EFFECTS OF PRE-EMERGENCE APPLICATION OF METOLACHLOR PLUS METOBROMURON (GALEX) ON THE GROWTH AND NUTRITIONAL QUALITY OF SOYBEAN (*Glycine max* (L.) Merrill)

BY

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A thesis submitted to the Postgraduate school, Ahmadu Bello University, Zaria, in partial fulfillment of the requirements for the degree of Master of Science in Botany

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NOVEMBER, 1988

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DECLARATION

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

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CERTIFICATION

This thesis titled "Effects of pre-emergence application of metolachlor + metobromuron (Galex) on the growth and nutritional quality of Soybean (Glycine max)". by SAMSON OLUWAGBEMILEKE ALONGE 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.

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AHMADU BELLO UNIVERSITY, ZARIA.

DEDICATION

This book is dedicated to the Lord Jesus Christ

ACKNOWLEDGEMENT

I give thanks to the Lord God, whose grace enabled me to carry out this research work, with success. My thanks to my supervisor Dr.(Mrs.) C.O. Ajakaiye, for her suggestions, counsel and motherly corrections at various stages of this work.

I do not forget the contributions of Dr. S.T. Lagoke, Dr. O. Olufajo and Mr. J. Adigun of Department of Agronomy, right from the begining to the end of this work.

I greatly appreciate the love and concern of Prof. Duro Adegboye whose counsel and life-style has helped me a lot in life and for allowing me to put this thesis in his computer. I also thank Prof. A.A. Olatunde, Mr. T. Babalola,Mr. H. Jimoh, Dr. and Mrs. Ibenu .Miss Rhoda Kantyok, Mrs. Lasis, Mr. Mopah, Mr. Ohaeri, Pa. Bala, for the various roles played by them ,to bring this work to a success.

Special thanks to Evang. David Bakare, Miss. Remi Alabi, Miss.Toyin Alonge Lola Fanimokun, Ibukun Alonge, Ayo Oduniyi, and all my brothers and sisters, who worked and prayed for the success of this research work. I also wish to thank Mr. Lawal, Dr. Asiribo, Mr. Otitoju, and I.A.R. Library staff for their assistance and co-operation whenever I called upon them.

Lots of thanks to Mr. Titus who typed this thesis and Mr. Adeola Adegboye who helped me in the use of the computer.

I greatly appreciate the precious support and counsels from my wife who worked with me and bore series of inconveniencies during the course of this research work. I also thank my parents and relatives for their support, love and concern for my studies. May God reward everyone of you and prosper you all in your ways.

ABSTRACT

Two field trials were conducted during 1986 and 1987 wet seasons, to investigate the effects of pre-emergence application of metolachlor + metobromuron (Galex) at five rates (0,1,2,3,and 4Kg a.i/ha.),and a hoe-weeding treatment on growth, leaf nitrate reductase activity, chemical composition of soybean cv.'Samsoy 2' at different growth stages.

Plant height, leaf area, number of root nodules, whole plant dry matter and ash content, leaf nitrate reductase activity,leaf nitrate-nitrogen and mineral elements were measured every fortnight from 2 to 12 weeks after emergence. Four weeks after flowering, the seed was sampled for seed protein, lipid, carbohydrate, nitrate-nitrogen, ash and mineral element compositions, until maturity when the seed was harvested and yield determined.

The pre-emergence application of metolachlor + metobromuron (Galex) did not adversely affect the germination and morphology of soybean seedlings except in 1987, when 3 and 4 Kg a.i/ha caused injury and death of the seedlings. Averaged over 1986 and 1987, the highest rate(4Kg a.i/ha) led to the production of the highest seed ash, seed nitrate, seed P, Mg and Fe, leaf nitrate and leaf Mn. However, it produced the lowest seed yield, seed Ca, seed carbohydrate and leaf nitrate reductase activity in soybean.The plants on 2Kg a.i/ha Galex treated plots had the highest leaf nitrate reductase activity, root nodule number.

leaf P, K and Zn, seed protein, seed Ca, Fe and seed yield. This herbicide rate also resulted in the lowest seed lipid, seed Zn, leaf total chlorophyll and leaf Mg.

The hoe-weeded soybean plant had the highest leaf chlorophylls a, b and total, and seed Zn, whereas, leaf nitrate, leaf P, Ca and seed Fe were lowest at this treatment. However, the unweeded soybean plants had the highest leaf Mg and Ca, but the lowest leaf area, plant dry matter, root nodule number, leaf P, K, Fe and seed ash.

The changes in all the parameters investigated, due to pre-emergence application of metolachlor + metobromuron (Galex) are discussed.

TABLE OF CONTENTS

Chapter		Page
	Title page	i
	Declaration	ii
	Certification	iii
	Dedication	iv
	Acknowledgement	v
	Abstract	vii
	Table of contents	ix
	List of Abbreviations in this thesis	xiii
	List of Tables	xvi
	List of figures	xx
1.0	INTRODUCTION	1
1.1	Classification and origin of soybean	1
1.2	Botanical description	1
1.3	Uses	2
1.4	Soybean production	3
1.5	Weed problem	4
2.0	LITERATURE REVIEW	7
2.1	Effect of herbicides on plant growth	7
2.2	Effect of herbicides on root nodules	10
2.3	Effect of herbicides on plant dry matter	11
2.4	Effect of herbicides on leaf area	12
2.5	Effect of herbicides on leaf chlorophyll	13
2.6	Effect of herbicides on plant carbohydrate	15
2.7	Effect of herbicides on plant lipid	17
2.8	Effect of herbicides on plant protein	18
2.9	Effect of herbicides on leaf nitrate reductase activity	2

	Page
2.10 Effect of herbicides on plant nitrate-nitrogen	25
2.11 Effect of herbicides on plant minerals composition	27
2.12 Effect of herbicides on plant ash content	30
3.0 MATERIALS AND METHODS	32
3.1 Description of site	32
3.2 Land preparation	32
3.3 Herbicides application	33
3.4 Observation and data collection	36
3.4.1 Leaf area	36
3.4.2 Plant height	36
3.4.3 Nodules	37
3.4.4 Dry matter	37
3.4.5 Ash content	37
3.4.6 Leaf nitrate reductase activity	38
3.4.7 Nitrate-nitrogen	39
3.4.8 Crude protein	40
3.4.9 Lipid	41
3.4.10 Carbohydrate	42
3.4.11 Leaf chlorophyll content	42
3.4.12 Mineral elements	43
3.5 Statistical analysis	44
4.0 RESULT	45
4.1 General observation	45
4.2 Plant height	46
4.3 Leaf area	49
4.4 Dry matter	51
4.5 Summary on growth parameters	53
4.6 Leaf chlorophylls a, b and total	54
4.7 Root nodules	58

	Page
4.8 Leaf nitrate-nitrogen(nitrate)	60
4.9 Leaf nitrate reductase activity	62
4.10 Soybean plant ash	65
4.11 Leaf mineral elements	67
4.11.1 Leaf phosphorus (P)	67
4.11.2 Leaf potassium (K)	69
4.11.3 Leaf calcium (Ca)	71
4.11.4 Leaf magnesium (Mg)	73
4.11.5 Leaf iron (Fe)	75
4.11.6 Leaf manganese (Mn)	77
4.11.7 Leaf zinc (Zn)	79
4.11.8 Summary on leaf mineral elements	82
4.12 Seed protein	82
4.13 Seed carbohydrate	86
4.14 Seed lipid	88
4.15 Seed mineral elements	91
4.15.1 Seed phosphorus(P)	91
4.15.2 Seed potassium(K)	94
4.15.3 Seed calcium(Ca)	94
4.15.4 Seed magnesium(Mg)	98
4.15.5 Seed iron(Fe)	98
4.15.6 Seed manganese(Mn)	102
4.15.7 Seed zinc(Zn)	104
4.15.8 Summary on mineral elements in seeds	104
4.16 Seed nitrate-nitrogen	105
4.17 Seed ash	108
4.18 Seed yield	110
5 DISCUSSION	114
5.1 Growth parameters	114

	Page
5.2 Chlorophyll	117
5.3 Nodule number	118
5.4 Leaf nitrate reductase activity	120
5.5 Nitrate-nitrogen	122
5.6 Protein	124
5.7 Lipid	125
5.8 Carbohydrate	127
5.9 Seed yield	128
5.10 Ash	129
5.11 Mineral elements	130
5.11.1 Phosphorus	131
5.11.2 Potassium	132
5.11.3 Calcium	133
5.11.4 Magnesium	134
5.11.5 Iron	135
5.11.6 Zinc	136
5.11.7 Manganese	137
5.11.8 Conclusion on mineral elements	138
5.12 General discussion	139
5.13 Summary and conclusion	145
REFERENCES	149

LIST OF ABBREVIATIONS IN THIS THESIS

^{o}C	degree centigrade
Ca	Calcium
CDAA	Allidochlor
Cm	Centimetre
Cu	Copper
Cv	Cultivar
2,4-D	2,4-Dichlorophenoxyacetic acid
DAF	Days after flowering
Dm^2	Square Decimeter
DMRT	*Duncan multiple range test*
FAD	Flavine adenine dinucleotide
Fe	Iron
Fig.	Figure
g	gram
g/ha	gram/hectare
ha	hectare
hr	hour
HW	Hoe-Weeding
IAA	Indole acetic acid
IITA	International Institute of Tropical Agriculture
K	Potassium
Kg	Kilogram
Kg.a.i/ha	Kilogram active ingredient per hctare
L.	Lineaus
LA	Leaf area
L./ha	Litre/hectare

LSD	Least Significant difference
M	Molar
m	metre
Mg	magnesium
mg	milligram
mg/g	milligram per gram
ml.	millilitre
mm	millimetre
mM	millimicron
Mn	Manganese
N	Normal
N	Nitrogen
Na	Sodium
NADH	Nicotinamide adenine dinucleotide hydrogen
NADPH	Nicotinamide adenine dinucleotide phosphate hydrogen
NAR	nitrate oxidoreductasé
NIR	nitrite oxidoreductase
No_2	nitrite
No_3, $N0_3$-N	nitrate, nitrate-nitrogen
nM	nanomicron
NR	Nitrate reductase
NRA	nitrate reductase activity
NSD	No significant difference
P	Phosphorus
ppm	part per million
r	correlation coefficient
TIBA	2,3,5-triiodobenzoic acid
um	micromoles

$umNo_2/gfr\text{-}wt\text{-}h\text{-}^{1}$	micromoles nitrite per gram fresh weight per hour
$umNo_2/mg$	micromoles nitrite per milligram
WAE	Weeks after emergence
WAF	Weeks after flowering
WP	Wettable powder
Zn	Zinc
%	percentage
>	greater than
=	equal to

LIST OF TABLES

Table 1: Mineral element composition of the soil used in planting in 1986 and 1987.

Table 2: Some aspects of climatic conditions of Samaru during the wet season of 1986 and 1987.

Table 3: Influence of pre-emergence application of metolachlor + metobromuron (Galex) on chlorophyll a content (mg/g) of soybean leaves in 1986 and 1987.

Table 4: Influence of pre-emergence application of metolachlor + metobromuron (Galex) on chlorophyll b content (mg/g) of soybean leaves in 1986 and 1987

Table 5: Influence of pre-emergence application of metolachlor + metobromuron (Galex) on total chlorophyll content (mg/g) of soybean leaves in 1986 and 1987

Table 6: Influence of pre-emergence application of metolachlor + metobromuron (Galex) on nodule number of soybean roots in 1986 and 1987

Table 7: Influence of pre-emergence application of metolachlor + metobromuron (Galex) on nitrate reductase activity of soybean leaves in 1986 and 1987

content (ppm) of soybean plant leaves in 1986 and 1987 78

Table 15: Influence of pre-emergence application of metolachlor + metobromuron (Galex) on Zinc content (ppm) of soybean plant leaves in 1986 and 1987 80

Table 16: Influence of pre-emergence application of metolachlor + metobromuron (Galex) on percent nitrogen content of soybean seeds in 1986 and 1987 85

Table 17: Influence of pre-emergence application of metolachlor + metobromuron (Galex) on percent phosphorus of soybean seeds in 1986 and 1987 92

Table 18: Influence of pre-emergence application of metolachlor + metobromuron (Galex) on percent potassium of soybean seeds in 1986 and 1987 93

Table 19: Influence of pre-emergence application of metolachlor + metobromuron (Galex) on percent Calcium content of soybean seeds in 1986 and 1987 95

Table 20: Influence of pre-emergence application of metolachlor + metobromuron (Galex) on percent Magnesium content of soybean seeds in 1986 and 1987 97

Table 21: Influence of pre-emergence application of metolachlor + metobromuron (Galex) on Iron content (ppm) of soybean seeds in 1986 and 1987 99

Table 22: Influence of pre-emergence application of metolachlor + metobromuron (Galex) on Manganese content (ppm) of soybean seed in 1986 and 1987 101

Table 23: Influence of pre-emergence application of metolachlor + metobromuron (Galex) on Zinc content (ppm) of soybean seed in 1986 and 1987 103

Table 24: Influence of pre-emergence application of metolachlor + metobromuron (Galex) on soybean seed yield (Kg.seed/plot (24.5m^2) in 1986 and 1987. ...

Table 25: Correlation between soybean plant parameters analysed in 1986 and 1987 (based on combined analysis of variance). 113

Table 26: Correlation of the parameters analysed in soybean leaves with metolachlor + metobromuron (Galex) treatment levels. 143

Table 27: Correlation of the parameters analyzed in soybean seeds with metolachlor + metobromuron (Galex) treatment levels. 144

LIST OF FIGURES

PAGE

Figure 1: Influence of pre-emergence application of metolachlor + metobromuron (Galex) on soybean plants height in 1986 and 1987 47

Figure 2: Influence of pre-emergence application of metolachlor + metobromuron (Galex) on soybean leaf area in 1986 and 1987 49

Figure 3: Influence of pre-emergence application of metolachlor + metobromuron (Galex) on soybean plant dry matter in 1986 and 1987 52

Figure 4: Influence of pre-emergence application of metolachlor + metobromuron (Galex) on soybean leaf nitrate-nitrogen in 1986 and 1987 61

Figure 5: Influence of pre-emergence application of metolachlor + metobromuron (Galex) on soybean seed protein in 1986 and 1987 83

Figure 6: Influence of pre-emergence application of metolachlor + metobromuron (Galex) on soybean seed carboydrate in 1986 and 1987 87

Figure 7: Influence of pre-emergence application of metolachlor + metobromuron (Galex) on soybean seed lipid in 1986 and 1987 89

Figure 8: Influence of pre-emergence application of metolachlor + metobromuron (Galex) on soybean seed nitrate-nitrogen in 1986 and 1987 106

Figure 9: Influence of pre-emergence application of metolachlor + metobromuron (Galex) on soybean seed ash in 1986 and 1987 109

CHAPTER ONE

INTRODUCTION

1.1 CLASSIFICATION AND ORIGIN OF SOYBEAN

Soybean (Glycine max L. Merrill) belongs to the family Leguminaceae, subfamily Papilionoides and genus Glycine L. The taxonomists believe that G. max was derived from Glycine ussuriensis, which is considered to be the progenitor of the cultivated forms (Norman, 1963). The actual origin of the cultivated form of soybean is unknown (Norman, 1963). However, it has been reported that the plant has its origin in the North and Central provinces of China and Manchuria, where it has long been cultivated and has remained, a major crop to this day (Nagata 1960a). It has been the most important legume in the advancement of the civilization of China, Manchuria, Korea and Japan.

1.2 BOTANICAL DESCRIPTION

Most cultivars of soybean are erect, bushy and about 20-180cm tall. They form root nodules in symbiotic association with Rhizobium japonicum for fixing nitrogen. They are annual legumes with green hairs on the stem, leaves, calyx and pods (Purseglove, 1974). Each pod contains one to four seeds. Soybean seeds differ in colour, but the common field varieties have spherical yellowish seeds with two large cotyledons. The food reserves of the seeds are stored in these cotyledons. More than half of the

nitrogen in the total tops of soybean is stored in the seed at maturity (Coppock, 1974).

1.3 USES

Soybean is grown for its protein and oil content all over the world. The chemical composition of soybean seeds varies with cultivars, soil and climatic conditions (Purseglove, 1974). The dried seeds contain 5.0 - 9.4% water, 29.6 - 50.3% protein, 13.5 - 24.2% fat, 14.0 - 23.9% carbohydrate, 2.8 - 6.3% fibre and 3.3 - 6.4% ash (Purseglove, 1974). The seeds are also rich in vitamins and contain appreciable quantities of vitamin B complex (Purseglove, 1974).

It is much more important as a source of protein especially in a country where majority of the populace are vegetarians or where the populace cannot afford animal protein which is very expensive (Bhan, 1976). With an average protein level of about 40% (containing all the essential amino acids) soybean provides a balanced diet in combination with cereal and is one of the cheapest sources of human protein requirements (IITA, 1983).

In Eastern Asia, the unripe seeds are eaten as vegetable and the dried seeds are eaten whole or processed into milk; a valuable protein supplement in infant foods. In Nigeria, there is a children's home near Ogbomoso (Kersey Home) which specialises in treating infants with severe symptoms of malnutrition (kwashiorkor) with soy milk (IITA, 1984). Soybean is also processed into Soya Ogi, soya meat

and soya cake (Eshalomi, 1987). A soup flavouring fermented paste, similar to that made from locust bean is prepared from soybean and used locally. In fact women in many African countries such as Ghana, Cameroon, Uganda, Rwanda and Zaire now use soybean in local dishes (IITA, 1984).

In the food industry, soybean is used in the production of livestock feeds, cooking oil, margarine, bakery products. yeast, milk and meat substitutes and brewing ingredients (Adegbulugbe and Obi, 1986). Since soybean oil represents about 20% total flour, the use of soy flour as a supplement in high protein breads also elewates the essential fatty acid content of the product (Coppock, 1974). Soybean oil forms the bulk of the oil being used in the United States of America, as salad oil and for manufacturing cooking oil and margarine. The oil is also used industrially in the manufacture of paints, Linoleum, oil cloth, printing inks, soaps, insecticides,disinfectants, adhesive, vitamins, antibiotics and other drugs (Purseglove, 1974; Adegbulugbe and Obi, 1986).

1.4 SOYBEAN PRODUCTION

The United States of America has been the largest producer of soybean since 1954 and its output has been expanding. The second largest producers are China and Manchuria. Other countries producing over 1 million tonnes/annum each are Canada, Brazil, Argentina, Columbia. Paraguay, Japan, North and South Korea, and the Soviet Union (Purseglove, 1974).

The crop is becoming increasingly important in Africa. In Zambia, soybean production has doubled every year for the past five years, and both small-scale and large-scale farmers are now realizing the profitability of growing the crop in rotation with maize (IITA, 1983). The main production areas of soybean in Nigeria are Benue State and Zonkwa region of Kaduna State (IITA, 1981). Small-scale farmers produce most of the soybean in Nigeria and production is estimated at 30.48 thousand tonnes/annum but a lot of this is sold in local markets for human consumption. However, there is need for greater production of soybean in this country since a large amount of soybean is imported as protein supplement for poultry feeds.

1.5 WEED PROBLEM

The production of soybean is usually hindered by weeds, which compete with the crop for nutrients, moisture, sunlight and space. The presence of weeds in soybean fields is known to reduce crop yield by 40 to 50% depending on the intensity of weed infestation (Bhan, 1976). Moody (1975) reported that soybean yield in Nigeria was reduced by about 60% due to uncontrolled weeds for at least 40 days by which time the crop forms a canopy and can successfully compete with weeds.

Olunuga and Akobundu (1980) observed that the inability of farmers to cope with excessive weed growth in Nigeria is attributable to the use of the hoe weeding which is a strenous, labour-intensive and expensive method of weed

control, which consequently, usually forces farmers to produce at subsistence levels.

Easton (1981) has suggested that adequate seed bed preparation and accurate application of herbicides offer a more effective weed control alternative to hand-pulling in soybean. There has been a very rapid increase in herbicide usage recently, with reduced emphasis on tillage and cultivation for weed control. However, since chemical weed control assumes an important role in crop production, which herbicides to use, what rates and what effect these herbicides have on the physiology and quality of the different varieties or experimental strains have become important questions (Johnson, 1969). Moreover, when pesticides enter into the physiological processes of the plant, the chemical composition of the plant and seed may be altered. For instance, photosynthesis was early recognised as the process that is inhibited or stimulated, but it was later discovered that herbicides act on more than one physiological processes (Jaworski, 1969). This can invariably inhibit or stimulate the synthesis of the biomolecules i.e. carbohydrates, proteins, and lipids.'

To maximise yield in the large-scale production of soybean, it is of utmost importance to employ chemical weed control method i.e. to use herbicides in controlling weeds in such farms. Galex (metolachlor + metobromuron) is commonly used in controlling weeds in soybean farms in Nigeria. Even though literature abounds on the effectiveness of this herbicide in controlling weeds and its

effects on the agronomic characteristics of soybean not much work has been done on the effect of the commonly used emulsificable concentrate, formulated mixture of metolachlor plus metobromuron (Galex 500EC) on the physiological and biochemical activities of the crop.

This study was therefore conducted to evaluate the effect of different rates of pre-emergence application of Galex on:

(i) Plant growth (plant height, leaf area and plant dry matter);

(ii) leaf nitrate reductase activity (NRA), chlorophyll level and mineral element composition at different growth stages; and

(iii) seed yield, protein, carbohydrate, lipids and mineral element composition at different growth stages of soybean (Glycine max L. Merrill).

CHAPTER TWO

LITERATURE REVIEW

Response of plants to herbicide treatments depends on the species, age, vigour and growth rate of the plant (Wort. 1964). Plant maturity or age in particular is a highly important and complex factor, involving numerous alterations in plant morphology, metabolism, composition and response to external factors. On the other hand, the action of herbicides on plant species is known to vary according to the nature of the herbicides, as well as its chemical form i.e. whether it is an acid, ester, etc (Wort, 1964). The concentration of the herbicide used, method of application size of droplet or dust particle applied, the wetting agent used etc are also factors which influence the responses of plant species to herbicide treatment.

Furthermore both the plant and the herbicides are in turn subject to influences of environmental factors. This complex interaction can be seen from this review of literature.

2.1 EFFECT OF HERBICIDES ON PLANT GROWTH

The development of soybean shoot has been reported to be influenced by herbicides. Deal et al. (1980) stated that the chloroacetamide group of herbicides are generally growth inhibitors, retarding root and shoot growth following seed germination. Deal and Hess (1980) observed that the degree of growth inhibition by metolachlor was a function of both

the concentration and duration of treatment. They concluded that it inhibits growth by preventing cell division and cell enlargement.

According to Shimabukuro et al. (1986) 2,4-D at 1 and 10um caused root shortening and thickening and reduced callus growth in maize and soybean. Soybean root growth was not affected by 10um diclofopmethyl whereas maize was inhibited by 1-10um of it.

The induction of callus growth in soybean roots by 10um 2,4-D reversed the growth inhibiting activity of 1um diclofopmethyl and induced callus growth. This antagonistic interaction between the two herbicides was reciprocal and the activity of either compound depended on the relative concentration of the other.

Kozaczenko et al. (1983) reported that metolachlor appeared to have no detrimental effect on the growth and development of spinach. Similarly, Chen (1985) observed that 40-60kg 2.5% trifluralin and 4-6 litres 50% Galex (metobromuron + metolachlor)/ha applied to field grown groundnuts and soybeans did not affect their growth and yield. However Ellis et al. (1983) found that a 14-day exposure to 10^{-6} M metolachlor caused a reduction in the length and weights of sweet corn seedlings by 30-50%. Prakash and Babber (1975) observed that when peas were treated with 15-45mg chlorbromuron/10cm two days after sowing, the pots were kept in dark at 25°C and 85% relative

humidity, chlorbromuron reduced germination while rates of 25-45mg/pot reduced shoot length but promoted root length.

Salhoff and Martin (1977) reported that treatment of soybean with atrazine/linuron did not lead to any change in its growth. However the report of Chang et al. (1975) showed that the growth of oat seedlings in sand was inhibited by metolachlor, the time of onset of inhibition after treatment being a function of herbicide concentration. They observed a 12 hour lag period following sub-irrigation with 2.5×10^{-4}M alachlor before growth inhibition could be detected.However, addition of Gibberellic acid by sub-irrigation simultaneously with alachlor treatment did not prevent growth inhibition. Similarly alachlor and trifluralin at 4kg/ha inhibited the root development of 25-day-old soybean plant. The Alachlor at 4kg/ha also significantly reduced the shoot growth of the plant (Burpee and Cole, 1978). Also the top growth of soybean seedling was reduced more when trifluralin was incorporated into the bottom 10cm of soil, but root growth was not affected by trifluralin placement (Kust and Struckmeyer, 1971).

According to Hoagland (1980) glyphosine and glyphosate and their possible metabolites were tested individually (at 0.5mM) or in a mixture (each at 0.5mM) for their effects on soybean growth. Most treatments inhibited its growth either as fresh weight accumulation or as root elongation over 72 hours in the light or dark. However glyphosine was generally the most inhibitory.

2.2 EFFECT OF HERBICIDES ON NODULES

Nodulation initiation and development is a continuing process as root development continues. Therefore, nodules of all ages may be present on a mature soybean plant root. In Sierra Leone, Hague and Bundu (1980) reported that soybean plant treated with Rhizobium, Nitrogen, molybdenum and mulch increased the number and weight of nodules compared with the control.

The influence of (a) 0.90kg fluorodifen/ha (b) 0.75kg pendimethalin (c) 0.45kg fluorodifen 0.37kg pendimethalin (d) 1.91kg chloramben (e) 0.95kg chloramben + 0.66kg alachlor, on soybean cv. UFU-I was studied by Rezende et al. (1985). They observed that the treatments had no effect on nodulation of the plant. Similarly Bollich et al. (1985) reported that application of recommended rates of several herbicides, which include 2.2kg alachlor, 0.6kg prometryn and 0.6kg metribuzin/ha had no effect on ethylene production and nodule number of soybean seedling when applied pre-emergence. Kust and Struckmeyer (1971); found that field treatment of soybean with trifluralin resulted in fewer production of nitrogen-fixing bacteria nodules. This inhibition of nodules formation by trifluralin was confirmed in the green house experiments.

In a similar experiment, Novo et al. (1986) showed that only prometryn caused a significant reduction in nodule and nodular dry matter content of soybean when it was treated with 0.96kg trifluralin and 1kg prometryn/ha together. Maftoun et al (1982) also studied the combined effects of

Metribuzin. Maftoun et al. (1982) showed that analysis of variance indicated that the interaction of soil salinity and trifluralin did not significantly affect root and top dry weight of soybean plants. Trifluralin alone however significantly reduced top dry yield.

In addition to these various factors, the rate of dry matter accumulation in the above- ground plant parts have been shown to vary among cultivar, season and soil fertility levels (Hanway and Weber, 1971a).

2.4 EFFECT OF HERBICIDES ON LEAF AREA (LA)

The soybean is generally a plant which grows 90-120cm in height, with the first leaves simple and opposite and all other leaves alternate and trifoliate. The increase in the area of leaves is at first solely by cell multiplication with the meristematic activity been marginal or distributed throughout the leaf blade, depending on plant species. The ultimate size of the leaf is determined by (a) the number of primodial cells (b) rate of cell division (c) duration of the phase of cell division and (d) size of individual matured cells (Gregory, 1956).

Shibles and Weber (1965) found that LA and growth rate of soybean to be nearly proportional. Ciha and Brun (1975) reported that leaf development is related to temperature. LA increases as temperature increases throughout the range of 18°C - 30°C. However, when light intensity increased from 19,300 to 32,300 lux LA of the terminal leaflet of the third trifoliate leaf was reduced in soybean cv. 'Haroso

plants grown under reduced light intensities, but in cv. Tosan No 89, 60% shading promoted leaf development.

