THE EFFECTS OF PERIOD OF WEED INTERFERENCE AND WEED CONTROL ON COWPEA (*Vigna unquiculata* (L.) walp)

BY

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DECLARATION

I hereby declare that this thesis has been written by me and that it is a record of my own research work. It has not been presented before in any previous application for a higher degree.

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CERTIFICATION

This thesis titled 'THE EFFECTS OF PERIOD OF WEED INTERFERENCE AND WEED CONTROL ON COWPEA (*Vigna unguiculata* (L.) Walp) by Timothy Tsuwe Sule, meets the regulations governing the award of the degree of Master of Science of Ahmadu Bello University, Zaria, and is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

This work is dedicated to the memory of my beloved late father Mr. Sule Lijam for all he was to me.

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ABSTRACT

Two field experiments were conducted during the 1987 wet season at Samaru in the Northern Guinea savanna ecological :Zone of Nigeria to study the effects of period of weed interference and weed control on cowpea (Vigna unguiculata (L,) Walp).

In the study, weed interference for 3 WAS did not adversely affect crop growth, yield and yield attributes. Cowpea was critically adversely affected by weeds between 3 and 9 WAS Once kept weed-free for 9 WAS no significant reduction in seed yield occured compared with the crop kept weed-free through-out, although maximum yield occured with the crops kept weed-free for 15 weeks.

In the weed control experiment, all the herbicide treatments significantly reduced weed infestation until 9 WAS Among the weed control treatments, metolachlor plus metobromuron at 1.5+1.5 kg a.i/ha followed by supplementary hoe-weeding at 6 WAS gave effective weed control and resulted in vigorous cowpea growth and significantly higher cowpea yield than the hoe-weeded controls Pre-emergence mixtures of diuron with metolachlor and alachlor each at 0.8+1.5 kg a.i/ha, each followed by post-emergence imazaquin at 0.2 kg a.i/ha at 3 WAS, resulted in comparable cowpea seed

yield to the highest obtained with metolachlor plus metobromuron followed by supplementary hoe-weeding . Plots hoe-weeded twice and those treated with alachlor plus diuron at 1.5+0.8 kg a.i/ha followed by supplementary hoe-weeding at 6 WAS had higher seed yield than the untreated control. With the exception of metolachlor plus diuron, all the other plots treated with half the rate of the pre-emergence herbicide mixtures only produced cowpea seed yield that were comparable to those [1] of the untreated control.

The pre-emergence herbicide treatments differentially depressed various aspects of cowpea growth like vigour, plant height, leaf dry weight and leaf area.

Uncontrolled weed growth throughout the crop life-cycle resulted in significant depression of cowpea growth parameters such as crop vigour, plant height, leaf production and caused cowpea seed yield reduction by 74.*2%* in the weed interference and 74,5% in the weed control trials.

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CHAPTER 1

INTRODUCTION

1.1 Production Trend and Uses of Cowpea

Cowpea (Vigna unguiculata L. Walp) a member of the family Leguminoseae is grown for food in the tropical and semi-tropical regions. World cowpea production in 1981 was estimated at 2.27 million tonnes from 7.7 million hectares (Rachie, 1985). According to Rachie (1985), current world realistic production levels may exceed 2.5 million tonnes of dry seeds on about 9 million hectares. Nigeria, Niger and Burkina Faso are the leading producers, among the 16 African countries which produce two thirds of the world's cowpea (Martin et al., 1976). Annual production by Nigeria and Niger was estimated at 850,000 and 217,000 tonnes, respectively, both representing about 49.3 per cent of the total world crop (Rachie, 1985). Other major producing countries in Africa include Ghana, Uganda, Kenya, Togo, Mali and Senegal. Some countries in Southern Europe, Asia and the U.S.A. also produce cowpea.

Cowpea seed is an important pulse in the tropics and sub-tropics, particularly in Africa. The dry pulse contains essential elements as well as 23.4% protein, 1.3% fat, 56.8% carbohydrates, 3.9% fibre and 3.6% ash

(Langworthy and Hunt, 1959). In tropical Africa, cowpea is primarily used in the form of dry seeds cooked as a pulse in a large variety of dishes while in India, they are used in dhal. The seeds are sometimes used as coffee substitute. As a dietary staple, it greatly improves human's bland unbalanced diet. In some areas of the humid tropics, cowpea provides more than half the plant protein in human diet. It is the key staple for the poorest sector of the developing countries. The tender green leaves and green pods are cooked as vegetables or as a relish in many areas of West Africa.

Cowpea is also used for fodder and as a quick growing cover crop under a wide range of conditions. Apart from providing a high proportion of its own nitrogen requirements, cowpea fixes about 60-70kg of N/ha in the soil for the succeeding crop (Rachie, 1985).

1.2 Constraints to Production of Cowpea

Cowpea is practically never grown as a sole crop in Africa; it is a component of mixed cropping systems, frequently being grown in association or relays with sorghum, millet and maize (Steele, 1972; Rachie and Roberts, 1974).

Although yield potential of the crop is high, averaging 1.5 to 3 tonnes/ha (Raheja and Hayes, 1975; Warui, 1979), actual yield in Nigeria is between 0.2 and 0.3 tonnes/ha (Muleba and Ezumah, 1985). Heavy biotic

pressures, particularly insects and other pests like weeds which often affect the plant throughout its life are some of the constraints affecting production.

1.3 Weeds and their Control in Cowpea

Weeds cause serious losses in cowpea through direct competition with the crop for light, water and nutrients and indirectly by harbouring insects pests and diseases and intercepting pesticides and reducing their effectiveness (Moody and Whitney, 1974). Uncontrolled weed growth was reported to cause 30 to 80% loss in cowpea grain yields (Moody, 1973; Nangju, 1980; Akobundu, 1982; Lagoke et al., 1982; Poku and Akobundu, 1983; Lagoke and Shebayan, 1988). In cowpea weed competition is most critical during the first 20 to 40 days of growth (Medrano et al., 1973; Moody, 1973; Fadayomi, 1979). Yield losses are however, negligible if the crop is weeded within 5 to 6 weeks of crop emergence (Moody, 1973; Fadayomi, 1979; Akobundu, 1984).

The common weed control methods in cowpea are hoe-weeding, cultivation, mulching and intercropping (Robles and Fabro, 1979). Of these methods, hoe-weeding is the most common practice among the small scale producers, though it is not adapted to large scale production because of its high labour requirement and tedium. Moody (1973) estimated that the two hoe-weedings

recommended for cowpea required about 21 man-days/ha which represented 36.2% of the total time of production. The increasing cost of labour and its unavailability at the peak period of requirement necessitates the use of alternative weed control methods (Lagoke et al., 1981c).

Akobundu (1984) had suggested that chemical weed control combined with other cultural practices such as hoe-weeding may be practical in reducing weed competition, crop loss and labour costs. Kasasian (1963) also indicated that the use of herbicide might be advantageous, not only where labour was in short supply but also due to the fact that large areas can be covered within a short period of time.

The use of herbicide has been reported to reduce cost of weed control hence cost of production and subsequently increase profitability in field and vegetable crops (Sinha et al., 1982; Ogunbile and Lagoke, 1986; Lagoke and Shebayan 1988). The spared labour could be utilized more profitably for bringing additional land under cultivation thus, enhancing overall production in Nigeria.

1.4 Objectives

The objectives of this study therefore were:

i) To determine the effect of periods of weed

interference on cowpea.

(ii) To evaluate various herbicide treatment combinations for weed control in cowpea.

CHAPTER 2

LITERATURE REVIEW

2.1 Effect of Period of Weed Interference on Cowpea

In Nigeria, yield losses due to uncontrolled weeds in cowpea range from 53 to 81 per cent (Moody, 1973; Reminson, 1978; Akobundu, 1980; Nangju, 1980; Lagoke et al., 1982). Losses in cowpea yield of 75 per cent due to a single weed species, Euphorbia heterophylla has been reported (IITA, 1977).

Cowpea is very sensitive to weed competition especially during the early stage of its life. In addition to competition with the crop for various factors of production such as nutrient, water and light, weeds also probably reduce root production and nodule formation of cowpea and also harbour insects and plant diseases thus compounding the losses from weeds (Moody and Whitney, 1974; Fadayomi, 1979; Reminson, 1978, Gofung, 1987). Ayeni (1982) observed that significant yield reduction occurred when weeds were allowed to infest the cowpea for at least six weeks in the early season crop and four weeks in the late season crop. Similarly, Fadayomi (1979) found that the highest yield was obtained from the plots maintained weed free from sowing to six weeks later.

Reminson (1978) reported that to obtain optimum yield from Ife Brown, the crop must be kept weed free throughout the life cycle of the crop.

The greatest loss in crop yield due to the presence of weeds occur during the critical period of weed competition; this is that period of the crop growth when it is most susceptible to weed competition (Nieto et al., 1968). For most crop, this period has been reported to be between three and four weeks after planting. In cowpea, several workers have suggested that the crop is most critically affected by weed competition during the first 40 days of its growth (Medrano et al., 1973; Ayeni, 1982). However, Garcia et al. (1973), Moody (1973) and Fadayomi (1979) have all reported that weeds compete with cowpea mainly during the first month of its growth.

2.2 Chemical Weed Control in Cowpea

Various chemicals that have been used either singly or in mixture to control weeds in cowpea include some chloroacetamides such as alachlor (2, chloro-N-(2,6 diethylphenyl)-N-methoxy-acetamide and metolachlor (2, chloro-N-(2, ethyl-6 methylphenyl)-N-(2, methoxy-1-methyl-ethyl), triazines like prometryne (2,4-diliso-propylamino-6-methylthio-1- 3, 5-triazine), substituted ureas such as diuron (3-(3,4-dichloro-phenyl)-1-dimethylurea) and metobromuron (3-(-4-bromophyl-1-

methoxy-1-methylurea) and miscellaneous such as fluazifop-butyl (butyl(2-(4-(5-trifluoro-methyl-2-pyridyloxy)phenoxy)propionate acid) and imazaquin (2-(4-isopropyl-4-methyl-5-oxo-2-imidazoline-2-yl) quinoline-3-carboxylic acid). Several investigators have reported the failure of such pre-emergence herbicides as alachlor, metolachlor, diuron, prometryne, metobromuron and their mixtures to give season-long weed control and the effectiveness of single supplementary hoe-weeding to pre-emergence herbicide for, season-long weed control in maize-okra, maize-pepper, sorghum-groundnut mixtures, potato, ginger and cowpea (Akobundu, 1978, 1980, 1982, 1984; Bakut, 1985; Gworgwor, 1985; Adejonwo et al., 1987; Bulus, 1987; Olorukooba, 1987). Lagoke and Shebayan (1988) also observed that the mixtures of diuron with metolachlor at 0.5+1.0 and 0.5+ 2.0 kg a.i/ha and metolachlor plus metobromuron did not have comparable weed score to the hoe-weeded at 3 WAS except after the supplementary hoe-weeding at 5 WAS.

2.2.1 Chloroacetamides

The chloroacetamides constitute a major sub-division of the amide class of herbicides which have a mono chloronated methyl in the R-1 position (Glenn et al., 1975). They are synthesised by reacting amine with chloro acetyl chloride (Crafts, 1961).

Chloroacetamides are principally used for the control of seedling grass and certain broadleaved weeds in vegetable and field crops. They are more effective in controlling grasses than broad-leaved weeds. Chloroacetamides are normally applied pre-emergence to the weeds and crops although some of them like propanil primarily have post-emergence activity (Anderson, 1977).

Chloroacetamides are less affected by variation in soil moisture and organic matter and leached readily in sandy soils and moderately so in loam or clay soils as they are adsorbed to soil colloids.

Chloroacetamides are readily absorbed by susceptible plants, primarily by seeds and first node of germinating seedlings and appear to be translocated primarily in the apoplast but limited symplastic movement occur (Klingman et al., 1975). The degree of susceptibility of various weeds to chloroacetamides could be directly related to the length of time required to initiate the metabolism of these chemicals after absorption and translocation in the plants. Those species that are able to metabolise the chemical as soon as it is absorbed within a short time of uptake, have only small amount of the chemical present in the tissues at any time. On the other hand, those species with delayed or slow metabolic capabilities accumulate relatively higher and therefore lethal

concentrations. The basis for selectivity of the chloroacetamides could therefore be attributed to the ability of the resistant plants to metabolise them at a rate sufficient to keep cellular levels below that required for growth inhibition in the leaves (Kearney and Kaufman, 1975). The chloroacetamides inhibit mitochondrial phosphorylation, mitotic cell division, cause disarrangement of cells and reduce respiration more in susceptible than in resistant species. Jarworski (1956) concluded that the chloroacetamides inhibit the activity of certain sulphdryl-containing enzymes involved in respiration and also stop growth.

Alachlor, a member of the chloroacetamides, is a cream coloured solid relatively insoluble in water with about 148ppm solubility at 25°C. It has an acute oral LD_{50} of 1800mg/kg and formulated as an emulsifiable concentrate (EC) and granules. The usual formulation is 480 emulsifiable concentrate (Martin and Charles, 1971). Alachlor is used principally as pre-emergence treatment to control annual grasses and certain annual broadleaved weeds in melon, maize, groundnut, soyabean, cowpea, tomato and yam (Lagoke et al., 1981b; Lagoke et al., 1982; Lagoke et al., 1984). It is also applied preplant and soil-incorporated and is sometimes either mixed or formulated with other herbicides to increase the spectrum of weeds controlled (Klingman et al., 1975;

Anon., 1978; Lagoke et al., 1981c; Nongu, 1982). Alachlor has been successfully used to control grass weeds in crops in the Nigerian savanna (Choudhary, 1980; Lagoke et al., 1981a; Lagoke et al., 1981b).

In Zambia, at Chilanga, when evaluated in legumes, at 1.8 kg/ha, alachlor gave very good control of grasses and also suppressed a good number of broadleaved weeds while at 3.8 kg/ha it was unacceptably toxic to legumes (Anon., 1978). At Ibadan, Nigeria, Akobundu (1984) reported that alachlor at 3.0 kg/ha significantly depressed yields of all cowpea cultivars grown on soils with 0.67 and 0.77 per cent organic carbon content but not when these cultivars were grown on a soil with 1.04 organic carbon content. Moody (1973) also observed crop toxicity with the treatments which included alachlor above 1.0 kg/ha. At Mokwa, in the Southern Guinea zone of Nigeria, alachlor applied at the rates of 1.5 and 3.0 kg a.i/ha depressed crop vigour in cowpea which exhibited symptoms like chlorosis along the leaf margin, leaf brittleness and serration of the leaf edge with the high rate (Lagoke et al., 1981c). The crop injury also persisted in the high rate of alachlor, resulting in significantly lower grain yield as compared with that obtained with hoe-weeded control. At Samaru, alachlor at 3.0 kg/ha gave significant reduction in the grass weeds as compared with the weedy check without adverse

effect on cowpea stand (Lagoke et al., 1981c). In India, Hosmani and Hosmani (1984) observed that alachlor at 2.0 kg/ha applied pre-emergence was effective in controlling weeds in cowpea without detrimental effect on the crop but the higher rates were toxic. Jain et al.,(1985) observed that alachlor at 3.0 kg/ha effectively controlled weeds in cowpea.

Mixtures of alachlor with other herbicides that are primarily broadleaved weed potent have been reported to enhance a broad spectrum control of weeds in cowpea (Lagoke et al., 1981c; Black et al., 1985). Mixtures of alachlor with prometryne at 1.5+1.0 kg/ha, linuron at 1.5+1.0 kg/ha, diuron at 1.5+0.8 kg/ha and metobromuron at 1.5+1.0 kg/ha combined good weed control with high grain yield of cowpea (Lagoke et al., 1981c). Alachlor plus diuron at 1.0+0.4 kg a.i/ha has been reported to give profitable weed control in cowpea at Samaru (Lagoke and Shebayan, 1986).

Metolachlor is a white to tan odorless liquid normally formulated as emulsifiable concentrate either alone or in mixture with other less soluble chemical as wettable powder or flowable to improve the spectrum of weed control (Klingman et al., 1975). It has a solubility of 530 ppm in water at 20°C and acute oral LD_{50} of 2,535 mg/kg.

Metolachlor is principally applied pre-emergence for selective control of annual grasses, yellow nutsedge (Cyperus esculentus) and certain broadleaved species in maize, groundnut and soyabean, potato, yam, cowpea, ginger, tomato, cotton, pepper, sunflower, benniseed, (Anon, 1983). Metolachlor has been reported to give effective weed control in cowpea when applied singly. Cornelius et al. (1976) reported effective control of Cyperus sp. with metolachlor applied at 3.36 kg/ha pre-emergence in cowpea. Other workers have observed that metolachlor applied pre-emergence at 2.24 to 3.36 kg/ha and above gave good control of weeds including Brassica sp., Echinochloa crus gallis and Chinopoduim album in cowpea (Jensen, 1978; Murphy and Marrow, 1979; Sundaru and Syam, 1979). Metolachlor at rates ranging from 2.0 to 3.0 kg/ha was well tolerated by cowpea and gave excellent weed control in cowpea resulting in yields that were comparable to the weed-free or hoe-weeded check (Akobundu 1978; Lagoke et al., 1982).

