STUDIES ON WEED INTERFERENCE AND CONTROL IN COTTON (*Gossypium* hirsutum L.)/COWPEA (unquiculata L. (Walp.)] MIXTURE AT SAMARU, NIGERIA

BY

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CERTIFICATION

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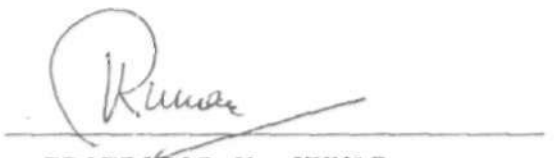
DECLARATION

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 in any previous publication for a higher degree.



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DEDICATION

This work is dedicated to my beloved mother, late RUKAYYATU ADAMU YAKUBU, who answered thecall ofthe Almighty Allah on the 27th June, 1992. May her soul rest in perfect peace in FIRDAUSI, AMEEN.

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ABSTRACT

Field experiments were conducted during the 1987, 1988 and 1989 cropping seasons on the farm of the Institute for Agricultural Research, Samaru (11°, 11[1]N; 07° 38[1]E), to evaluate the effects of period of weed-interference and weed control on the performance; of 3:1 replacement population cotton/cowpea mixture.

The losses caused by weed-infestation throughout the life cycle of the crops in the three seasons were averaged at 96.2% for seed cotton and 90.1% for cowpea grain yields, compared with those kept weed-free throughout. Weed-infestation throughout the crop life cycle also reduced the yield components, namely flower and boll counts of cotton, by 85 to 94.8%, pod count of cowpea by about 80.4%, as well as dry matter of cotton and cowpea crops by about 78.2% and 82.0%, respectively.

Regression of cotton/cowpea mixture's yields on weed dry matter indicated that, every 1 kg increase in weed weight, reduced seed cotton and cowpea grain yields by 0.19 kg/ha and 0.2kg/ha, respectively.

The critical period of weed competition in cotton/cowpea mixture was between 3 and 6 weeks after sowing cotton (WASC) using cotton as top canopy crop grown in the traditional "Gicci" system. The most effective herbicide treatment in this mixture was alachlor plus diuron at 1.0 + 0.4 kg a.i./ha followed by (fb) supplementary hoe-weeding (SHW) at 6 WASC, which out-yielded two hoe-weedings by 9.1% and the weedy check by 90.3% in terms of seed cotton yield. This treatment, however, resulted in seed cctton yield that was 13% lower than that of three hoe-weedings. In component cowpea, alachlor plus diuron at 1.0 + 0.4 kg a.i./ha fb SHW gave grain yield that was higher than those of two

and three hoe-weedings,and the weedy check by 27.5%, 16.2% and 80.6%, respectively.

Revenue realised in excess of chemical weed control cost was N7,685/ha, compared with N6,215.00 for three hoe-weedings, and N5,495.00, for two hoe-weedings.

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CHAPTER 1

INTRODUCTION

Mixed cropping system is the practice of growing two or more crops in mixture, simulteneously on the same piece of land, whereby inter-row and intra-row competition prevails. In Nigeria, this practice is common among the traditional farmers of the savanna region. This is because, the system ensures flexibility in the use of labour, risk distribution, better utilization of land, capital and consistent annual returns. In addition, it checks sporadic spread of weeds and diseases, thereby reducing their cost of control and improving the quality of the crop's produce (Okigbo and Greenland, 1976).

Traditional farmers in the cotton growing zones of the Nigerian savanna, usually inter-crop their cotton crop with cowpea using the "Gicci" system (Anon., 1977). This is a traditional practice of planting crops at equidistant and at right angle to each other in order to minimise inter-row and intra-row competition. Cotton which is the main crop in this mixture, is planted in June/July and inter-cropped with cowpea 2 to 5 weeks later.

The cotton lint is a source of raw material to the textile industries and also to the local weavers. The cotton fuzz is used for rope making and surgical absorbent. Cowpea on the other hand, provides a balanced diet containing protein to the farmer, while the cowpea haulms and seeds of cotton are

used for livestock fattening (Anon., 1978). The cowpea crop is reported to fix 60 to 70 kg N/ha in the soil, which could be absorbed by either the deep rooted crop like cotton or any succeeding cereal crop like sorghum (Rachie, 1985). The photosensitive cowpea which trails on the soil surface, may probably have its yield unaffected by the upright cotton, as possible competition for moisture, light and nutrient is minimised. The important insect pests infesting cotton viz. The red boll worms and the coreid bugs on cowpea pods are susceptible to cymbush (cypermethrine). Therefore it become logical to control these insects using the same insecticidal sprays, especially at flowring stage of cotton and cowpea crops (fisher et al., 1987).

Cotton/cowpea mixture in the Guinea savanna has consistently yielded about 35% more than sole cotton (Raheja et al., 1982).

Cotton is an extremely slow growing crop, during the first 7 weeks, and is known to attain full canopy in 10 - 12 WAS (Kumar et al., 01985). However, most aggressive weeds like Cynodon species and Cyperus species, infesting the crop reached full canopy in a period of only 3 - 9 WAS (Burns and Buchanan, 1968). Consequently, severe weed-infestation in cotton fields could result in yield loss ranging from 71 to 79% (Dadari et al., 1983; Laçoke et al., 1985). Weed species infesting cotton at initial and later part of the crop's life

cycle, include grasses, sedges and broadleaved weeds. These fast growing weeds, could smoother the young cotton seedlings, impede the effectiveness of insecticidal sprays, impair the quality of farm produce and compound the problem of bush fire in the destruction of the entire crop or its mixture (Lagoke et al., 1985).

In the Nigerian savanna, cowpea is extensively grown mostly in mixture with other crops as the last arable crop before the end of the rainy season. Although the yield potential of the crop is as high as 3.0 t/ha, (Raheja and Hayes, 1975; Warui, 1979). The actual yield, however, ranges between 0.2 and 0.3 t/ha (Anon., 1978). Heavy biotic pressure particularly weeds, are some of the constraints affecting production and can cause yield reduction of 53 to 90% (Lagoke and Shebayan, 1987). Cowpea tolerates weed competition more successfully than many tropical crops, because of its more rapid establishment and growth.

The critical period of weed-competition in cotton lies between 4 and 6 WASC, while in cowpea it lies between 6 and 9 WASC (Dadari et al., 1987; Sule, 1988).

Crop weed competition in sole cotton and sole cowpea, may not be the same with that of cotton/cowpea mixture due to variation in their time of planting and stages of growth. Effective weed control, throughout the life cycles of cotton or cowpea will ensure adequate moisture and nutrient for flowering, boll and pod formations (Lagoke and Choudhary,

1982).

Hoe-weeding which is labour intensive, tedious, costly and inefficient, is the most common method of weed control in mixed cropping system (Anon., 1988). In Nigeria, the scarcity and high cost of manual labour, has made the use of herbicides an alternative weed control practice in sole crop cotton or cowpea. The use of alachlor, metolachlor, norflurazon or diuron was found to be comparable to two hoe-weedings and very profitable (Fisher and Lagoke, 1982). However, there is need to evaluate these herbicide combinations in cotton/cowpea mixture as the two crops may have different levels of tolerance to the herbicides.

In view of the above, field experiements were undertaken with the following objectives:

1. To study the effect of period of weed interference and determine the critical period of weed competition in cotton/cowpea mixture.
2. To evaluate the performance of some herbicides for selective weed control in cotton/cowpea mixture.

CHAPTER 2

LITERATURE REVIEW

2.1 The Savanna region

The savanna ecological zone of Nigeria covers an estimated area of about 550,851 km^2, between latitude 6°27' - 14°N; longitude 2°44' - 14°42'E of Greenwich. It is divided into the southern Guinea, the northern Guinea, the Sudan, and the Sahel savanna.

The major rainfall peaks occur during June - July and also September south of latitude 09°N; northwards these converge to give a single wet season with a maximum precipitation in August. The common characteristic of the rainfall is a gradual increase in the amount of precipitation, in successive ten days period with the advance of the rainy season (Kowal and Kassam, 1978). The beginning of the rainy season, is usually faced with low soil moisture due to in frequent rainfall and high evaporative demand, making land preparation and cropping practice difficult (Kowal and Kassam, 1978). The performance of a crop in this region is thus affected by how well its life cycle fits into the prevailing growing season. A crop like cowpea whose growth period is short performs well, if other factors are not limiting (ECK, 1986). Rainfall starts differently within the savanna region, for example, March/April in southern Guinea; May/June in northern Guinea, June/July in the Sudan and Sahel savanna. Due to the variation in the rainfall pattern of the region,

the peasant farmers grow numerous crops at different times of the growing season. The variation in the climate of the region has encouraged the farmers to adopt mixed cropping in order to avoid crop failure in case of abrupt cessation of rain in the Sahel/Sudan savanna and to make efficient use of long growing season in the Guinea savanna. Adequate moisture supply during the reproductive phase of crops is very important (Salter and Goode, 1967; Kiniry and Musser, 1988) and in the savanna both the amount and the distribution of rainfall in August seem to be very important determinants in the final crop yield (Kowal and Kassam, 1978). The agroecological suitability of the savanna region has encouraged the production of cereals, fibre, legumes and other crops in the crop mixtures. Livestock production of cattle, sheep, goats and birds is practised for meat and cash returns. In turn, the residue and trashes of the farm produces are fed directly to them.

2.2 "Gicci" system of planting

Plants in a community interact with each other, when it is between plants of different species, it is often referred to as "Inter-specific" interaction (Willey and Health, 1969). This will also depend on the relative time of sowing, the arrangement on cropping pattern and the proportion of the crops grown in mixture ('Harper, 1961; Donald, 1963; Khan et al., 1974). Thus, for the small scale farmers in the savanna sub-region, intercropping patterns and efficient management

is very vital both for maximum returns and for his farming enterprise.

The "Gicci" system is a practice of growing crop in widely spaced rows at equidistant and proportionately parallel at right angle to themselves, which might be cereal, fibre or legume intercropped later, in order to minimise inter and intra-row competition. The aim of this system is to develop cropping pattern that would make the most productive use of the current rainfall; to enhance the provision of present and future food, feed and fibre requirements of the local people and the market potentialities of the community.

From a village to village survey, it was understood that most farmers in this region plant cereal-cereal mixture (sorghum-millet, sorghum-maize or sorghum-finger millet, etc.), cereal-legume mixture (Maize-cowpea; Groundnut-maize, etc.), fibre-legume mixture (cotton-cowpea or cotton-groundnut, etc.), within the savanna region. The majority of the small scale farmers in the savanna region do practice any of the above mixtures under "Gicci" system, after realizing its benefits (Anon., 1988).

Baker (1982) reported that the major management constraint to the small scale farmer was labour, and the "Gicci" mixed cropping was more efficient in labour utilization than sole cropping. Fisher (1984) reported that in the "Gicci" system, mixtures of maize-groundnut -

cowpea-cotton, resulted in higher returns than sole crops of groundnut in a three years trial, conducted at Samaru. He further concluded that crop spacing affected the productivity of the system, and that sowing cereals every 1.37m significantly reduced groundnut yield compared with sowing at 2.74m in the "Gicci" system (Baker, 1975 and 1978). Farmers in the savanna region have been practising mixed cropping using the "Gicci" system,with little emphasis on experimental procedures, which they believed are cumbersome in execution and evaluation and practically unrealiable to follow.

2.2.1 Importance of mixed cropping

Mixtures result in more efficient utilization of environmental resources (light, water, nutrients, temperature, etc.) by the plants of different height, canopy spread, nutrient requirements, and maturity (Anon., 1983). In addition, diseases and insect pests may not spread as rapidly in mixtures because of differential susceptibility to the pests and pathogens. Mixed cropping provides insurance against crop failure, because if a component crop fails, the other may not. Farmers also prefer mixed cropping, because it provides a steady supply of a range of products for the family and helps to spread labour costs more evenly, throughout the cropping season. Mixed cropping may be used to suppress weeds, thereby reducing the cost of weed control and improving the quality of product (Okigbo and Greenland, 1976). The savanna agro-ecological zone is conducive for the production of varied

crops, especially under the "Gicci" system (Anon., 1980).

Cotton/cowpea mixture, has consistently yielded about 35%, more than the sole crop cotton, as judged by relative total yield in the Guinea savanna zone of Nigeria (Raheja et al., 1982). This system is widely spread on localized pattern in the savanna zone of Nigeria, especially where cotton crop is produced successfully. The SAMCOT, 6 and cowpea Kano, 1696 can be successfully intercropped for optimum yield. Highest yields of cotton and reasonable yields of cowpea can be obtained on the same ridge (Anon., 1988).

2.3 Competition

2.3.1 Nature of competition

The formation of wide row spacing, the prevailing of wetting/drying cycles, cloudy and high relative humidity conditions are associated with increase in weed population and growth. Cotton grows very slowly, producing less (gm) dry weight/plant during the first seven weeks after sowing (WAS) [(Kumar et al., 1982a and 1982b)]. There is therefore a need for a weed-free seedbed during this early period of growth. The presence of weeds during flowering and boll formation stages of cotton, compete with the crop for moisture, light and nutrients.

After boll formation and during crop maturity, weeds strongly compete with cottor for moisture, which is usually limiting during the cessation of rains at the end of the growing season (Faulkner and Smithson, 1972; Kumar et al.,

1982b). Weeds can also impede the impact of insecticidal sprays, by covering the cotton plant when spraying. Weeds in cotton can shed seeds and leaf debris on the open cotton bolls; thus reducing the quality of the cotton produced (Klingman and Ashton, 1975). Dry season fire (bush burning) is a common practice among the village dwellers, therefore a very weedy cotton field can be proned to fire, thus result in yield losses.

Seed cotton yield losses ranging from 50 - 96%, due to severe weed-infestation has been reported in Nigeria (Anon., 1981). A decrease of one (1) kg dry weed weight, has resulted an increased seed cotton yield of 0.7 kg/ha (Kumar et al., 1982b). Studies by Ivy and Baker (1972), Buchanan and Crowley (1977), have shown that the competition of prickly sida with cotton can cause a yield reduction of up to 41%, while Prentice (1972) and 'Horowitz (1973) also indicated a seed cotton yield reduction of 74%, due to weed competition. Buchanan and Burns (1970) recorded a considerable decrease in cotton plant height, when the crop was infested with pig weed (Amaranthus retroflexus L.) cocklebur (Xanthium pensylvanicum L.) and tall morning glory (Ipomea purpurea L.). They further found that, the presence of weeds in cotton could result in yield reduction due to decrease in boll number, boll and seed weights, however, stand of cotton was not affected by weed competition.

Crowther (1943) reported that delaying the first weeding in cotton till eight weeks after sowing resulted in 30%, loss in seed cotton yield. In the Sudan, delaying the first weeding until six weeks reduced the seed cotton yield by 75%, and additional weeding later, had little effect since it only increased yield by 20% (Kerkhoven, 1964). The same author while working in the poorly drained soil of Kafue flat in Zambia, found an increase of 74% in cotton yield from the crop weeded at six weeks. Delay in the removal of weeds till two weeks after sowing can lead to a linear decrease in plant height, boll number and seed cotton yield (Singh and Singh, 1971). In another study conducted by Beltrao et al. (1974) at Paraiba and Per Nambuco State, South America, they found that yield losses in cotton due to weed competition, was greatest during the first eight weeks or more and the plant height, boll number and leaf number were reduced. The high demand for both moisture and nutrients eight weeks after sowing cotton crop has necessitated weed removal at flowering stage (Lawes, 1968).

Faulkner and Smithson (1972) while working at Samaru, reported that after boll formation and during crop maturity the presence of weeds strongly compete with the crop for moisture which becomes limiting at the end of the rainy season. Marthinez and Nieto (1968) reported that maximum spring cotton yield in Mexico required a weed-free period of 60 days after emergence and that no yield loss occur if weeds

were removed within 30 days of emergence. Thomas and Schwerzel (1970) found that weeds emerging after hand cultivation at four to eight weeks of crop emergence, did not reduce seed cotton yield. Drennan and Jenings (1977) while working in the Sudan Gezira, reported that the critical period of weed competition in cotton occurred between four to ten weeks after crop emergence. In Colombia, South Africa, the critical period of weed competition in cotton is between three and six weeks after sowing (Chaves, 1970). According to Rogers et al. (1976), cotton has two to four weeks weed-free requirement where Amaranthus retroflexus L.was the dominant weed. Full season weed competition in June - July sown cotton crop,is reduced by 62 - 74% (per cent) seed cotton yield (Dadari et al., 1987) in Nigeria savanna. The critical period of weed competition in the June sown cotton and the July-sown cotton was between 4 - 6 WAS and 2 - 6 WAS, respectively (Dadari et al., 1987).

2.3.2 Weed competition in cowpea

Grain yield losses due to uncontrolled weed in cowpea in Nigeria ranged from 53 to 8[illegible]% (Moody, 1973; Remison, 1978; Akobundu, 1980; Lagoke et al., 1982; Lagoke and Shebayan, 1987). Losses in cowpea grain yield of 75%, due to the infestation of Euphorbia heterophylla L., has been reported (IITA, 1977). In addition to competition for various factors of production, weeds also reduce root production and nodule formation of cowpea and also harbour insects and plant

diseases, thus compounding the losses due to weeds (Moody and Whitney, 1974; Fadayomi, 1979). In another report by Ayeni (1983), he observed a significant grain yield reduction when weeds were allowed to infest the crop for at least six weeks in the early season. Weeds compete with cowpea for nutrient, moisture, light, space and also show a faster rate of root elongation and development than the crop (Fadayomi, 1979; Ayeni et al., 1984). Elimination of weeds, should therefore be expected to save yield losses due directly to competition and indirectly as hosts for insects, pests and pathogens (Akinyemiju, 1987; Akinyemiju and Echendu, 1987). The greatest loss in crop yield due to the presence of weeds, occurred during the critical period of the crop growth, when it is most susceptible to weed competition (Nieto et al., 1968). Several investigators have suggested that, cowpea is most critically affected by weed competition during the first 30 - 40 days of its growth (Fadayomi, 1979; Ayeni, 1983). In the Nigerian savanna, the critical period of weed-interference with cowpea crop lies between 6 and 9 WAS (Sule, 1988).

2.4 Weed control

The compatibility of component crops in mixtures have assisted in the supression of weeds as long as the environmental conditions are favourable. The utilization of crops with the spreading morphology like cowpeas, in mixture with cereals or fibre crops may reduce the competitive effects

of weeds (Litsinger and Keith, 1976). This happen, because a more complete cover is provided by the mixture, which reduces light penetration to the soil, which in turn reduces weed growth. Weed control by cultural and mechanical practices such as hoe-weeding, use of bullocks and tractors depend to a large extent on the type of crops in the mixture and their pattern of planting. Fisher and Lagoke (1982) reported that the use of hand tools such as hoe for weed control in mixtures was found to be more effective than mechanical weeding with ox or tractor drawn power. The use of herbicides as reported by (Anon., 1984) has shown an increased advantage in groundnut/millet mixture.

2.4.1 CHLOROACETAMIDES

The chloroacetamide herbicides have monochloronated methyl in their R-1 position (Gleen et al., 1975) which determines selective control of seedling grass and certain broadleaved weeds in field crops. These are more effective in the control of grasses than broad-leaved weeds. Such herbicides are normally applied pre-emergence to the weeds and crops with some post-emergence activities (Anderson, 1977).

Chloroacetamide herbicides are less affected by variation in soil moisture, organic matter, and can be readily leached in sandy soils. The herbicides are absorbed and translocated in the apoplast and symplastic movement (Klingman et al., 1975). The herbicides are known to inhibit mitochondrial

phosphorylation, mitotic cell division, cause disarrangement of cells and reduce respiration in susceptible species. Jarworski (1956) reported that, the chloroacetamides inhibit the activity of Sulphdryl-containing enzymes involved in respiration and also stop plant growth.

2.4.1.1 Alachlor

Alachlor [(2 - chloro - 2, 6 - diethyl-N-methoxymethyl acetamide] is a cream coloured solid and relatively insoluble in water with about 148 ppm solubility at 25°C (Martins and Charles, 1971). It is formulated as an emulsifiable concentrate (EC) and granules. Alachlor is used as pre-emergence herbicide to control annual grasses and certain annual broadleaved weeds in maize, groundnut, cowpea, cotton, tomato, etc. (Lagoke et al., 1982).

Alachlor is primarily absorbed by the shoots of the emerging seedlings and secondarily by the crops' roots from where it is translocated throughout the plant. It also inhibits protein synthesis in susceptible plants (Anon., 1967). Uptake and translocation of alachlor was greater under higher temperature in young weed seedlings and rapidly metabolised (Robert et al., 1980). In cotton, early uptake of alachloroccurred in the root tissue (Eshel, 1968) while in giant foxtail (Setaria faberi Herrm.) absorption is in the region above the plant seed (Knake and Wax, 1968). In yellow nutsedge alachlor absorption is largely in the tissue (Stem and rhizome/root) as reported by (Armstrong et al., 1973).

Alachlor can be lost by volatilization under high temperature and relative humidity (Hargrove and Merkle, 1971). Tolerance of common bean to alachlor is marginal and depends on cultivars, herbicide placement, temperature, and soil moisture (Cieslar and Burning, 1974; Putnam and Rice, 1979). It was reported by Hammerton (1971), that alachlor at 1.7 kg a.i./ha gave 6 weeks long effective weed control without crop damage. Akobundu (1979), observed that, pre-emergence application of alachlor caused severe injury on crops when the application was made to moist rather than dry soils. Toro and Sion (1976) stated that the best yield of seed cotton was obtained, when alachlor at 1.15 kg a.i./ha plus diuron at 1.0 kg a.i./ha were applied pre-emergence. In field trials at Surutin, Brazil; Azevedo et al. (1978) reported that, best weed control and highest seed cotton yield were obtained with alachlor plus diuron at 1.0 + 1.0 kg a.i./ha applied pre-emergence. The efficacy of alachlor at higher rates gave high crop growth and yield, and lower weed dry matter (Anon., 1981). In another report by Keeley et al. (1987) alachlor at 1.68 - 3.36 kg a.i./ha gave 60 - 80% control of Cyperus esculentus L. for 6 weeks and all plots controlled with the herbicide gave higher yields of seed cotton than manually weeded plot. Bryson and Dale (1985) reported that application of granules, containing alachlor and metolachlor did not give good control of Sorghum halepenses L. and cotton yields were significantly higher than from the

untreated plots. On a sandy loam soil, alachlor and diuron caused more injury to cotton crop at 2.5 + 1.2 kg a.i./ha, but resulted in higher seed cotton yields when compared to metolachlor plus cynazine treated plots (Anon., 1984). It was observed that, alachlor plus diuron at 2.0+0.8kg a.i./ha followed by supplementary hoe-weeding at Samaru, resulted in effective control of weeds in cotton as well as in cowpea crops (Anon., 1984; Lagoke et al., 1988).

