THE EFFECT OF ALACHLOR-ATRAZINE MIXTURE AND DIURON ON WEED CONTROL, GROWTH AND YIELD OF MAIZE AND THEIR RESIDUAL EFFECT ON GROWTH, NODULATION AND YIELD OF COWPEA.

BY

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DECLARATION

I wish to declare that with the exception of references to other research works which have been duly cited, this work is the result of my own original research and that this thesis has not been presented either in part or whole for another degree elsewhere.

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I will bless the Lord at all times; His praise shall continually be in my mouth and my soul shall make her boast in the Lord. (Ps. 34:1-2).

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ABSTRACT

Two field experiments were carried out from July 1993 to January 1994 at the University of Ghana farm, Legon. The first experiment investigated the effects of two pre-emergent herbicides alachlor-atrazine mixture and diuron at the manufacturers' recommended rates and at rates 50% above those recommended on weed control, growth and yield of maize variety 'Abeleehi'. The second experiment carried out on the same plots determined the residual effects of these herbicides on two varieties of cowpea 'Asontem' and 'Bengpla'.

At the two rates rate of 5l/ha (1.8kg + 1.0kg ai/ha) and 7l/ha (2.5kg + 1.4kg ai/ha) for alachlor and atrazine mixture and 1.12kg/ha (0.9kg ai/ha) and 1.68kg/ha (1.3kg ai/ha) for diuron investigated both broad-leaved weeds and grasses were controlled efficiently in maize, although the effectiveness of the chemical weed control did not differ significantly from the hand-weeding method.

With regards to their influence on the growth and development of maize plants, alachlor-atrazine mixture was tolerated better by the plants than diuron. Highest grain yield was recorded on plots treated with alachlor-atrazine mixture at the manufacturer's recommendation of 1.8kg + 1.0kg ai/ha. Increases in the concentration of both herbicides were toxic to the maize.

Diuron had a significantly adverse carry over effect on the succeeding cowpea crops, resulting in very low yields. Alachlor-atrazine mixture at the two rates applied

which may otherwise be toxic to cowpea appeared degraded from plots by the time of the second cropping, approximately fourteen weeks after application since there were no significant adverse effects on cowpea crops.

Although there appeared not to have been a differential response in the influence of the residual effect of the herbicides on the growth of cowpeas, varietal differences were detected for some of the characters investigated. Overall 'Asontem' emerged a better succeeding crop with maize in which alachlor-atrazine mixture at the manufacturer's recommended rate had been employed for weed control.

Inspite of its relative unsuitability for weed control in maize in this study, it was suggested that diuron at rates lower than the manufacturer's recommended could be tested to ascertain the usefulness of this herbicide for adequate weed control without injury to maize plants before ruling it out as one of the choices of herbicides for weed control in maize.

CHAPTER ONE

INTRODUCTION

Maize (*Zea mays* L.) is the most important cereal cultivated in Ghana (PPMED, 1991). It is grown in all the ecological zones of the country during the major rainy season. A second cropping of maize using early maturing varieties is also practiced in the ecological zones with adequate rainfall during the minor rainy season (Anon, 1993). In some of the areas where a second cropping of maize is not done in the minor season as a result of insufficient rainfall, the cultivation of leguminous crops is commonly practiced.

Maize is a fast growing crop taking approximately 90-120 days to mature depending on the variety used (Anon, 1993). It however has a slow initial growth rate until the reproductive organs are initiated 20-40 days after planting (Purseglove, 1981). As a result of this slow initial growth rate, the wide spacing of 80-90cm by 40cm recommended in Ghana exposes the crop to severe weed competition at the early and critical stages of growth. This is partly because the weeds also benefit from the plentiful supply of moisture and liberal applications of fertilizers under which the crop is cultivated.

If left unchecked, the severe weed competition retards the growth of the crop and results in low yields. Season-long competition from grasses and broad leaved weeds in maize has been reported to cause respectively 92% and

85% loss of the potential yield of the maize. Weedy periods as short as 10 days can cause losses of 10% of the potential yield if they occur within the first four weeks after sowing. It is therefore recommended that weeds should be effectively controlled over the period of 28 to 60 days after emergence (Deat, 1982).

While efficient weed control during the initial stages of maize growth has been achieved by a combination of mechanical, cultural and chemical methods in the developed countries, weed control is still dependent on cultural and manual methods in the developing countries (Akobundu, 1987). Maize production in the developing countries is therefore often on a small scale where these methods suffice.

To ensure that production is optimized to cater for the ever-increasing population in these developing countries, cheaper, easier and more efficient methods of weed control need to be employed. Several researchers have suggested chemical methods as a suitable alternative under large scale production. If properly administered, chemical methods ensure higher yields than all other methods of weed control in maize (Saggers, 1976; Deat, 1982; Gill, 1982).

Among herbicides recommended for chemical weed control in maize, triazine-based herbicides are those mostly employed world-wide. Other herbicides include amide-based and substituted urea herbicides (Parker, 1967). Even though not much research has been conducted on these herbicides in Ghana, there are several forms currently available on the Ghanaian market.

In recent years, government has removed all subsidies on agrochemicals imported into the country rendering them expensive to local peasant farmers. For these farmers with limited financial resources, the use of herbicides with residual effects to ensure prolonged weed control may appear attractive. However, since crop rotation forms an integral part of farming systems in Ghana, it is essential to ensure that rotation crops are not susceptible to the residues of herbicides employed for weed control in maize.

In the light of the above, there is a need to evaluate some of these herbicides in order to recommend effective, efficient, reasonably cheap and environmentally friendly types to the Ghanaian farmer. Two pre-emergence residual herbicides recommended for maize were therefore selected for this study with the following objectives:

(1) To evaluate the efficiencies of weed control of the two herbicides,at different rates

(2) to assess the influence of the two herbicides on the growth and yield of maize and

(3) to investigate the residual effects of these herbicides on the growth, nodulation and yield of cowpea.

CHAPTER TWO

LITERATURE REVIEW

2.1 Importance of weeds in tropical Agriculture

Weeds together with insects and diseases constitute the major constraints in agriculture. Unlike the other two groups, weeds can substantially reduce yields without obvious signs of damage to the crop. Their significance in agriculture is therefore often overlooked (Terry, 1983). A weed is generally defined as a plant that does more harm than good and has a habit of encroaching where it is not wanted (Koch, 1982; Rhoads, Gowgani, Croissant and Mitich, 1989).

Weeds can survive under marginal environmental conditions and are able to utilize immediately any available moisture, nutrients and light for germination and quick development. These are factors that have contributed to their persistence over several decades as compared to other plants (Swarbrick and Mercado, 1987).

Weeds have been classified based on life cycle, habitat, growth habit, degree of undesirability or noxiousness and morphology. In the tropics, classification based on the morphology of the weed is however the most popular. Under this, weeds are put into two broad groups based on their leaf characteristics. Narrow-leaved weeds with parallel venation are monocots while broad leaved weeds are dicots and have a net venation (Akobundu, 1987).

Weeds are rarely absent from arable lands and in the tropics their control takes more time and labour than any other single farm operation (Armitage and Brook, 1977). Delaying weeding in an attempt to spread the labour load has often resulted in crop yield losses (Carson, 1979). Despite this, weed control still remains one of the most under exploited practices for improving crop production in the tropics. Yield losses due to weeds alone have been estimated to be greater than 50% of the potential yield of cultivated crops in the tropics (Deat, 1982; Terry,1983).

Besides their direct effect on yield, weeds can also cause a reduction in crop quality, affect harvest operations and also serve as alternate hosts for plant diseases and animal pests (Kasasian, 1971). Weeds are however not without some virtue. In some traditional African societies, they serve as pot herbs, as a rich source of local medicines and may be used as feed for livestock (Kasasian, 1971; Akobundu, 1991). Vega (1982) noted that weeds are an important component of the agroecosystem. Zandstra and Motooka (1978) have emphasised further the importance of weeds in integrated pest management techniques.

2.2 Weed management practices in tropical Africa

Weed control practices can generally be grouped into four major methods namely cultural, physical/mechanical, biological and chemical methods. Though weeds can be managed by any one of these methods, a combination of two or more methods often gives a more efficient control

(Kasasian, 1971; Akobundu, 1987; Rhoads *et al.*, 1989).

In developed countries, chemical weed control is by far the most advanced and popular method. Whereas in tropical Africa, weed control is still predominantly by cultural and physical methods. Although these two methods were suitable under long term fallow periods, they are no longer very efficient. This is because increasing human population pressure on arable land has decreased land available for agriculture. Shifting cultivation is therefore no longer possible in most places and continuous farming on land with reduced fallow periods has resulted in an increase in weed growth (Deat, 1982; Akobundu, 1991). Coupled with the above are industrialization and urbanization in most parts of tropical Africa. These have brought in their wake a reduction in the labour force available for crop production. Consequently, many more farmers are looking into alternative weed management and control practices for reducing production costs and maximising yield (Kukula, 1985).

Zuofa and Tariah (1992) suggested that an ideal weed control method for the small-holder farmer should entail minimum labour, ease of application, require low cash inputs and maximise returns. They noted that herbicides satisfy most of these conditions but their use requires training, experience and precision in choosing the right herbicide for a given crop or crop combination. Several other researchers have also proposed herbicides as a means of overcoming the labour constraint (Mani *Tripathial*, *Bhagwani and Mathur*, 1970; Shetty, Krantz and Obrien, 1977).

Parker and Vernon (1982) reported that the use of herbicides would increase yields over the traditional methods of weed control as a result of more effective control of weeds at the initial and critical stages of plant growth. This is so because farming activities in tropical Africa are predominantly done during the rainy seasons and the wet conditions can affect traditional farming practices. Secondly, owing to the reduction in labour force required for chemical weed control, farm labour can be used more efficiently. Farm sizes could be increased and since the use of both organic and inorganic fertilizers have been encouraged in recent times, total grain yield of maize could be greatly enhanced.

However, obvious limitations to the use of herbicides by farmers due to the high illiteracy rate led Kukula (1985) to suggest that efforts towards increasing chemical weed control in tropical Africa could be undertaken by extension services under the supervision of weed specialists.

2.3 Role of herbicides in Ghanaian agriculture

The employment of agrochemicals in Ghana as in many parts of tropical Africa is gradually gaining popularity. This is because increases in population and industrialization have reduced land available for farming. Most farmers generally crop continuously on the same piece of land and are compelled to use agrochemicals for economic returns.

Owing to the obvious signs of damage arising from nutrient deficiencies and insect and disease attack, use of chemical fertilizers and pesticides is by far more common than other agrochemicals. Weeds are controlled by cultural and physical (manual) methods with farmers depending on their families for labour. The success of such farms is due to the fact that areas cultivated are small and family labour is enough for weeding. Research has however shown that manual weed control can be quite uneconomical where large areas are being cultivated (Lerch and Zemp, 1982; Akobundu, 1991). Although the use of herbicides can be employed, the low resource base of most farmers in Ghana and the high level of illiteracy will make a total reliance on chemical weed control impossible. Alternatively, the combination of physical methods with chemical methods following an adequate education of farmers on the use of herbicides is most likely to improve crop production far above the current level.

