THE EFFECTS OF VARIETIES, PHOSPHORUS AND STAGE OF GROWTH AT APPLICATION ON THE TOLERANCE OF COWPEA (*Vigna unquiculata* (L.) Walp.) TO NORFLURAZON

BY

ZAKARIYYA ADAMU ABDULKAREEM

A thesis submitted to the Postgraduate School
Ahmadu Bello University
in partial fulfilment of the requirements for
the Degree of Master of Science in Agronomy

DEPARTMENT OF AGRONOMY
FACULTY OF AGRICULTURE
AHMADU BELLO UNIVERSITY
ZARIA, NIGERIA.

JUNE, 1984

(Copyright Reserved)

CERTIFICATION

This thesis entitled 'THE EFFECTS OF VARIETIES, PHOSPHORUS AND STAGE OF GROWTH AT APPLICATION ON THE TOLERANCE OF COWPEA (*Vigna unquiculata* (L.) Walp.) TO NORFLURAZON' by Zakariyya Adamu Abdul-Kareem meets the regulations governing the degree of Master of Science of Ahmadu Bello University, Zaria, and is approved for its contribution to scientific knowledge and literary presentation.

(DR. S.T.O. LAGOKE)
Chairman, Supervisory Committee

(DR. L.A. NNADI)
Member, Supervisory Committee

(PROF. J.Y. YAYOCK)
Head, Agronomy Department

(PROF. G.E. OSUIDE)
Dean, Postgraduate School

Date: 8-VIII-84

AHMADU BELLO UNIVERSITY
ZARIA, NIGERIA.

DECLARATION

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

Z.A. Abdul-Kareem

Date: 2nd April, 1984

The above declaration is confirmed.

DR. S.T.O. Lagoke
Chairman, Supervisory Committee

Date: 2nd April, 1984

DEDICATION

This work is dedicated to my parents for nurturing me and their tireless efforts to provide me with good education the odds notwithstanding and to Almighty Allah for guiding me and making their efforts fruitful.

ACKNOWLEDGEMENTS

I wish to express my sincere gratitute and thanks to Dr. S.T.O. Lagoke, Chairman of the Supervisory Committee for his untiring encouragement, meaningful suggestions and constructive cristicisms in the conduct of this investigation and write-up of the thesis. The same appreciation goes to Dr. L.A. Nnadi and the late Professor M.K. Moolani, members of the Supervisory Committee, who made valuable contributions at various stages of the project and during the write-up of the thesis.

I also wish to acknowledge the assistance rendered by Mr. A.H. Choudhary and Dr. A.A. Ibraheem. To Mm. B. Tanimu and Mr. J.A.Y. Shebayan I shall always remain most grateful for their moral support, encouragement, and assistance throughout the period of my study.

I am also indebted to the technical staff of the defunct Weed Science Section particularly Gabriel Ikwuje, the typists Mr. M.O. Balogun and Miss D.A. Odigboagha and all others who helped me in one way or the other towards the success of this work.

Finally, I wish to express my heartfelt appreciation to Professor J.Y. Yayock, Head of Agronomy Department for his encouragement and guidance and to the Director I.A.R. and the Department of Agronomy for providing the necessary facilities which led to the successful completion of the study.

ABSTRACT

Two greenhouse experiments and nine field trials were conducted on the Institute for Agricultural Research Farm, Samaru, between 1981 and 1982, to evaluate the effects of varieties, levels of phosphorus and stages of crop growth at the time of herbicide application on the tolerance of cowpea to norflurazon.

The varietal response trials were conducted both in the greenhouse and in the field using four cowpea varieties namely Ife Brown, IAR/ACC.335, IAR/ACC.341 and IAR/ACC.355. The other two sets of trials were only conducted in the field using Cv Ife Brown. Phosphorus levels evaluated were 0, 40 and 80 kg $P_2 O_5$/ha while the stages of growth of crop at the time of application were pre-emergence, at emergence, three weeks after emergence and six weeks after emergence, Norflu razon was applied pre-emergence at the rates of 0, 0.2, 0.4 and 0.8 kg a.i./ha in the varietal and phosphorus trials. Rates of 0, 0.4, 0.8 and 1.2 kg a.i./ha were used in the growth stage trial.

Norflurazon at the rates of 0.4 kg a.i./ha and above in both the greenhouse and field trials resulted in cowpea leaf chlorosis irrespective of crop variety, phosphorus level or stage of crop growth of crop at the time of application. Reduction in leaf and root dry matter production was observed although the toxicity of the herbicide was more severe in the greenhouse.

The cowpea varieties used responded differentially to the herbicide treatments as reflected especially in leaf dry

weight in the greenhouse and shoot dry matter production in the field, with varieties ACC.355 and Ife Brown exhibiting more tolerance in the greenhouse and field respectively. However, in most cases the interactions between the herbicide rates and cowpea varieties were not significant,, Norflurazon was more toxic at 0.8 kg a.i./ha than the lower rates.

Increasing the level of applied phosphorus from 40 to 80 kg P_2O_5/ha did not result in added advantage on cowpea grain yields. Phosphorus application slightly obviated norflurazon toxicity on cowpea, especially at the rate of 0.8 kg a.i./ha.

Norflurazon applied at emergence appeared to be more toxic to cowpea than when applied at any other stage of growth although the effect was non-significant. However, the crop tolerated up to 0.4 kg a.i./ha of the herbicide irrespective of stage of growth.

TABLE OF CONTENTS

CHAPTER		Page
1	Dedication...	i
1.2	Acknowledgements...	ii
	Abstract...	iii
	List of Conterts...	v
	List of Tables...	vii
	List of Appendices...	ix
1	INTRODUCTION...	1
1.1	Origin and distribution...	1
1.2	Adaptation...	1
1.3	Uses...	2
1.4	Production and constraints...	2
1.5	Mechanical weed control methods and their limitations...	3
1.6	Chemical weed control in cowpea...	3
1.7	Objectives...	5
2	REVIEW OF LITERATURE...	6
2.1	Chemical group and site of uptake of norflurazon...	6
2.2	Mechanism of action of norflurazon and related compounds...	6
2.3	Selectivity of norflur-zon in legumes...	10
2.4	Differential tolerance of crop varieties to herbicides...	11
2.5	The selectivity of pyridazine herbicides in crops...	14
2.6	Stage of growth and herbicide tolerance...	16
2.7	Fertilizers and herbicide activity... ...	17
3	MATERIALS AND METHODS...	19
3.1	Greenhouse experiments...	19
3.1.1	Greenhouse operations...	19
3.2	Field trials...	20

CHAPTER		Page
3.2.1	Field operations and fertilization...	21
3.2.2	Planting and spacing...	21
3.2.3	Treatments...	22
3.2.4	Experimental design, replication and plot sizes...	22
3.2.5	Herbicide application...	23
3.2.6	Crop protection...	23
4	RESULTS...	25
4.1	Differential response of cowpea varieties to norflurazon...	25
4.1.1	Greenhouse experiment...	25
4.1.2	Field trials...	29
4.2	Effect of phosphorus on the tolerance of cowpea to norflurazon... ..	36
4.2.1	Shoot dry weight...	36
4.2.2	Grain yield...	38
4.2.3	Dry haulm weight...	42
4.3	Tolerance of cowpea to norflurazon applied at different stages of growth...	42
4.3.1	Shoot dry weight and plant height... ...	42
4.3.2	Grain yield...	45
4.3.3	Haulm dry weight...	45
5	DISCUSSION...	49
5.1	Differential tolerance of cowpea varieties to norflurazon...	50
5.2	Effect of phosphorus on the tolerance of cowpea to norflurazon... ..	52
5.3	Tolerance of cowpea to norflurazon applied at different stages of growth...	53
6	SUMMARY AND CONCLUSIONS...	54
	LITERATURE CITED...	56
	APPENDICES...	66

LIST OF TABLES

TABLE		Page
1	Effects of varieties and norflurazon on the dry weights of roots, stem and leaf of cowpea in the greenhouse at Samaru... ...	26
2	Interaction between varieties and norflurazon on leaf dry matter production of cowpea in the greenhouse in 1981...	28
3	Effects of varieties and norflurazon on root nodules and plant height of cowpea in the greenhouse at Samaru...	30
4	Effects of varieties and norflurazon on the shoot dry weight of cowpea in the wet season at Samaru...	31
5	Interaction between varieties and norflurazon on shoot dry matter production of cowpea at 3 WAS at Samaru, 1981...	33
6	Effects of varieties and norflurazon on plant height of cowpea in 1981 wet season at Samaru...	34
7	Effects of varieties and norflurazon on grain yield of cowpea at Samaru...	35
8	Effects of varieties and norflurazon on dry haulm weight of cowpea at Samaru...	37
9	Effects of phosphorus and norflurazon on shoot dry weight at Samaru...	39
10	Interaction between phosphorus and norflurazon on shoot dry weight of cowpea at 6 WAS at Samaru in 1982...	40
11	Effects of phosphorus and norflurazon on grain yield of cowpea at Samaru...	41
12	Effects of phosphorus and norflurazon on dry haulm weight of cowpea at Samaru...	43
13	Effects of time of application and norflurazon on shoot dry weight and plant height of cowpea at 9 WAS at Samaru, 1981...	44

LIST OF APPENDICES

APPENDIX		Page
1	Physico-chemical properties of Samaru soil...	66
2	Crop vigour score scale...	67
3	Rainfall distribution during the period April - October, 1981 and 1982...	68
4	Mean squares from analysis of variance for root, stem and leaf dry weights of cowpea varieties sown in the greenhouse as affected by different rates of norflurazon at Samaru in 1981 and 1982...	69
5	Mean squares from analysis of variance for nodule count and plant height of cowpea varieties sown in the greenhouse as affected by different rates of norflurazon at Samaru in 1981 and 1982...	70
6	Mean squares from analysis of variance for shoot dry weight (at different stages of growth) and haulm dry weight of cowpea varieties as affected by different rates of norflurazon at Samaru in 1981...	71
7	Mean squares from analysis of variance for shoot dry weight (at different stages of growth), grain yield and haulm dry weight of cowpea varieties as affected by different rates of norflurazon at Samaru in 1982...	72
8	Mean squares from analysis of variance for plant height (at different stages of growth) of cowpea varieties as affected by different rates of norflurazon at Samaru in 1981...	73
9	Mean squares from analysis of variance for shoot dry weight (at different stages of growth) and haulm dry weight of cowpea as affected by different phosphorus levels and rates of norflurazon at Samaru in 1981...	74
10	Mean squares from analysis of variance for shoot dry weight (at 3 and 9 WAS) and grain yield of cowpea as affected by different levels of phosphorus and rates of norflurazon at Samaru in 1982...	75

APPENDIX

		Page
11	Mean squares from analysis of variance for shoot dry weight at 6 WAS and haulm dry weight of cowpea as affected by different levels of phosphorus and rates of norflurazon at Samaru, in 1982...	76
12	Mean squares from analysis of variance for shoot dry weight and plant height at 9 WAS and haulm dry weight of cowpea as affected by rates of norflurazon sprayed at different stages of growth at Samaru, in 1981...	77
13	Mean squares from analysis of variance for haulm dry weight and grain yield of cowpea as affected by rates of norflurazon sprayed at different stages of growth at Samaru, in 1982...	78
14.	Mean squares from analysis of variance for haulm dry weight and grain yields of cowpea varieties as affected by different rates of norflurazon at Samaru in the 1981/82 dry season...	79
15	Mean squares from analysis of variance for haulm dry weight and grain yield of cowpea as affected by different levels of phosphorus and rates of norflurazon at Samaru in the 1981/82 dry season...	80
16	Mean squares from analysis of variance for haulm dry weight and grain yield of cowpea as affected by rates of norflurazon applied at different stages of growth at Samaru in the 1981/82 dry season...	81
17	Common and chemical names of the herbicides and insecticides mentioned in the text...	82

Chapter 1

INTRODUCTION

1.1 Origin and Distribution

Cowpea (Vigna unguiculata (L.) Walp.) is widely cultivated in the tropical regions of the world although it originated in Central Africa where it has been in cultivation for several centuries and from where it was introduced to Asia, Mediterranean region and the United States of America (Purseglove, 1974). Cowpea exists in a large variety of form, from small errect plants, maturing in two months or less to prostrate plants with 4 m long trailing vines. Pod shape and seed size also vary considerably in this crop. The plants are indeterminate in growth; they continue to grow until killed by some adverse condition such as frost or lack of moisture.

1.2 Adaptation

The crop can be grown under a wide range of climatic conditions but it is sensitive to cold and is killed by frost. Cowpea withstands considerable drought and moderate amount of shade. It succeeds on nearly all kinds of soils provided they are well-drained. Clays, silts and heavy loams come into the category of suitable soils for cowpea production. It is sometimes grown on very poor acid soils to improve them. Optimum environmental conditions for its growth include warm weather, well-drained rich soils with (pH of 6 to 7) with a good but not too heavy rainfall.