Mixtures of metolachlor with various herbicides such as diuron, metobromuron and prometryne have been reported to give selective weed control in cowpea by many workers (Akobundu, 1978; Hussain, et al., 1979; Lagoke et al., 1982; Poku and Akobundu, 1983; Black et al., 1985). At Mokwa, among various treatments evaluated, metolachlor plus prometryne at 1.5+1.0 kg a.i/ha was

outstanding in giving effective weed control and high cowpea yield (Lagoke et al., 1982). Other mixtures which also gave effective weed control and comparable yield to the best included metolachlor plus metobromuron at 1.5+1.0 kg/ha and metolachlor plus diuron at 1.5+0.8 kg/ha. At Ibadan, Akobundu (1978) found that mixture of metolachlor plus metobromuron at 1.25+1.25 kg/ha, gave effective weed control and comparable yields to the weeded check. Poku and Akobundu (1983) observed that the formulated mixture of metolachlor and metobromuron (Galex) was the only treatment that gave significantly higher yield of cowpea than the untreated control.

2.2.2 Substituted Urea

By substituting three of the hydrogen atoms of urea with other chemical groups, such as phenyl, methyl and methoxyl groups, effective herbicides called the substituted urea derivatives are produced (Klingman and Ashton, 1975). Generally, they are of low water solubility with acute oral LD_{50} of between 1500-11,000 mg/kg. They are usually formulated as wettable powders; the only common liquid formulation is flowable since they are insoluble in water and many common organic solvents. They are principally used for the selective pre-emergence or early post-emergence control of weed seedlings in certain croplands and non-selective control of annual and perennial weeds in non-croplands.

Substituted ureas are most effective when applied pre-emergence to weeds but addition of surfactants enhances their post-emergence control of weed seedlings.

Substituted ureas are usually adsorbed to the soil colloids and resist leaching and remain in the upper one inch of soil layer at the dosage applied for selective weed control in croplands. As a class, urea herbicides are relatively persistent in the soils. Under favourable moisture and temperature conditions, most of them can be expected to persist for three to six months in the soil at selective rates and 24 months or more at higher nonselective rates (Klingman and Ashton, 1975).

Most urea herbicides are readily absorbed by the roots and rapidly translocated to the upper plant parts via the apoplastic system. When applied to the leaves, they are also translocated apoplastically. The actual amount absorbed and translocated from the roots to shoot varies greatly with the compound.

Urea herbicides are subjected to degradation by higher plants but the rate varies with different species. Demethylation is the primary detoxification mechanism for the urea. A microsomal enzyme system carries out the demethylation of the urea herbicide. Molecular

oxygen and NADPH or NADH are required co-factors for this reaction. Demethoxylation also occurs in compounds containing methoxyl group. Following dealkylation and dealkoxylation or both, the molecule may be subjected to hydrolysis. This will involve deaminization and decarboxylation yielding the corresponding aniline. The aniline may be subjected to oxidation to yield the corresponding nitrite or conjugated with normal cellular constituents (Ashton and Crafts, 1973).

Inhibition of photosynthesis is generally acknowledged as the primary site of action of the urea herbicides. This involves a blockage of electron transport between Q, primary electron acceptor for photosystem II (Ps II) and plastoquinone (PQ). This prevents the formation of adenosine triophosphate (ATP) and nicotinamide-adenine dinucleotide (NADPH) which are required for carbon dioxide fixation, thus inhibiting Hill reaction.

Phytotoxic effects of urea derivative herbicides are primarily observable in the leaves. The leaves may show mere chlorosis which develops slowly with low rates of application of the herbicide or a water-soaked appearance that becomes necrotic in few days at high rates (Ashton and Crafts, 1973). Selectivity is based on differences in rates of absorption and translocation between species (Ashton and Crafts, 1973).

Diuron is an odourless, white crystalline solid formulated as wettable powder. Diuron formulations are compatible with most herbicides with which they might be mixed (Klingman et al., 1975). It has solubility in water of 42ppm at 25°C and is soluble in acetone and benzene and has acute oral LD_{50} of 3400 mg/kg for rats (Hodge, 1967). Diuron is used pre-emergence at low rates for the selective control of germinating broad-leaved weeds and grasses in crops such as cotton, sugar cane, cowpea, pineapple, grapes, apples, peas, maize-okra mixtures, yam and ginger (Lagoke et al., 1981c; Lagoke et al., 1982; Anon., 1983; Lagoke et al., 1986a; Lagoke et al., 1986b; Olorukooba, 1987; Lagoke and Shebayan, 1987). Diuron applied singly or in mixture as post-emergence is most effective on Digitaria ciharsis, Ipomoea sp., Centoscema pubiscense, Vernonia galamensis and a number of sedges (Anon., 1984). In a field trial at Samaru, to evaluate pre-emergence herbicide in cotton, diuron was among the promising herbicides (Lagoke et al., 1985). At Mokwa, diuron at 1.6 kg/ha combined good weed control with high grain yield of cowpea (Lagoke et al., 1981c). Lagoke et al., (1982) reported that application of pre-emergence metolachlor plus diuron at 1.0+1.5 and 1.5+1.0 kg a.i/ha resulted in significantly lower weed scores until harvest, high crop vigour score at 8 weeks after sowing and higher cowpea grain yield than the untreated control.

Kure (1981) also reported that metolachlor plus diuron at 1.5+0.8 kg/ha combined effective weed control with high crop yield of cowpea at Samaru.

Metobromuron, which is formulated singly as 'Patoran', a wettable powder, is also commonly formulated in mixture with metolachlor as 'Galex' an emulsifiable concentrate. It has a water solubility of 330 ppm and an acute oral LD_{50} of 3000mg/kg for rats (Glenn et al., 1975). Metobromuron may be applied pre-emergence alone or in mixture with other herbicides for season-long weed control of many annual grasses and certain broadleaved weeds in crops like potato, maize, cowpea, sorghum, ginger, pepper and tomato (Ashton, 1978; Glenn et al., 1975; Lagoke et al., 1981; Adigun et al., 1982; Sinha and Lagoke, 1982; Lagoke et al., 1983; Bulus, 1987; Olorukooba, 1987; Lagoke and Shebayan, 1988). In a field trial to evaluate the efficiency of different herbicides, metolachlor plus metobromuron (Galex) was reported to give the best weed control in maize, groundnut and cotton mixture (Chandra-Singh, 1982). Galex has also been observed to give profitable weed control in cowpea (Fadayomi, 1979).

Olunuga (1981) and Lagoke et al. (1982) both found that metobromuron alone and in mixtures like alachlor plus metobromuron at 1.0+1.6 kg/ha, metolachlor plus

metobromuron at 1.5+1.0 kg/ha, chloroamben plus metobromuron at 2.0+1.0 kg/ha, pendimethalin plus metobromuron at 1.5+1.0 kg/ha all combined effective weed control with high seed yields in cowpea. Lagoke and Shebayan (1984) found that metolachlor plus metobromuron at 1.0+1.0 and 1.5+1.5 kg a.i/ha, especially when followed by one supplementary hoe-weeding, consistently resulted in good weed control and cowpea seed yield comparable to two and three hoe-weedings.

2.2.3 Triazines

Triazines are heterocyclic nitrogen derivatives. The name heterocyclic designates a ring structure composed of atoms of different kinds. In this case the ring is composed of nitrogen and carbon atoms. Most triazine herbicides are symmetrical, with alternating carbon and nitrogen atoms in the ring. One exception is metribuzin which is assymetrical. Members of the diamino-s-triazine herbicide may be placed in the chlorine, methoxyl or methylthio subgroups based on whether the substitution at the 2-position of the ring structure is a chlorine (cl) atom, a methoxyl ($-o-CH_3$) group or a methylthio ($-S-CH_3$) group. The triazines are commonly formulated as wettable powders as well as flowable, particularly the chloro-triazines and methylthio triazines because of

their low solubility in water and many common solvents. The principal use of the triazine herbicides is the selective pre-emergence and early post-emergence control of seedlings of broadleaved weeds in cropland. They also control some grass seedlings.

Triazines are adsorbed to soil colloids and resist leaching. However, leaching does occur to some extent depending on the soil type, herbicide involved as well as the volume of percolating water moving through the soil (Anderson, 1977).

Triazine herbicides are readily absorbed by roots and readily translocated exclusively in the apoplastic system throughout the plant. Triazine herbicides are absorbed by leaves but translocation from them is essentially nil (Ashton and Crafts, 1973).

The phytotoxic symptoms of the triazines is foliar chlorosis followed by necrosis. According to Crafts (1973), the rate of degradation of traizine herbicide in higher plants varies greatly with different species. In resistant species, triazines are rapidly degraded while in susceptible species, they degrade slowly; thus the rate of degradation appears to be the basis for selectivity. The process of degradation occurs in three reactions:

i) hydroxylation of the ring in the number 2 position with dechlorination, demethoxylation or demethylthiolation;

ii) dealkylathion of the alkyl side chain(s) in the 4- and in 6- position and

iii) conjugation involving the displacement of the 2-chloro group with glutathione.

The mechanism of action of the triazine herbicides in higher plants is a blockage of photosynthesis. More especially their site of action is the blockage of electron transport between Q, primary acceptor for photosynthesis system II (Ps II), and plastoquinone (PQ).

Prometryne, a symmetrical triazine, is a white crystalline solid with a water solubility of 48ppm at $20^{o}C$ which is usually formulated either as a wettable or as flowable in combination with other herbicides. It has an acute oral LD_{50} of 3750 mg/kg for rats. Prometryne has been shown to selectively control annual broadleaved weeds and grasses when applied pre-emergence or post-emergence in cotton, okra, potato, onion, soyabean, cowpea, groundnut, yam, melon, ginger and millet (Hilton et al., 1974; Lagoke et al., 1981b; Lagoke et al., 1982; Lagoke et al., 1984; Bulus, 1987; Lagoke and Shebayan, 1986; Lagoke et al., 1986; Olorukooba, 1987; Lagoke and

Shebayan, 1988). Lundy (1964) reported that prometryne applied pre-emergence at 2.24 kg a.i/ha controlled weeds in cowpea without any crop injury. Volodin and Lavionova (1977) reported that prometryne applied pre-emergence at 2.0 kg/ha was effective against weeds in cowpea. At Mokwa in 1978, prometryne applied at 2.0 kg/ha pre-emergence combined good weed control with high grain yield. However, in 1979, under wetter conditions, crop injury and stand loss was observed (Lagoke et al., 1982).

Based on the trial conducted at Mokwa in 1979, metolachlor plus prometryne at 1.5+1.0 kg/ha applied pre-emergence was very effective against broadleaved weeds and grasses (IAR, 1980). According to Sundaru and Syam (1979), thiobencarb plus prometryne at 7.5 kg product/ha applied pre-emergence was most effective against grasses. At Nyamkpala, Ghana, alachlor plus prometryne at 1.0+1.0 kg/ha was the best treatment in groundnut (Carson, 1979). Mixtures of prometryne that have been reported to combine effective weed control with high seed yields in cowpea include chloramben plus prometryne at 2.0+1.0 kg/ha, pendimethalin plus prometryne at 1.5+1.0 kg/ha and norflurazon at 0.5+1.0 kg/ha (Lagoke et al., 1982). Kure (1981) at Samaru, found that metolachlor plus prometryne at 1.5+1.0 kg/ha was the best treatment in cowpea.

2.2.4 Miscellaneous herbicides

Fluazifop-butyl, whose trade name is fusilade is a light straw-coloured, odourless liquid with a water solubility of 2ppm at ambient temperature (Anon., 1983). It is formulated as emulsifiable concentrate. Fluazifop-butyl has an oral LD_{50} of 4350 mg/kg for rats (Anon., 1983). It may be applied post-emergence for the selective control of grass weeds in broadleaved and other non-graminaceous crops such as onions, tomato, bananas, groundnuts, cotton, soyabean, potato and cowpea (Anon., 1983; Lagoke et al., 1985; ICI, 1981). When applied pre-emergence or incorporated before planting, fluazifop-butyl still shows good selectivity but twice to four times the post-emergence rates are required to give the same degree of weed control.

Symptoms are often not evident until a week after application although growth usually ceases within 48 hours. Nodes and growing points become necrotic, young leaves show chlorosis followed by necrosis and there is a general loss of vigour. Death usually occurs after three to five weeks.

Fluazifop-butyl is quickly absorbed through the leaf surfaces. It is transported in both xylem and phloem, accumulating at growing points in the plant and affecting the meristematic tissues of nodes and

buds (ICI, 1981). Laboratory studies suggest that fluazifop-butyl interfers with adenosine triophosphate production. Fluazifop-butyl is rapidly hydrolysed in plants to fluazifop, which is then very slowly cleaved at the pyridine ether bond (ICI, 1981).

Fluazifop-butyl is rapidly degraded in moist soils, in which it has a half-life of less than nine weeks. The major degradation product is fluazifop which persists in sandy soils with very low organic matter content. Cold and dry conditions prolong its persistence in the soil. Applied post-emergence in cotton, groundnut, soya-bean and cowpea, fluazifop-butyl gave excellent control of grass weeds (Knott, 1982; Braithwaite and Martin, 1982; Dallyn and Sweet 1970; Wickpe et al., 1983; Lagoke et al., 1985; Kavani et al., 1986). In a field trial at Samaru, Nigeria fluazifop-butyl applied in mixture with diuron controlled Cynodon dactylon, Rottboellia cochinchinensis, Digitaria ciliaris, Ipomoea sp. Centrosema pubescence and Vernonia galamensis in cowpea (Anon., 1984). Braithwaite and Martin (1982) reported that fluazifop-butyl applied post-emergence at 0.25 to 3.0 kg/ha in cowpea when annual grass weeds were 4-8 leaf stage and perennial grasses at about 6-leaf stage gave excellent control for 4 to 21 days and unacceptable control for 42 days after treatment. Kavani et al. (1986) also reported that fluazifop-butyl at 0.25 and 0.37 kg/ha,

applied post-emergence in combination with an interrow cultivation, 40 to 45 days after sowing, gave pod yields of cowpea of 1.21 t/ha. In another trial at Samaru, fluazifop-butyl plus diuron at 1.0+0.8 kg/ha applied post-emergence resulted in high cotton yield (Lagoke et al., 1985).

Imazaquin, the common name for "Scepter", is a selective broad spectrum herbicide for weed control in beans and cowpeas when applied both pre-emergence and post-emergence (Parker and Wilson, 1986). It is formulated both as an emulsifiable concentrate and water dispersable granules 70% w/w a.i. Symptoms of phytotoxicity include stunting and chlorosis which develop into necrosis of tissues in susceptible plants. The new and young leaves are sometimes distorted while patchy chlorosis develops later on older sprayed leaves. In general, necrosis and death are usually preceeded by a pronounced chlorosis (Richardson et al., 1984).

Imazaquin is absorbed by the roots and foliage and translocated to other plant parts in both the xylem and phloem (Shaner et al., 1983). The uptake of imazaquin has however been suggested to be mainly through the root (Orwick et al., 1983).

Imazaquin reduces growth and inhibits mitosis, chlorophyll, carotenoid and amino acid syntheses

(Birk and Duke, 1986; Delvin and Kosganski, 1986). In trials carried out both in the greenhouse and field, imazaquin applied both pre-emergence and post-emergence at rates ranging from 0.025 to 0.4 kg/ha has been reported to effectively and selectively control a wide range of weeds such as Amaranthus, Cyperus rotundus, C. esculentus, Oxalis latifolia, Sorghum halepens, Ipomoea lacunosa, Sida spinosa and Euphorbia maculata in cowpea (Oneil et al., 1985; Retzinger and Rogers, 1985). At 0.025 kg/ha, legume crops including cowpea tolerated imazaquin but were however damaged a little at 0.1 kg/ha in the greenhouse. At higher rates, a wide range of weeds including Rottboellia cochinchinensis was controlled by imazaquin (Parker and Wilson, 1986). Applied pre-emergence in mixture with other herbicides, imazaquin gave season long weed control in soyabean (Johnston and Webb, 1985; Wilson and Hines, 1986; IITA, 1984). Gofung (1987) found that imazaquin and its mixture with metolachlor at 0.25+1.25 kg a.i/ha in soyabean and groundnut and at 0.15+1.25 and 0.33+1.25 kg a.i/ha in cowpea gave effective weed control and high yield.