Despite not being a popular practice among peasant farmers, a small proportion of commercial farmers cultivating export crops such as pineapple employ herbicides on their farms. There are several herbicides on the Ghanaian market and steps are already being taken to introduce these to other farmers through the Ministry of Food and Agriculture and several non-governmental organizations (N.G.Os).

A list of herbicides currently available in Ghana and the crops for which they are recommended is provided in Appendix 1. The current status of each herbicide is also indicated. The list is made up mostly of s-triazine, substituted urea and amide herbicides.

2.4 Weed control efficiency, crop tolerance and residual effects of triazines, substituted urea and amide herbicides

Triazine herbicides, usually referred to as s-triazines are a group of herbicides that show a high degree of crop tolerance and soil activity. Uptake of all herbicides in this group is mostly through plant roots. Foliar uptake is also possible with the more soluble ones. Triazine herbicides can be applied pre-plant, pre-emergence or post-emergence. They act by inhibiting photosynthesis in susceptible species. Examples are atrazine, simazine and terbuthylazine.

The substituted urea herbicides currently employed in the tropics are the phenyl ureas. These herbicides can be used for weed control selectively at low rates. At high rates, they are often employed for total weed control in non-crop areas. Such herbicides are not easily leached from treated soils. Substituted urea herbicides are taken up mostly through the plant roots and are transported via the transpiration stream to the site of action. They also inhibit photosynthesis by blocking electron transport in susceptible species. Examples are diuron, metobromuron and terbuthiuron.

Amide herbicides generally have chemical structures that make it difficult to conveniently put all of them into one group. Some members of this group are applied post-emergence and have no soil activity. Others are soil applied and can act on germinating weed seeds. Application could be pre-plant or pre-emergence and can be employed for selective weed control in a wide range of crops. Examples are alachlor, metolachlor and butachlor (Parker, 1967; Kasasian, 1971; Brian, 1976; Akobundu, 1987).

The above groups of herbicides can be used alone or in combination with each other at low rates for a more thorough weed control. The possibility of mixing two groups together is however dependent on the compa tibility between the them,the level of tolerance of crops being cultivated and the cropping system being used.

2.4.1 Weed control efficiency

Tripathi and Moolani (1972) using simazine and atrazine applied under different levels of organic matter in maize reported a better weed control than hand-weeding. Buchanan and Hiltbold (1973) also reported that atrazine applied pre-emergent or post-emergent controlled broadleaf weeds and grasses effectively. Gill and Brar (1974) using atrazine, simazine, nitrofen and alachlor for weed control in maize observed very effective control of annual grasses and dicots by atrazine and simazine. Nitrofen and alachlor though not as effective as the triazines also proved efficient against the same weeds. They therefore concluded that a combination of atrazine or simazine with alachlor or nitrofen at reduced rates, would give very good weed control comparable to that obtained by using a high dose of one herbicide only. The reduced rates would also reduce the persistence in the soil thereby making them less harmful to rotation crops.

Testing the effect of various herbicides on nutrient uptake by weeds in winter maize, Sanghwan, Panwar and Malik (1989) observed that a combination of alachlor and atrazine at 1.0kg and 0.5kg per hectare respectively applied pre-emergent gave a significant reduction in dry weight of total weeds. Contrary to previous report by Gill and Brar (1974), they noted that the combination was not as effective as atrazine alone used pre-emergence.

Although there is not much information on the use of substituted urea herbicides for weed control in maize, a lot of research has been done on the use of diuron for weed control in well rooted crops such as cotton and and also in pineapple (Dhuria and Leela, 1971; Akobundu, 1987; Wilson, 1989; Arnold *et al.*, 1990). Isom (1969) reported that low rates of diuron (0.5-1.4 lb/acre or 0.52kg-1.45kg/ha) consistently controlled weeds in small grains. Wilson and Warsham (1988) tested a combination of non-selective herbicides for 'difficult to control' weeds in no-till corn and soybeans and reported that the addition of diuron or linuron to paraquat improved the control of horseweed and ragweed.

2.4.2 Crop tolerance

Apart from effecting weed control, triazine, substituted urea and amide herbicides may also promote growth, reduce senescence and even improve protein content of certain crops (Mani *et al*., 1970; Cherry, 1976; Ebert and Dumford, 1976).

Ebert and Dumford (1976) found that normal pre-emergence applications of simazine and atrazine for weed control increased forage maize yields two to three times over that of untreated plots. Prendeville (1968) however reported a reduction in dry weight of roots and shoots of maize plants when simazine was used for weed control. There was however an increased uptake of nitrogen from the soils.

Using atrazine and metolachlor at 0.75kg ai/ha on farmer -managed fields, Tareen *et al.* (1991) reported that in six locations tested, yield increased significantly with the use of the herbicide. Maximum yield increases over the control were 314.3% but the overall average yield increase was 83.1%. Low doses of atrazine in a mixture with alachlor as a pre-emergent herbicide has also been reported to give high yields in maize without being phytotoxic to wheat used as a rotation crop (Gill and Brar, 1974).

Most herbicides may have an initial depressing effect on the growth of the crop. This effect often diminishes with age of the plant. However, where such herbicides are used indiscriminately above the recommended rates, their effect on the crop is often adverse. Gill, Sandhu, Mehra and Singh (1988) reported a reduction in maize plant height when atrazine and simazine were employed for weed control. This depression however disappeared by harvest time. Mani *et al.* (1970) explained that the ability of maize to hydrolyse triazine and amide herbicides into non-phytotoxic forms has aided in the plant's tolerance of those herbicides. Substituted ureas are however not readily degradable and in maize their effects have been quite unfavourable (Smith and Sheets, 1967). More favourable results were reported using alachlor and atrazine in sorghum than diuron. Increased doses of all these herbicides above the recommended rates resulted in severe stunting and high mortality of sorghum plants. The effects were most severe in the diuron treated plots (Khare *et al.*, 1986).

Muzik (1969) reported that wheat planted in late autumn and sprayed with diuron among other herbicides was less damaged than under a similar treatment in spring. He explained that low temperature during autumn reduced uptake of herbicides by wheat.

Studying the effects of several herbicides on growth of rhizobia and development of root nodules, Kao and Wang (1981 b) noted that alachlor and linuron did not show a strong growth- inhibiting effect during the lag phase of rhizobium growth in pure culture. They further reported a complete degradation of 50 ppm linuron by *Rhizobium leguminosarum* and *Rhizobium japonicum*. They observed that linuron and alachlor did not affect the germination rate of soybean and peanut but seedling growth and development were retarded (Kao and Wang, 1981a). Dates of flowering and maturity were also delayed confirming the susceptibility of the crops to these herbicides though rhizobia were not affected.

Alvavez-Solis, Vega-Cala, Cardenas and Tasistro (1990) studying the nodulation and yield of common bean treated with herbicides under two different tillage conditions, also reported that linuron and alachlor among other herbicides did not affect nodulation. Kaszubiak (1966) reported that simazine was not toxic to rhizobia strains that he tested.

2.4.3 Residual effect

Persistence of herbicides in soil and sensitivity of rotational crops to these herbicide residues are some of the factors that promote the threat of damage to crops planted after herbicide application (Monks and Banks, 1991).

Pea and wheat crops following maize on plots treated with simazine and atrazine were reported to have been affected significantly by residues of the herbicides. Under high moisture regimes, wheat was more susceptible to the residues than pea (Tripathi and Moolani, 1972). Under dry conditions, the persistence level was much higher than under the moist conditions. This was attributed to lower leaching as well as low removal of the herbicides by maize which was cropped before the wheat and pea. Similar observations were also reported by Mani *et al.* (1970). They found that on plots treated with high doses of simazine and atrazine during maize cultivation, wheat cultivated in rotation with the maize died immediately after germination. The plants that survived were severely stunted.

Using clover, (*Trifolium subterraneum)* in a bioassay to study the residual effects of certain selected herbicides including atrazine and chlorsulfuron, Eberbach and Douglas (1991) observed that the two herbicides persisted in concentrations sufficient to be toxic to the seedlings after four months. In another report, Buchanan and Hiltbold (1973) observed that soybean yields in sandy loam were not significantly reduced by atrazine carried over from 3.36 kg/ha applied pre-emergent to maize earlier on in the same season. The soybeans were planted several months after application and there was virtually no residual effect of the atrazine because it had a half-life of 20 days for the rate of 3.36kg/ha applied.

Gill and Brar (1974) also observed no residual effects on wheat grown in a rotation with maize on plots treated with atrazine, simazine, alachlor and nitrofen. High temperatures and high moisture in the Punjab State were believed to have aided in the breakdown of these herbicides to non-phytotoxic levels.

Work by Armstrong, Chester and Harris (1967) and Harris (1967) showed that atrazine in contact with soil degraded faster than atrazine in aqueous solution. The increased degradation was attributed to microbial breakdown as well as a non-biological constituent.

2.5 Composition and mode of action of Alachlor-Atrazine mixture and Diuron

2.5.1 Alachlor-Atrazine

It is a pre-emergent flowable liquid herbicide formulated from a combination of 350g/l alachlor and 250g/l atrazine. Alachlor is an amide-derivative herbicide which is normally soil applied and most effective on germinating weed seeds. It is taken through the roots and in maize it is readily degraded into a non-phytotoxic metabolite (Cremlyn, 1979; Akobundu, 1987). It persists in the soil for up to twelve weeks but no carry over effect of this herbicide has been reported in the humid tropics (Martin and Worthing, 1974; Brian, 1976; Akobundu, 1987).

Atrazine, an s-triazine herbicide is often used alone or in combination with other herbicides (Klingman, Ashton and Noordhoff-Lyman, 1982). It is applied either as soil or as a foliar treatment (Parker, 1967). This herbicide is also readily taken up through the roots and accumulates in the leaf margins. Persistence of atrazine following pre-emergence application ranges from two to several months. This range depends on weather and soil conditions. Certain crops including maize, sorghum and sugarcane can hydrolyse atrazine into a non-phytotoxic form. As such the herbicides can be employed for successful weed control in such crops (Kasasian, 1971; Naylor, 1976; Cremlyn, 1979; Akobundu, 1987).

2.5.2 Diuron

Diuron, a substituted urea herbicide is made up of 80% active diuron and 20% innert ingredients. It is often applied pre-emergent and acts best against germinating weeds. It is most useful in well established fields or deep-rooted plants. Diuron is soil applied and uptake is via the plant roots (Hay, 1976). It has low solubility and is not easily leached from treated soils since it is readily adsorbed unto soil colloids. Usually only 50% of soil applied sample gets degraded in 90 to 180 days after application (Martin and Worthing, 1974). Diuron acts by preventing photosynthesis through blocking of the Hill reaction.

2.6 Summary of Literature Review

Inspite of the very high labour input for agriculture in tropical Africa, crop yields have been consistently low due to poor farm management parctices.