1.3 Uses

In Africa, the dried bean of cowpea is mainly used for human consumption as an important source of plant protein. The dried cowpea contains 21.4% protein, 1.4% fat, 60.8% carbohydrates, 3.4% ash and a food value of 3,506 kca. The green cowpea which is usually used in the preparation of salad contains 9.4% protein, 0.5% fat, 23% carbohydrate and 1.4% ash with a food value of 1,367 kca (Langwarthy and Hunt, 1959). In Nigeria, cowpea forms the most important source of plant protein. The dried beans are cooked solely or mixed with rice or may be ground into meal which is used in making bean cake such as "alale" (boiled type) and "kosai" (fried type). The young shoots and leaves are also eaten as vegetable. The haulms are useful in making pasutre and hay which are high in protein for livestock.

1.4 Production and Constraints

Most of the world cowpea crop is grown in West Africa and Nigeria is by far the most important producer. In Nigeria, about 1 million metric tonnes of cowpea was produced from about 4 million hectares of land (Hartmans, 1983). Although Nigeria is the leading producer of cowpea seeds in the world, grain yield per hectare is generally low as compared with those of other countries; about 189 kg/ha was reported for Nigeria in 1975 (Anonymous, 1975). Recently, Hartmans (1983) reported an average grain yield of 250 kg/ha for Nigeria compared with 3,103 kg/ha and 651 kg/ha reported for Egypt and Malawi respectively (Anonymous, 1975). The low yield in Nigeria has been attributed to the

the fact that the crop is rarely planted sole, the unreliable distribution of rainfall in northern Guinea savanna which is the major area of production, lack of suitable and highly adapted varieties and the high susceptibility of the crop to weed competition, and diseases and pests attack (Stanton et al., 1966; Lagoke et al., 1982; Hartmans, 1983; Singh, 1983). Weed competition constitutes an important factor limiting cowpea production. Moody (1973) has reported up to 50% reduction in cowpea yields in Nigeria due to weed competition. About 57% loss in grain yield was attributed to unchecked weeds in the Guinea savanna zone of Nigeria (Lagoke et al., 1982)

1.5 Mechanical Weed Control Method and Their Limitations

In Nigeria, weeds are commonly controlled in cowpea with hoe. Apart from being labour-intensive, hoe cultivation as a weed control method has other short-comings. Wood (1970) considered the method unwieldy and advocated chemical control. It causes injuries to the roots thereby pre-disposing the roots to attack by diseases (Kasasian, 1971). The mechanical weed control by means of modern implements is rather too expensive for an average Nigerian farmer. The increasing cost of labour and its scarcity at the peak period of requirement necessitates the use of alternative weed control methods.

1.6 Chemical Weed Control in Cowpea

As present, weed control by means of herbicides in cowpeas has been reported to have high potential. Researchers have reported tremendous success in the use of herbicides in

cowpea and its mixtures with other crops. Among various chemicals applied singly or in mixture in cowpea, Akobundu (1978) has reported that[1] fluorodifen at 3.5 kg a.i./ha, sulfallate at 8.0 kg/ha, metolachlor at 2.0 to 3.0 kg a.i./ha and metolachlor plus metribuzin at 1.5 kg plus 0.25 kg a.i./ha gave excellent weed control in cowpea and the yields were comparable to weed-free check. Fadayomi (1979) observed that metolachlor plus metobromuron at a total rate of 2.5 kg a.i./ha effectively controlled most of the annual weeds in cowpea and produced yield that was comparable with those of hand-weeded treamtnets while metolachlor at 2.5 kg a.i./ha effectively controlled many annual grasses and most broad-leaf weeds but failed to control Amaranthus spinousus Linn. Effective control of grass weeds growing in cowpea was also reported by Akobundu (1982) using metolachlor at 2.0 to 3.0 kg a.i./ha, PCPA at 10.0 kg a.i./ha or pendimethalin at 2.0 or 2.5 kg a.i./ha. Lagoke et al. (1982) observed in field trials that pre-emergence application of metolachlor at 1.5 and norflurazon at 1.0 kg a.i./ha gave selective control of grass weeds in cowpea. Subsequent reports at Samaru further confirmed the selective use of norflurazon alone at 1.0 kg a.i./ha and in mixture with diuron at 0.5 and 0.8 kg a.i./ha for weed control in cowpea (Anonymous, 1982).

---

[1] Chemical names of herbicides, insecticides and fungicides mentioned in the text are given in appendix 17.

1.7 Objectives

Norflurazon has been shown to have promise for weed control in cotton (Gossypium hirsutum Linn.) (Solano et al., 1976; Jordan and Bridge, 1976 and Anonymous, 1979a). Cowpea - cotton mixture is a common practice in the Nigerian savanna. While there is adequate information on the selectivity of norflurazon in cotton there is posity of information on the response of cowpea to this herbicide in the Nigerian savanna. Research results have shown that the performance of soil applied herbicides is affected by fertilizers (Bagaev and Kalimullina, 1968; Owen et al., 1970 and Gupta and Lamba, 1978). Crop plant tolerance to herbicides has also been reported to depend on the growth stage at which the herbicides are applied (Klingman and Ashton, 1975). Similarly, it has been reported that crop varieties exhibit differential tolerance to some pyridazine herbicides. Abernathy et al. (1978) attributed the differential response of cotton varieties to fluridone to the possession of glands; glanded cultivars were found to tolerate the herbicide more than the glandless ones. Since different cowpea varieties are being recommended for various ecological zones it is therefore important to study their differential response to norflurazon. This study was therefore undertaken to evaluate:

(i) The differential response of four cowpea varieties to norflurazon,

(ii) The effect of different phosphorus levels on the tolerance of cowpea to norflurazon, and

(iii) The response of cowpea to norflurazon applied at different stages of crop growth.

Chapter 2

LITERATURE REVIEW

2.1 Chemical Group and Site of Uptake of Norflurazon

Norflurazon (4-chloro-5-methylamine-2(3-trifluoromethylphenyl) pyridazin-3 (2H)-one) is a member of heterocyclic compounds. These are organic herbicides with benzene ring structure consisting of different atoms. Heterocyclic compounds are further subdivided into bipyridylium quaternary ammonium salts, pyridines, pyridazines, pyrimidines, triazine and miscellaneous heterocyclic compounds. Norflurazon belongs to the subdivision of pyridazines. Other members of this subgroup included maleic hydrazide, pyrazone, credazine, metaflurazone and fluridone. Norflurazon basically consists of two benzene rings with different groups attached. It is mainly a pre-emergence herbicide and absorption is usually through the foliage and the roots, the latter being more important (Rincon and Warren, 1979). Yaklich et al. (1974) observed that the uptake of norflurazon in cranberry (Vaccinium macrocarpon Linn.) plants was rapid and translocation was from root to shoot.

2.2 Mechanism of Action of Norflurazon and Related Compounds

The main site of action of norflurazon is the shoot; the foliage being severely affected. It inhibits carotenoid synthesis in various plants (John and Hilton, 1976; Pardo and Schiff, 1977 and Frosch et al., 1979), causing light-grown seedlings to emerge with chlorotic leaves and to die

following exhaustation of food reserves (Bartels and Watson, 1970). Carotenoid synthesis inhibition is due to inhibition of dehydrogenation reactions which follows phytoene (a carotenoid precursor) formation, which resulted in chlorotic leaves in corn (Zea mays Linn.) (Devlin et al., 1979) in wheat (Triticum vulgare Vill.) (Bartels and Watson, 1978) and in bean (Phaseolus vulgaris Linn.) (Pardo and Schiff, 1977). In addition, the herbicid blocked membrane formation and chlorophyll synthesis in growing and resting cells of Euglena gracillis at concentrations of 20 to 100 ppm without affecting cell viability (Vaisberg and Schiff, 1976). Phytoene accumulated in dark-grown resting cells of Euglena gracilis treated with norflurazon, when plastid development was induced by light. This suggests that norflurazon blocked carotenoid biosynthesis immediately after phytoene. Devlin and Doubert (1973) reported a reduction in pectin content of fresh cranberry plant following application of norflurazon at the rate of 27 kg a.i./ha. They detected no phytotoxicity on vine growth or appearance in plots treated with 9 kg/ha of norflurazon, but at 13.4 kg/ha a temporary chlorosis at the base of the cranberry leaf blade was observed. They however, observed more extensive and permanent chlorosis caused by the herbicide applied at the rates of 18 and 27 kg/ha. Devlin and Karczmarczyk (1975) showed that norflurazon activity in plants is light dependent. They studied the influence of the herbicide on chlorophyll development in wheat, maize and alfalfa (Medicago sativa Linn.) under relatively high (10, 760 lux) and low (10.76 lux) light intesities, and observed that chlorophyll production was

markedly reduced in wheat and maize at 1 ppm norflurazon and high light; a similar response in alfalfa required only 0.1 ppm norflurazon. Under low light intensity, the influence of norflurazon was greatly reduced.

Strang and Rogers (1974) studied the absorption, translocation and metabloism of norflurazon in cotton, maize and soybean (Glycine max (L.) Mss.). The results of the analysis showed that norflurazon was more readily absorbed by the roots and translocated to the shoots by maize (very susceptible) and soybean (susceptible) than by cotton (tolerant). Most of the herbicide absorbed by cotton was retained in the roots and much of the limited quantity translocated to the shoot was localized in the lysigenous glands. Degradation of norflurazon occurred more readily in the susceptible species than in the tolerant species. Therefore, the basis for the greater tolerance of cotton to norflurazon relative to maize and soybean appears to be associated with less absorption and translocation rather than degradation.

Like norflurazon, fluridone inhibited carotenoid synthesis in wheat seedlings and caused the accumulation of the colourless carotenoid precursors, phyteene and phytofluene (Bartels and Watson 1978). Phytotoxic symptoms of fluridone include retardation of growth and leaf chlorosis followed by necrosis. Following root absorption, Berard et al. (1978) observed that trifoliate leaves of soybean, which expanded during exposure to fluridone, were severely chlorotic and bleached, whereas the cotyledons formed prior to the herbicide treatment were not affected, even though they also contained fluridone. It

was suggested that fluridone disrupts the development or stability of newly formed pigments.

The investigation on the metabolic sites of action of fluridone was carried out (Rafii et al., 1979) using isolated mesophyll cells of cotton (tolerant) and red kidney bean (susceptible). At the highest concentration (10^{-4}M) and the longest incubation period (2 hours), fluridone inhibited phyotosythesis, RNA synthesis and protein synthesis 59, 56 and 32%, respectively, in cotton; 24, 21 and 14% respectively, in bean. Lipid synthesis and respiration were only slightly affected. Metaflurazon also inhibits Hill reaction in photosynthesis in Sorghum halepense L. It caused 50% inhibition of Hill reaction at a concentration of 5×10^{-5}M when applied through the soil. It also reduced photosynthesis at 10^{-3}M, 10^{-4}M and 10^{-5}M (Spilsbury, 1972). Reduction in root development and chlorosis of vines were caused by metaflurazone at 27 kg/ha (Devlin and Demoranville, 1974) while it damaged the photosynthetic redox system and caused a strong bleaching in unicellular alga, Bumilleriopsis filiformis (Borger and Schlue, 1976). Similarly, reduction in photosynthesis and flow of C^{-14} assimilates to flowers and suckers of tobacco following the application of maleic hydrazide at 6 to 9 kg/ha was reported (Evtushenko et al., 1973); the herbicide at 0.4 and 0.5% were responsible for complete pollen sterility in Capsicum annum Linn. and Datura alba Linn. (Chauhan and Singh, 1972). Like other pyridazinone herbicides, pyrazon induces leaf chlorosis in many plants. Bean plants treated with pyrazon at 100 ppm during

germination started showing signs of chlorosis five days later. Chlorosis started to appear at the leaf margins, progressed inward, and intensified until the leaves were dead (Rodebush and Anderson, 1970). Romanovskaya and Straume (1975) demonstrated that the rate of pyrazon absorption and translocation in bean increased with increasing temperatures (13 to 27°C), and its toxicity was also greater at a high light intensity (0.2 cal/cm^2) than at low light intensity (0.1 cal/cm^2). They suggested that the herbicidal action of pyrazon involved an inhibition of photosynthesis and subsequent photo-oxidation reactions. Earlier on, Eshel (1969) tried to determine the influence of pyrazon on photosynthesis using 10 weed and crop species. He concluded that the herbicide strongly inhibited O_2 evolution from leaf disks of smapled plants. He observed that in most cases a concentration of 5×10^{-5}M reduced photosynthesis approximately 50%.

