO (1973) the recommended daily total protein intake is about 60 grams per caput of which about 40 grams should be of plant protein. In Ghana only about 10.2 grams of this daily protein requirement is met. As a result, Oraca-Tetteh (1976) reported that about 10% of all children in Ghana suffer from 'Kwashiorkor' with about 50% showing milder forms of it.

The animal industry in Ghana produces only 20 percent of the country's meat requirements (Fianu, 1990) therefore the rest has to come through expensive importation which the average Ghanaian cannot afford the quantity needed to maintain good health.

Over the years stockmen have relied on the natural grassland which is made up of indigenous grass species which have not gone through any improvement. In Ghana the Guinea Savanna vegetation belt where livestock could be raised successfully is infested with tsetseflies, experience water scarcity and bush fires during the dry season which destroys the existing poor pastures. These problems are serious enough to demand alternative sources of cheap protein to solve the problem of protein malnutrition of both man and livestock.

Initially cowpeas and groundnuts have largely served the protein needs in the diets of the people, but at the moment cowpea is susceptible to several fungal, bacterial and viral diseases than any of the other grain legumes grown. Insect pests both on the field and in storage constitute the single most important constraint to cowpea production in Ghana. Severe attacks of flower thrips for example may also cause total crop failure.

Attempts to control these pests chemically is not only expensive but also damaging to other useful insects and the environment. In general the protein yields of cowpea and groundnuts are low as they provide an average of 23 - 25% and 26% protein, respectively. In addition the protein quality is somewhat deficient in the essential amino acids including methionine and cystine. Poor storage of groundnuts may promote moulding, and produce a toxin (aflatoxin) that is poisonous to man and livestock.

At the moment the most promising legume in terms of yields, freedom from diseases and pests as well as quality and quantity of its protein and oil is soybean which is described as "crop of the planet" or "miracle bean". Insect damage to soybean may be negligible and there may not be the need to apply insecticides during crop growth. Soybean contains high quality protein of 40 percent of the total bean. It is a good dietary source of calcium and phosphorus (Singh *et al*, 1987). The oil is highly digestible, high in unsaturated fatty acids and contains no cholesterol. The high protein content has substantial levels of most essential amino acids. The oligosaccharide which causes flatulence in legumes is minimal in soybean compared with other grain legumes which makes it an ideal food for infants.

The yield of protein from soybean on weight for weight basis is approximately twice that of meat, cowpea, lima bean and four times that of cereals (MOA/Extension publication, 1989).

Soybean meal can be incorporated into traditional Ghanaian dishes such as "Banku", "Tuozaafi", "Aprapransa", "Kenkey", Palm-nut soup, Gravy, Joloff, "Tuubaani", "Koose", "Koko" and weanimix for infants. In Northern Ghana, it is particularly popular in the making of "Dawadawa" a flavouring for soups and stews (Ghana/CIDA, GDP, 1992). In the Medium Term Agricultural Recovery Programme of the Ministry of Food and Agriculture (MOFA) in Ghana, soybean has been classified as a priority crop and a promising food needed to give a nutritionally balanced meal for Ghanaians, and to provide a domestic source of oils and soya products to supplement feed rations in the livestock and poultry industries in the country.

In spite of these laudable potentials and superiority of soybean over other legumes in terms of low pest infestation, diseases and high protein, this crop is not without problem in its cultivation. One of the major constraints in soybean production is weed competition. It is believed that this problem will have to be solved before the potential benefits of the crop will be realized.

The National Agricultural Research Project (NARP) sponsored by the World Bank has realized the nutritional importance of the crop and is undertaking research into removing the various agronomic bottlenecks in its production. Unfortunately, these studies do not include weed management and therefore there is an urgent need to fill this knowledge gap.

Weeds interfere with soybean by competing for light, nutrients and water. Weeds reduce yields of soybean by between 12 - 80 percent depending on the weed density and species (Haygood *et. al.*, 1980). The average yield losses of soybean due to weed competition in Nigeria and India were about 50% (Moody and Whitney, 1974). In addition, weeds were found to reduce the quality and yield of soybean seed (Carson, 1980). The ideal control method in each location depends on the cropping system, farm size and resource-base of the farmers as well as other socio-economic considerations. Most farmers use physical means in controlling weeds. It is adapted to small farm sizes of less than one hectare but it is not timely and frequently employed to prevent the yield losses caused by early weed competition. Where the farm size is large, physical control becomes laborious, unattractive and often lacking during the early stages of crop growth when weed competition is critical. To improve the timeliness and efficiency of handweeding, it may be prudent to determine the critical competition period between weeds and soybean, so as to determnne when and how often to handweed soybean in order to minimize weeding cost and optimise yields.

Chemical weed control could offer farmers the opportunity to remove drudgery associated with handweeding. With chemical control, weeds can be selectively controlled without injury to crops. Pre-emergence herbicides in particular may protect the crop from the adverse effects of early weed competition, reduce field labour demand for weeding, reduce erosion by not disturbing the soil and are less likely to be adversely affected by erratic weather conditions than the other methods of weed control. Chemical weed control may be suitable to small scale commercial operators who can afford and have the knowledge of using herbicides.

Some of the established pre-emergence herbicides include Galex (*metobromuron* + *metolachlor*), for broad-spectrum control of annual weeds, and Stomp (*pendimethalin*), which best controls *Rottboelia* spp and other annual grasses (Akobundu, 1987). In view of this, it was expedient to include and compare the cost-effectiveness of these two herbicides against the traditional handweeding practices. Varying weeding regimes were also adapted to determine the critical competition period between weeds and soybean.

Knowing the extent of early weed free period necessary to produce optimum yields will greatly ease the process of selecting type and rate of pre-emergence herbicide suitable for soybean production in the area in question. It may also be logical to determine whether residual carry-over effect of the herbicides might prove injurious or detrimental to the follow-up crop in the rotation in particular and to the environment in general.

The specific objectives of this study were as follows:-

(a) To determine experimentally the critical competition period so as to realize when and how often to weed in soybean.

(b) To determine the most practical and cost effective weed management practice in soybean.

(c) To determine residual action of the herbicide on the field by bioassay technique.

CHAPTER TWO

LITERATURE REVIEW

2.1 Economic Significance and Distribution of Soybean

Soybean (Clycine max (L) Merrill) is believed to have originated from North-eastern China, although the genus Glycine is also known to have other possible centres o.f origin namely eastern Africa and Australia (Weiss, 1983).

Domestication of Glycine max began in China around 1700-1100 BC (Hymowitz, 1970). The crop was introduced into the United States of America in 1765 and Africa in the early 19th Century (Akem, 1991). According to Mercer-Quarshie and Nsowah (1975), the crop was introduced in Ghana in 1909.

Within the past three or four decades, soybean has become a prominent source of protein for animal diets and has gained popularity around the globe for human nutrition. The world production of soybean increased by 55% from 58.1 million to 89.9 million tonnes from 1976-1984 and yields from 1536 kg/ha to 1727 kg/ha. Developing countries as a group produce 26.3 million tonnes (29%) with Africa producing 200,000 tonnes (0.22%). Yields in Africa were lowest at 660 kg/ha in 1984 (Singh *et. al.*, 1987).

2.1.1 Benefits/Merits

Approximately 40% high quality protein content:- The crop is known to contain about 40% high quality protein which can thus improve the quality of traditional diets to help combat the widespread of malnutrition in Africa.

Diseases and pest resistance and drought tolerance:- Soybean is known to be less susceptible to pests and diseases in the field and that the crop is also resistant to parasitic weeds such as Striga and can tolerate drought fairly well.

Nitrogen fixation:- Soybean fixes more nitrogen in the soil on its own. Due to this reason, it is an excellent rotation crop for cereals such as maize and sorghum because the yields of these crops improve when planted after soybean.

Resistance to storage insect pest:- Very little damage is caused to stored grains of soybean by insects pests.

Good yields:- Improved varieties of soybean give good yields in most situations without the use of nitrogen fertilizers, inoculum or insecticides. Cultivars of soybean have been developed which can stand erect without lodging and which will hold the seeds when ripped without shattering, Purseglove (1987).

2.2 Taxonomy and Morphology

Soybean is an annual plant which belongs to the family leguminosae and sub-family Papilionoideae. Most cultivars are erect, varying in height from 12cm to 200cm and may be sparsely or densely branched depending on the cultivar and growing conditions (Carlson, 1973).

The leaves are alternately arranged and are mostly trifoliate. Soybean seeds are borne in pods containing one to four seeds each. The weight of 100 seeds range from 5-40g, but most grain cultivars range from 10-20g per 100 seeds (Purseglove, 1987). It has been documented by Singh (1976) that, varieties with small seeds tend to survive tropical storage conditions better than those with large seeds.

2.3 Ecology

Moisture is required for good germination of soybean (5-7 days after sowing) and pod filling. A dry sunny weather is also needed for maturation and drying of the pods (Mederski *et. al.*, 1973). The crop tolerates a wide range of soil conditions but does best on well drained fertile loamy soils.

According to Weiss (1983), soybean can thrive in soils with pH ranging from 5.8 to 7.0, but pH between 6 and 6.5 is desirable since acid soils reduce nodule bacteria activity, and also the availability of magnesium and calcium. Being a short day plant, flowering occurs when the day length becomes shorter than the critical value for a particular variety. Bernard and Weiss (1973), recorded that tropical day lengths are shorter than the critical day lengths of most varieties.

2.4 Nutrient Management

Carter and Hartwig (1962) observed that generally no benefit is obtained from nitrogen fertilizer on well nodulated soybean. However, sufficient phosphorus application may be needed to ensure early ripening and high yield. Brinkman (1970) also asserted that soybean is capable of exhibiting the phenomenon of "hidden hunger" so that although no nutrient deficiency symptoms may be shown, the yield would be drastically reduced.

2.5 Nodulation

Nodulation of soybean occurs best in the presence of *Rhizobium japonicum* a bacteria, which is absent in most African soils especially in areas where soybean had not been grown previously in such areas. It is known that soybean nodulates freely with the cowpea strain of rhizobium.

2.6 Seed Yield in some Tropical Countries

Soybean is capable of achieving yields in excess of 4 tonnes/ha in the tropics. In Morocco, an average yield of 5044 kg/ha was recorded between 1979 and 1989. Likewise an average yield of 4704 kg/ha has been recorded in Egypt (Kolarall *et. al.*, 1985). Manful (1983) also obtained a mean grain yield of 4451 kg/ha in trials when he worked on some soybean varieties in Cape Coast. On the other hand, in Africa grain yield of soybean could be as low as 146 kg/ha (Singh *et. al.* 1987).

2.7 The Concept of a Weed

The definition of a weed has varied, depending on the effects that weeds are perceived to have on food production, recreative activities and aesthetic values of humans (Akobundu, 1987). The Oxford English Dictionary defines a weed as: A plant not valued for use or beauty, growing wild and rank and regarded as cumbering the ground or hindering the growth of superior vegetation.

A weed is defined as a plant which is part of an ecosystem that is in dynamic state of change. It interferes with human activity and/or welfare, and it occurs spontaneously in human disturbed habitats (Akobundu, 1987).

2.8 Economic Losses Caused by Weeds in Agriculture

2.8.1 Direct losses caused by weeds

Weeds reduce crop yield by interfering with crop growth. This includes competition with crops for nutrients, light and water. It also includes the introduction of chemicals into the soil that will adversely affect the growth of crop plants (allelopathy). Percentage yield losses due to uncontrolled weed growth in Ghana have been determined in the following crops as Soybeans 53%, Groundnut 54% and Cowpea 67% (Akobundu, 1980a).

Weeds reduce the quality of harvested agricultural products. The presence of weed seeds such as those of *Rottboellia cochinchinensis* in maize or rice, and *Sclerocarpus africans* or *Solanum nigrum* in cowpea or soybean reduce the market value of each of these crops. The presence of weeds can also reduce the quality of forages or make them unpalatable or even poisonous to livestock.

Weeds have been found to interfere with harvesting operations and thereby increase the cost of harvesting. Where *Mucuna pruciens* predominates as a weed it may be difficult to find workers willing to work even at higher pay than normal as harvestors. Heavy weed infestation may also interfere with speedy drying of crops and generally slows down harvest operations, thus increasing cost of harvesting.

The actual cost of weed control far exceeds that of any other crop pest. Part of the higher cost of weed control is due to the absence of genetic resistance to weeds among crops as is known to exist for most of other crop pests.

It is estimated that some 1800 weed species cause serious economic losses in crop production and about 300 of these weed species are responsible for the serious economic losses in cultivated crops throughout the world (Chandler, 1984).

Yield losses incurred from weed growth vary according to the nature of the weeds and their relative populations. It also depends on the environmental factors which determine the resources available for growth (Harper, 1961).

Generally, annual losses caused by weeds in the agriculture of developing countries have been estimated to be 125 million tonnes of food, a quantity sufficient to feed 250 million people (Parker and Fryer, 1975).

In the 1980's it was estimated that the crop loss due to weeds was approximately 7% in Europe and 16% in Africa. At the crop level it was 10.6% in rice, 15.1% in sugarcane and 5.8% in cotton (Fletcher, 1983).

Euphorbia heterophylla is particularly trouble some in soybeans. It is considered a serious or principal weed in 10 countries and as a common weed in 37 countries (Holm *et. al.*, 1979). Although *Euphorbia heterophylla* infests over 25% of the soybean fields in Brazil and it was estimated that densities up to 75 plants/m^2 reduced yield by only 12% (Hoffmann *et. al.*, 1975).

Yield losses were much greater in the U.S.A. where 8 plant/m^2 competing for 8 weeks, 12 weeks and full season lowered yields by 19, 21 and 33% respectively. More than fifty plant/m^2 often resulted in crop failure (Nestor *et. al.*, 1979), and six weeks free of *Euphorbia heterophylla* competition was usually adequate for maximum soybean yield (Langston and Harger, 1983).