From the studies of Bounce (1978), on the effect of water stress on leaf expansion of cotton and soybean, was the report that, low relative humidity resulted in low leaf water potentials and turgor in all cases and in reduced leaf expansion rates in most cases.

The influence of herbicides on LA of plants is very scanty in literature. However, Oritani (1978) studied the effect of light intensities and TIBA (2,3,5-triodobenzoic acid) on soybean cv. 'Harosoy' and ''Tosan' No. 89 TIBA was found to reduce their leaf expansion. This TIBA effect was greatest under conditions where leaf expansion tended to be large.

2.5 EFFECT OF HERBICIDES ON LEAF CHLOROPHYLL

The chlorophyll content of soybean leaves was said to decrease continuously from full expansion to senescence (Wickliff and Aronoff, 1962) but probably does not limit photosynthesis until it became very low. According to Silvius et al. (1978) chlorophyll and soluble protein continued to increase beyond the attainment of full expansion by soybean leaves, but were not accompanied by further increases in photosynthetic rates. Furthermore, Wetterau et al. (1978) observed that during aging of soybean cotyledons, the total chlorophyll and the number of chloroplast reached a maximum on the tenth day after germination, and decreased rapidly during senescence.

A lot has been reported about the effect of herbicides on chlorophyll content of leaves in the literature. For instance Vekshin and Bukina (1973) reported that metobromuron at 2.5 to 3kg/ha (applied pre-emergence) increased the chlorophyll content of Valeriana officinalis leaves. There was a reduced chlorophyll-b level and inhibited formation of carotenes in maize at the 3- to 4-leaf stage, when treated with 1.3 or 3kg prometryn/ha and 5 or 8kg atrazine/ha. However at 6 to 7 leaf stage, chlorophyll-b concentration was increased by both herbicide treatmnents. The stimulatory effects were attributed to metabolism of the herbicide in soybean seedling. Atrazine also reduced total chlorophyll in the hypocotyls, while glyphosate did not, but atrazine + glyphostate resulted in chlorophyll content similar to that of atrazine alone (Hoagland, 1984).

However, wheat cv. Kolibri plants treated with metabenzthiazuron responded by a decreased chlorophyll a/b ratio and an increased proportion of grana to stroma lamellae (Fedtke et al. 1977).; Chen (1986) showed that incubating Anabaena (strains CH_2 and CH_3) for 24 hours with butachlor, thiobencarb or bromacil led to decrease in their chlorophyll content and photosynthetic activity. Hiranpradit et al. (1972) also showed that Bromacil concentrations at 0.0225 and 0.0375 ppm significantly depressed both percentage and total amount per plant of chlorophyll nitrogen + lipid-nitrogen of 28 day-old soybean

plants. Similarly, paraquat at 50um increased the ratio of chlorophyll content/hypocotyl) by 50% after 72 hours of application to intact light and dark-grown soybean seedlings.

2.6 EFFECT OF HERBICIDES ON PLANTS CARBOHYDRATE (CHO)

Starch and sugars in soybean cv. Norman were stored in the pod walls and exported to the seeds as the leaves began to die. According to Dunphy and Hanway (1976) the percentage of water soluble carbohydrate in leaves of soybean vars. 'Hark' and 'Amsoy' increased throughout the growing season but decreased in the stems , petioles and pods as the seeds developed .The free sugar levels in leaves during seed-filling varied from an increase to no change to a decrease across the 3 years. Starch levels increased to a maximum and in 2 of the 3 years declined as the plant approached maturity. In the cultivars 'Amsoy' and 'Harosoy' the CHO represented 13 to 15% of the dry matter in the seed at 25 DAF (days after flowering). The percentage CHO dropped slightly as the seeds developed and then increased again to approximately its original value at maturity (Yazdi-Samadi et al. 1977).

Soon after the introduction of substituted ureas, Cooke (1955) observed that the sugar content of plants tested with monuron decreased sharply. Wessels and Van der Venen (1956) reported almost simultaneously that several substituted ureas were very efficient inhibitors of Hill reacton of isolated chloroplasts. Overbeek (1964) reported that the

activity of metobromuron occurs through interference with photosynthesis by inhibiting Hill reaction, thereby rendering the susceptible plant incapable of carbohydrate synthesis. The responses of soybean plants to sub-lethal rates of metribuzin and to low light intensities were similar (Fedtke, 1979). Both treatments decreased soluble reducing sugars by 33% and chlorophyll a/b ratio of 24%. The similar response of light limited and of chemically photosynthesis-inhibited plant is thought to be induced by a CHO stress or another parameter related to a decreased rate of photosynthetic electron flow. Fedtke et al. (1977) also reported that wheat cv. Kolibri plants treated with methabenzthiazuron responded with a decreased concentration of soluble reducing sugars. Zawislak et al (1986) treated three potato cv. with igrater 50 (terbutryne + metobrumoron) hexone (metribuzin) maloran 50WP (chlorbromuron) and saturn L (benthiocarp + linuron) at 3 doses. Doses above the recommended dose caused reductions in the starch content of tubers of 'Narew' and 'Pola'. Notwithstanding, as herbicide dose increased, so weed control increased to 75-95%. Bil et al. (1985) also indicated that linuron changed the cyclic to non-cyclic photophosphorylation ratio which decreased the carbohydrate synthesis in barley ears, thus increasing the translocation of metabolites from the organs into the grain and the biosynthesis of grain protein.

Apart from herbicides, carbohydrate content of soybean is also influenced by its nutrition. Eaton (1950) found total carbohydrate (including starch) to be higher in

soybean leaves, stems or roots when phosphorus was limiting than when phosphorus levels were adequate. Hymowitz and Hsu (1969) also found that nitrogen, phosphorus and potassim fertilizer had little influence on total sugar content of soybean seed with all values between 11.8 and 13% total sugar.

2.7 EFFECT OF HERBICIDES ON PLANT LIPID

The fat in soybean cotyledon is said to occur in submicroscopic droplets surrounded by a membrane which contains protein, lipoprotein, phospholipids, and nucleic acids (Kahn, 1959). According to Kahn et al. (1958) the membrane is of significance in the synthesis of the oil as well as in its degradation. Rubel et al. (1972) reported in 'Acme', 'Chippewa' and 'Harosoy 63' soybean at approximately 23 days after flowering the composition of the seeds was about 30% protein and 5% oil. From 24-40 DAF, oil percentage increased rapidly to 20%. During the remainder of the development of soybean seed percentage values of the components remained essentially constant. According to Wilson and Rine (1978), lipid synthetic activity was highest in immature soybean cotyledons at 30 DAF. Furthermore about 70% of the total lipid of matured soybean seed was produced early in cotyledon development (30-50 DAF).

The lipid synthesis of plants has also been influenced by herbicide treatments. In cotton, $1x10^{-4}$M metolachlor did not inhibit the uptake of acetate-2-^{14}C or Malonic acid-2-^{14}C into excised root tip. The incorporation of

these precursors into lipids (including phospholipids) synthesised by cotton root tips were also not inhibited by metolachlor (Mell et al. 1982).

Vekshin and Bukina (1973) reported that metobromuron at 2.5 to 3kg/ha applied pre-emergence, had no effect on the essential oil content of Valeriana officinalis roots. The oil and fatty acid composition of soybean seeds was not affected by 0.84kg/ha treatment of trifluralin (Johnson and Jellum, 1969). Although Penner and Meggit (1970) found no changes in total oil content of soybean seed after treatment with trifluralin, nitralin and vernolate, they did observe an effect on the quality of the oil. Linoleic acid content was increased and stearic acid was reduced.

Lixandru et al. (1975) also investigated the effect of application of nitrogen, phosphorus, potassium and trace elements on acculation of lipids. Seed lipid contents was shown to decrease by application of nitrogen except for a small increase with ammonium sulphate. But it increased by application of molybdenum, copper, Boron or cobalt.

Appelqvist (1978) indicated that increasing the rates of nitrogen fertilizer generally decreases seed oil content and increases protein content. The effect of potassium was very viariable, but in many cases an increase in oil content is observed. However the effect of soil nutrition on the fatty acid composition of the harvested soybean seeds was very small (Appelqvist, 1978).

2.8 EFFECT OF HERBICIDE ON PLANT PROTEIN

According to Hammond et al. (1951) the total nitrogen in the soybean plant nearly trippled during seed development. About two-thirds of the protein in the stem, and about three-fourths of that in the leaves, in mid-season is said to be redistributed before maturity. However, the seed accumulation of N far exceeds that lost from other above ground parts. Block and Weiss (1956) reported that some eighteen amino acids containing about 95% of the protein-N are present in soybean protein, although traces of many other amino acids are probably present. Most of the protein is located in protein bodies, which increase in number as the cell develops, ultimately being tightly packed in the cells of many but not all parenchyma cells of the cotyledons (Bils and Howell, 1963).

The leaves are also capable of protein synthesis (Racusen and Aronoff, 1954) but when removed from the plant they rapidly lose this capability. According to Sinclair and de Wit (1976) the protein in the leaves are mobilized towards the developing pods with their high protein seeds, this however leads to leaf senescence.

According to Yazdi-Samadi et al. (1977) oil and protein (mg/seed) increased until maturity in soybean cv. 'Harosoy 63' but leveled off before maturity in cv. 'Steele'. More than 70% of the total protein of soybean seed during development is produced 30-50 days after flowering (Cherry, 1980). Hill and Breidenbach (1974) showed that less than 5% of the total protein of the mature seed had been accumulated by 12 DAF. Protein accumulation was very rapid between 12

and 28 DAF and then declined, ceasing at the onset of seed desiccation. Thereafter actual protein levels decreased slightly.

Among the factors that influence the protein content of plants is herbicides. For instance the chloroacetamide herbicides control weeds by altering protein synthesis in these weeds (Deal et al. 1980 and Duke et al. 1975). A concentration of 10^{-5}M metolachlor decreased leucine uptake: by cucumber root tips, but not its incorporation into protein, whereas 10^{-4}M metolachlor strongly reduced leucine incorporation into protein (Pillai et al. 1979). When alachlor, metolachlor, CDAA and propachlor were tested for inhibition of (^{3}H)-leucine incorporation into protein. Incorporation of (^{3}H)-leucine into trichloroacetic acid-insoluble protein was inhibited in oat seedlings grown in sand culture and treated 12 hours at 1 x 10^{-4}M with these chloroacetamides (Deal et al. 1980). In field trials soybean cv. 'Hungarian small' was given post-sowing applications of Aresin (Monolinuron) Igran (terbutryne) or prometryne each at 1-3kg/ha. Protein-N content in the leaves and roots was increased at the lower application rates (Lalova, 1973).

Protein synthesis in leaves during flowering was inhibited at the higher rates, but crude protein content in the seed was unaffected. All the herbicides increased the tryptophan content in the plant and this stimulated protein synthesis in the leaves (Lolava, 1973). Evzikov and Zhukova (1984) reported that 2kg/ha, Linuron or Treflan (Trifluralin) increased the protein content of soybean seeds

while 2kg/ha prometryn decreased it. According to Bil et al. (1985) when barley plants were sprayed with 100g/ha Linuron 5-7 days before harvest, grain filling and grain protein were significantly higher than in the control. Similarly monuron and diuron substantially increased the protein content of brown rice (De Datta et al. 1972). 'The treatment of 2-week-old pea seedlings with 2g/L diuron resulted in a 25% increase in seed protein content. Methabenzthiazuron treatment on wheat cv. Kolibri plants resulted in increased protein level in the plants leaves (Fedtke et al. 1977). Hoagland (1980) reported that Glyphosine and glyphosate as individual (at 0.5mM) or in a mixture (each at 0.5mM) did not influence the total soluble protein in the axes, however glyphosate increased the total free amino acids and ammonia in many systems.

Application of 10^{-7} and 10^{-6}M fluazifop-butyl increased protein synthesis in soybean hypocotyls by 33 and 27% respectively. Application of 10^{-4}M, however, inhibited protein synthesis by about 50% (Peregoy and Glenn 1985). According to Hiranpradit et al. (1972) soybean plants treated with Bromacil took up about 18% more nitrate-N than untreated control which resulted in significantly higher accumulation of protein nitrogen + nucleic acid-nitrogen in the plants. Overall there was also an increase in amino acids that form the constituents common to nearly all protein molecules. Application of TIBA (2,3,5-triiodoberzoic acid) to soybean plants increased photosynthetic activity, total-N, protein-N, soluble protein and non-protein-N

content (Oritani, 1978).

From the results, it was concluded that photosynthetic activity of soybean leaves is regulated through protein metabolism and this in turn is under the control of hormones that are concerned with leaf expansion. Apart from the herbicides, the major environmental factors affecting quality and quantity of protein in plants are water(Sokolova and Klran, 1977) and nutrients (Lixandru et al. 1975 and Appelqvist, 1978).

2.9 EFFECT OF HERBICIDES ON LEAF NITRATE REDUCTASE ACTIVITY (NRA)

The enzyme nitrate reductase (NR) which is the rate-limiting enzyme in multi-step reduction of nitrate, is an induced enzyme, that is, its synthesis is stimulated by the presence of the substrate NO_3 ion. The enzyme is a flavoprotein containing flavine adenine dinucleotide (FAD), cytochrome 6557 and molybdenum as its prosthetic group (Norman 1978; Fido and Notton, 1984). The reaction that it catalyses is the reduction of NO_3 to NO_2 which it does at the expense of a reduced coenzyme, either NADH or NADPH.

Two proteins with NR activities were isolated from young first leaves of soybeans. They were designated as NADH-NR and NADPH-NR because of their different affinities for the reduced pyridine nucleotides (Jolly, 1976). Apart from the presence of NR in soybean leaves its activity has also been reported in the roots (Samphantharak, 1974: Randall et al.1978 and Crafts-Brandner and Harper 1981).

According to these authors NRA in the leaf was higher than in the root tissues, but root tissue had higher specific NRA (umoles NO_2/mg protein) than leaf tissues and the root accounted for 30% of whole plant NRA.

The NRA in soybean plant varies with leaf position and from season to season. The most recently expanded trifoliate leaf has the highest NRA, while newly emerging leaves and older leaves have low NR activities on a unit weight basis (Harper and Hageman, 1972). According to Hatim (1981) NRA was maximum at leaf position 4 and decreased in leaves above and below this position on soybean plants. Furthermore, fresh weight and NRA decreased with maturity. Manam et al (1977) reported that, NRA was high during the vegetative stage of soybean, but gradually decreased until flowering and then fell rapidly in non-stressed plants. In stressed plants, NRA started falling rapidly in the early flowering stage.

Apart from these, herbicides also influence the activity of NR in soybean plants. Results of investigation by Lolas (1980) on the effect of alachlor, metolachlor and oryzalin on soybean leaf NRA shows that there was no significant difference between the control and the treated. Soybean responded to sublethal rates of metribuzin with an increase in NR level (Fedtke, 1979). Also, the NRA of pea leaves treated with Basagram (Bentazone) was enhanced, whereas application of 2,4-D to the plant inhibited it (Petkov, 1979). Aminotriazole was also shown to inhibit NRA in soybean cell culture (Suen, et al.1979). However,

application of metobromuron, metribuzin, alachlor, trifluralin and their combinations increased NRA in soybean leaves during early growth stages, metobromuron, metribuzin and their combinations with alachlor were the most effective (Peneva, 1980).

The application of diuron to Phaseolus vulgaris inhibited the increase in activity of NADH-nitrate oxidoreductase (NRA) and reduced benzylviologen nitrite oxidoreductase (NRA) similarly, Diuron, both in the light and in the dark resulted in an increase in activity which reached a higher level on addition of sucrose. Similarly, white light (W) increased extractable NADH-NRA in root and cotyledonary tissues of soybean seedlings over a 5-day period (Duke et al.1982). However, norflurazon, which causes chlorophyll bleaching in white light, reduced the initial NRA induction rate in roots and cotyledons, but in cotyledons of norflurazon-treated plants NRA increased more rapidly than in the control after 24-hour of white light, with activity level 3-fold those of control seedlings after 5 days. Durandin (1973) also reported that NRA in barley seedlings grown under blue light was increased, but it was decreased in those grown under red light. Application of Gibberellin decrease the activity of NR in seedling grown under blue and especially red light. Sahulka (1974) showed that NRA was not influenced by IAA. Nitrite reductase activity was slightly depressed by IAA after 24-hour incubation. Also, Kinetin decreased NRA significantly after 9-hour and slightly decreased it after 24 hours incubation.

The results obtained indicated that the depression of NRA by Kinetin probably contributed to the negative effect of Kinetin on lateral root formation in pea root segments grown in nitrate medium.

2.10 EFFECT OF HERBICIDES ON PLANT-NITRATE NITROGEN (NO_3-N)

Soybean can absorb Nitrogen from the soil in three forms: as nitrate ions, as ammonium ions, or as organic compounds such as amino acids or urea. Of these ,NO_3 is the most far important because of its relative stability in the soil and because the other forms tend to be converted to NO_3 by the action of various soil micro-organisms. Once absorbed by the root system, the NO_3 ion must be metabolically reduced to the level of amino-acid-N before it is of any value to the plant. The reduction of NO_3 ions which occur in the leaves in most plants can also occur in the roots of soybean (Craft-Brander and Harper 1981). Any alteration in this process of NO_3 reduction by the NR enzyme system will simultaneously alter the NO_3 concentration of the plant.

The NO_3 content of several organs of plants has been reported by many workers (Crawford et al. 1961; Henwa 1962). Generally the stem has the highest NO_3 concentration, followed (in a decreasing order) by roots. leaves and floral parts. The basal part of the stem and the lowest leaves tend to have higher NO_3 level, than the top stem portion and highest leaves.

The nitrate concentration in vegetative parts of plants was said to decrease very rapidly with time, and they were very responsive to changes in solution (Brevedan et al.1977; Giles et al. 1977). This change in the concentration of NO_3 in soybean plant with age are usually larger than changes in the total NO_3 (Thibodeau and Jaworski 1975). According to Brevedan et al. (1977), the concentration of N and NO_3 in the vegetative parts of the plant decreased from initial bloom to mid-pod-fill.

Giles et al. (1977) also indicated that NO_3-N content of sugar Beet (Beta vulgaris) decreased exponentially through the growing season. The rate of change was a function of soil NO_3-N content (0-120cm depth). However, Funkhouser and Garay (1981) observed that the NO_3 content of both soybean seedlings and algal cultures substantially increased during N starvation, in nutrient solution. The nitrate level in soyben seedling was at least eight times greater than that in the seeds after two to three weeks. Since no fixed NO_3 compounds were included in the nutrient solution fed those plants, the NO_3 must have been formed by nitrification. This could have been mediated either by some micro-organism in the system or by the plant itself.

In 1953, Berg and McElroy observed that Russian pigweed and Canada thristle sprayed with 2,4-D contained a high level of NO_3-N. But soybean root treated with 2,4-D showed reduced NO_3 uptake and NO_3-N did not accumualate in the leaves (Freiberg and Clark, 1952). Fedtke (1979), however demonstrated that metribuzin treatment, on soybean at low

light intensities increased both NR and NO_3-N levels of the plant. Similarly, Hiranpradit et al. (1972) reported that soybean plants treated with 0.0225ppm (0.086 uM) Bromacil took up about 18% more NO_3-N than the untreated plants and this resulted in significantly higher accumulation of protein-N as well as nucleic acid-N in the plants. There was also an overall increase in amino acids that form the constituents common to nearly all protein molecules.

2.11 EFFECT OF HERBICIDES ON PLANT MINERAL ELEMENTS COMPOSITION

Nutrient uptake with time follows the same sigmoid curve as dry matter accumulation. The rate increases and remains fairly constant until senescence begins when the uptake decreases to zero (Hanway and Weber, 1971b). The rate of the nutrient uptake is proportional to the concentration in the soil solution and to the extent of the root system with a proportionality constant dependent on the species of plant and the ion in question.

The concentration of a mineral element (amount per unit dry weight) is therefore high in a seedling soon after emergence, may change a little for sometimes, but eventually decreases. Prior to the onset of seed formation, 60% of N, 55% of (P) and 60% of (K) has been absorbed by plant into the stems and leaves (Hanway and Weber, 1971b). Since the seed ultimately contains 68% of the total N, 73% P, and 56% of the K absorbed, a major source of these elements for seed-filling must be the stem and the leaves and petioles

which have not fallen from the plant. Togari et al. (1955) found evidence to suggest that N, P, and K are supplied to the seed directly from the roots as well as remobilised from reserves in other plant parts. Calcium (Ca) did not appear to be translocated from other organs and its supply to the seed depends on continued root uptake.

According to Jones et al. (1977) the P concentration of soybean leaves decreased throughout the season and it was slightly higher following application of P but did not change much with the application of potassium. The potassium concentration in leaves also decreased throughout the season and was much enhanced by the application of K but was scarcely affected by application of P. Hanway and Weber (1971a) also reported that N in the leaves, petioles and stems of nodulated plants without N fertilizer usually decreased as the plant developed during the season. However N in the seeds increased slightly from 6.5 to 6.8% between the period of plant's full-bloom and full-pod development. Bhangoo and Albritton (1972) indicated that fertilizer application increased the N and K content of both the soybean leaves and grain and depressed their Ca and Magnesium (Mg) content after application of 112kgN/ha, or 40kgP/ha; and 75kgK/ha fertilizer on soybean cv. "Lee" growing in the field.

Herbicides also have been found to influence mineral element content of crop plants. Ellis et al. (1983) used nutrient techniques and found that a 14-day exposure to concentration of about 10^{-6}M metolachlor caused a decrease

in the accumulation of Ca, Mg, K and P and this reduction was also accompanied by decrease in sweet corn growth. However a 4-day exposure of sweet corn seedling to 2.8 and 5.6 x 10^{-6}M metolachlor (separately) did not have any significant effect on the growth and nutrient accumulation of the crop, when treatments were followed by a 9-day incubation in metolachlor-free nutrient solution. In a rainfed trials in 1979-1980, application of 1.5kg atrazine - 2L metalachlor or 2L.alachlor or 2L ethafluralin/ha pre-emergence to maize, had no adverse effect on the growth of the plants and only slightly increased the level of N, P. Mg, K, Ca, Na, Mo, Cu, Zn and Fe in maize leaves (Simeonova and Stoimenova, 1984).

Duke et al. (1986) showed that when 0.5 and 1mM glyphosate was applied to soybean roots and leaves respectively, both treatments reduced uptake and translocation of Ca^{2+} and not K^{+}. Glyphosate had no effect on the K^{+} distribution. Similarly 0-4L./ha trifluralin had no effect on Ca, Mg and S uptake or their redistribution in soybean cv. 'Parana' plants (Rosolem et al. 1984). However, Maftoun et al. (1982) indicated that trifluralin at 1 ppm significantly decreased phosphorus concentration in soybean.

Hiranpradit et al. (1972) also reported that application of 0.0225ppm Bromacil on 28-day old soybean plants, significantly increased both percentages and total amount of N and P in plant shoots, compared to the untreated plants. The increases in total amounts of N and P per plant were up to 15.0 and 15.6% respectively, more than the

untreated plants. Pahuja et al. (1985) also studied the effects of 10 herbicides, 1-2 hand weedings, weed free conditions and a weedy control on the quality of soybean crops. Nitrogen and phosphorus contents in seed and crop residues and also their uptake by plants were highest in the weed free treatment and lowest in the weedy control. Weeding once or twice did not differ significantly from weed-feee treatment in respect of nutrient contents.

2.12 EFFECT OF HERBICIDES ON PLANT ASH CONTENT

The ash correspond to the mineral salt that has been absorbed from the soil, but does not include nitrogen since this element passes off in the combustion process along with carbon, hydrogen and oxygen. According to Meyer et al. (1968) the total ash content of plant tissues and organs varies from a fraction of 1% to 15% or even more of the dry weight of the plant material. Krober and Cartter (1962) have shown that the ash account for about 6% of the dry weight in mature soybean seed.

According to Goss (1973) there is a direct relationship between the available inorganic elements content of the soil and the ash content of the plant. Hopper (1925) also reported that as corn advanced in maturity from tassel to the ripe stages, the crude fibre, crude protein and ash decreased. However, Jyang (1977) observed a positive correlation between protein and ash, but fat and ash were negatively correlated.

The various factors that affect the availability of the mineral elements in plants also affect their ash content. However, unlike the mineral elements, delibrate report of herbicide effects on ash content of plants are very scarce or unavailable in the literature.

CHAPTER THREE

MATERIALS AND METHODS

3.1 DESCRIPTION OF SITE

Two field trials were conducted at the botanical garden of the Department of Biological Sciences, Ahmadu Bello University, Samaru (Lat. 11°11'N, Long. 07°38'E and Altitude 686M above sea level), Zaria during the 1986 and 1987 wet seasons, to evaluate the effect of metolachlor [∝-chloro-6-ethyl-N-(2-methoxy-1-methylethyl)-0-acetoluidide] plus metobromuron [N-(4bromophenyl)-N-methoxy-N-methylurea] (Galex) - a recommended mixture, on the growth and physiological processes of soybean. The soil type at the site of the experiment was sandy loamy. The chemical compositions of the soil are contained in Table 1. A total of about 821.40mm and 689.70mm rainfall occurred during the period of the trials in 1986 and 1987 respectively. Details of some climatic conditions during the period are contained in Table 2.

3.2 THE LAND PREPARATION

Hoes were used to make a total of 36 plots after clearing the land. Each plot was 3.5 x 7m, with an interplot spacing of 1.5m, in which ridges were made to separate the plots. Soybean 'Samsoy 2' seeds were drilled in 75cm rows. The plots received a basal application of 30kgN, 60kgP_2O_5, and 40kgK_2O/ha as calcium ammonium nitrate

(26%N), single superphosphate (18% P_2O_5) and muriate of Potash (60kg K_2O) respectively, immediately after sowing.

3.3 HERBICIDE APPLICATION

The herbicide (Galex) was applied pre-emergence, using 'Hardi sprayer', 2 days after sowing. The sprayer's spraying volume was 98 litres per hectare (ha). This back-mounted sprayer was used to apply Galex at the rates of 0, 1, 2, 3 and 4 kg a.i/ha. (Metolachlor and metobromuron in Galex is mixed at 1:1). In addition to the above there was also a hoe-weeding (H.W) treatment, to serve as the second control(weeding was done at 4 and 8 weeks after emergence). these summed up to a total of six treatments. The treatment were arranged in a randomised block design with three replications.

Table 1: Mineral element composition of the soil used in planting in 1986 and 1987.

Element	1986	1987
Nitrogen (N)	0.053%	0.113%
Phosphorus (P)	15.0ppm	17.18ppm
Potassium (K)	85.0ppm	60.38ppm
Calcium (Ca)	262.50ppm	281.25ppm
Magnesium (Mg)	85.0ppm	89.63ppm
Manganese (Mn)	54.0ppm	35.40ppm
Iron (Fe)	68.0ppm	320.00ppm
Zinc (Zn)	3.7ppm	4.80ppm
	pH = 6.0	pH = 6.15

Table 2: Some aspects of climatic conditions of Samaru during the wet season of 1986 and 1987.