CHAPTER 3

3. MATERIALS AND METHODS

3.1 Experimental Sites

Two field experiments were conducted on the farm of the Institute for Agricultural Research (I.A.R.) Samaru (11^{o} 11' N, 07^{o} 38' E) in the Northern Guinea Savanna of Nigeria during the 1987 wet season to determine the effect of period of weed interference and evaluate herbicide mixtures in cowpea. The site used for the two trials was cropped to sweet potato during the 1986 wet season. The soil of the site of the trial was a sandy clay loam. Details of the physico-chemical composition of the soil are contained in Table 1.

A total of 972mm rainfall was received during the period of crop growth. Details of the distribution of rainfall, relative humidity, temperature and sunshine hours in 1987 at Samaru are shown in Table 2.

The most prevalent weed species observed at the site of the trial were grasses, especially at the early stage of crop growth and broadleaved weeds which infested the field at the later stage of crop growth. Details of type of weed species and the level of occurence at the site of the trials are contained in Table 3.

Table 1: Physico-Chemical analysis of soil at the experimental site at Samaru

Soil Composition	Soil Depth (cm) 0-20	20-40
Particle size (%)		
Sand	50.00	50.00
Silt	28.00	26.00
Clay	22.00	25.00
Soil textural class	Sandy Clay Loam	
Soil pH in water	5.10	5.20
pH in 0.01M Ca Cl_2	4.55	4.70
Organic carbon (%)	0.61	0.44
Total nitrogen (%)	0.07	0.056
Available P (ppm)	1.575	0.35
Exchangeable Bases (meq/100g of soil)		
Sodium Na	0.16	0.16
Potassium K	0.21	0.22
Calcium Ca	3.85	4.30
Magnesium mg	0.76	0.5
Cation Exchange Capacity (meq/100g of soil)	7.35	7.9

Table 2: Total rainfall, mean temperature, relative humidity, at ten-day interval during the period of the trial, 1987 wet season.

Month	Date	Total Rainfall (mm)	Mean Temperature (°C) Max.	Min.	Relative Humidity (%) A.M.	P.M.	Sunshine (hours)
MAY	1 - 10	Nil	38.7	21.3	36.0	10.7	9.9
	11 - 20	Nil	38.6	23.4	47.7	16.8	8.1
	21 - 31	135.7	33.4	22.0	66.6	45.6	8.5
JUNE	1 - 10	85.4	29.8	20.6	81.5	63.5	6.4
	11 - 20	8.2	32.1	21.8	71.2	53.8	8.9
	21 - 30	45.1	30.1	21.0	76.7	68.2	7.5
JULY	1 - 10	52.3	30.5	20.6	77.6	61.7	8.4
	11 - 20	102.4	30.6	20.3	78.9	64.3	7.9
	21 - 31	118.0	29.2	19.7	82.6	68.6	6.8
AUGUST	1 - 10	105.4	29.9	19.9	83.0	67.7	7.0
	11 - 20	75.2	28.5	19.2	86.6	76.6	5.1
	21 - 31	85.4	29.2	20.4	86.5	72.8	6.1
SEPTEMBER	1 - 10	33.0	29.9	20.4	78.7	64.8	8.0
	11 - 20	57.1	30.4	20.4	75.9	65.6	7.1
	21 - 30	12.0	31.0	20.3	73.2	59.1	8.9
OCTOBER	1 - 10	42.6	30.8	20.0	73.4	57.1	8.0
	11 - 20	Nil	31.4	18.7	62.6	47.3	9.4
	21 - 31	Nil	30.9	14.1	28.4	28.8	8.3

Table 2 (Contd')

Month	Date	Total Rainfall (mm)	Mean Temperature (°C) Max.[1]	Min.[2]	Relative Humidity (%) A.M.[3]	P.M.[4]	Sunshine (hours)
NOVEMBER	1 - 10	Nil	31.2	11.4	22.0	19.0	9.4
	11 - 20	Nil	31.3	12.8	23.7	19.7	9.2
	21 - 31	Nil	33.0	13.0	22.3	18.1	10.0
DECEMBER	1 - 10	Nil	32.5	12.7	24.5	18.9	8.5
	11 - 20	Nil	29.5	11.6	20.9	16.7	8.9
	21 - 31	Nil	29.5	13.5	27.3	21.6	7.4

1 Maximum
2 Minimum
3 Ante meridian
4 Post meridian

Source; Meteorological Unit, Institute for Agricultural Research, Samaru, Zaria, Nigeria.

Table 3: List of common weed species at the experimental site, Samaru, 1987 Wet sSeason

Type of Weeds	Level of Weed Infestation.
Grasses	
Cynodon dactylon (L.) Pers	*
Digitaria ciliaris (Tetz.) Kocht.	*
Eleusine indica (L.) Gaertn.	***
Eragrostis ciliaris (Linn.) R. Br.	**
Pennisetum pendicellatum Trin.	*
Setaria barbata (Lam.) Kunth	*
Broadleaved weeds	
Commelina benghalensis (L.)	***
Corchorus tridens	**
Eclipta prostrate (Linn.) L.	*
Eurphorbia heterophylla (Linn.)	***
Eurphorbia hirta Linn.	**
Ipomoea eriocarpa R. Br.	***
Vernonia pauciflora (Willd.)	***
Vigna racemosa	**
Sedges	
Cyperus rotundus (L.)	*

* = Low infestation
** = Moderate infestation
*** = Heavy infestation

3.2 Cultural Practices

The experimental site was ploughed, harrowed and ridged in July, 1987. After harrowing, single superphosphate was applied at the rate of 37.0kg P_2O_5/ha before 75cm wide ridges were made. Two seeds per hole of cowpea dressed with benomyl (as Benlate) and thiram and aldrin (as Aldrex 'T') were planted on the ridges at an intra-row spacing of 25cm.

3.3 Experimental layout and Treatments.

The two trials were laid out in a randomised complete block design and replicated three times. The gross and the net plot sizes were 11.25m^2 and 6.75m^2, respectively. This gave five and three ridges per gross and net plots, respectively. There were two sets of ten treatments in the weed interference trial (Table 4). In one set of treatments, plots were kept weed-free for 3, 6, 9 and 12 weeks after sowing (WAS) cowpea and subsequently, left weed-infested till harvest. In the other set of treatments, plots were kept initially weed-infested for the corresponding periods and subsequently kept weed-free until harvest. Two treatments in which the plots were either kept weed-free or weed-infested until harvest were included for comparison.

Table 4: Details of treatments for the weed interference trial **in Cowpea** at Samaru, 1987 Wet Season

Treatments	Code
Periods of weed interference	*
Weed free for 3 WAS	*
Weed free for 6 WAS	*
Weed free for 9 WAS	*
Weed free for 12 WAS	*
Weed free until harvest	*
Weed infested for 3 WAS	**
Weed infested for 6 WAS	**
Weed infested for 9 WAS	**
Weed infested for 12 WAS	**
Weed infested until harvest	**

WAS = Weeks after sowing

* = Plot kept weed free for various periods **and subsequently allowed to** be infested by weeds until harvest.

** = Plot kept weed infested for various **periods and subsequently kept** weed free until harvest.

In the weed control experiment, 16 herbicide mixtures, were applied pre-emergence and compared with two hoe-weedings, at 3 and 6 weeks after sowing (WAS) and an untreated check. The 16 pre-emergence herbicide treatments were made up of four herbicide mixtures each applied alone or followed by supplementary weed control such as hoe-weeding, post-emergence application of the pre-emergence herbicide at half the rate used earlier or imazaquin at 0.2 kg a.i/ha, The post-emergence herbicide treatments consisted of mixtures of fluazifop-butyl and imazaquin either directed or overall at different rates. Details of the treatments are contained in Table 5.

3.4 Crop Protection

Small hand hoes were used for weed removal both in the weed interference and the weed control trials according to the treatments.

The application of Benlate and Dithane M 45 at the rate of 0.6 kg + 2.5 kg/ha in water commenced at 6 weeks and continued forthnightly for the control of fungal diseases. Cypermethrine (as Cymbush 10 e.c.) and dimethoate (as Perfekthion 40 e.c.) were each applied forthnightly at the rate of 0.75 litre/ha each as tank mixture using a Knapsack sprayer, beginning from 3 WAS until harvest to control insect pests.

Table 5: Details of herbicide treatments for the weed control trials in Cowpea at Samaru, 1987 Wet Season.

Pre-emergence Herbicide	Rate a.i./ha	Post-emergence[1] Herbicide	Rate kg a.i/ha
Metolachlor + Metobromuron	1.5 + 1.5	2 3	
Metolachlor + Metobromuron	1.5 + 1.5	Hoe-weeding	
Metolachlor + Metobromuron	1.5 + 1.5	Metolachlor+Metobromuron	0.75+0.75
Metolachlor + Metobromuron	1.5 + 1.5	Imazaquin	0.2
Metolachlor + Prometryne	1.0 + 1.0	-	
Metolachlor + Prometryne	1.0 + 1.0	Hoe-weeding	
Metolachlor + Prometryne	1.0 + 1.0	Metolachlor + Prometryne	0.5 + 0.5
Metolachlor + Prometryne	1.0 + 1.0	Imazaquin	0.2
Alachlor + diuron	1.5 + 0.8	-	
Alachlor + diuron	1.5 + 0.8	Hoe-weeding	
Alachlor + diuron	1.5 + 0.8	Alachlor + diuron	0.75 + 0.4
Alachlor + diuron	1.5 + 0.8	Imazaquin	0.2
Metolachlor + diuron	1.5 + 0.8	-	
Metolachlor + diuron	1.5 + 0.8	Hoe-weeding	
Metolachlor + diuron	1.5 + 0.8	Metolachlor + diuron	0.75 + 0.4
Metolachlor + diuron	1.5 + 0.8	Imazaquin	0.2

TABLE 5 (Contd')

Pre-emergence treatments	Post-emergence treatments	Rate (kg a.i/ha)
-	Fluazifop-butyl + Imazaquin	0.5+0.2 overall
-	Fluazifop-butyl + Imazaquin	0.5+0.2 directed
-	Fluazifop-butyl + Imazaquin	1.0+0.2 overall
-	Fluazifop-butyl + Imazaquin	1.0+0.2 directed.
Hoe-weeding at 3 and 6 WAS		
Untreated Control		

1 Post-emergence herbicide applications at 3 weeks after sowing (WAS)

2 All supplementary hoe-weedings done at 6 WAS.

3 WAS = Weeks After Sowing.

3.5 Herbicide Application

In the weed control experiment, the pre-emergence herbicides were applied one day after sowing while the post-emergence herbicide applications were done at 3 WAS, either as directed or overall application (Table 5). All the herbicide treatments were applied with a Knapsack sprayer in about 240 litres/ha spray volume at a pressure of 2.1 kg/cm^2 using a deflector nozzle.

3.6 Data Collection

3.6.1 Weed Cover Score

Weed cover score was taken at 4, 6, and 9 WAS and at harvest. A scale of 0 to 10 was used, where 0 represented no weed cover and 10 represented complete weed cover.

3.6.2 Weed Weight

In both the weed interference and weed control experiment, weed samples were taken from $0,75m^2$ quadrats before each weeding was done and at harvest. The samples were cleared free of soil and weighed fresh and oven-dried at 70^oC to constant weight for dry matter determination. In the weed interference trial, weed weight per plot was determined by adding the cumulative

weights of weed produced at the time of each weeding and at final cowpea picking.

3.6.3 Crop Growth Parameters

Stand count was taken at seven days after sowing, 6 WAS and at harvest from the net plot in order to assess the effect of the treatments on crop establishment.

Crop vigour score was taken at 6 and 9 WAS using a scale of 0 to 10, where 0 was scored for a plot with completely dead plants and 10 for a plot with the most vigorous plants. Among other parameters taken were plant height, leaf area, number of pods and seeds per pod, leaf dry weight and stand count at harvest. Leaf area was measured by the use of leaf area metre.

Using systematic sampling, four plants were removed from each plot at 3, 6, 9 and 12 WAS, cleaned and separated into leaves and stems, oven-dried for about 48 hours at $70^{o}C$ to constant weight to determine dry matter production.

3.6.4 Yield and Yield Components

In the two experiments, harvesting of seed started at 9 WAS after some pods had dried. Altogether three pickings were done. The pods picked from each net plot were counted, weighed, threshed, and the seeds weighed.

Data collected on yield components included the number and weight of pods/ha, number of seeds per pod and weight of seeds/ha as well as weight of 1000 seeds.

3.7 Data Analysis

The data were subjected to analysis of variance for test of significance and treatment means were compared using Duncan Multiple Range Test at five per cent level of probability. Correlation coefficient and regression analyses were also done on appropriate parameters.

Predicted yields of cowpeas grain as affected by periods of weed interference were estimated using the equation:

$$Y = a + b_2 z_2 + b_3 z_3$$

where Y = yield/weed dry matter production and z_2 and z_3 are functions of time of weeding period, such that the slope is zero at t = 0 (time of sowing) and t = 15 (time of harvesting) and a, b_2 and b_3 are regression coefficients. The reconstituted equation in cubic and quadratic forms are:

$$Y = a + bt + b_2 t^2 + b_3 t^3$$

$$Y = a + bt + b_2 t^2$$

The equations give a relationship of yield/weed

dry matter production and weeding time which has a zero slope at both t = 0 and t = 15 weeks.

In the weed control trial, (fig. 3), seed yield of the different treatments as percentage of the untreated check was obtained using the following equation:

$$A - B = \frac{C}{B} \times 100 = D$$

where A = yield of the appropriate treatment, B = yield of the untreated check, C = the difference between A and B and D = percent of the untreated check.

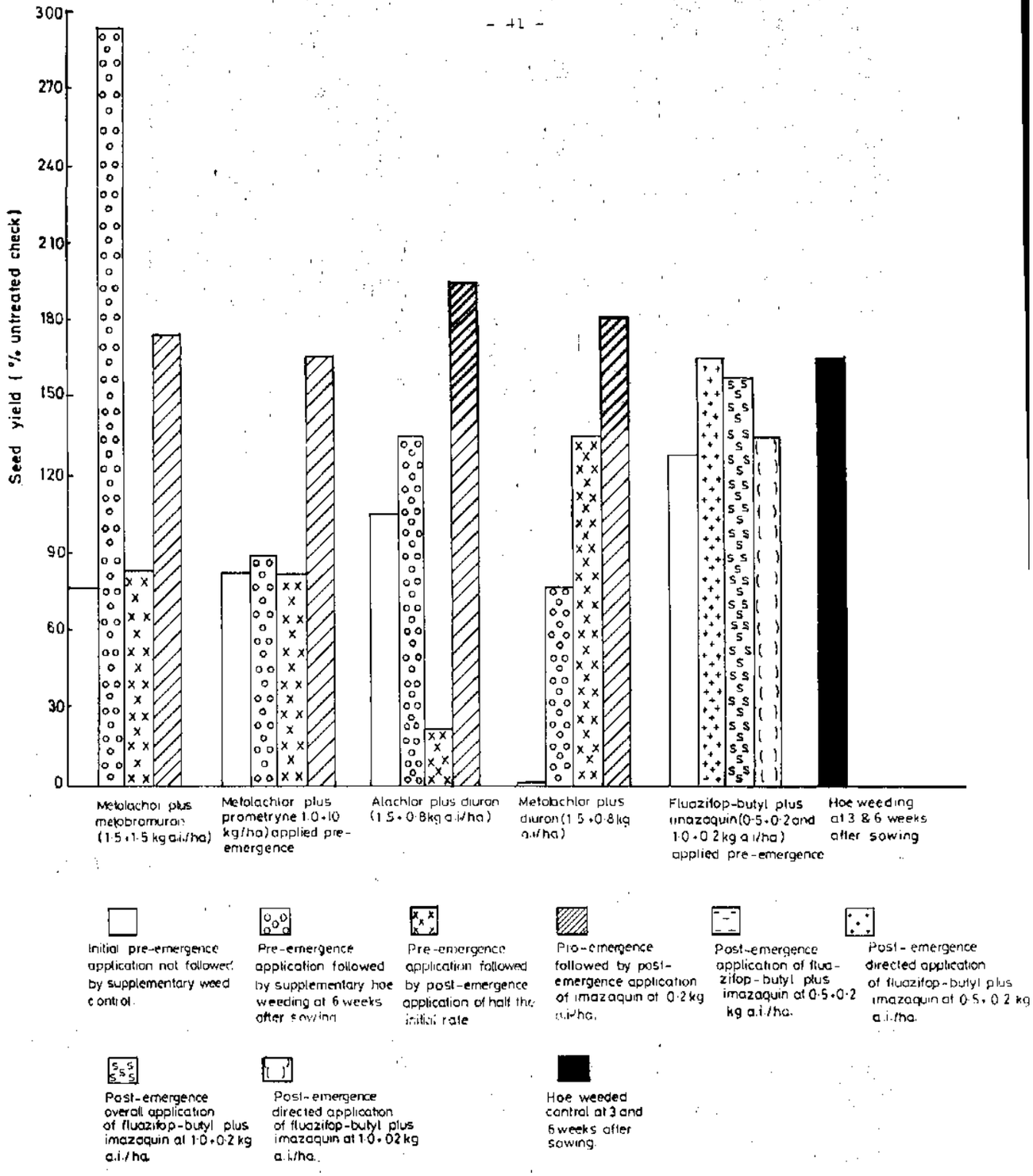


Fig. 3. Cowpea grain yield of the different treatments as percentage of the untreated check.