2.8.2 Indirect losses caused by weeds

Weeds may serve as alternative hosts for many plants diseases and animal pests including insects, rodents, birds, that attack crops. Weeds also serve as alternate hosts for many arthropods, nematodes, bacterial and fungal diseases.

The presence of weeds imposes a limit on farm size. Farmers generally cultivate only the area that they know from experience that they will be able to keep weed-free. Such a constraint on farm size reduces productivity and the over all food supply that a community can produce.

Weeds such as *Imperata cylindrica* become fire hazards in the dry season throughout the savanna vegetation zone. Other grasses that pose such danger include *Andropogon* spp, *Pennisetum* spp and *Chromolaena odorata*.

In countries that depend heavily on human labour for weeding, children often have to miss school at peak weeding periods. This reduces the quality of education that these children can get during their formative years (Akobundu, 1987).

2.9 Weed Competition

The awareness that weeds compete with crops is probably as old as the domestication of crops. Weed losses caused by weeds are "hidden" losses in contrast to the damage done by insects, rodents, plants diseases and most other pests.

Competition is defined by Aldrich (1984) as the relationship between two or more plants in which the supply of a growth factor falls below their combined demands. These growth factors are light, nutrients, water, oxygen and carbon dioxide (Akobundu, 1987).

The competitiveness of weeds varies with species, density and weight and with duration of weed infestation. Weeds compete with crops for soil nutrients, water and light.

According to Heydendroff-Schell etc. al. (1983) the critical period of weed competition in soybean is varied and depends on the crop planting density. These authors recommended weeding opeations during the first 70 days after sowing at 100cm between rows, during the first 55 days when at 75cm and 30 days when at 18cm. Some weeds such as Poinsettia

(*Euphorbia heterophylla*) are very competitive because they are able to grow more rapidly than crops and produce canopy over under environmentally stressed conditions. These early growth advantages make this weed very competitive in both cowpea and soybean (Akobundu, 1987).

Weeds are most injurious early in the life of a crop. The precise time and duration of the period of maximum competition depends on many factors, such as the relative speed of growth of the crops and weeds, the density of planting, the variety grown, the time of moisture and nutrients stress. For most annual crops if the crop suffers much competition during the first quarter of its life it has suffered irreparably, and conversely, that if it has been well tended during this period subsequent weed growth is unlikely to have much effect on crop yields (Kasasian and Seeyave, 1969).

The general rule of the critical period of competition being one-third to half the life cycle of the crop varies considerably among crops. In soybean which often takes 120 days to mature, keeping the crop free of weed for the first 42 days from planting assures near maximum productivity (FA0, 1994, Adapted from Mercado, 1979).

2.9.1 Nutrient Level

If soil nutirients are abundant, weed competition is less important. In many tropical and sub tropical areas, soils are nutrients poor and thus competition is critical. In Nigeria, research showed that allowing weeds to compete with sorghum for 4 weeks when nitrogen was applied resulted in a 23% yield loss compared to keeping the crop weed-free all season. However, if nitrogen was not applied, this period of competition caused a 69% yield loss (Okafor and Zitta, 1991).

2.10 Cyperus rotundus

Cyperus rotundus is one of the most serious perennial weeds of the tropics. It is found in more countries, regions and localities of the world than any other weed (Holm et.al., 1977). It can grow in nearly any soil type and pH and the level of moisture and organic matter. It is found in cultivated field and in any neglected area (Doll. 1986).

Often known as purple nutsedge, it is rated as one of the most injurious weeds in soybean. Rhizomes grow from 1 to 30cm horizontally before the tips turn upward to form new aerial shoots with another basal bulb. This results in chains of tubers being formed, some as deep as 40cm in the soil. Up to 90% of the tubers are formed in the top 15cm of soil (FAO, 1994). Tuber production is approximately one tuber per day per plant for the first 90 to 140 days (Smith and Fick, 1937; Rao, 1968; Fuentes and Doll, 1976). Studies in Israel have found that a single tuber planted in the field can spread 90cm in two months and at the end of two seasons, averaged an increase in area of 2.8m^2/month (Horowitz 1972). Tuber population reached an equivalent of 10,130,000/ha. In Argentina, 3850 shoots were produced by one tuber in 6 months (Rodrigvez and Rainero, 1983), and in the U.S.A. tubers spaced 90cm apart formed the equivalent of 11,000,000 tubers and bulbs and 7,7000,000 shoot/ha in one season (Hauser, 1962b).

The weed is well suited to compete for nutrients, water and in the early growth stages, for light because it merges and grows more rapidly than most crops. While it iis a weed of small stature relative to most crops, it can cause serious yield losses. It iis a strong competitor for nitrogen and it can remove many kilograms of nutrients from the soil. Over 50% of these used after the weeds have emerged but before they get too tall to interfere with hoeing operations. Hoe weeding is applicable to both annual and perennial weeds.

The time spent weeding varies among crops, depending on the cropping pattern, spacing and spatial arrangement of crops. It is still the most time consuming single operation in the production of most crops in the tropics. Time spent weeding is affected by the age of the weeds. Druijff and Kerkhoven (1970), evaluating weeding efficiency in irrigated cotton in Eastern Kenya noted that farmers spent twice the time weeding cotton field covered with weeds up to 30cm tall as they spent on similar cotton fields with light cover of tiny weeds. These authors observed that delaying the first weeding by 2 weeks increased initial labour demand by three times.

In maize production farmers concerned by high labour cost have resorted to doing one late weeding rather than two timely weedings, in spite of the yield reduction which is known to occur where such practices are carried out (Allan, 1974; Armitage and Brook, 1976; Vernon, 1980). Among the advantages of hand hoeing are that:

Both annual and perennial weds can be controlled.

It is an effective weed control method for row crops.

It provides a clean seed bed and loosens the soil.

It is adapted to small farm sizes of less than one hectare.

Hand hoeing also has the following disadvantages:-

Weeds are usually established in crops before farmers start weeding.

It is labour intensive and involves a lot of physical exertion, and is expensive particularly where cheap labour is in short supply.

It is unsuitabale where farm size is larger than 1.5 hectare.

Effective hoe weeding depends on rainfall and soil moisture conditions because failure rates of weeding are higher in wet soils than when done during a dry spell.

It predisposes the soil to erosion as a result of the clean weeding and loosening up of the soil.

Hand hoeing has a high risk of crop damage in many root and tuber crops.

2.12 Herbicides

Herbicides are important and essential components of weed management in world agriculture. They have been pivotal in the attainment of food sufficiency by the developed countries and will inevitably play an important role in the tropics as this region moves from food deficiency to surplus food production. While many insecticides, such as the chlorinated hydrocarbons have reportedly created major environmental pollution problems, problems from the use of herbicides have been few and even poorly documented. Again herbicides have had a better safety record in the history of agriculture, with fewer accidents, than most farm machinery and household tools. If herbicides are handled properly they will continue to play useful roles in food production throughout the world. The increasing world population and the attendant need to increase food production, if only to meet and maintain present production levels, are indications that herbicide use most increase in order for farmers to produce these crops efficiently (Akobundu, 1987).

2.1.2.1 Metolachlor

In Ghana the two recommended pre-emergency herbicides for use in soybean are Galex (*metolachlor* + *metobromuron*) and Stomp (*pendimethalin*). Galex is a binary mixture of *metolachlor* and *metobromuron*. *Metolachlor* is an acid amide herbicide. It is a soil-applied herbicide that is effective on germinating weeds. They are applied as pre-emergence. The Acetamide group of herbicides to which metolachlor belongs, are growth inhibitors, and specifically, inhibit shoot and root growth of weed seedlings. This accounts for their use as pre-emergence herbicides. *Metolachlor* is mostly used in the tropics as a pre-emergence herbicide for weed control in maize, cowpea, soybean and groundnuts. The introduction of the herbicide safener cyometrinil (concept) has extended the use of *metolachlor* to sorghum (Ellis et. al., 1980). Ebert and Ramsteiner (1984) reported that the mechanism of cyometrinil protection of sorghum from *metolachlor* injury is by preventing *metolachlor* from inhibiting the synthesis of the long chain (C_{28} to C_{30}) fatty acid constituents of the sorghum epicuticular wax.

Metolachlor is available as formulated mixtures with a wide range of herbicides that include *metobromuron*. Broad leaf weeds absorb metolachlor through both shoot and roots, while uptake by grasses is through the shoot. Translocation in plant is apoplastic with accumulation in mature leaves of treated plants following root uptake (Ahrens and Davis, 1978). Mode of action appear to be the inhibition of protein and lipid synthesis. It does not persist in tropical soil even when used at rates up to 6.0 kg/ha (Utulu, *et. al.*, 1986).

2.12.2 Metobromuron

Metobromuron belongs to the substituted ureas group of herbicides. It is mostly used in tropical agriculture. *Metobromuron* is a photosynthetic inhibitor. It causes the blockage of electron transport in photosystem II. At normal dose it is a selective herbicide that causes chlorosis or yellowing followed by necrosis in susceptible plant species.

It is soil applied and it is taken up via plant roots. Translocation in plants is apoplastic even when foliar uptake has taken place (Bayer and Yamaguchi, 1965, Geissbuhler *et. al*., 1975). The urea herbicides are readily adsorbed to soil colloids and are not easily leached from treated soils. *Metobromuron* is more effective on broad leaf weed seedlings than on grasses. *Metobromuron* does not prevent weed-seed germination but rather kill the weed seedling that absorb the herbicide from treated soils. It is used for selective control in cowpeas, soybeans and tobacco. Herbicide efficacy is greatly improved by tank-mixing it with *metolachlor*.

2.12.3 Pendimethalin

Pendimethalin belongs to the dinitroaniline herbicides. It is less volatile and can be applied pre-emergence without soil incorporation. Several field studies show that the dinitroaniline herbicides also have fungicidal properties. Grinstein *et. al.* (1976) reported that pretreatments of solanaceous crops with these herbicides increased their resistance to several root diseases.

Dinitroanilines inhibit photosynthesis (Aston and Crafts, 1981). They degrade readily in the soil through the action of microorganisms (Zimdahl and Gwynn, 1971). *Pendimethalin* is used for grass weed control in many crops ranging from maize, soybean and other vegetable crops. *Pendimethalin* has a narrow weed control spectrum which can be considerably broadened by tank mixing with *metobromuron*. It is to date a practical solution to *Rottboellia cochinchiensis* problem in maize in the tropics.

2.12.4 Herbicide Combinations

The prolific weed growth in the humid tropics makes it necessary to combine herbicides in order to get good control of the heavy and mixed weed populations. Herbicide mixtures have many distinct advantages over the single products. Some of the advantages of herbicide mixtures and reasons for the increasing use of formulated mixtures are as follows:-

Herbicides are used in combination to broaden the spectrum of weeds controlled by a given herbicide application. The use of a herbicide that kills mainly grasses or only broad leaves will still leave the farmer with so many weed species that are not controlled.

The combination of a pre-emergence herbicide with the contact herbicide will increase weed control effectiveness because the pre-emergence herbicide will prevent reinfestation after the existing seedling weeds have been controlled by the post-emergence herbicide in the mixture. An example of this type of bebefit is the use of Tamarice (a mixture of propanil and thiobencarb) for weed control in rice.

Mixtures can be used to reduce the cost of labour required to apply herbicides. A pre-plant herbicide can be tank-mixed with a pre-emergence herbicide, thus making one pass over the field to apply them rather than separate passes to apply each of the herbicides.

Herbicide combinations improve crop safety since low doses of herbicides are used in mixtures compared to rataes used when each of the herbicide is used alone for the same weed problem. Herbicide combinations also make it possible to use certain herbicides in multiple-cropping systems where two or more crops of varying tolerance to the herbicides are involved. For example, cassava is sensitive to atrazine, even at a low rate (1.0kg/ha) that will not adequately control weeds for up to 4 weeks in this crop in the humid tropics. On the other hand, Primextra (2.5 kgai/ha), a formulated mixture of atrazine (0.83kg/ha) and metolachlor (1.67kg/ha) is routinely used pre-emergence for weed control in maize/cassava, and maize/cassava/yam intercropping systems.

2.12.5 Processes influencing the deactivation or disappearance of soil-applied Herbicides

The environmental factors that have the greatest impact on soil-applied hebicides are rainfall and temperature. They have direct effects on the biological and non-biological processes that influence plant uptake of soil-applied herbicides, and the action of these herbicides in soils. A soil-applied herbicide may be adsorbed and become unavailable to the weeds, it may be leached into deeper soil layers out of reach of weeds or be decompsed by soil microorganisms. Processes that affect the fate of soil-applied herbicides may include the following:-

2.12.5.1 Leaching

It is a physical process by which a herhicide may be moved from the surface to deeper layrs of the soil profile. Leaching of herbicide is affected by the chemical properties of the herbicide, the soil texture, solubility of the herbicide, adsorption of the herbicide and by the amount of water reaching the soil. While the urea herbicides resist leaching, the amide herbicides are readily leached in the soil. A soil-applied herbicide may completely lose its efficacy as a result of lleaching if it is applied on very llight soils that are low in colloidal fractions.

2.12.5.2 Microbial Decompsition

Many soil microorganisms depend on the degradation of organic compoiunds for energy and food. Some of these microbes can adapt themselves to use some herbicides as a source of food. Microorganisms may produce the enzymes that carry out the breakdown of herbicides, or produce substances that catalyse enzyme reaction associated with the breakdown. Microbial degradation of herbicides is of such wide occurrence that it is considered as the major process associated with herbicide degradation in soil.

2.12.5.3 Herbicide uptake by plants

Plants remove herbicides from the soil in the course of absorbing water and nutrients. If the plants are susceptible to these herbicides they are killed, but if not the herbicides are detoxified iin the plants. Herbicide removal by plants reduces the efficacy of the herbicides (Burrill and Appleby, 1978).