2.3 Selectivity of Norflurazon in Legumes

Although norflurazon has been reported to show promise for weed control in many crops, little information is available on its selectivity in legumes. Jordan and Barrentine (1978) reported a satisfactory weed control and good tolerance in soybeans with norflurazon applied to a silt loam soil. In contrast, soybean was found to be susceptible to norflurazon at 0.5 ppmw by Strang and Rogers (1974). A similar observation was made when the herbicide was applied to soybean at the rate of 2.2 kg a.i./ha although the injury was not significant (Sharp et al., 1978). Using norflurazon (0.5 kg a.i./ha) in combination with either prometryne at 1 kg a.i./ha, diuron at

treated with either paraquat at 1%; diuron at 0.5% or DSMA at 1% by volume. Differential response of cotton varieties to prometryne and fluometuron was also observed by McCall (1976). He attributed resistance and susceptibility to fluometuron to genotype. Differential response of cotton cultivars to herbicides is also determined by glands. When fluridone was applied to different cultivars of cotton, Abernathy et al. (1978) observed that glanded cultivars tolerated the herbicide more than the glandless ones. Raghunathan et al. (1974) studied varietal reactions of guinea corn (Sorghum bicolor (L.) Moench.) to 2, 4-D, dicamba and atrazine, each at two doses of 0.5 and 1.0 kg/ha, 2.2 and 4.4 l/ha, and 1.0 and 2.0 kg/ha respectively. They observed differential response to the herbicides at the various levels, with the differences becoming more pronounced with increase in herbicide rates. Significant difference among wild oat lines (Avena fatua Linn.) in response to diallate, triallate and barban was reported by Jacobsohn and Anderson (1968) which they attributed to different genetic constitution among the oat lines. Anderson (1964) correlated resistance of corn lines to simazine and atrazine to stalk rot and corn borer resistance. Of five inbred lines of corn studied, three with known resistance to stalk rot and corn borer were found to be much more resistant to simazine and atrazine than were two inbreds which were susceptible to stalk rot and corn borer. In explaining the basis for this phenomenon in maize with atrazine, Palmer and Grogan (1965) however correlated tolerance with the amount of 2-glycoside

derivative of 2, 4-dihydroxy-7-methoxy-1, 4-benzoxin-3-one in maize lines. The greater the concentration of the metobolite in a line, the more tolerant the line. The work of Grogan et al. (1963) had earlier revealed that a recessive gene was responsible for complete susceptibility in maize lines to both atrazine and simazine.

In vegetables, Werner and Putnam (1980) attributed differential atrazine tolerance among cucumber cultivars (Cucumis sativus Linn.) to differences in plant morphology and rate of translocation of the herbicide. In tomato (Lycopersicon esculentum Mill.) however, differential tolerance was related to the rate of detoxification by metabolism within the tomato leaves, which was approximately two-fold greater in the tolerant Fireball seedlings (Stephenson et al., 1976).

Hardcastle (1979) observed differential tolerance to metribuzin by varieties of soybeans. The soybean variety 'Coker 102' was more susceptible to metribuzin injury than were 'Harden', 'Bragg', 'Bienville', 'Hampton 266A' or 'Coker 318.' He observed a marked varietal difference in movement of ^{14}C-metribuzin to the above ground parts and concluded that this difference was partially responsible for the differences in the varieties' tolerance to the herbicide. In their studies with 'PI 229.342' and 'Clark' cultivars of soybean, Hayes and Wax (1975) however noted that there was slightly greater translocation and about a two-fold greater foliar absorption of bentazon in the sensitive cultivar (PL 229.342) than in the tolerant cultivar, 'Clark 63'.

Clark 63 metobolized bentazon faster than did PT 229.342. They concluded that differential bentazon metabolism appeared to be the main cause of the differential responses of these soybean cultivars to the herbicide. Significant differential varietal response was observed with metribuzin at 0.66 and 1.12 kg/ha applied to 28 cultivars of cowpea immediately after sowing. Crop stand and pod yield were also significantly affected (Phatak and Glaze, 1978).

2.5 The Selectivity of Pyridazine Herbicides in Crops

Wain and Smiths (1981) identified absorption, retention and stability of herbicide within the plant tissue and the potential activity of the compound at the site of action as the main factors that determine the response of plants to herbicides. The amount of herbicide accumulated in the cell is also important in deterrining the response to herbicides. Romanovs kaya and Straume (1975) for example, showed that the phytotoxicity of pyrazone was directly proportional to the accumulation of the unbound form of the herbicide in plant cells. After spraying pyrazone 80% at 1.6 and 4.8 kg a.i./ha on seedlings of 14 species of dicotyledons and monocotyledons in pot trials, they observed that most of the 14 weed species demonstrated the ability to inactivate the herbicide depending on the rate of accumulation in cells. With slow herbicide entry they observed that even sensitive plants were able to bind herbicide molecules in the inert-N-glucoside complex, and therefore concluded that in the field, the selectivity of the herbicide depended both on the rate of

its inactivation in plants and its differential absorption by plant roots. Limited translocation of fluridone in plants was found to be the main factor determining its selectivity (Berard et al., 1978). They studied the absorption, translocation and metabolism of fluridone in seven-day-old seedlings of cotton, soybean, and maize as well as 21-day-old rice (Oryza sativa Linn.) seedlings in culture solutions containing 6.07×10^{-7}M ^{14}C-fluridone. The concentration of fluridone in the plants increased throughout the experiment in all species; however, about one half of the total amount absorbed was taken up in the first 24 hours, very little of the radioactivity moved from the roots to the shoots in cotton; 86% remained in the roots after 7 days. In contrast, the radioactivity in the roots of soybean, maize and rice, after seven days, was 67, 65, and 19% respectively. Phytotoxic symptoms were observed in soybean, maize and rice after 3 to 5 days exposure to the herbicide; however, no injury was observed in cotton even after a 21-day treatment. They concluded that the tolerance of cotton to fluridone was primarily attributed to the limited translocation of the herbicide. A similar experiment was conducted by Strang and Rogers (1974) with norflurazon. They observed that the herbicide was more readily absorbed by the roots and translocated to the shoots by maize (very susceptible) and soybean (susceptible) than by cottor (tolerant). Most of the herbicide absorbed by cotton was retained in the roots and much of the limited quantity translocated to the shoot was localized in the lysigenous glands. Degradation of norflurazon occurred

more readily in the susceptible species than in the tolerant species. They therefore concluded that the basis for the greater tolerance of cotton to norflurazon relative to maize and soybean appeared to be associated with less absorption and translocation rather than degradation.

2.6 Stage of Growth and Herbicide Tolerance

The stage of growth of plants plays a very important role in determining their response to a given herbicide. Pre-emergence treatments which kill germinating weed seeds or seedlings commonly have little or no effect on established weeds. In general younger plants are more susceptible to herbicides because of higher percentage of meristematic tissues (Klingman and Ashton, 1975). Thus, plant's tolerance to herbicide increase with the age of the plant. Application of diclofmethyl at up to twice the recommended rates to a range of pea (Pisum sativum Linn.) varieties sown in the greenhouse at 2, 3, 4 or 5 weeks after emergence was tolerated, but in the field the greater tolerance was observed at 4 and 5 weeks after emergence compared with 2 and 3 weeks after emergence (Anonymous, 1981). Similarly, Belien et al. (1979) who applied metamitron at the rate of 3.5 kg a.i./ha to beet (Beeta vulgaris Linn.) at different growth stages namely, pre-plant, pre-emergence, and various post-emergence timings ranging from the cotyledonary to the 5- to 6-leaf stage of the crop observed that beet was more susceptible if treated during emergence and at the cotyledonary stage. They therefore recommended that metamitron should not be applied to the crop

at these stages. However, some crop plants have been observed to be more susceptible to certain herbicides at their later growth period. When Pardo and Encina (1977) applied methabenzthiazuran either at the 3-leaf stage or at full tillering of wheat, at 1.5, 2.0, 3.0, 4.0 and 6.0 kg product/ha they found that yields were higher with the earlier application time probably because the young crop had less leaf-area for herbicide interception and absorption than the older crop. Similarly, Harris and Ritter (1981) applied paraquat to maize at 4 growth stages namely, pre-emergence, spike stage, 3-leaf stage and 5-leaf stage and observed that pre-emergence and spike stage applications resulted in a little to no injury to the crop and no yield reduction as compared with other times of application.

2.7 Fertilizers and Herbicide Activity

Fertilizers are a common component of plant environment in modern agriculture. Although they are applied for the benefit of the crop plants the associated weeds also share these plant nutrients. Herbicides have been found to interact with fertilizers in fields. In general, fertilizers may increase or decrease the activity of herbicides depending on the rates and type of both herbicides and fertilizers and the prevailing environmental conditions which are also known to exert some influence on the activity of herbicides. Increase in herbicide activity was reported by McKercher and McGregor (1980) when they applied nitrogen fertilizers as NH_4^+ on oats sown in pots and field. Increased toxicity of herbicides to crops was attributed to increased absorption

of the herbicide due to the presence of certain fertilizers (Papova, 1980). He showed that atrazine was more toxic in the presence of PK than in the presence of NP or NK. When carrot (Daucas carota Linn.) growing in the growth chamber was supplied with fertilizer in the ratio of N: P_2O_5: K_2O (32.6: 14.3: 53.1) Bagaev and Kalimullina (1968) observed that carrots without fertilizers were least affected by propazine. In contrast, some researchers have reported that presence of fertilizers reduced the activity of applied herbicides. Significant reduction in the toxicity of atrazine to oat plant was reported by Brenchiley and Appleby (1967) when they added nutrient solutions containing different levels of magnesium to tomato and oat plants growing in sand culture. A reduction in toxicity due to fertilizers was also reported by Owen et al. (1970) who observed that severe injury caused by post-emergence application of high rates of diuron on maize and atrazine on sorghum was reduced in the presence of high rate of fertilizer (240 kg N, 160 kg P and 160 kg K per hectare) as opposed to one quarter or one-half of these amounts. Increasing rate of phosphorus has been reported to decrease the initial activity of alachlor (Rahman, 1980). As the rate of the herbicide was increased higher levels of phosphorus were required to alter its phytotoxicity. But with atrazine, Penner (1974) observed increased activity of the herbicide due to phosphorus and concluded that fertilizers somtimes invigorate meristematic activity in crop plants and make them become susceptible to herbicides.

Chapter 3

MATERIALS AND METHODS

The project consisted of three sets of experiments, one of which was conducted in the greenhouse and the field while the other two were sited at the Institute for Agricultural Research Farm, Samaru ($11^{o}11'N, 07^{o}38'E$) in the northern Guinea savanna. Samaru soil is clay-loam, well-drained but low in organic matter and cation exchange capacity. Details of the soil physico-chemical characteristics are contained in Appendix 1

3.1 Greenhouse Experiments

In the greenhouse experiments, the cowpea varieties that are likeky to be proposed for recommendation in the Savanna ecological zones were evaluated for their differential tolerance to the different rates of norflurazon. The varieties were Ife Brown, [1]IAR/ACC.335, IAR/ACC.341 and IAR/ACC.355.

3.1.1 Greenhouse operations

The experiment was conducted during the 1981 and 1982 dry seasons. Sixty-four plastic pots (in each experiment) each having a diameter of 16.5 cm and volume of 2.4 l were filled with about 2.0 kg of soil obtained from the Institute for Agricultural Research Farm, Samaru.

---

[1]IAR/ACC. Cowpea varieties being developed by the Institute for Agricultural Research, Samaru.

The soil was thoroughly mixed with single superphosphate and muriate of potash at the equivalent of 40 kg and 30 kg/ha of P_2O_5 and K_2O, respectively before watering to field capacity. Four cowpea seeds were then sown in each pot before they were labelled and arranged in a marked area on the floor of the screen house for herbicide application. Norflurazon at the rates of 0, 0.2, 0.4 and 0.8 kg a.i./ha was applied pre-emergence with a knapsack sprayer, in about 200 l/ha spray liquid volume, using a green deflector nozzle, at a pressure of 2.1 kg/cm^2. After spraying, the pots were transfered to the greenhouse bench and arranged in a randomized complete block design with four replications. To ensure adequate moisture supply, the pots were watered twice, in the morning and evening. At two weeks after sowing, the plants were randomly thinned to two per pot.

The cowpea plants were harvested at 6 weeks after sowing. Data recorded at harvest included crop vigour score using 0 - 10 scale (Appendix 2), plant height, number of root nodules and leaves per plant and weight of fresh plant parts. Harvested plant parts were oven-dried at 70^{o}C to constant weight for dry matter determination. Data were analysed statistically and treatment means compared using least significant difference where F value were significant.

3.2 Field Trials

All the field experiments were conducted in 1981 and 1982 wet seasons and 1981/82 dry season under irrigation. The three sets of experiments conducted in the field were:

I Differential tolerance of cowpea varieties to norflurazon;

II Effect of phosphorus on cowpea tolerance to norflurazon; and

III Susuceptibility of cowpea to norflurazon applied at different stages of crop growth.

Scab disease caused by fungal infection in the 1981 wet season which precluded grain production necessitated the repetition of the trials in 1981/82 dry season and 1982 wet season.

3.2.1 Field operations and fertilization

During the wet season, the experimental plots were disc-harrowed twice at two-week interval before making 75 cm wide ridges. In the dry season however, the interval between the two disc-harrowing was one week and the ridge width was 60 cm, in order to facilitate adequate supply of irrigation water through the furrow. In experiments I and III single superphosphate and muriate of potash were broadcast before ridging at the rates of 40 kg P_2O_5 and 30 kg K_2O per hectare, respectively. However, for experiment II which involved different phosphorus levels only single superphosphate was applied at the rates of 0, 40 kg and 80 kg P_2O_5/ha as side-dressing after crop emergence.

3.2.2. Planting and spacing

The wet season experiments were sown in the second week of July while in the dry season the crop was sown in the first week of February, and given regular irrigation at 5-day interval. Four seeds were sown per stand at 3 cm depth at

intra-row spacing of 30 cm. These were thinned to two plants per stand at two weeks later at random.