Month	% Relative Humidity	Rainfall (mm)	Temperature (^{0}C)
1986			
July	67.70	293.60mm	27.90
August	71.10	322.10	28.60
September	67.40	205.70	28.90
October	49.90	NIL	31.10
November	26.40	NIL	31.50
1987			
July	65.00	276.70	30.10
August	72.40	268.30	29.20
September	63.20	102.10	30.40
October	44.00	42.60	31.00
November	18.90	NIL	31.80

3.4 OBSERVATION AND DATA COLLECTION

Sampling of the soybean plants for analysis was done at 2, 4, 6, 8 and 12 weeks after emergence (WAE). The following measurements were taken at each samping. The plant sampled from each plot was analysed for dry matter. ash content, leaf area, and number of root nodules on each plant. In addition the plant height, leaf chlorophylls. nitrate reductase activity (NRA), and mineral element concentration of the leaves were also determined fortnightly. Protein, carbohydrate, lipid. nitrate-nitrogen, ash, and mineral elements concentration of the seeds were also evaluated at 4, 5, 6, 7, 8 and 9 weeks after flowering (WAF) as the seeds developed till the final harvesting of the dried seeds.

3.4.1 LEAF AREA

Three plants were selected randomly and uprooted from the replicated plots of each treatment. All the leaf blades on each plant were removed from the petiole, washed and dried with 9cm whatman filter paper and their area was measured with leaf area meter, model LI-300, for each sampled plant. This was done at 2, 4, 6, 8, 10 and 12 WAE.

3.4.2 PLANT HEIGHT:

Three plants were randomly selected on each plot for height determination. The height (part of the plant from soil surface to the tip of apical bud) of each plant was

measured with meter rule. This was done at 2,4,6,8,10 and 12WAE.

3.4.3 NODULES

Plants were uprooted with the aid of garden fork. The root of the 3 plant replicates randomly selected from each plot were washed with water gently. All the nodules on the root of each plant were removed and counted as total root nodule per plant, fortnightly between 2-12 WAE.

3.4.4 DRY MATTER

The plant used for leaf area determination was later used for this analysis. The whole plant (i.e. root, stem and the detached leaves) was washed and dried with 9cm whatman filter paper. The stem was cut into pieces with knife before each plant was weighed (fresh weight) on Mettler balance into labelled envelopes. The plant in each envelope was placed in an oven maintained at 70°C until a constant weight was obtained for dry matter determination. The dried samples, was weighed. This was done fortnightly as indicated above.

3.4.5 ASH CONTENT

The oven dried sample, weighed for the dry matter determination was ground separately in a mortar. These ground sample was each weighed into a crucible of known weight, which had been labelled according to treatment. The crucibles plus the samples in them were placed in a furnace, maintained at 550°C, and left until they were completely

ashed (a eriod of about 30 hours). At the end of this period, the crucibles were transferred into a desiccator to cool before re-weighing them. The plant's ash content, expressed as percentage of dry matter was calculated as follows:

$$\frac{W_2 - W_1}{W_o} \times 100$$

where W_o = weight of the dry matter

W_1 = Weight of empty crucible

W_2 = Weight of crucible plus the ash

3.4.6 LEAF NITRATE REDUCTASE ACTIVITY (NRA):

The newly expanded, young leaves between the third and fourth positions on the top of soybean plant were randomly selected for this analysis, from each plot. The nitrate reductase activity in the samples was determined using the combined methods of Klepper et al. (1971) and Radin (1973). Leaf punches (2mm in diameter, obtained with 2mm cork borer) weighing 0.3g was obtained for each sample. This was introduced into specimen tubes containing 5ml of the incubation medium, made up of equal volumes of 0.1M potassium phosphate buffer (pH 7.5), 1% propanol, 0.1M potassium nitrate and 0.5mg/ml chloramphenicol at the rate of 2 drops per 5ml of the incubation medium. Blank incubation medium was prepared as above, but potassium nitrate was substituted with deionized water. The samples in the specimen tubes were incubated in a water-bath containing water at 30°C;. The tubes were removed from the

water-bath after 30 mins. of incubation and the reaction was stopped by adding 3ml. of 1% sulphanilamide in 3N Hydrochloric acid to each tube. Colour was developed by adding 3ml. of 0.02% N-1-Napthylene diamine dichloride to each tube, and the absorbance of the assay in each was read at 540nM in corning colorimeter. With the use of a standard curve plotted from absorbance of known concentrations of potassium nitrite, the nitrite released in each sample was expressed as micro-moles nitrite per gram fresh weight per hour (um NO_3/gfr-wt-h-^{1}).

3.4.7 NITRATE-NITROGEN

The combined methods of Nelson et al. (1954), Wooley et al. (1960) and Ranjhan and Krishna (1980) was used to determine the nitrate-nitrogen level of the leaves and the seeds. The fresh leaves left after determination of NRA was oven-dried and ground. One gram of the ground sample was added to 100ml of O.1N Hydrochloric acid in a stoppered conical flask, to extract the nitrate content, for one hour. The solution was later filtered using 15cm Whatman filter paper. About 0.5g of Bray's indicator powder was added to one millilitres of the filtrate and 9ml of 20% acetic acid solution in a centrifuge tube which was stoppered and shaken for one minute. The tubes containing the solution were centrifuged for 5 minutes, after which the optical density of the solution was measured at 520nM in a corning colorimeter. The amount of nitrate-nitrogen expressed on dry matter basis was calculated as:

$$\% \text{ Nitrate} = \frac{\text{Nitrate microgram/ml from curve}}{\text{Sample weight x 10 on dry matter basis}}$$

The Bray's indicator powder contained, 100g of Barium sulphate (dried at 105°C over night) 10g of Manganese (II) sulphate monohydrate, 2g finely powdered zinc, 75g of powdered citric acid, 4g of sulfanilic acid and 2g of 1-naphthylamine. The analysis for leaf nitrate content was carried out along with leaf nitrate reductase activity at 2, 4, 6, 8, and 10 WAE. Whereas seed nitrate content was determined at 4, 5, 6, 7, 8 and 9 WAF.

3.4.8 CRUDE PROTEIN

The seeds of soybean were randomly selected from each plot at 4, 5, 6, 7, 8 and 9 WAF, for seed crude protein, lipid, carbohydrate and mineral elements determination. These samples were each dried in oven maintained at 70°C to constant weight, before they were ground into fine powder. Two grams of the powdered sample was weighed into 300ml Kjeldahl flask for determination of the crude protein content by macro-kjeldahl method (Jackson 1972). Kjeldahl catalyst containing 10g of potassium sulphate and 0.5g copper sulphate was added to the sample along with 30ml of concentrated sulphuric acid.

This sample was digested in Fume cupboard until a clear slightly yellow solution was obtained. The content of the flask was transferred into a 500ml volumetric flask after cooling; 200ml of distilled water plus 100ml of 11.25N sodium hydroxide was added. This flask was fitted to the

macro-kjeldahl distillating apparatus for distillation process. The distillate was collected in a 250ml conical flask containing 100ml of 0.5N sulphuric acid and 0.5ml methyl red indicator. The distillate was titrated with a standard sodium hydroxide solution (0.25N). Total nitrogen percent on dry weight basis was calculated using this formula:

$$\frac{0.014(B-A)N \times 100}{\text{Weight}} = \% \text{ Nitrogen}$$

where B = Volume in millilitre of the standard sodium hydroxide solution (0.25N) used to neutralise the acid in blank determination.

A = Volume in millilitre of the standard sodium hydroxide solution used to neutralize the excess acid in the test with the material.

N = Normality of standard sodium hydroxide solution.

The percent nitrogen was multiplied by 6.25 to obtain the crude protein content of the samples.

3.4.9 LIPID

Soxhlet extraction apparatus was used for lipid determination. Empty thimble was weighed and 5gram of the dried, powdered seed sample was introduced into it and reweighed. The thimble's mouth was plugged with fat free absorbant cotton, and placed in the soxhlet apparatus which was filled with petroleum ether (40-60^{o}C) and Ethanol (a

mixture at 1:1) for the lipid extraction. The extraction lasted for about 6 hours after which the thimble was removed, and dried in an oven (set at 105°C) till a constant weight was obtained, before the thimble was reweighed. The lipid content expressed as percentage on dry matter basis was calculated with this formula:

$$\text{Percent Lipid} = \frac{\text{Weight of fat} \times 100}{\text{Weight of sample}}$$

3.4.10 CARBOHYDRATE

Following the determination of seed protein, lipid and ash, the seed carbohydrate was determined as follows. The sum of the average percent values of seed protein, lipid and ash of each sample was subtracted from the sample's dry matter.

Percent carbohydrate = DM - (Protein + Ash + Lipid)

where DM = percent dry matter

3.4.11 LEAF CHLOROPHYLL CONTENT

This was determined through the method of Withman et al. (1971). One gram of fresh leaves sampled for NRA from each plot was weighed into a clean mortar. The chlorophyll was extracted by grinding the sample with 80% acetone and filtering it repeatedly until all the chlorophyll was removed. The final, volume of the filtrate was adjusted to 100ml with acetone. The absorbance of the filtrate of each sample was read with corning colorimeter (Model 253) at 6-5

and 663nM. The chlorophyll content of the sample was calculated with the formula below:

mg chlorophyll a/g tissue

$$= (12.7\ (A_{663}) - 2.69(A_{645}) \times \frac{V \times W}{1000}$$

mg chlorophyll b/g tissue

$$= (22.9(A_{645}) + 4.68(A_{663}) \times \frac{V \times W}{1000}$$

mg total chlorophyll/g tisue

$$= (20.2(A_{645}) + 8.02(A_{663}) \times \frac{V \times W}{1000}$$

where, W = Weight of fresh leaf sample

V = Final volume of chlorophyll solution

A = Absorbance at the given wave-length.

3.4.12 MINERAL ELEMENTS

One-half gram of the remaining powdered seed and leaf dry samples at 2, 4, 6, 8, 10 and 12 WAE (for leaves) and 4, 5, 6, 7, 8 and 8 WAF (for seeds), was each wet digested in a Kjeldahl flask as described by Jackson (1972). About 20ml of digestion mixture (contained 650ml of Nitric acid, 20mls of sulphuric acid and 80ml of perchloric acid) was added to the sample for digestion, which lasted for about 3 hours. After digestion, the flask was allowed to cool before washing the digest with distilled water into a 100ml volumetric flask and made up to mark.

The levels of the following mineral elements: Calcium (Ca), Magnesium (Mg), Zinc (Zn), Manganese (Mn) and Iron (Fe) were determined with the use of Perkin-Elmer atomic absorption spectrophotometer, while phosphorus (P) was determined colorimetrically using spectronic 20 at 440nm. Potassium (K) was estimated with the flame-photometer:

$$\text{ppm element} = \frac{\text{constant} \times (a-b) \times \text{dilution factor} \times \text{volume}}{\text{sample weight}}$$

where a = sample reading

b = blank reading

$$\% \text{ element} = \frac{\text{ppm Mineral element}}{10{,}000}$$

The constant was obtained from the standard curve prepared for each element.

3.5 STATISTICAL ANALYSIS

All data were subjected to statistical analysis which include analysis of variance of each year's data, and combined analysis of variance for both years. Least significant difference (LSD) values at 5% level of probability were used to compare data for sampling dates and treatment, where there was any significant difference at 5% probability ($P = 0.05$). The mean values were ranked through the use of Duncan multiple range test, and correlation coefficient between some of the parameters was also calculated.

CHAPTER FOUR

R E S U L T S

4.1 GENERAL OBSERVATION

On the whole, soybean 'Samsoy 2' seed germination and seedling morphology were not significantly influenced by the application of metolachlor + metobromuron in both years. In 1987, however, more than 75% and 25% of seedlings from plots sprayed with 3 and 4kga.i/ha metolachlor + metobromuron respectively were destroyed.

In 1986, at two weeks after emergence (WAE) weed seedlings were seen on the unweeded and hoe-weeded control plots. Fewer weed seedlings (approximately 40% of that on unweeded control) appeared on plots with 1kga.i/ha metolachlor + metobromuron treatment, but were virtually absent on plots with 2, 3, and 4kga.i/ha of the herbicide. Beginning from 4WAE weeds started appearing on plots which had 2-4kg.a.i/ha of metolachlor + metobromuron. Subsequently the weeds on all the plots increased in height and in number throughout the later part of the investigation.

The weeds found and identified on all the plots after harvesting the soybean seeds in 1986 and 1987 were similar although their population differed based on herbicide treatment. The weeds that appeared in both years include: Indigofera pulchra, Ageratum conyzoides, Mitrocarpus scabra, Verno nia pauciflora, Buchnera hispida, Pennisetum

pedicellatum, Crotolaria retusa, Blumea aurita, Hyparrhenia rufa and Starchyterpheta angustifolia.

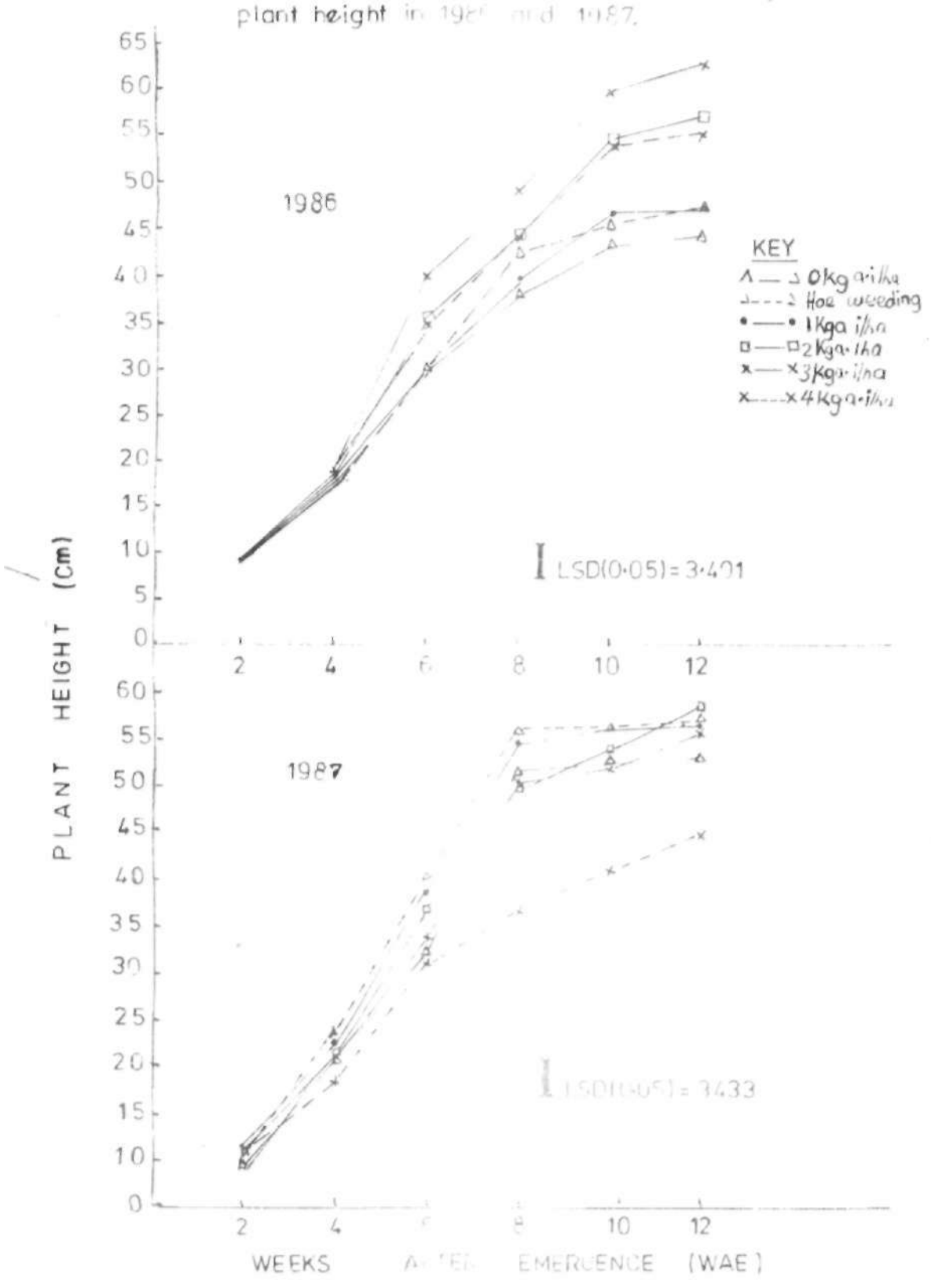
4.2 PLANT HEIGHT

Soybean plant height increased with age, irrespective of herbicide treatments (Figure 1). Average height of 52.21 and 53.98cm was obtained at 12WAE in 1986 and 1987 respectively. The plant height seemed to remain constant after 10WAE by which time the pods and seeds were developing. The increase in soybean plant height, irrespective of herbicide treatment positively correlated with age in both years.

The plants with the highest height were obtained on the 3kga.i/ha metolachlor + metobromuron treated soybean plots in 1986 unlike the plants on the hoe weeded plots which was recorded the highest height in 1987. The difference in height of the plants on 3kga.i/ha and 2kga.i/ha metolachlor + metobromuron treated plots was not significant in 1986 (Fig. 1). Also the height of plants on the unweeded and hoe-weeded control and 1kga.i/ha metolachlor + metobromuron treated plots were not significantly different from each other, but their values were lower than the height of the plants on 2 and 3kga.i/ha metolachlor + metobromuron treated plots.

In 1987, the height of the hoe-weeded plants was significantly higher than that obtained from the 4kg.a.i/ha metolachlor + metobromuron treated plots but it was not significantly higher than that of plants on the 1, 2, and 3kga.i/ha treated plots.(Fig.1) . In 1986 the unweeded

Eight influence of pre- and post application of Metolachlor + Metribuzuron (Galex) on Soybean plant height in 1986 and 1987.



plants had the lowest height, while the height of plants on the 4Kg a.i/ha metolachlor + metobromuron treated plots was the lowest in 1987. The mean soybean plant height of 37.24cm observed in 1987, irrespective of age and treatment was not significantly different from 34.59cm recorded in 1986.

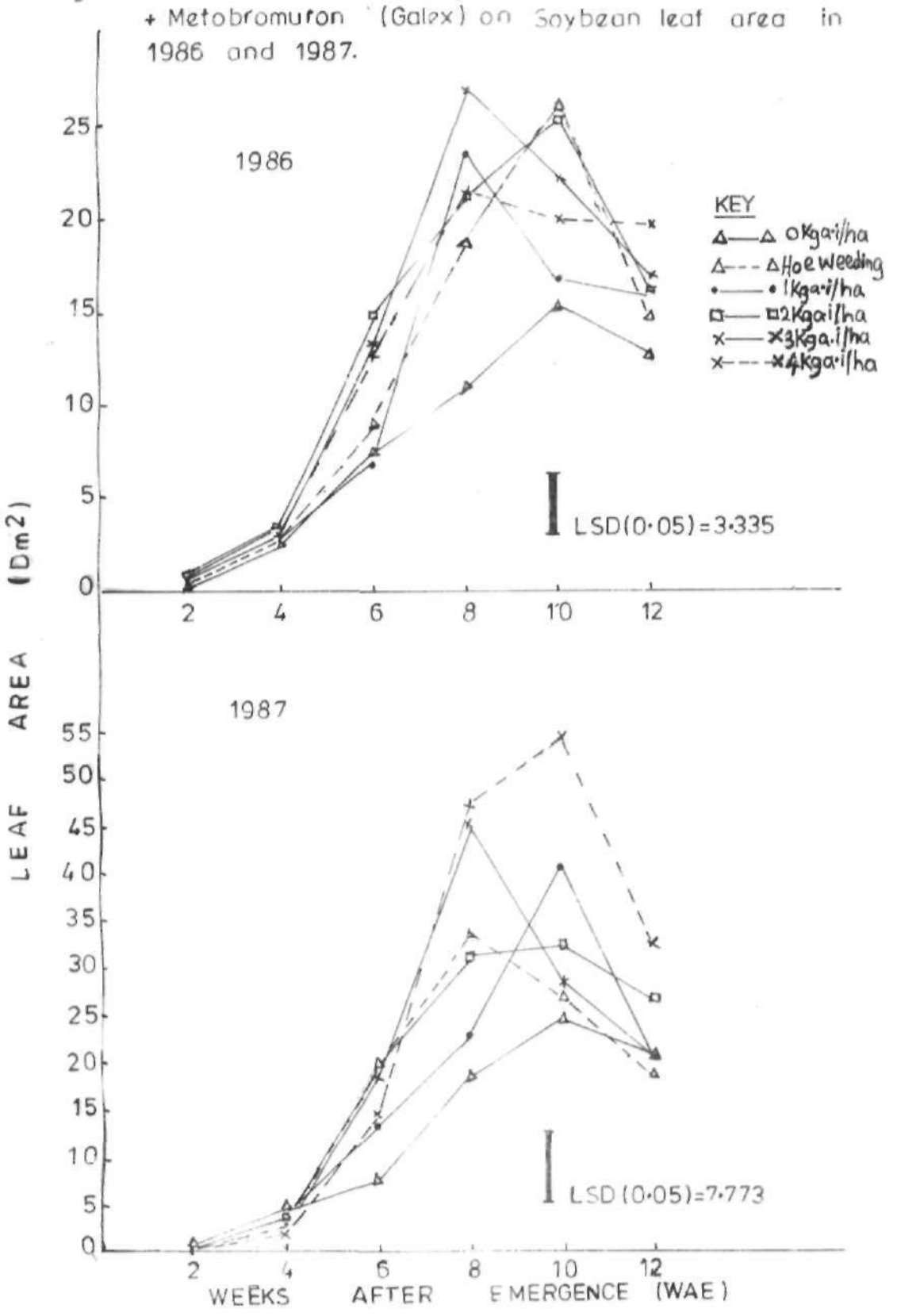
The treatment x age interaction was significant in both years. In both years, the plant height of all the treatment was generally similar between 2 and 6WAE. In 1986 the 2-4kg.a.i/ha metolachlor + metobromuron treated plots had plants whose height was significantly higher than that of other treatment from 6WAE. In 1987 plant height was not significantly different among the treatments, except the lower plant height in the 4kga.i/ha metolachlor - metobromuron treated plots from 8WAE.

4.3 LEAF AREA (LA)

Leaf area increased consistently in all the treatments from 2-8WAE in 1986 and 1987 (Figure 2). The LA values between 8-10WAE were significantly higher than the values obtained at other sampling dates in both years (Fig. 2). The LA at the 2 and 4 WAE in both years were significantly lower than the observed LA in subsequent sampling dates. Leaf area correlated positively ($r = 0.87$ and 0.83 respectively) with plants age in both years.

In 1986 the leaf area irrespective of age, increased with herbicide treatments from 1-3kga.i/ha, while in 1987, it increased from 1-4kga.i/ha (Fig. 2). The highest LA of

Fig.2. Influence of pre-emergence application of Metolachlor + Metobromuron (Galex) on Soybean leaf area in 1986 and 1987.



13.75Dm^2 irrespective of age was recorded from plants on 3kga.i/ha metolachlor + metobromuron treated plants in 1986, but the LA of 25.18Dm^2 obtained in 4kga./ha treated plant was the highest in 1987. There was no significant difference in the LA of soybean plants on 0.kga.i/ha (unweeded control) and 1kga.i/ha metolachlor + metobromuron treated plots in 1986, but each value was lower than the leaf area on other treated plots (Fig. 2). Similarly in 1987, the leaf area obtained on 4kga.i/ha metolachlor + metobromuron treated plots was significantly higher than the observed plants LA in other treated plots.

However, the differences in leaf area of all the treatments except 4kga.i/ha metolachlor + metobromuron treatment was not significant in 1987 (Fig. 2). Combined Analysis of variance of the two year data showed that LA under 2, 3 and 4kga.i/ha metolachlor + metobromuron treatment were not significantly different from each other. The unweeded control (0kga.i/ha) treatment had the lowest LA of 10.53Dm^2, but this value was not significantly different from the 14.04Dm^2 LA recorded for the 1kga.i/ha metolachlor + metobromuron treatment. The mean soybean LA of 18.49Dm^2 obtained in 1987 was significantly higher than the 11.92Dm^2 observed in 1986. The soybean LA is positively correlated with the herbicide treatment levels in both years (Table 26).

Similar to the plant height in 1986, the treatment x age interaction effect on leaf area indicated that, leaf area of the plants on hoe weeded control and the herbicide

treated plots was not significantly higher than that of unweeded plants until the 8WAE when leaf production was at the peak. However, at the same 8WAE in 1987, the LA observed from plants on the hoe-weeded plots was significantly higher than that of plants on unweeded plot and 1kga.i/ha metolachlor + metobromuron treated plots.

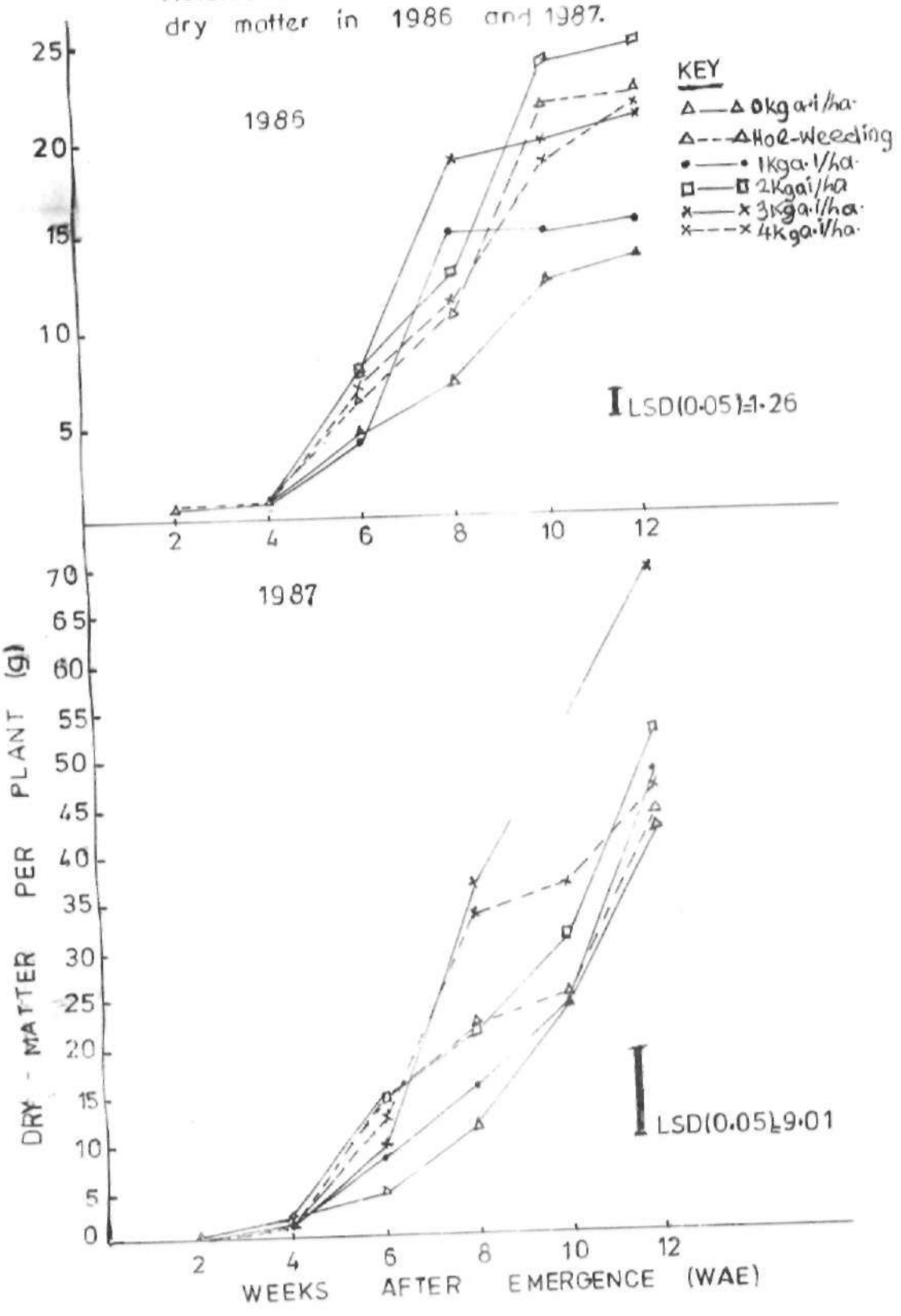
In both years, LA positively correlated with plant height dry matter, total chlorophyll and root nodule number However, LA had negative correlation with plant ash (Table 25) and with the leaf mineral element contents N, P, K, Mg. Fe and Zn, but positive correlation with Calcium and Manganese in both years.