2.12.5.4 Photodecomposition

The molecules of some herbicides are unstable in light, especially the dinitroanilines and thiocarbamates. They are readily degraded when left on the soil surface for an extended period of time. Photodecomposition plays an important part in the degradation of pre-emergence herbicides. It is the ultraviolet wavelength of sunlight that is responsible for most photodecomposition of herbicides in the field. Light energy is absorbed by the molecules of light - sensitive herbicides, and this radiant energy destabilizes the herbicide molecules, causing them to lose their herbicidal activity or become more phytotoxic.

2.13 Methods of Weed Assessment

Two methods exist for assessing the species composition of an area. These are the quadrat and line transect methods (Brown, 1954). The traditional representation of a quadrat is by a square frame (Brown, 1954). Quadrats vary a great deal in their sizes. The size is usually determined by the morphological characteristics of the species in the vegetation to be sampled and the homogeneity of the vegetation. Where a vegetation is made up of grasses which grow in tussocks, a quadrat smaller than the tussock unit may not be appropriate because the frequency values may be affected (Greig-smith. 1960). Small quadrats are appropriate for the study of small plants e.g. 10 x 10cm or 25 x 25cm quadrats may be used for the study of arable weeds, whilst large quadrats may be used for scrub and woodlands (Gold-Smith and Harrison, 1976).

Bauver (1943) has compared the relataive efficiency of quadrats and transects and reported that where the vegetation involved consisted of individuals of the same size, the quadrat and transects gave comparable results. However, for the assessment of a vegetation in an area where there are no serious topographical effects, the quadrat has mostly been used (Kershaw, 1971).

The sampling procedure of a vegetation could be random, systematic or a combination of both. The random sampling procedure usually deals with the use of table of random numbers, thus giving every point in the field, the chance of being sampled. The use of the random procedure is favoured by some scientists because it allows for the estimation of the mean values and the standard error. The systematic sampling from them is also favoured by other scientists, including Finney (1950).

He proposed that even though systematic sampling of a vegetation does not allow for the estimation of the standard error it does so for the mean values. Bourdeau (1953) reported that precision is increased where randomization is restricted, especially whre density is of interest. Greig-Smith (1960) proposed a combination of the random sampling and the systematic sampling as a means of restricting randomization.

According to Gold-Smith and Harrison (1976), the two main methods of weed measurements can be grouped under (a) Destructive and (b) Non-destructive.

Destructive method of weed measurements are undesirable where further observations are required in the long term and where the area of investigation is of some outstanding natural beauty or of biological interest.

With the non-destructive method, no significant damage is done to the plant community so further observation can be carried out to measure long term changes in the flora. The destructive method is used where dry matter is of interest.

Methods used for vegetative analysis may also be qualitative or quantitative. Qualitative measures are quick and less laborious to use but they can be subjective and liable to personal bias. They also lack the precision necessary for scientific analysis (Haizel, 1956). There are four criteria involved in quantitative botanical analysis (Brown, 1954) and they are:-

(a) Frequency, (b) area of cover, (c) numbr, (d) weight.

Frequency: It is a measurement of the distribution of the plant species in a community. It expresses the homogeneity or otherwise of the community. The frequency of occurrence is given by the formula:

$$\frac{\text{No. of quadrats in which a species occurs}}{\text{Total number of quadrats sited}} \times 100$$

derived by Greig-Smith (1960). If the right size of quadrat with respect to the growth form of the vegetation is used, an indication of the pattern of the vegetation can be provided.

Area of cover: gives a measure of the percentage of the land area covered by the plants in the community. It is estimated by the perpendicular projection of the ground of the serial parts of the individuals under consideration Greig-Smith (1964) expressed it as a percentage. It can also be measured as the basal area cover and estimated by the area to which the individual is rested at ground level.

Numbers:- The individual plants or weed species are counted and presented as abundance percentage composition by number, or population density. Numbers have been recommended as a more reliable criteria to use in botanical analysis than frequency (Greig-Smith, 1964). This is because quadrat size has no effect on the relationship between the plant species when their numbers are considered.

Weight:- Use of weight as an indicator of botanical composition is laborious, expensive and is of little economic application to weed investigation on arable land (Brown, 1954).

2.14 Herbicide Bioassay

2.14.1 Use of Bioassay

Bioassay is the measuement of a biological respond by living plants in order to determine the presence or concentration of chemical in a substrate. Bioassays for the presence of herbicides are usually conducted with sensitive plant species. A soil bioassay involve the growing of an indicator plant species in a herbicide treated soil, and then comparing the response of the test plants to similar plants grown in untreared soil or in soil containing known herbicide concentrations.

Bioassays are generally used as a quantitative measurement of the biologically active concentration of a herbicide known to be present (Robert-E, 1972). A major advantage of the biological assay is the assurance that the phytotoxic activity of the herbicide molecule is what is being measured. Many bioassay methods are highly sensitive, and accurate determinations are possible with some herbicides at concentrations as low as 0.0075ppm Funderburk *et. al.* (1963).

Plant growth is directly influenced by ambient environmental condition such as light, temperature, watering level and humidity. Variations in these factors may cause a greater plant response than the herbicide under test.

Considerable species variation in susceptibility to a given herbicide and in some instances individual plant variation within a species may be apparaent. For example, weak seedlings may be more susceptible to the herbicide than vigorous ones, or small seeds may respond diffently than larger seeds of the same species. Bioassay procedures that allow selection for individual plant uniformity increases reproducibility and reliability. Long periods of time may permit herbicide degradation during the course of the experiment (Leasure 1964 and Parker 1965).

Bioassay measurements may be determined by total plant response. This is normally noted as a suppression or inhibition of plant growth, chlorosis, or by harvesting the plants and expressing the growth as green (wet) weight or dry weight. If conditions are kuniform green weight may often be more meaningful in bioassays than dry weight as recently dead and necrotic plants may have the same dry weight per plant as green healthy ones.

2.14.2 Choosing Bioassay Species

Test plants species used must be sensitive enough to detect very small amounts of herbicide. If the concentration range is large, it may be necessary to use two or more species with different degrees of sensitivity. The species chosen must also exhibit a gradual increase in susceptibility with increasing herbicide concentrations.

CHAPTER THREE

3.0 MATERIALS AND METHODS

The studies were carried out in three (3) main experiments. Two (2) of the experiments were conducted at the Teaching and Research Farm of the School of Agriculture, University of Cape Coast. The third experiment was carried out in the Research Laboratory, School of Agriculture, from September to December, 1994. The three experiments were repeated in April to July 1995.

3.1 EXPERIMENTAL SITE

The experiment was conducted on the Teaching and Research Farm of the School of Agriculture, University of Cape Coast. According to meterological data, Cape Coast has a bimodal rainfall pattern; the main season begins in April and ends in July, the peak falls in June while the minor season is from September to November with a peak in October. The total annual rainfall is variable, and ranges between 930 millimetre and 1200 millimetre.

The experimental area has been subjected to many years of cultivation that has changed the climax vegetation considerably. The climax vegetation of the area was described as coastal thicket with the presence of forest perennials such as *Ficus exasperata*, *Albizia zypia* and *Hippocrata pallens*.

Presently the vegetation of the area is coastal savanna (Rose-Innes and Clayton, 1977) and consists of predominantly annual herbs like *Tridax procumbence*, *Amaranthus spinosis*, *Ipomea involucrata* and annual grasses such as *Brachiara lata*. Perennial dicots such as *Ipomea involucrata* and sedges such as *Cyperus rotundus* were also found.

The soils of the experimental area had been described by Asamoah (1973) as the Benya series under the Edina/Benya/Udu compound association (Utisol). The soil has a clay to loam texture with fine granular and friable texture; the top soil is of medium depth and a loose structure. The soil has a medium internal drainage, medium run off and is moderately permeable (Asamoah, 1973).

3.1.1 History of Experimental Area

The area was cropped continuously with cowpea only in the main season. There was no cropping in the minor season. Before the experiment, the area had been fallowed for almost one year.

3.2 EXPERIMENT ONE

Determination of the critical competition period between soybean and weeds.

3.2.1 Soil Analysis

Before the start of the experiment, soil samples were taken from the site for the following analysis:-

3.2.1.1 Determination of Soil pH

The determination of soil pH was based on the method adopted by IITA (1985). Sample soil from the field was air-dried and sieved with 2mm sieve. Twenty (20) grammes of the sieved soil was measured into a 50ml beaker. Twenty millilitres (20ml) of distilled water was added and allowed to stand for 30 minutes while with a rod, stirring was made occasionally. The electrodes of the pH meter was inserted into the partly settled suspension and the pH value recorded.

3.2.1.2 Determination of Soil Nitrogen

Soil nitrogen determination was by means of the method described by Allen-Stewarte *et. al.* (1974) and IITA (1985). Soil samples collected were air-dried and sieved. Chemical analysis was carried out for total nitrogen. Half a gramme (0.5g) of the air-dried sample was measured into 30ml Kjeldahl flask and was completely digested with 20ml concentration of H_2SO_4, 3ml salicylic acid-sulphuric acid mixture with potassium sulphate catalyst. The completely digested sample was distilled in a distillation apparatus and the distillate collected into 5ml boric acid indicator. The distillate was then titrated with 0.02 N HCl and the titre value was used to calculate the percentage total nitrogen sample.

3.2.1.3 Determination of Potassium

To 5gm of soil sample was added 30ml of 1N ammonium acetate solution and shaken on a mechanical shaker for 2 hours, and also centrifuged for 10 minutes at 2,000 r.p.m. The supernatant was transferred into a 100ml volumetric flask. Another 30ml of NH_4 OAC solution was added and shaken for 30 minutes. The process was repeated three times. From the prepared stock potassium standard solution, concentrations between 0 and 10 ppm was prepared. A calibration curve was prepared from the concentrations. This curve was used to determine potassium (ppm) in the sample solution. The determined value was further used to determine the value of potassium in the soil smaple IITA (1985).

3.2.1.4 Determination of Available Phosphorus

The colorimeter method was used (IITA, 1985). One (1) gramme soil sample was measured into a centrifuged tube and 7ml Bray No. 1 solution added. It was mechanically shaken for one minute and centrifuge for 15 minutes at 2,000 r.p.m. 2ml supernatant solution was measured, 10ml of distilled water was added with 4ml Reagent B. This was made up to 25ml by adding distilled water. Blue colour was allowed to develop for 15 minutes and thus phosphorus concentration was determined on a spectrometer at 660 mm wave length. This value was used to calculate the available phosphorus in the sample.

3.2.1.5 Determination of Organic Carbon

Percentage carbon content was determined using Walker-Black method as described by IITA (1985) and Allen *et. al.*, (1974).

3.2.2 Land Preparation and Experimental Design

The land was ploughed using a disk plough and harrowed after 6 days. Levelling was done by using hoe and rake. An area of 19m x 40m was demarcated for the experiment. The area was pegged out into 40 plots each plot measuring 4m x 3m. The Randomised Complete Block Design (RCBD) was used. There were 10 treatments, 9 of which were varying weeding regimes and one treatments as a weedy control with 4 replications. The treatments were as follows:-

1. No weeding till harvest after seedling emergence.
2. Continuous weeding till harvest (kept weed free).
3. First weeding at 10 days after seedling emergence and kept weed free.
4. First weeding at 20 days after seedling emergence and kept weed free.
5. First weeding at 30 days after seedling emergence and kept weed free.
6. First weeding at 40 days after seedling emergence and kept weed free.
7. Weed free for the first 10 days after seedling emergence only.
8. Weed free for the first 20 days after seedling emergence only.
9. Weed free for the first 30 days after seedling emergence only.
10. Weed free for the first 40 days after seedling emergence only.

The soybean variety `Anidaso' was used with plant spacing of 75cm between rows and 5cm within rows. Each plot was made up of six rows.

3.2.3 Method of Weed Control

Physical control method of hoeing was employed as required.

3.2.4 Pest control

Apart from weeding there was no pesticide (insecticide) application since there was no visible sign of insect pest attack during the growth period till harvest.

3.2.5 Harvesting

This was done when the crop became dry on the field. Plants from the middle four rows of each plot were cut using a sharp knife at the base. The outer 2 rows were left as borders.

3.2.6 Data Collected

3.2.6.1 Plant Height Per Treatment (cm)

Random sample of five plants per plot of a specific treatments were chosen. Height measurements were taken at physiological maturity. The average for the five was computed for every treatment plot.

3.2.6.2 Number of Pods Per Plant Per Treatment

The total number of pods from 5 randomly selected plants of specific treatments were counted and the average for the five plots was computed for every treatment plot.

3.2.6.3 1000 Seed Weight (g)

Five different 1000 seed weights from each treatment plot yield were counted, weighed and recorded. The mean of the five different 1000 seed weights was computed for every treatment plot.

3.2.6.4 Grain Yield Per Treatments (Kg/ha)

The middle four rows of each treatment plots were harvested, shelled and the grains weighed to determine the yield per plot. The average yield of specific treatment plots was extrapulated to kg/ha basis.

Summary of data collected was:-

1. Plants height at maturity per treatment.
2. Number of pods per plants at harvest.
3. 1000 seed weight (g).

4. Grain yield per treatment (kg/ha).

5. Identification of weeds (agrestals) present on the treatment plots.

3.2.7 Weed Identification

A handbook of West African Weeds (Akobundu, 1987) was used as an aid in identifying the weeds present on the experimental plots. Weeds which could not be identified immediately in the field were taken to the Herbarium at the Botany Department for identification.

3.2.8 Percentage weed free yield per treatment

The average grain yield per treatment was recorded for the various weeding regimes (treatments). The percentage weed free yields were calculated in the treatments as follows:-

$$\% \text{ weed free yield} = \frac{\text{Treatment yield (kg/ha)}}{\text{Weed free yield (kg/ha)}} \times 100$$

A graph of % weed free yield was plotted against days of weeding on the horizontal axis. From the curves obtained, the critical competition period was determined at an acceptable yield target of 70% of the weed free yield.

This was done by reading off the point on the % weed free yield axis which corresponded with a point of intersection of the 2 curves to give a corresponding weeding periods on the horizontal axis. This weeding period (days) at 70% weed free yield gave the period of competition between the weeds and the soybean.