At 10 days after sowing, plants that failed to germinate were resupplied. All the plots were hoe-weeded when necessary to keep them weed-free throughout the period of crop growth to prevent weed-crop competition.

3.2.3 Treatments

In experiment I, cowpea varieties, namely: Ife Brown, IAR/ACC.335, IAR/ACC.355 and IAR/ACC.341, were used as the main treatments; in experiment II phosphorus levels 0, 40 and 80 kg/ha were the main treatments while in experiment III, times of herbicide application, namely: pre-emergence, emergence and at 3 and 6 weeks after sowing were the main treatments. In epxeriments I and II, the sub-treatments consisted of norflurazon at 0, 0.2, 0.4 and 0.8 kg a.i./ha while 0, 0.4, 0.8 and 1.2 kg a.i./ha were the sub-treatments for experiment III. Except for experiment I, where diffe-rent varieties of cowpea were used, Ife Brown was the only cowpea variety used in experiments II and III.

3.2.4 Experimental design, replication and plot sizes

A randomised complete block design with four replications was adopted for all the trials conducted in 1981 wet and 1981/82 dry seasons. The trials conducted in the 1982 wet season were laid down in a split-plot design with four replications. The gross and net plot sizes in all the trials were 20.25 m^2 and 11.7 m^2, respectively during the wet season, while the gross and net plot sizes for the 1981/82 dry season trial were 12.96 m^2 and 7.2 m^2.

3.2.5 Herbicides application

All the herbicide treatments were applied in about 250 l/ha spray liquid using a knapsack sprayer, with a deflector nozzle, at a pressur of 2.1 kg/cm^2. The herbicide was applied at pre-emergence, one day after crop sowing in experiments I and II. In experiment III applications were done at the specified stages of crop growth, according to the treatments.

3.2.6 Crop protection

Cowpea plant is highly susceptible to insect and fungal attack, especially from the pre-flowering stage - about five weeks after sowing. Adequate pest and disease controls are therefore necessary for good grain yield. In 1981 wet season carbaryl (Vetox 85) at the rate of 2.2 kg/ha and cypermethrin (Cymbush) at the rate of 2.5 l/ha were applied at the intervals of seven days beginning from five weeks after sowing to the time of picking. In 1981/82 dry season only Carbaryl was applied at one week interval beginning from the time of flowering to about one week to first picking. In 1982 wet season, Cypermethrin and 40% dimethoate (Perfekthion) each at the rate of 2.5 l/ha were sprayed at the interval of seven days beginning from six weeks after sowing to the time of picking. To avoid fungal infection which occurred in 1981 wet season trial, Benomyl (Benlate) was applied weekly at the rate of 375 g/ha, commencing from 5 weeks after sowing before the onset of flowers until the first pod picking. A knapsack sprayer was used in applying Carbaryl and dimethoate while cypermethrin was applied with ULV sprayer. Each pesticide was applied separately.

3.2.7 Observations

All observations were made from the net plots. Height of 12 plants were measured in each plot and average recorded per plant. In experiments I and II the measurements were made at 3, 6 and 9 WAS while the observation was made at 9 weeks after sowing (WAS) only in experiment III since the treatment application was completed at 6 WAS. For shoot dry weight determination twelve plants were cut to ground level in each plot and their shoots oven-dried at 70°C to constant dry weight. The plots were sampled at 3, 6 and 9 WAS in experiment I and II and at 9 WAS in experiment III for the reason given earlier.

The dry pods of each plot were picked when ripe and weighed before threshing. The seeds obtained after threshing were also weighed. After the final picking the cowpea haulms were cut and left for a week in the field to enable the fresh vines and some of the remaining leaves to dry before recording their weight. The haulm for each plot was then weighed.

The data collected were subjected to statistical analysis of variance. The differences between the treatment means were compared using the Least Significance Difference (LSD) where F values were significant.

Chapter 4

RESULTS

In 1981 wet season, only a few pods were produced because of the scab disease resulting from severe infection by a fungus (Sphaceoloma sp.); no data on grain yields are therefore presented. Similarly, no data on dry matter production are presented for the trials conducted in the 1981/82 dry season due to the inhibitory effect of cold temperature on germination and the growth of the crop initially.

Both in the greenhouse and in the field, some leaves of the plants sprayed with norflurazon, especially at 0.8 kg and 1.2 kg a.i./ha, exhibited chlorotic symptoms and epinastry within two weeks after crop emergence. It was observed that these two symptoms were more pronounced and persisted longer in the pot experiment conducted in the greenhouse than in the field.

4.1 Differential Tolerance of Cowpea Varieties to Norflurazon

4.1.1 Greenhouse experiment

Dry matter production: The effect of varieties on plant parts, namely, root, stem and leaves was not significant in the two greenhouse experiments - mean of herbicide effect (Table 1). Herbicide effect on the plant part was however, significant in the 1982 greenhouse experiment. Norflurazon at 0.4 and 0.8 kg a.i./ha resulted in lower root and stem dry weight, compared with the untreated control. In this trial,

Table 1: Effects of varieties and norflurazon on the dry weights of root, stem and leaf of cowpea in the greenhouse at Samaru.

Treatments	Dry matter production (g/plant)					
	Root		Stem		Leaf	
	1981	1982	1981	1982	1981	1982
Cowpea varieties	Means of norflurazon rates					
Ife Brown	1.40	1.10	0.80	1.00	1.20	0.80
ACC.335	1.50	1.10	0.80	0.90	1.30	0.80
ACC.341	1.60	1.20	1.10	1.00	1.30	0.80
ACC.355	1.50	1.10	1.00	0.10	1.10	0.70
S.E. ±	0.08	0.07	0.09	0.08	0.05	0.06
LSD (0.05)	NS	NS	NS	NS	NS	NS
Norflurazon rates (kg a.i./ha)	Means of cowpea varieties					
0.0	1.70	1.30	1.10	1.20	1.20	0.90
0.2	1.50	1.20	0.93	1.00	1.20	0.80
0.4	1.50	1.10	0.88	0.90	1.30	0.80
0.8	1.40	0.90	0.75	0.80	1.20	0.60
S.E. ±	0.08	0.07	0.09	0.08	0.05	0.06
LSD (0.05)	NS	0.196	NS	0.22	NS	0.15

norflurazon reduced leaf dry matter production significantly compared with the untreated control, only when applied at 0.8 kg a.i./ha, while non-significant depression was also observed with 0.2 and 0.4 kg a.i./ha. Although the effect of herbicide on stem dry weight was not significant, it was slightly depressed by norflurazon at 0.4 and 0.8 kg a.i./ha in 1981.

A significant variety - herbicide interaction on leaf dry matter production was observed in the 1981 experiment (Table 2). Leaf dry weight was significantly reduced in ACC.341 by norflurazon at 0.8 kg a.i./ha compared with the control, while it was increased in variety ACC.355 by norflurazon at 0.4 and 0.8 kg a.i./ha. In Ife Brown, leaf dry matter production in the plots treated with norflurazon at 0.4 and 0.8 kg a.i./ha was significantly lower than that of 0.2 kg a.i./ha. Slight but non-significant increase in leaf weight were observed in Ife Brown and ACC.355 varieties treated with norflurazon at 0.2 kg a.i./ha, compared with the untreated control.

Nodule count: As shown in Table 3, both the varieties and herbicidal effect on nodule count were significant in 1981 and 1982. Ife Brown had significantly higher nodule count than all the other varieties while varieties ACC.341 and ACC.355 produced similar number of nodules per plant in both trials. Variety ACC.335 produced the least number of nodules in both years which was significantly lower than those of the other varieties.

In 1981, norflurazon at 0.8 kg a.i./ha resulted in lower nodule count than the other rates of the herbicide and the

Table 2: Interaction between varieties and norflurazon on leaf dry matter production of cowpea in the greenhouse in 1981.

Norflurazon rates (kg a.i./ha)	Ife Brown	Dry leaf weight (g/plant) ACC.335	ACC.341	ACC.355	Mean
0.0	1.2	1.4	1.4	0.8	1.2
0.2	1.4	1.2	1.2	1.0	1.2
0.4	1.1	1.3	1.3	1.4	1.3
0.8	1.0	1.2	1.1	1.3	1.2
Mean	1.2	1.3	1.3	1.1	

S.E. (variety x herbicide) ± = 0.10

LSD (0.05) (variety x herbicide) = 0.28

untreated control. Similarly, nodule count of 27 obtained with the highest rate of norflurazon was significantly lower than those of 0.2 kg a.i./ha and the untreated control, but comparable with those of 0.4 kg a.i./ha.

Plant height: Varietal effect on plant height was only significant in 1981. Plants of variety ACC.341 were significantly taller than those of the other varieties which virtually had the same height (Table 3). In 1982, plants of variety ACC.335 were shorter than those of the other varieties, although the varietal effect on plant height was not significant.

Herbicide effect was however significant in 1982. Norflurazon at 0.4 and 0.8 kg a.i./ha resulted in significantly shorter plants than the untreated control. Norflurazon at 0.8 kg a.i./ha also resulted in shorter plants than the lower rates.

4.1.2 Field trials

Shoot dry weight: In 1981 wet season, the effect of variety on shoot dry matter production was only significant at three weeks after sowing (Table 4). Varieties ACC.335 and ACC.355 had similar dry matter produdction which were significantly higher than those of ACC.341 and Cv Ife Brown. The effect of variety was not significant on dry shoot weight during 1982 wet season.

Herbicide effect was however, significant at 3 and 6 WAS in 1981 and at 3, 6 and 9 WAS in 1982 wet season. In 1981, at both stages of sampling norflurazon at 0.8 kg a.i./ha

Table 3: Effects of varieties and norflurazon on root nodules and plant height of cowpea in the greenhouse at Samaru.

Treatments	Nodule count/plant		Plant height (cm)	
	1981	1982	1981	1982
Cowpea varieties				
Ife Brown	54	45	30.9	32.2
ACC.335	30	23	27.8	28.8
ACC.341	45	35	35.5	33.9
ACC.355	43	34	29.8	32.2
S.E. ±	2.74	3.25	1.62	1.62
LSD (0.05)	7.61	9.00	4.50	NS
Norflurazon rates (kg a.i./ha)				
0.0	45	41	32.9	36.0
0.2	47	37	30.5	34.4
0.4	44	32	32.0	31.4
0.8	35	27	28.5	26.4
S.E. ±	2.74	3.25	1.62	1.62
LSD (0.05)	7.61	9.00	NS	4.49

Table 4: Effects of varieties and norflurazon on the shoot dry weight of cowpea in the wet season at Samaru.

Treatments	Dry shoot weight (kg/ha)					
	3 WAS*		6 WAS		9 WAS	
	1981	1982	1981	1982	1981	1982
Cowpea varieties	Means of norflurazon rates					
Ife Brown	165	262	2536	2736	6227	6918
ACC.335	258	251	2836	2707	5976	6672
ACC.341	156	229	2611	2711	5740	6756
ACC.355	249	242	2776	2473	6422	5518
S.E. ±	7	17	100	109	699	512
LSD (0.05)	20	NS	NS	NS	NS	NS
Norflurazon rates (kg a.i./ha)	Means of cowpea varieties					
0	227	278	2836	2880	7193	7220
0.2	218	251	2845	2754	6740	6711
0.4	209	245	2611	2582	5831	6227
0.8	174	211	2467	2411	4600	5705
S.E. ±	7	15	100	103	699	309
LSD (0.05)	20	44	278	276	NS	892

*WAS = weeks after sowing.

resulted in lower shoot dry matter production compared with the control. During 1982 wet season, while norflurazon at 0.8 kg a.i./ha resulted in lower shoot weight than the control at 3 WAS, both 0.4 and 0.8 kg a.i./ha depressed shoot weight significantly at 6 and 9 WAS.

Significant variety-herbicide interaction was only observed at 3 WAS in 1981. In Cv Ife Brown and ACC.335, significant depression in shoot weight was observed with norflurazon at 0.8 kg a.i./ha, while both 0.4 kg and 0.8 kg a.i./ha reduced it in ACC.355 compared with the corresponding control. In ACC.341, non-significant increase in shoot weight was observed with 0.4 kg a.i./ha (Table 5).

Plant height: Plant height was measured at 3, 6 and 9 WAS in 1981 wet season only (Table 6). Plant heights were significantly affected by varieties at all stages of growth while herbicide effects were only significant at 3 and 9 WAS. At 3 WAS, ACC.335 plants were taller than those of Cv Ife Brown and ACC.341. Similarly ACC.355 plants were also significantly taller than those of ACC.341. However, at 6 and 9 WAS, Cv Ife Brown had taller plants than the other varieties which had similar heights.

At 3 WAS, all the herbicide rates resulted in significant height depression compared with the control. At 9 WAS, norflurazon at 0.4 kg and 0.8 kg a.i./ha resulted in significantly shorter plants than the untreated control.

Grain yield: Data on grain yields for the 1981/82 dry season and 1982 wet season trials are shown in Table 7.

Table 5: İnteraction between varieties and norflurazon on shoot dry matter production of cowpea at 3 WAS at Samaru, 1981.