4.4 DRY MATTER

Generally in 1986 and 1987, soybean plant dry matter inceased with age (Fig. 3). This led to the high positive correlation between dry matter and age of plant (r = 0.90 and 0.94 respectively) in both years.

In 1986 and 1987, the highest soybean dry matter was observed at the 12WAE. The dry matter values at the 2 and 4 WAE in each year was significantly lower than the values obtained at other sampling dates (Fig. 3). In 1986 the plants on 2Kg a.i/ha metolachlor + metobromuron treated plots had the highest dry matter, while in 1987 the highest dry matter was obtained at 4Kg.a.i/ha. The dry matter produced by plants on the unweeded plots was the lowest in 1986 and 1987. In 1986, the difference in dry matter content of the plants on the unweeded and 1kga.i/ha metolachlor -

Fig. 3. Influence of pre-emergence application of Metolachlor + Metobromuron (Galex) on Soybean plant dry matter in 1986 and 1987.



metobromuron treated plots was not significant. In 1987, with the exception of plants on 4Kg.a.i/ha metolachlor - metobromuron treated plots, the dry matter content of plants from all the treatments was not significantly different.

However, combined analysis of variance of the two-year data showed that the plants on 4kga.i/ha metolachlor - metobromuron treated plots had the highest dry matter content of 19.56g/plant, followed by the 16.23g/plant recorded from plants on 2Kg.a.i./ha metolachlor - metobromuron treated plots. The lowest dry matter 10.52g/plant was produced by the plants on the unweeded plots.

In 1986 and 1987 the dry matter content of plants from all the treatments was not significantly different from 2-4WAE. In 1986 the dry matter content of plants on unweeded and 1kga.i/ha metolachlor + metobromuron treated plots was lower than that observed in other treatments from 10-12WAE. The treatment x age interaction was not significant in 1987.

4.5 SUMMARY ON GROWTH PARAMETERS

Leaf area increased most rapidly with a 454.56% (calulation was based on combined data of 1986 and 1987) increase from 2-4WAE and 102.73% increase between 4 and 6WAE. Plant height also had 98.80% increase between the 2 and 4WAE, and 73.44% from 4-6WAE. Although the increase in soybean plant dry matter was low (0.278%) between 2 and 4WAE, it had 23.24% increase between 4 and 6WAE and 24.91% increase between 8 and 10WAE.

4.6 LEAF CHLOROPHYLLS a, b, AND TOTAL

In 1986 and 1987 chloropyll a, b and total increased with age (Table 3-5). In 1986, the highest soybean leaf chlorophyll a, b and total were obtained at 12WAE, whereas the lowest values of these chloropohyll types were obtained at 2WAE (Tables 3-5). However in 1987 the lowest values of these chlorophyll types occurred at 2WAE, while the highest values were obtained at 10WAE. Statistical analysis showed that in both years, there was no significant difference in the values of these chlorophyll types at the 10 and 12WAE. The correlation of chlorophyll a with age was r = 0.99 and 0.84, chlorophyll b was r = 0.99 and 0.89 and the total chlorophyll was r = 0.997 and 0,83 respectively, in both years.

The plants on 2kga.i/ha metolachlor + metobromuron treated plots had the highest values of chlorophyll a, b and total in 1986. These values (Tables 3-5) were not significantly higher than the values obtained in other treatments. However, in 1987 the plants on unweeded soybean plots had the highest leaf chlorophyll a, b and total. The plants on 2kga.i/ha metolachlor + metobromuron treated plots had the lowest chlorophyll a and total content, while the plants on 4kga.i/ha metolachlor + metobromuron treated plots had the lowest chlorophyll b content. These differences in chlorophyll content was significant.

The treatment x age interaction was not significant in both years on the leaf chlorophylls. The combined analysis

Table 3: Influence of pre-emergence application of Metobromuron + Metolachlor (Galex) on chlorophyll a content of soybean leaves in 1986 and 1987

Galex Kg a.i/ha	PLANTS (WAP) 2	4	6	8	10	12	Mean	r	LSD
	Chlorophyll a content (mg/g fresh weight of leaf tissues)								
1986									
0	0.83a	0.87a	0.97a	1.12ab	1.23a	1.21b	1.05b	0.69	0.092
1	0.86a	0.96a	0.93a	0.96b	1.44a	1.46a	1.10ab	0.88	
2	0.90a	1.00a	1.11a	1.25a	1.33a	1.39ab	1.16a	0.95	
3	0.87a	0.89a	1.00a	1.21a	1.28a	1.42ab	1,11ab	0.76	
4	0.89a	0.88a	1.04a	1.27a	1.39a	1.46a	1.16a	0.92	
H.W.	0.74a	0.95a	1.15a	1.19ab	1.31a	1.51a	1.14ab	0.69	
Mean	0.85	0.93	1.03	1.17	1,33	1.41	1.12		
LSD (0.05)	= 0.092								0.226*
1987									
0	0.87a	0.95a	0.91a	1.06a	1.15a	1.06a	1.00a	0.85	0.097
1	0.71a	0.88a	0.94a	0.93a	1.00a	0.95a	0.90ab	-0.01	
2	0.68a	0.83a	0.95a	0.93a	0.97a	0.83a	0.89b	0.64	
3	0.95a	0.94a	0.96a	0.95a	0.99a	0.86a	0.94ab	- 0.38	
4	0.80a	0.88a	0.92a	0.94a	0.98a	1.00a	0.92ab	0.27	
H.W.	0.80a	0.96a	0.96a	0.95a	1.11a	1.04a	0.97ab	0.84	
Mean	0.83	0.91	0.94	0.96	1.02	0.96	0.94		
LSD (0.05)	= 0.097								0.238*

(a) Figures followed by the same letter(s) a column in each year are not significantly different ($p = 0.05$) using DMRT.

(b) *represent the LSD for treatment X age interaction.

Table 4: Influence of Pre-emergence application of Metobromuron + Metolachlor (Galex) on chlorophyll b content of soybean leaves in 1986 and 1987.

1986

Galexz Kg a.i/ha	PLANT'S AGE (WAE) Chlorophyll b content (mg/g fresh weight of leaf tissues) 2	4	6	8	10	12	Mean	r	LSD
0	0.47a	0.50a	0.59a	0.61a	0.69ab	0.67b	0.59a	0.40	0.065
1	0.47a	0.48a	0.56a	0.66a	0.84a	0.88a	0.65a	0.75	
2	0.50a	0.54a	0.69a	0.70a	0.73ab	0.82ab	0.66a	0.37	
37	0.52a	0.60a	0.59a	0.61a	0.66b	0.66b	0.61a	0.43	
4	0.43a	0.56a	0.57a	0.58a	0.74ab	0.84a	0.62a	0.67	
H.W.	0.45a	0.50a	0.65a	0.64a	0.72ab	0.86a	0.64a	0.64	
Mean	0.47	0.53	0.61	0.63	0.73	0.79	0.63		
LSD (0.05) = 0.65									0.16*

1987

0	0.46a	0.47a	0.46a	0.56a	0.53a	0.73a	0.54a	0.58	0.048*
1	0.45a	0.45a	0.46a	0.47a	0.54a	0.51b	0.49ab	0.23	
2	0.43a	0.39a	0.43a	0.50a	0.60a	0.44b	0.47b	0.53	
3	0.48a	0.44a	0.44a	0.49a	0.48a	0.47b	0.47b	0.30	
4	0.43a	0.42a	0.42a	0.46a	0.50a	0.51b	0.46b	0.90	
H.W.	0.43a	0.48a	0.45a	0.55a	0.59a	0.55b	0.51ab	0.79	
Mean	0.45	0.44	0.45	0.51	0.54	0.54	0.49		
LSD (0.05) = 0.048									0.117

(a) Figures followed by the same letter(s) within a column, in each year, are not significantly different (P-0.05) using DMRT.

(b) * represent the LSD for treatment X age interaction.

Table 5: Influence of Pre-emergence application of Metobromuron + Metolachlor (Galex) on Total Chlorophyll content of Soybean leaves in 1986 and 1987.

1986

Galex Kg a.i/ha	PLANT'S AGE (WAE) Total Chlorophyll Content (mg/g fresh weight of leave tissues								
	2	4	6	8	10	12	Mean	r	LSD
0	1.35a	1.47a	1.45b	1.80a	1.82b	1.92b	1.64b	0.61	0.151
1	1.32a	1.44a	1.49b	1.62a	2.27a	2.34a	1.75ab	0.84	
2	1.40a	1.70a	1.93a	1.87a	1.94ab	2.11ab	1.83a	0.51	
3	1.39a	1.48a	1.66ab	1.87a	1.87b	2.02ab	1.72ab	0.77	
4	1.32a	1.46a	1.78ab	1.95a	1.84b	2.30ab	1.78ab	0.95	
H.W.	1.18a	1.46a	1.84ab	1.87a	1.96ab	2.37a	1.78ab	0.68	
Mean	1.54	1.78	1.75	1.83	1.72	1.78	1.75		
LSD (0.05) = 0.151									0.7*

1987

0	1.36a	1.42a	1.37a	1.63a	1.88a	1.59a	1.54a	0.78	0.100*
1	1.16a	1.33a	1.47a	1.44ab	1.48bc	1.43a	1.39bc	0.61	
2	1.22a	1.26a	1.38a	1.33b	1.57bc	1.37a	1.35c	0.59	
3	1.38a	1.40a	1.43a	1.44ab	1.47bc	1.33a	1.41bc	-0.21	
4	1.26a	1.31a	1.39a	1.36ab	1.42c	1.51a	1.38bc	0.64	
H.W.	1.25a	1.44a	1.40a	1.49ab	1.71ab	1.59a	1.48ab	0.88	
Mean	1.05	1.36	1.41	1.45	1.59	1.47	1.43		
LSD (0.05) = 0.10(									0.25

(a) Figures followed by the same letter(s) within a column, in each year, are not significantly different (P=0.05) using DMRT.

(b) * represent the LSD for treatment X age interaction.

of variance of the data in 1986 and 1987 showed that there was no significant difference in leaf chlorophylls a, b and total content of all the treatments. Furthermore the average values of all these chlorophyll types in 1986 was higher than the values obtained in 1987. The correlation of total chlorophyll with dry matter was positive in both years.

4.7 ROOT NODULES

In 1986 and 1987 root nodules were unobservable at the 2WAE (Table 6). The nodules were however observed on the roots from the 4 WAE to the end of the period of the investigation. Irrespective of treatments, the nodule number per plant increased with the plants age up till 10WAE when the highest nodule number was observed in both years. The correlation of soybean root nodules with the age of plant was r = 0.87 and 0.80 respectively in 1986 and 1987.

In 1986, the 4kga.i /ha metolachlor + metobromuron treatment produced plants with the highest number of nodules, while the lowest number of nodules per plant was recorded on plants from unweeded plots. This value was significantly lower than that of other treatments. In 1987 there was no significant difference in the number of nodules per plant due to the herbicide treatments.

However, the combined analysis of variance of 1986 and 1987 data showed that herbicide treatment effects on the number of nodules per plant was significant. The root nodule number on the unweeded plants was lower than that

Table 6: Influence of pre-emergence application of Metobromuron + Metolachlor (Galex) on number of root nodules on soybean plants in 1986 and 1987.

1986

Galex Kg a.i/ha	PLANT'S AGE (WAE) 2	4	6	8	10	12	Mean	r	LSD
0	0a	17b	19d	48b	71a	47b	34b	0.87	7.47
1	0a	30ab	34cd	82a	73a	59ab	46a	0.82	
2	0a	42a	37bcd	60b	74a	50ab	44a	0.78	
3	0a	43a	54ab	66ab	73a	43b	47a	0.66	
4	0a	30ab	61a	67ab	76a	67a	50a	0.88	
H.W.	0a	29ab	42abc	48b	67a	69a	43a	0.96	
Mean	0	32	41	62	72	56	44		
LSD (0.05) = 7.47									18.2*

1987

0	0a	12a	27ab	26a	39a	31a	23a	0.89	7.17
1	0a	11a	21ab	42a	43a	40ab	26a	0.93	
2	0a	05a	33ab	35a	52a	50a	29a	0.95	
3	0a	12a	18b	34a	53a	26b	24a	0.80	
4	0a	01a	16b	24a	57a	38ab	23a	0.89	
H.W.	0a	07a	38a	32a	41a	34ab	25a	0,82	
Mean	0	0.8	25	32	48	37	25		
LSD (0.05) = 7.17									17.56

(a) Figures followed by the same letter(s) within a column, in each year, are not significantly different (P=0.05) using DMRT.

(b) * represent the LSD for treatment X age interaction.

observed on plants on other plots whose nodule number in turn was not significantly different.

The combined analysis of variance showed that the treatment x age interaction was not significant in the two years. The mean number of nodules (44 nodules) produced by soybean plant in 1986, irrespective of age and herbicide treatments, was significantly higher than the mean (25 nodules) obtained in 1987. LSD(0.05) = 0.12. The correlation between nodule number and leaf nitrate was positive (Table 25).

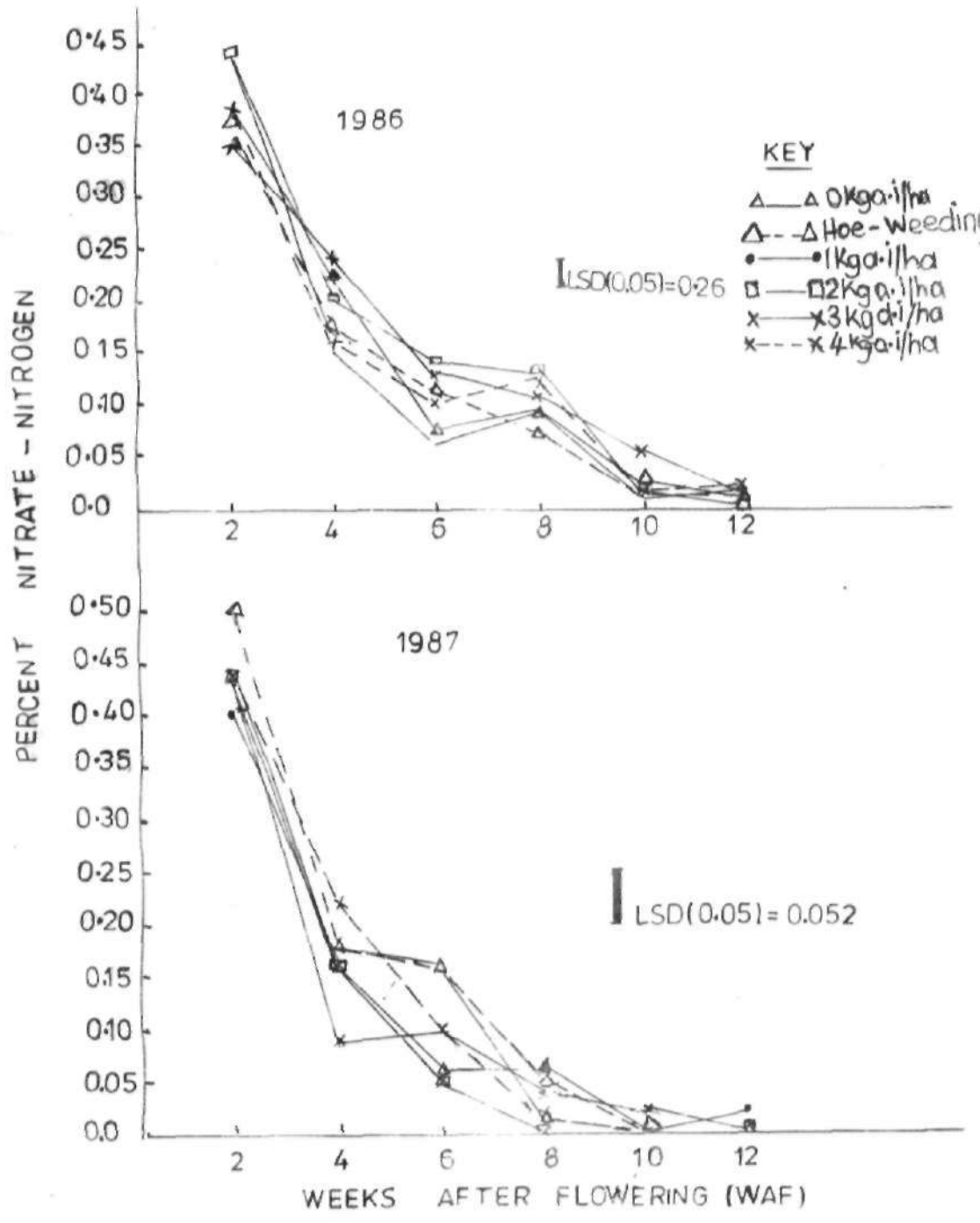
In 1986, the herbicide treatments, especially at 2 and 3kga.i/ha stimulated the production of higher root nodules above that of the control up to 8WAE. From 10WAE, when nodule production was at peak, there was no significant difference in root nodules per plant due to the herbicide treatment.

4.8 LEAF NITRATE-NITROGEN (NITRATE)

The soybean leaf nitrate level decreased with plant's age in both years (Fig. 4). In 1986 and 1987, the highest soybean leaf nitrate irrespective of herbicide treatment was observed at 2WAE, while the lowest leaf nitrate was obtained at 12WAE in both years. The correlation of leaf nitrate with plants age was r = -0.91 and -0.88 respectively, in 1986 and 1987.

In 1986, the highest mean soybean leaf nitrate irrespective of age, was obtained in plants on 2kga.i/ha

Fig. 4. Influence of pre-emergence application of Metolachlor + Metobromuron (Galex) on Soybean leaf nitrate - nitrogen in 1986 and 1987.



metolachlor + metobromuron treated plots, while the lowest leaf nitrate occurred in the plants on hoe-weeded plot in 1986. This difference in leaf nitrate content due to the herbicide treatments was significant in 1986. In 1987, the differences in leaf nitrate due to the herbicide treatment was not significant. The combined analysis of variance of the two years data showed that, the overall differences in leaf nitrate of the various treatments was not significant.The level of leaf nitrate in the treatments in decreasing order was: 4Kg > H.W > 2Kg > 0Kg > 3Kg > 1Kg.

In 1986, the treatment x age interaction was significant. The leaf nitrate level in the hoe-weeded and the unweeded soybean plant was similar throughout the sampling period. However the leaf nitrate in plants on the herbicide treated plots was generally higher than the values obtained in plants from the control treatments between 2 and 6WAE. Subsequent to this, the leaf nitrate in all the treatments were similar. However in 1987 the age x treatment interaction was not significant as indicated by the combined analysis.

4.9 NITRATE REDUCTASE ACTIVITY (NRA)

Generally the leaf nitrate reductase activity decrease with the age of the soybean plants in both years (Table 7). Although not significant, the NRA at 8 WAE was higher than that of 6WAE in both years. The correlation coefficient of NRA with the plant age was r = -0.92 and -0.96 respectively in both years.

Table 7: Influence of pre-emergence application of Metobromuron + Metolachlor (Galex) on nitrate reductase activity of soybean leaves in 1986 and 1987.

1986

Galex Kg a.i/ha	PLANT'S AGE (WAE) Leaf nitrate reductase activity (umole No_2-gfr-wt-h) 2	4	6	8	10	Mean	r	LSD
0	137.22a	84.17b	9.39a	18.36a	2.22a	50.27b	-0.91	13.8*
1	120.55ab	50.45c	16.85a	16,86a	1.69a	41.28b	-0:90	
2	119.92ab	184.59a	15.82a	17.76a	7.68a	68.75a	-0.77	
3	117.77ab	100.85b	10.10a	25.25a	4.58a	51.77b	-0.85	
4	131.66a	72.05bc	16.47a	13.58a	2.17a	47.19b	-0.92	
H.W.	93.39b	44.76c	11.41a	44.33a	0.94a	38.97b	-0.81	
Mean	120.90	89.48	13.06	22.69	3.21	49.71		
LSD	(0.05) = 12.60							30.8*

1987

0	157.16ab	49.69de	19.25a	22.66a	0.68a	45.89c	-0.86	17.0*
1	105.21a	117.14bc	32.64ac	40.47a	0.05a	77.30b	-0.94	
2	149.60b	148.21b	36.17a	61.82a	0.00a	79.16b	-0.91	
3	190.53ab	207.32a	56.99a	58.42a	0.02a	100.66a	-0.92	
4	59.96c	69.39de	46.60a	36.93a	6.58a	46.48c	-0.96	
H.W.	199.37a	94.40cd	38.95a	47.16a	0.03a	75.98b	-0.92	
Mean	160.46	114.36	38.53	42.19	1.23	71.58		
LSD	(0.05) = 16.36							40.08*

(a) Figures followed by the same letter(s) within a column, in each year are not significantly different (P=0.05) using DMRT.

(b) * represent the LSD for treatment X age interaction.

The plants on 2Kga.i/ha metolachlor + metobromuron treated plots had the highest NR activity value, while the hoe-weeded soybean plant had the lowest NR activity in 1986 (Table 7). However, in 1987, the highest leaf NR activity was obtained from plants on 3Kga.i/ha metolachlor + metobromuron treated plots and the lowest NRA value was from the plants on 4Kga.i/ha metolachlor + metobromuron treated plots. In 1987 plants on 3Kga.i/ha metolachlor + metobromuron treated plots had higher NR activity than the controls; whereas the NRA in plants on 1 and 2 kga.i/ha metolachlor + metobromuron treated plots was not significantly different (Table 7).

These differences in leaf NRA, due to the herbicide treatment was significant in each year. The combined analysis of variance of the two years data showed that the 76.22 umolesNO_2/gfr.wt.h-^{1}; in plants on 3Kga.i/ha metolachlor + metobromuron treated plots was the highest: this was followed by the 73.96 umoles-NO_2/gfr.wt.h-^{1} in plants on 2Kga.i/ha metolachlor + metobromuron treated plots. The 46.90 umolesNO_2/gfr.wt.h-^{1} in plants on 4Kga.i/ha metolachlor + metobromuron treated plots was the lowest. However this difference in the leaf NRA due to the herbicide treatment was on the whole significant.

Conversely, the soybean leaf NRA of 71.58 umolesNO_2/gfr.wt.h-^{1}, irrespective of age and treatment, obtained in 1987 was higher than the 49.70 umolesNO_2/gfr.wt.h-^{1} recorded in 1986. In both years the herbicide treatments especially 2 & 3Kga.i/ha stimulated a

higher leaf NRA above that of the controls(unweeded and hoe-weeded), between 2 and 4WAE when the NRA was very high after which there was no significant differences in the leaf NRA of all the treatments. The leaf NRA negatively correlated with root nodules but positively with leaf nitrate and seed protein in both years.

4.10 SOYBEAN PLANT ASH

The percentage ash of the whole soybean plant decreased with plants age in both years (Table 8) irrespective of treatment, plant ash was highest at 2WAE . In both years, the lowest plant ash occurred at 12WAE, but these values were not significantly lower than the values obtained at the 10WAE (Table 8). The plant ash content correlated negatively ($r = -0.90$ and 0.81) respectively in both years, with the age of soybean plant.

Averaged across sampling dates, in 1986 the hoe-weeded soybean plants had the highest ash content, while in 1987, plants on plots that received 1Kga.i/ha metolachlor - metobromuron treatment had the highest ash content (Table 8). However, these values was not significantly higher than the ash content of the plants on other herbicide treated plots in both years.

The treatment x age interaction effect on soybean plant ash content was significant in both years. Generally there was no significant difference in ash content of the plants on all the plots from 4 WAE. The major differences in plants ash content was enhanced at 2 WAE.In 1986 the ash

Table 8: Influence of Pre-emergence application of Metobromuron + Metolachlor (Galex) on ash content of soybean plants in 1986 and 1987.

1986

Galex Kg a.i/ha	PLANT'S AGE (WAS) Ash content of soybean plant (%/g dry weight of plant biomass) 2	4	6	8	10	12	Mean	r	LSD
0.	30.04a	14.38c	10.94b	09.48a	08.24a	06.85a	13.32bc	-0.85	1.34
1	33.13a	19.08a	12.65ab	09.05a	07.98a	06.99a	14.81a	-0.90	
2	25.44b	15.63bc	13.31ab	09.07a	07.10a	06.74a	12.88c	-0.93	
3	23.71b	15.84abc	14.30ab	08.96a	08.31a	06.70a	12.97c	-0.95	
4	26.61b	15.24bc	13.45ab	09.81a	08.01a	07.43a	13.35bc	-0.91	
H.W.	30.51a	18.59ab	15.76a	10.93a	08.27a	07.12a	15.20a	-0.94	
Mean	28.17	16.46	13.40	09.55	07.99	06.97	13.76		
LSD (0.05) = 1.34									3.28*

1987

0	23.53b	12.53a	07.76a	07.65a	06.53a	06.01a	10.67bc	-0.84	1.74
1	34.56a	10.74a	09.58a	08.15a	06.52a	06.46a	12.70a	-0.76	
2	32.86a	10.36a	09.38a	08.41a	07.38a	05.59a	12.33ab	-0.77	
3	19.73b	10.24a	09.79a	08.71a	06.84a	06.44a	10.29c	-0.96	
4	22.73b	10.34a	09.99a	08.97a	07.91a	07.24a	11.20abc	-0.79	
H.W.	23.72b	12.04a	08.87a	08.19a	07.04a	07.00a	11.14abc	-0.83	
Mean	26.91	11.04	09.23	08.35	07.04	06.47	11.39		
LSD (0.05) = 1.74									4.26*

(a) Figures followed by the same letter(s) within a column, in each year, are not significantly different (P=0.05) using DMRT.

(b) * represent the LSD for treatment X age interaction.

content of plants on the two controls and 1kga.i/ha metolachlor + metobromuron treated plots was significantly higher than the observed values on plants from other plots. However at the same time, 2WAE in 1987 the plants on 1 and 2kga.i/ha metolachlor + metobromuron treated plots had highest plant ash content.

The plant ash content was positively correlated with leaf N, P, K, Mg, Fe and Mn but negatively correlated with leaf calcium content in both years.

4.11 LEAF MINERAL ELEMENTS

4.11.1. LEAF PHOSPHORUS

Soybean leaf phosphorus decreased with age, thereby having a negative correlation of r = -0.95 and -0.98 respectively with age of the plant in both years (Table 9).

Leaf P at each successive sampling dates was significantly different from the values obtained at the other sampling dates in both years. In 1986, the 0.25% leaf P in plants on unweeded and hoe-weeded plots, averaged across sampling dates, was the lowest, while the 0.27% P in plants on 1Kga.i/ha metolachlor + metobromuron treated plots was the highest. In 1987, the plants on the unweeded control, 1 and 3Kg.a.i/ha metolachlor + metobromuron treated plots however, had the lowest leaf P of 0.25% while the 0.27% leaf P was obtained in plants on 2Kga.i/ha metolachlor + metobromuron treated plots . These differences in leaf P due to the herbicide treatment was in each year significant. Furthermore, the mean soybean leaf P, irrespective of age

Table 9: Influence of Pre-emergence application of Metobromuron + Metolachlor (Galex) on Phosphorus content of Soybean leaves in 1986 and 1987.