3.2.9 Data Analysis

Analysis of variance was carried out on all the data collected on the treatment plots, at the 5% level of significance. Duncan's Multiple Range Test was used to assess significant differences between treatment means.

3.3 EXPERIMENT TWO

Comparison among chemical, manual and chemical plus manual weeding regimes.

3.3.1 Soil Analysis

Before the treatments were effected, soil samples were taken for the following analysis:

(a) Soil pH using soil pH meter. IITA (1985).

(b) Nitrogen by Kjedahl's method. Allen-Stewarete *et. al. (1974) and IITA (1985).*

(c) Potassium using the flame photometer. IITA (1985).

(d) Available phosphorus. Using the colorimeter method, IITA (1985).

(e) Organic carbon.

Percentage carbon content was determined using Walker-Black method as described by IITA (1985) and Allen *et. al.*, (1974).

3.3.2 Land Preparation and Experimental Design

The land was ploughed using a disk plough and harrowed after 6 days. Levelling was done by using hoe and rake. An area of 20m x 50m was demarcated for the experiment. The area was pegged out into 48 plots each measuring 4m x 3m. The RCBD was used. There were 12 treatments, each treatment was replicated 4 times.

The treatments were as follows:-

1. No weeding till harvest.
2. Continuous weeding till harvest (kept weed free).
3. Galex (*metolachlor* + *metobromuron*) applied at 1.5 kg a.i./ha. No hand weeding till harvest.
4. Galex applied at 2.0 kg a.i./ha. No hand weeding till harvest.
5. Galex applied at 1.0 kg a.i./ha plus one hand weeding at 35 days after crop emergence.
6. Stomp (*pendimethalin*) applied at 1.5 kg a.i./ha. No hand weeding till harvest.
7. Stomp applied at 2.0 kg a.i./ha. No hand weeding till harvest.
8. Stomp applied at 1.0 kg a.i./h.a. Plus one hand weeding at 35 days after crop emergence.
9. Galex at 1.0 kg a.i.ha plus stomp at 1.0 kg a.i./ha. No hand weeding till harvest.
10. One hand weeding at 3rd week after crop emergence.
11. One hand weeding at 6th week after crop emergence.
12. Two hand weedings at 3rd and 6th week after crop emergence.

The soybean variety used was 'Anidaso' with plant spacing of 75 cm x 5 cm. Each plot was made up of 6 rows.

3.3.3 Method of Weed Control

Hoeing was carried out in all the treatments which required weeding at a particular time during the experiment. The pre-emergence treatments were applied a day after planting. All the herbicides treatments were applied in a spray volume of 220 l/ha by using a lever operated Knapsack sprayer.

3.3.4 Data collected

1. Plant height at maturity.
2. Number of pods per plant.
3. 1000 seed weight per treatment (g).
4. Yield per treatment (kg/ha).

3.3.5 Weed Assessment

To evaluate the performance of the 2 pre-emergence herbicides, a quadrat which measured 50 cm x 50 cm was sited at the centre of each herbicide treatment plot including that of the weedy control plot 35 days after crop emergence. The various weed species within each quadrat were identified, counted and their fresh weight as well as dry weights determined. Weed control was expressed in terms of percentage effectiveness calculated as follows:

$$\%\ \text{Weed Control} = \frac{\text{No. of weeds or fresh weight of weed per treatment}}{\text{No. of weeds or fresh weight of weed per weedy control}} \times 100$$

The percentage data were transformed to the arcsine and analysis of variance carried out.

3.3.6 Data Analysis

The analysis of variance was carried out on all the data collected. Duncan's multiple range test were used to assess significant difference between treatment means at P = 0.05.

3.3.7 EXPERIMENT THREE: Bioassay to determine residual action of herbicide in the field.

Soil samples were randomly taken from the herbicide treated plots after the soybeans were harvested. Soil samples from the same treatments plots were bulked, air dried and sieved. Two hundred grammes (200g) of the bulked soil samples of each treatment was placed in a plastic cup of 8cm depth with drainage holes made at the bottom of the cups. There were six replications of every treatment including the untreated control. Each of the 200g soil sample, that is the treatment samples and the control, was mixed with $40cm^3$ of water.

3.3.8 Test Plants

Sorghum and millet were used as test plants in the determination of the residual activity of the herbicides in the soil. Of the 6 replications of a specific treatment, three replications were seeded with sorghum and the other three seeded with millet. Six pre-germinated seeds of each test plant were planted in each cup. These were allowed to grow for 6 days. The length of the shoots was measured and the corresponding fresh weight and dry weight of the shoots were determined.

3.3.9 Standard Curves Determination of Herbicides

Commercial formulations of the two pre-emergence herbicides were used in this test. A 1% stock solution of Galex [50% active ingredient (ai)] and a 1% stock solution of Stomp (50% active ingredient) were prepared. Dilutions of 1, 3, 5, 10, 20 and 100 ppm were prepared out of each herbicide stock solution.

Soil samples of 200g dried and sieved from untreated control plots were mixed evenly with 25cm^3 of each of the prepared dilutions and placed in plastic cups. Each treatment was replicated six times. To each plastic cup of soil herbicide mixture was added 20cm^3 of water. Three of the six replicates for each treatment were seeded with pre-germinated sorghum and the other three replications seeded with pre-greminated millet. The lengths of the shoots were measured and their correspond-ing fresh and dry weights determined at six days after planting of the pre-germinated seeds in the cups.

Standard curves for the herbicides were obtained from plot of fresh weight of sorghum and shoot length of millet expressed as percentage of untreated control plants against herbicide concentration (ppm).

3.3.10 Residual activity of herbicide in treated plots

The residual activity of herbicide in treated soil samples were determined by reading off the point on the concentration axis which corresponded with the point of intersection of the appropriate standard curve and the fresh weight of sorghum and millet expressed as percent of untreated control plants.

3.4 DATA COLLECTED

3.4.1 Plant Height (cm)

The heights of six plants of a specific treatment in a plastic cup, including the control were measured. The average for the 6 was computed for each cup treatment.

3.4.2 Fresh Weight of Shoot (g)

Six plants of a specific treatment in the plastic cups including the control was harvested at the base. The shoots were quickly weighed. The average fresh shoot weight was computed for each crop treatment.

3.4.3 Dry Weight Determination

The shoots of the 2 test plants for the various herbicide soil mixtures and soil treatments as well as the untreated control were placed in envelopes and kept in an oven at a temperature of 80°C until a constant weight was achieved after 2 days.

CHAPTER FOUR

RESULTS

The chemical characteristics of the soil on which the experiment plots was sited are shown in Table 1.

Table 1: Soil characteristics of experimental site, 1994 and 1995 Seasons.

Soil character	1994		1995	
	Mean Value %	Range %	Mean value %	Range %
Nitrogen	0.08	0.6 -0.11	0.08	0.06-0.09
Potassium	0.02	0.01-0.03	0.25	0.02-0.03
Organic carbon	1.18	0.97-1.36	1.25	1.12-1.53

In 1994 the pH of the soil ranged between 5.9-6.4 with a mean value of 6.0. The phosphorus content range between 22.0 ppm - 64.14 ppm with a mean of 41.17 ppm.

In 1995 the pH of the soil ranged between 5.9 - 6.4 with a mean value of 6.0. The phosphorus content ranged between 22.04 - 42.81 ppm with a mean of 35.50 ppm.

4.1 Experiment One: Determination of Critical Period of Competition between Weeds and Soybean

4.1.1 Weed Competition (1994) - Minor Season

The major weed species found in the experimental area were *Cyperus rotundus* L., *Panicum maxima* Jacq., *Trianthema portulacastrum* L. *and Commelina bengalensis* L. with the *Trianthema portulacastrum* dominating about 65% of the total land area. There was a 67% reduction in soybean yield as a result of unchecked weed competition as seen in Table 2.

A delay of 40 days or more in weeding caused a significant reduction of 81.82% in grain yield, while at least 40 days of weed-free conditions after planting were able to prevent a significant reduction in yield, by giving a 75% weed free yield. Weed-free periods after the first 10 and 20 days of weed infestation were necessary to give significant yields of 90 and 80 % respectively (Table 2).

The critical period of weed competition for soybean was graphically determined as seen in Fig. 4.1. At an acceptable yield of 70% of the potential it was determined that the critical period of competition was between 23-35 days after crop emergence.

4.1.2 Grain Yield and its Parameters

Completely weed-free plot gave the highest yield of 992 kg/ha but this was not significantly different from yields obtained from plots infested with weeds for the first 10 and 20 days only and also plots which were kept weed-free for the first 20 and 40 days only.

Table 2: Effect of Duration of Weed Competition on Yield and its Components of Soybean, 1994 Cape Coast Minor Season

Weeding Treatment	Grain Yield (kg/ha)	% Reduction In Yield	No. of Pods/ Plants	Plant Height (cm)	1000 Seed Wt. (g)
Weed infested first 10 days only	896. ef	10	30 def	64 cde	81.36 bcd
Weed infested first 20 days only	795 def	19.89	29 def	68 bcde	93.51 ab
Weed infested first 30 days only	506 bcd	49.10	35 cde	62 de	77.01 bcd
Weed infested first 40 days only	179 a	81.82	20 f	60 e	79.91 bcd
Completely weed free	992 f	0	58 a	76 ab	77.93 bcd
Weed first 10 days only	395 abc	59.81	39 bcd	73 abc	98.23 a
Weed first 20 days only	683 cdef	31.11	49 ab	79 a	77.46 bcd
Weed first 30 days only	610 bcde	38.44	56 a	71 abcd	92.88 abc
Weed first 40 days only	748 def	24.53	46 abc	69 bcde	73.36 d
Unweeded control	324 ab	67.31	24 ef	68 bcde	74.11 cd
S.E.	91.78	-	3.78	2.89	5.11
C.V. (%)	29.93	-	19.33	8.35	12.39

*Means within column and followed by similar letters are not significantly different at P = 0.05, according to Duncan's Multiple Range Test.

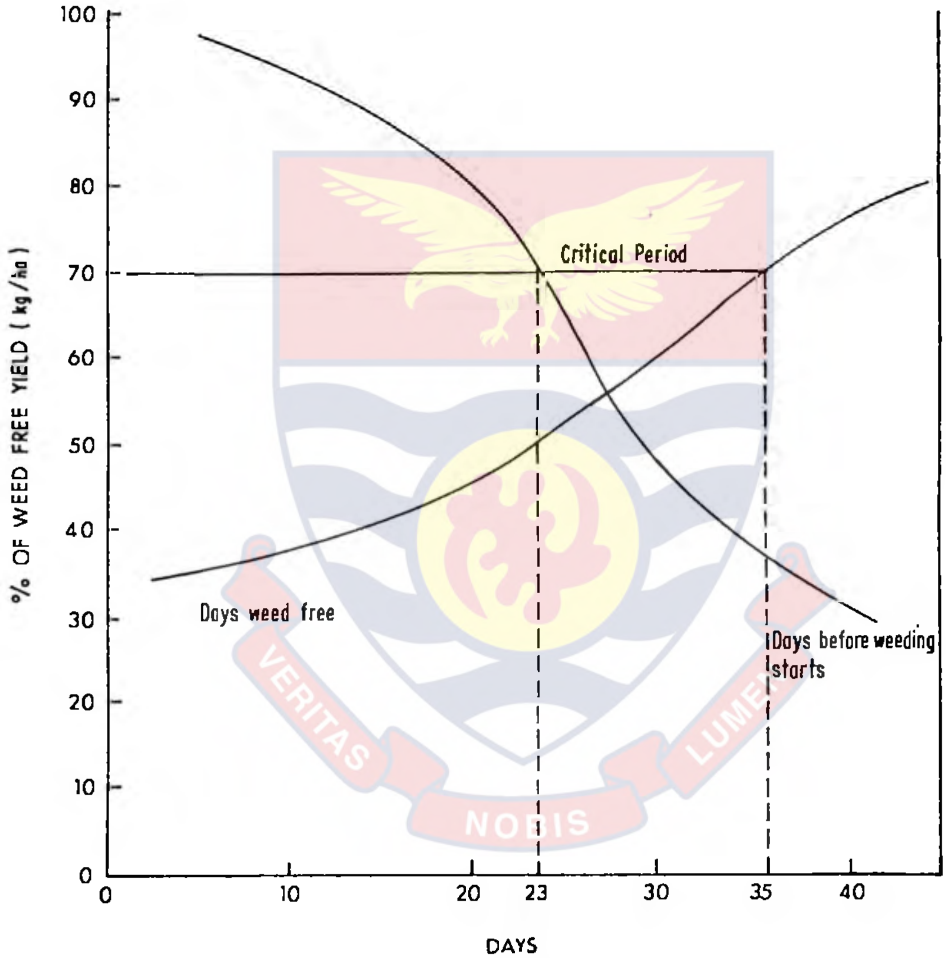

FIG. 4.1 : CRITICAL PERIOD FOR WEED COMPETITION FOR SOYBEAN

(1994 – CAPE COAST MINOR SEASON)

Unweeded control or plots infested with weeds throughout gave the least yield of 179 $kgha^{-1}$. This was however not significantly different from treatment kept weed free for only first 10 days (Table 2).

Weed-free plots for first 20 days gave the highest plant height of 79.20 cm and this was significantly different from plant heights in treatments kept weedy from first 10 to 40 days after crop emergence. The lowest plant height was obtained in the weed infested for the first 30 days treatment.

The completely weed-free plots gave the highest number of pods per plants of 58, though it was not significantly different from those of weed-free first 20 days and 30 days as seen in Table 2. Weed infestation for first 40 days gave the lowest number of pods per plant of 20.

Weed-free for the first 10 days of crop emergence gave the highest 1000 seed weight of 98.23g, though it was not significantly different from those of weed infested 20 days only and weed-free first 30 days only. Weed-free for first 40 days recorded the lowest 1000 seed weight of 73.36g though this was not significantly different from that of weed infested completely which was 74.11g (Table 2).