In Zambia, Chilanga Research Station, alachlor at1.8 kg a.i./ha gave a very good control of grasses and also suppressed good number of broadleaved weeds while at 3.8 kg a.i./ha, it was toxic to legumes (Anon., 1978). Toxicity effect was observed on cowpea with treatments which include alachlor above 1.0 kg a.i./ha. In India, Hosmani and Hosmani (1984) observed that alachlor at 2.0 kg a.i./ha applied pre-emergence was effective in controlling weeds in cowpea without detrimental effect on the crop but the high rate of 4.0 kg a.i./ha was toxic. Jain et al. (1985) observed that alachlor at 3.0 kg a.i./ha gave an effective control of weeds in cowpea. In the southern Guinea savanna zone of Nigeria (Mokwa) alachlor applied at the rate of 1.5 and 3.0 kg a.i./ha depressed crop vigour in cowpea (Lagoke et al., 1981). At Samaru alachlor at 3.0 kg a.i./ha gave a significant reduction in grass weeds as compared with the weedy check without adverse effect on cowpea stand (Lagoke et al., 1981c).

2.4.1.2 Metolachlor

Metolachlor

[2-Chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxy-1-methylethyl) acetamide] is marketed by the trade name 'DUAL' and formulated as an emulsifiable concentrate (E.C.) is mainly applied pre-emergence in crops (Klingman and Ashton, 1975). It has a solubility of 530 ppm in water at 20°C. Metolachlor is a germination inhibitor, active mainly on grasses at the rates of 1.0 - 2.5 kg a.i./ha and also on sedges and broad-leaved weeds depending on soil and climatic conditions (Martins and Worthing, 1977). It is selective in cotton, maize, pepper, peanuts and gives effective weed control in cowpea when applied solely (Anon., 1977). A broader spectrum of weed control to include broadleaved species is possible, if metolachlor is combined with other herbicides (Dill and Dunford, 1978; Peak, 1980; Lagoke et al., 1982). It has a residual activity of 8 - 12 weeks depending on soil and climatic conditions. Metolachlor has been introduced as a grass weed herbicide, especially effective against weeds of the genera, Setaria, Echinochloa, Panicum and Digitaria sp. (Gerber et al., 1974). It acts by altering the membrane structures at the biochemical and histological levels (Ebert, 1980). At used rates on sandy loam soils, metolachlor provided 8 weeks control (Buchholz et al., 1981) of weeds. Mobility of Metolachlor could increase through leaching down to 45 cm depth (Bouman, 1988) and

absorption/bioactivity of this herbicide was found to be correlated with organic matter and clay content (Jerome and Peter, 1982). Metolachlor is reported to inhibit lipid synthesis, protein synthesis, root elongation and plant growth (Zimdahl and Clark, 1982).

In an experiment conducted at Samaru, metolachlor plus terbutryne at 2.0 + 1.0 kg a.i./ha resulted in low bolls but high seed cotton yields (Anons., 1984). In another report by Lagoke et al. (1982a) metolachlor at 1.5 kg a.i./ha had significantly higher broad-leaved weed weight than the weedy check. It was further reported that metolachlor at 1.5 kg a.i./ha and its mixture with prometryne, diuron and metobromuron at 1.0, 8.0 and 1.0 kg a.i./ha were comparable to that of the hoe-weeded control. Cornelius et al. (1976) reported that pre-emergence application of metolachlor at 3.36 kg a.i./ha gave effective control of Cyperus esculentus (L.). In Uganda, metolachlor at 3.0 kg a.i./ha, reportedly gave 54 to 77% and 72 to 77% control of broadleaved and grassy weeds at 6 WAS. In another experimenttagged pre-extension of herbicide application in cotton in Benin, Gaborel (1987) reported that 160g of metolachlor plus 240g of dipropetryne gave highly significant yields in cotton seed, ranging from 288 - 611 kg/ha. Yields of seed cotton were excellent when both broadleaved and grassy weeds were controlled with metolachlor at2.5 kga.i./ha (Keeling et al., 1989).

Field trials indicated that metolachlor applied pre-emergence at 2.24 to 3.36 kg a.i./ha gave good control of weeds in cowpea (Jensen, 1978; Murphy and Marrow, 1979). Metolachlor at rates ranging from 2.0 to 3.0 kg a.i./ha, was well tolerated by cowpea and gave excellent weed control in cowpea, resulting in yields that were comparable to weed-free or hoe-weeded check (Akobundu, 1978; Lagoke et al., 1982). In trials conducted in 1980 and 1984 seasons, metolachlor plus metobromuron (Galex) at 1.0 + 1.0 and 1.5 + 1.5 kg a.i./ha, especially when followed by supplementary hoe-weeding, consistently resulted in good weed control and high cowpea grain yields comparable to two and three hoe-weedings (Lagoke et al., 1988). Fadayomi et al. (1979) reported that 2.5 kg a.i./ha, of metolachlor alone was only comparable in weed control and cowpea seed yield to two hoe-weedings. Metolachlor at 0.5 and 1.0 kg a.i./ha, alachlor at 1.0 and 2.0 kg a.i./ha, all at pre-emergence application reduced weed dry matter and gave an average cowpea grain yield of 1.9 t/ha and the number of pods/plant increased with yield (Masood, 1988). Lagoke et al., 1982) reported that application of pre-emergence metolachlor plus diuron at 1.0 + 0.5 and 1.5 + 1.0 kg a.i./ha, resulted in significantly lower weed scores until harvest, high crop vigour score at 8 WAS and high cowpea grain yield than the untreated control. Kure (1981) also reported that metolachlor plus diuron at 1.5 + 0.8 kg a.i./ha, combined effective weed control with high crop yield of cowpea at

Samaru.

2.4.2 SUBSTITUTED UREA

By substituting three of the hydrogen atoms of urea with other chemical groups, such as phenyl, methyl and methoxy groups, substituted derived herbicides are formed (Klingman and Ashton, 1975). These are of low water solubility, formulated as wettable powders, containing 80% of active ingredient (80 WP). Such herbicides are principally used for the selective pre-emergence control of weed seedlings in certain field crops and non-selective control of annual and perennial weeds. Substituted ureas are usually absorbed to the soil colloids and resist leaching and remain in the upper 25 cm of the soil layer at the level applied for selective weed control in cropland. 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 (Klingman and Ashton, 1975). Most urea herbicides are readily absorbed by the roots and rapidly translocated to the upper parts via the apoplastic movement. Demethylation, dealkylation, demethoxylation, deaminization and decarboxylation, all are responsible for detoxification of urea herbicides (Ashton and Crafts, 1973). Inhibition of photosynthesis is acknowledged as the primary site of action of the urea herbicide. This in turn prevents the formation of ATP and NADPH, which are required for CO_2 fixation, thus inhibiting Hill reaction.

2.4.2.1 Diuron

Diuron [3-(2,4-dichlorophenyl)-1,1-dimethyl urea] is marketed under the trade name "KARMEX" which has a water solubility, of 42 ppm at 25°C, contains 80% active ingredient (Hodge, 1967). Diuron is lost more rapidly in moist than dry soils (Sheets and Crafts, 1957) and insoils at high temperature (Talbert and Fletchall, 1964). Diuron at the rate of 1 - 2 kg a.i./ha, had its phytotoxicity concentration reduced from the soil within 28 - 56 WASC, under humid conditions (Hills et al., 1955) and movement of this herbicide is restricted to the top 15 cm of soil with small amount being leached below this depth (Leonard et al., 1974; Khan et al., 1975). Degradation of diuron occurred by means of microbial activity (Sheets, 1964). Diuron is used pre-emergence at low rates for the selective control of germinating broadleaved weeds and grasses in crops such as cotton, cowpea, pears, ginger, citrus (Lagoke et al., 1982; Anon., 1983; Lagoke and Shebayan, 1987). In a field trial in Ecuador, Toro et al., (1972) reported that, the most economic weed control in cotton was diuron plus alachlor at 1.5 + 1.5 kg a.i./ha. In another trial in Tanzania in 1970, diuron applied at 1.0 and 2.0 kg a.i./ha, caused slight chlorosis in cotyledons. Buendia et al. (1976) in a cotton trial in Brazil, obtained the best result by pre-emergence application of diuron at 2.0 kg a.i./ha, on silty loam soil. Pre-emergence application of diuron at 0.75 kg a.i./ha, gave 78% control of weeds and

highest net return (Ahlawat, 1978). Arle and Hamilton (1977) reported effective weed control in cotton, when diuron mixed with trifluralin were applied to cotton at pre-emergence. Hurst and Smith (1978), reported that Butralin plus diuron at 2.25 kg a.i./ha, gave an excellent control of Sorghum halepense L. in cotton, when applied pre-emergence. Hamdoun and Babiker (1978) reported that pre-emergence application of diuron, gave a satisfactory weed control during the early stage of cotton growth and additional hoe-weeding 6 WAS is necessary. Sherift et al. (1974) reported that diuron at 2.0 kg a.i./ha applied pre-emergence controlled weeds and increased seed cotton yield. Bazam (1976) reported that, diuron at 2.5 kg a.i./ha applied post-emergence controlled grass weeds for 10 weeks. In India, it was reported that, effective weed control and highest seed cotton yields were obtained with normal hand-weedings followed by diuron at 0.75 kg a.i./ha, pre-emergence and 0.75 kg a.i./ha, post-emergence (Gomase et al., 1986). In field trials at Surubim, Azevedo et al. (1981), reported that, highest yields of seed cotton were obtained with 1.5 kg diuron and was as efficient as two hoe-weedings. Brar and Gill (1985) in an experiment on pre- and post-emergence herbicides for weed control in cotton reported that, diuron at 0.8 kg a.i./ha, applied pre-emergence effectively controlled annual weeds. Jain and Jain (1975) conducted rainfed trials and reported that, 65 - 85% control of weeds was obtained with pre-emergence and

post-emergence application of diuron at 0.75 kg a.i./ha each and resulted to the highest seed cotton yield of 1.7 t/ha. Early application of diuron is desirable for the control of weeds in cotton at Mokwa, Daudawa and Samaru (Lagoke et al., 1985). Diuron applied singly or mixed with alachlor and also in combination with inter row cultivation, was more effective than herbicides alone or ccnventional methods; seed cotton yield was markedly increased (Jain et al., 1982). Diuron at 0.75 - 1.5 kg a.i./ha, gave over 90% control of weeds, double the yield of seed cotton compared with the unweeded control and was as good as six hand-weedings (Ahlawat, 1974). In another report by Ansari (1988) diuron plus MSMA at 2.0 kg a.i./ha + 1.0 litre/ha produced 2.0 t/ha seed cotton yields. In a field trial on cotton at Samaru (Lagoke et al., 1985) reported that, mixtures of metolachlor plus diuron at 1.5 + 0.8 kg a.i./ha, and alachlor plus diuron at 1.0 + 0.4 kg a.i./ha, were effective in the control of weeds and resulted in high cowpea grain and seed cotton yields respectively (Lagoke et al., 1988). At Mokwa, diuron at 1.6 kg a.i./ha, combined good weed control with high grain yield of cowpea (Lagoke et al., 1981c).

2.4.2.2 Norflurazon

Norflurazon [(4-chloro-5-methylamino-2-(3- α,α,α trifluoromethylphenyl) pyridazone-3-one)] is formulated as a wettable powder containing 80% active ingredient under the trade name "Zorial". It is applied pre-emergence and the

residues persist in soils with low organic matter. Herbicide problems associated with norflurazon include, persistence and limited selectivity to rotational crops (Bauman, 1981). Norflurazon is particularly effective against grasses and sedges. Treated plants first display chlorosis along the veins of the leaf. This is soon followed by complete chlorosis and death of the leaf. The pattern of chlorotic development suggests that it parallels translocation of the herbicide, at the tip of the shoot, and margin of the leaf being the last to bleach. High rate of norflurazon was necessary for effective control of weeds in soil high in organic matter and clay components (Chi- chu and Merkle, 1984). The mode of action of norflurazon is the inhibition of phytoene synthetase (Sandmann et al., 1980) inhibition of basic dehydrogenation in the carotenoid biosynthesis (Bartels and Watson, 1978) inhibitior of Hill reaction (Eder, 1979) alteration of linolenic/linoleic acid (John, 1976; Eder, 1979) and influence of chloroplast ribosomes (Eder, 1979). In an experiment conducted at wayside, Mississippi, Hunter and Barton (1983) reported that, 1.68 kg a.i./ha norflurazon applied pre-emergence resulted in an effective control of grass weeds and a relatively high seed cotton yield. In a trial in 1985, norflurazon was applied pre-emergence to control Cyperus rotundus L. and showed high selectivity to cotton (Hunter and barton, 1983). In another experiment (Rogers et al., 1981b) reported that, combination of cynazine

and norflurazon gave better weed control and higher seed cotton yield. Baker (1978) reported that norflurazone at the rate of 1.0 to 2.0 kg a.i./ha, controlled annual grasses satisfactorily when applied pre-emergence to cotton. Hamdoun and Babiker (1978) observed that pre-emergence application of norflurazon followed by supplementary hoe-weeding at 6 WAS gave a satisfactory weed-control, throughout the growing season. In the Sudan savanna, a field dominated by Cyperus rotundus L., pre-emergence application of norflurazon at 1.0 kg a.i./ha, followed by MSMA at 2.0 kg a.i./ha at post-emergence, gave a season long weed control and good seed cotton yield (Anon., 1977). A mixture of norflurazon plus diuron at 0.8 + 0.8 kg a.i./ha, gave effective weed control for 5 WAS, with high seed cotton yields comparable to hoe-weeded control (Lagoke et al., 1986). Metolachlor at 1.5 to 3.0 kg a.i./ha, prometryne at 2.0 kg a.i./ha, and norflurazon at 1.6 kg a.i./ha, combined a good weed control with high grain yield of cowpea (Lagoke et al., 1982a). In another report by Lagoke et al. (1982b) that alachlor at 1.5 kg a.i/ha, metolachlor at 1.5 - 3.0 kg a.i./ha, norflurazone at 1.8 kg a.i./ha, diuron at 1.6 kg a.i./ha, and prometryne at 2.0 kg a.i./ha, gave a lower weed score with significant high grain yield of cowpea than the unweeded plot and was comparable to the hoe-weeded treatments. Metolachlor at 1.5 kg a.i./ha tank-mixed with either pendimethalin or trifluralin at 0.75 kg a.i./ha, provided the widest spectrum

of weed control and resulted in the highest cowpea grain yields (Stall et al., 1990).

In 1982, cotton yield was in the order of 3 hoe-hoeing, greater than herbicides + hoeing, greater than herbicides alone (Signgh et al., 1988).

2.4.3 Weed control in crop mixture

Mixed cropping may alter the balance of competition in favour of the crops against the weeds. For example, farmers take advantage of good drought tolerance in millet which is often established before the emergence of weeds. In such a system, the first weeding may be delayed and combined with ridge splitting and sowing of the main crop. The utilization of a crop with spreading plant type may reduce competition in the mixture. Biological control may also be used to suppress weeds in situations where a low rate of herbicide is used (Elemo et al., 1988). In the past, field researchers, have identified selective herbicides for various sole crops, but relatively little attention has been paid to screening herbicides for mixed cropping (Anon., 1983). Lagoke et al.(1982b) have enumerated problems, associated with the use of herbicides in crop mixtures in the Nigerian savanna and attributed the little research conducted in this area to the problems. It has been found that sorghum/millet mixture with acetamides (alachlor and metolachlor) applied 3 - 4 WAS, could be used pre-emergence to groundnut, cotton or cowpeas sown

later in mixture with the cereals (Elemo et al., 1988). Alachlor was used in the early 1970s and it gave a good weed control in maize-soybean mixture (Akobundu, 1978). However linuron had earlier been reported to be highly selective in millet/sorghum/cowpea mixture at Samaru (Anon., 1977). In experiments conducted at Samaru, Nigeria, on millet/sorghum/groundnut mixture using alachlor, metolachlor and Igran combi (terbutryne) herbicides, effective weed control was achieved (Anon., 1983 and 1984). Alachlor plus prometyne or metolachlor plus prometryne, gave a good weed control in maize/cotton/cowpea mixture (Anon., 1983 and 1984). Linuron applied one day after sowing millet followed by alachlor plus diuron gave effective weed control in millet/cotton/cowpea mixture (Anon., 1983). At Samaru in Nigeria, millet-sorghum-groundnut "Gicci" mixture, metolachlor at 1.5 kg a.i./ha; alachlor, at 1.5 kg a.i./ha, and a mixture of metolachlor and terbutryne, applied pre-emergence to groundnut at 7 and 8 weeks after sowing millet and sorghum, have given a very good weed control (Anon., 1983). It has been suggested that application of alachlor plus diuron at 1.0 + 0.4 kg a.i./ha or metolachlor plus diuron at 1.0 + 0.4 kg a.i/ha, followed by supplementary hoe-weeding at 6 WAS, is the best for cotton/cowpea mixture (Elemo et al., 1988). 2.5

CHAPTER 3

MATERIALS AND METHODS

3.1 Experimental sites

3.1.1 Location

Two field experiments were conducted on the farm of the Institute for Agricultural Research, at Samaru (11°11';N07°38'E), in the northern Guinea savanna ecological zone during the 1987, 1988 and 1989 wet seasons. In Experiment I,(Weed Competition Study) the effect of period of weed-interference on cotton/cowpea mixture and the critical period of weed competition in the mixture was determined, while various weed control treatments were evaluated in the mixture in Experiment II (Weed Control Study).

3.1.2 Climate

The climatic elements prevailing during the growing seasons are depicted in tables 1(a) to 1(d). The mean seasonal minimum air temperature during 1987-89 growing seasons ranged from 17.7 to 18.00, while the maximum ranged from 31.5 to 32.00, during the period. Highest relative humidities of 78.9%, 78.6% and 76.4%, were observed in August of each growing season respectively and the total rainfall received during the wet seasons were 972.2mm, 1156.7mm and 748.6mm for the 1987, 1988 and 1989 seasons. Sunshine durations were relatively longer (8.4 hours/day) in the month of October, and shorter (5.6 hours/day) during the month of

Table 1(a): Mean monthly Temperatures, relative humidity and Sunshine hours, at Samaru.

Year/Weather Observation	June	July	August	September	October
			Mean Air Temperature C		
1987 (Max.)	22.0	90.3	87.7	91.3	93.1
(Min.)	63.7	60.5	59.6	61.1	52.8
1988 (Max.)	92.0	84.4	85.0	87.7	92.9
(Min.)	60.2	60.5	58.2	57.8	47.3
1989 (Max.)	92.2	88.2	83.7	86.6	86.1
(Min.)	60.0	54.9	57.9	55.8	49.8
			Mean relative humidity per cent		
1987 (A.M.)	213.4	239.1	256.0	227.8	164.4
(P.M.)	181.5	194.5	217.1	189.5	128.5
1988 (A.M.)	226.3	249.4	258.1	230.8	108.1
(P.M.)	180.2	199.2	222.1	200.2	92.5
1989 (A.M.)	219.4	200.1	245.1	228.2	158.7
(P.M.)	174.1	121.2	213.5	194.7	134.0
			Mean Sunshine hours per day		
1987	22.9	23.1	18.2	24.0	26.5
1988	21.3	16.3	16.8	17.7	27.04
1989	21.9	20.2	17.3	18.8	25.3

Source: Meteorological Unit, Institute for Agricultural Research, Samaru, Zaria, Nigeria

Table 1(b): Total Rainfall, mean temperature, relative humidity and sunshine at ten day interval during the period of the trial, 1987 wet season.

MONTH	Days	Total Rainfall (mm)	Mean Temperature (^{o}C)		Relative Humidity (%)		Sunshine (Hours)
			Max.	Min.	A.M.	P.M.	
JUNE	1-10	62.2	29.8	20.6	81.5	63.5	6.4
	11-20	16.2	32.1	22.0	71.2	53.8	8.9
	21-30	45.2	30.1	21.1	78.7	64.2	7.5
JULY	1-10	52.3	30.5	20.6	77.6	61.7	8.4
	11-20	106.4	30.6	20.1	78.9	64.3	7.9
	21-31	118.0	29.2	19.8	82.6	68.5	6.8
AUGUST	1-10	84.4	30.0	20.0	83.0	67.7	7.0
	11-20	75.5	28.5	19.2	86.6	76.6	5.1
	21-31	87.4	29.2	20.4	86.4	72.3	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	24.1	9.1

Source: Meteorological Unit, Institute for Agricultural Research, Samaru, Zaria.

Table 1(c): Total Rainfall, mean temperature, relative humidity and sunshine, at ten day interval during the period of the trial, 1988 wet season

MONTH	Days	Total Rainfall (mm)	Mean Temperature (°C)		Relative Humidity (%)		Sunshine (Hours)
			Max	Min.	A.M.	P.M.	
JUNE	1-10	47.3	30.1	19.0	77.0	63.2	7.7
	11-20	17.2	32.2	21.5	74.4	54.6	8.2
	21-30	68.7	29.7	19.7	74.9	62.4	5.4
JULY	1-10	50.8	29.1	19.6	82.0	64.0	6.9
	11-20	48.2	27.3	19.7	84.0	68.9	3.3
	21-31	82.6	28.0	21.2	83.4	66.3	6.1
AUGUST	1-10	98.4	27.1	19.4	85.3	72.8	4.7
	11-20	109.9	27.6	19.2	83.4	77.0	5.7
	21-31	194.2	30.3	19.6	89.4	72.3	6.4
SEPTEMBER	1-10	76.5	28.8	19.4	80.1	72.8	6.0
	11-20	71.0	29.4	19.0	72.8	65.0	5.0
	21-30	44.8	29.5	19.4	77.9	62.4	6.7
OCTOBER	1-10	NIL	29.7	17.5	47.5	29.7	8.0
	11-20	NIL	31.7	15.4	33.2	31.7	9.2
	21-31	NIL	31.5	14.4	27.4	31.5	9.8

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

Table (1d): Total Rainfall, mean temperature, relative humidity and sunshine, at ten day interval during the period of the trial, 1989 wet season

MONTH	Days	Total Rainfall (mm)	Mean Temperature (°C)		Relative Humidity (%)		Sunshine (Hours)
			Max	Min.	A.M.	P.M.	
JUNE	1-10	55.4	31.9	20.8	70.6	55.2	7.8
	11-20	21.0	31.9	20.5	69.0	54.0	8.5
	21-30	48.0	28.4	18.7	79.8	64.9	5.5
JULY	1-10	26.9	30.0	15.7	74.0	63.0	8.0
	11-20	31.5	28.9	19.4	59.5	28.9	6.4
	21-31	101.3	29.3	19.8	66.6	29.3	5.8
AUGUST	1-10	55.1	27.4	19.5	82.4	76.8	4.2
	11-20	29.8	27.8	19.4	81.3	69.7	6.5
	21-31	76.0	28.5	19.0	81.4	67.0	6.6
SEPTEMBER	1-10	78.7	28.6	19.1	81.7	70.6	5.4
	11-20	29.9	30.1	19.2	77.8	65.3	6.9
	21-30	9.7	27.9	17.5	68.7	58.8	6.5
OCTOBER	1-10	51.9	30.0	19.3	74.9	63.5	7.5
	11-20	1.0	30.7	17.8	61.7	48.1	8.1
	21-31	NIL	25.4	12.7	22.1	22.4	9.7

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

August in each of the growing seasons. Details of effective rainfall, crop cultivars/density, sowing and harvesting dates are shown in Fig. 2.