1986

PLANT'S AGE (WAE)

Phosphorus content of Soybean leave (%/g dry weight of leaf biomass)

Gales Kg a.i/ha	2	4	6	8	10	12	Mean	r	LSD
0	0.27a	0.29ab	0.29ab	0.22a	0.22a	0.19a	0.25c	-0.86	0.005
1	0.36a	0.34a	0.32a	0.24a	0.21a	0.17a	0.27a	-0.98	
2	0.34a	0.34a	0.24ab	0.30a	0.20a	0.16a	0.26b	-.90	
3	0.27a	0.30ab	0.31a	0.30a	0.22a	0.19a	0.27a	-0.71	
4	0.32a	0.23b	0.32a	0.30a	0.20a	0.21a	0.26b	-0.63	
H.W.	0.32a	0.32ab	0.21b	0.25a	0.19a	0.17a	0.25c	-0.98	
Mean	0.31	0.30	0.29	0.27	0.21	0.18	0.26		
LSD (0.05) = 0.005									0.086*

1987

0	0.37cd	0.34b	0.29d	0.25a	0.15b	0.08c	0.25c	-0.98	0.0062
1	0.42a	0.32cd	0.32c	0.20b	0.14b	0.09c	0.25c	-0.98	
2	0.42a	0.37a	0.36a	0.21b	0.15b	0.09c	0.27a	-0.98	
3	0.40b	0.32cd	0.34b	0.21b	0.15b	0.12ab	0.26b	-0.97	
4	0.36d	0.32cd	0.32c	0.20b	0.17a	0.13a	0.25c	-0.97	
H.W.	0.38c	0.31d	0.33bc	0.26a	0.15b	0.11b	0.26b		
Mean	0.39	0.33	0.33	0.22	0.15	0.10	0.26		
LSD (0.05) = 0.0062									0.015*

(a) Figures followed by the same letter(s) within a column, in each year, are not significantly different (P=0.05) using DMRT.

(b) * represent the LSD for treatment X age interaction.

and herbicide treatment was 0.26% in each year. The level of P in the treatments in decreasing order was: 2Kg > 3Kg > 1Kg > 4Kg = H.W > 0Kg (Based on the average of the two year data).

In 1986, the plants on 2-4Kga.i/ha metolachlor + metobromuron treated plot had a significantly higher leaf P at the 8WAE, over that of the controls. This differences was not obtained at other sampling dates. However in 1987 the plants on 1 and 2Kg a.i/ha metolachlor + metobromuron treated plots had higher leaf P than the controls at 2WAE, but at 8WAE the control had higher leaf P compared to the plants on herbicide treated plots. This treatment x age interaction was significant in each year.

4.11.2 LEAF POTASSIUM (K)

Soybean leaf K content decreased with age especially after 6WAE in 1986 and 1987 (Table 10) with a correlation coefficient of r = -0.75 and -0.90 respectivey. The leaf K irrespective of galex treatment from 4 and 6WAE was significantly higher than the values obtained in other sampling dates (Table 10). In both years the lowest leaf K level was recorded in the 12WAE.

However the analysis of variance showed that the plants on 4Kg.a.i/ha metolachlor + metobromuron treated plots had the highest leaf K irrespective of sampling dates, in 1986, while the leaf K obtained in plants on 3Kg.a.i/ha metolachlor + metobromuron treated plots was the highest in 1987. These leaf K values were not significantly

Table 10: Influence of pre-emergence application of Metobromuron + Metolachlor (Galex) on Potassium content of soybean leaves in 1986 and 1987.

1986

Galex Kg a.i/ha	PLANT'S AGE (WAE) Potassium content of soybean leaves (%/g dry weight of leaf biomass) 2	4	6	8	10	12	Mean	r	LSD
0	1.64c	1.86cd	1.60d	1.69d	1.12d	1.05a	1.49c	-0.83	0.0084
1	1.69b	1.90b	1.92b	1.91b	1.08e	1.04a	1.59c	-0.73	
2	1.60d	1.88bc	2.00a	1.93ab	1.28a	0.95c	1.61b	-0.66	
3	1.55e	1.93a	1.93b	1.77c	1.22b	0.96c	1.56d	-0.70	
4	1.77a	1.85d	2.00a	1.94a	1.26a	0.95c	1.63a	-0.75	
H.W.	1.79a	1.71e	1.86c	1.78c	1.17c	1.01b	1.55d	-0.82	
Mean	1.67	1.86	1.89	1.84	1.19	0.99	1.57		
LSD	(0.05) = 0.0084								0.021*

1987

0	1.84a	1.85b	2.00c	1.47c	0.96d	0.97b	1.52b	-0.91	0.0076
1	1.80b	1.76c	1.90e	1.53b	1.01c	0.96b	1.49c	-0.92	
2	1.76c	1.92a	2.08b	1.44d	0.95d	0.97b	1.52b	-0.87	
3	1.85a	1.85b	2.10a	1.48c	1.01c	0.97b	1.54a	-0.91	
4	1.77c	1.76c	1.85f	1.42c	1.07a	1.05a	1.49c	-0.93	
H.W.	1.60d	1.84b	1.93d	1.59a	1.04b	1.04a	1.51b	-0.79	
Mean	1.77	1.83	1.98	1.49	1.01	0.99	1.51		
LSD	(0.05) = 0.0076								0.019*

(a) Figures followed by the same letter(s) within a column, in each year, are not significantly different P=0.05) using DMRT.

(b) * represent the LSD for treatment X age interaction.

higher than the observed levels in other treatments in both years (Table 10). The level of K in the treatment in increasing order was: 2Kg > 4Kg > 3Kg > 1Kg > H.W > 0kg.

The treatment x age interaction was significant in both years. In 1986 with the exception of 2 and 12WAE, the plants on the 4Kga.i/ha metolachlor + metobromuron treated plots had higher leaf K, compared to the plants on the unweeded plots and hoe-weeded plots, similarly in 1987, the plants on 2 and 3Kga.i/ha metolachlor + metobromuron treated plots had higher leaf K compared to the hoe-weeded plant from 2-6WAE but from 8-12WAE the hoe-weeded plants had higher leaf K than plants from most of the herbicide treated plots.

4.11.3 LEAF CALCIUM (Ca)

Unlike other elements, leaf Ca content of soybean was positively correlated (r = 0.88 and 0.75 in 1986 and 1987 respectively) with age, since it increased with the age of the plant.

In both years the leaf Calcium content of unweeded plants was significantly higher than values for other treatments (Table 11). The combined analysis of variance of the two-year data showed that, the differences in the calcium level of all the treatment irrespective of age was significant. The unweeded control treatment had the highest leaf Calcium (0.94%) [LSD = (0.05) = 0.086]. The level of Calcium in the treatments in decreasing order was: 0Kg > 4Kg > 2Kg > H.W > 3Kg > 1Kg.

Table 11: Influence of pre-emergence application of Metobromuron + Metolachlor (Galex) on calcium content of soybean leaves in 1986 and 1987.

1986

Galex Kg a.i/ha	PLANT'S AGE (WAE) Calcium content of soybean leaves (%/g dry weight of leaf biomass) 2	4	6	8	10	12	Mean	r	LSD
0	0.71a	0.86b	1.00a	0.95a	1.51a	1.63a	1.11a	0.94	0.0079
1	0.63c	0.75e	0.77f	0.88c	1.00e	1.25d	0.88d	0.88	
2	0.67b	0.79d	0.81e	0.91b	1.16b	1.27c	0.94c	0.98	
3	0.60d	0.68f	0.91c	0.94a	1.14c	1.47b	0.96b	0.96	
4	0.48e	0.88a	0.95b	0.91b	1.02d	1.47b	0.95bc	0.90	
H.W.	0.72a	0.83c	0.88d	0.83d	1.15c	1.26cd	0.95bc	0.92	
Mean	0.64	0.80	0.90	0.90	1.16	1.39	0.97		
LSD (0.05) = 0.0079									0.019*

1987

0	0.42c	0.42f	0.73a	0.73a	0.83b	1.26b	0.78a	0.93	0.0061
1	0.30d	0.48e	0.58e	0.69b	0.72d	1.06e	0.65d	0.96	
2	0.45b	0.58b	0.65c	0.61d	0.94a	1.11d	0.72b	0.93	
3	0.41c	0.65a	0.75a	0.65c	0.62f	1.07e	0.69c	0.78	
4	0.50a	0.56c	0.61d	0.58e	0.70e	1.35a	0.72b	0.78	
H.W.	0.50a	0.50d	0.67b	0.69b	0.75c	1.13c	0.71b	0.91	
Mean	0.44	0.53	0.66	0.66	0.76	1.16	0.71		
LSD (0.05) = 0.0061									0.015*

(a) Figures followed by the same letter(s) within a column, in each year, are not significantly different (P=0.05) using DMRT.

(b). * represent the LSD for treatment X age interaction.

In 1986, the soybean plants on the unweeded plots consistently had higher leaf Calcium compared with the plants on herbicide treated plots, throughout the sampling dates. Similarly in 1987, the unweeded plant contained higher leaf calcium than most of the galex treated plants at 6, 8 and 12WAE.

4.11.4 LEAF MAGNESIUM (Mg)

The magnesium content of soybean leaves decreased with age of plant (Table 12). Thus there was a negative correlation (r = -0.99 and -0.98 in 1986 and 1987 respectively) between leaf magnesium and plant age. The highest Mg level, averaged across herbicide treatments occurred at the 2WAE. The lowest leaf Mg in 1986 and 1987 occurred at 12WAE. The observed leaf Mg level in the unweeded soybean plant, irrespective of age was the highest among all the treatments in 1986, while the lowest leaf Mg was observed in plants on 2-4Kg.a.i/ha metolachlor - metobromuron treated plots (Table 12).

Similarly in 1987, the unweeded plant had the highest leaf Mg compared to the plants on 2Kg.a.i/ha metolachlor + metobromuron treated plots with the lowest leaf Mg. This difference in leaf Mg due to the herbicide treatments was significant in both years (Table 12). The mean soybean leaf Mg irrespective of age and herbicide treatments was 0.36% in 1986 and 0.34% in 1987. The herbicide treatment generally increased the leaf Mg content of soybean plants at 4WAE compared to the unweeded control,

Table 12: Influence of pre-emergence application of Metobromuron + Metolachlor (Galex) on magnesium content of soybean leaves in 1986 and 1987.

1986

Galex Kg a.i/ha	PLANT'S AGE (WAE) Magnesium content of soybean leaves (%/g dry weight of leaf biomass) 2	4	6	8	10	12	Mean	r	LSD
0	0.43b	0.4Cbc	0.40ab	0.34b	0.33b	0.31a	0.37a	-0.90	0.0055
1	0.41c	0.43a	0.41a	0.38a	0.30c	0.22d	0.36b	-0.90	
2	0.43b	0.41b	0.38c	0.31c	0.27e	0.27b	0.35c	-0.85	
3	0.46a	0.44a	0.37d	0.29d	0.29cd	0.27b	0.35c	-0.75	
4	0.43b	0.44a	0.40ab	0.31c	0.28de	0.27b	0 35c	-0.88	
H.W.	0.43b	0.41b	0.39bc	0.35b	0.35a	0.25c	0 36b	-0.83	
Mean	0.43	0.42	0.39	0.33	0.30	0.26	0.36		
LSD (0.05) = 0.0055									0.014*

1987

0	0.49a	0.41b	0.40b	0.35a	0.25b	0.27a	0.36a	-0.96	0.0057
1	0.50a	0.40c	0.36c	0.35a	0.25b	0.21e	0.35b	-0.98	
2	0.41b	0.42b	0.37c	0.32b	0.25b	0.23cd	0.33d	-0.97	
3	0.31d	0.44a	0.44a	0.32b	0.25b	0.24bc	0.34c	-0.81	
4	0.41b	0.44a	0.40a	0.25c	0.30a	0.25b	0.34c	-0.86	
H.W.	0.43b	0.40c	0.39b	0.35a	0.26b	0.22de	0.34c	-0 95	
Mean	0.44	0.42	0.39	0.32	0.26	0.24	0.34		
LSD (0.05) = 0.0057									0.014*

(a) Figures followed by the same letter(s) within a column, in each year, are not significantly different (P=0.05) using DMRT.

(b) * represent the LSD for treatment X age interaction.

but the unweeded plants had higher leaf Mg from 10-12WAE compared to the plants on the herbicide treated plots in 1986. In 1987, while the leaf Mg content of the unweedec plants was similar to that of plants on 1Kg.a.i/ha metolachlor + metobromuron treated plants, it was higher than that of plants on other herbicide treated plots at 2WAE, but at 4WAE the plants on the herbicide treated plots generally contained higher leaf Mg, compared to the unweeded plants. This situation was reversed from 8-12WAE.

The correlation of leaf Mg with leaf total chlorophyll for the two years was r = 0.62. The level of Mg in the treatments in decreasing order was: 0Kg > 1Kg > H.W > 4Kg > 3Kg > 2Kg.

4.11.5 LEAF IRON (Fe)

In 1986 and 1987, the iron content of soybean leaves generally decreased with age except for the slight increase at 12WAE (Table 13). However, the leaf Fe level and plant age were negatively correlated (r = -0.12 and 0.27 respectively) in both years.

The leaf Fe content of plants on 3kg a.i/ha metolachlor + metobromuron treated plots was significantly higher: than the observed values in other treatments. However leaf Fe in the plants on unweeded plots, 1 and 4kg.a.i/ha metolachlor - metobromuron treated plots was not significantly different from each other. The leaf Fe in plants on the unweeded plots was the lowest (Table 13).

Table 13: Influence of pre-emergence application of Metobromuron + Metolachlor (Galex) on Iron content of soybean leaves in 1986 and 1987.

1986

Galex Kg a.i/ha	PLANT'S AGE (WAE) Iron content of soybean leaves (ppm/g dry weight of leaf biomass) 2	4	6	8	10	12	Mean	r	LSD
0	1197b	625a	150d	103b	153b	450a	446e	-0.66	7.25
1	1190d	696d	150d	190a	100c	437a	461d	-0.70	
2	1143c	700d	213c	197a	157b	453a	477c	-0.71	
3	1300a	1117a	247b	180a	157b	440a	574a	-0.77	
4	1023c	829b	150d	197a	153b	420b	462d	-0.71	
H.W.	1060a	750c	320a	197a	213a	450a	498b	-0.75	
Mean	1152	786	205	177	156	442	486		
LSD (0.05) = 7.25									17.80*

1987

0	1057a	607c	350c	550c	530a	703d	633f	-0.41	5.72
1	940e	533e	407c	613b	507b	913b	652d	-0.002	
2	1200b	653a	397c	657a	453c	460e	703b	-0.37	
3	953e	557d	507b	520d	413e	803c	626e	-0.30	
4	1250a	630b	560a	400f	450c	1100a	732a	-0.22	
H.W.	1147b	607c	350d	503e	437d	923b	665c	-0.25	
Mean	1091	598	429	541	468	884	669		
LSD (0.05) = 5.72									14.04*

(a) Figures followed by the same letter(s) within a column, in each year, are not significantly different (P=0.05) using DMRT.

(b) *. represent the LSD for treatment X age interaction.

In 1987, the plants on 4kg.a.i/ha metolachlor + metobromuron treated plots had the highest leaf Fe, while the observed leaf Fe in plants on 3kg a.i/ha metolachlor + metobromuron treated plots was the lowest. The differences observed in the soybean leaf Fe due to herbicide treatments was significant in both years. The mean soybean leaf Fe of 486.31ppm observed in 1986 irrespective of age and herbicide treatment was significantly lower than the 668.40ppm obtained in 1987 [LSD (0.05) = 66.27]. The level of leaf Fe in the treatments in decreasing order was 3kg > 4kg > 2kg > H.W. > 1kg > 0kg. The treatment X age interaction effect on leaf iron was significant in each year. In 1986, the plants on 3kg a.i/ha metolachlor + metobromuron treated plots had the highest leaf Fe compared to other herbicide treatments from 2-6WAE, but the leaf Fe in plants on all the herbicide treated plots was similar from 8 - 12WAE. In 1987, the plants on 2 and 4kg a.i/ha metolachlor + metobromuron treated plots was higher than that of plants on the unweeded and hoe-weeded plots from 2-6 WAE, whereas, the unweeded plant had higher leaf Fe compared to the 2kg a.i/ha metolachlor + metobromuron treated plots from 10-12 WAE.

4.11.6 LEAF MANGANESE (Mn)

Averaged across treatments, leaf manganese decreased up to 6WAE, thereafter it increased till the final sampling at 12WAE, in both years (Table 14). The highest leaf Mn concentration was obtained at 12 WAE. The correlation of leaf Mn with age of plant was r = 0.58 and 0.38 respectively in 1986 asnd 1987.

Table 14: Influence of pre-emergence application of Metobromuron + Metolachlor (Galex) on Manganese content of soybean leaves in 1986 and 1987.

1986

Galex Kg a.i/ha	PLANT'S AGE (WAE) Manganese content of soybean leaves (ppm/g dry weight of leaf biomass) 2	4	6	8	10	12	Mean	r	LSD
0	81c	74c	98a	80.b	117a	120b	95.00b	0.82	0.974
1	100b	100a	81b	71c	89d	99c	90.00c	-0.21	
2	73[d]	76c	74c	79b	98c	139a	89.33d	0.83	
3	103a	98b	59e	69c	80e	122b	88.50[e]	0.12	
4	100b	98b	72c	79b	107b	139a	99.17a	0.61	
H.W.	99b	99b	69d	99a	109b	120b	99.17a	0.52	
Mean	92.6	90.83	75.50	79.50	100	123	93.61		
LSD (0.05) = 0.974									2.387*

1987

0	71c	75b	62b	65b	70c	80c	70.50b	0.40	1.605
1	69c	65c	66a	65b	76b	75d	69.33bc	0.24	
2	80b	65c	60b	62bc	80a	99b	74.33a	0.51	
3	71c	64c	56c	70a	75b	71e	67.83c	-0.34	
4	81a	65c	53c	56d	75b	120a	75.00a	0.50	
H.W.	84a	80a	61b	61c	65d	71e	70.33b	-0.39	
Mean	76	69.00	59.67	63.17	73.50	86.00	71.22		
LSD (0.05) = 1.605									3.95*

(a) Figures followed by the same letter(s) within a column, in each year, are not significantly different (P=0.05) using DMRT.

(b) * represent the LSD for treatment X age interaction.

In 1986 the leaf Mn (irrespective of age) observed in plants on the hoe-weeded and 4kg a.i/ha metolachlor - metobromuron treated plots was the highest. Similarly in 1987 the plants on the 4kg a.i/ha metolachlor + metobromuron treated plots had the highest leaf Mn which was not significantly different from the observed in plants on the 2kg a.i/ha galex treated plots. These differences in the leaf Mn level due to the herbicide treatments was significant in each year. The level of leaf Mn in the treatments in decreasing order was 4kg > H.W. > Okg > 2kg > 1kg > 3kg.

In 1986, the leaf Mn in the unweeded plants was generally lower compared to the observed values in plants on the herbicide treated plots from 2-4WAE, but this was reversed from 6-10 WAE. The 2 and 12WAE marked the period of highest leaf Mn. The leaf Mn in the hoe-weeded plants was higher than that of the plants on 4kg a.i/ha metolachlor + metobromuron treated plots from 2 - 8 WAE. The hoe-weeded plants had higher leaf Mn than the plants on all the herbicide treated plots at 2-4 WAE, but the reverse was the case from 10-12 WAE.

4.11.7 LEAF ZINC (Zn)

The soybean leaf Zn increased from 2-4 WAE, after which it declined with age in both years (Table 15). The highest leaf Zn was recorded at 4WAE in both years and this was significantly higher than the levels obtained at other

Table 15: Influence of pre-emergence application of Metobromuron + Metolachlor (Galex) on Zinc content of soybean leaves in 1986 and 1987.

1986

Galex Kg a.i/ha	PLANT'S AGE (WAE) Zinc content of soybean leaves (ppm/g dry weight of leaf biomass) 2	4	6	8	10	12	Mean	r	LSD
0	68a	79c	61c	58c	67a	63a	66.00a	-0.46	0.57
1	58c	75d	66b	55d	61b	55c	61.67d	0.47	
2	62b	82b	67ab	68a	56c	48e	63.83c	-0.68	
3	53d	100a	63b	58c	5[illegible]c	51d	63.33c	-0.44	
4	51e	72e	58d	60b	60b	48e	58.17e	-0.31	
H.W.	68a	78c	68a	60b	6[illegible]b	57b	65.17b	-0.81	
Mean	60	81	63.83	59.83	59.83	53.67	63.03		
LSD (0.05) = 0.57									1.391*

1987

0	128a	113f	98c	89d	65e	60e	92.17d	0.99	0.643
1	116b	172a	118b	100c	75b	63d	107.33a	-0.80	
2	80e	115e	120a	79f	68d	73b	89.17f	0.52	
3	75f	141c	90d	114a	75c	68c	93.50c	-0.40	
4	90[illegible]	118d	83e	109b	78a	72b	91.67e	-0.54	
H.W.	109a	116b	73f	81e	68d	76a	95.33b	-0.64	
Mean	99.60	137.50	97.00	95.30	71.17	69.67	94.86		
LSD (0.05) = 0.643									1.567*

(a) Figures followed by the same letter(s) within a column, in each year, are not significantly different (P=0.05) using DMRT.

(b) * represent the LSD for treatment X age interaction.

sampling dates.The correlation between Zn level and age of plant was r = -0.45 and -0.49 respectively in both years.

The unweeded soybean plant had the highest leaf Zn content in 1986 while in 1987 the plants on the 1kg a.i/ha metolachlor + metobromuron treated plots had the highest leaf Zn, averaged across sampling dates. On the other hand, the lowest Zn levels were recorded from the plants on 4kg a.i/ha metolachlor + metobromuron treated plots in 1986 and 2kg a.i/ha metolachlor + metobromuron treated plots in 1987 (Table 15). These differences in leaf Zn in response to the herbicide treatments was significant in each year.

The combined analysis of the 2-year data showed that the 84.53ppm Zn obtained in the plants on 1kg a.i/ha metolachlor + metobromuron treated plots was the highest, this was followed by 80.42ppm Zn in the hoe-weeded plants. The 75.03ppm Zn in the plants on 4kg a.i/ha metolachlor - metobromuron treated plots was the lowest. This differences in leaf Zn due to the herbicide treatments was significant on the whole. However, the 63.03ppm mean leaf Zn, irrespective of age and herbicide treatment, in 1986 was significantly lower than 94.86ppm Zn recorded in 1987 [LSD (0.05) = 8.02]. The level of leaf Zn in the treatments in decreasing order was: 2kg > 1kg > 4kg > H.W. > 0kg > 3kg.

The unweeded and hoe-weeded plants had higher leaf Zn content at 2, 10 and 12 WAE compared to the plants on herbicide treated plots, whereas the plants on herbicide treated plots (especially 2 and 3kg a.i/ha) had higher leaf

Zn at 4 WAE in 1986. In 1987, the plants on 1kg a.i/ha metolachlor + metobromuron treated plots had higher leaf Zn compared to other treatments at 4 WAE. Similarly from 8-12 WAE the herbicide treatments produced higher leaf Zn compared to the unweeded control treatment.

4.11.8 SUMMARY ON LEAF MINERAL ELEMENTS

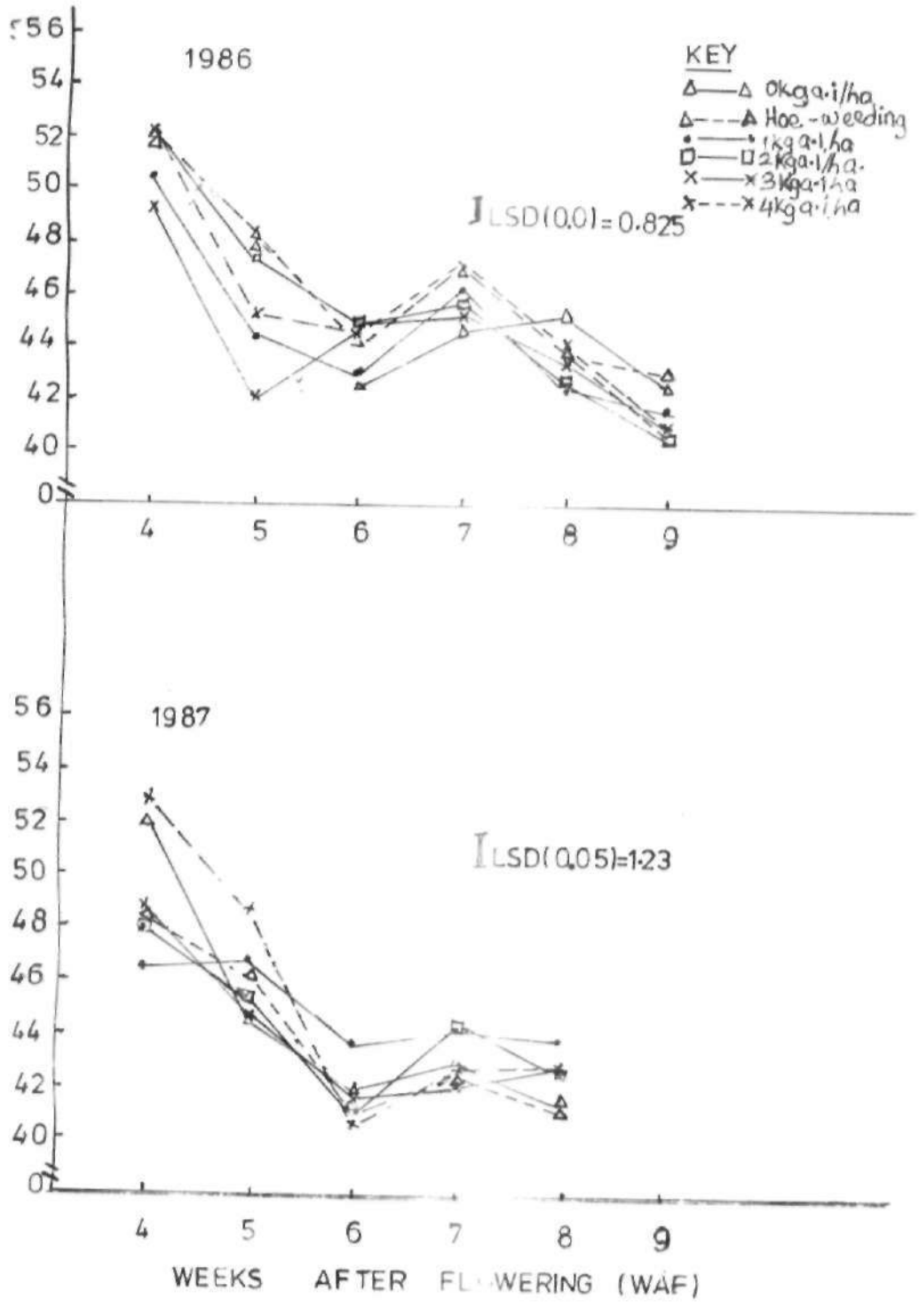
The soybean leaf phosphorus and magnesium decreased with plant maturity in both years, whereas the calcium level increased with the age of the plant. The leaf iron decreased in level till the 10 WAE, while manganese decreased also till 6 WAE, before the level of each element subsequently increased. On the other hand Zn level increased from the 2-4 WAE and leaf potassium from 2-6 WAE before they decreased with age in both years.

The level of these mineral elements in soybean leaf, in decreasing order was: K > Ca > Mg > P > Fe > Mn > Zn. The herbicide treatments significantly increased the level of leaf phosphorus, potassium and iron above that of the unweeded control treatment. Conversely, the unweeded control had a significantly higher level of leaf calcium and magnesium than the plants on the treated plots.