4.1.3 Weed Competition (1995) Major Season

The major weed species found in the experimental area were Cyperus rotundus L., Tridax procumbense L., Cynodon dactylon (L.) Pers., Panicum maxima Jacq., Trianthema portulacastrum L. and Euphorbia heterophylla L., with the Cyperus rotundus L. dominating about 85% of the total land area. There was a 81% reduction in soybean yield as a result of unchecked weed competition Table 3.

A delay of 40 days or more before weeding caused a significant reduction of 60% in soybean grain yield, while at least 40 days of weed-free conditions after crop emergence were able to prevent a significant reduction in yield by giving an 84% weed-free yield. Weed-free periods after the first 10 days of weed infestation were necessary to give significant yield of 90% (Table 3), while weed infestation for more than 10 days after crop emergence was able to cause a significant reduction of 70% in soybean grain yield.

The critical period of weed competition for soybean was graphically determined at an acceptable yield of 70%, to be between 20-32 days after crop emergence (Fig. 4.2).

4.1.4 Grain Yield and its Parameters

From Table 3 the completely weed-free treatments gave the highest significant yield of 4060 kg/ha. Unweeded control recorded the least yield of 771 kg/ha which was significantly lower than yields in the other treatments.

Table 3: Effect of Duration of Weed Competition on Yield and its Components of Soybeans, 1995 Cape Coast Major Season

Weeding Treatment	Grain Yield (kg/ha)	% Reduction In Yield	No. of Pods/ Plants	Plant Height (cm)	1000 Seed Wt.(g)
Weed infested first 10 days only	3664 g	10	123 a	62.10 ab	86.75 abc
Weed infested first 20 days only	2654 e	35	90 a	54.96 bc	82 ab
Weed infested first 30 days only	2397 d	41	85 a	56.28 abc	86.75 abc
Weed infested first 40 days only	1624 c	60	97 a	48.48 cd	82.00 ab
Completely weed-free	4060 h	0	126 e	62.47 ab	101.25 d
Weed free first 10 days only	1228 b	70	110 a	54.72 bc	82.50 ab
Weed free first 20 days only	2450 d	40	117 a	63.68 a	92.50 bcd
Weed free first 30 days only	2510 d	38	96 a	52.31 c	90.75 bcd
Weed free first 40 days only	3419 f	16	108 a	62.85 ab	91 bcd
Unweeded control	771 a	81	42 b	43.50 d	75.75 a
S.E.	46.93	-	13.36	2.58	3.680
C.V. (%)	3.79	-	26.71	9.23	8.34

* Means within column and followed by similar letters are not significantly different at P = 0.05, according to Duncan's Multiple Range Test.

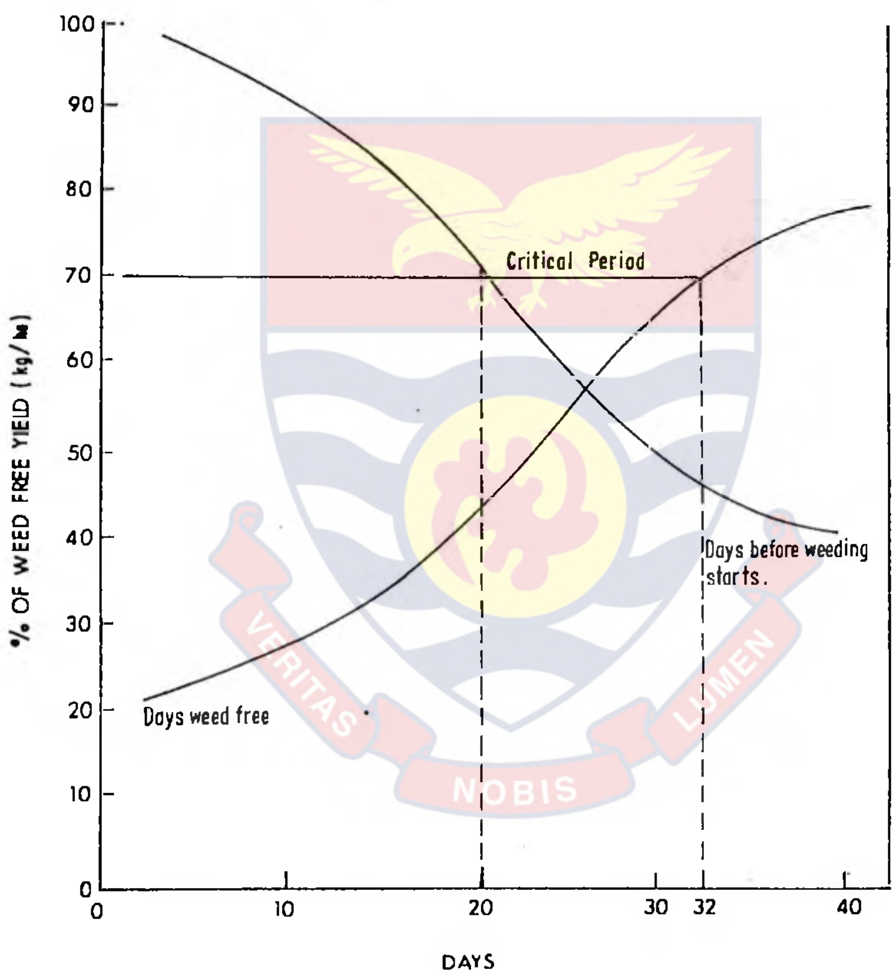

FIG. 4.2 : CRITICAL PERIOD OF WEED COMPETITION FOR SOYBEAN

(1995 – CAPE COAST MINOR SEASON)

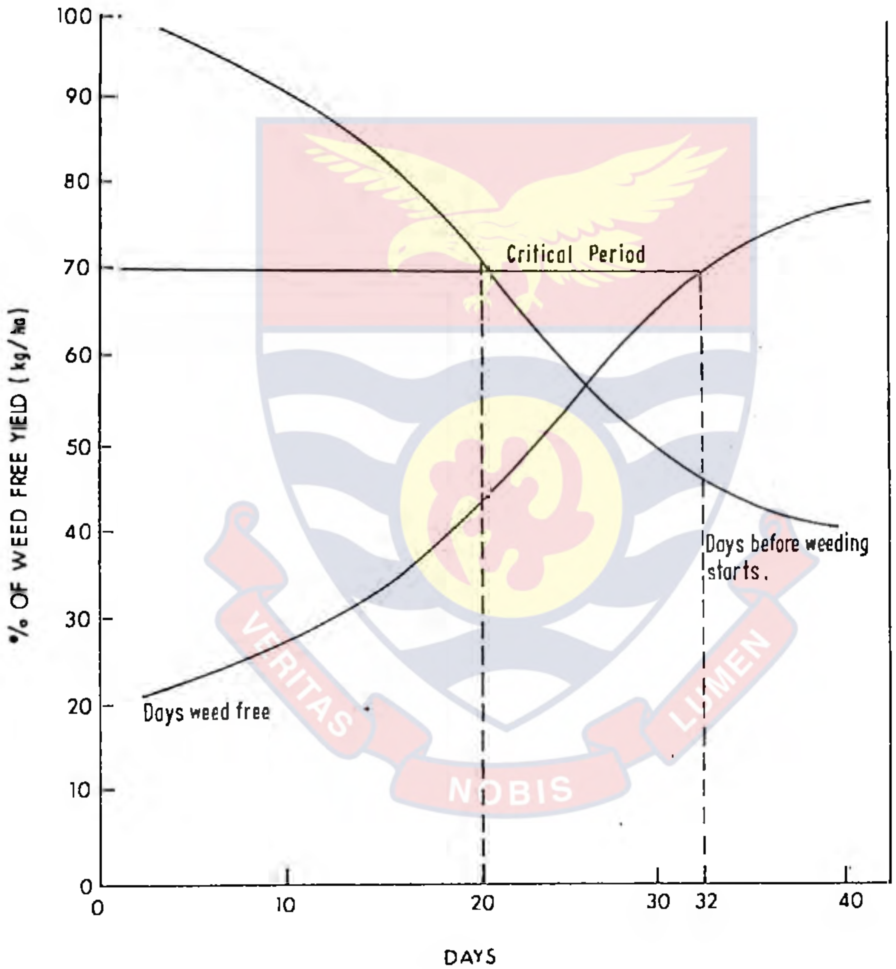

FIG. 4.2 : CRITICAL PERIOD OF WEED COMPETITION FOR SOYBEAN
(1995 – CAPE COAST MINOR SEASON)

Weed infested for first 10 days only gave a yield of 3664 kg/ha and the longer the delay in first weeding the more significant was the yield reduction.

Weed infested first 30 days only, weed-free first 20 days only and weed-free first 30 days only had yields of 2397 kg/ha, 2450.0 kg/ha and 2510 kg/ha respectively and these were not significantly different from each other. Weed-free first 20 days plots gave the highest plant height of 63.68cm but this was not significantly different from completely weed-free and weed-free for first 40 days. Weed infested throughout or unweeded control registered the least plant height of 43.5cm. This was not significantly different from the first 40 days of weed infestation which recorded 48.48cm (Table 3).

Completely weed-free plots recorded the highest number of pods per plant of 126 which was not really significantly different from the other treatments with the exception of weed infested throughout plot which recorded 42 and this was significantly different from all the various treatments.

Completely weed-free gave the highest 1000 seed weight of 101.25g. This was not significantly different from weed-free first 20, 30 and 40 days which recorded 92.5g, 90.75g and 91.0g respectively (Table 3).

4.2 Experiment Two: The effects of Stomp and Galex at different rates in the control of weeds in soybean

4.2.1 Weed Control 1994 Minor Season

The best weed management practice in terms of grain yield was the treatment which was completely maintained weed-free throughout the growing season. Yield in this treatment was however only significantly higher than those of unweeded control, weeding at 6^{th} week only, and Galex at

1.0 kg a.i./ha + one hoeing at 35 days after emergence. Among the herbicides, Stomp at 1.5 kg a.i./ha produced the best relative yield followed by Galex at 2.0 kg a.i./ha but differences were not significant from the other herbicides.

The combination of Galex and Stomp gave the highest yield of 696 kg/ha although this was not significantly different from the rest of the herbicides. Handweeding at 3rd week, 3rd and 6th week after crop emergence gave relatively higher yields than the herbicides, with hand- weeding at 3rd and 6th week registering the highest grain yield of 812 kg/ha. This was however not significantly different from the herbicides.

Table 4: Effect of different weed management practice on weeds, grain yield and yield components of Soybean, Cape Coast 1994 Minor Season

Treatment	% Weed Control at 35 days	Yield (Kg/ha)	No. of Pods/ Plants	Plant Height (cm)	1000 Seed Wt. (g)
Galex 2.0 Kg a.i./ha	81 a	647 ab	67 b	52.89 ab	75.97 bcde
Galex 1.5 " "	75 a	592 ab	47 e	48.95 abc	74.58 cde
Galex 1.0 + Hoeing at 35 days	66 a	497 bc	49 de	50.25 abc	74.40 de
Stomp 2.0 Kg a.i/.ha	76 a	542 abc	61 bc	42.51 c	74.39 e
Stomp 1.5 " "	84 a	659 ab	53 cde	46.08 bc	73.34 e
Stomp 1.0 + hoeing at 35 days	58 a	541 abc	51 cde	47.36 abc	72.87 e
Galex + stomp 1.0 + 1.0 Kg a.i./ha	76 a	696 ab	78 a	48.49 abc	72.60 e
Weeding at 3rd week only	-	760 ab	36 f	48.35 abc	83.55 abc
Weeding at 6th week onl y	-	258 cd	29 f	41.42 c	73.69 e
Weeding at 3rd and 6th week	-	812 ab	61 bc	56.71 a	85.95 a
Completely weed-free	-	832 a	58 bcd	56.61 a	84.01 a
Unweeded control	-	186 d	29 f	48.96 abc	70.80 e
S.E.	5.66	95.34	3.25	3.09	2.84
C.V. (%)	18.63	32.56	12.52	12.60	7.44

*Means within column and followed by similar letters are not significantly different at P = 0.05, according to Duncan's Multiple Range Test.

Correlations between grain yields and either total number of weeds, fresh weight or dry weights of weeds at 35 days after emergence were 0.5788, -0.6896 and -0.4905 respectively. The implication was that yields were dependent on the levels of weed control, and could be predicted by the level of weed control at 35 days after crop emergence.

Fresh weight of weeds which gave a higher correlation was then used to calculate percentage (%) weed control at 35 days after emergence (Table 4). At 35 days of crop emergence there was no significant difference between the herbicide treatments in terms of % weed control even though Stomp at 1.5 kg a.i./ha recorded the highest % weed control of 84.42, followed by Galex at 2.0 kg a.i./ha, with Stomp at 1.0 kg a.i./ha + hoeing giving the lowest control of 58.04% (Table 4).

4.2.2 Components of Soybean Yield

From Table 4, Stomp + Galex at the rate of 1.0 + 1.0 kg a.i./ha produced the highest number of pods per plants of 78, which was significantly better than the rest of the treatments, especially Galex at 2.0 kg a.i./ha and weeding at 3rd, and 6th week only which had 61 and 61 pods per plant respectively. The weedy control and weeding at 6th week gave the lowest of 29 pods per plant as seen in Table 4.

Weeding at 3rd and 6th week gave the highest plant height of 56.71cm though this was not significantly different from the herbicide treatments with the exception of Stomp at 2.0 and 1.5 kg a.i./ha. Weeding at the 6th week only recorded the least height of 41.42cm. but this was not significantly different from any of the herbicide treatments except Galex at 2.0

kg a.i./ha.

4.2.3 Weed Control 1995 Major Season

Galex at 1.5 kg a.i./ha recorded the highest % weed control of 68% and was significantly higher than obtained in the other herbicide treatments. The rest of the herbicide treatments were however not significantly different from each other with Stomp at 2.0 kg a.i./ha recording the worst % weed control of 25%.