3.3 Field characters

Soil samples were taken from 0 - 15 cm depth before land preparation and analysed for both physical and chemical properties. Particle size distribution was determined by hydrometer method (Day, 1965). Soil organic carbon, total nitrogen and phosphorus after extraction were determined by Walkely-Black(Allison, 1965), micro-Kjedahl (Bremner, 1965), and ammonium molybdate blue (Bray and Kurtz, 1945) methods respectively. After extraction, exchangeable base calcium and magnesium were determined using atomic absorption. Spectrophotometry, sodium and potassium were determined by flame emission spectrophotometry, while cation exchange capacity was determined using IN ammonium acetate (pH 7.0) saturation, followed by displacement of the adsorped ammonium (Chapmay, 1965).

Details of the physical and chemical properties of the soil are summarized in Table 2.

The common weed species observed at the sites are shown in Table 3.

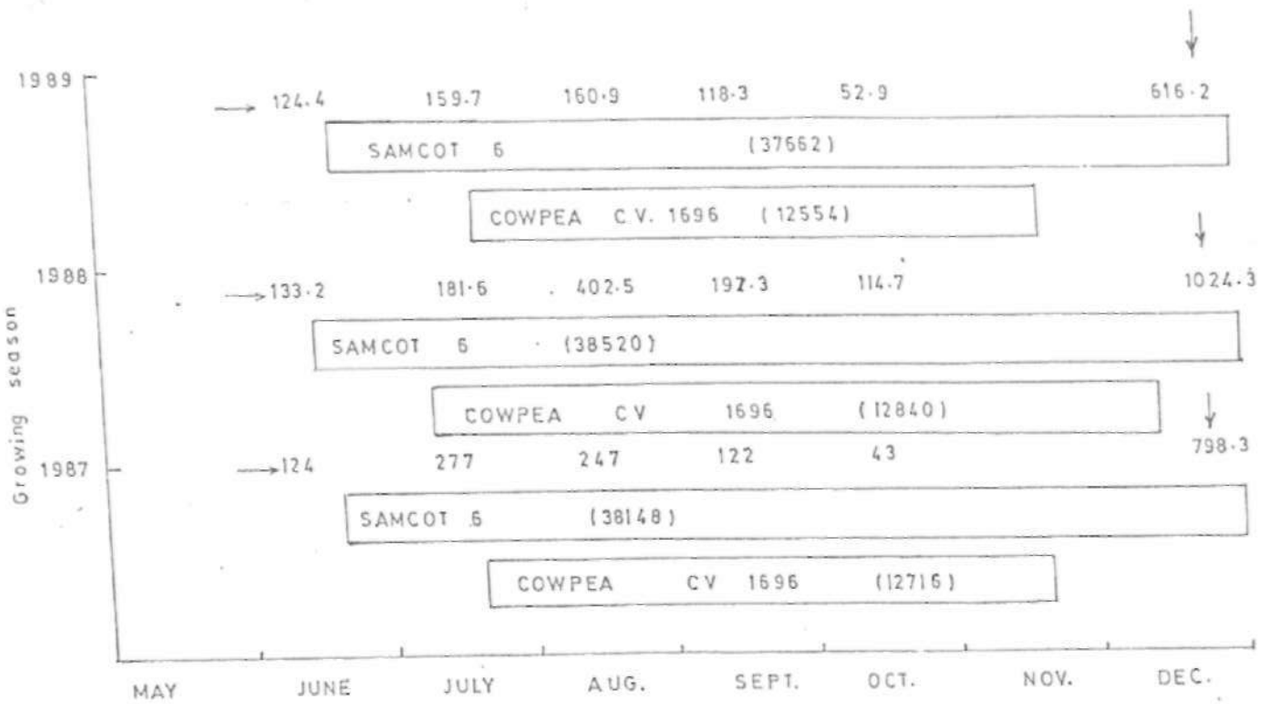


Figure 2. Crop sequence and cultivars used in three growing seasons. Left and right hand margins show planting and harvesting dates respectively. Plant population per/ha shown ( ) Arrow shows (↓) effective rainfall in mm of monthly and seasonal rainfall.

Table 2: Physico-chemical properties of the soil taken at a depth of 0 - 15cm at the experimental site, I.A.R. Farm, Samaru.

	Season		
	1987	1988	1989
Mechanical composition		%	
Clay	9.6	8.0	10.0
Fine Silt	27.6	20.0	24.0
Coarse silt	62.8	62.0	66.0
Class	SANDY		LOAM
Chemical properties			
pH (H_2O)	5.3	5.7	5.6
pH (0.01m $Cacl_2$)	4.9	5.0	5.1
Organic carbon	0.324	0.292	0.540
Total - N	0.256	0.039	0.081
Available P in (ppm)	1.63	4.50	2.70
Exchangeable bases (Meq./100g/soil)			
Ca	2.84	2.84	2.62
Mg	0.88	0.91	0.90
K	0.18	0.28	0.42
Na	0.05	0.21	0.22
CEC (Meq/100g/soil)	5.44	4.24	5.20

Table 3: Common weed species that dominated the experimental sites of the trial (Cotton/cowpea mixture) at Samaru, 1987-89.

Species	Family	% Occurrence
Sedges		
Cyperus esculentus Linn.	Cyperaceae	14
Cyperus rotundus Linn	Cyperaceae	5
Grasses		
Digitaria ciliaris (Willd.) Koel.)	Poaceae	13
Cynodon dactylon (L.) Pers.	Poaceae	12
Digitaria horizontalis. Wald.	Poaceae	8
Dactyloctenium aegyptium (L.) Beauv	Poaceae	15
eleusine indica (L.) Gaertn.	Poaceae	5
Eragrostis atrovirens (Desf.) Trin. ex stend.	Poaceae	10
Rottboellia exaltata (L.) P. Beauv ex Roem, and Schult	Poaceae	10
Others		8
Broadleaved		
Acanthospermum hispidium DC	Asteraceae	14
Ageratum conyzoides L.	Asteraceae	8
Amaranthus spinosus L.	Amaranthaceae	7
Cassia obtusifolia L.	Caesalpiniaceae	13
Cassia mimosoides L.	Caesalpiniaceae	7
Chrysanthellum americanum (L.) Vatke	Compositae	8
Crotolaria retusa Linn.	Fabaceae	10
Mikarnia cordata (Burm.F) B.L. Robinson	Compositae	5
Mitracarpus scaber. Zucc.	Rubiaceae	3
Vernonia galamensis (Willd.) Less,	Asteraceae	15
Vernonia perrottetii Sch. Dip.	Asteraceae	3
Others		7

0 - 5% minor occurrence; 6 - 10% moderate occurrence; 10 - 15% high occurrence.

3.4 Treatment and Experimental Design

3.4.1 Experiment I: Weed Competition Study in Cotton/Cowpea Mixture

In the weed competition experiment, 12 treatments of various periods of weed interference were evaluated in a randomized complete block design using four replicates. In six treatments, plots were initially kept weed-free for 2, 4, 6,

8, 10 WASC, and until cottcn harvest, and subsequently the plots were left weedy throughout. Fields visits of 4-5 days intervals were made to ensure absence of weeds for various periods according to the treatments. The weeds were usually removed by hand pulling or hoe-weeding.

In another set of six treatments plots were initially weed-infested for various periods similar to those of weed-free treatments, and were subsequently controlled until harvest. All operations involving weed removal were the same as in the weed-free treatments. Details of the treatments are contained in table 4. The gross and net plot sizes were 4.5m x 4.5m and 1.5m x 3.6m, respectively.

Table 4: Details of Weed-interference experiment in Cotton/Cowpea mixture at Samaru

Treatment
Duration of weed-interference
Weed-free period+
2 WASC
4 WASC
6 WASC
8 WASC
10 WASC
24 WASC (until harvest).
Weed-infested period++
2 WASC
4 WASC
6 WASC
8 WASC
10 WASC
24 WASC (until harvest).

WASC = Weeks after sowing cotton

\+ = Plots kept weed-free for a specified period and subsequently allowed to be infested by weeds until harvest.

++ = Plots allowed to be weed-infested for a specified period and subsequently kept weed-free until harvest.

3.4.2 Experiment II: Weed control study in cotton/cowpea mixture

In the weed control experiment twelve treatments were evaluated in a randomised block design of four replicates. In the nine of the herbicide combinations, three of the treatments were of alachlcr plus diuron at 2.0 + 0.8kg a.i./ha, metolachlor plus diuron at 2.0 + 0.8kg a.i./ha and norflurazon plus diuron at C.8 + 0.8kg a.i./ha, applied pre-emergence. The other six treatments were the low rates of these herbicide combinations followed by three of their split applications and the other three were followed by supplementary hoe-weedings all at 6 WASC. The other treatments included three hoe-weedings at 3, 6 and 9 WASC, two hoe-weedings at 3 and 6 WASC, and the weedy check. The hoe weeding operations were according to the treatments and weed sample collection was as stated in experiment I. Details of the treatments are contained in table 5. The gross and net plot sizes were 4.5m x 4.5m and 1.5m x 3.6m, respectively.

Table 5: Details of weed control treatments in Cotton/Cowpea mixture at Samaru.

Treatment	Rate (kg a.i./ha) Pre-emergence	Post-emergence
Alachlor+diuron	2.0+0.8	-
Alachlor+diuron	1.0+0.4 fb*	1.0+0.4
Alachlor+diuron	1.0+0.4 fb	SHW[1]
Metolachlor+diuron	2.0+0.8	-
Metolacholr+diuron	1.0+0.4 fb	1.0+0.4
Metolachlor+diuron	1.0+0.4 fb	SHW
Norflurazon+diuron	0.8+0.8	-
Norflurazon+diuron	0.4+0.4 fb	0.4+0.4
Norflurazon+diuron	0.4+0.4fb	SHW
Hoe-weeded check	-	3,6&9WASC[2]
Hoe-weeded check	-	3&6 WASC
Weedy check	-	-

*fb = Followed by

1 SHW = Supplementary hoe-weeding.

2 WASC = Weeks after sowing cotton.

3.5 Cultural practices

3.5.1 Land preparation and fertilizer application

The experimental sites were ploughed once and disc-harrowed twice, within two weeks of the establishment of rains. Single superphosphate at the rate of 40kg p_2O_5 and muriateof potash at the rate of 20kg K_2O per hectare,were broadcast uniformly after the second harrowing and before ridging at 75 cm width. Calcium ammonium nitrate at 30kg N/ha, was equally split-applied at 3 and 6 WAS at 6 cm depth in bands and 10 cm away from the crop row in all the experiments.

3.5.2 Planting

Cotton (SAMCOT-6) was sown on June 20 of each of the three growing seasons. About seven seeds were sown per hill at an intra-row spacing of 45cm. Gaps were filled at 14 days after sowing. The cotton crop was thinned to two plants per stand at three weeks after sowing cotton, to give an average population of about 38,043 cotton plants per hectare (Fig.3). Two seeds of cowpea (cv. Kano, 1696) were interplanted with cotton on July 25th of each growing season, at an intra-row spacing of 1.8m, after every three stands of cotton in the "Gicci" cropping pattern (Fig. 1). The density comprised of three stands of cotton as the main crop to one stand of cowpea (3:1). The cowpea crop gaps were filled 10 days after sowing to give a plant population of about 12,703 cowpea plants per

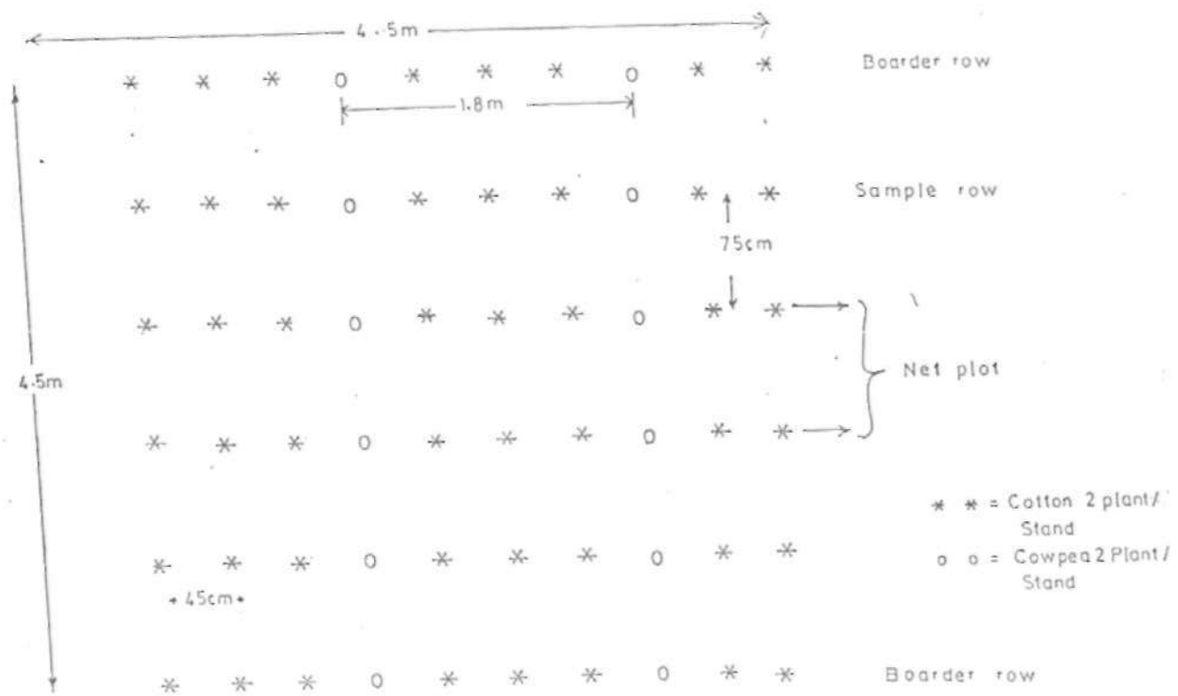


Figure 1. simplistic schematic presentation of the sequential arrangement of cotton/cowpea stands in the GICCI system of mixed cropping.

hectare.

3.5.3 *Herbicide application*

All the pre-emergence herbicides were applied one day after sowing cotton and the post-emergence at 6 WAS also, using a Knapsack sprayer equiped with a polijet nozzle and operated at a pressure of about 2.1kg/cm^2. The delivery rate of the sprayer was about 220 l/ha of the spray liquid. Herbicides were sprayed early in the morning to minimise spray drift as the weather was always calm.

3.5.4 *Hoe-weeding*

The frequency of the weeding operations in both weed-free and the weed-infested plots in experiment I, was in accordance with the treatment's requirement. However, before each weeding operation weed samples were collected from the plots, using a quadrat of 0.25m^2. The samples were then oven-dried at 70°C to constant weight, before weighing. In experiment II, hoe-weeding was carried out either as a main or as a supplementary treatment. Weed sample collection was as in experiment I.

3.5.5 Pest control

The cotton/cowpea mixture was sprayed thrice at bi-weekly interval with a low volume insecticide tank mixture of 500g cypermethrin (cymbush 10EC) with 500g dimethoate (Perfekthion 40EC) to improve control of cotton leaf rollers and of cowpea coreid bugs. The fungicide, applied separately was a tank mixture of 300g a.i./ha benomyl (Benlate 50 WP) with 200g a.i/ha Mancozeb(DithaneM45), applied in low volume, to the cowpea at 4 WAS to control the incidence of fungal diseases.

3.5.6 Crop harvest

Hand picking of seed cotton started 24 WASC, in rows 3 and 4 (net plot) and continued for three weeks. This operations of picking cotton started when 50% of the bolls were opened.

Cowpea dry pods were also hand pick from the same rows as was in the cotton plots. This was done at 17 WASC, when the cowpea pods were 30-45% dried.

3.6 Data collection

3.6.1 Emergence count

Seedlings were counted 2 WASC cotton and 10 days after sowing (DAS) cowpea, to assess the effect of herbicides on crop emergence per plot.

3.7 Weed-infestation

3.7.1 Weed flora

Various weed species growing in the field were collected and identified at 3 WASC and 10 WASC in each of the trials,

using 1.0m^2 quadrat. Weed species inside the quadrat were counted and seperated into broadleaved and grasses. The relative magnitude of the weed species was recorded as percentage of total coverage.

3.7.2 Weed cover score

The weed cover score was assessed in experiment I. Plots were scored for weed infestation using a 0 to 10 scale, at harvest. Zero (0) was given to plots without weeds and 10 to plots with complete weed cover.

3.7.3 Weed dry weight

Samples of fresh weeds were taken from 0.25m^2 quadrat in each plot before any weeding was done and from all plot at harvest. The weed were cleaned free of soil and overn dried at 70°C to constant weight. Cummulative weed dry matter production per plot in the weed-interference experiments was determined by adding up all the weed dry weight at each weeding and at harvest.

3.8 Crop components

3.8.1 Cotton and cowpea vigour score

The vigour score was assessed at 8WASC, using the scale of 0 - to 10. A score of ten was given to the plot with most healthy plants and zero to the plots with completely dead plants (4 for height or vine length; 4 for canopy or leaf spread and 2 for colour). The plots scaled from 2.5 to 5.0 were considered of healthy plants and those scaled above 5.0 were very healthy.

3.8.2 Plant height, flower and boll count of cotton

Four plants of cotton were randomly selected and tagged from the sample row (second to border row) at 10WASC. These plants were used for height measurement at 10WASC, cummulative flower count at 12WASC and boll count at 18WASC. The plant height measurement was from the basal part of each plant to the last growing using a wooden ruler graduated in meter length. Flower count was cn daily interval, starting from 8WASC and the boll count at crop harvest.

3.8.3 Cowpea vine length ard pod count

Two plants of cowpea were randomly selected and tagged with string from sample row for vine length measurement at 15WASC and pod count at harvest. The vine of the entire cowpea was straightened and measured from the base to the tip of the longest point of the plant, using meter ruler. Number of pods per stand were counted and recorded per plot.

3.8.4 Crop dry matter

At the time of first cotton picking, random samples of two stands per plot were cut from border row at the ground level. The same was done for cowpea at 17 WASC cotton. These were oven-dried at 70°C to a constant weight for dry matter assessment of the crops.

3.8.5 Yields

Harvesting of cotton and cowpea was done from the two

inner-most rows of each plot as the net plot of 5.4m^2. Picking for the two crops was done thrice in each plot.

3.8.6 Stand count

Crop stands were counted at harvest, from the two net plot, to assess the effect of treatments on the crop's establishment.

3.9 Economic analysis

3.9.1 Partial economic analysis

The cost of the herbicide/their applications, man-day and the yields revenue generated during the study period were computed for profit rating. This was done by comparing the market prices/costs of the input used during the study period.

3.9.2 Data analysis

The data collected were subjected to statistical analysis and variance as described by Little and Hill (1972). Differences between the treatment means in experiments I and II were compared using the Duncan Multiple Range Test (Duncan,1955). Correlation and regression analyses werealso done. Pooled mean analysis of vdata collected were subjected to statistical analysis of variance of cowpea grain yield, seed cotton yield and weed dry matter production are shown in Appendices 2, 3, 4, 5 and 6, respectively.

CHAPTER 4

4.1 RESULTS

During the three growing seasons, the mean minimum and maximum air temperature of 12.7 and 32.2°C respectively as well as mean relative humidity of 78.7% were obtained in the month of August (Tables 1(a), 1(b), 1(c), and 1(d)). The total annual rainfall (21157mm) in 1988 was about 10% higher than the long term seasonal mean of 1052mm, while the 972mm and 749mm obtained in 1987 and 1989 respectively were 8% and 29% lower than the long-term mean.

4.2 Weed competition study

The results on the effect of weed-interference on weed dry matter accumulation and the growth and yield of cotton and cowpea in the mixture, are presented in Tables 6 to 20.

4.2.1 Cotton

4.2.1.1 Seed cotton yield

Period of weed-interference significantly affected seed-cotton yield in the three growing seasons (Table 6). Seed cotton yield increased significantly as weed-free periods increased from 2 to 6 weeks, in 1987. Plots kept weed-free for 2 and 4 weeks only in the pooled data and for 2 weeks only in 1988, had lower seed cotton yield than those kept weed-free throughout. In 1987, plots kept weed-free initially for 6 WASC and more, and those infested for 2 WASC only produced seed cotton yields comparable to those kept weed-free throughout the crop life cycle. Plots kept weed-free for 4

3 WASC and more, and weed-infested for up to 6 WASC and less in 1988, as well as those kept weed-free for 8 WASC and more, and those infested for 2 WASC only in 1989, produced seed cotton yields comparable to those of the plots kept weed-free throughout. The pooled seed cotton yield data for the three years also followed the trend observed for the 1987 trial.

Seed cotton yield of the plots kept weed-free for 2 WASC only in all the trials and those kept weed-free for up to 4 WASC in 1989 and in the pooled results did not differ significantly from those of the corresponding plots kept weed-infested until harvest. Similarly, weed-infestation for 10 WASC in 1987, 1989 and the pooled result and 8 WASC in 1988 resulted in seed cotton yields comparable to infestation throughout the crop's life-cycle.

In plots kept weed-free initially, the highest increase in seed cotton yield of 409 kg per hectare per week was due to weed removal between 4 and 6 WASC, in the pooled results for all the trials.

Table 6: Effect of period of weed-interference on seed cotton yield in cotton/cowpea mixture at Samaru.

Treatment	Seed Cotton Yield			
	1987	1988	1989	Pooled mean
	kg/ha			
Weed-free period				
2 WASC[1]	22ef[2]	474bc	275de	325ef
4 WASC	771cd	945ab	320de	679de
6 WASC	156ab	1484a	1439c	1496abc
8 WASC	1612a	1425a	1935ab	1657abc
10 WASC	1764a	1497a	2119ab	1793ab
Until harvest	1791a	1575a	2287a	1884a
Weed-infested period				
2 WASC	1692a	1336a	2017ab	1682abc
4 WASC	1130bc	986ab	1651bc	1256bc
6 WASC	921cd	973ab	1512bc	1155cd
8 WASC	790cd	622bc	560d	657de
10 WASC	274ef	476bc	193de	314ef
Until harvest	42f	133c	41e	72f
SE (±)	129	196	168	164

1 WASC = Weeks after sowing cotton.
2 Means within a column followed by the same letter do not differ significantly at 5% level of probability according to Duncan's multiple range test (DMRT).

With initial weed-infestation, maximum reduction of 273, 236, 248 and 81 kg/ha/week occurred respectively between 2and 4 WAS in 1987 and 1988 and between 6 and 8 WASC in 1989 and pooled results. The critical period of weed competition in cotton as observed in figure 3, lies between 3 and 6 WASC.

Using the regression equation, within a weed dry weight range of 1000 to 4,250 kg/ha, seed cotton yield loss of 0.19 kg/ha was incurred, for every kg weed dry matter productionin the pooled results (Fig. 4).

Uncontrolled weeds throughout the crop life cycle resulted in 97.5, 91.6, 98.2 and 96.2%, loss in seed cotton yield in 1987, 1988, 1989 and the pooled results, respectively, compared with the appropriate maxima.

4.2.1.2 Cotton bolls

In all the trials highest boll counts were obtained in plots weed-infested for 2 WASC (Table 7). Plots kept weed-free for 4 WAS, 6 and 8 WASC, and more in 1987, 1988 and 1989, respectively, as well as those infested for up to 6 WASC in 1987 and 1989 and 10 WASC in 1988, produced boll counts comparable to the appropriate maxima in each trial. Boll counts obtained from plots kept weed-free initially for 2 WASC in 1987,2 and 4 WASC in 1988 and 1989 respectively, aswellas those weed-infested for 8 and 10 WASC in 1987 did not differ significantly from those of plots weed-infested throughout the crop life-cycle.