CHAPTER 4

RESULTS

4.1 Effect of period of Weed Interference on the growth and yield of cowpea and cumulative weed dry matter production

4.1.1 Crop Vigour Score and Stand Count

The effect of period of weed interference was significant on crop vigour score at 6 and 9 WAS but not on stand count at harvest (Table 6). Plants weed-infested until 6 WAS had lower crop vigour score than those kept weed-free for 3 and 6 WAS. Those plants weed-infested for 3 WAS however did not differ significantly from those kept weed-free initially for various periods.

At 9 WAS, crop vigour score was least on the plots weed-infested for the same period and significantly lower than those of the plants kept weed-free for various periods initially. However, crop vigour score on the plots weed-infested for various periods initially did not differe significantly from themselves.

4.1.2 Leaf dry weight

The effect of periods of weed interference was significant on dry weight of leaves per plant at 9 WAS (Table 6). Plants kept weed-free for 9 WAS had higher

Table 6: Effect of period of weed interference on stand count, crop vigour score, leaf dry weight, leaf area of cowpea and weed dry matter production at Samaru in 1987 wet season.

Period of weed control	Stand Count at harvest.	Crop[3] Vigour Score		Leaf dry weight/ plant at (g)	Leaf Area (cm^2)/plant	Weed dry matter production (kg/ha)
		6 WAS	9 WAS	9 WAS	9 WAS	
Weed free for 3 WAS	28	9.33a[4]	9.00a	25ab	1663.28a	1625bc
Weed free for 6 WAS	29	9.33a	9.17a	28ab	2051.16a	913bc
Weed free for 9 WAS	30		9.14a	31a	2191.86a	780bc
Weed free for 12 WAS	27		-[2]	-	-	439c
Weed free till harvest	30		-	-	-	422c
Weed infested for 3 WAS	27	8.30ab	8.30ab	25ab	1604.04a	318c
Weed infested for 6 WAS	27	8.00b	8.30ab	23ab	1280.89a	2698b
Weed infested for 9 WAS	26		7.80b	18b	100.00a	4105a
Weed infested for 12 WAS	26			-	-	4673a
Weed infested till harvest	26			-	-	5365a
SE ±	2.678 NS	0.470	0.545	4.104	362.075	48.905

1 Weeks after sowing.

2 Treatments had not been applied at the time of observation.
3 Crop vigour taken where 0 represented no weed cover and 10 represented complete weed cover
4 Means followed by the same letter(s) within a treatment are not significantly different at 5% level using Duncan Multiple Range Test (DMRT)
NS = Non significant.

leaf dry weight than those weed-infested for the same period. However, plots weed-infested for shorter periods and those similarly kept weed-free produced leaf dry weights that were comparable to those of the plots kept weed-free for 9 WAS and those similarly weed-infested.

4.1.3 Leaf area

Although leaf area was not significantly affected by periods of weed interference at 9 WAS, it was apparent that plots kept weed-free for 3 weeks only and those weed-infested for 3, 6 and 9 WAS had very low values compared with those either kept weed-free for 6 or 9 WAS (Table 6). The lowest value of 1100cm^2 obtained in plots infested for 9 WAS was about 50% of the maximum obtained on the plots kept weed-free for the corresponding period.

4.1.4 Haulm dry weight

The plots weed-infested throughout the crop life cycle had significantly lower haulm dry weight at harvest than the highest obtained on those kept weed-free until 6 and 9 WAS (Table 7).

4.1.5 Number of seeds per pod

Though number of seeds per pod was not significantly affected by periods of weed interference, the number of seeds per pod produced by plants in plots weed-infested

Table 7: Effect of period of weed interference on haulm weight, number and weight of pods, number of seeds/pod, seed size and seed yield of cowpea at Samaru in 1987 Wet Season.

Period of weed interference	Haulm weight (kg/ha)	Number of pods/ ha.	Number of seeds/ pod	Pod weight (kg/ha)	Weight of of 1000 seeds (g)	Seed yield (kg/ha)
Weed free for 3 WAS[1]	1111ab	939bcd	9.27	1386b	119.7b	1275b
Weed free for 6 WAS	1733a	1257a	7.3	1498ab	135.3ab	1348ab
Weed free for 9 WAS	1733a	1085ab	8.33	1934a	131.3ab	1539ab
Weed free for 12 WAS	1111ab	888bcd	8.62	1764ab	133.0ab	1220b
Weed free till harvest	1357ab	1068ab	8.90	1787ab	143.0a	1598a
Weed infested for 3 WAS	1234ab	798bcde	8.07	1402b	134.7ab	1265b
Weed infested for 6 WAS	863ab	1043ab	9.27	1394b	123.0b	1265b
Weed infested for 9 WAS	1481a	694cde	7.4	572c	114.3b	522c
Weed infested for 12 WAS	986ab	520cde	6.47	467c	116.1b	413c
Weed infested till harvest	468b	488e	6.83	520c	115.7b	458c
SE ±	0.200	94.511	1.067 N.S.	144.2	0.664	105.163

[1] Weeks after sowing
NS = Non significant
Means followed by the same letter(s) within a treatment are not significantly different at 5% level using Duncan Multiple Range Test (DMRT).

for 12 WAS and until harvest were lower than those of all the other treatments (Table 7).

4.1.6 Number and weight of cowpea pods

The number of cowpea pods was significantly affected by periods of weed interference. Crops subjected to various periods of weed-infestation initially and those kept weed-free initially for 3 WAS only, produced lower number of pods than the crops kept weed-free for 6 WAS (Table 7). However, only crops weed infested for 9 WAS and more produced significantly lower pod number than those weed-free throughout. Although not significant, pod number apparently decreased with increasing periods of weed infestation. Pod number of crops weed-infested throughout crop life cycle was reduced by 61.2%, compared with the maximum obtained in the trial.

The pod weights of cowpea crops weed-infested for 9 WAS and more were similar to those of the crops weed-infested initially for shorter periods and those kept weed-free for 3 WAS only. Pod weight of crop weed-infested throughout crop life cycle was reduced by 66.82%.

4.1.7 Weight of 1000 seeds

Cowpea seed size as estimated by 1000 seed weight was significantly affected by periods of weed interference. The crop kept weed-free till harvest had significantly higher weight of 1000 seeds

than those weed-infested for 6 WAS and more than that kept weed-free initially for 3 WAS only. Crops kept weed-free for 6 and 9 WAS and that weed-infested for 3 WAS produced similar weights of 1000 seeds but did not differ significantly from the highest and the least obtained in the trial (Table 7).

4.1.8 Seed Yield

Seed yield was significantly affected by periods of weed interference (Table 7). Crops kept weed-free throughout the life cycle of the crop produced 1598 kg/ha grains of cowpea which differed significantly from those kept weed-free initially for 3 WAS and those weed-infested for 6 WAS and more. Although cowpea seed yields were similar for crops weed-infested for 9 WAS and more, they were significantly lower than those of the plots infested for shorter periods. Similar to the observation on pod weight, keeping crop weed-infested for extra 3 weeks beyond 6 WAS resulted in loss of 734 kg/ha of cowpea seeds while crop kept weed-free for extra 3 weeks beyond 6 WAS resulted in gain of 191 kg/ha of cowpea seed.

4.1.9 Predicted yields of cowpea seeds as affected by periods of weed interference

Figures 1 and 2 contain curves on predicted values of total cowpea grain yields and weed dry matter production, respectively, as related to weeding periods.

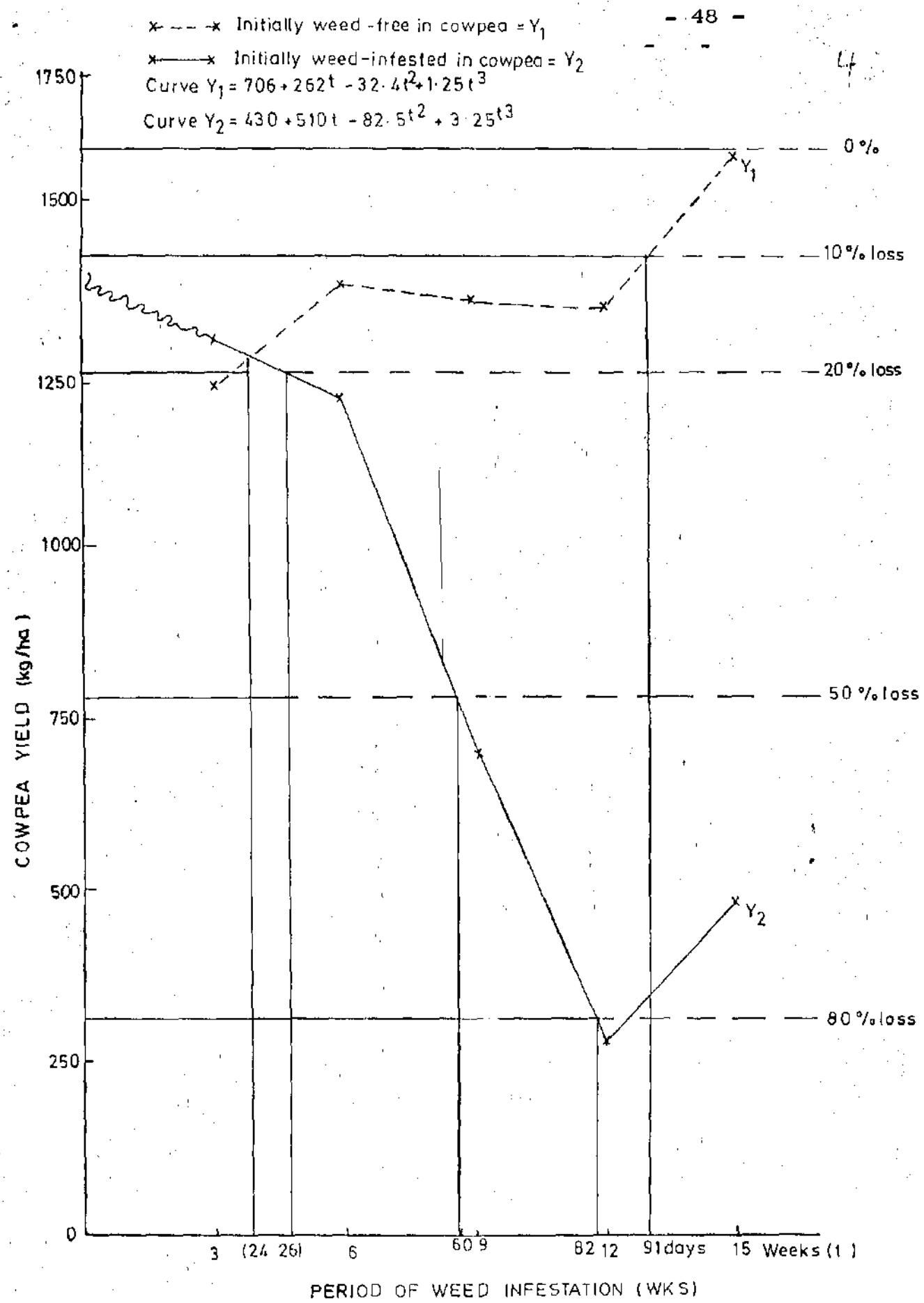


Fig. 1. Fitted values of total cowpea yields as affected by period of weed interference, Samaru, 1987

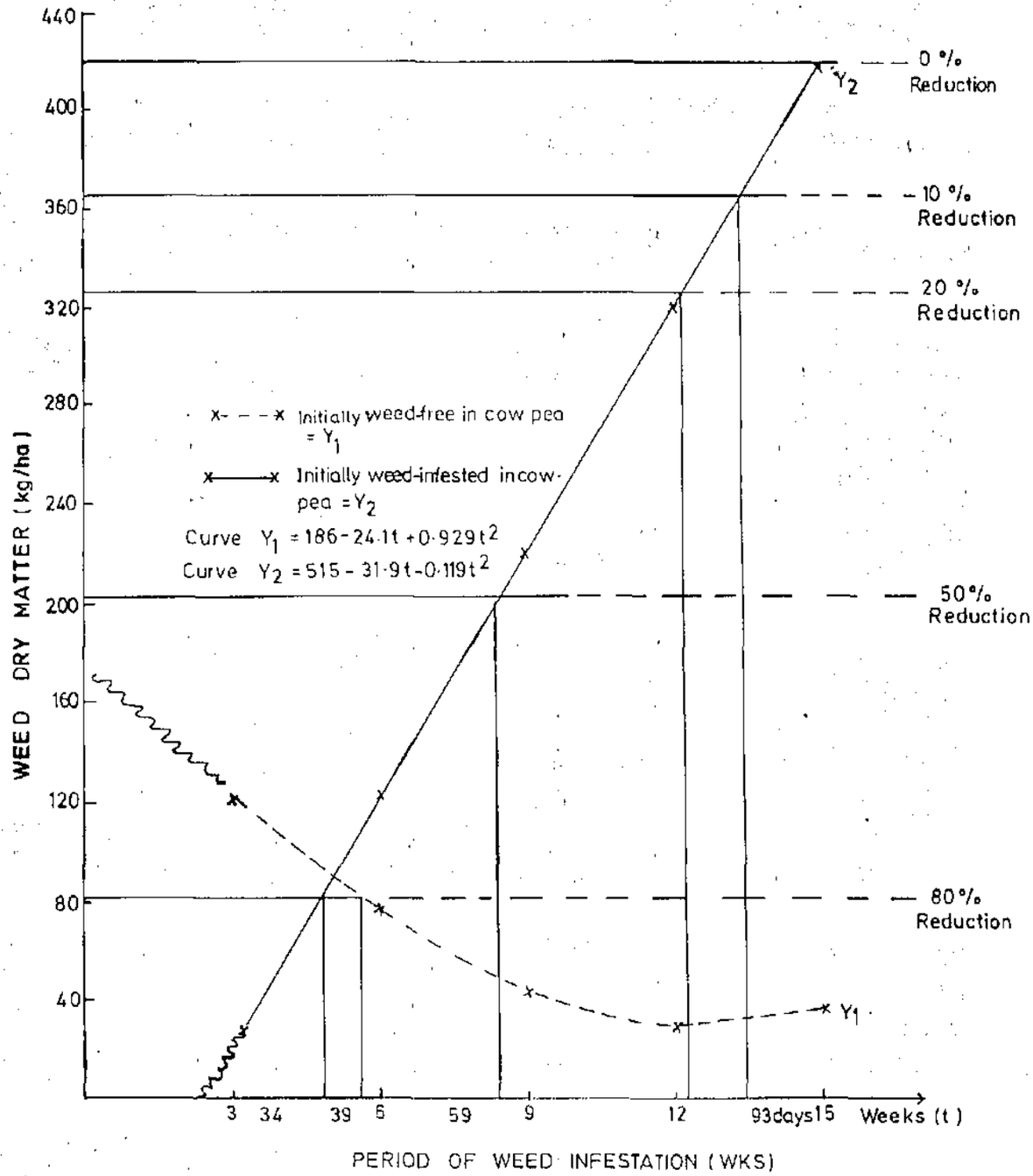


Fig. 2. Fitted values of total weed dry matter production as affected by period of weed interference at Samaru, 1987.

The equations give a relationship of yield/weed dry matter production and weeding time which has a zero slope at both t = 0 and t = 15 weeks. The estimated coefficient of determinations for linear, quadratic and cubic equations are indicated in tables 8 and 9. With coefficient of determination of 45.9% and 92.2% (table 8) for plots kept weed-free and those weed-infested initially respectively, it was apparent that the best fitted curve for predicted cowpea grain yield in response to weed interference period in this trial was cubic equation.

Weed dry matter production was however best fitted with the use of quadratic equation, the coefficient of determination for the plots kept weed-free and weed-infested initially were 91.5 and 98.6% respectively (Table 9).