Although the control of weeds on most farms tends to absorb most of the labour input in tropical Africa, the level of weed-control attained does not compliment the high labour input. For this reason some researchers from tropical Africa came to the conclusion that a suitable weed control practice for the tropical African farmer should be one that minimized labour and maximized yield making labour available for other farm practices. The most suitable weed control method under this circumstance was observed to be the chemical control following adequate and effective training.

In Ghana specifically, despite several forms of herbicide available on the world market, amide, triazine and substituted urea groups of herbicide have dominated the market. These groups of herbicides are soil-acting and can control weeds over a prolonged period making their use both efficient and economical. These herbicides can be applied either pre-plant, pre-emergence or post-emergence. They can also be applied alone or in combination with each other based on their compa tibility, the level of tolerance of the crop and the cropping system being used. The combination of two or more herbicides however tends to be more suitable since only small amounts of each group of herbicides are used thereby reducing the carry over effect in the soil.

Besides the regular use of these herbicides for weed control, it was also reported that the triazine herbicides can promote the growth of certain crops. For such crops their ability to tolerate these groups of herbicides is mainly dependent on the fact that they posses certain enzymes which can metabolize the active ingredients of the herbicides into non-toxic forms.

It was also reported that other abiotic factors such as temperature, soil structure and soil moisture also influence the efficiencies of various herbicides. The particular period it takes for any of these herbicides to break down in the soil however significantly determines the crops cultivated following their application for weed control in the first cropping. It also came to light that although most leguminous crops are susceptible to some triazine, amide and urea herbicides, these do not have any detrimental effects on rhizobia in the soil.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Experimental site characteristics

Two field experiments were carried out at the University of Ghana Farm, Legon. The site used had been left fallow for three years prior to this study. Broad leaved weeds at the site of the experiment included *Celosia trigynal, Croton labatus, Euphobia hetrophylla, Indigofera hirsuta Cassia obstusifolia, Phyllanthus amarus* and *Schrankia leptocarpa*. Grasses included *Paspalum orbiculare, Digitaria horizontalis, Brachiaria jubata, Setaria pallide-fusca, Cyperus esculentus* and *Cyperus rotundus*.

The soil at the site belongs to the Nyigbenya-Haatso series. It is sandy clay loam in texture, low in fertility and slightly acidic. The site was cleared of weeds, ploughed and harrowed before the start of the first experiment.

3.2 Experiment I: Effect of herbicides on weed control and growth of maize

This experiment was aimed at investigating the efficiencies of two herbicides and hand-weeding on weed control in maize. The influence of the herbicides on maize growth and yield was also evaluated. The study was carried out from July 1993 to October 1993.

Maize variety 'Abeleehi' developed by the Grains Development Board of the Crops Research Institute of Ghana was used in this experiment. 'Abeleehi' is a streak resistant, white dent maize which matures in about 105 days. Seeds were purchased from the Aglow Seed Company in Accra. The two herbicides, alachlor -atrazine mixture and diuron were obtained from Wienco Agricultural Chemicals, Airport and Chemico Industries, Tema respectively.

A randomized complete block design with four replications was employed in the experiment. There were six treatments as follows: alachlor-atrazine mixture and diuron at manufacturers' recommended rates and also at 50% over the recommended rates of each, hand-weeding and no weed control (no herbicide; no hand weeding).

Alachlor-atrazine mixture at a rate of 1.8kg + 1.0kg ai/ha and diuron at 0.9kg ai/ha are the manufactures' recommended rates. The higher rates of 2.5kg + 1.4kg ai/ha of alachlor-atrazin mixture and 1.3kg ai/ha of diuron were adopted to reflect what may occur should one use rates above the recommended. Hand-weeding was used to evaluate the influence of the chemicals on the growth of maize. Although two hand-weedings at four and eight weeks after planting were proposed for this study, only one hand-weeding at six weeks after planting using a hand-held hoe was done. This arose as a result of the relatively slow growth of weeds on experimental plots due to low rainfall. An absolute control check of no-herbicide and no hand-weeding which served as the sixth treatment was used only in evaluating the weed control efficiencies of the weed control alternatives adopted for this study and not as one of the weed control alternative.

Alachlor-atrazine mixture was applied using a CP15 knapsack sprayer with a prolijet nozzle. The pressure relief valve was set at low (1.5kg/cm^2 - 20psi).

A volume of 23.1ml of alachlor-atrazine mixture in 1.8 l of water served as the manufacturer's recommended rate for an area of 11.52m^2 (5.0l in 300l of water for one hectare). For the higher rate of the same herbicide, 32.3 ml was mixed in the same volume of water to cover the same area size (7.0l in 300l of water for one hectare).

Diuron was however applied as a dry powder in bands along the rows of maize. To apply the manufacturers recommended rate (1.12kg/ha) on a plot size of 11.52m^2, 5.2g of the powder was mixed thoroughly with a small amount of dry soil collected from the site of the experiment before application. For the higher rate (1.68kg/ha), 7.8g of the powder mixed thoroughly with dry soil was applied.

All the herbicide treatments were applied after sowing but before emergence of maize seeds.

Maize seeds were sown at a spacing of 0.8m between rows and 0.4m between hills in a row. Seeds were sown three per hill and the plants were thinned out to two plants per hill two weeks after emergence. Each plot was 2.0m by 7.2m and four inner row plots were used for data collection. Irrigation was applied using an over-head sprinkler irrigation system once a week until tasseling and on each occasion water was applied for about eight hours. Rainfall became more regular after this period and irrigation was therefore applied only when necessary.

Compound fertilizer 15-15-15 (N-P-K) at a rate of 250kg/ha was applied in bands along the rows. Insect pests, mostly stem borers were controlled using Furadan 3G at a rate of 30kg/ha six weeks after emergence.

The maize cobs were harvested 110 days after planting, dehusked and further dried in the sun for three weeks before yield records were taken.

3.3 Experiment II: Evaluation of residual effects of herbicides on growth and yield of cowpea.

The second experiment was conducted from November 1993 to January 1994 on the same site as the first experiment. The site was first cleared of all maize stubble to control the activities of termites. The area was then manually weeded using a hoe.

This experiment aimed at evaluating the residual effect of the herbicides applied in experiment one on the performance of succeeding cowpea crop. Two varieties of cowpea were employed in the study. The experimental design was a split-plot with four replications. The treatment plots of experiment one served as the main plot treatments while the two varieties of cowpea were used in the sub-plots. The varieties used were 'Asontem' and 'Bengpla'. Both are early-maturing (60-75 days) erect varieties, developed by the Grain's Development Board of the Crops Research Institute of Ghana.

The cowpeas were planted at a spacing of 0.75 m by 0.2 m to prevent intertwining since they sometimes grow viny. Each subplot was 2.0m by 3.0 m and accommodated five rows with nine hills per row. The three inner rows were used for record purposes.

Three seeds per hill were planted and these were then thinned to two plants per hill two weeks after emergence. Irrigation was applied once a week until flowering after which water taps ceased to run. Weeds were controlled by hand-hoeing at two weeks and again five weeks after planting. Pre-flowering insect pests were controlled using Karate 2.5 EC at a rate of 0.6 l/ha 30 and 40 days after planting. Post-flowering insect pests were controlled using Perfekthion at a rate of 1.2 l/ha 50 days after planting.

Harvesting of cowpeas started 58 days after planting and continued for 10 days owing to the indeterminate flowering pattern observed for both varieties used.

3.4 Data collection and statistical analysis

3.4.1 Weed control assessment

I. Weed intensity under each weed control alternative was recorded at 6 weeks and 12 weeks after planting using a 20 x 20 cm quadrat. The quadrat was placed at 8 randomly selected spots in each plot and the number of weeds within each quadrat was counted.

II. The percent relative efficiency of each weed control alternative using the absolute control as a check was estimated using the formula of Ramamoorthy (1991) as follows:

$$\text{Weed Control Efficiency (\%)} \quad 100 \left[\frac{\text{[Total number of weeds in RxTy]}}{\text{[Total number of weeds in RxAc]}} \times 100 \right]$$

Where Rx Ty = Any treatment in a particular replicate.

Rx Ac = The absolute control treatment in the same replicate.

3.4.2 Growth and yield of maize

(i) Days to emergence : Number of days from sowing till 50% of plants emerged in a plot.

(ii) Days to tasseling : Number of days from sowing till 50% of record plants tasseled.

(iii) Days to silking : Number of days from sowing till 50% of record plants silked.

(iv) Shoot dry weight at tasseling (g) : Shoots of four randomly selected record plants per plot were harvested at first node above soil level. The shoots were chopped into pieces, dried in an oven at

		80°C for 72 hours and weighed.
v) Percent nitrogen concentration of shoots at tasseling	:	The Boric acid method (Appendix II) was used.
(vi) Plant mortality at maturity	:	The percentage of the number of maize plants that had died at maturity. This was based on the number of surviving plants per plot compared to the expected plant population.
(vii) Plant height at maturity (cm)	:	Average height of ten randomly selected record plants per plot. Height was measured from the base of plant at soil level to the base of the tassel.
(viii) Ear length (cm)	:	Average length of ten randomly selected ears from record plants. Each ear was dehusked and measured from the base to the tip.

(ix) Ear diameter (cm) : Diameter of the ear calculated from circumference of ten randomly selected maize ears from record plants. The circumference was taken at the mid-section of the dehusked ears.

(x) Number of kernel rows per ear : Number of kernel rows per ear of ten randomly selected maize ears from record plants per plot.

(xi) Number of kernels per row : Average number of kernels found on kernel row of ten randomly selected maize ears from record plants per plot.

(xii) Number of kernels per ear : The total number of kernels per cob of ten randomly selected ears per plot. This number was obtained by multiplying the number of kernel rows by the number of kernels per row and finding the average.

(xiii) 100 Seed weight : Weight of hundred seeds selected at random from the bulk of kernels shelled from record plants.

(xiv) Yield per plot (g): Grain yield per plot. This was obtained by multiplying the total weight of kernels from ten ears/plot by the plant stand at maturity and dividing through by ten.

(xv) Yield per hectare (kg): This was obtained by converting the yield per plot (plot size 11.52m^2) to yield per hectare by multiplying by a factor of 0.868.

3.4.3 Growth, nodulation and yield of cowpea

(i) Days to seedling emergence : Number of days from sowing till 50% of plants emerged in a plot.

(ii) Days to flowering : Number of days from sowing till 50% of record plants flowered.

(iii) Plant height at flowering (cm) : Average height of four randomly selected record plants per plot. The height was measured from the base of plant at soil level to the apex.

(iv) Shoot dry weight (g): Average weight of shoots of four randomly selected record plants per subplot. The shoots were cut at the soil level, chopped into pieces, dried in an oven at 80°C for 72 hours and weighed.

(v) Number of nodules per plant at flowering : Obtained as a count of nodules on the roots of four randomly selected record plants per subplot and averaged.

(vi) Number of effective nodules per plant at flowering : Obtained by splitting open all nodules from the four randomly selected plants per subplot and counting those with a pinkish core and averaging over four.