In plots kept weed-free initially, the highest increase in boll number of 17 per week/stand were obtained, with further weed removal between 2 and 4 WASC in 1987, and 6 bolls/week/stand in 1988, and 8 bolls/week/stand in 1989 between 4 and 6 WASC. The highest reduction in boll number were obtained between 8 and 10 WASC in 1987, and 6 and 10 WASC in 1988 with initial infestation.

Weed-infestation throughout crop life cycle reduced the number of cotton bolls/stand by 91.8, 95.2 and 97.5% in 1987, 1988 and 1989, respectively, compared with appropriate maximum in each trial.

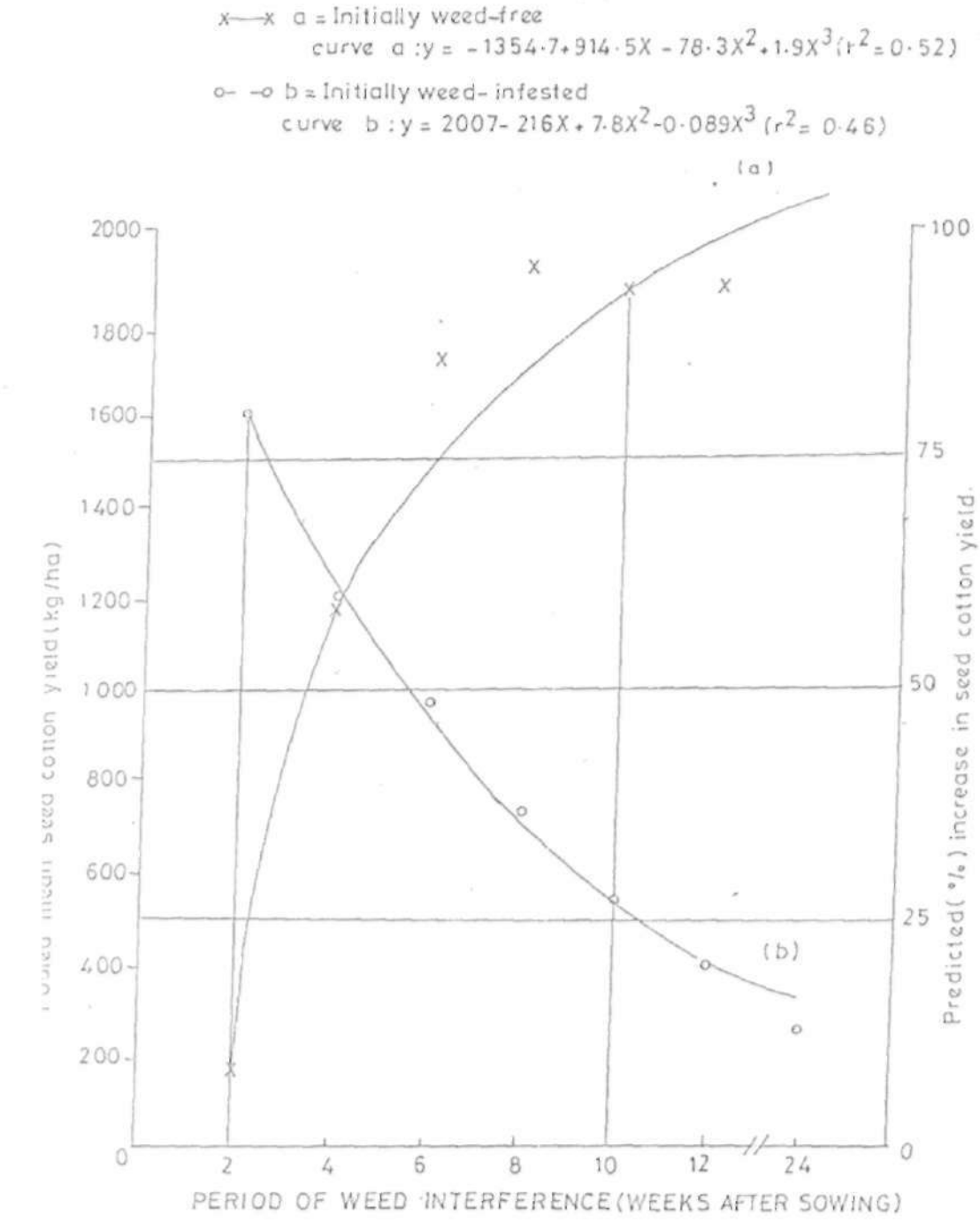
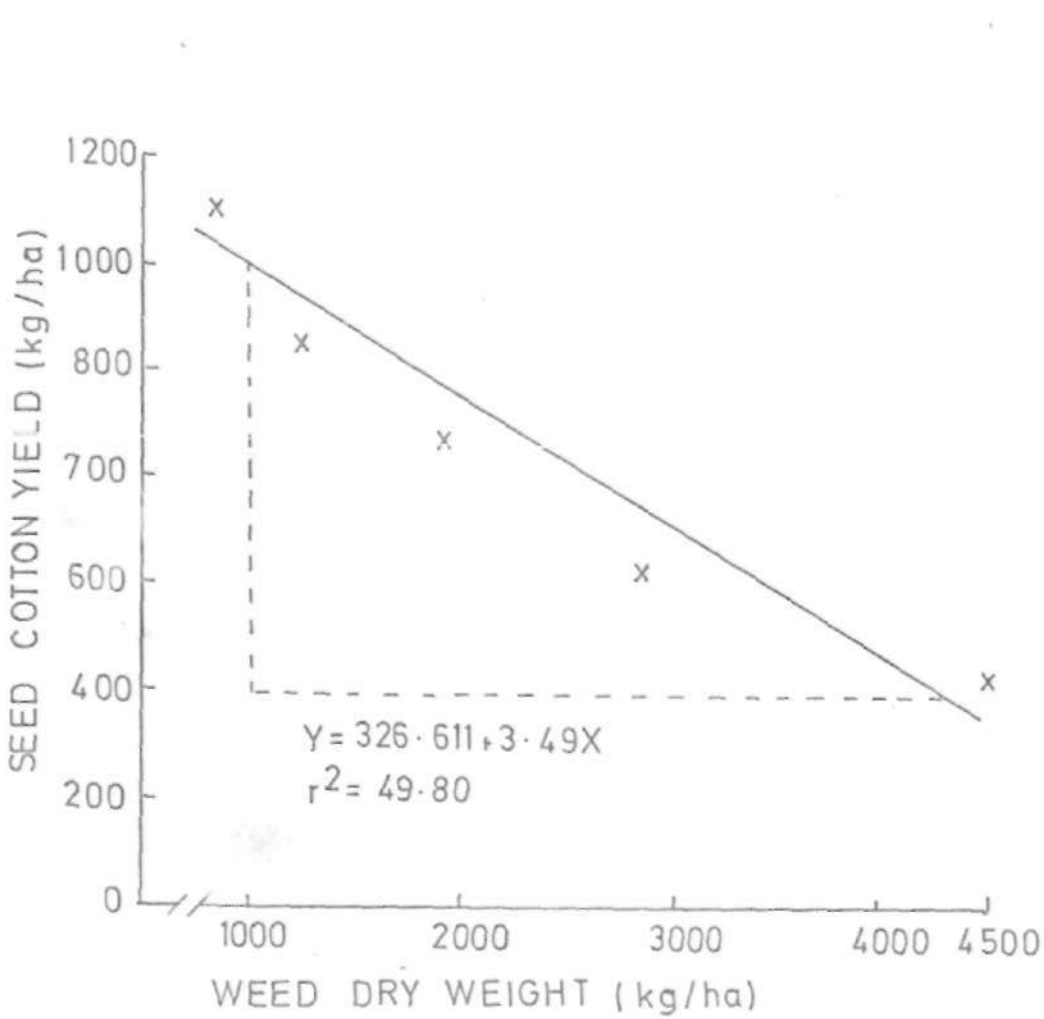


Fig.3. Regression of seed cotton yield on period of weed interference (1987-1989 mean). Each point is the mean of 12 values.



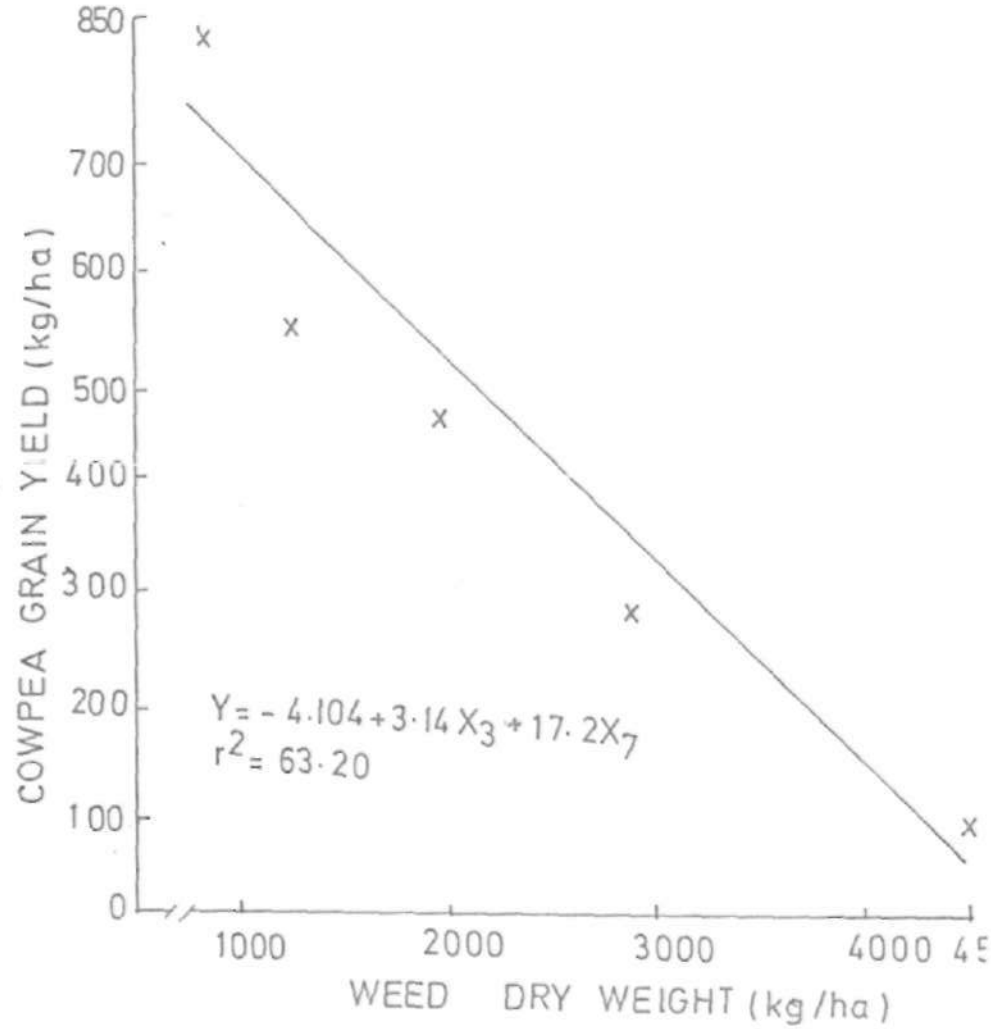


Fig. 4. Regression of seed cotton and cowpea grain yields on weed dry weight in cotton/cowpea mixture. Each (x) is the mean of 12 values.

Table 7: Effect of period of weed-interference on cotton boll count at first picking in cotton/cowpea mixture.

Treatment	Cotton Boll Count		
	1987	1988	1989
	Number/stand		
Weed-free period			
2 WASC[1]	17.0cde[2]	19.0cd	9.0ef
4 WASC	48.0abcd	22.0bcd	14.0def
6 WASC	48.0abcd	34.0abc	29.0bc
8 WASC	58.0ab	36.0abc	34.0ab
10 WASC	58.0ab	33.0abc	34.0ab
Until harvest	58.0ab	41.0ab	38.0a
Weed-infested period			
2 WASC	61.0a	50.0a	45.0a
4 WASC	46.0abc	50.0a	34.0ab
6 WASC	44.0abc	43.0ab	34.0ab
8 WASC	31.0bcde	31.0abc	23.0bcd
10 WASC	15.0de	38.0abc	18.0de
Until harvest	5.0e	2.4d	1.2f
SE (±)	9.0	7.2	4.0

1. WASC = Weeks after sowing cotton.
2. Mean within a column followed by the same letter do not differ significantly at 5% level of probability according to Duncan's Multiple Range Rest (DMRT).

4.2.1.3 Cotton flower

In all the trials, flower production of cotton stands on crop kept weed-free for 10 WASC and those weed-infested for 2 WASC only, were comparable to those kept weed-free until harvest (Table 8). Similarly, cotton stands kept weed-free for 6 and 8 WAS in 1988 and those weed-infested for 4 WASC only, produced number of flowers comparable to those kept weed-free throughout. In 1987 and 1988, weed-infestation until harvest, caused significantly lower flower production than infestation for various periods of up to 10 WASC while flower production in 1989 for infestation until 8 and 10 WASC were comparable.

Weed-infestation throughout the crop's life cycle reduced flower number by 82.0, 88.8 and 83.9% in 1987, 1988 and 1989 respectively, compared with appropriate maximum in each trial.

Table 8: Effect of weed-interference on cotton flower* production in cotton/cowpea mixture.

Treatment	Cotton Flower		
	1987	1988	1989
	number/stand		
Weed-free period			
2 WASC[1]	18.0b[2]	12.0de	9.0ef
4 WASC	20.3b	17.5cd	10.8def
6 WASC	20.0b	24.3ab	15.0cd
8 WASC	19.8b	25.8a	16.0bc
10 WASC	26.5a	26.5a	19.8abc
Until harvest	29.5a	25.0a	24.8a
Weed-infested period			
2 WASC	24.3ab	22.5abc	22.0ab
4 WASC	23.0ab	19.8abc	16.8bc
6 WASC	20.0b	17.0bcd	13.8cde
8 WASC	19.4b	12.8de	8.3f
10 WASC	19.0b	9.5e	8.0f
Until harvest	5.3c	2.8f	4.0f
SE (±)	2.4	2.0	1.8.

* = Cumulative flower count up to 50% flowering.
1 WASC = Weeks after sowing cotton.
2 Mean within a column followed by the same letter do not differ significantly at 5% level of probability according to Duncan's Multiple Range Rest (DMRT).

4.2.1.4 Cotton crop vigour

In all the trials, plants kept weed-free until 8 and 10 WASC and those infested for 2 WASC only, had vigour scores comparable to those kept weed-free throughout (Table 9). In addition, plants kept weed-free and weed-infested for 6 WASC in 1987 and those kept weed-free for 4 and 6 WASC in 1989 have vigour scores comparable to those kept weed-free throughout. Weed-infestation up to 10 WASC in 1987 and 6 WAS in 1988 resulted in similar vigour score to infestation throughout crop life cycle while in 1989 infestation throughout resulted in lower score than all the other periods of weed-interference.

4.2.1.5 Cotton plant height

Height of cotton plants was only significantly affected by period of weed-interference in 1988 and 1989 seasons (Table 10). When plants of plots kept weed-free for various periods and those infested for 2 and 4 WASC had heights comparable to those of plots kept weed-free throughout but taller than those infested throughout. Similarly, plants infested for 6 WASC and more did not differ significantly in height from those infested until harvest.

4.2.1.6 Crop dry matter production

Crop dry matter production was significantly affected by period of weed-interference in all the trials (Table 11). The plots kept weed-free until 10 WASC produced cotton dry matter comparable to those kept weed-free until harvest in all the

trials. In addition, plots weed-infested for 2 WASC in 1988 and those kept weed-free for various periods except at harvest in 1989 produced cotton dry matter comparable to the respective weed-free plots throughout. Uncontrolled weed growth reduced cotton dry matter production by 63.7%, 89.2% and 77.4% in 1987, 1988 and 1989 respectively compared with the appropriate maximum in each trial.

Table 9: Effect of period of weed-interference on vigour[1] score of cotton plants at flowering in cotton/cowpea mixture.

Treatment	Cotton Vigour Score		
	1987	1988	1989
Weed-free period			
2 WASC[2]	3.9bcd[3]	5.5cd	6.8c
4 WASC	3.9bcd	4.8de	7.7ab
6 WASC	4.1abcd	6.8bc	7.9ad
8 WASC	4.4abc	7.8a	7.9a
10 WASC	5.1ab	8.6a	7.7ab
Until harvest	5.5a	8.3a	8.1a
Weed-infested period			
2 WASC	5.5a	8.3a	8.1a
4 WASC	4.8abc	4.8de	7.4b
6 WASC	5.1ab	3.0f	5.1d
8 WASC	3.4cd	2.4f	4.6de
10 WASC	2.8de	3.5ef	4.4e
Until harvest	1.8e	2.9f	3.1f
SE (±)	0.5	0.4	0.2

1 Crop vigour score using scale (0 - 10); where 0 = completely killed plant; 10 = most healthy plant.
2 WASC = Weeks after sowing cotton
3 Mean within a column followed by the same letter do not differ significantly at 5% level of probability according to Duncan's Multiple Range Rest (DMRT).

Table 10: Effect of period of weed-interference on height of cotton plants at final picking in cotton/cowpea mixture.

Treatment	Cotton plant height		
	1987	1988	1989
	cm		
Weed-free period			
2 WASC[1]	83.7a[2]	44.3abc	50.8ab
4 WASC	60.1a	47.5ab	49.5ab
6 WASC	62.1a	48.4ab	50.7ab
8 WASC	52.5a	49.3ab	48.2ab
10 WASC	55.6a	51.a	48.9ab
Until harvest	55.6a	52.6a	50.9ab
Weed-infested period			
2 WASC	49.9a	51.1a	55.4a
4 WASC	51.0a	44.3abc	49.2ab
6 WASC	56.3a	33.5cd	40.5bc
8 WASC	54.3a	34.8cd	40.2bc
10 WASC	53.7a	38.8bcd	40.1bc
Until harvest	54.8a	29.1d	36.3c
SE (±)	11.2	2.4	3.3

1 WASC = Weeks after sowing cotton

2 Mean within a column followed by the same letter do not differ significantly at 5% level of probability according to Duncan's Multiple Range Rest (DMRT).

Table 11: Effect of period of weed-interference on cotton dry matter production in cotton/cowpea mixture at harvest.

Treatment	Cotton Dry matter		
	1987	1988	1989
	g/stand		
Weed-free period			
2 WASC[1]	13.5c[2]	7.1c	24.0ab
4 WASC	15.5bc	18.3bc	28.5ab
6 WASC	17.8bc	19.2bc	30.0a
8 WASC	22.3bc	21.6bc	31.3a
10 WASC	25.0ab	25.0abc	33.0a
Until harvest	35.3a	39.4ab	38.3a
Weed-infested period			
2 WASC	17.5bc	46.3a	38.5a
4 WASC	16.0bc	17.6bc	38.0a
6 WASC	15.0bc	13.5c	33.5a
8 WASC	14.8c	9.1c	30.3a
10 WASC	13.5c	8.0c	21.3ab
Until harvest	12.8c	5.c	8.7b
SE (±)	3.0	6.7	6.0

1 WASC = Weeks after sowing cotton.
2 Mean within a column followed by the same letter do not differ significantly at 5% level of probability according to Duncan's Multiple Range Rest (DMRT).

4.2.1.7 Cotton stand

The cotton stand count was only significantly affected by period of weed-interference in the 1988 season. Plots kept weed-free for 2 and 6 WASC and those infested for 6 WASC and more, resulted in significantly lower cotton stand than the maximum obtained in plots kept weed-free for 8 WASC only (Table 12).

4.2.2 Cowpea

4.2.2.1 Grain yield

In 1987, the maximum cowpea grain yield was obtained with weed-infestation for 2 WASC only (Table 13). Plots kept weed-free initially for 6 WASC and more, produced cowpea grain yield comparable to the maximum, while yields of the plots kept weed-free for 2 WASC only and those infested for 10 WASC were comparable to those of the plots infested throughout the crop life-cycle in the trial. Plots weed-infested for various periods and those kept weed-free for 4 WASC produced grain yields that were comparable to those kept weed-free for 2 WASC only.

In 1988, 1989 and pocled results, maximum grain yields were obtained from the plots kept weed-free until harvest. Plots kept weed-free until 6 WASC and more in 1987, 1988 and pooled results, and those kept weed-free for 8 WASC in 1989 as well as those weed-infested for 2 and 4 WASC only in 1989 produced grain yields that were comparable to the maximum and significantly higher than the least obtained from plots

weed-infested throughout.

Weed-infestation, throughout crop life-cycle resulted in 94.6%, 79.7%, 97.6% and 90.1%, reduction in cowpea grain yield compared with the appropriate maxima in 1987, 1988 and 1989 and the pooled results respectively. Weed-free periods of 5 and 8 WASC and more or weed-infested period of 2 WASC, 4 WASC and until harvest resulted in 25%, 50% and complete loss in cowpea grainyield (Fig.5). Within a range of 1,000 to 4,250kg/ha, weed dry weight, cowpea grain yield loss of 0.20kg/ha was incurred for every kg weed dry matter production in the pooled result (Fig. 4).

Table 12: Effect of period of weed-interference on final stand count at final picking of cotton in cotton/cowpea mixture.

Treatment	1987	1988	1989
	Stands/ha		
Weed-free period			
2 WASC[1]	32851a[2]	32407bcd	35682a
4 WASC	34086a	36728ab	33804a
6 WASC	29887a	32407bcd	37325a
8 WASC	30381a	37089a	33335a
10 WASC	34333a	35648abcd	34978a
Until harvest	34590a	32948abcd	38264a
Weed-infested period			
2 WASC	3285a	34928abc	37795a
4 WASC	29393a	35648ab	36621a
6 WASC	33098a	29887cde	38030a
8 WASC	36309a	27006e	38499a
10 WASC	36309a	27726de	38030a
Until harvest	32851a	28266de	36856a
SE (±)	2964	1656	1878

1 WASC = Weeks after sowing cotton
2 Mean within a column followed by the same letter do not differ significantly at 5% level of probability according to Duncan's Multiple Range Rest (DMRT).

Table 13: Effect of period of weed-interference on cowpea grain yield in cotton/cowpea mixture.

Treatment	Cowpea Grain Yield			
	1987	1988	1989	Pooled Mean
	kg/ha			
Weed-free period				
2 WASC[1]	143de[2]	448bc	207de	266bc
4 WASC	203cd	475bc	234de	304bc
6 WASC	579abcd	545abc	566bcd	563ab
8 WASC	684abcd	683ab	612abc	660ab
10 WASC	848abc	860ab	626ab	778ab
Until harvest	918ab	952a	956a	942a
Weed-infested period				
2 WASC	1176a	600abc	713ab	830a
4 WASC	491bcd	520abc	674ab	562abc
6 WASC	410bcd	505abc	489bcd	468abc
8 WASC	569abcd	465bc	410bcd	481abc
10 WASC	224cde	408bc	248cde	293abc
Until harvest	64e	193c	23e	93c
SE (±)	208	136	115	153

1 WASC = Weeks after sowing cotton
2 Mean within a column followed by the same letter do not differ significantly at 5% level of probability according to Duncan's multiple range test (DMRT).

x—x a = Initially weed-free
curve a : $y = -680 + 412X - 36{\cdot}5X^2 + 0{\cdot}91X^3 (r^2 = 0{\cdot}07)$

o-·-o b = Initially weed-infested
curve b : $y = 2168{\cdot}8 - 711{\cdot}2X + 70{\cdot}4X^2 - 1{\cdot}86X^3 (r^2 = 0{\cdot}23)$.