4.12 SEED PROTEIN

The soybean seed protein decreased with seed maturity, with the exception of a slight but non-significant increase at the 7 WAF in both years (Fig. 5). The highest seed protein content was obtained at 4 WAF, in both years. There

Fig. 5 Influence of pre-emergence application of Metolachlor +Metobromuron (Galex) on Soybean seed protein in 1986 and 1987.



was a decline in the seed protein content between 5 and 6 WAF and after 7 WAF. The correlation of seed protein level in the seed with the age of the seed was r = -0.85 and -0.84 in 1986 and 1987 respectively. The range of seed protein content during soybean seed development was 41.60 - 51.31% in 1986 and 42.34 - 49.61% in 1987.

The hoe-weeded soybean plants had the highest seed protein level in 1986, while the plants on 4kg a.i/ha metolachlor + metobromuron treated plots had the highest in 1987. In 1986, the plants on 3kg.a.i/ha metolachlor - metobromuron treated plots had the lowest seed protein while the hoe-weeded plants had the lowest seed protein content in 1987. The differences in seed protein in response to the herbicide treatments was significant in each year.

The combined analysis of variance of the two-year data showed that the 45.77% seed protein in plants that received 2kg a.i./ha metolachlor + metobromuron treatment was the highest, followed by the 45.71% seed protein in the plants on 4kg a.i/ha metolachlor + metobromuron treated plots. However the 44.33% seed protein in plants on 3kg a.i/ha metolachlor + metobromuron treated plots was the lowest.

The treatment X age interaction was significant on the seed protein in each year. In 1986, the seed protein in all the treatments was not significantly different (except the lower seed protein in plants on 3kg a.i/ha metolachlor - metobromuron treated plots) at 4 WAF. While the seed protein in the unweeded plants was lower than the observed

Table 16: Influence of Pre-emergence application of Metobromuron + Metolachlor (Galex) on nitrogen content of soybean seeds in 1986 and 1987.

1986

Galex	PLANT'S AGE (WAE) Nitrogen content of soybean seeds (%/g dry weight of seed biomass)								
Kg a.i/ha	4	5	6	7	8	9	Mean	r	LSD
0	8.30ab	7.65a	6.79a	7.14b	7.23a	6.79a	7.32a	-0.78	0.18
1	8.07ab	7.11bc	6.86a	7.40ab	6.80a	6.66a	7.15bc	-0.76	
2	8.36a	7.59a	7.19a	7.65a	6.82a	6.48a	7.35a	-0.90	
3	7.80b	6.73c	7.16a	7.25ab	6.92a	6.56a	7.08c	-0.68	
4	8.35a	7.25ab	7.11a	7.55ab	7.13a	6.56a	7.32a	-0.80	
H.W.	8.32ab	7.72a	7.07a	7.53ab	7.00a	6.88a	7.42a	-0.87	
Mean	8.2	7.34	7.03	7.42	6.98	6.66	7.27		
LSD (0.05) = 0.18									0.44*
					1987				
0	8.32a	7.11b	6.68a	6.86a	6.60a		7.11ab	-0.83	0.22
1	7.41c	7.48ab	7.01a	7.04a	6.99a		7.19ab	-0.87	
2	7.68bc	7.27ab	6.54a	7.09a	6.79a		7.07ab	-0.71	
3	7.97ab	7.17b	6.66a	6.72a	6.83a		7.07ab	-0.80	
4	8.40a	7.77a	6.48a	6.82a	6.83a		7.27a	-0.81	
H.W.	7.75bc	7.39ab	6.58a	6.79a	6.61a		7.02b	-0.88	
Mean	7.94	7.37	6.66	6.89	6.78		7.12		
LSD (0.05) = 0.20									0.49*

(a) Figures followed by the same letter(s) within a column, in each year, are not significantly different (P=0.05) using DMRT.

(b) * represent the LSD for treatment X age interaction.

in plants on the herbicide treated plots at 6 and 7 WAF, it was generally higher at 9 WAF. In 1987, the seed protein in all the treatment was significantly not different at 5-8 WAF. At 4 WAF, the unweeded plants and plants on 4kg a.i/ha metolachlor + metobromuron treated plots had a significantly higher seed protein compared to other treatments.

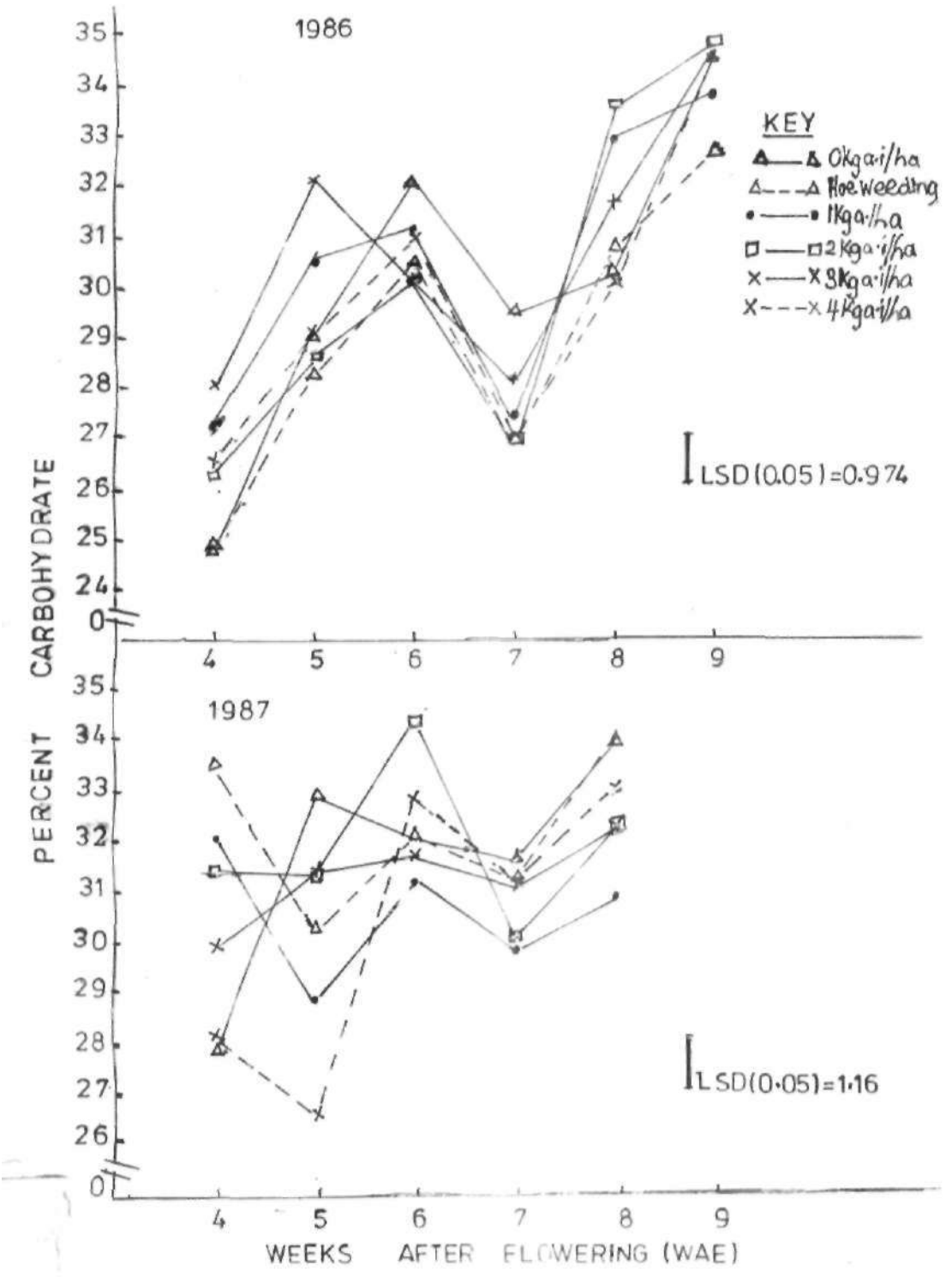
Since the seed protein is a 6.25 factor of seed nitrogen the trend of soybean seed nitrogen (Table 16) is therefore the same as the seed protein. The seed nitrogen in decreasing order in the treatments was: 4kg > 2kg > 0kg > H.W. > 3kg > 1kg.

4.13 SEED CARBOHYDRATE

The soybean seed carbohydrate level was generally low. when compared with seed carbohydrate level of other crop plants (Fig. 6). Soybean seed carbohydrate level generally increased from 4-6 WAF and declined at 7 WAF; before it increased again at 8 WAF in both years. The correlation of seed carbohydrate with seed age was r = 0.79 and 0.72 n 1986 and 1987 respectively.

The 30.71% seed carbohydrate obtained in plants on 3kg a.i/ha metolachlor + metobromuron treated plots was the highest in 1986, this was followed by the 30.45% carbohydrate obtained in plants on the 1kg a.i/ha metolachlor + metobromuron treated plots. The lowest seed carbohydrate was obtained in plants on hoe-weeded plots. This differences in seed carbohydrate due to the herbicice

Fig. 6 Influence of pre-emergence application of Metolachlor + Metobromuron (Galex) on Soybean seed carbohydrate in 1986 and 1987.



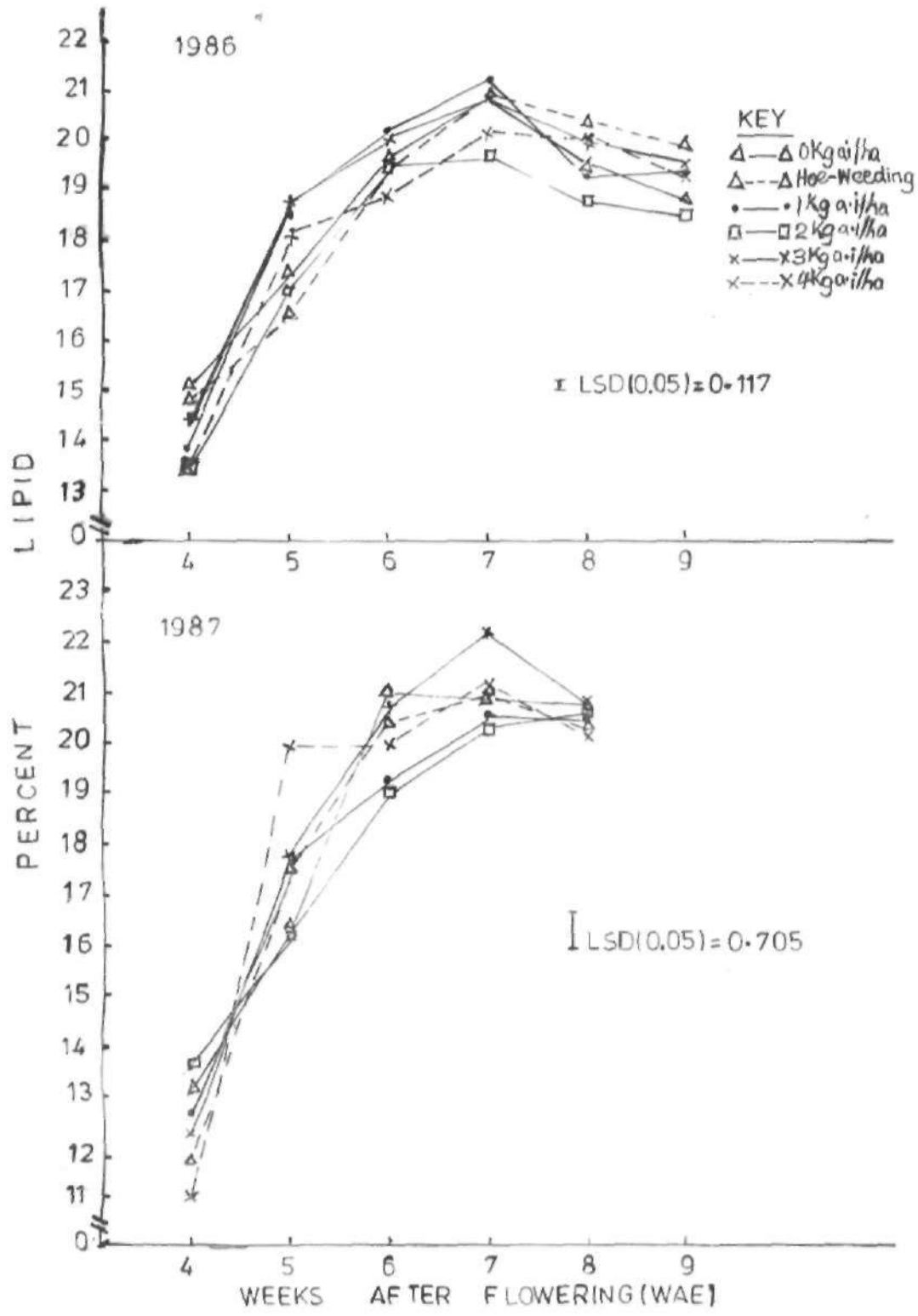
treatment was significant. However, in 1987, the difference in seed carbohydrate of the treatments was not significant. The combined analysis of variance of 1986 and 1987 data showed that the differences in seed carbohydrate due to the herbicide treatments in the two years was on the whole not significant.

The treatment X age interaction was not significant on seed carbohydrate in 1986. In 1987, the seed carbohydrate in the control plants was generally not significantly different from one sampling date to another, compared to the plants on herbicide treated plots. The seed carbohydrate in plants on most of the herbicide treated plots was not significantly different from each other at 6-8 WAF (with the exception of higher seed carbohydrate level in plants on 2kg a.i/ha metolachlor + metobromuron treated plots at 6 WAF). On the other hand the seed carbohdyrate in plants on 4kg a.i/ha metolachlor + metobromuron treated plots was significantly lower than the observed values in other treatments.

4.14 SEED LIPID

In 1986 and 1987, the seed lipid content, averaged across herbicide treatments increased with seed development up till 7 WAF, after which a non-significant decline was observed (Fig.7).The lowest seed lipid was recorded at 4 WAF, in both years, while the highest seed lipid was obtained at 7 WAF in both years. The correlation of seed

Fig. 7 Influence of pre-emergence application of Metolachlor + Metobromuron (Galex) on Soybean seed Lipid in 1986 and 1987.



lipid with age of seed was r = 0.76 and 0.88 in 1986 and 1987 respectively.

The plants on 3kg a.i/ha metolachlor + metobromuron treated plots produced the highest seed lipid content in 1986 and 1987 (Fig. 7). Likewise, 2kg a.i/ha metolachlor - metobromuron treatment also produced the lowest seed lipid in both years. In 1986, the seed lipid in plants on 3kg a.i/ha metolachlor + metobromuron treated plots was significantly higher than the values obtained in other treatments. While the differences in seed lipid was significant in 1986, it was not significant in 1987.

The mean value of the 2-year data showed that the galex treated plants had lower seed lipid except for the 18.83% seed lipid in plants on the 3kg a.i/ha metolachlor - metobromuron treated plots which was significantly higher than the values obtained in plants of other treatments. This was followed by 18.48% seed lipid in the unweeded plants and 17.97% in the plants on 2kg a.i/ha metolachlor - metobromuron treated plots was the lowest. This differences in seed lipid due to herbicide treatments was on the whole significant [LSD (0.05) = 0.29).

The treatment X age interaction was significant in each year on seed lipid. In 1986, the seed lipid in hoe-weeded plants was significantly higher at 4, 8 and 9 WAF, but lower at 5WAF compared with the plants on herbicide treated plots. In 1987, the seed lipid in plants on 4kg a.i/ha metolachlor + metobromuron was lower at 4 WAF, but higher at 5 WAF

compared to other treatments, while the seed lipid in all treatments was not significantly different at 8 WAF, the seed lipid in plants on 1 and 2kg a.i/ha metolachlor + metobromuron treated plots was lower compared to other treatments at 6 and 7 WAF.

4.15 MINERAL ELEMENTS

4.15.1 SEED PHOSPHORUS (P):

The percent phosphorus in soybean seed decreased with seeds age in both 1986 and 1987 (Table 17). The highest seed P level, irrespective of treatment, was obtained at 4 WAF in both years. The correlation coefficient of seed P and stage of seed maturity was r=-0.81 and -0.87 in 1986 and 1987 respectively.

In 1986 and 1987, the seed P level of soybean plants on 4kg a.i/ha metolachlor + metobromuron treated plots was significantly higher than seed P of plants of other treatments while the unweeded plants had the lowest seed P in both years. The combined analysis of variance of two-year data showed that soybean seed P level of 0.49% in plants on 4kg a.i/ha metolachlor + metobromuron treated plots was significantly higher than the seed P level of plants in other treatments (Table 17). The level of seed P in the treatments in decreasing order was: 4kg > 2kg > 1kg > 3kg > H.W. > 0kg.

The treatment X age interaction was significant on seed P in each year. In 1986, seed P of the plants on the

Table 17: Influence of pre-emergence application of Metobromuron + Metolachlor (Galex) on Phosphorus content of soybean seeds in 1986 and 1987.

1986

Galex Kg a.i/ha	PLANT'S AGE (WAE) Phosphorus content of soybean seeds (%/g dry weight of seed biomass) 4	5	6	7	8	9	Mean	r	LSD
0.	0.57d	0.51d	0.47c	0.44c	0.43c	0.40c	0.47f	-0.71	0.005
1	0.65b	0.51d	0.48c	0.46b	0.48a	0.39c	0.50d	-0.77	
2	0.67a	0.57a	0.50b	0.51a	0.46b	0.46a	0.53b	-0.91	
3	0.57c	0.55b	0.51b	0.50a	0.48a	0.43b	0.51c	-0.88	
4	0.67a	0.58a	0.55a	0.50a	0.48a	0.43b	0.54a	-0.87	
H.W.	0.63b	0.53c	0.51b	0.46b	0.43c	0.39c	0.49e	-0.65	
Mean	0.63	0.54	0.50	0.48	0.46	0.42	0.51		
LSD (0.05) = 0.005									0.0122*

1987

0	0.47c	0.36f	0.34d	0.32e	0.29c	0.36d	-0.69	0.002
1	0.50b	0.40c	0.36c	0.35b	0.31b	0.38b	-0.72	
2	0.46d	0.37e	0.34d	0.34c	0.36a	0.37c	-0.73	
3	0.46d	0.41b	0.33e	0.33d	0.29c	0.36d	-0.96	
4	0.61a	0.51a	0.43a	0.38a	0.29c	0.44a	-1.00	
H.W.	0.50b	0.39d	0.37b	0.34c	0.29c	0.38b	-0.69	
Mean	0.50	0.41	0.36	0.34	0.31	0.38		
LSD (0.05) = 0.00182								0.00445*

(a) Figures followed by the same letter(s) within a column, in each year, are not significantly different (P=0.05) using DMRT.

(b) * represent the LSD for treatment X age interaction.

Table 18: Influence of pre-emergence application of Metobromuron + Metolachlor (Galex) on Potassium content of soybean seeds in 1986 and 1987.

1986

Galex Kg a.i/ha	PLANT'S AGE (WAF) Potassium content of soybean seeds (%/g dry weight of seed biomass) 4	5	6	7	8	9	Mean	r	LSD
0	1.74d	1.69a	1.48ab	1.43b	1.24e	1.23d	1.47e	-0.98	0.0097
1	1.98a	1.60b	1.40d	1.50a	1.40c	1.37a	1.54b	-0.82	
2	1.97a	1.56c	1.45c	1.45b	1.36d	1.24d	1.51d	-0.90	
3	1.5[illegible]	1.45d	1.46bc	1.43b	1.45b	1.32c	1.45f	-0.86	
4	1.9[illegible]	1.60b	1.48ab	1.40c	1.48a	1.43a	1.55a	-0.80	
H.W.	1.8[illegible]	1.60b	1.50a	1.40c	1.43b	1.43a	1.53c	-0.84	
Mean	1.84	1.58	1.46	1.44	1.39	1.34	1.51		
LSD (0.05) = 0.0057									0.02*

1987

0	1.92[illegible]	1.60c	1.32d	1.28a	1.24a		1.45b	-0.88	
1	1.92[illegible]	1.64b	1.20d	1.28a	1.21b		1.45b	-0.88	0.005
2	1.84[illegible]	1.61c	1.28b	1.28a	1.21b		1.44c	-0.93	
3	1.88[illegible]	1.54d	1.20d	1.25b	1.17c		1.41d	-0.90	
4	1.92[illegible]	1.76a	1.34a	1.24b	1.20b		1.49a	-0.95	
H.W.	1.78[illegible]	1.63b	1.13e	1.28a	1.24a		1.41d	-0.81	
Mean	1.87	1.63	1.23	1.27	1.21		1.44		
LSD (0.05) = 0.0046									0.011*

(a) Figures followed by the same letter(s) within a column, in each year, are not significantly different (P=0.05) using DMRT.

(b) * represent the LSD for treatment X age interaction.

herbicide treated plots was generally higher compared to the controls in all sampling dates. Similarly in 1986, the plants on 1 and 4kg.a.i/ha metolachlor + metobromuron treated plots had higher seed P compared to the unweeded plants throughout the sampling dates.

4.15.2 SEED POTASSIUM (K)

The potassium content of soybean seed also decreased with seed maturity in both years (Table 18). For instance, the highest seed K level was obtained at 4 WAF. These values were each significantly higher than the seed K obtained at 5 WAF in both years. The correlation coefficient of seed K with seed maturity was r = -0.91 and -0.90 in 1986 and 1987 respectively.

In both years the seed K level of plants on 4kg a.i/ha metolachlor + metobromuron treated plots, irrespective of age was higher than the observed seed K level of other treatments. This differences was significant in each year (Table 18). The level of seed K in the treatments in decreasing order was: 4kg > 1kg > 2kg > H.W. > 0kg > 3kg.

In 1986, most of the herbicide treatments produced plants with higher seed K at 4, 8 and 9 WAF, but lower seed K at 5 WAF compared to the unweeded plants. However, in 1987, the hoe-weeded plants had lower seed K at 4 and 6 WAF, but higher seed K at 8 WAF, compared to the plants on the herbicide treated plots.

4.15.3 SEED CALCIUM (Ca)

Table 19: Influence of Pre-emergence application of Metobromuron + Metolachlor (Galex) on Calcium content of soybean seeds in 1986 and 1987.

1986

0 Galex Kg a.i/ha	PLANT'S AGE (WAF) Calcium content of soybean seeds (%/g dry weight of seed biomass)								
	4	5	6	7	8	9	Mean	r	LSD
0	0.45c	0.26d	0.25d	0.21d	0.23c	0.26a	0.28e	-0.66	0.004
1	0.50b	0.28c	0.41b	0.39b	0.19d	0.23b	0.33b	-0.74	
2	0.38e	0.30b	0.43a	0.43a	0.38a	0.24b	0.36a	-0.33	
3	0.40d	0.39a	0.24d	0.26c	0.28b	0.24b	0.30d	-0.80	
4	0.54a	0.29bc	0.21f	0.26c	0.23c	0.25a	0.30d	-0.67	
H.W.	0.44a	0.39a	0.30c	0.24c	0.19d	0.24b	0.32c	-0.89	
Mean	0.47	0.32	0.31	0.330	0.25	0.25	0.32		
LSD (0.05) = 0.0042									0.010

1987

0	0.36d	0.41b	0.40a	0.33d	0.33b		0.36c	-0.59	0.003
1	0.46b	0.43a	0.40a	0.35c	0.33b		0.40a	-0.40	
2	0.43c	0.38c	0.36c	0.43a	0.33b		0.39b	-0.54	
3	0.50a	0.43a	0.38b	0.38b	0.33b		0.40a	-0.40	
4	0.30e	0.35c	0.36c	0.33d	0.31c		0.34d	-0.14	
H.W.	0.43c	0.43a	0.36c	0.43a	0.34a		0.40a	-0.64	
Mean	0.42	0.41	0.38	0.38	0.33		0.38		
LSD (0.05) = 0.0034									0.008

(a) Figures followed by the same letter(s) within a column, in each year, are not significantly different (P=0.05) using DMRT.

(b) * represent the LSD for treatment X age interaction.

In 1986 and 1987, the calcium level of soybean seed decreased with seed maturity (Table 19). The lowest seed Ca levels was at 9 and 8 WAF (harvest) respectively in both years, while the highest seed calcium level was obtained at 4 WAF in both years. The correlation coefficient of seed Ca with seed maturity was r = -0.87 and -0.95 respectively in 1986 and 1987.

In 1986, the plants on 2kg a.i/ha metolachlor + metobromuron treated plots had the highest seed Ca level, while in 1987, it was the plants on 2 and 3kg a.i/ha metolachlor + metobromuron treated plots that had the highest seed Ca. The lowest seed Ca content was obtained in unweeded plants in 1986 and in plants on 4kg a.i/ha metolachlor + metobromuron treated plots in 1987. These differences was significant in each year. The seed Ca content of the treatments in decreasing order was: 2kg > 1kg > H.W. > 3kg > 0kg > 4kg.

In 1986, the herbicide treatments resulted in higher seed Ca at 5 and 7 WAF, but lower seed Ca at 9 WAF (except the plants on 4kg a.i/ha metolachlor + metobromuron treated plots) compared to the unweeded treatments. In 1987, the plants on the herbicide treated plots (except 4kg a.i/ha metolachlor + metobromuron treatment) had higher seed Ca at 4 and 7 WAF, than the unweeded plants. But the seed Ca in all the treatments (except hoe-weed and 4kg a.i/ha metolachlor + metobromuron treatments) was not significantly different from each other at 8 WAF.

Table 20: Influence of pre-emergence application of Metobromuron + Metolachlor (Galex) on Magnesium content of soybean seeds in 1986 and 1987.

1986

Galex Kg a.i/ha	PLANT'S AGE (WAF) Magnesium content of soybean seeds (%/g dry weight of seed biomass) 4	5	6	7	8	9	Mean	r	LSD
0	0.24c	0.27a	0.26a	0.23a	0.21a	0.23a	0.24a	-0.63	0.021
1	0.32a	0.25a	0.24a	0.23a	0.24a	0.23a	0.25a	-0.76	
2	0.26bc	0.25a	0.25a	0.23a	0.25a	0.22a	0.24a	-0.78	
3	0.29abc	0.23a	0.26a	0.25a	0.25a	0.23a	0.25a	-0.60	
4	0.31ab	0.22a	0.25a	0.23a	0.23a	0.23a	0.25a	-0.63	
H.W.	0.27abc	0.27a	0.26a	0.24a	0.25a	0.23a	0.25a	-0.73	
Mean	0.28	0.24	0.25	0.24	0.24	0.23	0.25		
LSD (0.05) = 0.021									0.051*

1987

0	0.24b	0.25ab	0.18c	0.18c	0.18ab		0.21c	-0.84	0.0046
1	0.26a	0.26a	0.22b	0.18c	0.19a		0.22b	-0.92	
2	0.26a	0.26a	0.23ab	0.20b	0.18ab		0.23a	-0.97	
3	0.24b	0.24bc	0.24a	0.22a	0.17b		0.22b	-0.83	
4	0.25ab	0.26a	0.18c	0.20b	0.19a		0.22b	-0.83	
H.W.	0.26a	0.23c	0.22b	0.19bc	0.19a		0.22b	-0.96	
Mean	0.25	0.25	0.21	0.20	0.18		0.22		
LSD (0.05) = 0.0042									0.0102*

(a) Figures followed by the same letter(s) within a column, in each year are not significantly different (P=0.05) using DMRT.

(b) * represent the LSD for treatment X age interaction.

4.15.4 SEED MAGNESIUM (Mg)

The magnesium content of soybean seed also decreased with the stage of seed maturity in both years (Table 20). In 1986 and 1987, the seed Mg content at 4 WAF was the highest irrespective of the herbicide treatments. The lowest seed Mg level was obtained at 9 WAF in 1986 and 8 WAF in 1987 i.e. the last sampling dates (final seed harvest for each year). The correlation of seed Mg with the stage of seed maturity was r = -0.79 and -0.97 respectively in 1986 and 1987.