Norflurazon (kg a.i./ha)	Shoot dry weight (kg/ha)				
	Ife Brown	ACC.335	ACC.341	ACC.355	Mean
0	178	284	142	302	227
0.2	196	267	142	267	218
0.4	178	284	178	196	209
0.8	107	196	160	231	174
Mean	165	258	156	249	

S.E. (variety x herbicide) ± = 14

LSD (0.05) (variety x herbicide) = 40

Table 6: Effects of varieties and norflurazon on plant height of cowpea in 1981 wet season at Samaru.

Treatments	Plant height (cm/plant)		
	3 WAS*	6 WAS	9 WAS
Cowpea varieties	Means of norflurazon rates		
Ife Brown	9.0	21.2	39.9
ACC.335	9.9	18.2	31.2
ACC.341	8.3	18.7	28.6
ACC.355	9.5	19.3	27.6
S.E. ±	0.30	0.70	2.9
LSD (0.05)	0.82	1.95	0.04
Norflurazon rates (kg a.i./ha)	Means of cowpea varieties		
0	10.0	20.4	38.9
0.2	8.8	20.1	35.3
0.4	8.8	19.3	27.8
0.8	8.1	17.9	25.2
S.E. ±	0.30	0.70	2.9
LSD (0.05)	0.82	NS	8.40

*WAS = weeks after sowing.

Table 7: Effects of varieties and norflurazon on grain yield of cowpea at Samaru.

Treatments	Grain yield (kg/ha)	
	1981/82 dry season	1982 wet season
Cowpea varieties	Means of norflurazon rates	
Ife Brown	1480	1985
ACC.335	1260	1714
ACC.341	1193	2160
ACC.355	894	2029
S.E. ±	116	138
LSD (0.05)	345	NS
Norflurazon rates (kg a.i./ha)	Means of cowpea varieties	
0	1402	2104
0.2	1329	2020
0.4	1140	1938
0.8	956	1825
S.E. ±	116	70
LSD (0.05)	NS	203

Table 8: Effects of varieties and norflurazon on dry haulm weight of cowpea at Samaru.

Treatments	Dry haulm weight (kg/ha)		
	Wet season 1981	Dry season 1981/82	Wet season 1982
Cowpea varieties	Means of norflurazon rates		
Ife Brown	4531	4236	3202
ACC.335	3656	3611	3267
ACC.341	3478	3422	3109
ACC.355	4367	2511	2704
S.E. ±	434	365	252
LSD (0.05)	NS	1013	NS
Norflurazon rates (kg a.i./ha)	Means of cowpea varieties		
0	4818	4027	3442
0.2	4734	3816	3218
0.4	3947	3262	2876
0.8	2534	2736	2747
S.E. ±	434	365	215
LSD (0.05)	1203	NS	NS

dry weight than the 0 kg P_2O_5 at 3 WAS. Only 40 kg P_2O_5 significantly increased shoot weight at 9 WAS in 1981 wet season and at 6 WAS in 1982 wet season (Table 9).

Herbicide effect on shoot dry matter production was significant at 3, 6 and 9 WAS in 1982 wet season. At 3 and 6 WAS, norflurazon at 0.8 kg a.i./ha resulted in significantly lower shoot weight than 0.2 kg a.i./ha and the untreated control, while at 9 WAS, 0.8 kg a.i./ha was only lower than the untreated control. In all cases where the effect of the herbicide was not significant, shoot weight tended to decrease with increase in the rate of applied norflurazon.

Phosphorus-herbicide interaction effect on shoot dry matter was significant at 6 WAS in 1982 wet season trial (Table 10). When no phosphorus was applied, 0.8 kg a.i./ha of norflurazon significantly reduced shoot weight as compared with either the untreated control or the 0.2 kg a.i./ha rate. When either 40 kg or 80 kg P_2O_5/ha of phosphorus was applied, however, no toxicity due to norflurazon was observed.

4.2.2 Grain yield

In 1981/82 dry season, phosphorus application resulted in a significant increase in cowpea grain yield as compared with the no phosphorus treatment. No significant difference was observed between 40 kg P_2O_5/ha and 80 P_2O_5/ha.

Effect of herbicide on grain yield was not significant in the 1981/82 dry season and 1982 wet season trials (Table 11). The results however, indicated that there was a non-significant decline in the grain yield as the herbicide rates increased, especially at 0.8 kg a.i./ha.

Table 9: Effects of phosphorus and norflurazon on shoot dry weight at Samaru.

Treatments	Shoot dry weight (kg/ha)					
	3 WAS*		6 WAS		9 WAS	
	1981	1982	1981	1982	1981	1982
Phosphorus levels (kg P_2O_5/ha)	Means of norflurazon levels					
0.0	293	233	2389	2571	6702	6096
40	369	258	2684	3013	7511	7065
80	356	247	2504	2747	7009	6438
S.E. ±	12	17	124	71	212	354
LSD (0.05)	36	NS	NS	239	611	NS
Norflurazon rates (kg a.i./ha)	Means of phosphorus levels					
0	350	281	2640	2963	7411	7132
0.2	343	267	2604	2868	7283	6883
0.4	344	240	2500	2723	7002	6326
0.8	320	196	2358	2554	6601	5790
S.E. ±	14	15	142	82	244	325
LSD (0.05)	NS	45	NS	247	NS	943

*WAS = weeks after sowing.

Table 10: Interaction between phosphorus and norflurazon on shoot dry weight of cowpea at 6 WAS at Samaru in 1982.

Norflurazon (kg a.i./ha)	Shoot dry weight (kg/ha)			
	P_0*	P_{40}	P_{80}	Mean
0	2791	3138	2960	2963
0.2	2747	3102	2756	2868
0.4	2471	3022	2676	2723
0.8	2276	2791	2596	2554
Mean	2571	3013	2747	

S.E. (Phosphorus x Herbicide + = 143

LSD (0.05) (Phosphorus x Herbicide) = 414

*P = P_2O_5 kg/ha.

Table 11: Effects of phosphorus and norflurazon on grain yield of cowpea at Samaru.

Treatments	Grain yield (kg/ha)	
	1981/82 Dry season	1982 Wet season
Phosphorus levels (Kg/P_2O_5)	Means of norflurazon rates	
0.0	1029	2144
40	1429	2213
80	1267	2182
S.E. ±	94	97
LSD (0.05)	272	NS
Norflurazon rates (Kg a.i./ha)	Means of phosphorus levels	
0	1413	2302
0.2	1345	2210
0.4	1182	2121
0.8	1025	2086
S.E. ±	108	78
LSD (0.05)	NS	NS

Herbicide-phosphorus interaction was not significant on cowpea grain yield in the two trials.

4.2.3 Dry haulm weight

Phosphorus effect was significant on dry haulm weight in 1981/82 dry season trial (Table 12). Phosphorus at 40 kg P_2O_5/ha produced significantly higher haulm weight than no phosphorus treatment. However, plants supplied with 80 kg P_2O_5/ha of phosphorus had slightly less but comparable dry haulm with those supplied with 40 kg P_2O_5/ha.

4.3 Tolerance of Cowpea to Norflurazon Applied at Different Stages of Growth

4.3.1 Shoot dry weight and plant height at 9 WAS

In this investigation, dry shoot weight and plant height were recorded at 9 WAS in 1981 wet season only. Although the time of herbicide application did not have a significant effect on shoot weight and plant height, plants sprayed at emergence appeared to have the lowest shoot dry matter production and were the shortest (Table 13).

Effect of norflurazon on shoot weight and plant height at 9 WAS was significant. Although all rates of the herbicide depressed shoot weight, it only resulted in significantly lower shoot weight than the control at 1.2 kg a.i./ha. Both 0.8 kg and 1.2 kg a.i./ha had significantly shorter plants than the control; 1.2 kg a.i./ha also resulted in significantly shorter plants than 0.4 kg a.i./ha.

Table 12: Effects of phosphorus and norflurazon on the dry haulm weight of cowpea at Samaru.

Treatments	Dry haulm weight (kg/ha)		
	1981 Wet season	1981/82 Dry season	1982 Wet season
Phosphorus levels (kg/P_2O_5)	Means of norflurazon rates		
0	4302	3028	3374
40	5127	4174	4163
80	4831	3731	3622
S.E. ±	268	271	243
LSD (0.05)	NS	783	NS
Norflurazon rates (kg a.i./ha)	Means of phosphors levels		
0	5010	4068	4009
0.2	5215	3883	3810
0.4	4685	3600	3612
0.8	4104	3025	3446
S.E. ±	310	313	280
LSD (0.05)	NS	NS	NS

Table 13: Effects of time of application and norflurazon on shoot dry weight and plant height of cowpea at 9 WAS at Samaru, 1981.

Treatments	Plant height (cm)	Dry shoot weight (kg/ha)
Time of herbicide application	Means of norflurazon rates	
Pre-emergence	71.7	7707
At emergence	55.4	6831
3 WAS*	65.3	7116
6 WAS	64.2	8158
S.E. ±	5.2	507
LSD (0.05)	NS	NS
Norflurazon rates (kg a.i./ha)	Means of time of application	
0	75.7	8336
0.4	68.0	8012
0.8	60.1	7614
1.2	52.8	5851
S.E. ±	5.2	507
LSD (0.05)	14.41	1404

*WAS = Weeks after sowing.

4.3.2. Grain yield

Neither the effect of crop growth stage at the time of application nor rates of herbicide on grain yield was significant. The herbicide-time of application interaction was also not significant. However, there was a gradual decline in cowpea grain yield with increase in the herbicide rate in both the 1981/82 dry season and 1982 wet season trials (Table 14).

4.3.3. Haulm dry weight

Effect of time of herbicide application was only significant in the trial conducted in 1981 wet season. Plants sprayed with the herbicide at 3 weeks after sowing (WAS) had significantly higher dry haulm weight than those sprayed at any other time (Table 15) while those sprayed at emergence had the least dry weight. No significant difference in dry haulm weight was observed between application at either 6 WAS or at pre-emergence.

The effect of rates of herbicide on dry haulm weight was significant in the 1981 and 1982 wet season trials. In 1981 all rates significantly reduced haulm weight compared with the unsprayed control. Norflurazon at 1.2 kg a.i./ha resulted in lower haulm weight than 0.4 and 0.8 kg a.i./ha. In 1982 only 0.8 kg and 1.2 kg a.i./ha caused a significant reduction compared with the control. Norflurazon at 1.2 kg a.i./ha however, resulted in lower weight than 0.4 kg a.i./ha. In the 1981/82 dry season trial, although the effect of herbicide was not significant at all rates the results showed a gradual decrease in the dry haulm weight as the rate of the

Table 14: Effects of time of application and norflurazon on grain yield of cowpea at Smmaru

Treatments	Grain yield (kg/ha)	
	1981/82 Dry season	1982 Wet season
Time of herbicide application	Means of norflurazon rates	
Pre-emergence	1778	1658
At emergence	1182	1605
3 WAS*	2062	1667
6 WAS	1253	1618
S.E. ±	240	62
LSD (0.05)	NS	NS
Norflurazon rates (kg a.i./ha)	Means of time of application	
0	26/6	1736
0.4	2462	1638
0.8	1707	1622
1.2	1253	1551
S.E. ±	240	44
LSD (0.05)	NS	NS

*WAS = Weeks after sowing.

Table 15: Effects of time of application and norflurazon on dry haulm weight of cowpea at Samaru.

Treatments	Haulm dry weight (kg/ha)		
	1981 Wet season	1981/82 Dry season	1982 Wet season
Time of herbicide application	Means of norflurazon rates		
Pre-emergence	3233	4676	3429
At emergence	2678	3854	2703
2 WAS*	3815	5578	2774
6 WAS	3360	4382	2786
S.E. ±	136	502	180
LSD (0.05)	378	NS	NS
Norflurazon rates (kg a.i./ha)	Means of time of application		
0	3807	5518	3276
0.4	3247	5047	3007
0.8	2880	4287	2825
1.2	2314	3638	2585
S.E. ±	136	502	130
LSD (0.05)	378	NS	375

*W.S = Week after sowing.

herbicide increased.

Herbicide-time of application interaction on haulm was not significant in all the trials.

Chapter 5

DISCUSSION

Both in the greenhouse and in the field norflurazon at the rates of 0.4 kg a.i./ha and above resulted in cowpea leaf chlorosis irrespective of crop variety, phosphorus levels or stage of growth of crop at the time of application. Norflurazon has been reported to inhibit carotenoid synthesis in leaves of various plants resulting in partial to total leaf chlorosis depending on the plant type and the concentration of the herbicide (Devlin et al., 1979). While total chlorosis was observed in wheat (Bartels and Watson, 1978), partial chlorosis was observed in corn (Devlin et al., 1979) and in broad bean, Phaseolus vulgaris (Pardo and Schiff, 1977). The chlorosis was attributed to the inhibition of carotenoid synthesis in plants which Bartels and Watson (1978) also attributed to inhibition of dehydrogenation reaction which followed phytoene formation.

Epinasty of the leaves of cowpea was also observed with norflurazon at 0.4 kg a.i./ha and above and this persisted for a longer period in the greenhouse than in the field. This was probably because plants were more susceptible to herbicides in the pots as a result of more exposure of the roots to the herbicide and consequently more herbicide uptake by the crop plant in the pot than in the field. Similar symptom which has been attributed to interference with transport of auxin in plants was observed with ethylene at sub-lethal dose (Gorter and Vander-Zweep, 1964) and with dalapon and EPTC at high rates in maize (Lagoke, 1978).