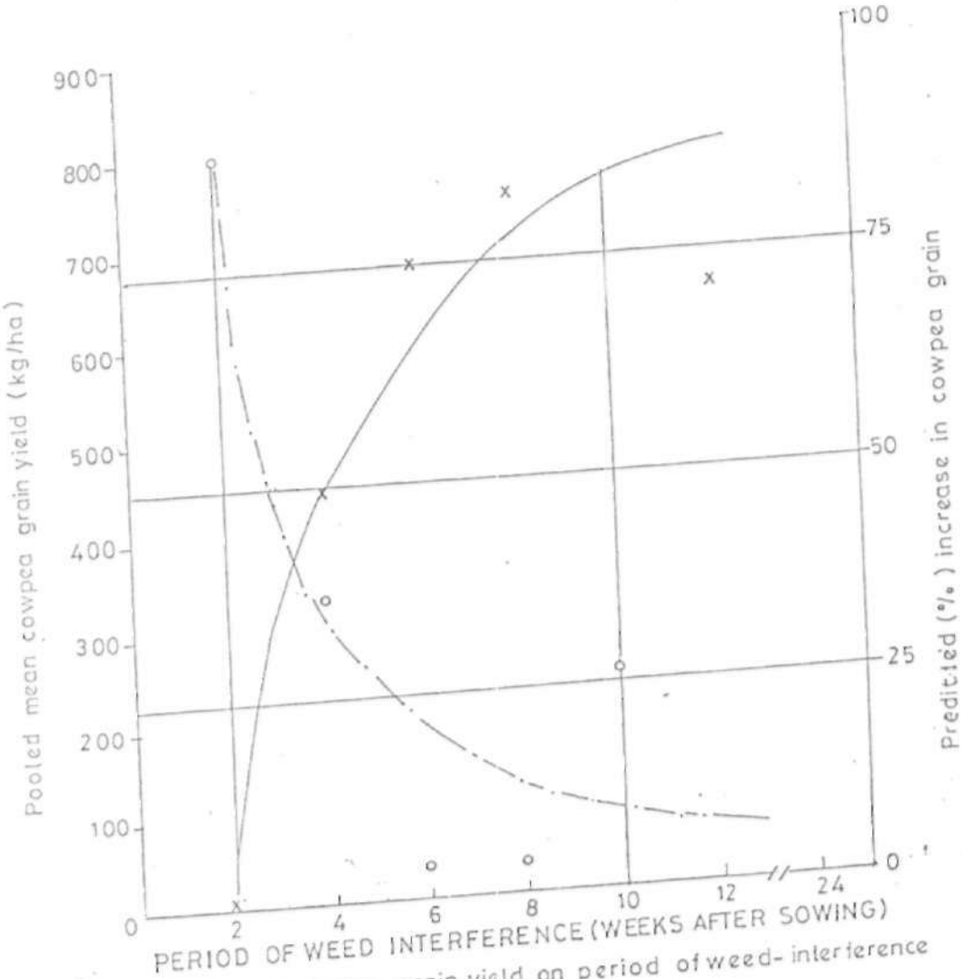


Fig.5. Regression of cowpea grain yield on period of weed-interference (1987-1989). Each point is the mean of 12 values.

4.2.2.2 Pod number per stand

The number of cowpea pods/stand was only significantly affected by periods of weed-interference in 1988 and 1989 wet seasons (Table 14). Plots kept weed-free throughout and those infested for 2 WASC only produced significantly more pods than those weed-infested until hervest in 1988 and 1989 seasons. In 1989 growing season, plots kept weed free until 10 WASC and those infested for 4 and 6 WASC in 1988 also produced significantly higher number of cowpea pods, than the least obtained in each trial.

4.2.2.3 Cowpea vine length

In the 1987 wet season, vine length of cowpea plants of plots kept weed-free for 6 to 10 WASC, and those weed-infested for 2 to 10 WASC were comparable to those kept weed-free throughout and significantly longer than those weed-infested throughout. Vine length of cowpea plants kept weed-free for 2 WASC was longer than those plots weed-infested throughout (Table 15).

During the 1988 growing season, all the plots kept weed-free initially for various periods and those weed-infested for 2 WASC only, resulted in canopy lengths comparable to those of plots kept weed-free throughout, and significantly higher than those weed-infested until harvest. Although similar to that of the plants kept weed-free until harvest, vine length of the plant weed-infested for 4 WASC was comparable to that of plots weed-infested until harvest.

significantly higher than those of the least obtained in the trial.

Table 14: Effect of period of weed-interference on number of cowpea pods per stand at harvest in cotton/cowpea mixture

Treatment	Cowpea Pod		
	1987	1988	1989
	number/stand		
Weed-free period			
2 WASC[1]	20.0a[2]	25.0ab	28.1ab
4 WASC	25.1a	24.3ab	32.0ab
6 WASC	52.0a	26.0ab	32.0ab
8 WASC	37.0a	41.0ab	33.2ab
10 WASC	25.0a	35.0ab	53.1a
Until harvest	55.2a	44.2a	57.3a
Weed-infested period			
2 WASC	51.1a	60.1a	51.0a
4 WASC	55.0a	54.0a	35.2ab
6 WASC	37.0a	53.2a	32.0ab
8 WASC	53.0a	30.1ab	28.0ab
10 WASC	44.1a	24.0ab	25.0ab
Until harvest	25.3a	3.5b	4.1b
SE (±)	11.01	13.03	14.07

1 WASC = Weeks after sowing cotton.
2 Mean within a column followed by the same letter do not differ significantly at 5% level of probability according to Duncan's multiple range test (DMRT).

Table 15: Effect of period of weed-interference on vine length of cowpea in cotton/cowpea mixture.

Treatment	Vine length of cowpea		
	1987	1988	1989
	cm		
Weed-free period			
2 WASC[1]	116.5bc[2]	99.0ab	114.5bc
4 WASC	105.7cd	94.5ab	80.8a
6 WASC	164.5abc	101.0ab	205.3a
8 WASC	178.5ab	116.3a	200.89a
10 WASC	198.8a	113.0a	181.3ab
Until harvest	203.3a	138.8a	164.5ab
Weed-infested period			
2 WASC	202.0a	102.3ab	202.0a
4 WASC	177.5ab	75.0abc	177.5ab
6 WASC	151.5abcd	40.2bc	104.5bc
8 WASC	146.8abcd	38.5bc	46.8c
10 WASC	154.0abcd	30.5c	76.5c
Until harvest	39.7cd	22.0c	39.8c
SE (±)	18.9	19.6	23.3

1 WASC = Weeks after sowing cotton
2 Mean within a column followed by the same letter do not differ significantly at 5% level of probability according to Duncan's multiple range test (DMRT).

In the 1989 wet season, plots weed-infested for 2 and 4 WASC and those kept weed-free for various periods and until harvest produced cowpea with significantly longer canopy length than those kept weed-free for 2 WASC and those weed-infested for 6, 8, and 10 WASC and until harvest. Generally, in all the 1987, 1988 and 1989 growing seasons, there were cowpea canopy growth reduction of 80.5%, 84.2% and 80.3% respectively, due to weed-infestation throughout the crop's life-cycle, compared with the appropriate maxima.

4.2.2.4 Crop vigour score

In all the trials, maximum vigour scores of cowpea was obtained on the plots weed-infested for 2 WASC only (Table 16). In 1987, plots kept weed-free for 8 and 10 WASC and until harvest as well as those weed-infested for 4 WASC resulted in vigour score comparable to the maximum and significantly higher than the least with the plots weed-infested throughout. In 1988, plots kept weed-free for 4 WASC and more had crop vigour scores comparable to the maximum and higher than the least. Plots kept weed-free for 2 WASC and those weed-infested for 4 WASC, also had significantly higher weed cover scores than those weed-infested until harvest.

Similarly, in 1989, plots kept weed-free until harvest and those weed-infested for 4 and 6 WASC resulted in vigour scores comparable to the maximum and higher than the least with weed-infestation throughout the crop's life-cycle. Vigour scores of the plots kept weed-free for 8 and 10 wasc were also significantly higher than those of the least obtained in the trial.

Table 16: Effect of period of weed-interference on cowpea vigour score[1] at flowering stage in cotton/ cowpea mixture.

Treatment	1987	1988	1989
Weed-free period			
2 WASC[2]	3.8cd[3]	6.2bc	1.3ef
4 WASC	4.3bcd	7.1ab	2.3def
6 WASC	5.1abcd	6.9ab	3.5cde
8 WASC	5.8abc	7.0ab	4.1bcd
10 WASC	5.8abc	6.8ab	4.3bcd
Until harvest	6.2ab	7.0ab	4.9abc
Weed-infested period			
2 WASC	7.3a	7.8a	7.3a
4 WASC	5.7abc	5.4cd	6.5ab
6 WASC	4.9bcd	3.7f	5.0abc
8 WASC	4.8bcd	4.8de	2.5ef
10 WASC	3.0d	4.3ef	2.8cdef
Until harvest	2.8d	4.5def	1.0f
SE (±)	0.7	0.3	0.7

1 Crop vigour score using scale (0 - 10); where 0 = completely killed plant and 10 = most healthy plant.
2 WASC = Weeks after sowing cotton
3 Means within a column followed by the same letter do not differ significantly at 5% level of probability according to Duncan's multiple range test (DMRT).

4.2.2.5 Cowpea dry matter

Maximum cowpea dry matter production was obtained on the plots kept weed-free throughout the crop's life-cycle in all the trials. The plots kept weed-free for 10 WASC in 1989 and those weed-infested for 2 WASC in all the trials produced dry matter comparable to the maximum. Plots kept weed-free for 2 and 4 WASC and those weed-infested for 10 WASC in 1987 and 8 and 10 WASC in 1989, did not differ significantly from those kept weed-infested throughout in cowpea dry matter production. (Table 17)

In 1988 however, all other plots were comparable to those infested throughout. Uncontrolled weeds throughout crop's life-cycle caused 79.7%, 68.4% and 98.0% reduction in cowpea dry matter production in 1987, 1988 and 1989 respectively, compared to those kept weed-free throughout.

4.2.3 Weeds

4.2.3.1 Weed cover score

In 1987, plots kept weed-free until harvest had significantly lower weed score than the others kept weed-free and weed infested for varicus periods. Plots kept weed-free for 2 and 4 WASC only, and those weed-infested for 8 and 10 WASC did not differ significantly in weed cover score, from those infested throughout (Table 18).

In the 1988, plots weed-infested for 2 WASC only, had weed score comparable to the least obtained with the plots kept weed-free throughout. Other periods of weed-interference

Table 17: Effect of period of weed-interference on cowpea dry matterproductionatharvestin cotton/cowpea mixture.

Treatment	Cowpea dry matter production		
	1987	1988	1989
	g/stand		
Weed-free period			
2 WASC[1]	68.9e[2]	31.0ab	33.9d
4 WASC	127.4de	18.0b	102.3cd
6 WASC	209.3c	34.0ab	209.3b
8 WASC	224.1c	25.0b	224.1b
10 WASC	248.7bc	24.5b	241.7ab
Until harvest	328.4a	63.3a	328.4a
Weed-infested period			
2 WASC	317.1ab	42.0ab	317.1a
4 WASC	219.6c	26.3b	219.6cb
6 WASC	199.9cd	17.3b	167.2bc
8 WASC	192.3cd	17.3b	47.3d
10 WASC	82.8e	23.8b	15.2d
Until harvest	66.6e	20.0b	6.6d
SE (±)	24.5	11.5	30.0

1 WASC = Weeks after sowing cotton
2 Means within a column followed by the same letter do not differ significantly at 5% level of probability according to Duncan's multiple range test (DMRT).

Table 18: Effect of period of weed-interference on weed cover score[1] at harvest in cotton/cowpea mixture.

Treatment	1987	1988	1989
Weed-free period			
2 WASC[2]	7.8ab[3]	6.3b	8.4b
4 WASC	7.8ab	5.4c	8.3b
6 WASC	7.1bc	2.6d	6.9cd
8 WASC	7.3bc	2.0e	6.3d
10 WASC	5.6cd	1.6fg	3.9f
Until harvest	1.5f	0.8h	1.6h
Weed-infested period			
2 WASC	3.8e	0.7h	2.7g
4 WASC	7.3bc	1.7f	5.3e
6 WASC	7.3bc	1.4f	7.3c
8 WASC	7.8ab	2.2e	7.2c
10 WASC	8.1ab	8.9a	8.3b
Until harvest	9.3a	9.1a	9.1a
SE (±)	0.60	0.10	0.20

1 Weed cover score using scale (0 - 10); where 0 = no weeds and 10 = complete weed cover.

2 WASC = Weeks after sowing cotton

3 Means within a column followed by the same letter do not differ significantly at 5% level of probability according to Duncan's multiple range test (DMRT).

resulted in significantly higher weed cover scores. The weed score of plots weed-infested for 4 and 6 WASC were similar to those kept weed-free for 10 WASC and were significantly lower than those kept weed-free for 8 WASC and those weed-infested for 8 WASC. Plots weed-infested for 10 WASC had weed cover scores comparable to those infested until harvest. In this trial, weed cover score decreases significantly as weed-free period increased.

In 1989, plots kept weed-free until harvest had significantly lower weed cover scores than others exposed to various weed-interference periods. Plots kept weed-free for 2 and 4 WASC had scores that were comparable to those weed-infested until 10 WASC, while those kept weed-free until 6 WAS had score comparable to those infested until 6 and 8 WASC. The plots weed-infested for 2 WASC only had significantly lower score than those infested for longer periods and those kept weed-free for various periods up to 10 WASC.

4.2.3.2 Weed dry matter

In all the trials, the least weed dry matter production was obtained on plots kept weed-free until harvest, while weed-infestation until harvest caused the highest weed dry matter production. Plots kept weed-free for 6 WASC and more and those weed-infested for 2 to 8 WASC only produced weed dry matter comparable to the least in 1987 (Table 19). Plots kept weed-free for 2 WASC and those infested for 10 WASC had similar weed dry matter production in the trial.

In 1988, plots kept weed-free for 8 and 10 WASC had weed dry matter comparable to the least, while those infested until 10 WASC did not differ significantly from those infested until harvest in weed dry matter. In the trial, plots weed-infested for 2 WASC produced similar weed dry matter to those kept weed-free for 2 to 8 WASC.

In the 1989 wet season, plots kept weed-free for 8 and 10 WAS and those infested for 2 WASC only, produced weed dry matter comparable to those kept weed-free throughout. Plots kept weed-free for 2 and 4 WASC did not differ significantly from those infested until 8 WASC in weed dry matter production.

On the basis of pooled mean for the three years, all the weed-interference periods produced lower weed dry matter than weed-infestation throughout the crop's life-cycle.

Among the interference periods, plots kept weed-free for 8 and 10 WASC and those infested for 2 and 6 WASC produced

Table 19: Effect of period of weed-interference on weed dry matter production at harvest in cotton/cowpea mixture.

Treatment	Weed dry matter production			
	1987	1988	1989	Pooled mean
	kg/ha			
Weed-free period				
2 WASC[1]	3172b[2]	1744.0cde	1812bc	2243bc
4 WASC	1800c	1500.0de	1636bcd	1645cde
6 WASC	1604cd	1208.0ef	1148de	1320def
8 WASC	772cd	764.0fg	1052defg	863fg
10 WASC	508d	332.0g	968efg	603fg
Until harvest	436d	232.0g	500g	389g
Weed-infested period				
2 WASC	548d	1276.0ef	664fg	829efg
4 WASC	612d	2020.0cd	1132def	1255def
6 WASC	1004cd	2372.0c	1248cdef	1168defg
8 WASC	1216cd	3200.0b	1412cde	1943cd
10 WASC	3092b	3404.0ab	2132b	2876b
Until harvest	6684a	3996.0a	2896a	4525a
SE (±)	387.40	205.10	178.00	257.30

1 WASC = Weeks after sowing cotton
2 Means within a column followed by the same letter do not differ significantly at 5% level of probability according to Duncan's multiple range test (DMRT).

weed dry matter that were comparable to those of the plots kept weed-free throughout. Plots weed-infested for 10 WASC, produced weed dry matter comparable to those kept weed-free for 2 WASC.

4.2.3.3 Relationship between various parameters and pooled mean seed cotton or cowpea grain yields, in cotton/ cowpea mixture.

As observed (Table 20) seed cotton yield was positively and significantly correlated to cowpea dry matter, cowpea canopy, cotton flower count, cotton plant height (12 WASC) and crop vigour score at 6 and 9 WASC (r = 0.705**, 0.620**, 0.495**, 0.353**, and 0.471** and 0.288**). It was also negatively correlated with weed cover score and weed dry matter at harvest (r = -0.362**, - 0.321**).

Cowpea grain yield was positively correlated with cowpea dry matter, cowpea vine, cotton boll count,cotton plant height (r = 0.500**, 0.267*, 0.476**, 0.326**) and negatively correlated with weed dry matter at harvest (r = -0.154).

A predicted maximum pooled mean yield of seed cotton of 2.2 tonnes was obtained on plots kept weed-free for 24 WASC (Fig. 3). A predictable 50% pooled mean seed cotton yield loss was made possible, when the crop was kept weed-free for at least 6 WASC and more compared with weed-free throughout.

A predictable pooled mean cowpea grain yield reduction of 32% was made possible on plots kept weed-free for 6 WASC and more (Fig. 5). A 75% cowpea grain yield loss was realised

when the crop was kept weed-infested for 5 WASC and more in the mixture.

A predictable pooled mean weed dry matter reduction of 50% was achieved on plots kept weed-free for8 WASC. Weed dry matter accumulation ofmore than 5t/ha could be predicted on plots kept weed-infested until harvest (Fig. 6).

Table 20: Matrix of correlation coefficients of pooled mean (1987-89) of various growth and yield components and seed cotton yield/cowpea grain yield in weed-interference experiments.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Seed Cotton yield															
Cowpea grain yield	0.163														
Cowpea dry matter	0.705**	0.50**													
Cowpea vine length	0.620**	0.267*	0.628**												
Cowpea pod count	0.118	-0.144	-0.029	0.017											
Cotton boll count	0.251*	0.476**	0.402**	0.391**	-0.139										
Cotton flower count	0.495**	-0.177	0.191	0.188	0.228*	-0.200									
Cotton dry matter	0.219*	-0.191	0.102	0.106	0.225*	0.172	0.299*								
Cotton plant height at 12 WASC	0.353**	0.326**	0.445**	0.454**	-0.218*	0.559**	0.090	0.044	0.623**						
Crop vigour 6WASC	0.417**	-0.204*	0.190	0.268**	0.048	-0.197	0.637**	0.331**	0.015	0.180					
Crop vigour 9WASC	0.228**	-0.001	0.058	0.185	0.033	0.101	0.401**	0.088	0.172	0.239*	0.163				
Weed cover 9WASC	0.103	0.184	0.370**	0.143	-0.261	0.148	-0.310**	-0.056	0.087	0.151	0.006	-0.363**			
Weed cover 6WASC	-0.362**	0.036	-0.094	-0.152	-0.167	-0.036	-0.487**	-0.268*	0.022	-0.070	-0.341	-0.326**	0.401**		
Weed dry matter	-0321**	-0.154	-0.179	-0.267**	0.019	-0.225*	-0.168	-0.115	-0.030	-0.088	-0.257*	-0.050	-0.084	0.211**	
Cotton stand at harvest	-0.083	-0.322**	-0.380**	-0.271**	0.190	-0.385**	0.365**	0.146	-0.203*	-0.248*	0.240*	0.298*	-0.465**	-0.291*	-0.001

*Significant at 5% level of probability (r^2 = 0.195);

**Significant at 1% level of probability (r^2 = 0.254).

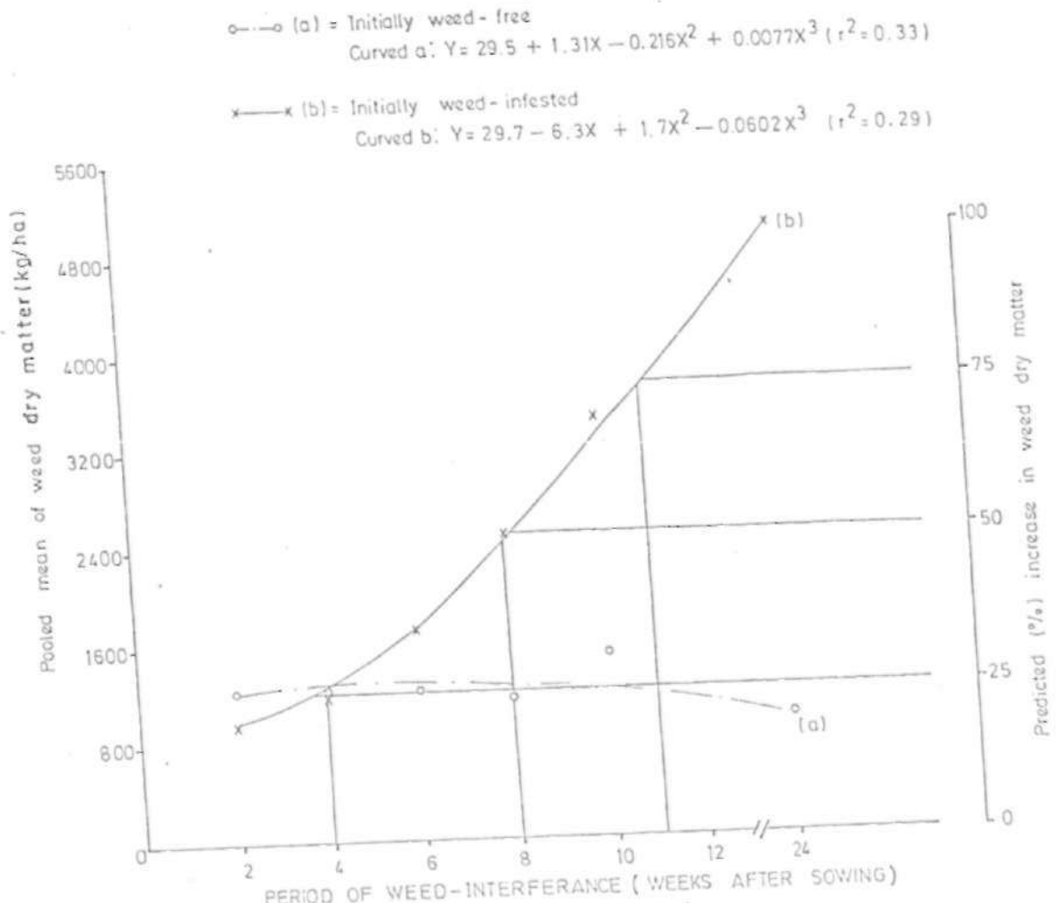


Fig 6. Regression of weed dry matter on period of weed-interference, weeks after sowing (1987-1989) Each point is the mean of 12 values

4.3 Weed control study

The effect of weed control treatments on weeds, growth, yield and yield components of cotton and cowpea in cotton/cowpea mixtures, are contained in Tables 21 to 38.