(vii) Nodule dry weight per plant (g) : Weight of nodules of four randomly selected plants per

		subplot dried in an oven at 80°C for 72 hours.
(viii) Number of pods per plant	:	Average number of pods of ten randomly selected record plants.
(ix) Number of seeds per pod	:	Average number of seeds threshed from ten randomly selected pods from record plants.
(x) 100 seed weight (g)	:	Weight of hundred seeds selected at random from the bulk of seeds threshed from ten record plants.
(xi) Plant stand	:	Number of plants per sub plot two weeks and eight weeks after planting.
(xii) Seed yield per plot (g)	:	Seed yield per plot. This was obtained by multiplying the total weight of seeds from ten record plants per sub plot by the plant stand at 8 weeks and dividing through by ten.

(xiii) Yield per hectare (kg) : Seed yield per plot (plot size 4.8m^2) was converted to yield per hectare by multiplying through by a factor of 2.083.

CHAPTER FOUR

RESULTS

4.1 Efficiency of Alachlor-Atrazine mixture and Diuron on weed control

Table 1 shows the weed population per plot and the weed control efficiency of alachlor-atrazine mixture and diuron at six and twelve weeks after application. The square-root transformation was used for the data on weed population per plot.

Significant differences ($P<0.05$) in number of weeds per plot were observed among the herbicide treatments six weeks after application. The lowest weed population was from plots treated with the high rate of alachlor-atrazine mixture . However at twelve weeks after application no significant differences in the number of weeds per plot occured among the herbicide-treated plots.

Despite the significant differences in weed population per plot at six weeks after application of herbicides, the efficiencies of these herbicides on weed control were not significantly different from each other. A similar trend was observed for the efficiencies of the herbicides at twelve weeks. An average drop of about 13% in the weed control efficiencies of the herbicides however occured at twelve weeks after application as compared to those at six weeks. At both six weeks and twelve weeks after herbicide application, the high concentration of alachlor-atrazine mixture produced the best weed control.

Table 1: Weed population per plot and weed control efficiencies of Alachlor-Atrazine mixture and Diuron six and twelve weeks after application (WAA)

Weed control alterna-tive	Weed population per plot		Weed control efficiency	
	6 WAA X±s.e	12 WAA X±s.e	6 WAA X ± s.e	12 WAA X ± s.e
Alachlor-Atrazine mixture 1.8kg+1.0 kg ai/ha	549 ± 8	369±7	73.7±2.2	73.9±2.1
Alachlor-Atrazine mixture 2.5kg+1.4 kg ai/ha	63 ± 3	207±5	97.3±0.6	86.0±1.3
Diuron 0.9kg ai/ha	441 ± 6	489±8	79.7±1.6	69.7 ± 1.7
Diuron 1.3kg ai/ha	459±10	531±10	81.0±1.8	67.8 ± 1.8
Hand-weeding		702±10		54.5 ± 2.6
LSD (5%)	90	N.S	N.S	N.S

N.S : Not significant

4.2 Influence of Alachlor-Atrazine mixture and Diuron on growth and development of maize

4.2.1 Days to seedling emergence, tasseling and silking

Approximately 50% of maize seedlings emerged five days after sowing in all the treatments. The number of days to 50% tassel and silk formation ranged from 59-62 and 64-67 days respectively among the treatments. Maize plants on plots treated with alachlor-atrazine mixture (1.8kg+1.0kg ai/ha) were first to tassel. These were followed by the plants on hand-weeded plots at a day's interval with the other three treatments tasseling two days later. A similar pattern was observed for silk emergence but plants on plots treated with alachlor-atrazine (2.5kg+1.4kg ai/ha) silked a day ahead of those on plots treated with diuron (data not shown).

4.2.2 Shoot dry weight, plant height and shoot nitrogen concentration at tasseling

Significant differences ($P<0.05$) among the weed-control alternatives were observed for shoot dry weight and plant height (Table 2). Though plants on hand-weeded plots had the highest shoot dry weight, this did not differ significantly from that of plants under alachlor-atrazine mixture (1.8kg+1.0kg ai/ha) treatment. The latter however had the highest plant height among all the treatments but again it did not differ significantly from the hand-weeded plants.

Treatment with diuron at 1.3kg ai/ha resulted in a severe stunting of maize plants. Consequently plant height and shoot dry weight were significantly reduced.

Differences among the treatments for shoot nitrogen concentration were not significant (Table 2). Nitrogen concentration ranged from 1.5% (alachlor-atrazine 2.5kg+1.4kg ai/ha) to 2.8% (Diuron 0.9kg ai/ha).

Table 2: Shoot dry weight, plant height and nitrogen concentration of maize as influenced by Alachlor-Atrazine mixture and Diuron

Weed control alternative	Shoot dry weight (g)	Plant height (cm)	Nitrogen concentration (%)
	X ± s.e	X ± s.e	X ± s.e
Alachlor-Atrazine mixture 1.8kg+1.0kg ai/ha	58.2 ± 1.7	146.2 ± 1.9	2.3 ± 0.5
Alachlor-Atrazine mixture 2.5kg+1.4kg ai/ha	40.0 ± 3.8	126.8 ± 2.0	1.5 ± 0.2
Diuron 0.9kg ai/ha	40.7 ± 5.9	119.6 ± 2.1	2.8 ± 0.4
Diuron 1.3kg ai/ha	35.3 ± 4.9	100.7 ± 2.5	1.9 ± 0.2
Hand-weeding	60.7 ± 4.5	142.7 ± 1.9	2.3 ± 0.5
LSD (5%)	13.8	15.2	N.S

N.S.: Not significant

4.2.3 Plant mortality

The effect of the herbicides on plant mortality is shown in Table 3. Since this data was taken to compare the way the two herbicides at the two different rates affected the survival of the maize, data on the control was not included. The arc-sine transformation was used for this data. Application of the recommended and higher rate of diuron were the most phytotoxic to maize resulting in 42% and 46% mortality respectively. Lowest mortality occured on plots treated with alachlor-Atrazine (1.8kg+1.0kg ai/ha). This mortality was significantly lower than all other treatments, and the relatively low value of 11% observed for the higher rate (2.5kg+1.4kg ai/ha) of the same herbicide compared to diuron indicated some level of tolerance to alachlor-atrazine mixture by the maize plants.

Table 3: Influence of Alachlor-Atrazine mixture and Diuron on mortality of maize plants

Weed control alternative	Plant mortality (%)
	X ± s.e
Alachlor-Atrazine mixture 1.8kg+1.0kg ai/ha	7 ± 0
Alachlor-Atrazine mixture 2.5kg+1.4kg ai/ha	11 ± 1
Diuron 0.9kg ai/ha	42 ± 2
Diuron 1.3kg ai/ha	46 ± 2
LSD (5%)	2

4.2.4 Grain yield and components of yield of maize as influenced by herbicides

Table 4 shows the grain yield of maize plants from plots with different weed control treatments. Grain yield from plots treated with alachlor-atrazine mixture (1.8kg+1.0kg ai/ha) was the highest. It was followed by yield from hand-weeded plots. The difference between these two treatments was not significant. A significant yield reduction of 22.6% however occured on plots treated with the higher rate (2.5.kg+1.4kg ai/ha) of alachlor-atrazine mixture .

Diuron at both rates (0.9kg ai/ha and 1.3kg ai/ha) resulted in significantly ($P<0.05$) lower grain yield in comparison with alachlor-atrazine mixture . Grain yield from plots treated with the recommended rate of Diuron was 41% of that from the recommended rate of alachlor-atrazine mixture (1.8kg+1.0kg ai/ha) and hand-weeded control and an increase in the rate of diuron resulted in a futher drop in yield to only 27%.

Significant differences among the herbicides were also observed for components of grain yield (Table 5). The largest maize ears were produced from plots treated with alachlor-atrazine mixture (1.8kg+1.0kg ai/ha). This was reflected in the bigger length and diameter of the ear. Subsequently, the number of kernels per row and number of kernels per ear were also high. Similar results were obtained from hand-weeded plots and no significant differences in components of yield were found between hand-weeding and recommended rate of alachlor-atrazine mixture. Values obtained from plots treated with alachlor-atrazine mixture (2.5kg+1.4kg ai/ha) though slightly lower were also not significantly different from the hand-weeded plots.

In contrast, diuron had a depressing effect on the size of the maize ear resulting in significantly lower values for components of grain yield.

Table 4: Grain yield of maize as influenced by weed control alternatives

Weed control alternative	Yield/plot (g)	Yield/ha (kg)
	X ± s.e	X ± s.e
Alachlor-Atrazine mixture 1.8kg+1.0kg ai/ha	8751.6 ± 462.5	7596.0 ± 401.5
Alachlor-Atrazine mixture 2.5kg+1.4kg ai/ha	6775.1 ± 431.0	5881.2 ± 374.2
Diuron 0.9kg ai/ha	3607.5 ± 1092.7	3131.5 ± 948.6
Diuron 1.3kg ai/ha	2344.3 ± 663.5	2035.0 ± 576.0
Hand-weeding	8655.8 ± 1045.0	7513.7 ± 907.1
LSD (5%)	1643.2	1423.1

Table 5: Influence of weed control alternatives on components of grain yield in maize

Weed control alternative	Ear length	Ear diameter	Number of kernel rows/ear	Number of kernels per row	Number of kernels per ear	100 seed weight (g)
	X ± s.e	X ± s.e	X ± s.e	X ± s.e	X ± s.e	X ± s.e
Alachlor-Atrazine mixture 1.8kg+1.0kg ai/ha	15.7 ± 0.7	4.7 ± 0.2	13 ± 0	33 ± 0	427 ± 30	29.1 ± 1.[illegible]
Alachlor-Atrazine mixture 2.5kg+1.4kg ai/ha	14.1 ± 0.3	4.5 ± 0.04	13 ± 0	28 ± 1	370 ± 7.1	26.2 ± 0.6
Diuron 0.9kg ai/ha	12.5 ± 1.6	4.3 ± 0.3	12 ± 1	25 ± 5	315 ± 67	26.3 ± 1.9
Diuron 1.3kg ai/ha	11.5 ± 1.1	4.1 ± 0.1	11 ± 1	21 ± 3	251 ± 43	25.9 ± 1.6
Hand-weeding	15.4 ± 0.2	4.7 ± 0.1	13 ± 0	32 ± 1	420 ± 21	28.4 ± 0.6
LSD (5%)	2.7	0.4	N.S	7	106	N.S

N.S.: Not significant

4.3 Residual effects of Alachlor-Atrazine mixture and Diuron on performance of two succeeding varieties of cowpea

4.3.1 Influence on plant stand

Alachlor-atrazine mixture and Diuron applied for weed control in the first experiment had no effect on the number of days to 50% emergence of cowpea seedlings. Both varieties 'Asontem' and 'Bengpla' emerged five days after sowing in all the treatments.