Table 5: Effect of different weed management practices on weed control, grain yield and its components of soybean, Cape Coast 1995 Major Season

Treatment	% Weed Control at 35 days	Yield (kg/ha)	No. of Pods/ Plants	Plant Height (cm)	1000 Seed Wt. (g)
Galex 2.0 kg a.i./ha	37 a	2052 cd	63 b	67.77 ab	109.75 c
Galex 1.5 " "	68 b	1782 bc	68 b	72.37 a	100.75 bc
Galex 1.0 + Hoeing at 35 days	48 a	1742 bc	71 b	74.21 a	110.25 c
Stomp 2.0 Kg a.i./ha	25 a	1543 b	70 b	52.51 d	109 c
Stomp 1.5 " "	33 a	1376 b	72 b	53.23 d	100.25 bc
Stomp 1.0 + hoeing at 35 days	43 a	1643 bc	65 b	62.48 bc	113 c
Galex + stomp 1.0 + 1.0 Kg a.i./ha	28 a	1589 b	63 b	52.93 d	134.25 d
Weeding at 3rd week only	-	1407 b	68 b	54.23 cd	104 bc
Weeding at 6th week only	-	853 a	51 b	51.94 d	88.50 ab
Weeding at 3rd and 6th week	-	2384 de	103 a	67.46 ab	103.75 bc
Completely weed-free	-	2534 e	108 a	70.87 ab	102.25 bc
Unweeded control	-	502 a	40 b	41.59 e	76 a
S.E.	6.52	136.6	8.58	3.00	5.26
C.V. (%)	34.38	16.89	24.32	10.02	10.10

*Means within column and followed by similar letters are not significantly different at P = 0.05, according to Duncan's Multiple Range Test.

4.2.4 Grain Yield (kg/ha)

The best treatments in terms of grain yield were the completely weed-free, weeding at 3rd and 6th weeks after crop emergence (w.a.e) and Galex at 2.0 kg/a.i./ha in descending order of importance. Besides, Galex at 2.0 kg a.i./ha produced yields significantly better than all the herbicides treatments that included Stomp with the exception of Stomp + weeding at 35 d.a.e.

The highest yield of 2534 kg/ha was recorded in the c/mpletely weed-free treatment but was not significantly different from the hand weeding at 3rd and 6th week. The unweeded control gave the lowest yield of 502 kg/ha and this was not significantly different from yields obtained from weeding at the 6th w.a.e. only.

4.2.5 Yield Parameters

Galex at 1.0 kg/a.i./ha + hoeing at 35 days of crop emergence recorded the highest plant height of 74.21cm (Table 5). However, this was not significantly different from crop height obtained in the straight Galex treatments of 2.0 and 1.5 kg a.i./ha. Weeding at 3rd and 6th week recorded plant height of 67.46cm and this was not significantly different from completely weed-free which registered 70.87cm.

The lowest plant height of 41.59cm was recorded in the weedy control and this was significantly inferior to the rest of the treatments.

Weeding at 3 and 6 w.a.e. and the completely weed-free treatments produced 103 and 108 pods per plants and there were significantly greater than the rest of the treatments. Differences between the two treatments was not significant. The unweeded control plots recorded 40 pods per plant and this was not significantly different from any of the herbicide treatments.

Galex + Stomp at 1.0 kg a.i./ha + 1.0 kg a.i./ha recorded the highest 1000 seed weight of 134.25g which was significantly higher than the rest of the treatments. This was followed by Stomp + hoeing at 35 days d.a.e., Galex at 2 kg a.i./ha and Stomp at 2 kg a.i./ha in the descending order of importance. All the three treatments had significantly higher seed-weight than the weedy and weeding at 6 w.a.e. treatments. The weedy treatment was, however, not significantly different in seed-weight from the weeding at 6 w.a.e treatment.

4.2.6 Spectrum of Weed Control

It was observed that in 1994 the recorded broadleaf weed species were eight (8) in number while the grass species were five (5) in number (Table 6). Both Galex and Stomp at the various application rates and in combination were able to control the broadleaf weeds effectively (90 - 100 % effectiveness) as seen in Table 6.

Table 6: Effect of Galex and Stomp applied alone and in combination on specific weeds in Soybean at 35 days of Crop emergence in 1994 Minor Season.

Weed	Galex (Kg a.i./ha)			Stomp (Kg a.i./ha)			Stomp + Galex (Kg a.i./ha)
	2.0	1.5	1.0	2.0	1.5	1.0	1.0 + 1.0
Grasses							
1. *Cyperus rotundus* L.	++ +	+	+	+	+	+	+
2. *Paspalum conjugatum*	+++	++	++	+++	+++	+++	+++
3. *Panicum maximum* Jacq.	+++	+++	+++	+++	+++	+++	+++
4. *Brachiara lata* Schumach	+++	+++	+++	+++	+++	+++	+++
5. *Cynodon dactylon* (L.) Pers.	+++	+++	+++	+++	+++	+++	+++
Broad Leaf Weed							
1. *Commelina bengalensis* L.	+++	+++	+++	+++	+++	+++	+++
2. *Croton lobatus* L.	+++	+++	+++	+++	+++	+++	+++
3. *Bourhavia diffusa* L.	+++	+++	+++	+++	+++	+++	+++
4. *Trianthema portulacastrum* L.	+++	+++	+++	+++	+++	+++	+++
5. *Portulaca quadrifida* L.	+++	+++	+++	+++	+++	+++	+++
6. *Euphorbia heterophylla* L.	+++	+++	+++	+++	+++	+++	+++
7. *Achanthospermum hispidium* DC	+++	+++	+++	+++	+++	+++	+++
8. *Tridax procumbense* L.	+++	+++	+++	+++	+++	+++	+++

+++ Very good effect (90 - 100% effectiveness)
++ Good effect (75 - 89% effectiveness)
\+ No useful effect (less than 75% effectiveness)

With the grasses, the effect was the same with the exception of *Cyperus rotundus* whose control was less than 75% effectiveness. Galex at 1.5 and 1.0 kg a.i./ha gave a good control (75-89% effectiveness) of *Paspalum conjugatum* compared with pure Stomp and the mixture which controlled it very well.

In 1995 the recorded grass species numbered four (4) whilst the recorded broadleaf species were six (6) as shown in Table 7.

Table 7: Effect of Galex and Stomp applied alone and in combination on specific weeds in Soybean at 35 days of Crop emergence in 1995 Major Season.

Weed	Galex (Kg a.i./ha)			Stomp (Kg a.i./ha)			Stomp+Galex (Kg a.i./ha)
	2.0	1.5	1.0	2.0	1.5	1.0	1.0 + 1.0
Grasses							
1. *Cyperus rotundus* L.	++	+	+	+	+	+	+
2. *Paspalum conjugatum*	+++	++	++	+++	+++	+++	+++
3. *Panicum maximum* Jacq.	+++	+++	+++	+++	+++	+++	+++
4. *Cynodon dactylon* (L.) Pers	+++	++	++	+++	++	++	++
Broad Leaf Weeds							
1. *Commelina bengalensis* L.	+++	+++	+++	+++	+++	+++	+++
2. *Achanthospermus hispidium* DC	+++	+++	+++	+++	+++	+++	+++
3. *Tridax procumbense* L.	+++	+++	+++	+++	+++	+++	+++
4. *Trianthema portulacastrum* L.	+++	+++	+++	+++	+++	+++	+++
5. *Vernonia cineria* L.	+++	+++	+++	+++	+++	+++	+++
6. *Euphorbia heterophylla* L.	+++	+++	+++	+++	+++	+++	+++

+++ Very good effect (90 - 100% effectiveness)
++ Good effect (75 - 89% effectiveness)
+ No useful effect (less than 75% effectiveness)

Both Galex and Stomp at the various application rates and in combination were able to control broadleaf weeds effectively (Table 7). Galex and Stomp each applied at the rate of 2.0 kg a.i./ha had good (75-89% effectiveness) control of *Cyperus rotundus*. However, Galex and Stomp applied at 1.5 and 1.0 kg a.i./ha, respectively failed to control *Cyperus rotundus* to any reasonable extent. The mixture of Galex and Stomp also provided useful control of the same weed. The high rates of Galex and Stomp controlled *Cynodon dactylon*, effectively. All the herbicide treatments effectively controlled *Panicum maximum*. Apart from Galex at 1.0 and 1.5 kg a.i./ha, the rest of the chemical treatments gave excellent control of *Paspalum conjugatum*.

Table 8: Percentage frequency of occurrence of weed species found on the herbicide treated plots at 35 days after crop emergence in 1994 and 1995 seasons.

Weed Species	1994 % Freq. of Occurrence	1995 % Freq. of Occurrence
Cyperus rotundus L.	87	96
Cynodon dactylon (L.) Pers	21	37
Panicum maximum L.	21	35
Triantherma portulacastrum L.	50	21
Achanthospermum hispidium DC	6	21
Tridax procumbense L.	6	31
Euphorbia heteroplylla L.	6	12
Commelina bengalensis L.	9	12
Paspalum conjugatum L.	50	3
Vernonia cinerea L.	-	12
Croton lobatus L.	28	-
Bourhavia diffusa L.	3	-
Portulaca quadrifida L.	3	-
Brachiaria lata Schumach	15	-

Of the total of 14 weed species found on the experimental plots, 13 were present in 1994 season and only 10 in the 1995 season (Table 8). The dominant weed species was *Cyperus rotundus* with percent frequency of occurrence of 85 in 1994 and 96% in 1995. *Paspalum conjugatum* recorded 50% frequency of occurrence in 1994 but in 1995 it recorded the least of 3.12%. Generally, the grases were kmore numerous than the broadleaf weeds with the exception of *Triantherma portulacastrum*, and to some extent *Tridax* procumbense and Croton lobatus.

Table 9: Financial Costs and Benefits of Use of Herbicides (Galex 2.0 Kg a.i./ha) in the Production of Soybean in 1995 Major Season

Extra Cedis/ha	Cost	Grains	cedis/ha
		1st Weeding	
Cost of 2 1 Galex 500 EC	16,000	12 man-days for weeding at 3rd week	24,000
10% depreciation on sprayer	7,500		
		2nd Weeding	
Labour for application 1 man-day	5,000	8 man-days for weeding at 6th week	16,000
	28,500		40,000
Value of lost grain i.e. 2384 - 2052 = 332kg 1 Kg = C300	99,600		
Total Extra Cost	128,100	Grains - Extra Cost	-88,100

Results of cost-benefit analysis of the most promising herbicide as against the best handweeding regime is shown in Table 9. Galex at 2.0 kg a.i./ha gave a yield of 2052 kg/ha kg/ha, while two handweedings at the 3rd and 6th week gave a higher yield of 2384 kg/ha. This provided an extraadded grain of 332 kg to the handweeding treatment.

The extra cost involved in the use of Galex at 2.0 kg a.i./ha was C128,000.00 made up of cost of the product, application cost and value of lost grain. Gains achieved in the use of the herbicide meanwhile totalled C40,000 consisting of savings in the two handweeding, so in effect there was a financial benefit of C88,100 in the use of handweeding at 3 and 6 w.a.e. over the herbicide application. Results of financial comparisons of the other herbicide treatments with the two handweeding are shown in Table 10.

Table 10: Cost-Efficiency of Herbicides

Treatment	Grain ¢	Extra Cost ¢	Margins ¢
Stomp 1.5 kg a.i./ha (1994)	40,000	70,400	-30,400
Stomp 1.0 kg a.i./ha + One hoeing (1994)	40,000	117,902	-77,902
Galex 1.0 kg a.i./ha + One hoeing (1995)	40,000	229,100	-189,100

In 1994 Stomp at 1.5 kg/hai gave a yield of 59 kg/ha and weeding twice at the 3rd and 6th week in the handweeding treatments gave a yeield of 812 kg/ha. This gave an extra grain yield of 153 kg to handweeding treatments. From Table 9 the total lextra cost for the herbicide application and the lost grain amounted to C70,400. On the other hand, herbicide application and the lost grain amounted to C70,400. On the other hand, handweeding had added grain of 153 kg valued at C300 per kilogram which amounted to a total gain of C30,400 over the use of herbicide (Table 9).

Stomp at 1.0 kg a.i./ha + one hoeing at 35 days of crop emergence gave a yield of 541 kg/hai, while handweeding at the 3rd and 6th week on the handweeding plot gave a higher yield of 812 kg/ha. This gave an extra added grain of 271 kg to the handweeding treatments. The extra cost of herbicide application and the value of lost grain amounted to C117,902. On the other hand, hand weeding had an added grain of 217 kg at a value of C300 per kilogram which amounted to a total gain of C77,902 over the use of herbicide.

Galex at 1.0 kg a.i./ha + one hoeing at 35 days of crop emergence gave a yield of 1742 kg/ha, while hand weeding at the 3rd and 6th week on the handweeding plot gave a higher yield of 2384 kg/ha. This gave an extra added grain of 642 kg to the handweeding treatment. The extra cost of herbicide application and the value of the lost grain amounted to C229,100.

4.3 Experiment Three: Determination of residual activity of herbicides in the soil by he bioassay technique

Preliminary experiments carried out by Carson (1976) at the Crop Research Institute, Nyankpala, Ghana between 1975-1977 and also Akobundu (1987) showed that millet and sorghum were suitable plants for the determination of residues of the two pre-emergence hrbicides used.

herbicide action. Fig.1 shows the response curves of Galex and Stomp resulting from plotting fresh weight (g) of sorghum in treated soils as a percentage of fresh weight of sorghum in untreated soil against herbicide concentration in ppm.