In figure 1, it was estimated that keeping the crop weed-free initially for 30 and 90 days after sowing resulted in about 10, and 20% loss in total yield respectively. Once the plots are infested for 32, 60 and 82 days, it is estimated that 20, 50 and 80% reduction in total yield would occur in cowpea (fig. 1). Cowpea (Ife Brown) was critically affected by weeds between 6 and 9 WAS. With this variety, it was required to keep the crop weed-free for 15 weeks of the life cycle in order to obtain maximum cowpea yield. It was

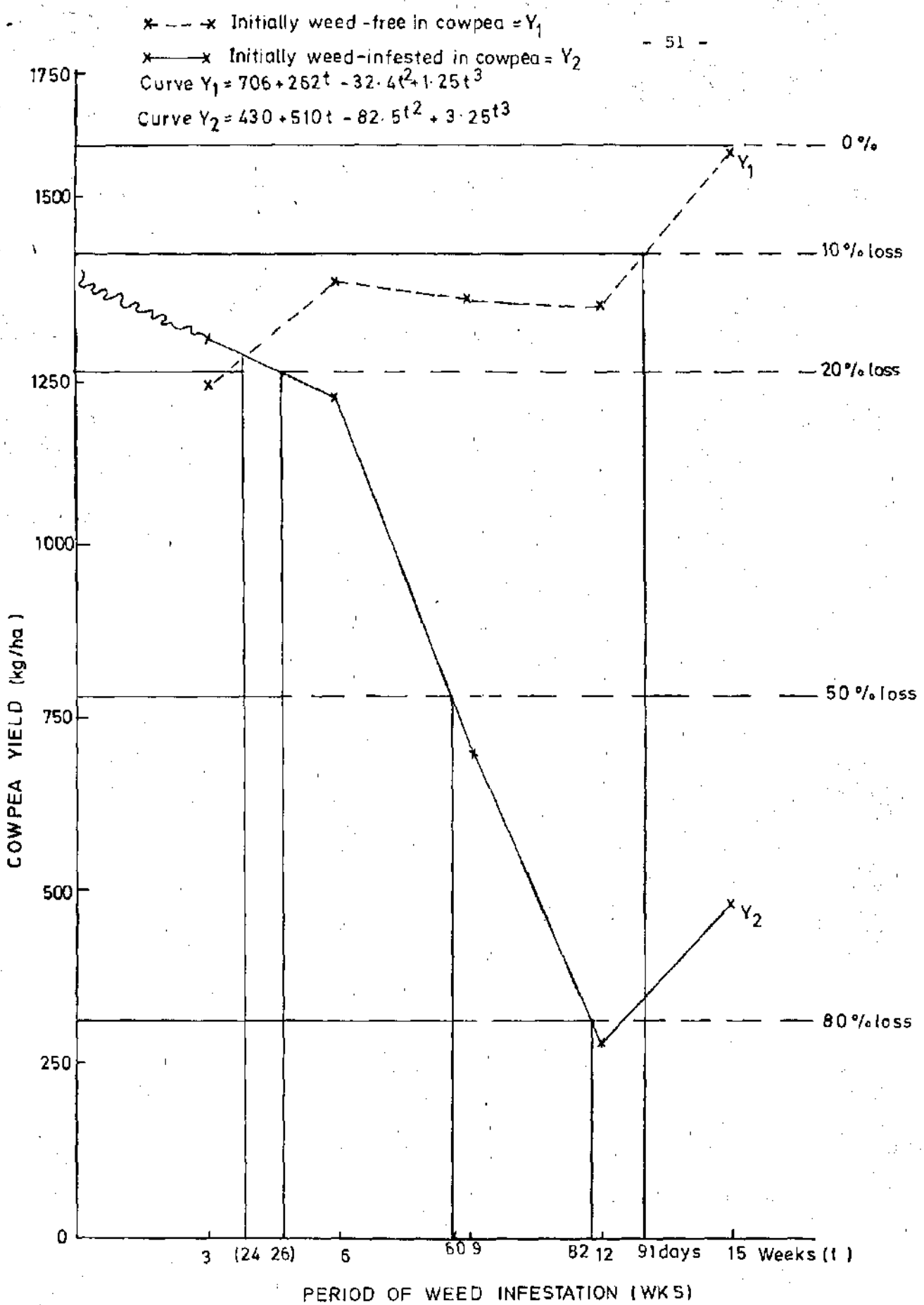


Fig. 1. Fitted values of total cowpea yields as affected by period of weed interference, Samaru, 198

Table 8: Regression analysis cowpea yield on periods of weed interference

	Weed free initially		Weed infested initially	
	Equation	Coefficient of determination (%)	Equation	Coefficient of determination (%)
Linear	$1187 + 21.0(t)$	31.3	$1574+85.6(t)$	75.9
Quadratic	$1273-4(t)+1.37(t^2)$	32.9	$1904-180(t)+5.25(t^2)$	79.5
Cubic	$706+262(t)-32.4(t^2)+1.25(t^3)$	45.9	$430+510(t)-82.5(t^2)+3.25(t^3)$	92.2

Table 9: Weed Dry Matter Production on period of weed interference

	Weed free initially		Weed infested initially	
	Equation	Coefficient of determination (%)	Equation	Coefficient of determination (%)
Linear	$128-7.43(t)$	81.5	$523-33.5(t)$	98.9
Quadratic	$186-24.1(t)+0.929(t^2)$	97.5	$515-31.4(t)-0.119(t^2)$	98.6
Cubic	$227-43.2(t)+3.35(t^2)-0.0895(t^3)$	98.9	$431+8.0(t)-5.12(t^2)-0.185(t^3)$	99.0

t = time (period of weed infestation in weeks)

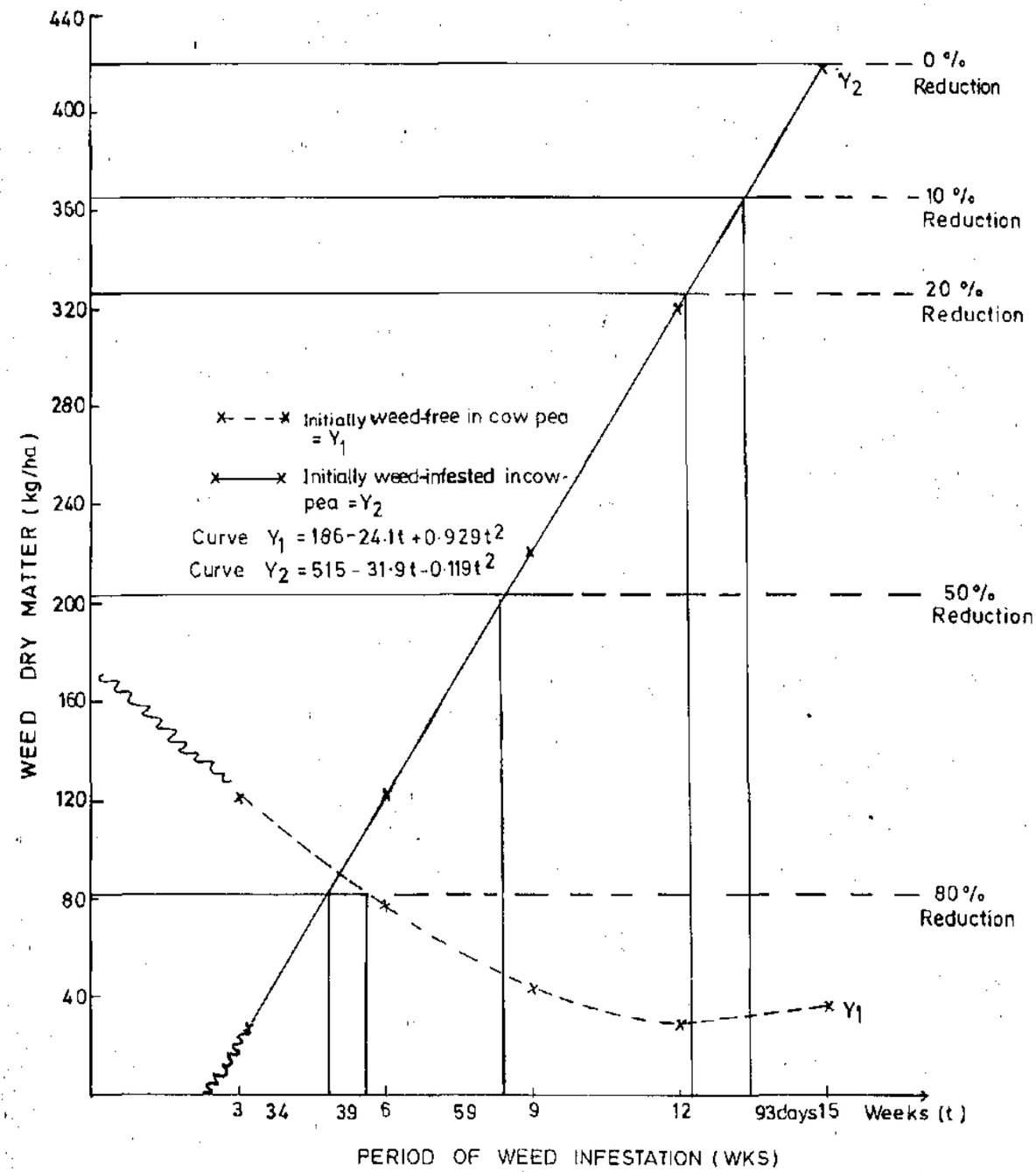


Fig. 2. Fitted values of total weed dry matter production as affected by period of weed interference at Samaru, 1987.

also estimated that if the plots were kept weed-free for 39 days after sowing is estimated that 80% reduction in weed growth was obtained. However, with initial weed-infestation for 93, 85, 59 and 34 days after sowing, that 10, 20, 50 and 80% subsequent reduction in weeds was estimated (fig. 2). The most rapid weed growth occured between 3 and 9 weeks (fig. 2).

4.1.10 Cumulative weed dry matter production

Cumulative weed dry matter production was significantly affected by periods of weed interference (Table 6). Plots kept weed-infested for periods of 3 weeks more than 6 WAS had the highest weed dry matter production. Weed dry matter production resulting from plots weed-infested till 9 WAS was significantly higher than the least obtained. The least weed dry matter production was obtained from plots that were weed-infested for 3 WAS and those kept weed-free for 12 WAS and until harvest.

4.1.11 Relationship between various parameters and cowpea grain yield in the weed-interference studies.

As indicated in Table 10, grain yield of cowpea at harvest was significantly positively correlated with number of pods per ha., pod weight per ha., crop vigour score at 6 WAS, weight of 1000 seeds and haulm dry weight at harvest. Weed cover score at 6 WAS and

Table 10: Correlation of grain yield of cowpea with various parameters in the weed interference studies at Samaru in 1987 wet season.

		1	2	3	4	5	6	7	8	9	10	11	12
1	grain yield	1.000											
2	Weight of 1000 seeds	.495*	1.000										
3	Number of seeds per pod.	.285	.314	1.000									
4	Number of pods per ha.	.705**	.458**	.357	1.000								
5	Pod weight per ha	.809**	.591**	.435	.781**	1.000							
6	Leaf dry wt. per plant at 3 WAS	.240	.361	.140	.261	.398	1.000						
7	Crop vigour score at 6 WAS	.61**	.477**	.293	.722**	.746**	.036	1.000					
8	Weed cover score at 6 WAS (broad-leaved weed.)	-.564**	-.58**	-.212	-.532**	-.613**	-.522**	-.325	1.000				
9	Weed cover score at 6 WAS(grasses)	-.586**	-.608**	-.218	-.516**	-.618**	-.345	-.436	-.592**	1.000			
0	Weed cover score at 6 WAS (sedges)	-.582**	-.51**	-.257	-.615**	-.661**	-.30	-.428	-.683**	.94**	1.000		
1	Cumulative weed dry matter production	-.482*	-.386	-.427	-.167	-.496*	-.39	-.182	-.159	-.221	-.146	1.000	
2	Leaf area at 9 WAS	.335	.409	.266	.187	.565**	.51**	.187	.655**	.404	.542**	.517**	1.000
3	Haulm dry weight/ ha.	.516**	.362	.082	.51**	.464*	.028	.266	.462*	.091	.222	.283	.228

[1] Weeks after sowing

* Significant at 5% level of probability (R^2 = 0.444)

* Significant at 1% level of probability (R^2 = 0.561)

cumulative weed dry matter production were also, negatively correlated with the grain yield of cowpea (Table 10).

4.2 The effect of weed control treatments on weeds

4.2.1 Weed Cover Score

The weed cover score for both grasses and sedges at 4 WAS, were significantly reduced by all the pre-emergence herbicides compared with the untreated control (Table 11). The mixture of fluazifop-butyl and imazaquin applied post-emergence however, resulted in significantly lower grass weed score but similar sedge weed score compared with the untreated control. The effect of the herbicide treatments on broadleaved weed cover score at 4 WAS was however, not significant.

The weed cover score at 6 WAS was taken before the second hoe-weeding of the hoe-weeded control and the supplementary hoe-weeding of herbicide treated plots. At 6 and 9 WAS, all the weed control treatments, including the hoe-weeded control, resulted in significantly lower weed cover score than the untreated control. In spite of the fact that the supplementary hoe-weeding was done at 6 WAS, the application of alachlor plus diuron resulted in the least weed cover score at 6 WAS and at 9 WAS. The weed cover score at 6 WAS for all the herbicide treatments except alachlor plus diuron followed either by

Table 11: Effect of weed control treatments on weed infestation in cowpea at Samaru, in 1987 wet season.

Herbicide treatments	Rate kg a.i/ha	followed by (fb)	WEED COVER SCORE					Weed dry matter production (kg/ha)
			4 WAS			6 WAS	9 WAS	
			G	BL	S			
Metolachlor + Metobromuron	1.5+1.5	-	0.00c	2.33	0.00c	0.92bc	2.50bc	1496b
Metolachlor + Metobromuron	1.5+1.5	6 WAS[1]	0.33bc	3.67	0.00c	0.67bc	1.83bc	700b
Metolachlor + Metobromuron	1.5+1.5	0.75+0.75	0.33bc	1.00	0.00c	0.68bc	2.00bc	1345b
Metolachlor + Metobromuron	1.5+1.5	Imazaquin 0.2	0.02c	2.67	0.00c	1.01bc	3.17bc	925b
Metolachlor + Prometryne	1.0+1.0	-	0.01c	1.33	0.00c	0.39bc	2.50bc	2883a
Metolachlor + Prometryne	1.0+1.0	6 WAS	0.32bc	1.67	0.00c	0.10bc	1.33bc	876b
Metolachlor + Prometryne	1.0+1.0	0.5+0.5	0.03c	1.89	0.00c	0.42bc	3.17bc	934b
Metolachlor + Prometryne	1.0+1.0	Imazaquin 0.2	0.00c	0.00	0.00c	1.27bc	1.35bc	506b
Alachlor + diuron	1.5+0.8	-	0.33bc	0.33	0.00c	0.21c	3.5bc	1266b
Alachlor + diuron	1.5+0.8	6 WAS	0.36bc	0.00	0.00c	0.01c	1.00c	430b

Table 11 Contd'

Herbicide treatments	Rate kg a.i/ha	followed by (fb)	WEED COVER SCORE					Weed dry matter production (kg/ha)
			4 WAS			6 WAS	9 WAS	
			G	BL	S			
Alachlor + diuron	1.5+0.8	0.75+0.4	0.00c	2.00	0.00c	1.5b	1.83bc	940b
Alachlor + diuron	1.5+0.8	Imazaquin 0.2	0.06c	2.80	0.00c	1.42b	1.80bc	743b
Metolachlor+diuron	1.5+0.8	-	0.27bc	1.83	0.00c	0.76bc	5.17b	1451b
Metolachlor+diuron	1.5+0.8	6 WAS	0.00c	0.00	0.00c	0.37bc	1.67bc	517b
Metolachlor+diuron	1.5+0.8	0.75+0.4	0.09c	0.33	0.00c	0.56bc	0.83c	1875ab
Metolachlor+diuron	1.5+0.8	Imazaquin 0.2	0.01c	2.00	0.00c	1.22bc	1.33bc	716b
Fluazifop-butyl + Imazaquin	0.5+0.2	Overall 3 WAS	1.01b	2.10	1.33b	1.02bc	0.83c	1063b
Fluazifop-butyl + Imazaquin	0.5+0.2	Directed 3 WAS	1.02b	3.00	2.00b	1.43b	3.33bc	1387b
Fluazifop-butyl + Imazaquin	1.0+0.2	Overall 3 WAS	0.76bc	2.67	1.33b	1.01bc	0.83c	1544b
Fluazifop-butyl + Imazaquin	1.0+0.2	Directed 3 WAS	1.00b	3.30	3.00a	1.47b	3.67bc	1203b
Hoe-weeding	3 WAS	6 WAS	0.04c	0.061	0.00c	1.50b	1.50bc	602b
Untreated control	-	-	2.30a	3.31	2.33ab	4.21a	7.00a	1028b
SE ±			0.333	1.122 NS	0.398	0.357	0.829	34.490

G = Grass weeds. Bl = Broadleaved weeds. [1]WAS = Weeks after sowing, NS = Non significant
Means followed by the same letter(s) within treatment are not significantly different at 5% level using Duncan Multiple Range Test (DMRT).

imazaquin or half the rate and fluazifop-butyl plus imazaquin at 0.5+0.2 and 1.0+0.2 kg a.i/ha directed was also lower than that for the hoe-weeded control which had only received one weeding.