Two weeks after emergence however, a significant ($P<0.05$) loss in plant stand was observed on the plots previously treated with diuron, compared to those on plots previously treated with alachlor-atrazine mixture or hand-weeded (Table 6). The reduction in plant stand was more pronounced on plots that received the high rate of diuron than on plots that received low rate of the same herbicide.

Data taken eight weeks after emergence showed a drop in the number of plants per plot in all the treatments as compared to data of the second week after emergence. Significant difference in the number of plants per plot among treatments was again apparent for only the diuron treated plots.

The two varieties of cowpea did not show a significant difference in their level of tolerance to the residual effects of the herbicides. Hence no significant interaction effect between cowpea variety and residual effect of herbicide was obtained. Log transformation of the data on plant stand was done before the analysis of variance.

Table 6: Residual effect of Alachlor-Atrazine mixture and Diuron on succeeding cowpea stand at two weeks and eight weeks after emergence.

Treatment Residue	Plant Stand			
	2 W A P		8 W A P	
	'Asontem' X ± s.e	'Bengpla' X ± s.e	'Asontem' X ± s.e	'Bengpla' X ± s.e
Alachlor-Atrazine mixture 1.8kg+1.0kg ai/ha	90 ± 0	90 ± 0	67 ± 2	67 ± 1
Alachlor-Atrazine mixture 2.5kg+1.4kg ai/ha	90 ± 0	90 ± 0	72 ± 3	70 ± 2
Diuron 0.9kg ai/ha	87 ± 1	83 ± 1	39 ± 3	42 ± 9
Diuron 1.3kg ai/ha	84 ± 1	83 ± 2	35 ± 5	39 ± 6
Control	90 ± 0	90 ± 0	66 ± 1	70 ± 2
LSD (5%)				
Residue, R	1		1	
Variety, V	N.S		N.S	
R X V	N.S		N.S	

N.S.: Not significant

4.3.2 Effect on plant height and shoot dry weight at flowering

Plant height and shoot dry weight of cowpeas were not significantly influenced by the residual effects of the herbicides (Table 7).

Though plant height of the variety 'Asontem' was significantly higher than that of variety 'Bengpla' the shoot dry weights of the two varieties were not significantly different from each other. No significant interaction between the residual effect and the variety was also observed for the two characters.

Table 7: Residual effect of herbicides on plant height (cm) and shoot dry weight (g) of cowpeas at flowering

Herbicide Residue	Plant Height (cm)		Shoot Dry Weight (g)	
	'Asontem' X ± s.e	'Bengpla' X ± s.e	'Asontem' X ± s.e	'Bengpla' X ± s.e
Alachlor-Atrazine mixture 1.8kg+1.0kg ai/ha	51.0±2.9	33.5±2.0	4.1±1.1	3.6±0.4
Alachlor-Atrazine mixture 2.5kg+1.4kg ai/ha	54.0±1.1	34.5±3.3	4.0±0.2	3.5±0.4
Diuron 0.9kg ai/ha	41.0±5.4	31.5±3.3	3.0±0.6	3.6±0.6
Diuron 1.3kg ai/ha	46.2±4.3	31.5±1.1	5.2±1.6	3.8±0.7
Control	47.3±1.9	31.8±3.0	3.4±0.6	4.3±1.3
LSD (5%)				
Residue, R	N.S		N.S	
Variety, V	4.2		N.S	
R X V	N.S		N.S	

N.S. : Not significant

4.3.3 Effect on nodulation

Table 8 shows data on number of nodules, number of effective nodules and nodule dry weight per plant at flowering of cowpea on plots previously treated with alachlor-atrazine mixture and diuron. There was no significant residual effect of the herbicides on any of the three characters.

Cowpea variety 'Asontem' however produced a significantly higher ($P<0.05$) number of effective nodules than variety 'Bengpla'. The interaction effect was not significant for all the nodulation characters.

Table 8: Residual effect of herbicides on number of nodules formed,number of effective nodules and nodule dry weight (g)

Herbicide Residue	Number of Nodules/Plant		Numberof Effective Nodules /Plant		Nodule Dry Weight(g)/Plant	
	'Asontem' X ± s.e	'Bengpla' X ± s.e	'Asontem' X ± s.e	'Bengpla' X ± s.e	'Asontem' X ± s.e	'Bengpla' X ± s.e
Alachlor-Atrazine mixture 1.8kg+1.0kg ai/ha	11 ± 3	9 ± 0	8 ± 4	4 ± 1	5.8 ± 2.4	5.8±0.4
Alachlor-Atrazine mixture 2.5kg+1.4kg ai/ha	12 ± 1	10 ± 1	7 ± 2	6 ± 1	6.4 ± 0.9	7.7±1.7
Diuron 0.9kg ai/ha	11 ± 2	8 ± 2	6 ± 1	5 ± 1	6.3 ± 1.1	3.7±1.1
Diuron 1.3kg ai/ha	10 ± 1	6 ± 0	5 ± 1	3 ± 1	3.0 ± 0.6	2.5±0.9
Control	10 ± 1	11 ± 3	8 ± 1	7 ± 2	7.3 ± 1.1	7.6±2.5
LSD (5%)						
Residue, R	N.S		N.S		N.S	
Variety, V	N.S		2		N.S	
RXV	N.S		N.S		N.S	

N.S.: Not significant.

4.3.4 Effect on seed yield and components of seed yield of cowpea

There was a significant reduction in seed yield on plots previously treated with diuron compared with plots previously treated with alachlor-atrazine mixture and the hand-weeded (Table 9). The yield reduction in the Diuron plots was about 40% compared to the control. Although the yield on plots previously treated with alachlor-atrazine mixture was not significantly different from the hand-weeded plots, a yield increase of 18% over the hand-weeded plots was obtained from plots previously treated with alachlor-atrazine mixture (1.8kg+1.0kg ai/ha).

Seed yield also differed significantly between the two varieties of cowpea. Variety 'Asontem' produced a higher yield of 138.7kg/ha above that of 'Bengpla'. No significant interaction effect was observed under seed yield also.

Differences in components of yield in response to residual effect of herbicides were not significant (Table 10). Differences between the two cowpea varieties were however significant for all the three characters investigated. The number of pods per plant and the number of seeds per pod were higher in variety 'Asontem' while the hundred seed was higher in variety 'Bengpla'.

Since both varieties of cowpea responded in a similar way to the residual effect of the herbicides, there was no significant interaction effect.

Table 9: Residual effect of herbicides on yield of two varieties cowpea

Herbicide Residue	Yield/Plot (g)		Yield/Hectare (kg)	
	'Asontem' X ± s.e	'Bengpla' X ± s.e	'Asontem' X ± s.e	'Bengpla' X ± s.e
Alachlor-Atrazine mixture 1.8kg+1.0kg ai/ha	360.8±56	255.7±32	750.6±117	531.8±66
Alachlor-Atrazine mixture 2.5kg+1.4kg ai/ha	331.3±67	189.3±30	706.7±140	393.8±60
Diuron 0.9kg ai/ha	136.2±16	141.4±30	283.4±33	294.1±63
Diuron 1.3kg ai/ha	192.5±53	121.9±28	400.4±110	253.5±58
Control	329.3±42	192.0±43	685.1±88	390.8±84
LSD (5%)				
Residue, R	99.5		283.6	
Variety, V	67.9		138.7	
R X V	N.S		N.S	

N.S.: Not significant

Table 10: Residual effect of herbicides on components of seed yield of cowpea

Herbicide Residue	Number of Pods/Plant		Number of Seed/Pod		100 Seed Weight (g)	
	'Asontem' X ± s.e	'Bengpla' X ± s.e	'Asontem' X ± s.e	'Bengpla' X ± s.e	'Asontem' X ± s.e	'Bengpla' X ± s.e
Alachlor-Atrazine mixture 1.8kg+1.0kg ai/ha	5 ± 1	3 ± 0	12 ± 1	10 ± 1	14.3 ± 0.6	14.6±0.4
Alachlor-Atrazine mixture 2.5kg+1.4kg ai/ha	4 ± 1	3 ± 1	12 ± 1	9 ± 1	14.0 ± 0.3	14.5±0.4
Diuron 0.9kg ai/ha	3 ± 0	4 ± 1	13 ± 1	9 ± 0	13.2 ± 0.4	14.6±0.2
Diuron 1.3kg ai/ha	6 ± 1	4 ± 1	12 ± 0	10 ± 1	13.1 ± 0.6	15.0±0.7
Control	4 ± 0	4 ± 1	12 ± 0	9 ± 1	14.5 ± 0.6	14.1±0.8
LSD (5%)						
Residue, R	N.S		N.S		N.S	
Variety, V	1		1		0.7	
RXV	N.S		N.S		N.S	

N.S.: Not significant.

CHAPTER FIVE

DISCUSSION

5.1 The efficiencies of the weed control alternatives

Rainfall during the period of the experiment was irregular and hence the growth of weeds appeared to have been much slower than would occur in a regular rainy season when maize is normally planted.

Analysis of weed population per plot showed significant differences among the weed control alternatives at six weeks. The lowest number of weeds were recorded on plots treated with the higher concentration of alachlor atrazine mixture (2.5kg + 1.4kg ai/ha). However, when the absolute control treatment in which no herbicide application or hand-weeding was effected was used as a check, the weed control efficiencies of the herbicides did not differ significantly from each other. This was attributed to the relatively poor growth of weeds on even the absolute control plots where no hand-weeding or herbicides were applied during the period of the experiment.

However the number of weeds per plot indicated a significant decrease in weed population on plots treated with the high rate of both herbicides. Results reported by Akiyemiju (1988) using alachlor-atrazine mixture for the control of both broad-leaved weeds and grasses in maize were similar to those observed in this study.

As relates to all biodegradable chemicals, the potency of the herbicides decreased considerably with time. This observation is supported by weed counts and weed control efficiencies taken twelve weeks after application compared to those taken at six weeks after application. With the exception of plots treated with alachlor-atrazine mixture at 1.8kg + 1.0kg ai/ha, which maintained its weed control efficiency over the twelve weeks period, there was a depreciation of about 10% in the weed control efficiencies of the other treatments. Luxuriant growth of the maize plants on plots treated with alachlor-atrazine mixture (1.8kg + 1.0kg ai/ha) contributed to an adequate closure of plant canopy. This ensured a considerable shading of the ground thereby controlling the growth of new weeds. The weed population on these plots were therefore relatively lower compared to the absolute control check.

Although one hand-weeding within three to four weeks after planting of maize is recommended, a second hand-weeding just before tassel formation may be necessary (Anon, 1993). In this study only one hand-weeding six weeks after planting was done as a result of the slow rate of growth of the weeds. Inspite of its execution six weeks after the application of the chemical treatments, hand-weeding had the lowest efficiency although this was not significantly different from the chemical treatments. This is because unlike the chemical method which destroys both germinating weed seeds and seedlings, hand-weeding turns to damage the above ground portion of the weeds without affecting the under-ground parts particularly of perennial weeds. Thus the ability of the predominant weed species on the control plots to propagate vegetatively caused a regeneration of these weeds after hand-weeding. The predominant weed species included *Commelina benghalensis, Digitaria ciliaris and Setaria pallide-fusca*.