Table 11: Regression of Stomp and Galex at varying concentrations on height, fresh weight and dry weight of sorghum

	Stomp		Galex	
	R-squared	F.Value	R-squared	F.Value
Height (cm)	0.9659	84.99	0.6449	5.45
Fresh weight (g)	0.9909	326.96	0.6890	6.65
Dry weight (g)	0.006	0.00	0.5729	4.02

Table 12: Field residual concentrations of the various herbicides treatments as determined by bioassay using fresh weight of sorghum shoot, 1994 season

Treatment	Rate in kg a.i./ha	Fresh weight as % of untreated control	Residual Concentration (ppm)
Stomp	2.0	76.43	0.55
Stomp	1.5	79.55	0.50
Stomp	1.0 + hoeing	83.63	0.40
Galex	2.0	85.85	0.70
Galex	1.5	93.94	0.35
Galex	1.0 + hoeing	96.58	0.25
Galex + stomp	1.0 + 1.0	82.15	0.33

Table 12 shows the residual concentration (ppm) of the various herbicides treatments obtained from boassay using sorghum shoot fresh weight.

Table 13: Field esidual concentrations of various herbicides treatments as determined bioassay using fresh weight of sorghum shoot, 1995 season

Treatment	Rate in kg a.i./ha	Fresh weight as % of untreated control	Residual Concentration (ppm)
Stomp	2.0	83.23	0.30
Stomp	1.5	87.65	0.36
Stomp	1.0 + hoeing	95.29	0.15
Galex	2.0	83.0	0.50
Galex	1.5	90.58	0.45
Galex	1.0 + hoeing	96.10	0.20
Galex + stomp	1.0 + 1.0	79.47	0.18

Sorghum was effectively sensitive to detect as little as 0.25 ppm in 1994 and 0.15ppm in 995 as seen in Tables 12 and 13.

In 1994 Stomp + Galex at the rate of 1.0 + 1.0 kg a.i./ha recorded a residual concentration of 0.33ppm. A lower residual concentration of 0.18ppm was recorded in 1995 as seen in Table 13. Galex at the rate of 1.0 kg a.i./ha plus hoeing at 35 days of crop emergence recorded the least residual concentration of 0.25ppm in 1994 and 0.20 ppm in 1995, on top fresh weight of sorghum.

With the millet both the fresh weight and dry weight gave lower variance ratios for linear regression as seen in Table 14, so millet shoot height only was used in the residual determination of the herbicides (Table 14 and 15).

Table 14: Regression of Stomp and Galex at varying concentration on height, fresh weight and dry weight of millet

	Stomp		Galex	
	Re-squared	F-value	Re-sqiared	F.Value
Height (cm)	0.9271	38.16	0.9909	324.96
Fresh weight (g)	0.7012	7.04	0.8133	13.07
Dry weight (g)	0.6470	5.50	0.7020	7.07

Table 15: Field residual concentration of the various herbicide treatments as determined by bioassay using millet shoot height, 1994 season

Treatment	Rate in kg a.i./ha	Fresh weight as % of untreated control	Residual Concentration (ppm)
		84.0	1.0
Stomp	2.0	84.2	1.0
Stomp	1.5	90.4	0.65
Stomp	1.0 + hoeing	81.2	0.65
Galex	2.0	85.4	0.40
Galex	1.5	88.3	0.35
Galex	1.0 + hoeing		
Galex + stomp	1.0 + 1.0	85.3	0.50

Figure 4.4 shows the standard response curves of Galex and Stomp resulting from plotting millet shoot height in treated soils as a percentage of shoot height of millet in untreated soil against herbicide concentration (ppm).

Table 16: Field residual concentration of the various herbicide treatments as determined by bioassay using millet shoot height, 1995 season.

Treatment	Rate in kg a.i./ha	Fresh weight as % of untreated control	Residual Concentration (ppm)
Stomp	2.0	85.6	0.90
Stomp	1.5	86.6	0.90
Stomp	1.0 + hoeing	90.5	0.60
Galex	2.0	83.60	0.55
Galex	1.5	90.94	0.30
Galex	1.0 + hoeing	94.9	0.38
Galex +stomp	1.0 + 1.0	82.98	0.50

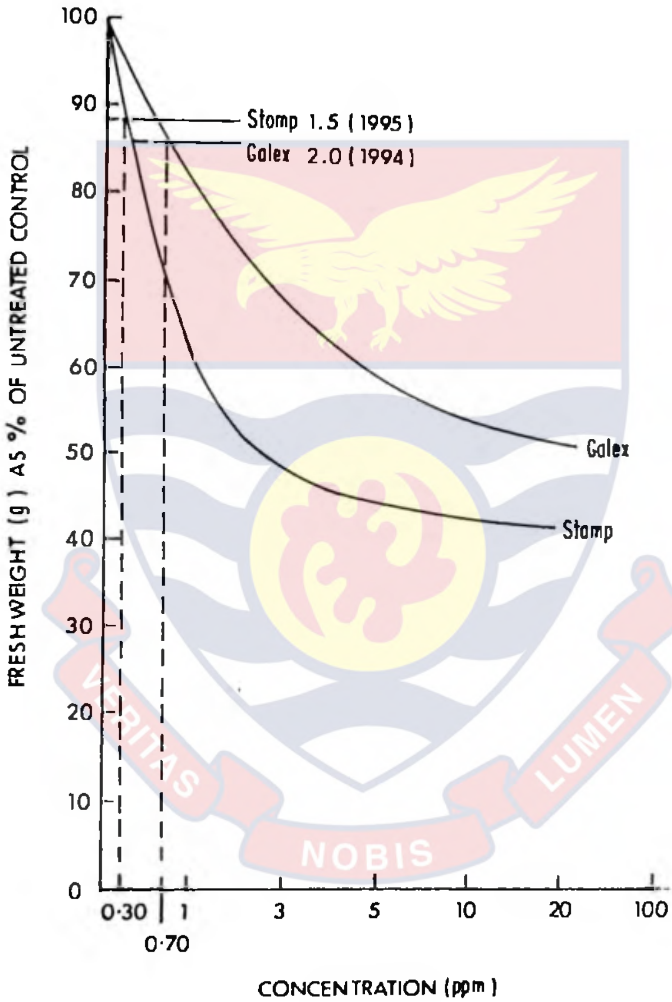

FIG. 4.3 : COMPARATIVE EFFECTS OF VARIOUS CONCENTRATIONS OF STOMP AND GALEX ON TOP FRESH WEIGHT OF SORGHUM

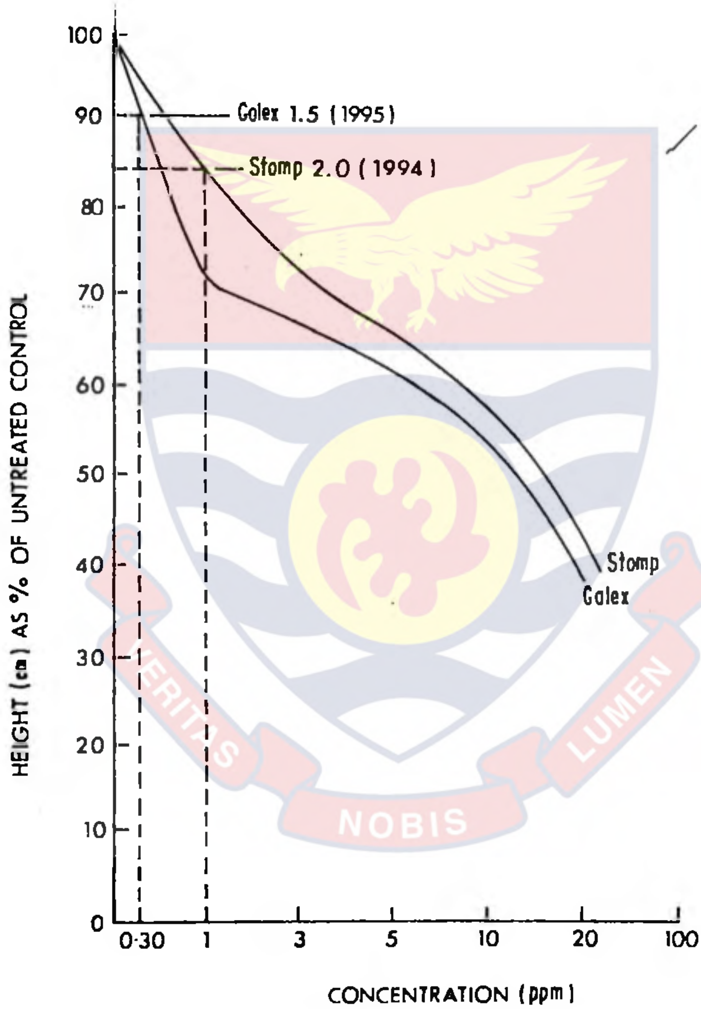

FIG. 4.4 : COMPARATIVE EFFECTS OF VARIOUS CONCENTRATIONS OF STOMP AND GALEX ON SHOOT HEIGHTS OF MILLET

Millet was sensitive enough to detect as little as 0.35 ppm of Galex at the rate of 1.0 + hoeing at 35 days of crop emergence in 1994 and 0.15 ppm of Galex at 1.0 kg/hai plus hoeing in 1995 on shoot height(cm) of millet.

Stomp at the rate of 2.0 and 1.5 kg a.i..ha recorded the highest residual concentrations of 1.0ppm in 1994. The same trend was observed in 1995 with residual concentration of 0.90ppm.

In general, it was seen from the standard curves shown in Fig.4.3 from which the chemical residues were determined that percent fresh weight of sorghum seedlings decreased as concentrations increased from 1ppm to 100ppm in both Galex and Stomp. The same was also seen in Fig.4.4. Here percent height of millet shoot decreased as herbicide concentrations increased from 1ppm to 100ppm in both herbicides.

CHAPTER FIVE

DISCUSSION

5.1 Critical Weed Competition

Results showed that unchecked weed growth caused a 67% and a 81% reduction in soybean yield in the 1994 and 1995 experiments, respectively.

The dominant weed species were *Triantherma portulocastrum* and *Cyperus rotundus* respectively. Both weed species could be described as efficient plants and therefore good competitors in contrast to soybean which is considered as less efficient and a poor competitor.

Efficient plants follow a photosynthetic or CO_2 reduction pathway known as Hatch and Slack pathway (Akobundu, 1987). Such plants are more efficient competitors with regard to soil moisture, light and nutrient absorption. Consequently the presence of *Cyperus rotundus* and *Trianthema portulacstrum* in a less efficient crop like soybean might be responsible for this relatively higher reduction in yield when unchecked.

The heavy infestation of *Cyperus rotundus* was probably due in part to its allelopathic properties whereby chemicals produced by *Cyperus rotundus* inhibited the growth of plant in the immediate vicinity (Friedman and Horowitz, 1971). It has also been reported by Lucena and Doll (1976) that soybean was very sensitive to the allelochemicals of *Cyperus rotundus* and that may have contributed to the high yield reduction of 81% in the 1995 experiment.

In the 1994 minor season experiment, total rainfall during crop growth was low (326.5 mm) as a result weed growth was not so profuse and vigorous as in the 1995 major season experiment where total rainfall was relatively higher (746.3 mm). The resultant severe weed competition could cause the relatively higher reduction in soybean yield due to unchecked weed growth in the 1995 main season experiment.

Yield reduction of 67% due to unchecked weed growth in the 1994 season compared favourably with 50% reduction in yield achieved in both India and Nigeria (Moody and Whitney, 1974) and the 53% reduction obtained in experiments conducted in Northern Ghana by Carson (1979). In these experiments the growing conditions, particularly the rainfall pattern, were similar and consequently comparable levels of yield reduction as a result of unchecked weed growth were in order.

The critical periods of weed competition between weeds and soybean were determined to be from 23 to 35 days and from 20 to 32 days after crop emergence in the 1994 and 1995 experiments, respectively. This meant that keeping the soybean weed-free during this period could prevent significant reduction in soybean yield. The corollary or inference was that it would not be profitable to weed before and after this period since crop yields would not be affected to a significant extent.

The basis for this may be that removal of weeds during the critical period would advance crop growth to such an extent that later establishment of weeds would have little chance of affecting soybean yield. The critical periods of competition were similar to those obtained by

Eaton et al., (1976) who reported no yield loss in soybean from weed growth before or after the critical period of 20 - 40 days later than soybean.

Factors that could influence the onset of the critical period and its duration included the quality of weed composition and density of weeds present per unit area, the total amount of rainfall, and the nature of land preparation. Comparing the minor and major season results, it would seem as though the relative densities of the dominant weeds, Cyperus rotundus and Trianthema portulacastrum, were responsible for differences in the onset and duration of the critical periods in the minor and major seasons.

Using the target of 70% of attainable yield to determine the critical period of competition was realistic because the higher the percentage of attainable yield the longer the duration of the critical period and consequently the greater the frequency of weeding required to keep it clean. For example, suppose a target of 90% of attainable yield was to be preferred in the major season, then by extrapolation the farmer would have to start controlling weeds from 10 to 40 days after crop emergence which may not be cost-effective.

In the 1994 and 1995 experiments, 40 days of early weed-free condition were required to give optimum grain yields. Results of work done by Carson (1979) even indicated that a much longer period of 56 days of early weed-free conditions were necessary for optimum yield. The discrepancy in the established periods among researchers could be due to the variety of soybean, plant population and spacing (Nangju, 1978), soil moisture regimes (Kasasian, 1971) soil type and density of weeds.

In the completely weed-free treatment there was little or no competition and as a result all the nutrients and moisture in the soil were made available for the growth and development of the soybean crop. This was manifested in enhanced plant vigour, height, number of pods per plant, grain yield and seed weight in both seasons. It was equally observed that as duration of weed competition increased soybean grain yield and its parameters and plant growth decreased.

The reverse sigmoid curve obtained in the response of yield to increasing duration of weed competition, however, indicated that yields may not start to decline immediately at low weed density and that there was a critical threshold level of duration of weed competition which must be exceeded before damage in the form of crop yield reduction could begin to occur.