At 9 WAS, only post-emergence application of fluazifop-butyl plus imazaquin at 1.0+0.2 kg a.i/ha caused higher weed cover score than the least obtained with sequential application of metolachlor plus diuron at 1.5+0.8 kg a.i/ha followed by half the rate at 0.75+0.4 kg a.i/ha at 3 WAS.

4.2.2 Weed dry matter production

The mixture of metolachlor plus prometryne at 1.0+1.0 kg a.i/ha resulted in higher weed dry matter production than all the other treatments. However, when no attempt was made to physically remove weeds or apply imazaquin, weed weight was similar to that of the untreated control although not significantly, (Table 11).

4.3 Effect of weed control treatments on the growth of cowpea

4.3.1 Stand Count

At 6 WAS and at harvest, metolachlor plus prometryne at 1.0+1.0 kg a.i/ha followed by half the rate, 3 weeks later, resulted in lower stand count than the

highest obtained with fluazifop-butyl plus imazaquin at 0.5+0.2 kg a.i/ha overall and hoe-weeding (Table 12). At 6 WAS, alachlor plus diuron at 1.5+0.8 kg a.i/ha, either followed by half the rate or imazaquin at 0.2 kg a.i/ha at 3 WAS and metolachlor plus diuron at 1.5+0.8 kg a.i/ha alone also resulted in lower stand count than the highest. Among the weed control treatments, only fluazifop-butyl plus imazaquin at 0.5+0.2 kg a.i/ha, applied overall and the hoe-weeded control resulted in higher stand count than the least obtained with alachlor plus diuron at 1.5+0.8 kg a.i/ha followed by half the rate. At harvest, plots hoe-weeded twice, and those treated with alachlor plus diuron at 1.5+0.8 kg a.i/ha alone had higher stand count than the least obtained with metolachlor plus prometryne at 1.0+1.0 kg a.i/ha followed by half the rate.

4.3.2 Crop Vigour Score

As observed with the stand count, metolachlor plus prometryne at 1.0+1.0 kg a.i/ha followed by half the rate 3 weeks later, resulted in significantly lower crop vigour score at 6 and 9 WAS compared with the best treatment. At 6 WAS, alachlor plus diuron also significantly depressed crop vigour score compared with the highest score. Among the herbicide treatments, metolachlor plus metobromuron at 1.5+1.5 kg a.i/ha followed by various supplementary weed control methods and all the post-emergence application of fluazifop-butyl plus imazaquin

Herbicide treatment	Rate kg a.i/ha	followed by (fb)	Crop vigour[2] score		Plant height (cm) at			Leaf dry wt. (g)/plant		Leaf Area (cm^2/plant		Stand Count at		
			6 WAS	9 WAS	3 WAS[1]	6 WAS	harvest	6 WAS	9 WAS	6 WAS	10 WAS	1 WAS	6 WAS	harvest
Metolachlor+Metobromuron	1.5+1.5	-	9.00ab	8.00a	11.67	23.53	27.27abcd	3.59ab	9.85b-f	3408bcd	1840b	42	56abc	41ab
Metolachlor+Metobromuron	1.5+1.5	SHW 6WAS	10.00a	9.33a	13.00	25.13	27.27abcd	4.17ab	14.40abcd	6054ab	4406a	53	56abc	42ab
Metolachlor+Metobromuron	1.5+1.5	0.75+0.75	9.67a	8.33a	12.17	21.83	28.27abc	5.38ab	13.31abcde	5504ab	1164a	44	57abc	42ab
Metolachlor+Metobromuron	1.5+1.5	Imazaquin 0.2	10.00a	9.17a	13.33	24.43	29.30a	6.62a	9.12bcdef	5148abcd	2501b	46	54abc	42ab
Metolachlor+Prometryne	1.0+1.0	-	8.67ab	8.00a	12.33	24.37	28.30abc	4.59ab	10.37bcdef	5097abcd	1250b	47	52abc	43ab
Metolachlor+Prometryne	1.0+1.0	SHW 6 WAS	9.00ab	8.67a	11.00	22.87	27.53abcd	3.30ab	8.06def	5236abcd	2190b	43	52abc	43ab
Metolachlor+Prometryne	1.0+1.0	0.5+0.5	7.67b	7.17b	10.67	22.77	27.83abcd	6.76a	8.57cdef	4927abcd	2157b	52	46bc	39b
Metolachlor+Prometryne	1.0+1.0	Imazaquin 0.2	9.33ab	9.00a	12.67	23.37	25.93cd	4.66ab	9.14bcdef	5264abcd	1336b	41	52abc	42ab
Alachlor + diuron	1.5+0.8	-	8.67ab	9.00a	11.33	22.53	27.57abcd	3.29b	5.34ef	4459abcd	1473b	55	52abc	44a
Alachlor + diuron	1.5+0.8	SHW 6 WAS	7.67b	8.50a	11.33	22.17	27.77abcd	2.83b	4.77ef	3694abcd	2512b	54	60ab	43ab
Alachlor + diuron	1.5+0.8	0.75+0.4	9.33ab	8.67a	11.00	25.10	27.75abcd	4.34ab	16.97abc	3659bcd	1716b	51	42c	43ab
Alachlor + diuron	1.5+0.8	Imazaquin 0.2	9.33ab	9.00a	12.00	26.87	29.00a	4.09ab	7.8def	6300a	1000b	53	49bc	42ab
Metolachlor + diuron	1.5+0.8	-	9.33ab	8.67a	13.33	22.80	28.50abc	3.84ab	8.83bcdef	3904abcd	1285b	40	47bc	43ab
Metolachlor + diuron	1.5+0.8	SHW 6 WAS	9.33ab	8.33a	12.33	24.80	27.10abcd	3.50ab	18.77a	26.12cd	1285b	43	53abc	42ab
Metolachlor + diuron	1.5+0.8	0.75+0.4	9.00ab	8.83a	11.33	23.50	27.77abcd	2.63b	5.98def	2481d	1086b	42	50abc	42ab
Metolachlor + diuron	1.5+0.8	Imazaquin 0.2	9.00ab	10.00a	11.33	24.80	28.30abc	2.69b	8.37cdef	5760ab	927b	49	55abc	42ab
Fluazifop-butyl+Imazaquin	0.5+0.2	Overall 3 WAS	10.00a	9.00a	12.33	25.50	28.63ab	4.65ab	9.76bcdef	4969abcd	960b	56	65a	43ab
Fluazifop-butyl+Imazaquin	0.5+0.2	directed 3 WAS	10.00a	8.50a	11.67	23.97	28.33abc	5.61ab	17.41ab	5048abcd	861b	50	56abc	40ab
Fluazifop-butyl+Imazaquin	1.0+0.2	Overall 3 WAS	9.67a	9.67a	11.67	23.93	26.30bcd	5.15ab	7.06def	4108abc	1116b	46	56abc	42ab
Fluazifop-butyl+Imazaquin	1.0+0.2	directed 3 WAS	9.67a	9.00a	13.33	25.53	28.17abc	6.78a	3.37f	4218abcd	1120b	50	60ab	43ab
Hoe-weeding at 3 & 6 WAS	3 & 6	WAS	9.67a	8.67a	13.00	25.67	26.87abcd	5.40ab	6.6def	5322abc	1396b	46	54abc	44a
Untreated control			10.00a	5.93b	11.67	25.17	25.33d	5.39ab	9.05bcdef	3976abcd	1178b	50	61ab	40ab
SE ±			0.594	0.646	0.799 NS	1.527 NS	0.788	0.994	5.070	845.078	553.037	5.070 NS	5.285	1.374

[1]WAS = Weeks after sowing. NS = Not significant
Means followed by the same letter(s) within treatment are not significantly different at 5% level of Duncan Multiple Range Test (DMRT)

2. Crop vigour score, where 0 represented dead plant and 10 represented the most vigorous plant.

resulted in higher crop vigour score than the least obtained. At 9 WAS, crop vigour score was only significantly depressed on the untreated plots compared with the best treatment (Table 12).

4.3.3 Plant height

Plant height was only significantly affected by weed control treatments at harvest (Table 12). Metolachlor plus prometryne followed by imazaquin, fluazifop-butyl plus imazaquin at 1.0+0.2 kg a.i/ha applied overall and the untreated control resulted in significantly shorter plants than the tallest obtained with metolachlor plus metobromuron and alachlor plus diuron, each followed by imazaquin at 0.2 kg a.i/ha.

4.3.4 Leaf dry weight

At 6 WAS, mixtures of diuron with alachlor and metolachlor each at 0.8+1.5 kg a.i/ha, either alone or followed by supplementary hoe-weeding, resulted in significantly lower leaf dry weight than the highest obtained with mixtures of metolachlor with metobromuron and prometryne at 1.5+1.5 and 1.0+1.0 kg a.i/ha followed by imazaquin at 0.2 kg a.i/ha and half the rate, respectively and fluazifop-butyl plus imazaquin at 1.0+0.2 kg a.i/ha applied directed (Table 12). At 9 WAS however, the mixture of metolachlor plus metobromuron at 1.5+1.5 kg a.i/ha, alachlor plus diuron at 1.5+0.8 kg a.i/ha, both either followed by half the rate or

supplementary hoe-weeding and fluazifop-butyl plus imazaquin applied directed or overall at 0.5+0.2 kg a.i/ha resulted in leaf dry weight comparable to the maximum obtained with metolachlor plus diuron at 1.5+0.8 kg a.i/ha followed by supplementary hoe-weeding and higher than the least leaf dry weight obtained with fluazifop-butyl plus imazaquin at 1.0+0.2 kg a.i/ha applied directed.

4.3.5 Leaf area

At 6 WAS, plants from the plots treated with metolachlor plus metobromuron supplemented with hoe-weeding and half the rate at 3 WAS and metolachlor plus diuron at 1.5+0.8 kg a.i/ha followed by imazaquin at 0.2 kg a.i/ha 3 weeks later and those hoe-weeded twice had leaf area that were comparable with the highest obtained from alachlor plus diuron at 1.5+0.8 kg a.i/ha followed by imazaquin at 0.2 kg a.i/ha at 3 WAS and significantly higher than those of the untreated control (Table 12). At 10 WAS, however, metolachlor plus metobromuron followed by supplementary hoe-weeding resulted in significantly higher leaf area than all the other treatments.

4.4 Effect on cowpea yield and yield attributes

4.4.1 Pod number/ha

Only plots hoe-weeded twice had pod number that

was comparable to the highest obtained with metolachlor plus metobromuron at 1.5+1.5 kg a.i/ha followed by supplementary hoe-weeding (Table 13). Mixtures of metolachlor with metobromuron and prometryne each at 1.5+1.5 and 1.0+1.0 kg a.i/ha followed by imazaquin at 0.2 kg a.i/ha and mixtures of diuron with alachlor and metolachlor, each at 0.8+1.5 and 0.8+1.5 kg a.i/ha followed by supplementary hoe-weeding also resulted in significantly higher pod number than the untreated control. Uncontrolled weeds throughout crop life cycle reduced pod number by 60.81% compared with the highest obtained in the trial.

4.4.2 Pod weight per ha.

The highest pod weight/ha was obtained with metolachlor plus metobromuron at 1.5+1.5 kg a.i/ha followed by supplementary hoe-weeding (Table 13). Both the hoe-weeded control and metolachlor plus diuron followed by imazaquin at 0.2 kg a.i/ha resulted in pod yields that were comparable to the maximum obtained. The other treatments with supplementary imazaquin application and its mixture with fluazifop-butyl, except at 0.5+0.2 kg a.i/ha applied overall, also resulted in higher pod weight than that of the untreated control. Though the least value was obtained from alachlor plus diuron at 1.5+0.8 kg a.i/ha alone, uncontrolled weeds throughout the crop life-cycle resulted in 73.11% reduction in pod weight compared with the highest obtained.

Table 13: Effect of weed control treatments on seed yield and yield attributes of cowpea at Samaru, 1987

Herbicide Treatments	Rate kg a.i/ha	followed by (fb)	Weight of Haulm (kg/ha)	Pod wt. per plot (Kg/ha)	No. of pods/ ha.	No. of seed per pod	Wt. of 1000 seeds (gm)	Seed yields (kg/ha)
Metolachlor+Metobromuron	1.5+1.5	-	833cd	1089c-g	1016cd	8bcd	126.60b	966bcd
Metolachlor+Metobromuron	1.5+1.5	6 WAS	1755a	2384a	2106a	12a	130.00ab	2136a
Metolachlor+Metobromuron	1.5+1.5	0.75+0.75	1111abcd	1118c-g	1190bcd	9abcd	139.00ab	1004bcde
Metolachlor+Metobromuron	1.5+1.5	Imazaquin 0.2	1660ab	1678bcd	1497bc	10ab	131.20ab	1490bc
Metolachlor+Prometryne	1.0+1.0	-	644cd	1122c-g	980cd	9abcd	135.80ab	984cde
Metolachlor+Prometryne	1.0+1.0	6 WAS	1300abcd	1184b-g	948cd	9abcd	131.20ab	1042bcde
Metolachlor+Prometryne	1.0+1.0	0.5+0.5	555d	1123c-g	966cd	9abcd	138.00ab	995bcde
Metolachlor+Prometryne	1.0+1.0	Imazaquin 0.2	1388abc	1716bcd	1454bc	10abc	141.60ab	1441bc
Alachlor + diuron	1.5+0.8	-	644cd	1049d-g	1017cd	9abcd	132.50ab	1110bcde
Alachlor + diuron	1.5+0.8	6 WAS	1022abcd	1425b-f	1521bc	8bcd	155.10a	1266bcd
Alachlor + diuron	1.5+0.8	0.75+0.4	1111abcd	747e-g	991cd	9abcd	122.10ab	669de
Alachlor + diuron	1.5+0.8	Imazaquin 0.2	744cd	170bcd	1088bcd	6d	139.70ab	1624ab

Table 13 Contd.

Herbicide Treatments	Rate kg a.i/ha	followed by (fb)	Weight of Haulm (kg/ha)	Pod wt. per plot (kg/ha)	No. of pods/ ha.	No. of seed per pod	Wt. of 1000 seeds (gm)	Seed yields (kg/ha)
Metolachlor + diuron	1.5+0.8	-	833cd	640g	1443bc	6d	137.50ab	555e
Metolachlor + diuron	1.5+0.8	6 WAS	922bcd	1059def	1035bcd	7bcd	138.20ab	944cde
Metolachlor + diuron	1.5+0.8	0.75+0.4	1300abcd	1494b-e	1399bcd	9abcd	135.00ab	1290bcd
Metolachlor + diuron	1.5+0.8	Imazaquin 0.2	1300abcd	1811abc	1349bcd	11ab	136.40ab	1520ab
Fluazifop-butyl+Imazaquin	0.5+0.2	Overall 3 WAS	1300abcd	1415bcd	1217bcd	8bcd	129.90b	1241bcd
Fluazifop-butyl+Imazaquin	0.5+0.2	Directed 3 WAS	922bcd	1672bcd	1374bcd	8bcd	135.80ab	1445bc
Fluazifop-butyl+Imazaquin	1.0+0.2	Overall 3 WAS	1388abc	1600bcd	1363bcd	8bcd	131.80ab	1395bc
Fluazifop-butyl+Imazaquin	1.0+0.2	Directed 3 WAS	922d	1567bcd	1354bcd	8bcd	130.10ab	1274bcd
Hoe-weeding	3 WAS	6 WAS	1388abc	1872ab	1644ab	9abc	139.90ab	1506bc
Untreated control	-	-	555d	791e-g	825d	7bcd	129.40b	545e
SE ±			0.205	222.281	185.390	1.034	0.646	19.372

[1] WAS = Weeks after sowing
Means followed by the same letter(s) with treatment are not significantly different at 5% level of Duncan Multiple Range Test (DMRT).