5.1 Differential Tolerance of Cowpea Varieties to Norflurazon

Ife Brown exhibited greater yield potential than the other varieties tested. It consistently produced the highest number of cowpea root nodules and with ACC.335, produced higher grain yield than ACC.355 in 1981/82 dry season. Similarly, in 1981, this variety had taller plants than the other varieties at 6 and 9 WAS. The beneficial effect of good nodulation on cowpea grain yield has been attributed to the supply of fixed nitrogen in direct response to the requirement of the plant, particularly during the plants period of demand for the nutrients for pod development and pod fill (Quilt and Dalal, 1979). Good nodulation in cowpea which was more with Ife Brown than with other varieties was reported to consistently promote branching and pod-set and pod retention which are yield contributing factors (Summerfield et al., 1977). However, in spite of low nodulation observed in the greenhouse, ACC.335 still produced higher grain yield than ACC.341 in the field.

It was apparent that in the greenhouse, norflurazon was phytotoxic to cowpea at 0.4 and 0.8 kg a.i./ha resulting in reduced production of absortive and photosynthetic organ, as reflected in root, leaf and stem dry matter production and plant height. Norflurazon at 0.8 kg a.i./ha also reduced cowpea nodulation in the greenhouse experiments. The data on root confirm the findings of Devlin and Demoranville (1974) who observed that norflurazon at high rates reduced root development in cranberry cuttings. Similarly in the

field, both 0.4 kg and 0.8 kg a.i./ha reduced shoot dry weight singificantly at 6 and 9 WAS in 1982 wet season. Significant depression in plant height even at 3 WAS by all the rates of norflurazon was also observed in 1981. The herbicide at 0.8 kg a.i./ha also caused a significant depress-ion in grain and haulm yields in 1982 and 1981 wet season respectively.

The apparently more persistent and severe phytotoxicity of norflurazon on cowpea in the field in 1982 wet season compared with 1981 wet season may be attributed to difference in soil moisture, as a result of rainfall within three weeks after application. In 1981, about 214 mm of rain was received while in 1982 wet season 117.4 mm was received. This result seems to suggest that the higher rainfall recorded in 1981 reduced the activity of the herbicide. However, Lagoke et al. (1982) attributed the reduction in cowpea grain yield by prometryne and linuron each at 2.0 kg a.i./ha in 1979 to high rainfall within a week of application, compared with non-phytotoxicity observed in 1978 when rainrall was less in the corresponding period. In determing the influence of soil-moisture content on herbicidal activity Grover (1970) found that bioactivity of picloram decreased as the soil-moisture content was increased and he attributed this to the effect of varying soil-moisture levels on the concentration of picloram in the soil-water phase.

Norflurazon at 0.2 kg a.i./ha however, did not have any adverse effect on all the cowpea varieties. The increase in leaf dry matter observed in Cv Ife Brown and ACC.355 when

norflurazon at 0.2 kg a.i./ha was applied in the greenhouse confirms the earlier report that norflurazon at sublethal dose exhibits auxin property by stimulating the growth of some plants as was observed in soybean (Hoagland and Duke, 1981).

Both in the greenhouse and in the field Ife Brown consistently exhibited better tolerance than the other varieties tested. This may well explain the difference in the selectivity of norflurazon in cowpea reported by Lagoke et al. (1982) and those obtained in this study. The other varieties were less consistent in their exhibition of tolerance to the herbicide. While ACC.355 appeared tolerant in the greenhouse, both 0.4 kg and 0.8 kg a.i./ha of norflurazon reduced its shoot weight in the field. Variety ACC.341 exhibited non-significant increase in shoot weight when treated with 0.4 kg a.i./ha only in the field.

5.2 Effect of Phosphorus on the Tolerance of Cowpea to Norflurazon

In this study, phosphorus at 40 kg P_2O_5/na consistently resulted in higher dry matter production, grain and haulm yields than no phosphorus treatment; no significant increase in both grain and haulm yield was observed with 80 kg P_2O_5/ha compared with 40 kg P_2O_5/ha. It has earlier been reported at Samaru that there was no advantage in applying more than 37 kg P_2O_5/ha to cowpea (Anonymous, 1979b).

In 1982 wet season, as reflected in the shoot weight, the phytotoxic effect of norflurazon at 0.8 kg a.i./ha in cowpea persisted till 9 WAS, although the effect did not

persist long enough to affect grain yields significantly. The reduction in shoot dry weight was however not observed in 1981, probably due to the reason given earlier.

A significant phosphorus - herbicide interaction on shoot dry weight was observed in 1982. Cowpea was apparently more susceptible to norflurazon when no phosphorus was applied. This may be attributed to reduced absorption of the herbicide by cowpea plants in the presence of phosphorus. Doll et al. (1970) showed that soybean roots took up significantly less amiben and atrazine at all three phosphate levels they tested.

5.3 Tolerance of Cowpea to Norflurazon Applied at Different Stages of Growth

Although the effect of time of application of norflurazon was not significant on shoot weight and plant height, it was generally noted that the lowest shoot dry matter and the shortest plants were recorded in plants sprayed at emergence. At this stage of growth the seedlings had fewer leaves whose chlorophyll contents were photodestroyed following inhibition of carotenoid synthesis by the herbicide (Develin and Demoranville, 1974) resulting in the inability to manufacture enough food needed for growth. This was confirmed by the significantly low dry haulm yield obtained with application at emergence. Belien et al. (1979) had earlier shown that beet was most susceptible to metamitron if treated during emergence and at the cotyledonary stage.

The toxic effect of norflurazon on shoot weight and plant height was significant at 0.8 and 1.2 kg a.i./ha which suggests that the crop tolerated up to 0.4 kg a.i./ha of norflurazon.

SUMMARY AND CONCLUSION

Two greenhouse experiments and nine field trials were conducted on the Institute for Agricultural Research Farm between 1981 and 1982 in order to evaluate the effects of variety, level of phosphorus and time of herbicide application on the tolerance of cowpea to norflurazon.

The cowpea varieties used responded differentially to the herbicide treatments although in most cases the interaction between the herbicide treatments and cowpea varieties was not significant. It was observed that toxicity due to norflurazon was more severe in the greenhouse than in the field. Norflurazon was more toxic to the crop at 0.8 kg and 1.2 kg a.i./ha. Ife Brown had more yield potentials and seems to tolerate the herbicide more than the other varieties tested. It was also observed that cowpea was less susceptible to norflurazon when phosphorus was applied. Doubling the recommended phosphorus level from 40 kg to 80 kg P_2O_5/ha was observed to have no added advantage on cowpea grain yields. Applying norflurazon to cowpea at emergence appeared to reduce the crops tolerance to the herbicide.

In using norflurazon for weed control in cowpea therefore the variety and phosphorus factors should be borne in mind. The herbicide could be used at pre- or post-emergence. However, for post-emergence application the crop must be allowed to grow for at least three weeks and the rate should not exceed 0.4 kg a.i./ha

For further work along this line it will be desirable to know the extent to which soil factors viz clay, organic matter, cation exchange capacity and pH affect cowpea tolerance to norflurazon.

LITERATURE CITED

Abernathy, J.R., Davis, J.L. and Keeling, J.W. (1978). 'Weed control in corn and sorghum with post-plant incorporated applications of dinitroaniline herbicides'. In Abstracts Meeting Weed Science Society of America 24 (Weed Abstracts 28(1): Abstr.44, 1978).

Akobundu, I.O. (1978). 'Chemical weed control in cowpea and soybean in Southern Nigeria'. In 3e symposium sur le Descherbage des cultures Tropicaler, Darkar, 2:120 (Weed Abstracts, 28(11): Abstr.3459, 1979).

Akobundu, I.O. (1982). 'Weed control in cowpea in the Humid Tropics'. Weed Science 30(4): 331 - 334.

Anderson, R.N. (1964). 'Differential response of corn inbr to simazine and atrazine'. Weed Science 12: 60 - 6[illegible].

Anonymous (1975). Production Year Book. Food and Agriculture Organization, Rome Italy, 555pp.

Anonymous (1979a). Cropping Scheme Meeting of Cotton and Other Fibres Improvement Programme of the Institute for Agricultural Research, Ahmadu Bello University, Zaria, Nigeria, 29pp. (Type-written).

Anonymous (1979b). Cropping Scheme Meeting of Cowpeas and Grain Legume Improvement Programme of the Institute for Agricultural Research, Ahmadu Bello University, Zaria, Nigeria, 26pp. (Type-written).

Anonymous (1981). Canada Agricultural Research Station, Annual Report 1980, Kentville, Nova Scotia, 258pp. (Weed Abstracts, 31(10): Abstr.3112, 1982).

Anonymous (1982). Cropping Scheme Meeting of Grain Legumes Improvement Programme of the Institute for Agricultural Research, Ahmadu Bello University, Zaria, Nigeria, 40pp. (Type-written).

Bagaev, V.B. and Kalimullina, K.K. (1968). 'The sensitivity of carrots to propazine in relation to mineral fertilizer levels'. Dokh. Tskh. 133: 281-7. (Weed Abstracts, 19(2): Abstr.826, 1970).

Bartels, P.G. and Watson, C.W. (1978). 'Inhibition of carotenoid synthesis by fluridone and norflurazon'. Weed Science, 26(2): 198 - 203.

Belien, J.M., Salembier, J.F. and Gomand, M. (1979). 'Application of metamitron at different growth stages in beets (Applications du mē tamitrone ā differents' stages de la vēgētation de la betterave. Behandelingen met metamitron op verschillende groeistadia van de biet Driemaandelijkse Publikatie Belgisch Institut lot Verbetering van de Biet). (Weed Abstracts, 30(12): Abstr.4216, 1981).

Berard, D.F., Rainey, D.P. and Lin, C.C. (1978). 'Absorption, translocation and metabolism of fluridone in selected crop species'. Weed Science, 26: 252 - 254.

Borger, P. and Schlue, U. (1976). 'Long effect of herbicides on the photosynthesis apparatus. Influence of diuron, triazines and pyridazinones'. Weed Research 16: 149 - 154.

Brenchiley, R.G. and Appleby, A.P. (1967). 'The influence of magnesium on the toxicity of atrazine on oat plant'. In Abstracts, Meeting of the Weed Science Society of America, 52. (Weed Abstracts, 18(104): Abstr.910, 1969).

Chauhan, S.V. and Singh, S.P. (1972). 'Effect of maleic hydrazide, FW-450 and dalapon on growth, flowering and pollen viability of Capsicum annum and Datura alba. Indian Journal of Plant Physiology, 15(1-2): 138 - 147. (Weed Abstracts, 25(11): Abstr.3467, 1976).

Devlin, R.M. and Deubert, K.A. (1973). 'Tolerance of cranberry (Vaccinium macrocarpon) to SAN - 9789: an experimental herbicide'. Weed Research, 14(4): 393 - 398.

Devlin, R.M. and Demoranville, I.E. (1974). 'Influence of dichlobenil and three experimental herbicides on bud break, terminal growth and root development of cranberry cuttings'. In Abstracts, 1974 Meeting of Weed Science Society of America, pp.14 - 15. (Weed Abstracts, 25(9): Abstr.2611, 1974).

Devlin, R.M. and Karczmarczyk, S.J. (1975). 'Influence of norflurazon on chlorophyll production'. In Proceedings Northeastern Weed Science Society, pp.161 - 168. In Ashton, F.M. and Crafts, A.S. Mode of Action of Herbicides, pp.405 - 455.

Devlin, R.M., Kisiel, M.J. and Kostusiak, A.S. (1979). 'The blocking of carotenoid synthesis in corn with the experimental herbicide R-4024'. In Proceedings Northeastern Weed Science Society, 33: 95 - 97. (Weed Abstracts, 29(2): Abstr.573, 1980).

Doll, J.D., Penner, D. and Meggitt, W.F. (1970). 'Herbicide and phosphorus influence on root absorption of amiben and atrazine. Weed Science, 8: 357 - 359.

Dunham, R.S. and Robinson, R.G. (1948). 'Response of flax varieties to 2, 4-D'. In Abstracts 5th Annual North-Central Weed Control Conference Research Report. p.40.

Eshel, Y. (1969). Effect of pyrazon on photosynthesis of various plant species. Weed Research, 9: 167 - 172.

Evtushenko, G.A., Belyaeva, A.V. and Kolov, O.V. (1973). 'The influence of M.H. for controlling broomrape on tobacco'. (In Vliyanie Fiziologicheski aktivnykh Soedinenii na obmen veshchestv i produktivnos rastenii, pp.53-69. (Weed Abstracts, 25(6): Abstr. 1519, 1976).

Fadayomi, O. (1979). 'Weed competition and cost effectiveness of different weed control alternatives in cowpea (Vigna unguiculata (Linn.) Walp.) cv Ife Brown'. In Proceedings of the 9th Annual Conference of the Weed Science Society of Nigeria, pp.43 - 46.