4.3.1 Cotton

4.3.2 Seed cotton yield

Seed cotton yield was significantly affected by the weed control treatments in all the trials and in the pooled results (Table 21). Maximum yields were obtained with three hoe weedings in 1987, 1988 and pooled results, and with norflurazon plus diuron at 0.4 + 0.4 kg, a.i./ha fb SHW in 1989. In all the trials and pooled results, mixtures of diuron with alachlor or metolachlor, each at 0.4 + 1.0 kg a.i./ha fb SHW, resulted in seed cotton yields comparable to the appropriate maximum and significantly higher than those of the corresponding weedy check.

In addition to those indicated, norflurazon plus diuron applied alone at 0.8 + 0.8 kg a.i./ha in 1989, and 0.4 + 0.4kg a.i./ha fb SHW in the pooled results, also resulted in yields comparable to the appropriate maximum and significantly higher than those of their corresponding weedy check.

In 1987 and 1988, metolachlor plus diuron at 1.0 +0.4 kg a.i/ha fb SHW resulted in significantly higher seed cotton yields than the same herbicide mixture applied alone at 2.0 +0.8 kg a.i./ha and its split application i.e. 1.0 + 0.4 fb 1.0 +0.4 kg a.i./ha. Application of alachlor plus diuron, at

Table 21: Effect of weed control treatments on seed cotton yield in cotton/cowpea mixture

Treatment	Rate (kg a.i./ha) [1] Pre-em.	[2] Post-em.	Seed cotton yield 1987	1988	1989	Pooled mean
			kg/ha			
Alachlor+diuron	2.0+0.8	-	211.2c	375.8cd	1146.1abc	578abcde
Alachlor+diuron	1.0+0.4	1.0+0.4	625.0bc	160.5d	217.4cd	334cde
Alachlor+diuron	1.0+0.4	SHW [3]	1198.0ab	1020.0ab	1117.abc	1112ab
Metolachlor+diuron	2.0+0.8	-	422.4c	282.3cd	925.0abcd	543bcde
Metolachlor+diuron	1.0+0.4	1.0+0.4	476.8c	97.5d	266.8bcd	280e
Metalachlor+diuron	1.0+0.4	SHW	1148.6ab	819.9ab	1123.9abc	1021abc
Norflurazon+diuron	0.8+0.8	-	160.6c	97.2d	1293.1ab	517bcde
Norflurazon+diuron	0.4+0.4	0.4+0.4	385.4c	89.4d	481.7bcd	319de
Norflurazon+diuron	0.4+0.4	SHW	788.0bc	663.9bc	1794.5a	1082ab
Hoe-weeded check	-	3,6&9WASC [4]	1501.8a	1078.2a	1254.8abc	1278a
Hoe-weeded check	-	3&6WASC	1156.0ab	994.5ab	881.8abcd	1011abcd
Weedy check	-	-	249.4c	56.4d	17.3d	108e
SE (±)	-	-	200.8	120.6	310.5	211

1 Pre-em. = Pre-emergence

2 Post-em. = Post-emergence at 6 WASC.

3 SHW = Supplementary hoe-weeding.

4 WASC= Weeks after sowing cottonm

5 Means within a column followed by the same letter do not differ significantly at 5% level of probability using Duncan's Multiple Range Test (DMRT).

1.0 + 0.4 kg a.i./ha fb SHW, caused higher seed cotton yield than the high rate alone (2.0 + 0.8 kg a.i./ha) in 1987 and both the high rate applied alone and its split application in 1988.

In 1989, norflurazon plus diuron at 0.4 + 0.4 kg a.i./ha fb SHW resulted in higher seed cotton than the split application of the high rate, while similar trends were observed with all the other herbicide mixtures in the pooled results. In all the trials, and the pooled results, no differences in seed cotton yield was observed between 2 and 3 hoe-weedings.

Uncontrolled weed growth throughout the crop life-cycle, resulted in 83.4%, 94.8%, 99.0% and 91.5% reduction in seed cotton yield, compared with the appropriate maximum in 1987, 1988, and 1989, and pooled results respectively

4.3.3 Cotton boll count

Maximum boll counts were observed with three hoe-weedings in 1987 and 1988 and with metolachlor plus diuron at 1.0 + 0.4 kg a.i./ha and norflurazon plus diuron at 0.4 + 0.4 kg a. i./ha, all fb. SHW in 1989 (Table 22).

Although both metolachlor plus diuron and alachlor plus diuron, each at 1.0 + 0.4 kg a.i./ha fb SHW, resulted in boll counts comparable to the maximum in 1987, only the later herbicide treatment was comparable in boll count in 1988. Boll count with alachlor plus diuron at 2.0 + 0.8 kg a.i./ha

Table 22: *Effect of weed control treatments on number of cotton boll count at final harvest in cotton/cowpea mixture.*

Treatment	Rate (kg a.i./ha)		Cotton boll count		
	1 Pre-em.	2 Post-em.	1987	1988	1989
			—numbers/stand—		
Alachlor+diuron	2.0+0.8	-	24.0cde[5]	23.0cdef	40.ab
Alachlor+diuron	1.0+0.4	1.0+0.4	31.0cd	33.0cd	21.ab
Alachlor+diuron	1.0+0.4	3 SHW	59.0ab	61.0ab	60.0a
Metolachlor+diuron	2.0+0.8	-	25.0cde	26.0cdef	45.0ab
Metolachlor+diuron	1.0+0.4	1.0+0.4	27.0cde	32.0cde	23.0b
Metalachlor+diuron	1.0+0.4	SHW	42.0abc	42.0bc	50.0a
Norflurazon+diuron	0.8+0.8	-	29.0cde	24.0cdef	40.0ab
Norflurazon+diuron	0.4+0.4	0.4+0.4	28.0cde	35.0c	25.0b
Norflurazon+diuron	0.4+0.4	SHW	37.0c	37.0c	60.0a
Hoe-weeded check	-	3,6&9WASC[4]	61.0a	63.0a	45.0ab
Hoe-weeded check	-	3&6WASC	39.0bc	37.0c	45.0ab
Weedy check	-	-	10.0e	7.0f	8.0f
SE (±)	-	-	6.0	10.0	10.0

1 Pre-em. = Pre-emergence

2 Post-em. = Post-emergence at 6 WASC.

3 SHW = Supplementary hoe-weeding.

4 WASC = Weeks after sowing cotton.

5 Means within a column followed by the same letter do not differ significantly at 5% level of probability using Duncan's Multiple Range Test (DMRT).

and norflurazon plus diuron at 0.4 + 0.4 fb. 0.4 + 0.4 kg.a.i./ha were significantly lower than those of their corresponding SHW treatments in 1987 and 1989 seasons.

In 1989, only the plots treated with split application of the herbicide mixtures produced lower boll count than the corresponding maximum. In the weedy plots, boll count were significantly reduced by 83.6%, 88.9% and 86.7% in 1987, 1988 and 1989, respectively, compared with the appropriate maxima in the trials.

4.3.4 Cotton flower production

The effect of weed control treatments on flower number per stand of cotton, was significant during the three years of the experiment. In all the years, the two hoe-weeding treatments resulted in significantly higher flower number than the corresponding weedy check (Table 23).

In 1987, alachlor plus diuron at 1.0 + 0.4 kg a.i./ha either fb. the same treatment at post-emergence or fb. SHW, and norflurazon plus diuron at 0.4 + 0.4 kg a.i./ha fb. SHW resulted in significantly higher flower count than the weedy check but comparable to the highest obtained with three hoe-weedings.

In 1988, all the weed control treatments caused higher flower number than the weedy check.

In 1989, all the herbicide treatments fb. SHW, resulted in higher flower number than the unweeded check but comparable to the hoe-weeded control. Split application of alachlor plus

Table 23: Effect of weed control treatments on cotton flower production in cotton/cowpea mixture.[1]

Treatment	Rate (kg a.i./ha)		Cotton flower count		
	Pre-em.[2]	Post-em.[3]	1987	1988	1989
			numbers/stand		
Alachlor+diuron	2.0+0.8	-	14.0bcd	13.0b	15c
Alachlor+diuron	1.0+0.4	1.0+0.4	170abcd	15.0b	17bc
Alachlor+diuron	1.0+0.4	SHW[4]	19.0abc	30.0a	35a
Metolachlor+diuron	2.0+0.8	-	14.0bcd	14.0b	20abc
Metolachlor+diuron	1.0+0.4	1.0+0.4	12.0cde	15.0b	15bc
Metalachlor+diuron	1.0+0.4	SHW	15.0bcd	17.0b	23abc
Norflurazon+diuron	0.8+0.8	-	11.0cde	13.0b	22abc
Norflurazon+diuron	0.4+0.4	0.4+0.4	16.0bcd	15.0b	16c
Norflurazon+diuron	0.4+0.4	SHW	21.0ab	16.0b	34ab
Hoe-weeded check	-	3,6&9WASC[5]	26.0a	31.0a	25.abc
Hoe-weeded check	-	3&6WASC	21.0ab	16.0b	22abc
Weedy check	-	-	3.0e	2.0c	4e
SE (±)	-	-	3.0	2.0	6

1 Cumulative flower count up to 50% flowering.

2 Pre-em. = Pre-emergence

3 Post-em. = Post-emergence at 6 WASC.

4 SHW = Supplementary hoe-weeding.

5 WASC = Weeks after sowing cotton.

6 Means within a column followed by the same letter do not differ significantly at 5% level of probability using Duncan's Multiple Range Test (DMRT).

diuron at 1.0 + 0.4 fb. 1.0 + 0.4 kg a.i./ha, as well as of norflurazon plus diuron at 0.4 + 0.4 fb. 0.4 + 0.4 kg a.i./ha significantly depressed the number of flowers compared with their split applications fb. SHW.

Uncontrolled weeds throughout the crop's life-cycle resulted in significant reduction of flower count by 88.5%, 93.3% and 88.6% in 1987, 1988 and 1989, respectively, compared with the appropriate maxima in the trials.

4.3.5 Cotton plant height

Height of cotton plants at 9 WASC was only significantly affected by weed control treatments in 1988 and 1989 seasons (Table 24).

In 1988, significantly shorter cotton plants occurred on plots treated with norflurazon plus diuron at 0.4 + 0.4 kg a.i./ha fb. SHW, as well as the two and three hoe-weeded controls and the weedy check, than those of the other weed control treatments except single and split application of alachlor plus diuron at 2.0 + 0.8 kg a.i./ha.

In 1989, plots given supplementary hoe-weeding to pre-emergence herbicide treatments had significantly taller plants than those given other herbicide treatments, or the hoe-weeded controls or the weedy check. The other herbicide treatments viz alachlor plus diuron and norflurazon plus diuron as well as two hoe-weedings, resulted in taller cotton plants than the weedy check in the trial.

Table 24: Effect of Weed control treatments on cotton plant height at 9 WASC in cotton/cowpea mixture

Treatment	Rate (kg a.i./ha)		Cotton plant height		
	Pre-em.[1]	Post-em.[2]	1987	1988	1989
			———Nos./stand———		
Alachlor+diuron	2.0+0.8	-	40.6a[5]	65.7ab	43.2bc
Alachlor+diuron	1.0+0.4	1.0+0.4	56.6a	65.7ab	37.0bc
Alachlor+diuron	1.0+0.4	SHW[3]	84.2a	78.6a	57.6a
Metolachlor+diuron	2.0+0.8	-	48.0a	77.9a	39.4bcd
Metolachlor+diuron	1.0+0.4	1.0+0.4	96.3a	75.9a	34.1cd
Metalachlor+diuron	1.0+0.4	SHW	87.9a	81.8a	55.0a
Norflurazon+diuron	0.8+0.8	-	73.7a	80.4a	44.2b
Norflurazon+diuron	0.4+0.4	0.4+0.4	74.7a	80.7a	46.5b
Norflurazon+diuron	0.4+0.4	SHW	55.7a	49.2b	62.1a
Hoe-weeded check	-	3,6&9WASC[4]	101.2a	48.3b	37.7bcd
Hoe-weeded check	-	3&6WASC	80.7a	47.0b	41.2bc
Weedy check	-	-	52.7a	45.6b	30.6d
SE (±)	-	-	18.6(NS)	6.8	3.1

1 Pre-em. = Pre-emergence
2 Post-em. = Post-emergence at 6 WASC.
3 SHW = Supplementary hoe-weeding.
4 WASC = Weeks after sowing cotton
5 Means within a column followed by the same letter do not differ significantly at 5% level of probability using Duncan's Multiple Range Test (DMRT).

4.3.6 Cotton dry matter production

In 1987, the cotton dry matter production in plots treated with norflurazon plus diuron at 0.4 + 0.4 fb. 0.4 + 0.4 kg a.i./ha and alachlor plus diuron at 1.0 + 0.4 kg a.i./ha fb. SHW were similar and significantly higher than those of the hoe-weeded controls and the weedy check (Table 25).

In 1988, plots treated with alachlor plus diuron at 1.0 + 0.4 kg a.i./ha either fb. 1.0 + 0.4 kg a.i./ha or SHW and metolachlor plus diuron at 1.0 + 0.4 fb. 1.0 + 0.4 kg a.i./ha, produced similar cotton dry matter that were significantly higher than that of the weedy check. Among the herbicide treatments, norflurazon plus diuron at 0.4 + 0.4 kg a.i./ha fb. SHW; resulted in cotton dry matter production that was significantly lower than the maximum obtained in the trial.

In 1989, alachlor plus diuron at 2.0 + 0.8 kg a.i./ha and norflurazon plus diuron at 0.4 + 0.4 kg a.i./ha fb. SHW resulted in similar cotton dry matter production that was significantly higher than that of the weedy check. Alachlor plus diuron at 1.0 + 0.4 fb. 1.0 + 0.4 kg a.i./ha, metolachlor plus diuron at 1.0 + 0.4 fb. 1.0 + 0.4 kg a.i./ha and norflurazon plus diuron at 0.4 + 0.4 fb. 0.4 + 0.4 kg a.i./ha resulted in lower cotton dry matter production, than the maximum obtained with alachlor plus diuron at 2.0 + 0.8 kg a.i./ha.

Table 25: Effect of weed control treatments on cotton dry matter production at harvest in cotton/cowpea mixture.

Treatment	Rate (kg a.i./ha)		Cotton dry matter production		
	Pre-em.[1]	Post-em.[2]	1987	1988	1989
			——g/stand——		
Alachlor+diuron	2.0+0.8	-	18.3bc[5]	17.4abc	73.8a
Alachlor+diuron	1.0+0.4	1.0+0.4	19.2bc	25.5a	37.5bc
Alachlor+diuron	1.0+0.4	SHW[3]	39.4ab	20.3ab	56.3abc
Metolachlor+diuron	2.0+0.8	-	7.0c	16.6abc	32.5bc
Metolachlor+diuron	1.0+0.4	1.0+0.4	21.6bc	24.1ab	35.0bc
Metalachlor+diuron	1.0+0.4	SHW	25.0bc	9.3abc	45.0abc
Norflurazon+diuron	0.8+0.8	-	18.9bc	10.9abc	53.8abc
Norflurazon+diuron	0.4+0.4	0.4+0.4	46.3a	19.9abc	32.5bc
Norflurazon+diuron	0.4+0.4	SHW	13.5c	6.9bc	62.5ab
Hoe-weeded check	-	3,6&9WAS[4]	8.0c	14.6abc	43.8abc
Hoe-weeded check	-	3&6WAS	5.2c	12.8abc	55.0abc
Weedy check	-	-	9.1c	5.0c	25.0c
SE (±)	-	-	6.8	5.3	10.0

1 Pre-em. = Pre-emergence
2 Post-em. = Post-emergence at 6 WASC.
3 SHW = Supplementary hoe-weeding.
4 WASC = Weeks after sowing cotton
5 Means within a column followed by the same letter do not differ significantly at 5% level of probability using Duncan's Multiple Range Test (DMRT).

Unchecked weed throughout the crop's life-cycle caused 80.3% reduction in the 1987 and 1988, and 66.1% reduction in crop's dry matter in 1989, compared with the appropriate maxima in the trials.

4.3.7 Cotton stand at harvest

In 1987, stand count of cotton at harvest with the hoe-weeded control and the weedy check were significantly lower than those of split application of high rates of the herbicide mixture tested as well as metolachlor plus diuron at 2.0 + 0.8 kg a.i./ha. The other herbicide treatments also resulted in higher stand count than the weedy check. (Table 26)

In 1988, plots treated with norflurazon plus diuron at 0.4 + 0.4 kg a.i./ha fb. SHW had the highest stand count of cotton over the weedy check, alachlor plus diuron and metolachlor plus diuron each at 1.0 + 0.4 fb. 1.0 + 0.4 kg a.i./ha, as well as plots treated with norflurazon plus diuron at 0.8 + 0.8 kg. a. i./ha, respectively.

In 1989, though the trend of the highest number of stand count was similar tothat of 1988, variations among the treatments were not at par.

4.4 Cowpea

4.4.1 Cowpea grain yield

Cowpea grain yield was significantly affected by the weed control treatments in all the trials and their pooled results (Table 27).

Table 26: Effect of weed control treatments on cotton stand at harvest in cotton/cowpea mixture.

Treatment	Rate (kg a.i./ha) Pre-em.[1]	Post-em.[2]	Cotton stands 1987	1988	1989
			stands/ha		
Alachlor+diuron	2.0+0.8	-	37037abcd[5]	38630ab	37630bc
Alachlor+diuron	1.0+0.4	1.0+0.4	41976a	35597bc	36797c
Alachlor+diuron	1.0+0.4	SHW[3]	37037abcd	40330ab	39542bc
Metolachlor+diuron	2.0+0.8	-	42387a	33951bc	34955c
Metolachlor+diuron	1.0+0.4	1.0+0.4	40741a	35491bc	35490c
Metalachlor+diuron	1.0+0.4	SHW	37655abc	37243abc	38345bc
Norflurazon+diuron	0.8+0.8	-	39918ab	34774bc	35650c
Norflurazon+diuron	0.4+0.4	0.4+0.4	40741a	39095ab	38095bc
Norflurazon+diuron	0.4+0.4	SHW	34157cd	42799a	45432a
Hoe-weeded check	-	3,6&9WASC[4]	32305cde	38478ab	38578bc
Hoe-weeded check	-	3&6WASC	31687de	37655ab	39456b
Weedy check	-	-	30864e	30659c	30655d
SE (±)	-	-	1893	1975	1875

1 Pre-em. = Pre-emergence

2 Post-em. = Post-emergence at 6 WASC.

3 SHW = Supplementary hoe-weeding.

4 WASC = Weeks after sowing cotton.

5 Means within a column followed by the same letter do not differ significantly at 5% level of probability using Duncan's Multiple Range Test (DMRT).

Table 27: Effect of weed control treatments on cowpea grain yield in cotton/cowpea mixture.

Treatment	Rate (kg a.i./ha)		Cowpea grain yield			
	Pre-em.[1]	Post-em.[2]	1987	1988	1989	Pooled mean
			kg/ha			
Alachlor+diuron	2.0+0.8	-	204.6b[5]	583.6bc	986.9ab	592abc
Alachlor+diuron	1.0+0.4	1.0+0.4	144.0bc	876.2ab	571.3bc	531abc
Alachlor+diuron	1.0+0.4	SHW[3]	567.0ab	1244.9a	1365.3a	1059a
Metolachlor+diuron	2.0+0.8	-	1215.3ab	553.9bc	582.5bc	784ab
Metolachlor+diuron	1.0+0.4	1.0+0.4	408.0b	1265.3a	634.4abc	769ab
Metalachlor+diuron	1.0+0.4	SHW	659.4ab	1311.6a	578.8bc	850ab
Norflurazon+diuron	0.8+0.8	-	1598.0a	922.6ab	812.5abc	1111a
Norflurazon+diuron	0.4+0.4	0.4+0.4	511.2b	168.6c	541.7bc	407abc
Norflurazon+diuron	0.4+0.4	SHW	656.0ab	1257.8a	582.5bc	832ab
Hoe-weeded check	-	3,6&9WASC[4]	441.0b	1324.6a	894.1bc	887ab
Hoe-weeded check	-	3&6WASC	352.0b	991.1ab	1161.2ab	835ab
Weedy check	-	-	52.0b	107.5c	148.4c	103c
SE (±)	-	-	354.0	179.1	222.6	252

1 Pre-em. = Pre-emergence

2 Post-em. = Post-emergence at 6 WASC.

3 SHW = Supplementary hoe-weeding.

4 WASC = Weeks after sowing cotton.

5 Means within a column followed by the same letter do not differ significantly at 5% level of probability using Duncan's Multiple Range Test (DMRT).

In 1987, the highest cowpea grain yield of 1598 kg/ha was obtained from the plots treated with norflurazon plus diuron at 0.8 + 0.8 kg a.i./ha. Among the other herbicide treatments, all the pre-emergence herbicides given SHW and metolachlor plus diuron at 2.0 + 0. 8 kg a.i./ha resulted in grain yields comparable to the highest. The hoe-weeded controls did not differ significantly in grain yield from the weedy check (Table 27).

In 1988, all the herbicide treatments fb. SHW, metolachlor plus diuron and alachlor plus diuron each applied split at 1.0 + 0.4 fb 1.0 + 0.4 kg a.i./ha, as well as norflurazon plus diuron at 0.8 + 0.8 kg a.i./ha alone and two hoe-weedings resulted in significantly higher cowpea grain yield than the weedy check and comparable to the highest with three hoe-weedings. Plots treated with single application of mixtures of diuron with alachlor and metolachlor each of 2.0 + 0.8 kga.i./ha, as well as split application of norflurazon plus diuron produced significantly lower cowpea grain yields than their corresponding mixtures fb SHW. The two hoe-weeded controls resulted in higher cowpea grain yield than the weedy check in this trial. In 1989, alachlor plus diuron at 2.0 + 0.8 kg a.i./ha alone and at 1.0 + 0.4 kg a.i./ha fb SHW as well as two hoe-weedings resulted in significantly higher cowpea grain yield than the weedy check.

Averaged over the three seasons, plots treated with alachlor plus diuron at 1.0 + 0.4 kg a.i./ha fb SHW and

norflurazon plus diuron at 0.8 + 0.8 kg a.i./ha, produced significantly higher cowpea grain yield than the weedy check. Uncontrolled weeds throughout crop's life-cycle, caused cowpea grain yield reduction of 96.8%, 91.8%, 89.7%, 90.7% in 1987, 1988, 1989 and pooled results, respectively compared with appropriate maxima.

4.4.2 Cowpea pod count

In 1987, metolachlor plus diuron at 1.0 + 0.4 kg a.i./ha fb. SHW, and norflurazon plus diuron at 0.8 + 0.8 kg a.i./ha, as well as two and three hoe-weedings, resulted in cowpea pod number, comparable to the highest with metolachlor plus diuron at 2.0 + 0.8 kg a.i./ha and significantly higher than the weedy check. (Table 28).

In the 1988 and 1989 rainy seasons, mixtures of diuron with alachlor and metolachlor each at 1.0 + 0.4 kg a.i./ha fb. SHW, norflurazon plus diuron at 0.8 + 0.8 kg a.i./ha alone, as well as three hoe-weedings resulted in significantly higher cowpea pod number than the weedy check. Two hoe-weedings also caused higher cowpea pods than the weedy check, in 1989.