4.4.3 Number of seeds per pod

Except when it followed alachlor plus diuron, supplementary application of imazaquin resulted in seed number per pod that was comparable to the highest obtained with metolachlor plus metobromuron followed by supplementary hoe-weeding. These treatments also resulted in significantly higher number of seeds per pod than the least obtained with metolachlor plus diuron alone (Table 13).

4.4.4 Weight of 1000 seeds

Except metolachlor plus metobromuron alone and alachlor plus diuron followed by half the rate, fluazifop-butyl plus imazaquin at 0.5+0.2 kg a.i/ha overall and untreated control, all the other treatments had similar weights of 1000 seeds, that were also comparable in value to the maximum obtained with alachlor plus diuron at 1.5+0.8 kg a.i/ha followed by supplementary hoe-weeding (Table 13).

4.4.5 Grain Yield

The highest cowpea yield was obtained with the mixture of metolachlor plus metobromuron at 1.5+1.5 kg a.i/ha followed by supplementary hoe-weeding (Table 13). Mixtures of diuron with alachlor and metolachlor each at 0.8+1.5 kg a.i/ha followed by imazaquin at 0.2 kg a.i/ha resulted in comparable grain yield to that of

the best herbicide treatment and significantly higher than the least produced with the untreated control. The other treatments involving post-emergence application of imazaquin as a supplement to pre-emergence herbicides or as mixture with fluazifop-butyl, also resulted in significantly higher grain than the untreated control. Alachlor plus diuron followed by hoe-weeding, metolachlor plus diuron at 1.5+0.8 kg a.i/ha followed by half the rate and the hoe-weeded control also resulted in significantly higher grain yield than the untreated control. Uncontrolled weed growth throughout the crop life-cycle resulted in 74.5% reduction in cowpea grain yield compared with the maximum obtained in the trial.

Figure 3 shows cowpea yield as per cent of the untreated control obtained with different supplementary weed control to pre-emergence herbicides. Although supplementary hoe-weeding gave the highest yield, in general, supplementary application of imazaquin consistently increased yield and was better than the hoe-weeded control when it followed metolachlor plus prometryne and alachlor plus diuron. The least yield advantage was obtained with split application. Post-emergence application of fluazifop-butyl plus imazaquin resulted in yields average that were comparable to the hoe-weeded control.

4.4.6 Haulm weight

In addition to the hoe-weeded control, mixtures of

metolachlor with metobromuron at 1.5+1.5 kg a.i/ha and prometryne at 1.0+1.0 kg a.i/ha, each followed by imazaquin at 0.2 kg a.i/ha and fluazifop-butyl plus imazaquin at 0.5+0.2 kg a.i/ha applied overall resulted in haulm yields that were comparable to the highest obtained from metolachlor plus metobromuron followed by supplementary hoe-weeding and significantly higher than the untreated control (Table 13). Mixture of metolachlor with metobromuron and prometryne, each either followed by supplementary hoe-weeding or imazaquin, also resulted in higher haulm weight than the same pre-emergence herbicide treatments without supplementary weed control methods. The supplementary application of imazaquin to all the pre-emergence herbicide treatments, except alachlor plus diuron, resulted in haulm yields that were comparable to the highest.

4.4.7. Relationship between various parameters and cowpea grain yield in the weed control studies.

The number and weight of pods/ha, number of seeds/pod, 1000-seed weight, plant height at harvest, crop vigour at 9 WAS, leaf dry weight at 6 WAS, leaf area at 10 WAS and haulm dry weight at harvest were significantly positively correlated with cowpea yields (Table 14). Weed cover score at 9 WAS and weed dry weight were also negatively correlated with cowpea grain yield (Table 14).

Table 14: Correlation of various parameters and cowpea grain yield in the weed control studies at Samaru in 1987 wet season

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
1	1.00															No. of leaves per plant
2	0.495**	1.00														Cowpea grain yield
3	0.516**	.362*	1.00													Pod weight per /ha
4	0.285	.314*	.082	1.00												No. of pods per /ha
5	.705**	.458**	.51**	.357**	1.00											No. of seeds per po
6	.809**	.591**	.464**	.435**	.781**	1.00										Weight of 1000 see
7	.335*	.409**	.266	.187	.565**	.51**	1.00									Plant height at harvest
8	.528**	.377*	.283	-.052	.563**	.701**	.517**	1.00								Crop vigour score at 9 WAS
9	.447**	.305*	.228	-.017	.404**	.515**	.155	.560**	1.00							Stem dry weight at 3 WAS
10	-.48**	-.386*	-.426**	-.168	-.495*	-.389**	-.159	-.198	-.258	1.00						Weed cover score at 9 WAS.
11	-.554**	-.444**	-.335*	-.305*	-.619**	-.642**	-.661**	-.518**	-.482**	-.395*	1.00					Cumulative weed dry weight
12	.482**	.352*	.26	.375*	.292	.302*	.482**	.403**	.341*	.105	.145	1.00				Leaf dry weight a 6 WAS
13	.206	-.007	-.028	.458**	.123	.51**	.615**	.398*	.401**	.701**	.515**	.539**	1.00			Haulm dry weight
14	.358*	.475**	.295*	.03	.222	.421**	-.162	.33*	.203	.096	.522**	.288	.005	1.00		Leaf area at 10 W
15	.108	.063	.271	-.04	.208	.173	-.082	.13	.34*	.337*	.023	.171	-.023	.171	1.00	Stand count at ha

* Significant at 5% level of probability (R^2 = 0.294)
** Significant at 1% level of probability (R^2 = 0.380)

1 = Number of leaves per plant
2 = Cowpea grain yield
3 = Pod weight per /ha
4 = Number of pods per /ha
5 = Number of seeds per pod
6 = Weight of 1000 seeds
7 = Plant height at harvest
8 = Crop vigour score at 9 WAS
*9 = Stem dry weight at 3 WAS
10 = Weed cover score at 9 WAS
11 = Cumulative weed dry weight
12 = Leaf dry weight at 6 WAS
13 = Haulm dry weight
14 = Leaf area at 10 WAS
15 = Stand count at harvest.

CHAPTER 5

DISCUSSION

The maximum yield of dry cowpea seeds of 2136 kg/ha obtained in the weed control trial during the study compares favourable with the range of 1.5 to 3 t/ha reported earlier in Nigeria by other workers (Moody,1973; Raheja and Hayes, 1975; Warui, 1979; Lagoke et al., 1982; Akobundu, 1973; Poku and Akobundu, 1983; Lagoke and Shebayan, 1987). The yield obtained in the trial is higher than the average yield of 1406 kg/ha reported for the same variety (Ife Brown) at Samaru, Zaria, Nigeria by Ortese (1984). The seeming superiority in the yield obtained may be attributed to the more efficient weed control method, i.e. chemical supplemented by hoe-weeding, used in this study. Similarly, in the weed interference trial, the maximum grain yield of cowpea of 1598 kg/ha was less than that obtained from the weed control trial. Olorukooba (1987) who obtained similar results with ginger attributed the lower yield from hand weeding, compared with herbicide to frequent disturbance of the crop during the manual weeding. Chinaka and Enyinnia (1975) earlier reported that the early elimination of weeds by herbicides at the vital stage of cowpea growth, when the crop was least resistant to adverse condition, could be the cause of increase in the yield and yield attributes and growth of the crop.

Moody (1973) also observed that hand-weeding is carried out after the weeds have exerted depressive effect on cowpea yield.

5.1 Effect of period of weed intereference on cowpea

The non-significant weed dry matter production during the first 3 weeks of crop growth reflected in the weed dry matter weight of plots kept weed-infested for 3 WAS only, agrees with Adigun (1984) in pepper, Bakut (1985) in maize-pepper mixture and Bulus (1987) in potato. They reported that provided weeds were subsequently removed, infestation for the first 3 WAS did not have adverse effect on the growth and yield of the crops. This was probably because weed had not established well enough to compete seriously with the crop at this stage. In contrast, both the crop growth parameters viz: crop vigour, leaf dry weight, leaf area and yields and yield attributes of cowpea were depressed by weed infestation until 6 WAS or more. Weed dry matter production from the plots was significantly high. Rapid weed growth occured between 3 and 9 WAS. This result conforms with that obtained by Ayeni (1982) and Fadayomi (1985) who both reported that cowpea yield was significantly reduced when weeds were associated with the crop for 6 WAS. Keeping the crop weed-infested for 9 WAS and subsequently removing the weeds did not obviate growth and yield depression of the crop compared with that weed-infested till harvest. Weed dry matter production

from plots kept weed-infested for 9 WAS and more did not differ significantly from those infested throughout and their subsequent removal was therefore not expected to alleviate crop growth and yield. On the other hand, although significant reduction in crop yield was also caused by weed infestation for 6 WAS, compared with the weed-free treatments, subsequent weed removal after 6 WAS, resulted in higher yield than the crop kept weed-infested throughout and similar to that kept weed-free for 3 WAS only. Crop kept weed-infested for a further 3 weeks beyond 6 weeks had the highest weekly loss of 244 kg/ha of cowpea grain yield while those kept weed-free for a further 3 weeks beyond 6 weeks resulted in the highest weekly gain of 63 kg/ha. The period between 3 and 9 WAS represents the period of maximum weed growth and critical period of competition with the crops in the trial. This result agrees with that of Medrano et al. (1973) and Ayeni (1982) who both reported that the critical period of weed competition occurs during the first 40 days of the crop growth. On the other hand a weed-free period for the first 30 days of growth will be required for optimum yield. This result is very important in the designing of a weed control strategy for cowpea especially if pre-emergence herbicides will be used. Any treatment that can effectively control weeds during this period will be desirable. While good yield can be obtained with effective weed control up to 6 WAS of crop growth, supplementary

weed control until 9 weeks will go a long way to ameliorating yield loss in the variety of the cowpea used as indicated in this trial. This probably accounts for the results obtained in the weed control trial where increased yields were obtained with supplementary weed control treatments compared with the pre-emergence herbicide treatments alone.

Crop kept weed-free initially for 3 weeks only had comparable leaf dry weight, crop vigour and leaf area and cowpea grain yield to those kept for 6, 9, 12 weeks but lower cowpea grain yield than that kept weed-free till harvest. In this trial, cowpea grain yields appeared to increase as the weed-free period increased, although not significantly in all cases. Also up to 12 WAS, crop yield decreased as the initial period of weed-infestation increased. These results agree with that of Reminson (1978) who reported that cowpea grain yields decreased with weeds intsnsity. The additional stress caused by the pulling of established weeds on the plots weed-infested until 12 WAS coupled with the fact that the competition with weeds was too late to be ameliorated was responsible for the seemingly lower yield with infestation until 12 WAS compared with infestation throughout. Keeping the cowpea plots weed-free for 3 weeks and leaving them unweeded till maturity of the crop resulted in mean cowpea grain loss of 20.2%

compared with the yield from weed-free check-plots. In this trial, weed association with the crop until 12 WAS resulted in 74.2% reduction in the total cowpea grain yield compared with the best obtained with the crop kept weed-free until harvest.

5.2 Effect of weed control treatments on cowpea.

All the weed control treatments significantly reduced weed cover until 9 WAS although pre-emergence alachlor plus diuron applied alone had higher weed cover than the least obtained with diuron plus metolachlor followed by half the rate, diuron plus alachlor followed by supplementary hoe-weeding and both rates of fluazifop-butyl plus imazaquin applied overall at 3 WAS. The highest weed dry matter production was not obtained with the unweeded control because most of the plants had senscenced at harvest when the weed sample was taken. Generally, plots without supplementary weed control to the primary weed control treatment had higher weed dry matter production resulting from broad leaf weeds like Vernonia sp. although the effect was not significant. The less effective weed control observed with the directed post-emergence application of fluazifop-butyl plus imazaquin compared with overall application may be attributed to the fact that the directed application did not cover the weed within the crop rows. As reflected in the weed dry matter production, supplementary application of

imazaquin at 0.2 kg a.i/ha to pre-emergence herbicides was comparable to supplementary hoe-weeding in performance. Similarly, Akobundu (1984) reported improvement in weed control and grain yield in cowpea with imazaquin applied post-emergence at 0.025 to 1.25 kg a.i/ha.

Except where the mixtures of metolachlor with metobromuron and diuron were followed by half the initial rate, supplementary weed control further reduced weed weight compared with pre-emergence control alone. Many workers have reported the beneficial effect of supplementary weed control to pre-emergence application in enhancing season long weed control and consequently comparable crop yield, (Adigun, 1984; Akobundu, 1984; Bakut, 1985; Gworgwor, 1985; Adejonwo et al., 1987; Lagoke and Shebayan, 1987). This is probably because pre-emergence herbicides by themselves at the rates applied did not persist long enough in the soil to take care of later emerging weeds. As reflected in the results, despite significant reduction in weed infestation observed at 9 WAS, the herbicide treatment produced differential effect on cowpea yield. This may be due to the differential residual effect of the various herbicide treatments. The high weed dry matter production obtained with many of the herbicide treatments where supplementary weed control was not done may be attributed to the later broadleaf weed infestation of the crop following effective control of grasses. It is significant to note that in this trial, supplementary removal of weeds and

application of imazaquin resulted in lower weed dry matter when they followed all the pre-emergence application.

In this trial, metolachlor plus metobromuron followed by supplementary hoe-weeding was outstanding, resulting in very high crop vigour, tall plants, high leaf dry weight and area, high number of pods, seeds per pod and high pod weight and seed yield. Seed yield with this treatment was only equalled by the mixtures of diuron with metolachlor and alachlor each followed by supplementary application of imazaquin at 0.2 kg a.i/ha. Even yields of plots hoe-weeded twice had significantly lower seed yield compared with the maximum obtained. Although supplementary hoe-weeding improved the performance of pre-emergence herbicide generally, metolachlor plus metobromuron (galex) performed better. Perhaps cowpea tolerates this mixture of herbicides better than the other mixtures.

Among the herbicide treatments, only metolachlor plus metobromuron had improved yield with supplementary hoe-weeding. No improvement in yield was obtained with other herbicide mixtures when supplementarily hoe-weeded. Lagoke and Shebayan (1987) earlier reported that metolachlor plus metobromuron at 1.5+1.5 kg a.i/ha, especially when followed by supplementary hoe-weeding, consistently resulted in good weed control and high

cowpea yields comparable to two hoe-weedings. Although Lagoke and Shebayan (1988) reported improvement in yield when pre-emergence herbicides are followed by supplementary hoe-weeding as indicated in this study, supplementary hoe-weeding however indicated improvement in cowpea seed yield only when it followed mixtures of metolachlor with metobromuron and prometryne and mixtures of alachlor with diuron.

Supplementary application of imazaquin was observed to improve the yield of cowpea in all the herbicide mixtures although only significantly when it followed mixtures of diuron with alachlor and metolachlor. It is significant to note that all the plots treated with supplementary imazaquin resulted in significantly higher cowpea yield than the untreated control. It therefore seems that imazaquin, applied at 0.2 kg a.i/ha at 3 WAS, could serve as a possible substitute for supplementary hoe-weeding at 6 WAS for season long weed control in cowpea and consequently high yield of the crop. Many investigators have reported very effective weed control and crop selectivity and consequently high yield in cowpea and soyabean when imazaquin was applied at 0.25+ 0.4 kg a.i/ha post-emergence (Poku and Akobundu, 1983; Oneil et al., 1985; Retzinger and Rogers, 1985; Gofung, 1987).

Except metolachlor plus diuron, split application of the herbicide mixtures resulted in similar cowpea

seed yield to the untreated control. The remaining herbicide treatments of split application did not differ significantly from the untreated control probably due to crop injury resulting from the higher rates,, particularly those of alachlor plus diuron. This result is suggestive of the detrimental effect of the use of the higher rates of alachlor plus diuron in the crop. Though injurious to the crop, the mixtures of metolachlor with prometryne and diuron, unlike the mixtures of alachlor with diuron, did not cause depression of the yields.

Post-emergence application of mixtures of fluazifop-butyl plus imazaquin at 0.5+0.2 and 1.0+0.2 kg a.i/ha either directed or overall, at 3 WAS, had similar cowpea grain yields and various comparable growth parameters. Without supplementary weed control, the post-emergence application of fluazifop-butyl plus imazaquin gave sufficient weed control that enabled the crop produce as much yield as two hoe-weedings control in this investigation.

Weed infestation of plots throughout the crop life cycle significantly depressed growth parameters like crop vigour, leaf production, height and yield and yields attributes. Cowpea seed yield reduction due to the untreated check was about 74.5% compared with the maximum obtained in the trial. The result conforms with earlier reports by many other investigators who obtained between 20 and 90% loss in yields of cowpea due to

uncontrolled weeds throughout its life cycle (Medrano et al. 1973; Moody, 1973; Akobundu, 1978; Lagoke et al., 1982; IITA, 1977; Gofung, 1987; Lagoke and Shebayan, 1988).