Friesan, H.A. (1949). 'Effect of 2, 4-D on Linseed flax varieties. Abstracts, Research Report 6th Annual North-Central Weed Control Conference, p.85.

Frosch, S.M., Bergfeld, R., Kleing, H. and Mohr, H. (1979). 'Inhibition of carotenoid biosynthesis by the herbicide SAN 9789 and its consequences for the action of phytochrome on plastogenesis'. Planta, 145(5): 497 - 505. (Weed Abstracts, 28(12): Abstr.4206, 1979).

Gorter, C.J. and Van dez Zweep, W. (1964). 'Morphogenetic effects of herbicides'. In Audus, L.J. Physiology and Biochemistry of Herbicides, pp.127 - 161. Academic Press, London and New York.

Grogan, C.I., Eastin, E.F. and Palmer, R.D. (1963). 'Inheritance of susceptibility of a line of maize to simazine and atrazine'. Crop Science, 3(5): 451.

Grover, R. (1970). 'Influence of soil moisture content on the bioactivity of picloram. Weed Science, 18: 110 - 111.

Gupta, O.P. and Lamba, P.S. (1978). 'Modern Weed Science.' Today and Tomorrow's Printers and Publishers, New Delhi, India, 421pp.

Hardcastle, W.S. (1979). 'Soybean (Glycine max) cultivar response to metribuzin in solution culture'. Weed Science, 27(3): 278 - 279.

Harris, T.C. and Ritter, R.L. (1981). 'Potential injury from late herbicide application in row tillage corn'. In Proceedings Northeastern Weed Science Society, p.35. (Weed Abstracts 30(12): Abstr.4150, 1981.

Hartmans, E.H. (1983). 'Proceedings of the All Nigerian Coordinated Cowpea Research Program, pp.7 - 9.

Hayes, R.M. and Wax, L.M. (1975). 'Differential intraspecific responses of soybean cultivars to bentazone'. Weed Science, 23: 516 - 522.

Hoagland, R.E. and Duke, S.O. (1981). 'Effects of herbicides on growth and extractable phenylalanine ammonialyase activity in light and dark-grown soybean (Glycine max) seedlings'. Weed Science 29(4): 433 - 439.

Jacobsohn, R. and Anderson, R.N. (1968). 'Differential response of wild oat lines to di-allate, tri-allate and barban. Weed Science 16(6): 491 - 494.

John, J.B. and Hilton, J.C. (1976). 'Structure versus activity of substituted pyridazinones'. Plant Growth Regulator Bulletin, 3(4): 38. (Weed Abstracts, 26(5): Abstr.1399, 1977).

Jordan, T.N. and Bridge, R.R. (1976). 'Selectivity of glyphosate to cotton cultivars, Johnsongrass and Bermudagrass'. In Proceedings 29th Annual Meeting Southern Weed Science Society, pp.53 - 57. (Weed Abstracts, 26(1): Abstr.66, 1977).

Jordan, T.N. and Barrentine, W.L. (1978). 'Soybean response to cotton herbicides'. In Abstracts 1978 Meeting Weed Science Society of America, p.25. (Weed Abstracts, 28(1): Abstr.86, 1979).

Kasasian, L. (1971). Weed Control in the Tropics. Leonard Hill, London, 307pp.

Klingman, G.C. and Ashton, F.M. (1975). Weed Science: Principles and Practices. John Wiley and Sons Inc., New York. 142pp.

Lagoke, S.T.O. (1978). Methods of control of spear grass (Imperata cylindrica) in maize. Unpublished Ph.D. Thesis. University of Ibadan, Ibadan, Nigeria. 359pp.

Lagoke, S.T.O., Choudhary, A.H. and Chandra-Singh, D.J. (1982). 'Chemical weed control in rainfed cowpea (Vigna unquiculata (L.) Walp.) in the Guinea Savanna zone of Nigeria'. Weed Research, 22(1): 17 - 22.

Langworthy, C.F. and Hunt, C.L. (1959). 'Use of corn, Kaffir and cowpeas in the home'. U.S. Dept. of Agric. Farmers' Bulletin, p.559. In The Production of Field Crops. McGraw-Hill Book Company, Inc. New York and London, 445pp.

McCall, D.A. (1976). 'Differences, mechanisms and genetics of herbicide response among selected cultivars of cotton, (Gossypium hirsutum L.)'. Ph.D. Thesis, Oklahoma State University, Oklahoma, U.S.A.

McKercher, R.B. and McGregor, W.R. (1980). 'Triallate phyto-toxicity and nitrogen fertilization'. Weed Science, 28(6): 740 - 744.

Millhollon, R.W. and Matherne, R.J. (1968). 'Tolerance of sugarcane varieties to herbicides'. Weed Science, 16(3): 300 - 303.

Moody, K. (1973). 'Weed control in cowpea'. In Proceedings of the Third Nigeria Weed Science Group Meeting, pp.13 - 22. (Weed Abstracts, 25(2): Abstr.446, 1976).

Osgood, R.V., Romanowski, R.R. and Hilton, H.W. (1972). 'Differential tolerance of Hawaiian sugarcane cultivars to diuron'. Weed Science, 20(6): 537 - 539.

Owen, E., Frank, K. and Davis, R. (1970). 'Effect of fertilizer levels on the phytotoxicity of herbicides to maize and sorghum'. In Abstracts of paper at 2. Seminde la Soc. Colombiana de control de Malezaz y Fivibgia vegetal (COMALFI), Bogotá, 52. (Weed Abstracts, 20(2): Abstr.504, 1971).

Palmer, R.D. and Grogan, C.O. (1965). 'Tolerance of corn lines of atrazine in relation to content of benzoxazinon derivative 2-glycoside'. Weeds, 13(3): 219-221.

Papova, D. (1980). 'The translocation and phytotoxicity of ^{14}C-atrazine in French beans in relation to and the level of mineral fertilizers'. Pochvoznanie i Agrokhimiya, 15(2): 77 - 84. (Weed Abstracts, 30(8): Abstr.2915, 1981).

Pardo, C.F. and Encina, R.G. (1977). 'Effect of Agren 3614, applied at 2 stages and 5 doses to wheat cv mexifen'. (Effecto do Agren 3614, applicado en dos ēpocas y cinco dois sobre trigo cultivar Mexifen in control de malezos). (Weed Abstracts, 30(1): Abstr.19, 1981).

Pardo, A.D. and Schiff, J.A. (1977). 'Plastid and seedling development in SAN 9789 treated etiolated bean seedlings. Abstract of paper presented at the Annual Meeting of the American Society of Plant Physiologists, Madison, Wisconsin. Plant Physiology, 59: 122.

Phatak, S.G. and Glaze, N.C. (1978). 'Field tolerance of Southern pea cultivars to metribuzin'. In Proceedings of the 31st Annual Meeting of the Southern Weed Science Society, p.168. (Weed Abstracts, 28(10): Abstr.3020, 1979).

Penner, D. (1974). 'The effectiveness of pesticide interactions'. Weeds Today 5(3): 13 - 14. (Modern Weed Science, Today and Tomorrow's Publishers and Printers, New Delhi, India. 421pp.

Purseglove, J.W. (1974). Tropical Crops Dicotyledons, Longmans Green, New York. 719pp.

Quilt, P and Dalal, R.C. (1979). 'Effect of soil mineral N levels and inoculation on nodulation, nitrogenase activity and grain yield of pigeon pea. Agronomy Journal, 71(3): 450 - 453.

Rafii, Z.E., Ashton, F.M. and Glenn, R.K. (1979). 'Metabolic sites of action of fluridone in isolated mesophyll cells'. Weed Science, 27: 422 - 426.

Raghunathan, G., Jagannath, M.K., Rajashekara, B.G. and Krishamurthy, K. (1974). 'Varietal reaction of sorghum to herbicides'. Indian Journal of Weed Science, 6(2): 88 - 96.

Rahman, A. (1980). 'Interaction of phosphorus and soil applied alachlor'. In Annual Report 1978/79, p.320. Ministry of Agriculture and Fisheries, New Zealand.

Rincon, D.J. and Warren, G.F. (1979). 'Effect of soil placement on the activity of herbicides on Cyperus rotundus L. Weed Research, 19(2): 81 - 87.

Rodebush, J.E. and Anderson, J.L. (1970). 'Morphological and anatomical effects of pyrazon on bean. Weed Science, 18: 443 - 446.

Romanovskaya, O.I. and Straume, O.P. (1975). 'On the ability of weed plants to inactivate the herbicide pyrazone.' Agrokhimiya, 12(5): 117 - 124. (Weed Abstracts, 25(1): Abstr.321, 1976).

Santelmann, P.W. and Scifres, C.J. (1966). 'The effect of post-emergence herbicides on the fibre quality of five cotton varieties'. In Abstracts Meeting of Weed Science Society of America, p.6 (Weed Abstracts, 16(4): Abstr.1172, 1967).

Santelmann, P.W., Scifres, C.J. and Murray, J. (1966). 'Influence of post-emergence herbicides on the fibre quality of selected cotton varieties'. Crop Science, 6(6): 561 - 562.

Singh, B.B. (1983). Proceedings of the All Nigeria Coordinated Cowpea Research Programme. pp.18 - 20.

Solano, J., Schrader, J.W. and Coble, H.O. (1976). 'Control of Spurred anoda in cotton'. Weed Science, 24(6): 553 - 556.

Spilsbury, R.D. (1972). 'The effect of MSMA and Sandoz 6706 herbicides on the metabolism of Johnsongrass'. Dissertation Abstract International, 33(6): 2443. (Weed Abstracts,2?(12): Abstr.2977, 1972).

Stanton, W.R., Drughty, J., Orraca-Jettch, R. and Stede, W.S. (1966). Grain Legumes in Africa. Food and Agriculture Organization of the United Nation, Rome. 183pp.

Stephenson, G.R., McLeod, J.E. and Phatak, S.C. (1976). 'Differential tolerance of tomato cultivars to metribuzin'. Weed Science, 24(2): 161 - 165.

Strang, R.H. and Rogers, R.L. (1974). 'Behaviour and fate of two phenylpyridazinone herbicides in cotton, corn and soybean'. Journal of Agricultural and Food Chemistry, 22(6): 117 - 125.

Summerfield, R.J., Dart, P.J., Huxley, P.A., Eaglesham, A.R.J., Mincliin, I.F.R. and Day, J.M. (1977). 'Nitrogen nutrition of cowpea (Vigna unquiculata). Effects of applied nitrogen and symbiotic nitrogen fixation on growth and yield'. Agronomy Journal, 71 71(3): 450 - 453.

Tandon, R.K. (1949). 'The response of flax to rates and formulations of 2, 4-D.' Agronomy Journal, 41(5): 213 - 218

Vaisberg, A.J. and Schiff, J.A. (1976). 'Events surrounding the early development of Euglena chloroplasts. Inhibition of carotenoid biosynthesis by the herbicide SAN 9789 and its developmental consequences'. Plant Physiology, 57(2): 260 - 269.

Wain, R.L. and Smith, M.S. (1976). 'Selectivity in relation to metabolism'. In Herbicides Physiology, Biochemistry and Ecology (Ed.), pp.279 - 299. Academic Press, London, England.

Werner, G.M. and Putnam, A.R. (1980). 'Differential atrazine tolerance within cucumber (Cucumis sativus)'. Weed Science, 28(2): 142 - 148.

Wood, I.M.W. (1970). 'Herbicides for the control of grassy weeds in the peanut crop at Katherine, N.T.'. Australian Journal of Experimental Agriculture and Animal Husbandry, 10: 462 - 466. (Weed Abstracts, 20(3): Abstr.1047, 1970).

Appendix 1: Physico-chemical properties of Samaru soil

Composition of Samaru soil	
Fine sand %	26
Coarse sand %	15
Silt %	41
Clay %	18
Organic carbon %	0.26
pH 1:1 (H_2O)	5.5
pH 1:2-5 (H_2O)	4.9
CEC (M.eq/100g soil)	3.4

Appendix 2: Crop vigour score scale

10 = Most healthy in the whole experiment

9 = Slight discoloration or lower vigour

8 = Slight discoloration and low vigour/discoloration and necrotic spots

7 = Distinguishable inhibition of growth

6 = Distinguishable inhibition of growth and slight discoloration/other injury symptoms.

5 = Distinguishable inhibition of growth and other injury symptoms.

4 = Definite growth reduction and severe toxicity symptoms but apparently still making some growth.

3 = Definite growth reduction, severe toxicity symptoms and less likely to survive

2 = Only few green tissues present

1 = Moribund

0 = Completely killed

Appendix 3: Rainfall distribution (mm) at Samaru during the period April - October, 1981 and 1982[1]

Period		1981	1982	Long term mean (1929 - 1982)
April	1 - 10	-	2.3	6.6
	11 - 20	26.2	26.8	10.6
	21 - 30	74.5	30.6	20.8
May	1 - 10	48.7	16.7	31.7
	11 - 20	37.3	22.1	32.9
	21 - 31	4.7	33.3	56.8
June	1 - 10	0.6	8.1	45.3
	11 - 20	100.5	69.7	57.3
	21 - 30	57.9	36.1	56.9
July	1 - 10	40.5	51.3	57.6
	11 - 20	85.7	76.5	71.9
	21 - 31	128.6	40.9	92.4
Aug.	1 - 10	26.0	33.9	81.1
	1 - 20	66.3	45.5	87.1
	21 - 31	188.3	111.3	106.7
Sept.	1 - 10	63.2	75.8	94.4
	11 - 20	62.3	33.0	74.7
	21 - 30	7.8	8.8	47.8
Oct.	1 - 10	-	45.8	20.7
	11 - 20	-	-	11.0
	21 - 31	-	-	3.5
Annual Total		1019	769	1077.1

[1]Source: Meteorological Unit, Institute for Agricultural Research, Samaru, Nigeria.