The traditional method of weed control in soybean is hand weeding and therefore by determining the critical competition period, it would be possible to improve the timeliness of handweeding operation by recommending when to start and stop weeding to make the operation more cost-effective. Secondly the determination of the extent of early weed-free periods necessary to obtain optimum yield could mean that the choice of straight or combination of pre-emergence herbicides must be limited to those that have soil-residual action close to or more than 40 days after crop emergence.

5.2 Comparison among Chemical, Manual and Chemical plus Manual Weeding Regimes

The relatively higher percentage weed control obtained in the 1994 minor season over the 1995 major season suggested that the herbicides were more potent in relatively dry conditions where weed growth was not profuse and vigorous. It was also reasonable to suggest that the higher total and frequency of rainfall in the major season increased leaching of the herbicide to depths beyond the root zones of some of the weeds and therefore decreased the level of weed control.

Another explanation might be that under the relatively dry conditions as occurred in the minor season, the herbicide molecules were not so strongly adsorbed to the soil's colloidal surfaces and were therefore readily available for absorption by the emerging shoots and roots of the weeds. On the other hand, the heavy rains of the major season could lead to the herbicide molecules being easily dislodged. Dislodgement of the herbicide molecules from the soil's colloidal surfaces then would promote some capillary movement to the surface where they could be vunerable to evaporation and photodecomposition processes.

It was also possible that the low percentage weed control obtained in the 1995 major season was due to the predominance of *Cyperus rotundus* (96% occurrence in 1995), which is known not to be effectively controlled by any of the herbicides (Akobundu, 1987). The relatively low numbers of *Brachiaria lata* in 1994 (15% occurrance) and its complete absence in 1995 major season, did suggest that both herbicides were capable of controlling this annual grass weed as was found by Akobundu (1987).

In northern Ghana Carson (1979) reported that Stomp at 1.0 kg a.i./ha effectively controlled both monocots and dicot weeds at 42 days after planting. The good yields obtained with the application of Stomp in these experiments seemed to indicate that it was also quite effective in the control of a wide range of the weeds experienced in these investigations. Galex is a mixture of two straight herbicides, *metolachlor* and *metobromuron*. *Metobromuron* is known to be most effective on annual dicots and less so on annual monocots. *Metolachlor*, on the other hand, is known to be more effective on annual grasses than the dicots. Besides, *metolachlor* belongs to the acid amide group of herbicides known to inhibit protein and lipid synthesis (Ahrens and Davis, 1978). *Metobromuron* is a substituted urea compound and known to act by interfering with photosynthesis by disrupting the flow of electrons from photosystem II to photosystem I. Thus the relative effectiveness of Galex may be due to the complementality of the two component herbicides in both their mode and sites of action and spectrum of weeds controlled. The other herbicide Stomp *(pendimethalin)*, is a straight herbicide belonging to the dinotroaniline group and is known to control mostly annual grasses including *Rottboellia* species by inhibiting the mitotic cell division in weed seedlings. As expected, it exhibited a very good control of annual grasses like *Brachiaria lata* in this study.

Both Galex and Stomp were more effective against weeds at the higher rate of 2.0 kg a.i./ha. This was in line with results of studies carried out on soybean at Mokwa, Nigeria, when Stomp at 2.0 kg a.i./ha and Galex at 2.5 kg a.i./ha gave the best weed control and grain yields (Singh *et. al.*, 1987). Results were also not different from those obtained by using Stomp in soybean in Northern Ghana (Carson, 1979) and very much in agreement with the manufacturer's recommended rates of application for optimum grain yields and weed control.

A very good percentage weed control of 76% was recorded in the 1994 minor season when Galex and Stomp were combined in a mixture. Explanation for this was that the two herbicides in combination increased the spectrum of control of both annual grasses and broad leaf weeds. Also their complementary mode and sites of action in the weeds might be a major factor for this observed synergy.

As a result of the heavy weed pressure found in the humid tropics, it may often be necessary to combine herbicides in order to control the heavy infestation of mixed weed populations more effectively. It has become increasingly evident over the years that herbicide mixtures have many distinct advantages over straight herbicides. This observation had also been reported by Carson (1975) on weed control in cotton, upland rice and on soybean grain yield (1976-77) in Northern Ghana. Akobundu (1983) also reported similar advantage of herbicide mixture producing higher soybean grain yield and a good control of weeds in Mokwa, Nigeria.

On the other hand the lowly 28% per weed control achieved with the tank mixture of Galex and Stomp might be due to the rain action which promoted vigorous weed growth, leaching of the herbicide mixture beyond the root zones of the weeds, and loss of herbicide through surface run-off. Also the presence of large numbers of the resistant weed *Cyperus rotundus* was partly the cause of the poor performance of the mixture.

From the study, the higher grain yields recorded from the hand weeding treatment at 3rd and 6th weeks over all the herbicide treatments suggested that the hand weeding was more effective in weed control for maximum yield than the use of herbicides.

Similar observations have been made by Poku and Akobundu, (1983 and 1984) in Ikenne, Nigeria. The superior performance of the two handweeding over the rest of the treatments was because the weeding dates were within the critical periods of weed competition and more importantly just happened to reduce weed competition to the level at which the crop performed its best. A more frequent handweeding regime such as obtained in the completely weedfree treatment could enhance soil erosion and loss of nutrients through leaching and lead to loss in crop yield.

Financial cost and benefits analysis of the use of herbicides and manual weeding revealed that grain yields obtained from hand weeding were higher than grain yields obtained from the herbicides treated plots for both 1994 and 1995 experiments. The analysis further revealed that there were losses associated with the use of herbicides to the tune of ₵88,100 as was the case in the use of Galex at 2.0 kg a.i./ha in 1995. This trend of financial advantage of manual weed control over chemical weeding was found in both the 1994 and 1995 seasons.

It could therefore be stated that the manual weed control was more financially rewarding than the use of herbicides provided that it was timely and frequent enough to fall within the critical competition period of the crop. However, this is only possible where farm sizes are not very large and labour is cheap and readily available. On the other hand in large holdings, the use of herbicides might be the best alternative of weed control provided pre-emergence herbicides could be found with at least 40 days of weed control action.

The very low residual concentrations of Galex detected five months after herbicide application implied that, the product would not pose any toxic problems for the subsequent crops.

Response curves for both herbicides showed that shoot fresh weight of sorghum decreased as the concentration of the herbicides increased. This trend was also observed by Carson (1975) in Northern Ghana when he used sorghum as a biossay crop for three rice herbicides.

Maize which was likely to follow legume in a rotation was not used for the bioassay, the reason was, as reported by Van Hoogstraten and Fine (1982), that maize was tolerant to *pendimethalin* and as such would not be sensitive enough to detect any residue of the herbicide. Similarly, Akobundu (1987) also reported that maize was able to degrade Galex readily into non-phytotoxic metabolites. Instead, sorghum and millet which were very sensitive to the herbicides were used.

The sensitivity of sorghum to *metolaclor* in Galex had been reported by Ellis *et al* (1980) who found that the use of *metolaclor* in sorghum was only possible in the presence of a herbicide safener, cynometrinil. That made it ideal for sorghum to be used as a test plant.

It has also been observed that the smaller the test plant seed for the bioassay, the more sensitive the test. As such millet was expected to be more sensitive to the straight herbicides and their combination than the sorghum. In the event, use of millet as a biossay crop proved to be relatively more sensitive and recorded bigger residual concentration values for the herbicides than the use of sorghum as a bioassay crop.

It was also observed that the residual levels of Stomp were relatively higher than those of Galex which confirmed the view that Stomp was more persistent in the soil than Galex at the same rate and therefore more likely to pose danger to sensitive follow-up crop.

In effect no level of residual concentration likely to prove injurious, phytotoxic or detrimental to subsequent crop growth and development was detected. Explanation for this could be that the factors responsible for the deactivation or disappearance of herbicides such as photodecomposition, leaching, uptake by plants, microbial decomposition and chemical decomposition, were all temperature and soil moisture dependent and therefore more active in the prevailing tropical conditions.

From the study it was observed that within the limits of the recommended application rates of the two pre-emergence herbicides the residue that would be left in the soil after harvesting would have no phytotoxic or detrimental carry over effect on subsequent crops that might follow the rotation.

CHAPTER SIX

SUMMARY

6.0 Weed control studies on soybean was carried out in Cape Coast, during the 1994 minor season and the 1995 major season. The study was carried out to determine the critical period of weed competition between weeds and the soybean; make comparisons between the use of herbicides, herbicide combination, herbicide and manual weed control, and manual weed control only, on weed control and the consequent grain yield and its components; to determine any residual or injurious activity of the herbicides in the soil to subsequent crops in the rotation.

The studies conducted revealed that:-

1. Unchecked weed growth caused a 67% and 81% reduction in soybean yield in the 1994 and 1995 experiments respectively.
2. The dominant weed species were *Trianthema portulacastrum* and *Cyperus rotundus* in the 1994 and 1995 seasons respectively. Both weed species could be described as efficient plants and therefore good competitors in contrast to soybean which is considered less efficient and a poor competitor.
3. *Cyperus rotundus* and *Trianthema portulacastrum* might be responsible for the relatively higher reduction in yield when unchecked.
4. The heavy infestation of *Cyperus rotundus* in the 1995 season was probably due in part to its allelopathic properties which affected soybean growth, development and yield.
5. Weed growth was profuse and vigorous in 1995 major season due to the relatively higher amount of rainfall.

6. The critical period of weed competition between weeds and soybean determined at a target of 70% attainable yields were found to be from 23 to 35 days and from 20 to 32 days after crop emergence in the 1994 and 1995 experiment respectively.

7. Keeping the soybean weed-free during the critical period could prevent significant reduction in soybean yield.

8. It would also not be profitable to weed before and after this period, since crop yields would not be affected to any significant extent.

9. Removal of weeds during the critical period would advance crop growth to such an extent that later establishment of weed would have little chance of affecting soybean yield.

10. Using the target of 70% attainable yield to determine the critical period of competition was realistic because the higher the percentage of attainable yield, the longer the duration of the critical period and consequently, the greater the frequency of weeding required.

11. Forty days of early weed-free conditions were required to give optimum yields.

12. As duration of weed competition increased, soybean grain yield and its parameters and plant growth decreased.

13. The relatively higher percentage weed control obtained in the 1994 minor season over the 1995 major season suggested that the herbicides were more potent in relatively dry conditions where weed growth was not profuse and vigorous.

14. The higher total and frequency of rainfall in the major season might have increased leaching of the herbicides to depths beyond the root zones of some of the weeds and therefore decreased the level of weed control.

15. The low percentage weed control obtained in the 1995 major season was due to the predominance of *Cyperus rotundus* which was known not to be effectively controlled by any of the herbicides.

16. Both herbicides were able to control all the dicot weeds and the annual grass *Brachiaria lata* found in the experimental area.

17. Both Galex and Stomp were more effective against weeds at the higher rate of 2.0 kgaiha^{-1}.

18. A very good percentage weed control of 76% was recorded in the 1994 minor season when Galex and Stomp were combined in a tank mixture.

19. The two herbicides in combination increased the spectrum of weed control for both annual grasses and broad leaf weeds.

20. A lowly 28% weed control was achieved with tank mixture of Galex and Stomp in 1995 season.

21. The poor performance of herbicides might be due to the relatively wetter conditions which promoted vigorous weed growth, leaching of herbicide mixture beyond the root zones of the weeds and the loss of herbicides through surface run-off.

22. The higher grain yields recorded from hand weeding treatment at 3rd and 6th weeks over all the herbicide treatments suggested that hand weeding was more effective in weed control for maximum yield than the use of herbicides.

23. The manual weed control was more financially rewarding than the use of herbicides provided that it was timely and frequent enough to fall within the critical competition period of the crop.

24. From the bioassay test, response curves for both herbicides showed that shoot fresh weight of sorghum and shoot height of millet decreased as the concentration of the two herbicides increased.

25. Of the two test plants, millet proved to be relatively more sensitive and detected higher residual concentration values than sorghum.

26. Residual levels of Stomp were relatively higher than those of Galex at the same application rates.

27. No level of residual concentration likely to prove injurious, phototoxic or deterimental to subsequent crop growth and development was detected.

CHAPTER SEVEN

CONCLUSION

Weed control studies on soybean which was carried out at the Teaching and Research Farm of the School of Agriculture, University of Cape Coast, during the 1994 minor season and the 1995 major season revealed that there was 67% reduction in yield in 1994 and 81% in 1995 as a result of unchecked weed growth. At a target of 70% attainable yield, the critical periods of competition were found to be between 23 to 35 days and 20-32 days after crop emergence in the 1994 and 1995 seasons respectively.

Also, soybean grain yield and its parameters and plant growth decreased significantly as duration of weed competition increased from 10 to 40 days after crop emergence. Since the traditional method of weed control in soybean is handweeding, the determined critical competition period will enable farmers to improve the timeliness of handweeding operation by knowing when to start and stop weeding and thereby making the operation more cost-effective.

Secondly, the determination of the extent of early weed-free periods necessary for optimum yields will enable the farmers to limit their choice of straight or combination of pre-emergence herbicides to those with soil-residual action close to or more than 40 days after crop emergence. The two herbicides employed in the study gave a relatively higher percentage weed control in the 1994 minor season than in the 1995 major season. This was attributed to the presence of *Cyperus rotundus* and *Trianthema portulacastrum* as dominant weed species in the 1995 major season which were described as efficient plants and therefore good competitors compared to soybean.

Both Galex and Stomp were more effective against weeds at the higher rate of 2.0 kg a.i./ha except *Cyperus rotundus*. Manual weed control gave relatively higher yields than chemical control and was also more financially rewarding. This was so, because, the two handweedings were timely and frequent enough and fell within the critical competition period of the crop. However this was only feasible where farm sizes are not very large and labour is cheap and readily available.

It was also found that within the limits of the application rates of 1.0 - 2.0 kg a.i./ha for both Stomp and Galex, there was no level of residual concentration likely to prove injurious, phytotoxic or detrimental to subsequent crop growth and development in the rotation was detected.

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