The more efficient control of weeds by the chemical method is in agreement with several reports which have compared chemical and manual methods of controlling weeds in cereals (Tripathi and Moolani, 1972; Rhoads *et al.*, 1985; Ramamoorthy, 1991).

5.2 **Effect of herbicides on growth of maize**

The results indicated that both alachlor-atrazine mixture and diuron at the manufacturers' recommended rates, and at rates 50% above the recommended had no effect on germination and emergence of maize seeds. However, three weeks after the establishment of maize seedlings, visible damage to the foliage was observed in the plots treated with diuron. Seedlings wilted and died resulting in a significant reduction in plant stand of these treatments as compared to the hand-weeded control and the alachlor-atrazine mixture treatments. The seedlings that survived on these plots were however severely stunted causing a reduction in both the plant height and shoot dry weight. The stunting effects were more severe in the plots treated with the higher concentration of diuron. The phytotoxicity of herbicide to maize has been reported to be the result of the rather slow metabolism of the active ingredient into a nonphytotoxic form in maize (Smith and Sheets, 1967).

Though plants on plots treated with alachlor-atrazine mixture at a rate of 1.8kg + 1.0kg ai/ha were not significantly different from plants on hand-weeded control plots as regards their shoot dry weight at tasseling, there appeared to be a small depression in the magnitude of the former. Nevertheless, by maturity, the depression had disappeared as was evident from the plant height. These observations support a report by Gill *et al.* (1988) which showed a depressing effect of triazine herbicides on maize plants at the initial stages. They further reported a complete erasure of this depression at maturity.

The increased concentration of alachlor-atrazine mixture to 2.5kg + 1.4kg ai/ha caused some level of reduction in the shoot dry weight of maize due to the stunting effect of this high rate compared to the lower rate of the same herbicide. Though Buchanan and Hiltbold (1973) explained that the ability of maize to metabolize both atrazine and alachlor into non-phytotoxic forms often account for the high level of tolerance of the herbicides by maize, Mani *et al.* (1970) reported that at high concentrations, the plant is unable to eliminate all the injury caused by herbicides. In this study the plants were injured by the high herbicide concentration and there was an increased plant mortality compared to the recommended rate for both herbicides.

Shoot nitrogen concentration was not affected significantly by any of the herbicides used. However, N-concentrations of plants from plots treated with diuron was slightly higher than those of plants from alachlor-atrazine treated plots. The results however differred from a report by Ebert and Dumford (1976) that there was a significant increase in shoot N-concentration of maize following the application of triazine herbicides.

5.3 Effects of herbicides on grain yield and components of yield

Grain yield of maize increased considerably under alachlor-atrazine mixture (1.8kg + 1.0kg ai/ha) compared to the other herbicide treatments. It was however not significantly different from the yield of plants that were hand-weeded. The results are similar to reports by Ebert and Dumford (1976) and Rhandhawa *et al* (1988). Diuron however caused a significant reduction of grain yield since it was phytotoxic to the plants. Yield from plots treated with diuron (0.9kg ai/ha) was only 42% of that from hand-weeded plots.

Though the difference in yield between the alachlor-atrazine mixture (1.8kg + 1.0kg ai/ha) and hand-weeding were not significant, a rather high standard error was observed for the former. Higher standard errors were also observed for the diuron treatments also. These reflected the lower precision obtained using manual application methods in the control of weeds such as the band placement of diuron and hand-held hoe compared to the use of a mechanical means such as the knap-sack sprayer. The latter method obviously produced a more uniform effect.

Jughenheimer (1976) reported that the yield of maize is greatly influenced by the number of kernel rows and number of kernels per row for each ear. From the current study, among six characters taken for the components of grain yield, the number of kernel rows and the hundred seed weight did not differ significantly among the weed control alternatives. Since only a single maize variety was used, the observation revealed that these two components of grain yield may be genetically controlled to a large extent.

Significant differences in the length and diameter of the maize ears were observed between the two herbicide treatments. Maize plots treated with alachlor-atrazine mixture at the recommended rate produced significantly longer ears than plots treated with diuron at the recommended rate. The same trend was observed for the higher rates of the two herbicides. The differences in the ear length and diameter between the recommended and higher rate of the same herbicide were however not significant. These latter observations were also made for the number of kernels per row and number of kernels per ear.

Hiranpradit and Foy (1973) reported that atrazine turns to increase the retention of chlorophyll in non-susceptible crop species thereby promoting the fixation of more carbon and hence more assimilates. Tellenaar (1977) also reported that assimilate supply to the developing ear is an important determinant of ear size. These reports may therefore explain the increase in the size of the maize ears and higher overall yield observed in the recommended alachlor-atrazine mixture treatment, which was not phytotoxic to the plants compared to the other treatments.

An increase of 50% in the rate of each herbicide could not be readily metabolized by the plants hence these resulted in injury to the crop. This caused a significant reduction in the yield of maize compared to its corresponding recommended rate. Khare *et al.* (1986) reported similar observations in sorghum. These results brought out the importance of using appropriate rates of suitable herbicides for weed control in crops to ensure a maximum output.

5.4 The residual effect of Alachlor-atrazine mixture and Diuron on growth and nodulation of cowpea

The number of days to seedling emergence of the two varieties of cowpea were not influenced by the residual effects of both herbicides. However a decline in plant population by 6% and 8% on plots previously treated with diuron, at the recommended and higher rates two weeks after emergence, indicated a significant carry over effect of this herbicide four and a half months after application. No significant reduction in plant stand was observed on plots previously treated with alachlor-atrazine mixture at this same time.

Leela (1988) reported a similar observation in a cowpea bioassay following the application of diuron.

The plant height and shoot dry weights of cowpea that survived on the diuron treated plots however did not differ significantly from those on plots previously treated with the alachlor-atrazine mixture. It was further observed that cowpea plant height and shoot dry weight on plots treated with diuron 1.3kg ai/ha though not significantly different from that of 0.9kg ai/ha were higher.

These observations brought to light the possibility of an escape rather than tolerance of the surviving plants from the residual effect of diuron. This occurence could have been enhanced by the band placement of the herbicide since it has a low solubility in water and tends to be greatly localized in the soil. As such its scope of action was reduced leaving some areas free of the herbicide.

The nodulation of cowpea crops was not significantly affected by the residual effects of alachlor-atrazine and diuron. There were also no significant differences in the number of effective nodules and the nodule dry weight per plant among the various weed control alternatives. Similar reports were made by Kao and Wang (1981a) and Goring and Laskowski (1982). They reported that most herbicides are generally not toxic or low in toxicity to rhizobia. However the effect of the herbicide on the plant root system is what determines the pattern of nodulation and subsequently the number of nodules present. In this study therefore, the lack of a significant detrimental effect on the nodulation of cowpea by diuron residues could be attributed to the fact that this chmical may be low in toxicity to the rhizobia. Otherwise as already indicated a probable escape of the surviving plants from the residual effects of the chemicals.

Significant differences were observed between the two cowpea varieties for plant height and number of effective nodules per plant only. Cowpea variety 'Asontem' was viny and had a significantly higher plant height than variety 'Bengpla' which was more determinate in growth habit. The number of effective nodules were also significantly higher in the former variety. Interaction effect between the cowpea varieties and the residual effect of the herbicides were not significant for all the growth and nodulation characters investigated.

5.5 The residual effect of the herbicides on seed yield and components of yield.

Seed yield from plots previously treated with alachlor-atrazine mixture were significantly higher than yield from plots previously treated with diuron. The lower seed yield of the latter were attributed to a significantly lower plant population on these plots.

There were no significant differences among the treatments for the number of pods per plant, number of seed per pod and the 100 seed weight. However as a result of the severe water stress suffered by the plants during the reproductive stage, these results may not be a true reflection of what will pertain under normal conditions of adequate soil moisture.

Differences in seed yield and components of yield between the two varieties of cowpea however were all significant. With the exception of the hundred seed weight which was significantly higher in variety 'Bengpla', variety 'Asontem' produced significantly higher values for all the other characters.

Inspite of the significant differences between the two cowpea varieties, the response of each variety to the residual effect of the herbicides was similar to the other and hence no significant interaction effect was observed for the seed yield and components of seed yield.

CHAPTER SIX

SUMMARY AND CONCLUSION

6.1 Summary

Two field experiments were conducted at the University Farm, Legon between July 1993 and January 1994. The first experiment investigated the effectiveness of two rates each of two pre-emergent herbicides, alachlor-atrazine mixture and diuron on weed control, growth and yield of a high yielding maize variety 'Abeleehi'. The second experiment tested the residual effects of the herbicides on two varieties of cowpea, 'Asontem' and 'Bengpla' grown immediately after the maize crop.

Application of alachlor-atrazine mixture and diuron at the manufacturers' recommended rate and at rates 50% above the recommended were as suitable as hand-weeding in the control of both broad-leaved weeds and grasses in maize. The herbicides also had a significant effect on the growth and yield of the maize crop.

Alachlor-atrazine mixture at 1.8kg + 1.0kg ai/ha was tolerated best by the maize variety 'Abeleehi'. This was manifested in approximately 82% plant stand at maturity and the highest grain yield of about 7.6 tonnes/ha. Increasing the concentration of alachlor-atrazine mixture to 2.5kg + 1.4kg ai/ha resulted in stunted growth of plants and a significant reduction in grain yield compared to the recommended rate.

Diuron turned out to be toxic to the maize plants even at the recommended rate of 0.9kg ai/ha. Plant mortality under this treatment was about 52%. The level of toxicity increased with the increase in the concentration of this herbicide also. Most of the plants that survived under these two treatments were severely stunted in growth resulting in a reduction of grain yield by more than 50% compared to the hand-weeded control.

In the second experiment, the residues of the herbicides did not significantly influence the number of days to emergence of the two cowpea varieties. After seedling establishment however, several seedlings on plots previously treated with diuron wilted and died confirming the presence of this herbicide four and a half months after its application. There were however no signs of any residual effects on plots previously treated with alachlor-atrazine mixture. The differential reduction in plant stand by diuron previously applied to maize was observed to be the primary cause of relatively low cowpea yields obtained under these treatments. This was because the growth characters and components of yield investigated in the second experiment did not differ significantly among the herbicide treatments.

Cowpea variety 'Asontem' produced an overall higher number of effective nodules and seed yield than variety 'Bengpla'. No significant interaction effect between the residual effects of the herbicides and the cowpea varieties were observed for all the characters investigated.

6.2 Conclusion

The use of herbicides for weed control in maize was as suitable as the hand-weeded method in this study. For each of the two herbicides tested at the manufacturer's rate and at rates 50% above the recommended, the former resulted in a better maize grain yield than the latter. Alachlor-atrazine mixture at 1.8kg + 1.0kg ai/ha emerged as the most promising herbicide treatment among all others. It selectively controlled 74% of weeds in the maize plants without negatively affecting the growth of the crop. It also resulted in the production of the overall highest yield of 7.6 tonnes/ha. No significant residual effect of alachlor-atrazine mixture was observed on cowpeas that were grown after the maize. Cowpea yield from these plots were also the highest.