4.4.3 Vine length

As shown in Table 29, during the 1987 season, only plots treated with alachlor plus diuron at 2.0 + 0.8 kg a.i./ha alone had cowpea plants with significantly shorter vine than the maximum obtained with three hoe-weedings and metolachlor plus diuron at 1.0 + 0.4 fb 1.0 + 0.4 kg a.i./ha. However, in 1988 and 1989 wet seasons, maximum length occurred with two

Table 28: Effect of weed control treatments on cowpea pods per stand at harvest in cotton/cowpea mixture.

Treatment	Rate (kg a.i./ha) 1 Pre-em.	2 Post-em.	Cowpea pods 1987	1988	1989
			——pods/stand——		
Alachlor+diuron	2.0+0.8	-	15.0c[5]	18.0ab	18.0abc
Alachlor+diuron	1.0+0.4	1.0+0.4	14.0c	18.0ab	13.0bc
Alachlor+diuron	1.0+0.4	SHW[3]	16.0bc	21.0a	21.0ab
Metolachlor+diuron	2.0+0.8	-	25.0a	16.0ab	16.0abc
Metolachlor+diuron	1.0+0.4	1.0+0.4	16.0bc	19.0ab	17.0abc
Metalachlor+diuron	1.0+0.4	SHW	18.0abc	22.0a	22.0ab
Norflurazon+diuron	0.8+0.8	-	24.0ab	21.0a	21.0ab
Norflurazon+diuron	0.4+0.4	0.4+0.4	17.0bc	11.0ab	16.0abc
Norflurazon+diuron	0.4+0.4	SHW	16.0bc	16.0ab	19.0abc
Hoe-weeded check	-	3,6&9WASC[4]	24.0ab	24.0a	26.0a
Hoe-weeded check	-	3&6WASC	19.0abc	18.0ab	21.0a
Weedy check	-	-	5.0c	3.0b	6.0c
SE (±)	-	-	3.00	5.00	4.00

1 Pre-em. = Pre-emergence

2 Post-em. = Post-emergence at 6 WASC.

3 SHW = Supplementary hoe-weeding.

4 WASC = Weeks after sowing cotton.

5 Means within a column followed by the same letter do not differ significantly at 5% level of probability using Duncan's Multiple Range Test (DMRT).

Table 29: Effect of weed control treatments on cowpea Vine length at harvest in cotton/cowpea mixture.

Treatment	Rate (kg a.i./ha)		Cowpea vine length		
	Pre-em.[1]	Post-em.[2]	1987	1988	1989
			——cm——		
Alachlor+diuron	2.0+0.8	-	81.3b[5]	135.3ab	110.3abc
Alachlor+diuron	1.0+0.4	1.0+0.4	140.3ab	148.0ab	98.0cd
Alachlor+diuron	1.0+0.4	SHW[3]	123.5ab	176.8ab	176.8abc
Metolachlor+diuron	2.0+0.8	-	152.3ab	188.3ab	188.3ab
Metolachlor+diuron	1.0+0.4	1.0+0.4	183.5a	159.3ab	84.3d
Metalachlor+diuron	1.0+0.4	SHW	159.0ab	141.5ab	155.3abcd
Norflurazon+diuron	0.8+0.8	-	139.3ab	181.3ab	131.3abcd
Norflurazon+diuron	0.4+0.4	0.4+0.4	130.8ab	158.3ab	158.3abcd
Norflurazon+diuron	0.4+0.4	SHW	117.3ab	130.8b	130.8abcd
Hoe-weeded check	-	3,6&9WASC[4]	183.3a	180.8ab	155.8abcd
Hoe-weeded check	-	3&6WASC	145.8ab	205.0a	205.0a
Weedy check	-	-	132.3ab	162.0ab	112.0bcd
SE (±)	-	-	27.4	21.3	24.4

1 Pre-em. = Pre-emergence
2 Post-em. = Post-emergence at 6 WASC.
3 SHW = Supplementary hoe-weeding.
4 WASC = Weeks after sowing cotton
5 Means within a column followed by the same letter do not differ significantly at 5% level of probability using Duncan's Multiple Range Test (DMRT).

hoe-weedings, while norflurazon plus diuron at 0.4 + 0.4 kg a.i./ha fb SHW, resulted in shorter cowpea vine than the maximum in 1988.

In 1989, mixtures of diuron with metolachlor and alachlor each at 0.4 + 1.0 kg a.i./ha fb 0.4-1.0kg a.i./ha, as well as weedy check, resulted in significantly shorter vine length than the maximum. The same herbicide mixtures applied alone at the rate of 2.0 + 0.8 kg a.i./ha resulted in vine length comparable to the maximum ard higher than the shortest with split application of metolachlor plus diuron at 1.0 + 0.4 fb 1.0 + 0.4 kg a.i./ha.

4.4.4 Crop vigour score

Pre-emergence herbicides followed by supplementary hoe-weeding as well as two and three hoe-weedings resulted in significantly higher cowpea vigour score, compared with weedy check, in the 1987 wet season (Table 30). Alachlor plus diuron at 2.0 + 0.8 kg a.i./ha and 1.0 + 0.4 fb 1.0 + 0.4 kg a.i./ha, also resulted in higher vigour score than the weedy check.

In 1988, plots treated with alachlor plus diuron at 1.0 + 0.4 kg a.i./ha, and norflurazon plus diuron at 0.4 + 0.4 kg a.i./ha, each fb SHW, resulted in vigour scores comparable to those of the two and three hoe-weedings, and significantly higher than that of the weedy check, and the rest of the herbicide treatments except metolachlor plus diuron at 1.0 + 0.4 kg a.i./ha fb SHW. The later herbicide treatment resulted in vigour scores comparable to that of norflurazon plus diuron at 0.4 + o.4 kg a.i./ha fb SHW. In this trial, alachlor plus diuron at 1.0 + 0.4 fb 1.0 + 0.4 kg a.i./ha and metolachlor plus diuron at 2.0 + 0.8 kg a.i./ha did not differ from the weedy check in cowpea vigour score.

In 1989, all the treatments of diuron mixtures with alachlor and metolachlor, as well as norflurazon plus diuron at 0.8 + 0.8 kg a.i./ha, resulted in higher vigour score than the weedy check. The other norflurazon plus diuron treatments as well as the hoe-weeded controls, caused cowpea vigour score comparable to that of the weedy check.

Table 30: Effect of weed control treatments on cowpea vigour score[1] 8 WASC in cotton/cowpea mixture.

Treatment	Rate (kg a.i./ha) Pre-em.[2]	Post-em.[3]	1987	1988	1989
Alachlor+diuron	2.0+0.8	-	4.4b[6]	5.0c	6.2bc
Alachlor+diuron	1.0+0.4	1.0+0.4	5.0b	4.3cd	7.1ab
Alachlor+diuron	1.0+0.4	SHW[4]	8.0a	8.1a	7.0ab
Metolachlor+diuron	2.0+0.8	-	4.0bc	4.4cd	7.0ab
Metolachlor+diuron	1.0+0.4	1.0+0.4	4.0bc	5.0c	7.0ab
Metalachlor+diuron	1.0+0.4	SHW	8.0a	7.2b	7.0ab
Norflurazon+diuron	0.8+0.8	-	4.1b	5.0c	8.0a
Norflurazon+diuron	0.4+0.4	0.4+0.4	4.1b	5.0c	5.4cd
Norflurazon+diuron	0.4+0.4	SHW	7.4a	8.0ab	4.0f
Hoe-weeded check	-	3,6&9WASC[5]	8.0a	8.1a	5.0de
Hoe-weeded check	-	3&6WASC	8.0a	8.0a	4.3ef
Weedy check	-	-	3.2c	4.0d	5.0def
SE (±)	-	-	0.3	0.2	0.3

1 Crop vigour score using scale (0 - 10), where 0 = completely killed plants and 10 = most healthy plants.
2 Pre-em. = Pre-emergence
3 Post-em. = Post-emergence at 6 WASC.
4 SHW = Supplementary hoe-weeding.
5 WASC = Weeks after sowing cotton
6 Means within a column followed by the same letter do not differ significantly at 5% level of probability using Duncan's Multiple Range Test (DMRT).

4.4.5 Cowpea dry matter production

In 1987, both alachlor plus diuron at 1.0 + 0.4 kg a.i./ha fb SHW and three hoe-weedings caused the production of significantly higher cowpea dry matter than the weedy check (Table 31).

In 1988 season, split application of metolachlor plus diuron applied at 1.0 + 0.4 fb 1.0 + 0.4 kg a.i./ha, and norflurazon plus diuron at 0.4 + 0.4 fb 0.4 + 04 kg a.i./ha caused the production of higher cowpea dry matter than the least obtained with alachlor plus diuron at 2.0 + 0.8 kg a.i./ha.

Table 31: Effect of weed control treatments on cowpea dry matter production at harvest in cotton/cowpea mixture.

Treatment	Rate (kg a.i./ha)		Cowpea dry weight		
	Pre-em.[1]	Post-em.[2]	1987	1988	1989
			g/stand		
Alachlor+diuron	2.0+0.8	-	32.7abc[5]	2.8b	31.0ab
Alachlor+diuron	1.0+0.4	1.0+0.4	19.3abc	13.9ab	20.5b
Alachlor+diuron	1.0+0.4	SHW[3]	48.5a	9.2ab	36.5ab
Metolachlor+diuron	2.0+0.8	-	23.7abc	12.0ab	25.0ab
Metolachlor+diuron	1.0+0.4	1.0+0.4	19.8abc	35.1a	23.0b
Metolachlor+diuron	1.0+0.4	SHW	19.5abc	15.1ab	63.3a
Norflurazon+diuron	0.8+0.8	-	25.4abc	12.4ab	43.0ab
Norflurazon+diuron	0.4+0.4	0.4+0.4	14.4bc	31.4a	15.0b
Norflurazon+diuron	0.4+0.4	SHW	21.5abc	8.6ab	17.3b
Hoe-weeded check	-	3,6&9WASC[4]	42.6ab	19.9ab	23.8b
Hoe-weeded check	-	3&6WASC	30.1abc	15.3ab	25.8ab
Weedy check	-	-	9.0c	29.4ab	20.5b
SE (±)	-	-	9.5	9.0	11.3

1 Pre-em. = Pre-emergence
2 Post-em. = Post-emergence at 6 WASC.
3 SHW = Supplementary hoe-weeding.
4 WASC = Weeks after sowing cotton
5 Means within a column followed by the same letter do not differ significantly at 5% level of probability using Duncan's Multiple Range Test (DMRT).

Only metolachlor plus diuron at 1.0 + 0.4 kg a.i./ha fb SHW resulted in significantly higher cowpea dry weight than the weedy check, in 1989.

Reduction in dry matter production of cowpea were 81.4%, 16.2% and 52.7% due to weed-infestation throughout crop's life-cycle in 1987, 1988 and 1989 respectively, compared with the appropriate maximum in each trial.

4.5 Weed

4.5.1 Weed population

Weed population was only significantly affected by weed control treatments in 1987 wet season (Table 32). In the trial broadleaved weed population was significantly lower in plots treated with norflurazon plus diuron at 0.4 + 0.4 kg a.i./ha and metolachlor plus diuron at 1.0 + 0.4 kg a.i./ha each given SHW, compared with their other corresponding herbicide mixture treatments. Alachlor plus diuron at 1.0 + 0.4 kg a.i./ha fb SHW had, resulted in lower broadleaved weed population than the split application of the mixture at 1.0 + 0.4 fb 1.0 + 0.4 kg a.i./ha.

The high rates of diuron with metolachlor and norflurazon, as well as split application of alachlor plus diuron reduced grass weed population significantly compared with their corresponding low rates fb SHW and two hoe-weedings. The indicated treatments of metolachlor and alachlor mixtures with diuron also resulted in lower weed population than the weedy check. Weed populations were not

Table 32: Effect of weed control treatments on weed population in cotton/cowpea mixture at 12 WASC.

Treatment	Rate (kg a.i./ha) Pre-em.[1]	Post-em.[2]	1987 Broadleaved	1987 Grasses	1988 Broadleaved	1988 Grasses	1989 Broadleaved	1989 Grasses
Alachlor+diuron	2.0+0.8	-	14.0abcd[5]	6.0bcde	6.0ab	8.0a	9.0a	4.0a
Alachlor+diuron	1.0+0.4	1.0+0.4	19.0a	2.0e	8.0ab	8.0a	4.0a	4.0a
Alachlor+diuron	1.0+0.4	SHW[3]	12.0bcd	10.0abcd	8.0ab	6.0a	6.0a	6.6a
Metolachlor+diuron	2.0+0.8	-	18.0ab	2.0e	8.0ab	6.0a	8.0a	4.6a
Metolachlor+diuron	1.0+0.4	1.0+0.4	18.0ab	2.0e	8.0ab	6.0a	5.0a	4.6a
Metalachlor+diuron	1.0+0.4	SHW	10.0cd	11.0abc	10.0a	6.0a	4.0a	8.0a
Norflurazon+diuron	0.8+0.8	-	16.0abc	5.0cde	4.0b	8.0a	4.0a	4.0a
Norflurazon+diuron	0.4+0.4	0.4+0.4	16.0abc	4.0de	6.0ab	8.0a	6.0a	6.0a
Norflurazon+diuron	0.4+0.4	SHW	8.0d	13.0a	6.0ab	8.0a	6.0a	6.0a
Hoe-weeded check	-	3,6&9WASC[4]	12.0bcd	9.0abcd	6.0ab	8.0a	6.0a	4.0a
Hoe-weeded check	-	3&6WASC	10.0cd	12.0ab	6.0ab	8.0a	4.0a	4.0a
Weedy check	-	-	10.0cd	10.0abcd	4.0b	4.0a	6.0a	6.0a
SE (±)	-	-	2.0	2.0	2.0	1.4	2.0	1.8

1 Pre-em. = Pre-emergence

2 Post-em. = Post-emergence at 6 WASC.

3 SHW = Supplementary hoe-weeding.

4 WASC = Weeks after sowing cotton.

5 Means within a column followed by the same letter do not differ significantly at 5% level of probability using Duncan's Multiple Range Test (DMRT).

significantly affected by the weed control treatments in 1988 and 1989 cropping seasons.

4.5.2 Weed dry weight

All the weed control treatments that received supplementary hoe-weeding at 6 WASC, metolachlor plus diuron at 2.0 + 0.8 kg a.i./ha and the hoe-weeded controls significantly reduced weed dry weight compared with the weedy check in the 1987 trial (Table 33). In 1988, all the herbicide treatments and three hoe-weedings resulted in significantly lower weed weight than the weedy check. Alachlor plus diuron at high rate either applied once or splited, resulted in higher weed dry weight than its low rate fb SHW and all the treatments of metolachlor plus diuron. Norflurazon plus diuron at 0.4 + 0.4 fb SHW caused higher weed dry matter production than the corresponding treatments of mixture of alachlor and metolachlor.

In 1989, all the weed control treatments, with the exception of split application of alachlor plus diuron at 1.0 +0.4 fb 1.0 + 0.4 kg a.i./ha, resulted insignificantly lower weed weight than the weedy check.

The pooled mean over the three seasons showed that herbicide treatments fb SHW, as well as, single and split application of metolachlor plus diuron at 2.0 + 0.8, and 1.0+ 0.4 fb 1.0 + 0.4 kg a.i./ha, have resulted in significantly lower weed weight, that were significantly lower than that of the weedy check but comparable to that of three hoe-weedings.

Table 33: Effect of weed control treatments on weed dry matter at harvest in cotton/cowpea mixture.

Treatment	Rate (kg a.i./ha) Pre-em.[1]	Post-em.[2]	Weed dry matter 1987	1988	1989	Pooled mean
			kg/ha			
Alachlor+diuron	2.0+0.8	-	2784ab[5]	3028bcd	890bc	2234ab
Alachlor+diuron	1.0+0.4	1.0+0.4	1832abc	3104bc	1000ab	1979be
Alachlor+diuron	1.0+0.4	SHW[3]	940c	796gh	620bcd	785ef
Metolachlor+diuron	2.0+0.8	-	1596bc	1340fgh	410d	1115cdef
Metolachlor+diuron	1.0+0.4	1.0+0.4	1952abc	1412efg	320d	1228cdef
Metolachlor+diuron	1.0+0.4	SHW	1280bc	1052gh	510cd	947def
Norflurazon+diuron	0.8+0.8	-	1876abc	2084def	340d	1433bede
Norflurazon+diuron	0.4+0.4	0.4+0.4	2420abc	2332cde	440d	1731bede
Norflurazon+diuron	0.4+0.4	SHW	1380bc	2588bcd	300d	1422bcdef
Hoe-weeded check	-	3,6&9WASC[4]	1160c	2588bcd	300d	1810bcd
Hoe-weeded check	-	3&6WASC	1664bc	3376ab	390d	1810bcd
Weedy check	-	-	3412a	4233a	1410a	3018a
SE (±)	-	-	464	283	124	290

1 Pre-em. = Pre-emergence

2 Post-em. = Post-emergence at 6 WASC.

3 SHW = Supplementary hoe-weeding.

4 WASC = Weeks after sowing cotton.

5 Means within a column followed by the same letter do not differ significantly at 5% level of probability using Duncan's Multiple Range Test (DMRT).

Weed weight with single pre-emergence application of alachlor plus diuron at 2.0 + 0.8 kg a.i./ha was comparable to that of the weedy check. Weed dry matter was negatively and significantly correlated with seed cotton yield, cotton flower count, cotton dry matter and cotton vigour score at 9 WASC (Table 34).

Table 34: Matrix of correlation coefficients of pooled mean (1987-1989) of various growth and yield components seed cotton yield/cowpea grain yields in weed control experiment.

	1	2	3	4	5	6	7	8	9	10	11	12	13	1
Cowpea grain yield	1.0000													
Cowpea pod count	0.0192	1.0000												
Cowpea dry weight	0.0522	0.1466	1.0000											
Cowpea Vine length	0.0890	0.1482	-0.0830	1.0000										
Seed cotton yield	-0.1085	0.2248*	0.1544	-0.0141	1.0000									
Cotton flower count 12WASC	-0.0613	0.2812**	0.1859	-0.0081	0.6511**	1.0000								
Cotton boll count	0.1345	0.1682	-0.0237	0.1519	-0.0707	0.0161	1.0000							
Cotton shoot height 9WASC	0.1255	0.2043	-0.0745	0.1964*	-0.1020	-0.0488	0.3783**	1.0000						
Cotton dry matter	-0.1467	0.0834	0.1113	-0.1391	0.5835**	0.4991**	-0.3195**	-0.1780	1.0000					
Cowpea vigour score 6WASC	-0.0754	0.2254*	0.0869	0.0181	0.2313*	0.2763**	0.4199**	0.0299	-0.0820	1.0000				
Cotton vigour scores 9WASC	-0.2679**	0.1761	0.1233	-0.0242	0.2663*	0.3024**	-0.2346*	-0.1983	0.2502*	0.4505**	1.0000			
Weed Score 6 WASC	0.0215	-0.3826**	0.0355	-0.1944	-0.1820	-0.1758	-0.4446**	-0.0883	0.0873	-0.4690**	-0.1146	1.0000		
Weed dry weight	0.0187	-0.1407	-0.1350	0.0434	-0.4151***	-0.4517**	0.1930	0.0481	-0.4339**	-0.1285	-0.2601*	-0.0405	1.0000	
Cowpea Stand count	0.1043	0.0866	-0.1890	0.0304	0.1780	0.1485	0.0402	0.1208	0.2435	-0.0508	-0.0716	-0.1136	-0.0715	1.0000

* Significant at 5% level of probability (r^2 = 0.195);

** Significant at 1% level of probability (r^2 = 0.254).

Table 35: Partial economic analysis of weed control treatments in cotton/cowpea mixture (1987 - 1989).

Treatment	Rate (kg a.i./ha) Pre-em.[1]	Post-em.[2]	Weed control cost (WCC) Pre-em.	Post-em.	WCC plus ** (a) N.00	Seed Cotton Pooled mean kg/ha	Revenue at N3.50/kg (b) N.00	Cowpea grain pooled mean kg/ha	Revenue at N4.50/kg (c) N.00	Total Revenue (d) N.00	Revenue in excess of weed contn cost (d - a) N.00
			/ha								
Alachlor+diuron	2.0+0.8	-	446.0	-	521.0	878	3073	572	2574	5647	5126
Alachlor+diuron	1.0+0.4	1.0+0.4	223.0	223.0	596.0	334	1169	551	2480	3649	3053
Alachlor+diuron	1.0+0.4	SHW[3]	223.0	750.0	973.0	1112	3892	1059	4766	8658	7685
Metolachlor+diuron	2.0+0.8	-	271.0	-	346.0	543	1901	784	3528	5429	5083
Metolachlor+diuron	1.0+0.4	1.0+0.4	135.5	135.5	421.0	280	980	769	3461	4441	4020
Metolachlor+diuron	1.0+0.4	SHW	135.5	750.0	835.5	1031	3609	850	3825	7434	6548
Norflurazon+diuron	0.8+0.8	-	192.0	-	267.0	517	1810	1111	5000	6810	6543
Norflurazon+diuron	0.4+0.4	0.4+0.4	96.0	96.0	342.0	319	1117	407	1832	2949	2607
Norflurazon+diuron	0.4+0.4	SHW	96.0	750.0	846.0	1082	3787	382	3744	7531	6685
Hoe-weeded check	-	3,6&9WASC[4]	150man-day/ha	2250.0	2250.0	1278	4473	887	3992	8465	6215
Hoe-weeded check	-	3 & 6WASC	100man-day/ha	1500.0	1500.0	1011	3539	768	3456	6995	5495
Weedy check	-	-	-	-	-	108	378	103	464	842	842

1 Pre-em. = Pre-emergence

2 Post-em. = Post-emergence at 6 WASC.

3 SHW = Supplementary hoe-weeding.

4 WASC = Weeks after sowing cotton. Cost of herbicides i.e. Alachlor = N175.00/kg; Diuron and weed control cost, Norflurazon = N120.00/kg each metolachlor = N140.00/kg/ha.

** = Cost of herbicide application = N75.00/ha per application; single = N75.00/ha; split application = N150.00/ha; Labour valued at N150.00 per man-day; all cost of other inputs being exclusive

CHAPTER 5

DISCUSSION

Crop productivity in cotton/cowpea mixed cropping system is greatly influenced by the nature of the competition among the component crops, weed-infestation as well as amount and distribution of rainfall during the growing seasons. The rainfall influences both crop yield and the degree of weed competition. The drying and wetting cycles, followed by high temperature (28 - 32°C) and high relative humidity (65 - 85%) between June and September, favours the rapid establishment of weeds early in the season and their subsequent vigorous growth which caused reduction in crop mixture's yield.

In the "Gicci" system evaluated, cotton/cowpea ratio was 3:1. The sub-optimal cotton population in the system intially allowed for severe weed-infestation, but later at the blooming stage of cotton, the fast-growing cowpea suppressed the weeds moderately.

The component cotton crop, which was sown in late June of 1987, 1988 and 1989 seasons, took between 160 - 180 days to attain maturity, while the inter-cropped cowpea (cv. Kano, 1996), a photo-period sensitive variety, which was planted late July, matured between 130 and 150 days depending upon the season. The maximum yields of the higher stratum cotton in 1987, 1988 and 1989 were 1.8, 1.6 and 2.3 t/ha, while the shorter stature cowpea yielded 1.2, 0.95 and 0.96 t/ha in 1987, 1988 and 1989, respectively.