Appendix 4: Mean squares from analysis of variance for root, stem and leaf dry weights of cowpea vaireties sown in the green house as affected by different rates of norflurazon at Samaru in 1981 and 1982

Source of variation	DF	Root		Stem		Leaf	
		1981	1982	1981	1982	1981	1982
Replication	3	0.25	0.37	0.66	0.23	0.27	0.30
Herbicide	3	0.25	0.67*	0.33	0.40*	0.04	0.25**
Variety	3	0.13	0.02	0.30	0.03	0.10	0.14
Variety x herbicide	9	0.04	0.03	0.03	0.02	0.20*	0.01
Error	45	0.09	0.08	0.14	0.10	0.04	0.05

*F value significant at the 5% level of probability

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

Appendix 5: Mean squares from analysis of variance for nodule count and plant height of cowpea varieties sown in the greenhouse as affected by different rates of norflurazon at Samaru in 1981 and 1982

Source of variation	DF	Nodule count		Plant height	
		1981	1982	1981	1982
Replication	3	52.64	108.67	52.9	3.07
Herbicide	3	395.56*	618.17*	58.73	236.40*
Variety	3	1563.72**	1215.60**	172.73*	72.60
Variety x herbicide	9	137.67	65.50	63.67	38.40
Error	45	120.51	168.60	42.17	41.90

*F value significant at the 5% level of probability

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

Appendix 6: Mean squares from analysis of variance for shoot dry weight (at different stages of growth) and haulm dry weight of cowpea varieties as affected by different rates of norflurazon at Samaru in 1981

Source of variation	DF	Shoot dry weight			Haulm dry weight at harvest
		3 WAS	6WAS	9 WAS	
Replication	3	0.27	6.53	2569.80	6978.42
Herbicide	3	1.20**	65.80*	2659.56	2266.27*
Variety	3	5.77**	37.50	535.74	546.19
Variety x herbicide	9	0.61**	20.30	261.87	90.68
Error	45	0.10	20.40	988.90	300.95

*F value significant at the 5% level of probability

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

WAS = weeks after sowing

Appendix 7: Mean squares from analysis of variance for shoot dry weight (at different stages of growth), grain yield and haulm dry weight of cowpea varieties as affected by different rates of norflurazon at Samaru in 1982

Source of variation	DF	Shoot dry weight			Grain yield	Haulm dry weight
		3 WAS	6 WAS	9 WAS		
Replication	3	2.80	11.90	533.30	94.00	328.80
Mean treatment (variety	3	0.37	30.40	828.70	71.47	127.20
Error (a)	9	0.58	24.20	590.30	38.40	128.10
Sub-treatment (herbicide)	3	1.50*	83.70**	854.00**	28.63**	204.40
Main trt. x sub-trt.	9	0.10	11.30	132.30	3.12	35.90
Error (b)	36	0.48	18.50	193.50	10.01	93.70

*F value significant at the 5% level of probability

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

WAS = weeks after sowing

Appendix 8: Mean squares from analysis of variance for plant height (at different stages of growth) of cowpea varieties as affected by different rates of norflurazon at Samaru in 1981

Source of variation	DF	Plant height		
		3 WAS	6 WAS	9 WAS
Replication	3	5.30	25.32	210.76
Herbicide	3	12.27**	20.65	663.09
Variety	3	7.48**	24.38*	469.13
Variety x herbicide	9	1.20	1.29	269.51
Error	45	1.40	7.88	134.71

*F value significant at the 5% level of probability

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

WAS = weeks after sowing

Appendix 9: Mean squares from analysis of variance for shoot dry weight (at different stages of growth) and haulm dry weight of cowpea as affected by different phosphorus levels and rates of norflurazon at Samaru in 1981

Source of variation	DF	Shoot dry weight			Haulm dry weight
		3 WAS	6 WAS	9 WAS	
Replication	3	0.60	80.80	625.94	73.71
Herbicide	3	0.30	24.03	196.48	356.16
Phosphorus	2	3.30**	44.90	339.10	353.71
Phosphorus x herbicide	6	0.20	1.40	12.91*	83.47
Error	33	0.30	29.60	90.51	146.35

*F value significant at the 5% level of probability

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

WAS = weeks after sowing.

Appendix 10: Mean squares from analysis of variance for shoot dry weight (at 3 and 9 WAS) and grain yield of cowpea as affected by different levels of phosphorus and rates of norflurazon at Samaru, in 1982.

Source of variation	DF	Shoot dry weight		Grain yield
		3 WAS	9 WAS	
Replication	3	2.20	135.34	22.80
Main treatment (phosphorus)	2	0.24	489.46	2.40
Error (a)	6	0.60	254.46	19.18
Sub-treatment (herbicide)	3	2.20**	545.68*	14.37
Main trt. x sub-treatment	6	0.15	48.62	1.77
Error (b)	27	0.36	160.46	9.24

*F value significant at the 5% level of probability

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

WAS = weeks after sowing

Appendix 11: Mean squares from analysis of variance of shoot dry wegith at 6 WAS and haulm dry weight of cowpea as affected by different levels of phosphorus and rates of norflurazon at Samaru in 1982

Source of variation	DF	Shoot dry weight 6 WAS	Haulm dry weight at harvest
Replication	3	132.6	64.59
Herbicide	3	49.0**	89.73
Phosphorus	2	100.95**	328.44
Phosphorus x herbicide	6	2.88	
Error	33	10.03	119.26

**F value significant at the 1% level of probability
WAS = weeks after sowing

Appendix 12: Mean squares from analysis of variance for shoot dry weight and plant height at 9 WAS and haulm dry weight of cowpea as affected by rates of norflurazon sprayed at different stages of growth at Samaru in 1981

Source of variation	DF	Shoot dry weight 9 WAS	Haulm weight at harvest	Plant height
Replication	3	1083.44	1004.70	964.89
Herbicide	3	2482.27**	795.65**	1562.20*
Time of spray	3	716.01	184.29**	715.95
Time x herbicide	9	72.21	31.41	309.23
Error	45	520.06	37.63	432.69

*F value significant at the 5% level of probability

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

WAS = weeks after sowing

Appendix 13: Mean squares from analysis of variance for haulm dry weight and grain yield of cowpea as affected by rates of norflurazon sprayed at different stages of growth at Samaru in 1982.

Source of variation	DF	Haulm dry weight at harvest	Grain yield
Replication	3	61.63	41.5
Main tretment (time of spray)	3	232.13	2.00
Error (a)	9	66.17	7.90
Sub-treatment (herbicide)	3	173.89*	11.40
Main trt. x sub-treatment)	9	20.34	3.50
Error (b)	36	34.09	4.00

*F value significant at the 5% level of probability.

Appendix 14:. Mean squares from analysis of variance for haulm dry weight and grain yields of cowpea varieties as affected by different rates of norflurazon at Samaru in the 1981/82 dry season.

Source of variation	DF	Haulm weight	Grain yield
Replication	3	180.29	24.59
Herbicide	3	682.51	82.37
Variety	3	955.50*	117.02*
Variety x herbicide	9	126.77	15.08
Error	45	270.44	31.35

*F value significant at the 5% level of probability.

Appendix 15: Mean squares from analysis of variance for haulm dry weight and grain yields of cowpea as affected by different levels of phosphorus and rates of norflurazon at Samaru in the 1981/82 dry season.

Source of variation	DF	Haulm weight	Grain yield
Replication	3	1543.59	195.30
Herbicide	3	310.67	46.34
Phosphorus	3	638.01*	81.60
Phosphorus x herbicide	9	49.65	6.29
Error	45	149.06	17.92

*F value significant at the 5% level of probability.

Appendix 16: Mean squares from analysis of variance for haulm dry weight and grain yield of cowpea as affected by rates of norflurazon applied at different stages of growth at Samaru, in the 1981/82 dry season.

Source of variation	DF	Haulm weight	Grain yield
Replication	3	3231.05	841.73
Herbicide	3	1395.35	296.63
Time of spray	3	1051.72	224.67
Time x herbicide	9	141.12	30.12
Error	45	510.73	119.50

Appendix 17: Common and Chemical names of the herbicides and insecticides mentioned in the text.

Common name	Chemical name
	Herbicides
Atrazine	2-chloro-4-ethylamino-6-propylamino-1,3,5-triazine
Barban	4-chlorobut-2-ynyl N-(3-chlorophyenyl) carbamate
Bentazone	3-isopropyl-2,1,3-benzothiadiazin-4-one 2,2-dioxide
Credazine	3-(2-methylphenoxy)-pyridazine
Dalapon	2,2-dichloropropionic acid
Diallate	S,2,3-dichloroallyl N,N-di-isopropyl (thiocarbamate)
Dicamba	3,6-dichloro-2-methoxybenzoic acid
Diclof-methyl	Methyl 2-(4-(2,4-dichlorophenoxy) Phenoxy)
Diuron	N'-(3,4-dichlorophenyl)-N,N-dimethylurea
DSMA	disodium methylarsonate
EPTC	S-ethyl N,N-dipropyl(thiocarbomate)
Fluometuron	N'-(3-trifluoromethylphenyl)-N,N-dimethylurea
Fluorodifen	4-nitrophenyl 2-nitro-4-trifluoro-methylphenyl ether
Fluridone	I-methyl-3-phenyl-5-(3-trifluoro methylphenyl)pyridin-4-one
Linuron	N-(3,4-dichlorophenyl)-N-methoxy-N-methylurea

Appendix 17 (Cont'd)

Maleic hydrazide	1,2-dihydropyridazine-3,6-dione
Metamitron	4-amino-3-methyl-6-phenyl-1,2,4-triazine-5(4H)-one
Metflurazone	4-chloro-5-(dimethylamino)-2-(3-trifluoromethylphenyl)pyridazine 3(2H)-one
Methabenzthiazuron	N-(benzothiazol-2-yl)-N,N'-dimethylurea
Metobromuron	N'-(4-bromophenyl)-N-methoxy-N-methylurea
Metolachlor	α-chloro-6-ethyl-N-(2-methoxy-1-methylethyl)-o-acetotoluidide
Metribuzin	4-amino-6-t-butyl-3-(methylthio)-1,2,4-triazin-5(4H)-one
Norflurazon	4-chloro-5-methylamino-2-(3-trifluoro methylphenyl)pyridazine-3-one
Paraquat	1,1'-dimethyl-4,4'-bipyridylium
Pendimethalin	N-(1-ethylpropyl)-2,6-dinitro-3,4-xylidine
Picloram	4-amino-3,5,6-trichloropicolinic acid
Prometryne	4,6-bisisopropylamino-2-metnylthio-1,3,5-triazine
Pyrazone	5-amino-4-chloro-2-phenylpyridazine-3(2H)-one
Simazine	2-chloro-4,6-biethylamino-1,3,5-triazine
Sulfallate	2-chloroallyl N,N-diethyldithio-carbamate
Triallate	S-2,3,3-trichloroallyl N,N-di-isopropyl (thiocarbamate)

Appendix 17 (Cont'd)

	Pesticides
Benlate	Methyl-1-(butylcarbamoyl)benzimidazole-2-carbamate
Cymbush	(±) Cyano 3-phenoxybenzyl(±)cis trans 3-(2-2-dichloro-vinyl)-2-2dimethyl cyclopropa-necarbaxylate
Dimethoate	O,O-dimethyl S- (N- methyl-carbamoylmethyl) phosphorodi thioate
Vetox	1-naphthyl methylcarbamate (1) in C A 1~ naphthylenyl methylcarbamate II

BIOGRAPHY: ZAKARIYYA ADAMU ABDULKAREEM

Name : Z.A. Abdul-Kareem

Date of Birth : 1 January, 1956

Business Address : Department of Agronomy, A.B.U., Zaria, Nigeria.

Home Address : P.O. Box 94, Samaru, Zaria, Nigeria.

Previous Qualifications:

Institution attended	From	To	Cert./Diploma/Degree
L.E.A. Primary School Kajuru	1962	1968	Primary Leaving Cert.
Govt.College, Kaduna	1969	1973	W. A. S. C.
School of Basic Studies, A.B.U., Zaria	1974	1975	I.J.M.B. Cert.
Ahmadu Bello University Zaria	1976	1979	B.Sc. Botany

Post(s) Held Since the Award of First Degree

Organization	From	To	Position
Inst. for Agric. Research, A.B.U., Zaria	1980	1981	Graduate Assistant
Inst. for Agric. Res., A.B.U., Zaria	1981	1984	Asst. Research Fellow

Year of Admission for Postgraduate Studies: 1984

Admission Number: MSc/AGRIC/6278/80-81