However inspite of efficient weed control on maize plots by diuron, the herbicide was very toxic to plants at even the recommended rate resulting in a significant reduction in grain yield. Some significant amount of the herbicide was also left behind in the soil after the maize crop and this severly affected growth and yield of the succeeding cowpea crops.

Although the two varieties of cowpea tested in the second experiment did not show any differential response to the residual effects of the herbicides, varietal differences were evident for some of the characters investigated. Variety 'Asontem' performed significantly better than variety 'Bengpla'.

The method of application of the two herbicides also influenced the results obtained in this study.

Whereas mixing thoroughly with water and spraying alachlor-atrazine mixture using a knap-sack sprayer provided a more uniform control of weeds on plots, the band placment of the dry diuron herbicide on other plots resulted in patches of completely weed-free and weedy zones on those plots.

Hand-weeding also did not provide as uniform control of weeds as the alachlor-atrazine mixture sprayed plots.

Further to these observations were the relatively higher standard errors recorded for the manual methods of application as compared to the mechanical method from some of the characters taken indicating a low level of precision under the former method.

It is therefore pertinent that the local farmers are taught adequate measures of weed control using the knap-sack sprayers and recommended rates of suitable herbicides if farm lands are to be cultivated on a large scale. Since this method helps minimize the labour required for weed control, more labour can be channelled into other farm activities which may inevitably increase crop yields.

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APPENDIX 1

Herbicides Available in Ghana

Common/Trade Name	Active Ingredient(s)	Crop(s) and Current Status	Group
1. Armanda	Glyphosate + Isopropylamine salt	Trial	Miscellaneous + Dinitroaniline
2. Atrazine	Atrazine	Corn, Sorghum. General use	S-triazine
3. Avirosan	Piperophos + Dimethametryne	Rice. Restricted use	S-triazine
4. Banvel	Dimethylamine salt of Dicamba	Cereals, Stubble Fields, non-crop areas. Trial	Substituted benzoic acid
5. Basagram	Bentazone + Propanil	Rice, Potatoes. General use	Amide
6. Basta 20 SL	Glufosinate Ammonium	General use	Miscellaneous
7. Bromacil	Bromacil	General use	Uracil
8. Bellater	Cyanazine + Atrazine	Maize. General use	S-triazine
9. Bladex	Cyanazine	Maize. General use	S-triazine
10. Cotodon 400 EC	Dipropetryn + Metolachlor	Cotton, Groundnuts, Soybeans. Provisional Approval	S-triazine + amide
11. Cotoprim	Metolachlor + Glyphosate + Terbutryn	Cotton Provisional Approval	Amide + s-triazine
12. Diuron 80WP/Karmex	Diuron	Cotton, Banana, Carrots, Tea, Citrus, Pineapple, Coffee. General use.	Substituted urea

13. Dual	Metolachlor	Corn, Soybeans, Potatoes, Limabeans, Dry Beans. General use.	Amide
14. Duplosan DP 600	Dichlorprop	Cereals. Trial	Phenoxy carboxylic acid
15. Focus	Cycloxydim	Non-Graminaceous Crops Trial	
16. Folar	Terbutylazine+Gly-phosate	Rubber, Oil palm, Coffee, cocoa, banana.General use	S-triazine + Miscellaneous
17. Frontier	Glyphosate	For use in plantations. General use.	Miscellaneous
18. Fusilade Super	Fluazifop-buthyl	Rubber, Oil palm, Coffee, Coconut, Tea, Cocoa. General use.	Phenoxycar boxylic acid
19. Galex 800 EC	Metobromuron + metalochlor	Soybean, Dry beans, Potatoes, Limabeans. General use	Substituted urea
20. Gardopat 600FW	Terbuthylazine+Pa-raquat	Pear. General use	S-triazine
21. Gardoprim 500FW	Terbuthylazine	Oil Palm. General use	S-triazine
22. Garlon 2	Terbuthylazine	Oil Palm. General use	S-triazine
23. Gesapax Combi 500FW	Ametryn	Pineapple. General use	S-triazine
24. Glyphogan 480SL/ Glyphosate	Glyphosate	General use	Miscellaneous
25. Goal	Oxyfluorfen	Onions, Crop and Non-Crop registration. Trial	Diphenylether
26. Gramoxone	Paraquat	Restricted use	Bipyridylium

27. Herbit Plus	Phenothiol	Paddy Rice. Trial	
28. Hyvar	Bromacil	Non-crop land. General use	Uracil
29. Kerb 50 WP	Propylamide	Woody Nurseries, Fruit Trees, Plantations. Trial	Amide
30. Lasso-Atrazine	Alachlor+Atrazine	Maize, Sugar-Cane. General use	Amide + S-triazine
31. Machete EC	Butachlor	Rice. General use	Amide
32. Oxadiazon 25 EC-12 C, PL2, PL12.	Oxadiazon	Rice. General use	Miscellaneous
33. Paracol	Paraquat + Diuron	Non-crop Areas. Trial	Substituted urea
34. Peltar Flow	Manaeb 50%+Triphonate methyl	Trial	
35. Pix 50	Mepiquat-Chloride	Herbicide + Growth Regulator. General use	
36. Polygram	Dithiocarbamate	Herbicide + Growth Regulator. General use	Carbamic acid
37. Primagram 500 FW	Atrazine + Metolachlor	Maize. General use	S-triazine + amide
38. Prime Plus 250 EC	2-Chloro-N(2-6-Clinitro-4 trifloromethyl) phenyl	Maize, Rubber. Trial	
39. Propagard 420 EC		Sorghum, Millet	
40. Rilof S395 EC	Piperophos + Propanil	Rice. Restricted use.	amide
41. Ronstar 25 EC, 12 L	Oxadiazon	Rice, Cotton, Soybeans. General use	Miscellaneous

42. Ronstar Plus 20,PL 12	Oxadiazon + Propanil	Rice. General use	Miscellaneous+amide
43. Round-Up	Glyphosate	Crop+Non-Crop Areas. General use	Miscellaneous
44. Satumil	Thibencarb	Trial.	
45. Simanex	Simazine	Maize, Pear. Trial	S-triazine
46. Solan 40	Pentanochlor	Trial	Amide
47. Spike	Terbuthiuron	General use	Substituted urea
48. Stamp F34	Propanil	Wheat, Barley, Oats. General use	Amide
49. Stomp 180 E, 30E, 33E, 330E, 4E, 500E, 3G	Pendimethalin	Corn, Cotton, Potatoes, Rice, Tobacco. General use	
50. Surcopr	Propanil	Rice. General use	amide
51. Terbutrex	Terbutryne	Potatoes. Trial	S-triazine
52. Tyllanex	Terbuthylazine	Oil Palm. Trial	S-triazine
53. Weed Master	DMA salt of Dicamba + DMA salt of 2, 4-D	Wheat, Maize, Barley, Non-Crop Land. Trial	Substituted benzoic acid

Source: Environmental Protection Council, 1994.

APPENDIX 2: PROCEDUCE FOR THE DETERMINATION OF PLANT NITROGEN USING THE BORIC ACID METHOD

(1) Take 500g of oven-dried sample into kjeldhal flask.

(2) Add selenium catalyst

(3) Add 20ml concentrated sulphuric acid

(4) Digest till clear

(5) Transfer into 250ml volumetric flask and make to volume

(6) Take 2ml aliquat of digest into distillation apparatus.

(7) Add 5ml 40% sodium hydroxide

(8) Distill into 5ml boric acid to which about three drops of methylene blue indicator has been added.

(9) Titrate distillate with 0.001M HCL from green to a purple end point.

(10) Calculate plant nitrogen (N) as follows

$$\% \text{ N} = \frac{0.001 \times 0.014 \times 250 \times 100}{500\text{mg (or } 0.5\text{g)} \times 2} \times (\text{X})$$

where X is the titre value.

APPENDIX 3: ANALYSES OF VARIANCE TABLES

Experiment one: Weed Control, Growth and Yield of maize

1. Shoot Dry weight of maize at tasselling

SV	DF	SS	MS	F_{obs}	$F_{exp.}$	
					1%	5%
Total	19	3315.79				
Block	3	203.33	67.78	0.85N.S	5.92	3.49
Treatmen t	4	2156.52	539.13	6.77**	5.41	3.26
Error	12	955.93	79.66			

2. Plant Height at Maturity

SV	DF	SS	MS	F_{obs}	$F_{exp.}$	
					1%	5%
Total	19	10167.9				
Block	3	3558.4	11861.1	12.30**	5.92	3.49
Treatmen t	4	5452.4	1363.1	14.10**	5.41	3.26
Error	12	1157.1	96.4			

3. Percentage Nitrogen concentration at Tasselling

SV	DF	SS	MS	F_{obs}	$F_{exp.}$	
					1%	5%
Total	15	11.78				
Block	3	2.41	0.80	1.67N.S	6.99	3.86
Treatmen t	3	3.58	0.89	186N.S	6.99	3.86
Error	9	5.79	0.48			

4. Plant stand at Maturity

SV	DF	SS	MS	F_{obs}	$F_{exp.}$ 1%	$F_{exp.}$ 5%
Total	15	0.389				
Block	3	0.052	3.12	3.4NS	6.99	3.86
Treatment	3	0.291	0.097	19.4**	6.99	3.86
Error	9	0.045	0.005			

N.S Not significant
** Highly significant (1%)

5. Plant Mortality at Maturity

SV	DF	SS	MS	F_{obs}	$F_{exp.}$ 1%	$F_{exp.}$ 5%
Total	15	2843.34				
Block	3	282.36	94.12	5.35*	6.99	3.86
Treatment	3	2402.79	800.93	45.50**	6.99	3.86
Error	9	158.39	17.60			

6. Ear Length

SV	DF	SS	MS	F_{obs}	$F_{exp.}$ 1%	$F_{exp.}$ 5%
Total	19	1105.06				
Block	3	25.14	8.38	2.75N.S	5.92	3.49
Treatment	4	43.42	10.86	3.56*	5.41	3.26
Error	12	36.50	3.04			

7. Ear Diameter

SV	DF	SS	MS	F_{obs}	$F_{exp.}$	
					1%	5%
Total	19	2.94				
Block	3	0.95	0.32	4.69*	5.92	3.49
Treatmen t	4	1.18	0.295	4.37**	5.41	3.26
Error	12	0.81	0.07			

8. Number of Kernels per Row per Cob

SV	DF	SS	MS	F_{obs}	$F_{exp.}$	
					1%	5%
Total	19	751.22				
Block	3	168.83	56.28	3.09	5.92	3.49
Treatmen t	4	364.35	91.09	5.01*	5.41	3.26
Error	12	218.04	18.17			

N.S Not significant
* Significant (5%)
** Highly significant (1%)