In 1986 and 1987, the unweeded soybean plants, irrespective of age, had the lowest seed Mg (Table 20). The differences in seed Mg due to the herbicide treatments was not significant in 1986, but significant in 1987. The seed Mg content in the treatments in decreasing order was: 1kg = 3kg > H.W. = 2kg > 4kg > 0kg.

The interaction of treatment X age was only significant in 1987 on seed Mg. The 1 and 2kg a.i/ha metolachlor - metobromuron treatments resulted in higher seed Mg in plants at 4 and 6 WAF compared with the unweeded control treatment. However, the combined analysis of 1986 and 1987 data showed that the treatment X age interaction was not significant in both years.

4.15.5 SEED IRON (Fe)

Soybean seed iron also decreased with seed maturity in both years (Table 21). In 1986, the highest seed Fe was

Table 21: Influence of pre-emergence application of Metobromuron + Metolachlor (Galex) on Iron content of soybean seeds in 1986 and 1987.

1986

Galex Kg a.i/ha	PLANT'S AGE (WAF) Iron content of soybean seeds (ppm/g dry weight of seed biomass) 4	5	6	7	8	9	Mean	r	LSD
0	130b	150a	120b	130b	100c	100c	121.67b	0.03	6.50
1	160a	150a	100c	100c	100c	150a	126.67b	-0.36	
2	150a	130b	120b	150a	150a	120b	136.67a	-0.50	
3	150a	160a	150a	100c	150a	130b	140.00a	-0.44	
4	100c	100c	150a	150a	100c	100c	116.67c	0.00	
H.W.	150a	150a	100c	110c	120b	100c	121.67b	-0.67	
Mean	140	140	123	123.3	120	116.67	127.33		
LSD (0.05) = 6.50									15.685*

1987

0	197a	197a	197a	197a	157	1c9.00a	-0.71	5.825
1	193a	187ab	200a	153d	157b	178.00bc	-0.78	
2	197a	190ab	157c	160c	167b	174.00c	-0.37	
3	170b	193ab	177b	197a	157b	178.00bc	-0.21	
4	197a	200a	157c	160c	190a	188.00a	-0.41	
H.W.	200a	183b	183b	163b	157b	181.00b	-0.18	
Mean	193.33	191.67	178.50	175	164.17	181.00		
LSD (0.05) = 5.317								13.01*

(a) Figures followed by the same letter(s) within a column, in each year, are not significantly different (P=0.05) using DMRT.

(b) * represent the LSD for treatment X age interaction.

observed at 4 and 5 WAF, while in 1987, the seed Fe at 4 WAF was the highest. The lowest seed Fe was obtained at the last sampling dates (9 and 8 WAF respectively) in both years. The correlation of seed Fe with seed age was r = -0.92 and -0.97 respectively in both years.

In 1986, the highest seed Fe, irrespective of age was recorded among the plants on 3kg a.i/ha metolachlor + metobromuron treated plots while the lowest seed Fe was recorded in the plants on 4kg a.i/ha metolachlor + metobromuron treated plots. In 1987, the unweeded soybean plants had the highest seed Fe, while the seed Fe in plants on 2kg a.i/ha metolachlor + metobromuron treated plots was the lowest. However, these differences in seed Fe due to the herbicide treatments was significant in each year (Table 21). The seed Fe content in the treatments in decreasing order was 3kg > 2kg > 0kg > 1kg > H.W. > 4kg.

In 1986, the plants on 2 and 3kg a.i/ha metolachlor + metobromuron treated plots had higher seed Fe consistently throughout the sampling dates, whereas, the plants on 4kg a.i/ha metolachlor + metobromuron treated plots had lower seed Fe at 4, 5, 8 and 9 WAF compared to other treatments. In 1987, all the treatments resulted in high and comparable seed Fe content, with the exception of the plants on 3kg a.i/ha metolachlor + metobromuron treated plots at 4 WAF. But at 8 WAF, all the treatments had lower seed Fe compared to plants on 4kg a.i/ha metolachlor + metobromuron treated plots.

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Table 22: Influence of pre-emergence application of Metobromuron + Metolachlor (Galex) on Manganese content of soybean seeds in 1986 and 1987.

1986

Galex Kg a.i/ha	PLANT'S AGE (WAP) Manganese content of soybean seeds (ppm/g dry weight of seed biomass)								
	4	5	6	7	8	9	Mean	r	LSD
0	60b	50b	50a	48a	40a	40ab	48.00b	-0.94	6.32
1	90a	64b	62a	60a	44a	30b	58.33a	-0.35	
2	86a	54b	50a	50a	52a	40ab	55.33a	-0.86	
3	76a	90a	54a	40b	40a	48a	58.00a	-0.79	
4	8[illegible]	54b	48a	54ab	44a	46ab	55.00a	-0.77	
H.W.	86[illegible]	60b	60a	44b	44a	46ab	56.67a	-0.87	
Mean	80.3	62	54.00	49.33	44	41.67	55.22		
LSD (0.05) = 5.32									15.[illegible]2*

1987

0	6[illegible]b	52d	46ab	46a	41a	45.20a	-0.95	NS
1	6[illegible]b	56cd	41b	45a	36a	47.80a	-0.93	
2	68ab	56cd	51a	50a	45a	54.00a	-0.94	
3	6[illegible]b	66ab	47a	42a	41a	51.40a	-0.89	
4	60[illegible]	70a	46ab	42a	41a	51.80a	-0.82	
H.W.	70a	62abc	45ab	50a	36a	52.60a	-0.94	
Mean	5[illegible].5	60.3	46.00	45.83	40.00	51.13		
LSD (0.05) = 5.99								8.35*

(a) Figures followed by the same letter(s) within a column, in each year, are not significantly different (P=0.05) using DMRT.

(b) * represent the LSD for treatment X age interaction.

4.15.6 SEED MANGANESE (Mn)

The soybean seed Manganese content decreased with seed maturity in both years (Table 22). In 1986, the seed Mn at 4 WAF, irrespective of herbicide treatment, was significantly higher than the values in subsequent sampling dates. Similarly in 1987, the seed Mn level at 4 and 5 WAF, was each significantly higher than the observed values in other sampling dates (Table 22). The correlation of soybean seed Mn with the seed maturity was r = -0.90 and -0.91 respectively in 1986 and 1987.

In 1986, seed Mn, on 1kg a.i/ha metolachlor + metobromuron treated plots, averaged across sampling dates, was highest, while the plants on 2kg a.i/ha metolachlor + metobromuron treated plots had the highest seed Mn in 1987. However, this value was not significantly higher than the seed Mn levels of other treatments only in 1987 (Table 22). The seed Mn content in the treatments in decreasing order was 3kg > 2kg > H.W. > 4kg > 1kg > 0kg.

Treatment X age interaction was significant in each year on seed Mn. At 4 WAF, the plants on herbicide treated plots had higher seed Mn compared to the unweeded plants. However the seed Mn of most treatments was generally not significaty different from 6-8 WAF. In 1987, the seed Mn in all the treatments was not significantly different at 4 WAF (except in hoe-weeded plant) and at 8 WAF (except the plants on 2kg a.i/ha metolachlor + metobromuron treated plots).

Table 23: Influence of pre-emergence application of Metobromuron + Metolachlor (Galex) on Zinc content of soybean seeds in 1986 and 1987.

1986

Galex Kg a.i/ha	PLANT'S AGE (WAF) Zinc content of soybean seeds (ppm/g dry weight of seed biomass) 4	5	6	7	8	9	Mean	r	LSD
0	90b	70ab	58ab	50c	55ab	60a	63.83b	-0.75	6.067
1	78b	65ab	60ab	55bc	63a	60a	63.50b	-0.69	
2	80b	63b	53b	41c	53ab	50a	56.67c	-0.76	
3	80b	68ab	55b	68ab	53ab	55a	63.17b	-0.79	
4	80b	65ab	45b	73a	45b	50a	59.67bc	-0.64	
H.W.	105a	80a	73a	55bc	63a	58a	72.67a	-0.87	
Mean	85.50	68.50	57.33	57.00	55.67	55.50	63.25		
LSD (0.05) = 6.067									14.50*

1987

0	93e	83c	76c	73c	76b	80.20d	-0.81	0.731
1	93e	95a	83a	78b	73c	84.40b	-0.62	
2	94de	86b	81b	78b	78a	82.40c	-0.67	
3	103b	86b	81b	82a	71d	84.60b	-0.65	
4	116a	86b	81b	78b	79a	88.00a	-0.81	
H.W.	98c	81d	76c	77b	71d	80.60d	-0.73	
Mean	99.50	86.17	79.67	77.67	74.67	83.37		
LSD (0.05) = 0.668								1.634

(a) Figures followed by the same letter(s) within a column, in each year, are not significantly different (P=0.05) using DMRT.

(b) * represert the LSD for treatment X age interaction.

4.15.7 SEED ZINC (Zn)

In both years the soybean seed Zinc level decreased with seed maturity (Table 23). The highest concentration of seed Zn was recorded at 4 WAF, irrespective of herbicide treatment. These values were significantly higher than the Zn values obtained at other sampling dates in each year (Table 23). The correlation of seed Zn with stage of seed maturity was r = -0.85 and -0.93 respectively in both years.

The seed Zn content of the hoe-weeded soybean plant, irrespective of stage of seed maturity in 1986, was significantly higher than the values obtained in other treatments (Table 23). While plants on 4kg a.i/ha metolachlor + metobromuron treated plots had the highest seed Zn in 1987. The differences in seed Zn due to the herbicide treatment was significant in each year. The seed Zn content in the treatments in decreasing order was: H.W. > 1kg > 3kg > 0kg > 2kg.

In 1986 the hoe-weeded plants had higher seed Zn contentfrom 4-6 WAF compared to the plants on herbicide treated plots, but at 9WAF, there was no significant difference in seed Zn of all the treatments. However, in 1987, the seed Zn of the hoe-weeded plant was significantly lower than the seed Zn content of plants on the herbicide treated plots at 5 and 6 WAF.

4.15.8 SUMMARY ON MINERAL ELEMENTS IN SEED

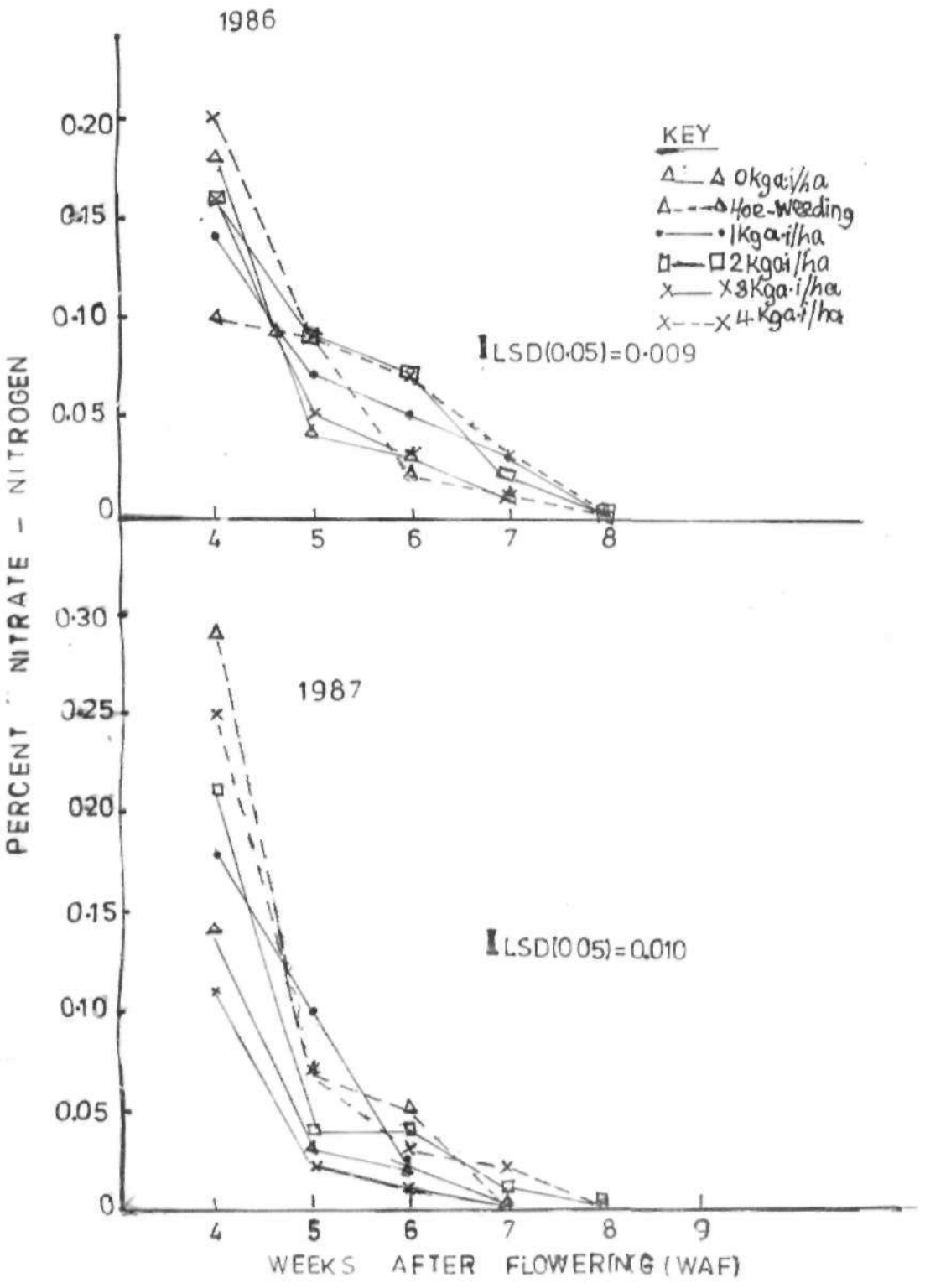
All the mineral elements analyzed in soybean seed decreased with seed maturity. The levels of these mineral elements in the seed in decreasing order was: N > K > P > Ca > Mg > Fe > Zn > Mn (This was based on the average seed content of each element in both years).

Generally, the plants on herbicide treated plots had significantly higher seed N, P, K, Ca, and Mn level than the unweeded control, whereas the differences in seed Mg in the treatments was not significantly different, as shown by combined analysis of variance of the two-year data. However, the soybean seed Zn level was significantly higher in hoe-weeded plants than the plants on the herbicide treated plots. The levels of nitrogen and phosphorus in the seed was higher than their levels in the leaves, however, the opposite was the case for K, Ca, Mg, Fe, Zn and Mn.

4.16 SEED NITRATE-NITROGEN

The nitrate-nitrogen level of soybean seed generally decreased with seed maturity in both years (Fig. 8). The seed nitrate level rapidly declined between 4 and 5 WAF in both years (Fig. 8) before its subsequently decreased further, gradually. The seed nitrate level at harvest (9 and 8 WAF respectively in both years) was below zero percent level in both years. The seed nitrate ranged from 0.0 - 0.16% in 1986 and 0.0 - 0.20% in 1987 (based on mean seed nitrate content per sampling dates, irrespective of treatments). The correlation of seed nitrate with seed

Fig. 8 Influence of pre-emergence application of Metolachlor + Metobromuron (Galex) on Soybean seed nitrate – nitrogen in 1986 and 1987.



maturity was r = -0.95 and -0.87 in 1986 and 1987 respectively.

In 1986, the differences in seed nitrate due to herbicide treatment was not significant. However in 1987, the seed nitrate in the hoe-weeded plants was the highest, followed by the seed nitrate obtained in the plants on 4kg a.i/ha metolachlor + metobromuron treated plots. The seed nitrate in plants on 3kg a.i/ha metolachlor + metobromuron treated plots in 1987 was the lowest recorded in the year. This differences in seed nitrate due to herbicide treatments was significant in 1987.

The combined analysis of variance of the two-year data showed that the 0.074% seed nitrate in plants on 4kg a.i/ha metolachlor + metobromuron treated plots was the highest, following this was the 0.064 and 0.063% seed nitrate in plants on 2kg a.i/ha metolachlor + metobromuron treated plots and on hoe-weeded plots respectively. While the 0.039% seed nitrate in plants on 3kg a.i/ha metolachlor - metobromuron treated plots was the lowest. These differences in seed nitrate was on the whole significant. The level of seed nitrate in the treatment in decreasing order was: 4Kg > 2kg > H.W. > 1kg > 0kg > 3kg.

In 1986 and 1987, the treatment X age interaction on seed nitrate was significant. The seed nitrate in the last two sampling dates in each year, in all the treatments was not significantly different. However in 1986, the seed nitrate in hoe-weeded plants was lower compared to the

plants on the herbicide treated plots at 4 and 6 WAF. Whereas in 1987, the seed nitrate in the hoe-weeded plants was significantly higher than the observed in the plants on most of the herbicide treated plots from 4-6 WAF.

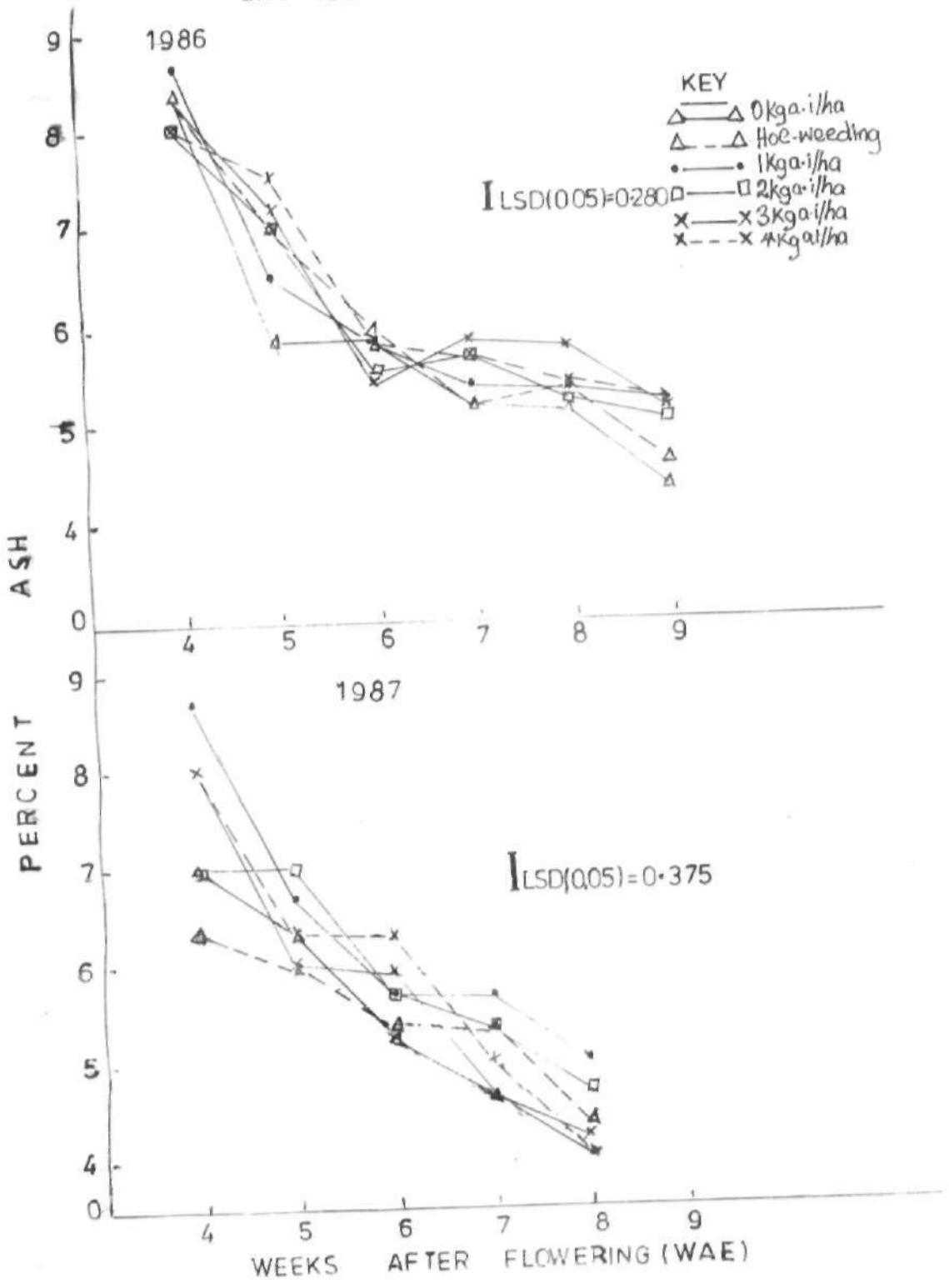
4.17 SEED ASH

Soybean seed ash value decreased with maturity in both years (Fig. 9). The 8.28 and 7.50% seed ash obtained at 4 WAF respectively in both years was the highest (irrespective of herbicide treatment). Conversely, the lowest seed ash was recorded at the last sampling dates (9 and 8 WAF respectively) in both years (Fig. 9). The seed ash ranged from 4.89 - 8.28% in 1986 and 4.37 - 7.50% in 1987 (Fig. 9). The correlation of soybean seed ash with seed maturity was r =-0.64 and -0.77 in 1986 and 198 respectively.

The unweeded soybean plants had the lowest seed ash content in both years, irrespective of age. This was followed by the seed ash content in the hoe-weeded plants in both years. In 1986, the plants on 4kg a.i/ha metolachlor - metobromuron treated plots had the highest seed ash, while the seed ash content of plants on 1kg a.i/ha metolachlor - metobromuron treated plots was the highest in 1987 (Fig. 9). The seed ash of the various herbicide treatments in 1986 was not significantly different except for the seed ash in the unweeded plants which was lower compared to other treatments.

The combined analysis of variance of the two-year data showed that the 6.24% seed ash in plants on 1kg a.i/ha

Fig 9 Influence of pre-emergence application of Metolachlor + Metobromuron (Galex) on Soybean seed ash in 1986 and 1987.



metolachlor + metobromuron treated plots was the highest, followed by the 6.13% seed ash obtained in plants on 4kg a.i/ha metolachlor + metobromuron treated plots. The 5.60% seed ash in plants on the unweeded plots was the lowest. This differences in seed ash due to the herbicide treatment was on the whole significant [LSD (0.05) =0.267].

The treatment X age interaction was significant on seed ash in each year. Generally there was no significant difference in seed ash of all the treatment at 4, 6, 7 and 8 WAF in 1986 and at 5-7 WAF in 1987. The seed ash in the unweeded plants was significantly lower than that in plants on most of the herbicide treated plots at 5 and 9 WAF in 1986 and at 4 and 8 WAF in 1987.

4.18 SEED YIELD

In 1986, seed yield from plants on 2, 3 and 4kg a.i/ha metolachlor + metobromuron treated plots were significantly higher than that from the unweeded control plants (Table 24). In 1987, the hoe-weeded plants had the highest seed yield of 2.45kg seed/plot ($24.5m^2$). The seed yield values of the unweeded and hoe-weeded plants was each about 60 and 74% respectively, of the highest seed yield recorded in plants on 4kg a.i/ha metolachlor + metobromuron treated plots in 1986. In 1987, there was no significant difference between the seed yield of the unweeded, hoe-weeded, 1 and 3kg a.i/ha metolachlor + metobromuron treated plots (Table 24). However, the plants on 4kg a.i/ha metolachlor + metobromuron treated plots, gave seed yield which was about

Table 24: Influence of pre-emergence application of Metobromuron + Metolachlor (Galex) on Soybean seed yield in 1986 and 1987

Year	Galex Kg. a i/ha Seed yield (kg. seed/plot (24.5m^2) 0	H.W	1	2	3	4	LSD
1986	1.94c	2.41bc	1.97c	2.58b	2.83ab	3.26a	0.589
1987	2.10d	2.45d	2.28d	2.36d	2.07d	0.65e	0.542
Mean	2.02f	2.43f	2.13f	2.47f	2.45f	1.96f	2.228

Figures followed by same letter(s) within a row in each year, are not significantly different (P = 0.05) using DMRT.

26.53% of the value obtained on the hoe-weeded plots. This value was significantly lower than the seed yield of other treatments.

The combined analysis of variance of the two-year data showed that the 2.47kg. seed yield/plot, from the plants on 2kg a.i/ha metolachlor + metobromuron treated plots was the highest, while the 1.96kg seed/plot from the 4kg a.i/ha metolachlor + metobromuron treated plots was the lowest. This differences in seed yield due to the herbicide treatments was not significant. The treatment X year interaction was significant. The seed production of the unweeded and hoe-weeded control plants was almost the same in the two years, whereas the seed yield of the plants on 3 and 4kg a.i/ha metolachlor + metobromuron treated plots in 1987 was greatly reduced compared to the observed values in 1986.

Table 25: Correlation between plant parameters analyzed in 1986 and 1987 (based on combined analysis of variance)

	Plant Dry Matter	Root Nodules	Plant Height	Leaf Area	Total Chloro phyll	Leaf NRA	Leaf No_3	Seed No_3	Seed Protein	Seed Carbohydrate	Seed Lipid	Seed Yield
Root Nodules	-0.274	1.000	-0.143	-0.611	0.899	0.091	0.277	0.176	0.155	-0.643	0.193	0.590
Plant DM	1.000	-0.274	-0.462	0.147	-0.394	-0.574	-0.451	0.182	0.102	0.135	0.059	-0.546
Plant Height	-0.462	-0.143	1.000	0.181	-0.259	0.966	0.168	0.061	-0.623	0.595	-0.397	0.582
Leaf Area	0.147	-0.611	0.181	1.000	-0.753	0.219	-0.178	0.136	0.330	0.398	-0.132	-0.519
Total Chlorophyll	0.443	0.899	-0.259	-0.753	1.000	-0.517	0.443	0.083	0.556	-0.663	0.218	0.508
Leaf NRA	-0.574	0.091	0.966	0.219	-0.517	1.000	0.90	-0.450	-0.755	0.749	-0.036	0.854
Leaf No_3	-0.451	0.277	0.168	-0.178	0.443	0.90	1.000	0.621	0.306	-0.176	-0.306	0.379
Seed No_3	0.182	0.176	0.061	0.136	0.083	-0.450	0.621	1.000	0.155	-0.030	-0.525	0.100
Seed Protein	-0.102	0.455	-0.623	-0.330	0.556	-0.755	0.306	0.155	1.000	-0.919	-0.052	-0.010
Seed Carbohydrate	0.135	-0.643	0.595	0.398	-0.663	0.749	-0.176	-0.030	-0.919	1.000	-0.238	-0.078
Seed Lipid	0.059	-0.193	-0.387	-0.132	0.218	-0.036	-0.306	-0.525	-0.052	-0.238	1.000	-0.222
Seed Yield	-0.546	0.590	0.582	-0.519	0.508	0.854	0.379	0.100	-0.010	-0.078	-0.222	1.000

CHAPTER FIVE

DISCUSSION

5.1 GROWTH PARAMETERS

The Soybean 'Samsoy 2' plant (irrespective of herbicide treatment) increased in dry matter slowly between 2-4 WAE and then more rapidly between 6-10 WAE. The slow increase in dry matter at this early stage of growth can be attributed to the fact that the leaf area which determines the light quantity available for photosythesis was still low. Furthermore the chlorophyll content of the leaves was low. These two factors could have resulted in low photosynthesis and dry matter production. Subsequent increase in soybean leaf area could have resulted in higher light interception, higher chlorophyll content and increased rate of photosynthesis. With the increase in leaf area, light interception was increased resulting in greater production of dry matter, as is evident from the 23.24% increase in dry matter between 4 and 6 WAE. Rapid leaf enlargement is important because leaves are the major light intercepting and photosynthesizing organ of plants. Shibles and Weber (1965) found leaf area and growth rate of soybean plant to be nearly proportional.