5.3 Relationship between various parameters and yield of cowpea in the weed interference and control studies

The significant positive correlation between cowpea grain yield and growth characters such as leaf dry weight and crop vigour may be attributed to the fact that these vegetative characters directly determined the amount of photosynthates available for plant growth and grain yield. This agrees with the findings of Singh et al., (1982) and Tenebe (1987) in which a highly significant and positive correlation between grain yield and vegetative growth was obtained.

The highly significant and positive correlation between number of pods, pod weight, number of seeds per pod and 1000 seeds weight with grain yield revealed these as important yield components and critical determinants of cowpea grain yield. The result obtained indicated that weed interference for 9 WAS reduced grain yield not by reducing seed per pod but by reducing pod weight/ha and seed size. Also increased yield by "galex" at 3.0 kg a.i/ha was not due to improved seed size but due to increase in number of pods/ha and number of seeds/pod. The results conform

with the studies elsewhere by Aryeetey and Liang, 1973; Chauhuan and Joshi, 1980; Oliveira et al., 1982; Singh et al., 1982; Tenebe, 1987, in which the number of seeds per plant and 1000 seed weight were found to be important yield components of cowpea.

CHAPTER 6

SUMMARY AND CONCLUSIONS

Two experiments were conducted during the 1987 wet season at Samaru (11^{o} $11^{'}$ N, 7^{o} $38^{'}$ E) in the Northern Guinea Savanna of Nigeria to study the effects of period of weed interference and weed control on (*Vigna unguiculata* (L.) Walp).

In the weed interference trial, ten periods of weed interference were laid out in a randomised complete block design in three replicates. One set of treatments consisted of plots kept weed-free initially for 3, 6, 9 and 12 weeks after sowing and subsequently weed-infested till harvest, while the other set consisted of plots kept weed-infested initially for 3, 6, 9 and 12 weeks after sowing and subsequently kept weed-free till harvest. Two treatments of weed-free and weed-infested throughout the crop life cycle were also included as controls.

In the weed control study, 18 herbicide treatments were compared with two hoe-weedings at 3 and 6 WAS and an unweeded control in a randomised complete block design with three replications. The herbicide treatments consisted of three metolachlor based mixtures viz: metolachlor plus metobromuron at 1.5+1.5 kg a.i/ha, metolachlor plus prometryne at 1.0+1.0 kg a.i/ha, and metolachlor plus diuron at 1.5+0.8 kg a.i/ha and alachlor

plus diuron at 1.5+0.8 kg a.i/ha, all applied pre-emergence, alone or followed by either hoe-weeding at 6 WAS or post-emergence application at 3 WAS of half the pre-emergence rate of the mixture or imazaquin at 0.2 kg a.i/ha at 3 WAS and post-emergence application of mixtures of fluazifop-butyl plus imazaquin at 0.5+0.2 and 1.0+0.2 kg a.i/ha at 3 WAS either directed or overall.

In the weed interference trial, weed-infestation initially for 3 WAS did not adversely affect cowpea growth yield and yield attributes, as reflected in the crop vigour score, leaf dry weight, leaf area and pod weight and number, seed yield and size of the crop. Similarly, no significant weed dry matter production occured during the first 3 weeks of crop growth as reflected in the result of the weed dry weight. In contrast with the crop growth parameters, yields and yield attributes of cowpea were depressed by weed infestation from 6 WAS. Weed dry matter production of the plots weed-infested for 6 weeks and more, were significantly higher than the least obtained with those kept weed-free for various periods and those weed-infested for 3 WAS. Subsequent weed removal after initial infestation for 9 WAS did not ameliorate weed infestation and the depression in the growth and yield of cowpea compared with weed infestation till harvest. Keeping the crop weed-free throughout the life-cycle

[illegible] and lowest weed weight.

Though significant reduction in crop yield was also caused by weed infestation for 6 WAS, compared with the weed-free treatment, subsequent weed removal after 6 WAS, resulted in higher yield than the crop kept weed-infested throughout and similar to that kept weed-free for 3 WAS only. Crop kept weed-infested for a further 3 weeks beyond 6 weeks i.e. till 9 WAS had the highest weekly loss of 244 kg/ha of cowpea grain yield while those kept weed-free for a further 3 weeks beyond 6 weeks resulted in the highest weekly gain of 63 kg/ha. The most rapid weed growth apparently occured between 3 and 6 WAS and the critical period of weed competition with the crop at 3 and 9 WAS in this trial. Any treatment that can effectively control weeds during this period will therefore be desirable while maximum yield can be obtained by keeping the crop weed-free for 15 weeks of the life-cycle of the crop.

In the weed control experiment, all the herbicide treatments significantly reduced weed infestation until 9 WAS. Among the weed control treatments, metolachlor plus metobromuron at 1.5+1.5 kg a.i/ha followed by supplementary hoe-weeding at 3 WAS gave effective weed control resulting in vigorous cowpea growth and significantly higher cowpea yield than the hoe-weeded control. Among the herbicide treatments, pre-emergence mixtures of diuron with metolachlor and alachlor at 0.5+1.5 kg a.i/ha respectively, followed by post-emergence application of imazaquin at 0.2 kg a.i/ha at 3 WAS,

resulted in comparable cowpea seed yield to the highest obtained with metolachlor plus metobromuron followed by supplementary hoe-weeding. The other treatments with supplementary post-emergence imazaquin at 0.2 kg a.i/ha and mixtures of fluazifop-butyl plus imazaquin at 0.5+0.2 and 1.0+0.2 kg a.i/ha, applied alone, either directed or overall, resulted in significantly higher cowpea grain yield than the untreated control. Other weed control treatments which also caused higher seed yield than the untreated control included two hoe-weedings, metolachlor plus metobromuron at 1.5+1.5 kg a.i/ha and alachlor plus diuron at 1.5+0.8 kg a.i/ha, each followed by supplementary hoe-weeding at 6 WAS and metolachlor plus diuron at 1.5+0.8 kg a.i/ha applied pre-emergence followed by imazaquin at 0.2 kg a.i/ha at 3 WAS. For supplementary hoe-weeding, mixtures of metolachlor with prometryne and diuron at 1.0+1.0 and 1.5+0.8 kg a.i/ha respectively, the treatments did not differ significantly from that of the unweeded control. With the exception of metolachlor plus diuron, all the other plots treated with half the rate of the pre-emergence herbicide mixtures produced cowpea seed yields that were comparable to those of the untreated control. Except when followed by metolachlor plus metobromuron, supplementary hoe-weeding did not result in significantly higher cowpea yield compared with the pre-emergence treatment alone. These herbicide treatments differentially depressed cowpea growth vigour, plant height, leaf dry weight and leaf area.

Uncontrolled weed growth throughout the crop life cycle resulted in significant depression of crop growth parameters such as crop vigour, plant height, leaf production and caused cowpea seed yield reduction by 74.2% in weed interference and 74.5% in weed control trial.

The conclusions that may be drawn from these results are:

(i) Pre-emergence herbicides, at the rate at which they were applied did not persist long enough in the soil as to take care of later emerging weeds. Thus supplementary weed control in the form of either hoe-weeding or post-emergence application of another herbicide was required.

(ii) Where labour is scarce, supplementary post-emergence application of imazaquin may be a suitable substitute.

(iii) Post-emergence application of the mixture of fluazifop-butyl without any supplementary weed control holds high potential for weed control in cowpea.

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Z Appendix 1: Common, chemical and trade names, LD_{50}, and solubility of the herbicides mentioned in the text.

Common Name	Chemical Name	Trade Name	LD_{50}	Solubility
Alachlor	2-chloro-2,6-diethyl -N-(methoxy-methyl) acetamide.	LASSO	1800mg/kg	148ppm
Diuron	3-(3,4-dichloro-phenyl) -1-dimethylurea	Karmex	3400mg/kg	42ppm
Fluazifop-butyl	butyl(2-(4-(5 trifluoro methyl-2-pyridyloxy) phenoxy propionate acid.	Fusilade	4350mg/kg	22ppm
Imazaquin	(2-(4-isopropyl-4-methyl-5-oxo-2-imidazoline-2-yl) quinoline-3-carboxylic acid.	Scepter		
Metobromuron	(3-(-4-bromophyl-1-methoxy-1-methylurea.	Patoran	3000mg/kg	330ppm
Metolachlor	2,chloro-N-(2,ethyl-6-methylphenyl)-N-(2, methoxy-1-methylethyl)	Dual	2535mg/kg	530ppm
Prometryne	2,4-diliso-propylamino-6-methylthio-1- 3, 5-triazine.	Gyesagurd	3750mg/kg	48ppm

Appendix 2: Fitted values for cowpea grain yield and weed dry matter production (kg/ha)

PERIOD IN WEEKS	COWPEA		Weed Dry Matter Production.	
	INITIALLY WEED-FREE	INITIALLY WEED-INFESTED	INITIALLY WEED-FREE	INITIALLY WEED-INFESTED.
0				
3	1234.15	1305.25	122.06	17.22
6	1381.60	1222.00	74.84	121.06
9	1350.00	706.00	44.35	222.76
12	1344.00	286.00	30.58	322.32
15	1564.75	486.00	33.53	419.73

Appendix 3: Values of regression coefficient for fitted curves on cowpea grain yield and weed dry matter production.

	COWPEA		Weed Dry Matter Production.	
	INITIALLY WEED-FREE	INITIALLY WEED-INFESTED	INITIALLY WEED-FREE	INITIALLY WEED-INFESTED
a	706	430	186	515
b	786	1530	-72.3	-94.2
b_2	-291.6	-742.5	8.361	-1.07
b_3	33.75	87.75		

Appendix 4: Means squares from analysis of variance for crop vigour score and stand count as affected by period of weed interference at Samaru in 1987 wet season.

Source of Variation	DF	Crop Vigour Score at 6 WAS	Crop Vigour Score at 10 WAS	Stand Count at Harvest
Replication	2	0.7000	1.658	13.434
Treatment	9	10.074**	9.237**	8.874
Residual	18	0.662	0.889	21.504
Total	29			

Appendix 5: Means squares from analysis of variance for leaf area as affected by period of weed interference at Samaru in 1987 wet season.

Source of Variation	DF	Leaf Area at 6 WAS	Leaf Area at 9 WAS
Replication	2	199632	1.345*
Treatment	9	4.965*	788075
Residual	18	963534	393287
Total	29		

* F value significant at 5% level of probability

** F value significant at 1% level of probability

WAS = Weeks after sowing.

Appendix 6: Means squares from analysis of variance for leaf dry weight as affected by period of weed interference at Samaru in 1987 wet season.

Source of Variation	DF	Leaf dry weight at 9 WAS
Replication	2	66.468
Treatment	9	103.604
Residual	18	50.521
Total	29	

Table 7: Means squares from analysis of variance for weed dry matter production as affected by period of weed interference at Samaru in 1987 wet season.

Source of Variation.	DF	Weed dry matter production
Replication	2	11641
Treatment	9	48076**
Residual	18	7172
Total	29	

* F value significant at 5% level of probability

** F value significant at 1% level of probability.

Appendix 8: Means squares from analysis of variance for haulm dry weight as affected by period of weed interference at Samaru in 1987 wet season.

Source of Variation	DF	haulm dry weight
Replication	2	0.132998
Treatment	9	0.208231
Residual	18	0.12
Total	29	

Appendix 9: Means squares from analysis of variance for cowpea seed yield and yields components as affected by period of weed interference at Samaru, in 1987 Wet Season.

Source of Variation	DF	Number of pods per hectare	Weight of pods per hectare	Number of seeds per pod	Weight of 1000 seeds	Seed weight
Replication	2	176643**	1.565*	4.229	2.995	940834**
Treatment	9	191452**	828593**	3.025	2.812	604942**
Residual	18	26796.1	162387.3	3.417	1.323	33177.6
Total	29					

* F value significant at 5% level of probability

** F value significant at 1% level of probability

Appendix 10: Means squares from analysis of variance for weed cover score (grasses, broadleaf and sedges) cumulative weed weight as affected by weed control treatments at Samaru in 1987 wet season.

Source of Variation	DF	Weed Cover Score at 6 WAS (Grasses)	(Broadleaf)	(sedges)	Weed dry matter Production
Replication	2	2.015**	5.773	1.697*	2472.86
Treatment	21	1.735**	4.505*	2.815**	5172.41 NS
Residual	42	0.332	3.778	0.474	3567.58
Total	65				

Appendix 11: Means squares from analysis of variance for crop vigour score as affected by weed control treatments at Samaru in 1987 wet season.

Source of Variation.	DF	Crop Vigour Score at 6 WAS	9 WAS
Replication	2	11.106	0.235
Treatments	21	1.426	2.125
Residual	42	1.058	1.249
Total	65		

* F value significant at 5% level of probability

** F value significant at 1% level of probability

Appendix 12: Means squares from analysis of variance for stand count as affected by weed control treatments at Samaru in 1987 wet season

Source of	DF	1 Stand count at		
		1 WAS	6 WAS	Harvest
Replication	2	43.8828	218.742	1.01953
Treatment	21	71.2872	86.2024	5.38058
Residual	42	77.1	83.774	5.665
Total	65			

Appendix 13: Means squares from analysis of variance for plant height as affected by weed control treatments at Samaru in 1987 wet season.

Source of Variation.	DF	Plant height at		
		3 WAS	6 WAS	9 WAS
Replication	2	8.19336	171.053	3.50781
Treatment	21	2.0823	5.15234	2.77511
Residual	42	1.915	6.989	1.864
Total	65			

* F value significant at 5% level of probability

** F value singifincant at 1% level of probability

WAS = Weeks after sowing.

Appendix 14: Means squares from analysis of variance for leaf dry weight as affected by weed control treatments at Samaru in 1987 wet season.

Source of Variation	DF	Leaf dry weight 6 WAS	9 WAS
Replication	2	2.95203	8.26099
Treatment	21	4.85407	50.7427**
Residual	42	2.963	20.455
Total	65		

Appendix 15: Means squares from analysis of variance for leaf area as affected by weed control treatment at Samaru in 1987 wet season.

Source of Variation	DF	Leaf Area 6 WAS	9 WAS
Replication	2	2.9504E+06	3.30042E+06
Treatment	21	3.19696E+06	1.88161E+06*
Residual	42	2.14181E+06	9.7172
Total	65		

* F value significant at 5% level of probability

** F value significant at 1% level of probability

WAS = Weeks after sowing.

Appendix 16: Means squares from analysis of variance for cowpea seed yield and yield components as affected by weed control treatments at Samaru in 1987 Wet Season.

Source of Variation.	DF	Number of pods per hectare	Weight of pods per hectare	Number of seeds per pod	Weight of 1000 seeds	Seed weight
Replication	2	344360	69356	3.213	0.475	21580
Treatment	21	263883**	537442**	5.351	1.305	416842**
Residual	42	103077	148182	3.203	1.25	108489
Total	65					

Appendix 17: Means squares from analysis of variance for haulm dry weight as affected by weed control treatments at Samaru in 1987 wet season.

Source of Variation	DF	haulm dry weight
Replication	2	1.724
Treatment	21	1.305
Residual	42	1.25
Total	65	

* F value significant at 5% level of probability

** F value singificant at 1% level of probability

WAS = Weeks after sowing.

BIOGRAPH

NAME	TIMOTHY TSUWE SULE (MR)
DATE OF BIRTH:	1 . 12 . 40
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PREVIOUS ACADEMIC QUALIFICATIONS

INSTITUTION ATTENDED	FROM	TO	CERTIFICATE/DEGREE AWARDED
Mt. St. Michael's Secondary School	1955	1960	W.A.S.C.
Pest Control Officers' Course, Zaria	March 1961	Feb. 1962	On-the-job-training
Self Improvement.			
Kansas State University Manhattan U.S.A	1980	1982	B.Sc. (Agriculture)

POST(S) HELD SINCE AWARD OF FIRST DEGREE

ORGANISATION	POSITION	FROM	TO
Ministry of Health, Zaria	Asst. Control Officer (Trg)	1961	1962
"	Asst. Control Officer	1963	1964
"	Control Officer	1965	1971
Federal Livestock Dept, Kaduna	Higher Control Officer	1972	1974
Federal Livestock Ogoja.	Senior Control Officer	1975	1976

ORGANISATION	POSITION	FROM	TO
Ministry of Agriculture, Makurdi.	Principal Agric. Supt. II (Pest Control)	1977	1979
"	Principal Agric. Supt. I	1980	1982
"	Asst. Chief Agricul-ture Officer	1982	1984
"	Deputy Chief Agriculture Officer	1985	date

YEAR OF ADMISSION FOR POSTGRADUATE STUDIES: 1987

REGISTRATION NUMBER: M.Sc./Agric./12333/87