9. Number of Kernel rows per cob.

SV	DF	SS	MS	F_{obs}	$F_{exp.}$	
					1%	5%
Total	19	31.75				
Block	3	4.80	1.60	1.23N.S	5.92	3.49
Treatmen t	4	11.39	2.85	2.19N.S	5.41	3.26
Error	12	15.56	1.30			

10. Number of Kernels per cob

SV	DF	SS	MS	F_{obs}	F_{exp} 1%	F_{exp} 5%
Total	19	180738.89				
Block	3	35765.85	11921.95	2.53	5.92	3.49
Treatment	4	88357.17	22089.29	4.68*	5.41	3.26
Error	12	56610.87	4717.57			

11. 100 Seed weight

SV	DF	SS	MS	F_{obs}	F_{exp} 1%	F_{exp} 5%
Total	19	144.22				
Block	3	51.38	17.13	3.53*	5.92	3.49
Treatment	4	34.61	8.65	1.78N.S	5.41	3.26
Error	12	58.23	4.85			

12. Seed Yield per plot

SV	DF	SS	MS	F_{obs}	F_{exp} 1%	F_{exp} 5%
Total	19	174753386.00				
Block	3	23862769.93	7954256.64	6.99**	5.92	3.49
Treatment	4	137241267.80	34310418.45	30.17**	5.41	3.26
Error	12	13648942.27	1137411.86			

N.S Not significant
* Significant (5%)
** Highly significant (1%)

13. **Seed Yield per hectare**

SV	DF	SS	MS	F_{obs}	$F_{exp.}$	
					1%	5%
Total	19	131680302.10				
Block	3	18028955.37	6009651.71	7.04**	5.92	3.49
Treatment	4	103414094.60	25853523.65	30.30**	5.41	3.26
Error	12	10237252.37	853104.36			

14. **Weed Population six weeks after herbicide application**

SV	DF	SS	MS	F_{obs}	$F_{exp.}$	
					1%	5%
Total	15	908.57				
Block	3	19.32	6.44	0.18N.S	6.99	3.86
Treatment	3	571.00	190.33	5.38*	6.99	3.86
Error	9	318.25	35.36			

15. **Weed population twelve weeks after herbicide application**

SV	DF	SS	MS	F_{obs}	$F_{exp.}$	
					1%	5%
Total	19	845.00				
Block	3	129.39	43.13	1.24N.S	5.92	3.49
Treatment	4	296.43	74.11	2.12N.S	5.41	3.26
Error	12	419.18	34.9			

16. **Weed control effeciency at six weeks after herbicide application**

SV	DF	SS	MS	F_{obs}	$F_{exp.}$	
					1%	5%
Total	15	3228.20				
Block	3	448.30	149.40	0.86N.S	6.99	3.86
Treatment	3	1218.30	406.10	2.34N.S	6.99	3.86
Error	9	1561.60	173.51			

N.S NOT SIGNIFICANT
* SIGNIFICANT (5%)
** HIGHLY SIGNIFICANT (1%)

17. **Weed control effeciency at twelve weeks after herbicide application**

SV	DF	SS	MS	F_{obs}	$F_{exp.}$	
					1%	5%
Total	19	6139.75				
Block	3	514.0	171.3	0.58N.S	5.92	3.49
Treatment	4	2059.50	514.9	1.73N.S	5.41	3.26
Error	12	3566.25	297.2			

N.S Not Significant

Experiment Two: Residual Effects of Herbicides on Cowpea Growth, Nodulation and Yield

18. Succeeding Crop Stand two weeks after sowing

SV	DF	SS	MS	F_{obs}	$F_{exp.}$	
					1%	5%
Blocks	3	14.0^{-05}	4.67^{-05}	2.25		
Residues	4	790.0^{-05}	197.0^{-05}	94.8**	5.41	3.26
Error (a)	12	25.0^{-05}	2.08^{-05}			
Main plots	19	828.0^{-05}				
Cowpeas	1	20.0^{-05}	20^{-05}	1.68N.S	8.68	4.54
RESIDUES x COWPEA	4	81.0^{-05}	20.25^{-05}	1.70N.S	4.89	3.06
Error (b)	15	179.0^{-05}	11.9^{-05}			
Subplots	39	110.0^{-05}				

19. Succeeding Crop Stand eight weeks after sowing

SV	DF	SS	MS	F_{obs}	$F_{exp.}$	
					1%	5%
Blocks	3	17.73^{-03}	5.91^{-03}	1.35		
Residues	5	685.04^{-03}	171.26^{-03}	39.2**	5.41	3.26
Error (a)	12	52.4^{-03}	4.37^{-03}			
Main plots	19	755.2^{-03}				
Cowpeas	1	3.61^{-03}	3.61^{-03}	0.38N.S	8.68	4.54
RESIDUES x COWPEA	4	4.81^{-03}	1.20^{-03}	0.13N.S	4.89	3.06
Error (b)	15	141.29^{-03}	9.42^{-03}			
Subplots	39	904.91^{-03}				

N.S - Not Significant
** - Highly significant (1%)

20. Plant Height at flowering

SV	DF	SS	MS	F_{obs}	F_{exp} 1%	F_{exp} 5%
Blocks	3	554.60	184.87	9.18		
Residues	4	303.60	75.90	2.98N.S	5.41	3.26
Error (a)	12	305.40	25.45			
Main plots	19	1163.60				
Cowpeas	1	2131.60	2131.60	105.87**	8.68	4.54
RESIDUES x COWPEA	4	130.40	32.60	1.62N.S	4.89	3.06
Error (b)	15	302.00	20.13			
Subplots	39	3727.60				

21. Shoot Dry weight at tasselling

SV	DF	SS	MS	F_{obs}	F_{exp} 1%	F_{exp} 5%
Blocks	3	45.97	15.32	14.31		
Residues	4	5.77	1.44	0.66N.S	5.41	3.26
Error (a)	12	26.27	2.19			
Main plots	19	78.00				
Cowpeas	1	0.31	0.31	0.29N.S	8.68	4.54
RESIDUES x COWPEA	4	7.31	1.83	1.71N.S	4.89	3.06
Error (b)	15	16.06	1.07			
Subplots	39	101.68				

N.S Not Significant
** Highly significant (1%)

22. Number of nodules per plant

SV	DF	SS	MS	F_{obs}	$F_{exp.}$ 1%	$F_{exp.}$ 5%
Blocks	3	61.88	20.63	1.88		
Residues	4	54.35	13.59	1.03	5.41	3.26
Error (a)	12	158.25	13.19			
Main plots	19	274.48				
Cowpeas	1	34.23	34.23	3.12N.S	8.68	4.54
RESIDUES x COWPEA	4	27.65	6.91	0.63N.S	4.89	3.06
Error (b)	15	164.63	10.98			
Subplots	39	500.98				

23. Number of effective nodules per plant

SV	DF	SS	MS	F_{obs}	$F_{exp.}$ 1%	$F_{exp.}$ 5%
Blocks	3	40.08	13.36	2.14		
Residues	4	41.65	10.41	0.57N.S	5.41	3.26
Error (a)	12	220.55	18.38			
Main plots	19	302.28				
Cowpeas	1	34.23	34.23	5.48*	8.68	4.54
RESIDUES x COWPEA	4	20.65	5.16	0.83N.S	4.89	3.06
Error (b)	15	93.63	6.24			
Subplots	39	450.78				

N.S Not significant
* - Significant (5%)

24. Nodule Dry weight per plant

SV	DF	SS	MS	F_{obs}	$F_{exp.}$ 1%	$F_{exp.}$ 5%
Blocks	3	46.61	15.5	1.72		
Residues	4	111.63	27.91	3.10N.S	5.41	3.26
Error (a)	12	108.03	9.00			
Main plots	19	266.27				
Cowpeas	1	2.11	2.11	0.33N.S	8.68	4.54
RESIDUES X COWPEA	4	15.82	3.96	0.62N.S	4.89	3.06
Error (b)	15	95.18	6.35			
Subplots	39	379.38				

25. Number of Pods per plant

SV	DF	SS	MS	F_{obs}	$F_{exp.}$ 1%	$F_{exp.}$ 5%
Blocks	3	13.10	4.37	5.56		
Residues	4	10.35	2.59	1.87N.S	5.41	3.26
Error (a)	12	16.65	1.39			
Main plots	19	40.10				
Cowpeas	1	12.10	12.10	15.45**	8.68	4.54
RESIDUES X COWPEA	4	11.15	2.79	3.56*	4.89	3.06
Error (b)	15	11.75	0.78			
Subplots	39	75.10				

N.S - Not significant
* - Significant (5%)
** - Highly significant (1%)

26. Number of Seeds per pod

SV	DF	SS	MS	F_{obs}	$F_{exp.}$	
					1%	5%
Blocks	3	15.20	5.07	3.38		
Residues	4	1.40	0.35	0.36N.S	5.41	3.26
Error (a)	12	11.80	0.98			
Main plots	19	28.40				
Cowpeas	1	72.90	72.90	48.60**	8.68	4.54
RESIDUES x COWPEA	4	6.60	1.65	1.10N.S	4.89	3.06
Error (b)	15	22.50	1.50			
Subplots	39	130.40				

27. 100 Seed weight (g)

SV	DF	SS	MS	F_{obs}	$F_{exp.}$	
					1%	5%
Blocks	3	2.75	0.92	0.95		
Residues	4	1.43	0.36	0.26N.S	5.41	3.26
Error (a)	12	16.84	1.40			
Main plots	19	21.03				
Cowpeas	1	5.40	5.40	5.64*	8.68	4.54
RESIDUES x COWPEA	4	6.25	1.56	1.63N.S	4.89	3.06
Error (b)	15	14.37	0.96			
Subplots	39	47.06				

N.S - Not significant
* - Significant (5%)
** - Highly significant (1%)

28. Seed Yield per plot (g)

SV	DF	SS	MS	F_{obs}	F_{exp} 1%	F_{exp} 5%
Blocks	3	27277.38	9092.46	1.71		
Residues	4	171904.40	42976.1	5.15*	5.41	3.26
Error (a)	12	100159.60	8346.64			
Main plots	19	299341.4D				
Cowpeas	1	80927.63	80927.63	15.25**	8.68	4.54
Residues x Cowpea	4	29176.13	7294.03	1.37N.S	4.89	3.06
Error (b)	15	79606.75	5307.12			
Subplots	39	489051.9				

29. Seed Yield per hectare (kg)

SV	DF	SS	MS	F_{obs}	F_{exp} 1%	F_{exp} 5%
Blocks	3	115698.00	38566.00	1.74		
Residues	4	149429.00	187357.30	5.43**	5.41	3.26
Error (a)	12	413750.00	34479.17			
Main plots	19	1278877.00				
Cowpeas	1	370295.00	370295.00	16.71**	8.68	4.54
Residues x Cowpea	4	137831.00	34457.75	1.56N.S	4.86	3.06
Error (b)	15	332449.00	22163.27			
Subplots	39	2119452.00				

N.S - Not Significant
* - Significant (5%)
** - Highly significant (1%)