These yield levels under the mixed cropping system were comparable to the findings of Lawes (1961) who had earlier obtained seed cotton yields of 1.0-2.5 t/ha from sole crop cotton. The rainfall was low in 1987 (793.6mm) but was well distributed and thus resulted in a marginal increase in seed cotton yield over that of 1988. The 1988 season had 10% additional rainfall (1157mm) over the long-term seasonal mean, that caused water-logging at flowering and boll development stages, and thus, reduced the seed cotton yield by 30%, compared to the best treatment yield of 1989 which was the best. Pearson and Darling (1958) and Brouner (1960) have also attributed the low seed cotton yield obtained under heavy rainfall to poor aeration in the root zone, low nutrient uptake and high pests and diseases build-up. Similarly, cowpea grain yield was 21% higher in 1987 compared with 1988, when there was excessive water-logging.

5.1 Effect of period of weed-interference on cotton/cowpea mixture.

Averaged over the three-seasons, the losses caused by weed-infestation throughout the life cycle of the crops, were 96.2% for seed cotton and 90.1% for cowpea grain yields, compared with those kept weed-free throughout the seasons. These yield reductions could be due to the fact that cotton which isa slow-growing crop during the first 7 WASC (Kumar et al., 1985) could not compete with the fast growing weeds. The cowpea, which was sown 5 weeks after sowing cotton, in

already weedy plots,was also smoothered by weeds, thus causing drastic yield reduction.

Weed-infestation throughout the crop life cycle also reduced the yield components, particularly flower and boll counts of cotton by 85 - 94.8%, pod count of cowpea by 80.4%, as well as dry matter of cotton and cowpea crops by 76.8 - 82%, respectively. The severe losses in the yields of cotton (96.2%)andcowpea (90.1%)were caused by the mean cumulative weed weight ofas much as 4.5 t/ha.

Lagoke et al. (1982a) and Kumar et al. (1989) also reported seed cotton yield loss of 70 - 97% in sole cropping system due to severe weed conpetition. However, cowpea grain yield reductions of between 34 to 80% in weedy plots, were reported in sole crop cowpea (Arevalo et al., 1977; Remison, 1978; Akobundu, 1980; Lagoke et al., 1983; Lagoke and Shebayan, 1988).

In these trials, weed-infestation initially for 2 WASC, did not adversely affect the growth and yield of cotton/cowpea mixture, probably because weeds had not established well enough to compete seriously with the crop at this stage. In addition, at the initial stages of growth, both crops and weeds have adequate amount of light, nutrient and water relative to their requirements. Hence, the crops are not seriously affected. Similar results reported in the Nigerian Savanna by several scholars, showed that weed-infestation for the first 3 WASC, did not cause significant depression in crop

growth and yield i.e cotton (Dadari et al., 1983), maize/pepper (Bakut, 1985), potato (Bulus, 1986), cowpea (Lagoke et al., 1987) and pepper (Adigun et al., 1992).

Weed-infestation periods of 4, 6, 8 and 10 WASC, resulted in 37, 52, 63 and 73% reduction in seed cotton and of 64, 75, 88 and 96% cowpea grain yields in cotton/cowpea mixture, compared with weed-free plot. Once cotton was infested with weeds for 6 WASC, when cowpea was only planted a week earlier, subsequent weed removal did not obviate the adverse effect of the initial weed competition in this mixture.

When cotton/cowpea mixture was kept weed-free initially for 6 WASC, subsequent weed-infestation did not cause significant reduction in the growth and yield components of the crops compared to weed-free plot. It is, however, apparent that weed-free period of 4, 6, 8 and 10 WASC, resulted in increase of 63, 75, 84 and 94% seed cotton, and 50, 70, 78 and 84% cowpea grain yields, respectively, compared with weed-infested throughout the season (Fig. 3 and 5).

These results indicated that weed removal in cotton/cowpea mixture for the first 6 WASC and more was absolutely necessary, and is comparable to keeping the mixture weed-free throughout the growing season. Earlier reports have emphasized the importance of weed removal in cotton at early stage of growth, so as to eliminate the adverse effect of weed competition (Kumar et al., 1985). Similarly, Sule (1988) also

reported that weed removal in sole crop cowpea for 9 WASC, could equally eliminate the adverse effect of weed competition in this crop.

It was also revealed that weed removal for up to 8 WASC, could cause as much as 75% weed dry matter reduction, as was observed in maize/cowpea (Ayeni, 1983) and in cotton (Dadari et al., 1983). However, weed-free period beyond 8 WASC, did not significantly improve the yields of cotton and cowpea in this mixture, as was reported under sole crop cotton by Martinez and Nieto (1968), Buchanan and Burns (1970), Thomas and Schwezel (1970) and Rogers et al. (1976).

Shorter weed-free period of 3 WASC only, resulted in significantly high seed cotton yield reduction over 50% in the cotton/cowpea mixture, emphasizing the need to remove weeds beyond this period to avoid yield losses. The result further confirmed that, weed-infestation 3 and 6 WASC was very critical in this mixture.

Regression of cotton/cowpea mixture's yields on weed dry matter indicated that, every 1kg increase in weed weight, reduced seed cotton and cowpea grain yields by 0.19kg/ha and 0.2kg/ha, respectively (Fig. 4). However, in a related study of sole crop cotton, Kumar et al., (1985) reported a seed cotton yield reduction of 0.7kg/ha. This variation in the yield losses could be due to the combined effect of inter/intra crop competition of the mixture with the weeds compared to may-sown, sole crop cotton in the later case. The

beneficial effect of cowpea on cotton performance in the 'Gicci' system was evident from the fact that cotton yield was positively correlated with cowpea canopy (r=0.620**) and cowpea dry matter (r=0.705**).

5.2 Critical period of weed competitionin cotton/cowpea mixture

Cotton crop kept weed-free between 3 and 6 WAS, produced seed cotton yield comparable to that of the weed-free control, while weed-infestation within this period caused mean reduction of 32 and 60% seed cotton, respectively. (Fig. 3). In cowpea crop, weed-free period between 3 and 5 WASC, was required to attain cowpea grain yield comparable to the weed-free control, while the presence of weeds within this period caused 50 and 75% of the grain yield reduction (Fig. 5).

The critical periods of cotton -weed competition, closely related to this study, were those reported from the research findings in sole cotton which lie between 4 and 8 WASC in Sudan (Prentice, 1972), and 10 WASC, in Columbia (Chaver, 197 0), and 4 and 6 WASC, in Nigeria (Dadari et al., 19830. Similarly, in sole crop cowpea, the critical period of weed-competition, was reported to lie between 4 and 6 WASC (Fadayomi, 1979; Ohlander, 1980, Ayeni, 1982). The high incidence of Cynodon dactylon L. and Cyperus sp. (Table 2) in the trials, probably caused the earlier onset of serious weed competition, compared to the findings of earlier workers.

Therefore, based on this study, the critical period of weed competition was between 3 and 6 WASC, using cotton as top canopy crop in cotton/cowpea mixture, grown in the traditional "Gicci" system.

5.3 Chemical weed control

The most effective herbicide treatment in this mixture was alachlor plus diuron at 1.0 + 0.4 kg a.i./ha fb SHW at 6 WASC, which out-yielded two hoe-weedings by 9.1% and the weedy check by 90.3% in terms of seed cotton yield. This treatment, however, resulted in seed cotton yield that was 13% lower than that of three hoe-weedings. The grain yield component of cowpea obtained in this treatment (alachlor plus diuron at 1.0 + 0.4kg a.i./ha fb SHW) was higher than those of two and three hoe-weedings by 27.5%, and 16.2% respectively.

The pooled mean (1987 - 1989) showed that, three hoe-weedings (3, 6 and 9 WASC) increased seed cotton yield by 20.9 and 91.5% over two hoe-weedings and the weedy check. In addition, cowpea grain yield increased by 13.4% over two hoe-weedings and by 88.4% over the weedy check, respectively.

The herbicide treatments viz. alachlor, metolachlor, norflurazon and their combination with diuron, each at their low rate fb split application or SHW at 6 WASC, significantly suppressed the broadleaved and the grassy weeds as was observed in the 1987 growing season. These herbicides reduced the weed density by 20 to 84% and weed dry weight by 46 to 73% (Tables, 32 and 33) producing mean seed cotton and cowpea gran

yields of 1.1 and 0.9t/ha, which were consistant with the findings of Toro et al (1972), Toro and Sion (1976) and Azevedo et al (1978).

In the 1989 season, norflurazon plus diuron at 0.4 + 0.4kg a.i./ha fb SHW, out-yielded twc and three hoe-weedings by 50.9% and 20.1% in respect of seed cotton yield.

This contrast was mainly due to the fact that, the 1989 season was marked by severe infestation of perennial weeds viz. Cynodon dactylon Pers. and Cyperus sp., which were effectively controlled by the herbicide, but reappeared in the hoe-weeded plots. The cowpea grain yield of this treatment was 34.9% and 48.9%, lower than three and two hoe-weedings, respectively. Although norflurazon plus diuron (0.8 + 0.8kg a.i./ha in 1987, has resulted in significantly higher cowpea grain yield than the three hoe-weedings, in the case of1988 and 1989 seasons, however, their grain yields were at par. The seed cotton yields of the treatment (norflurazon plus diuron at 0.8 +0.8kg a.i./ha in 1987 and 1988) were also significantly lower than their appropriate maxima. Similarly, high rate of norflurazon plus diuron (0.8 + 0.8kg a.i./ha) was as effective as the low rates of all the pre-emergence treatments fb SHW, with respect to seed cotton yield in 1989 and cowpea grain yield in the pooled mean (1987-1989).

Increasing the rate of norflurazon in the herbicide mixture, intensified the bleaching and chlorotic symptoms

observed in the perennial weeds and consequent reduction in total weed dry matter. Norflurazon has been reported to cause photo-oxidation (John, 1976) and dehydrogenation on weeds, which resulted in leaf chlorosis in plants and consequent reduction in weed dry weight (Urbach et al., 1976; Kunnert and Boger, 1979). The performance of these herbicide combinations were enhanced when supplemented with hoe-weedings at 6 WASC, a period believed to be critical to cotton-weed competition (Dadari et al., 1983; Lagoke et al., 1987), thus causing increase in cotton yield by a margin of about 99% (Table 16). The beneficial effect of the supplementary hoe-weeding was reflected both in increased bolls and seed cotton yield in 1987 to 1989; cowpea pods in 1988 and 1989, as well as cowpea grain yield in the pooled mean, as observed with alachlor and metolachlor each plus diuron (1.0 + 0.4kg a.i./ha) fb SHW. These results are in conformity with the findings of Hamdoun (1979), Maruganodon and Ali (1986).

Based on the pooled mean, all the herbicide combinations split-applied, resulted in cowpea grain yield comparable to the weed-free check. However, the seed cotton yield obtained was significantly lower than the appropriate maximum. This was probably due to the negative correlation between cowpea grain and seed cotton yields (r= -0.1085).

The pooled mean of the three growing seasons showed that, all herbicide combinations fb SHW, the high rate, as well as the split application of metolachlor plus diuron (2.0 + 0.8

and 1.0 + 0.4 fb 1.0 + 0.4kg a.i./ha) resulted in significantly lower weed dry weight than the weedy check, but comparable to three hoe-weedings. The adverse effect of these treatments on weed weight was not only favourably reflected on the yields of cotton and cowpea, but also on their yield components viz, boll number (r = 0.451**), crop dry matter (r = 0.584**), crop vigour (r = 0.451**), cowpea canopy r = 0.196*), and cowpea pod (r = 0.221**) (Table 32). This was probably due to low level of weed-infestation, which consequently resulted in low cumulative weed dry weight of 0.8 to 1.4 t/ha in the pooled mean. However, the detrimental effect of weeds on this crop mixture was confirmed by correlation (r = -0.4151**) between weed dry weight and seed cotton yield. Every 1 kg/ha increase in weed dry weight, within a range of 1,000 - 4250kg/ha, decreased the seed cotton yield by 0.19kg/ha and the cowpea grain yield by 0.2 kg/ha.

Diuron, mixed with alachlor, metolachlor and norflurazon was found to have a moderate persistence range of 4 to 6 WASC as observed by weeds emergence in the fields (Table 1). Similarly rapid degradation and dissipation of such herbicides under incubation were also reported by Sheet and Crafts (1957), Vaswami and Kumar (1979). At high soil temperatures of 30 to 40°C, diuron dissipated at a faster rate (50% loss between 20 - 24 WASC) as reported by Talbert and Fletchall (1964). The other herbicides in combination with diuron also had shorter activity period (4 - 7 WASC) in these field trials

as their persistence was probably modified by the tropical conditions (Keeling et al., 1989). However, persistence of alachlor under temperate environment ranged from 20 - 30 weeks (Hargrove and Merkle, 1970), and for metolachlor, it was 7 - 10 weeks (Balinova and Deneva, 1987).

The 50% dissipation of norflurazon (Hubbs and Lavy, 1990), alachlor or metolachlor (Zimdahl and Clark, 1982; Moon and Walker, 1991) at high soil temperatures (30° - 40°C) was mainly by thermal and microbial degradation. The leaching and surface run off, during the rainfall period of July - September in maize/cotton mixture at Samaru, was estimated to be about 28% under mixed crop condition (Kumar et al., 1985) indicating the possibility of the herbicidal losses. The dissipation and degradation of the herbicides under the Samaru condition (at soil temperature of 27 - 33°C) probably caused losses in the activity of herbicide combinations within 4 to 6 weeks after sowing cotton (Zimdahl and Clark, 1982;, Hubbs and Lay, 1990;, Moon and Walker, 1991). This justifies the need for post-emergence manual hoe-weeding or herbicide application in the Nigerian Savanna (James et al., 1976; Lagoke et al., 1982). The ideal herbicides are those that control weeds effectively and selectively during the critical crop stages and dissipate by the time weed control is no longer required, that is 6 to8 WAS. Therefore, alachlor plus diuron at 1.0 + 0.4kg a.i./ha fb SHW appears to be a promising herbicide combination in this study.

It is apparent that weed control is indispensable for profitable production of cotton and cowpea grown in mixture. The most promising herbicide treatment in this study, was alachlor plus diuron at 1.0 + 0.4kg a.i./ha fb SHW, which had a revenue of N7,685.00/ha in excess of weed control cost compared with N6,215.00 for three hoe-weedings and N5,495.00, for two hoe-weedings. (Table 37). Further research is however, needed to study the effect of higher population of component cotton/cowpea mixture on crop-weed competition and testing selective herbicides with longer persistence (8 - 9 WAS) in order to replace supplementary hoe- weeding.

CHAPTER 6

SUMMARY AND CONCLUSION

Three field experiments were conducted at the Institute for Agricultural Research Farm, Samaru (11°11'07° 38'E) during 1987, 1988 and 1989 wet seasons.

Experiment I (Weed interference study) consisted of six levels of weed-free periods (2, 4, 6, 8 and 10 WASC, and until harvest) and six levels of weed-infested periods (2, 4, 6, 8, 10 and until harvest). Experiment II (Weed control study) consisted of nine herbicide combinations. Three treatments of alachlor plus diuron at 2.0 + 0.8kg a.i./ha, metolachlor plus diuron at 2.0 + 0.8kg a.i./ha, and norflurazon plus diuron at 0.8 + 0.8kg a.i./ha, were applied pre-emergence. The other six treatments, were low rates of these herbicide combinations followed by three of their split applications and the other three, followed by supplementary hoe-weedings. Other treat-ments included three hoe-weeded; two hoe-weeded and the weedy checks.

The drying and wetting cycles, followed by high temperature (28 - 32°C) and high relative humidity (68 - 85%) between June and September, favoured the rapid establishment of weeds early in the season and their vigorous growth later, caused average losses of 96.2% in seed cotton, and 90.1% in cowpea grain yields in the weedy check, respectively.

Weed-infested periods of 4, 6, 8 and 10 WASC, resulted in 37, 52, 63 and 73% reduction in seed cotton and of 64, 75, 88

and 96% cowpea grain yields, respectively, compared with weed-free plot. It is, however, apparent that weed-free periods of 4, 6, 8 and 10 WAS, resulted in increase of 63, 75, 84 and 94% seed cotton and 50, 70, 78, and 84% cowpea grain yields, compared with weed-infested throughout the season. Regression of cotton/cowpea mixture's yields on weed dry matter indicated that, every 1 kg increase in weed dry weight, within a range of 1,000 to 4,250 kg/ha, decreased the seed cotton and cowpea grain yields by 0.19 and 0.2kg/ha, respectively.

The critical period of weed competition in cotton/cowpea mixture was between 3 and 6 WASC, with cotton as top-canopy crop, grown under the traditional 'gicci' system.

The most effective herbicide treatment in this mixture was alachlor plus diuron at 1.C + 0.04kg a.i./ha fb SHW, which out-yielded two hoe-weedings by 9.1% and the weedy check by 90.3% in terms of seed cotton yield. This treatment,however, resulted in seed cotton yield that was 13% lower than that of three hoe-weedings. The grain yield of the component cowpea crop obtained with alachlor plus diuron at 1.0 + 0.4 kg a.i./ha,
fb SHW was higher by 27.5% and 16.2%, than those of two and three hoe-weedings, respectively.

The herbicides alachlor, metolachlor, norflurazon and their combination with diuron, each at their low rates fb SHW, significantly suppressed the weeds for 4 to 6 WASC, compared

with the weedy check. These herbicides reduced the weed density by 20 to 80% (1987) and the weed weight by 52 to 74% (Table 34), producing mean seed cotton and cowpea grain yields of 1.1 and 0.9 t/ha.

In the 1989 season, norflurazon plus diuron at 0.4 + 0.4kg a.i./ha fb SHW out-yielded two and three hoe-weedings by 50.9% and 20.1%, in respect of seed cotton yield. This contrast was mainly due to the fact that, the 1989 season, was marked by severe infestation of perennial weeds viz, Cynodon dactylon Pers. and Cyperus sp., which were effectively controlled by the herbicide, but reappeared in the hoe-weeded plot. The cowpea grain yield of this treatment was 34.9% and 48.9%, lower than three and two hoe-weedings, respectively.

The performance of these herbicide combinations were enhanced when supplemented with hoe-weedings at 6 WASC, a period believed critical to cotton-weed competition, thus causing increasein cotton yield by a margin of 99%(Table 16).

In the case of using alachlor plus diuron at 1.0 + 0.4kg a.i./ha fb SHW, the revenue in excess of weed control realized, was N7,685/ha, compared with N6,215.00, for three hoe-weedings and N5,495.00, for two hoe-weedings.

Further research is however, needed to study the effect of higher population of component cotton/cowpea mixture on crop-weed competition and testing selective herbicides with longer persistence (8-9WAS) in order to make supplementary hoe-weeding unnecessary.

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APPENDICES

Appendix 1 : Detailed information of the herbicides used in weed control experiments.

Common name	Chemical name	Trade name	Formulation	Solubility in water
Diuron	3- (3,4 - dichloro phenyl) - 1, 1 - dimethylurea	Karmex	W.P., 80%	42ppm
Alachlor	2 -chloro -2^1,6^1-diethyl- N -(methoxy - methyl) acetainilide	Lasso	E.C., 48%	242ppm
Metolachlor	2-chloro - N - (2-methoxy-1 - methyl) acetamide	Dual	E.C., 50%	530ppm
Norflurazon	4 - chloro - 5-(methylamino) - 2 - (α, α, α-trifluoro - m - tolyl)- 3 - (2H)- pyridazinone	Zorial	W.P., 80%	28ppm

Appendix 2: Fitted values of weed dry weight, seed cotton and cowpea grain yields (kg/ha) as affected by period of weed interference.

Initial weed-free period (weeks)	(Pooled mean) weed weight	Seed cotton	Cowpea grain
2	1300	176	5.7
44	1300	1173	440
6	1200	1500	600
8	1180	1700	700
10	1500	18700	780
24	980	2000	830
Initially weed-infested period			
2	1000	1600	800
4	1200	1200	300
6	1700	920	200
8	2500	700	120
10	3400	520	90
24	5000	400	709

Appendix 3: Pooled mean squares (1987 - 1989) of analysis of variance of weed weight, cotton flower count, boll count and seed cotton yield as affected by weed-interference.

Source of variation (S.V)	DF	Weed weight	Cotton flower	Boll Number	Seed cotton yield
Reps. Stratum	3	289.0	34.2	216.0	31964
Years	2	1859.1	2483.6	14272.7	2261678
Error (a)	6	132.6	254.7	107.1	61973
Total	8	564.2	811.9	3648.5	611899
Reps. Yrs. x Unit x Stratum					
Treatments	11	5042.1	817.3	854.5	2496524
Years x treatments	22	3946.9	140.0	345.8	358142
Error (b)	99	186.4	30.2	110.0	54228
Total	132	1217 .8	114 .1	211 .3	308405

Appendix 4: Pooled means squares (1987 - 1989) of analysis of variance of weed weight, canopy length, pod count and cowpea grain yield as affected by weed-interference.

Source of variation (S.V)	DF	Weed weight	Canopy length	Pod count	Cowpea grain yield
Reps. Stratum	3	289.0	2408	1354.0	18448.2
Years	2	1859.1	66743	3770.3	567748.8
Error (a)	6	132.6	208	264.2	17254.2
Total	8	564.2	16842	1140.8	14323.1
Reps. Yrs. x Unit x Stratum					
Treatments	11	5042.1	21659	1681.8	665783.0
Years x treatments	22	3946.9	4501	365.4	663402.4
Error (b)	99	186.4	1714	509.1	31530.9
Total	132	1217.8	3841	582.9	189697.1

Appendix 5: Pooled mean squares (1987 - 1989) of analysis of variance of weed weight, number of cotton flowers, boll number and seed cotton yield as affected by weed control treatments.

Source of variation (S.V)	DF	Weed weight	Flower number	Boll Number	Seed cotton
Replication stratum	3	169.3	20.5	52.5	73858
Years	2	20989.6	1585.7	10140.3	4286386
Error (a)	6	231.7	150.0	60.0	112683
Total	8	5421.2	508.9	2580.1	1156109
Reps. Yrs. x Unit x Stratum					
Treatments	11	2223.4	446.4	1690.7	498529
Years x treatments	22	1361.4	102.5	345.7	207399
Error (b)	99	259.1	47.8	98.9	9445
Total	132	605.5	90.1	272.7	146944

Appendix 6: Pooled mean squares (1987 - 1989) of analysis of variance of weed weight, canopy length, pod number, and cowpea grain yield as affected by weed control treatments.

Source of variation (S.V)	DF	Weed weight	Canopy length	Pod Number	Cowpea grain yield
Rep. Stratum	3	169.3	6694	64.9	4951
Years	2	20989.6	8121	22.0	327253
Error (a)	6	231.7	275	32.9	7000
Total	8	5421.2	2237	30.2	87063
Reps. Yrs. x Unit x Stratum					
Treatments	11	2223.4	6020	391.3	51808
Years x treatments	22	1361.4	2412	63.8	48935
Error (b)	99	259.1	2400	73.8	12507
Total	132	606.5	2704	98.6	21854

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