According to Brougham (1956) both percent solar radiation interception and rate of dry matter production

increased with leaf area production of pasture. Davidson and Donald (1958) also had similar report from clover stands. Hence the increase in dry matter production with increase in leaf area (LA) being reported here.

There was also little or no change in soybean plant height and dry matter production between 10 and 12 WAE. while there was a decrease in leaf area. This was probably due to lack of production of new leaves to replace the leaves that abscissed. By 10 and 12 WAE, senescence had set in and especially the lower leaves abscissed. Since new leaves were no longer produced to replace them, this culminated in the loss of organ of dry matter production. Similar report was obtained by Davidson and Donald (1958) from an investigation on the growth of subterranean clover. Vegetative growth was said to cease at about the time seed enlargement started. This observed low rate of growth as the plant approaches physiological maturity, is also in agreement with the findings of Egli and Leggett (1973) who reported that with the onset of flowering, the determinate line of soybean had grown to 84% of its maximum height and by the time pod development commenced produced 87% of its maximum dry matter.

The fact that the unweeded soybean plant had the least plant height and leaf area indicate that the growth (especially enlongation and enlargement) of the plant was hindered by the presences of weeds. On the herbicide treated plots weeds were highly reduced, therefore the growth of soybean plants on these plots was not hindered. The weeds

observed on these unweeded (untreated) plots probably competed vigorously with the crop plant for soil nutrients and water which are necessary for growth.

That the 4kg.a.i/ha metolachlor + metobromuron treated plots had lower plant stands and height probably because the herbicide concentration was far above optimum (being above the commonly used rate of 2-2.5kg a.i/ha metolachlor - metobromuron), thus leading to the death of a lot of the seedlings before 2WAE. Similar results were obtained by Kells (1984) when 2.2kga.i/ha Cyanazine/ha was followed with 0.28kg a.i/ha Metribuzin/ha for weed control in field grown soybean. The survival of some of the soybean seedlings was probably due to differential absorption of the herbicide by the dead and the survived seedlings. This treatment (4kg a.i/ha) probably delayed the growth and maturity of soybean plants that survived by about a week, because the plants on treated plots flowered a week after the seedlings on other treatments had started flowering.

Walker et al. (1963) reported that monuron or diuron, in combination with either phorate or disyston, caused growth retardation or stand loss to a greater degree than either pesticide used alone. Since there was reduced competition within the surviving plants, on 4kg a.i/ha metolachlor + metobromuron plots, the plants became bushy, because they probably were diverting most of their assimilates to the production of branches rather than the main stem. This was confirmed as it had the highest leaf area and dry matter/plant, averaged over the two years.

However, the higher growth of the plants on the herbicide treated plots, over that of the two control treatments contradicted the report of Chen (1985) that metolachlor - metobromuron (2-3kg a.i/ha) did not affect the growth of groundnut and soybean.

The greater plant height and leaf area recorded in 1987 over that of 1986 was probably due to higher soil nitrogen (0.113% N) compared to the 0.053% soil nitrogen in the soil used in 1986. This encouraged the early growth of the plants before the nodules were formed.

5.2 CHLOROPHYLL

The increase in soybean leaf chlorophyll as obtained in this study indicates that the synthesis of chlorophyll increases with age, probably to meet the increasing demand for photosynthate in the plant. This is similar to the report of Silvius et al. (1978), Wetterau et al. (1978) and Wickliff and Aronoff (1962). For the plant to meet the demand for carbohydrate in growth processes, synthesis of other biomolecules, respiration and for filling the seeds. the plant needs to increase the synthesis and concentration of chlorophyll as observed in this investigation. This increasing concentration of chlorophyll was made possible through the accumulation of the mineral elements necessary for its synthesis at the early stage of the plants growth.

The higher level of chlorophyll a, b, and total in 1986 compared with 1987, might had been due to higher accumulation of leaf nitrate, nitrogen and magnesium in 1986

than 1987. These elements are important constituent of chlorophyll and are therefore necessary for its synthesis. The chlorophyll a/b ratio in the two years was 1.8:1. This was lower than the expected 2:1 ratio, probably because the leaves had not attained their maximum chlorophyll content or the herbicide decreased the chlorophyll a/b ratio of the leaves, by hindering the synthesis of chlorophyll a. This is similar to the report of Fedtke et al. (1977), that Methabenzthiazuron decreased chlorophyll a/b ratio of wheat.

The positive correlation of the chlorophyll types sampled, with the plant age contradicts the report of Hemphill and Venkeleswaran (1978) that chlorophyll formation was negatively correlated with growth in all soybean phenotypes studied by them. The lack of significant difference in leaf chlorophyll content of the plants from the two controls and herbicide treatments in both years is similar to the report of Hoagland (1984), that glyphosate did not influence the chlorophyll content of soybean seedling.

5.3 NODULE NUMBER

Nodule initiation and development is a continuous process as root development continues. At the second week after emergence, the nodules were still not observable, even though their development might have been initiated. This deviates from the report of Bergersen (1958) that the first nodules appeared on 'Lincolon' soybean 9 days after planting. However, according to Thibodeau and Jaworski

(1975) a significant mass of nodules was not formed until the plants were 5-6 weeks old. At this stage the nodule growth became exponential. It reached a maximum when soybean pods had fully elongated and are beginning to fill.

The observed increase in nodule number with increase in plant age might have been made possible by the rapid development of the root system. The nodules also increased to meet the nutrient and moisture demand of the plant. Secondly, with increase in leaf area and rate of photosynthesis, more photosynthate which are necessary for the growth of nodules were probably made available. Thirdly, the increase in nodule number might have occurred in order to meet the nitrogen-requirement of the plant which increased greatly with growth activities (especially seed filling) betweem seedling and maturing.

The decline observed in the nodule number later, was probably due to scenescence of the old nodules, which could not be replaced with new ones, due to reduced or no growth of the root after the emergence of pods. The photosynthate available for nodule initiation and development would probably have declined sharply as the pods developed. This was similar to the findings of Lawn and Brun (1974b).

The higher soybean mean number of nodules in 1986 compared with 1987 might have been due to the high level of soil initial nitrogen (0.113% N) observed in 1987 compared with 0.053% N in 1986. High soil nitrogen has been found to be inhibitory to nodule formation of soybean. Weber (1966)

reported fewer nodules, when fertilizer nitrogen was applied.

The lower nodule number of the plants on 4kg a.i/ha metolachlor + metobromuron treated plots was probably due to the inhibitory effect of the rate on nodule initiation and development. This was similar to the report of Bollich et al. (1985) which showed that the application of recommended rates of several herbicides had no effect on nodule number of soybean seedlings, when applied pre-emergence. Rezende et al. (1985) also showed that nodulation of soybean cv. UFV-1 was not affected by fluorodifen, pendimethalin, chloramben, chloramben + alachlor and Fluorodifen + Pendimethalin.

5.4 LEAF NITRATE REDUCTASE ACTIVITY (NRA)

The high NR activity at the 2 WAE coincided with the period of high nitrate-nitrogen concentration of soybean leaves. This corroborates the reports of several workers that nitrate (NO_3) stimulate nitrate reductase (NR) synthesis and activity (Beevers and Hageman 1972, and Norman 1978), since the enzyme is substrate inducible (Deckard et al. 1973; Ajakaiye, 1981).

The decline in leaf NRA with soybean maturity was probably due to reduction in nitrate-nitrogen in the leaf even as observed in this investigation. Similar decrease in NRA with age was reported by Nyera and Hageman (1976) Manam et al (1977); Tann et al. (1981) and Hatim (1981). According to Streeter (1972a) the nitrate levels in the

leaves are closely related to the NR activity in the leaves. The positive correlation of the leaf nitrate with leaf nitrate reductase activity (r = 0.77 and 0.75 respectively in 1986 and 1987) showed this close association. This was similar to the report of Harper and Hageman (1972).

The slight increase in NRA in the 8 WAE might have been due to increase in nitrogen fixation taking place in the rapidly growing root nodules. This was necessary to meet the nitrogen requirement of the seeds. Thibodeau and Jaworski (1975) also had a similar report. The peak of leaf NR activity observed at the 2WAE, was contrary to the report of Anderson (1979), that NR activity in soybean leaves reached a maximum at 69 days after sowing. This might have been due genetic variability of soybean (Harper et al. 1972).

Based on the average of the two-year data, the leaf NRA from the plants on the herbicide treated plots was slightly higher than the observed NRA in the control plants. However, this slight but significant higher leaf NRA. occurred only in plants on the 1, 2 and 3kg a.i/ha metolachlor + metobromuron treated plots. At these rates. the herbicide treatment probably induced the synthesis of higher NR level, consequently the higher NRA observed in these treatments. This was similar to the report of Petkov (1979) that the NRA of pea leaves treated with Basagram (Bentazone) was enhanced. However the lower leaf NRA observed in plants on 4kg a.i/ha metolachlor + metobromuron treated plots could be due to the toxic effect of the

herbicide at high concentration. It was probably not due to lack of nitrate in the leaves to stimulate the enzyme, since the plant on this plots had the highest level of leaf nitrate. It might be that the high herbicide concentration inhibited the activity of the NR enzyme. Similar report by Suen et al. (1979) indicated that high levels of Ammotriazole inhibited the NRA in soybean cell culture. However, the higher leaf NRA of the plants on herbicide treated plots over that of the control, contradicted the report of Lolas (1980), who found no significant difference between the soybean leaf NRA of the control and those treated with metolachlor and oryzalin.

5.5 NITRATE-NITROGEN (No_3-N)

The high soybean leaf nitrate-nitrogen at the early stage of growth as observed in these trials indicates a high rate of nitrate-nitrogen absorption in the seedling roots. This was in addition to the activity of nitrogen-fixing bacteria (Rhizobium japonicum) in the nodules. According to Streeter (1972a) and Thibodeau and Jaworski (1975), this high nitrate indicates that the plant obtained most of its nitrogen from the soil nitrate. This high nitrate level was necessary for the generation of NR activity which could possibly lead to the synthesis of high level of protein needed for the rapid growth of the plant at this early stage. The leaf nitrate-nitrogen level became reduced later because of its reduction (by nitrate reductase) to nitrite, ammonia and later to protein. It might have also been due to redistribution of the leaf nitrate to the stem and later

to the seeds. This decline in nitrate could also have been brought about as a result of reduced uptake of nitrate by the root, as a result of reduction of soil nitrate-nitrogen around the plant root, due to nitrate leaching and removal by the growing plants. Similar result was reported by Giles et al. (1977) in sugar beet and Brevedan et al. (1977) in soybean. They showed that nitrate concentration in the vegetative part of these plants decreased very rapidly (or exponentially), with time and they were very responsive to changes in the level of nitrate in the nutrient solution.

Similar to the leaf nitrate-nitrogen, the highest soybean seed nitrate occurred at 4WAF, probably due to high rate of absorption of nitrate from the soil and high nitrogen fixation in the nodules, and partly from the leaves by redistribution. According to Harper and Hageman (1972) nitrate uptake by the soybean plant from nutrient solution increased rapidly as the plant progressed from the initial flowering stage up through the mid-pod fill.

The decrease in seed nitrate starting from 5WAF, was probably due to decrease in nitrate uptake by the plant. Harper and Hageman (1972) reported that the rate of nitrate uptake decline with growth stages following mid-pod fill. Secondly it might have been due to growth dilution, because dry matter accumulated faster than uptake of nitrate by the plant to fill the seeds. Thirdly, it might have been the result of the activity of nitrate reductase which reduced the nitrate to nitrite, ammonia and invariably to protein. Apart from the earlier greenish colour of the seeds, reports

are available on the presence of NRA in non-green plant tissues. For instance, Varner (1968) reported that NRA can be detected in extracts of barley aleurone cells which have been incubated with nitrate.

The soybean leaf nitrate-nitrogen of the two controls and herbicide treatments was not significantly different. Freiberg and Clark (1952) also reported that soybean root treated with 2,4-D had reduced nitrate and nitrate did not accumulate in the leaves. Frank and Grisgsby (1957) investigated the effects of several herbicides (includding chloropropham and dinoseb) on nitrate levels of 14 plant species. The nitrate content of 2 species was increased. that of four species was decreased while in eight species. there was no significant change. The higher seed nitrate in the plants on metolachlor + metobromuron treated plots, was probably a result of higher rate of nitrate absorption. which might had previously brought about the high leaf nitrate, high NRA in the leaf (except in 4kg a.i/ha) and consequently high seed nitrate. Fedtke (1979) demonstrated that metribuzin treatment on soybean at low light intensities increased both NR and nitrate-nitrogen levels of the plant. Hiranpradit et al. (1972) also reported that soybean plants treated with 0.0225ppm Bromacil took up about 18% more No_3-N than the untreated controls.

5.6 PROTEIN

The seed protein content was highest at 4 WAF. This high rate of protein synthesis might have resulted from the

redistribution of amino acids from the leaves to the developing seed for rapid synthesis of protein in the seed. At this period also nodule growth had reached its maximum, as observed in this investigation. This would have probably increased nitrogen fixation to the maximum. Thibodeau and Jaworski (1975) reported that the rate of increase in nitrogen fixation is exponential between the flowering and early pod-fill stages (a period of 8-9 days) during which a consideraqble quantity of fixed nitrogen are supplied to the plant. According to Rubel et al. (1972) and Cherry (1980) a high percentage of soybean seed protein is synthesized between 24-50 days after flowering.

The decrease in seed protein from 5 WAF as observed in this study was probably due to growth dilution within the seed due to, increased synthesis of other biomolecules i.e. lipids and carbohydrates. Yazdi-samadi et al. (1977) reported the levelling off and subsequent slight decrease in soybean seed protein from 50 days after flowering. Johnson et al. (1966) also had similar result in corn.

This higher soybean seed protein due to metolachlor + metobromuron treatment compared to the control is similar to the report of Evzikov and Zhukova (1984), that Linuron or trifluralin increased the protein content of soybean seeds. The mean soybean seed protein 45.95%, recorded in this investigation is within the range (25.5 - 58.90% protein) reported by Krober and Gibbons (1962).

5.7 LIPID

The low level of seed lipid observed at the 4 WAF coincided with a period of low seed carbohydrate level and high protein level. This might have been so because, the synthesis of lipid is based on acetate which is obtained in the course of carbohydrate metabolism, i.e.respiratory breakdown of carbohydrate . Furthermore the immature seed probably has more protein forming material sent to it from the leaves and stem of the plant. Since fatty acids are synthesized from acetate which is a product of carbohydrate metabolism, the lipid content of the seed is therefore bound to be low as long as the carbohydrate content is low. Similarly it will increase along with the carbohydrate content. Such increase in both seed lipid and carbohydrate was observed at the 6WAF. This trend in lipid sythesis was similar to that reported by Yazdi-Samadi et al. (1977). They reported that soybean seed oil content at 10 days after flowering (DAF) was only 3.5% in 'Harosoy 63' and 4.1% in 'Steel'. Then from 20-40 DAF in both cultivars the greatest amount of oil was synthesized. This oil level essentially remained constant during the remainder of seed development.

The significantly higher seed lipid in plants on 3kg a.i/ha metolachlor + metobromuron treated plots and the slight increase in seed lipid of those on 1kg a.i/ha plots above that of the controls showed that, the herbicide treatments enhanced the synthesis of lipid. It probably compensated for the low seed protein observed in plants on 3kg a.i/ha metolachlor + metobromuron treated plots. The treatments possibly enhanced the activity of enzymes

responsible for lipid synthesis at the expense of protein synthesizing enzymes.

5.8 CARBOHYDRATE

The general gradual increase in seed carbohydrate in 1986 and 1987 irrespective of treatment was probably due to continuous synthesis of carbohydrate in the pod and its remobilization into the seed, along with the carbohydrate from the stem and the leaves. This findings on the whole, was similar to the report of Hu Hsu (1970). He observed that the percent seed carbohydrate in soybean cvs. 'Amsoy' and 'Harosoy' dropped slightly as the seeds developed and then increased again to approximately its original value at maturity.

The decrease in seed carbohydrate at the 7 WAF corresponded with a concomitant increase in seed lipid. Probably because carbohydrate being the precursor of lipid synthesis was being converted into lipid at a rate higher than carbohydrate synthesis. In addition, remobilization of carbohydrate from the pod wall into the seed might have declined since the pod wall was old and therefore rate of photosynthesis might have decreased. The subsequent increase could have been caused by decrease in the lipid synthesis and higher remobilization of carbohydrate from the large senescing leaves.

The lack of significant difference in seed carbohydrate of the plants on the two controls and herbicide treated plots showed that the herbicide had no effect on the

carbohydrate metabolism of the plant. This probably stem from the fact that the herbicide treatments did not affect the leaf chlorophyll content and probably photosynthetic rate.

5.9 SEED YIELD

The reduced yield of the unweeded plants compared to the other treatments except plants on 4kg a.i/ha metolachlor + metobromuron treated plots was probably due to the adverse effect of weed infestation. Weeds compete with crop plants for nutrients, water and space. Therefore reducing the plants growth as could be seen in the low height and leaf area recorded in the unweeded treatment compared to the plants on the herbicide treated plots. Sajjapongse and Wu (1985) showed that soybean seed yields were reduced when weeds growth was unchecked during its growing season.

The reduced seed yield observed from plots that received 3 and 4kg a.i/ha metolachlor + metobromuron treatment, especially in 1987 was due to the injury and death of the plant seedlings by the treatments, which was highly concentrated and above the commonly used rate of 2.2-5kg a.i/ha . The plant stands of plots that received this 3 and 4kg a.i/ha metolachlor + metobromuron was greatly reduced in 1987 due to injury and death. The fact that no death or injury was caused by these treatments in 1986 was probably due to the reduction of the herbicide concentration in the soil due to leaching by rainfall and chemical degradation, at about 3 weeks after herbicide application.

when the seeds were replanted. The fact that, at 4 weeks after herbicide application, small but scattered weed seedlings were found growing on herbicide treated plots is an evidence of degradation of the herbicide by soil and climatic factors Peter and Weber (1985) and Utulu et al. (1986) also reported similar degradation of herbicides. The non-significant difference in the seed yield of the two controls and herbicide treatments as shown by combined analyses of variance was similar to the report of Chem (1985) that 40-60kg, 2.5% trifluralin and 4-6L.5% metolachlor + metobromuron did not affect the yield of groundnut and soybean.

5.10 ASH

The ash content of the whole soybean plant was high at the 4 WAE. The plant ash normally corresponds roughly to the mineral salts that had been absorbed from the soil, but does not include nitrogen. These mineral elements are needed for the various metabolic activities that culmunate in the rapid growth of the plant at this early stage. However the general decline in the soybean plant ash was probably because the replenishment of mineral elements as plant grew did not keep pace with the rate at which the absorbed mineral elements are incorporated. Furthermore the root growth also probably fell behind the shoot growth as the plant developed. The products of photosynthesis therefore accumulated faster than mineral ions are absorbed (Milthorpe and Moorby 1979). This led to the continued

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decrease in ash content of the whole soybean plant and the seed ash with age.

Hopper (1925) also observed that as corn advanced in maturity from tassel to the ripe stage, the ash content decreased. However the high soybean seed ash at 4 WAF was probably due to remobilization of mineral elements from the leaves and stems into the seeds.

The higher seed ash in the plants on the herbicide treated plots over the unweeded plants was probably the overall result of the increases in level of individual elements brought about by the herbicide treatments. The herbicide treatment reduced the weed population on the treated plots and the competition of the weeds for these elements was minimized, therefore more of these elements were available for soybean plants absorption. Simeonova and Stoimenova (1984) reported atrazine + Metolachlor or alachlor or ethafluralin applied pre-emergence, slightly increased the contents of N, P, Mg, K, Ca, Na, Mn, Cu, Zn and Fe in Maize leaves. However, this contradicts the report of Ellis et al. (1983) that Metolachlor, decreased the accumulation of Ca, Mg, K, and P in sweet corn.

However, the observed non-significant difference in the whole soybean plant ash of the plants from all the treatments is similar to the report of Rosolem et al. (1984) that trifluralin had no effect on Ca, Mg, and S uptake or their distribution in soybean cv. 'Parana' plants.

5.11 MINERAL ELEMENTS

5.11.1 PHOSPHORUS:

The high level of leaf phosphorus at the 2 WAE was probably due to high rate of absorption, due to high concentration of the element in the soil at that time. This high leaf phosphorus level was necessary because its presence along with coenzymes allows the sugars to be metabolised by the plant and acts as an energy carrier.

The slight decline in leaf phosphorus between the 2-6 WAE probably due to redistribution of phosphorus from the leaves to the growing points and the stem, before the seed development. The decline in leaf phosphorus between 10-12 WAE might have been due to remobilization of phosphorus into the developing seeds. Similar decline in leaf phosphorus with plant age was observed by Borst and Thatcher (1931) Hammond et al. (1951) and Togari et al. (1955) also showed that 40-80% of the phosphorus in the seed may have been translocated from the pods, leaves and stems, assuming that all the phosphorus disappearing from these organs moved into the seeds.

Similar to the leaf phosphorus, the high seed phosphorus at 4WAF might had been due to high rate of P translocation from the leaves into seeds. The decline in seed P from the 5WAF must have been due to growth dilution within the seed. This is similar to the report of Sale and Campbell (1980).

The increase in soybean seed phosphorus induced by metolachlor + metobromuron treatments was probably a result

of stimulation of phosphorus absorption from the soil by herbicide treatments. Secondly, it could have been due to few weeds on these plots, that competed for this element, compared to the unweeded control plots. This was contrary to the report of Maftoun et al. (1982) that Trifluralin at 1ppm significantly decreased P concentration of the root and shoot of soybean. But Nashed and Ilnicki (1968a) reported that Linuron, when applied to the roots of soybean increased the phosphorus uptake 30 to 50%.

5.11.2 POTASSIUM

The high leaf potassium between the 4 and 6 WAE, was probably due to high level of soil potassium and high rate of absorption by soybean seedlings. This high K content was probably needed for the synthesis of protein which is needed in growth and for effective functioning of respiratory enzymes e.g. pyruvate kinase. Similar report was obtained by Borst and Thatcher (1931) in soybean and by Wagner (1932) and Peterson et al. (1974) in Oat. The decline observed from 4WAE was probably due to remobilization of potassium from leaf, first to the stem and later to the developing seeds.

The seed potassium had a similar pattern to leaf potassium, but it had its peak at 4 WAF. This report was similar to that of Togari et al. (1955) and Sale and Campbell (1980), although the observed range of seed potassium (which declined from 2.9% to 1.6% at maturity), by Togari et al. (1955) was slightly higher than the seed

potassium level observed in this study. The higher leaf and seed K content in plants on herbicide treated plots was probably due to enhanced K absorption from the soil. Or due to low competition from few weeds on the plots, for potassium.

5.11.3 CALCIUM

The leaf calcium level apart from being higher than the observed seed calcium level increased with maturity while seed calcium level delcined with maturity. The increase of leaf calcium level probably showed absence of redistribution of leaf calcium to the other parts of the stem, and a continuous accumulation of calcium in the leaf even during seed development. However it is surprising that its level was not lowered even as the biomolecules accumulated. This high level of calcium was porobably needed for cementing the cells,being continuously produced at the growing points, and also important for other metabolic processes.

The immobility of calcium in the plant is well recognised (Ohlrogge, 1963). The seed calcium was probably derived right from the soil. This might have been the reason for the lower seed calcium compared with the leaf calcium, since the soil calcium level would have reduced greatly at the time of seed development, due to continuous absorption since emergence. The decline in seed calcium with seed age, was probably due to growth dilution in the seeds. The observed seed calcium level even though higher

than that reported by Sale and Campbell (1980) also declined with seed maturity, as they had earlier discovered.

The higher level of calcium in soybean leaf of unweeded control in comparison with other treatments, suggest that the herbicide might have reduced the uptake of calcium by soybean plants, compared to the unweeded control. Or, since the unweeded plant had a reduced growth, it might have accumulated calcium in its tissue, which could had been used for expansion and elongation of its shoot. Due to this lack of expansion it probably had high dry matter, and Ca content compoared to its fresh weight. According to Nashed and Ilnicki (1968b), Diphenamid decreased the uptake of calcium, causing the shoot of cabbage to show reduction of calcium. Duke et al. (1986); also showed that application of 0.5 and 1mM glyphosate to soybean roots and leaves respectively, reduced uptake and translocation of calcium . However these are contrary to the report of Sun (1969) that atrazine increased the calcium content of soybean shoot.

5.11.4 MAGNESIUM

The high leaf magnesium (M_g) at 2-4 WAE was probably brought about by high rate of M_g absorption from soil. This was necessary because it is an essential part of chlorophyll and is necessary for chlorophyll synthesis. This high leaf M_g could have contributed to the increase in chlorophyll level observed from the 4 WAE.

The decline in leaf Magnesium level from 8 WAE, with soybean plant maturity is similar to the report by Hashimoto

(1953). It was probably due to growth dilution within the leaf, or due to its redistribution to stem. Similarly the soybean seed magnesium level also declined with maturity. The observed mean leaf Magnesium of 0.35% is similar to the 0.367% magnesium reported in soybean leaves by Webb et al. (1954). However the lower concentration of magnesium in the seeds as compared to the leaf was probably due to low remobilisation of magnesium from the vegetative parts of soybean to the seeds. On the other hand, the soil magnesium level might had declined during pod development due to continuous absorption by the growing plants. This lower level in the seed compared to leaf did not occur in case of nitrogen and phosphorus, the concentrations of which are higher in the seed, relative to the leaf.

The high level of leaf Ca and Mg in the unweeded plants compared to the plants on metolachlor + metobromuron treated plots showed that the herbicide reduced uptake of Ca and Mg from the soil. However, the observation of the highest seed Ca in plants on the herbicide treated plots was probably due to the fact that, the inhibition of Ca uptake by the herbicide treatments has been reduced or removed probably as the herbicide became reduced in the soil. One would have expected high seed Ca and Mg in the unweeded plants; as they occurred in the leaf. The high seed Mg level compared to seed Ca content buttress the fact that calcium is immobile in plants, while magnesium is fairly mobile, this could have been responsible for the maintenance of high seed Mg in the unweeded plants.

5.11.5 IRON

The high leaf iron (Fe) at 2 WAE was probably the result of high rate of Iron absorption from the soil. This is necessary because it is required in the synthesis of chlorophyll, and it forms part of the cytochrome which is important in photosynthesis and respiration. The leaf Fe level also declined from the 4 WAE with plant maturity similar to the other elements. However the leaves showed ability to accumulate Fe during seed development as shown in a rise in Fe level at 12 WAE in both years. It was probably due to continuous or stimulated absorption of Iron during seed development, probably for seed filling. Peterson et al. (1974) had a similar report on Oat. The seed Fe was high up till the 6 WAF before it declined. Similar report on soybean was also published by Sale and Campbell (1980).

The higher leaf and seed iron observed in 1987 over that of 1986 was due to higher soil Fe of 320ppm in 1987 compared to 68ppm soil Iron in 1986. However, the observed Fe level of soybean leaf and seed in this study is fairly within the range (32-1100ppm Iron) reported by Weiss (1943).

5.11.6 ZINC

The initial rise in leaf Zinc between the 2 and 4 WAE indicates high rate of Zinc (Zn) uptake by soybean for a longer period during the early growth stages of the plant. This was probably due to its role in chlorophyll synthesis and the growth of the plant. The decline in seed Zn level from 4 WAF was probably due to cellular dilution during

growth. However the observed Zinc level in this study is fairly within the range (10-90ppm Zn) reported by Ohlrogge (1963) for soybean.

However the leaf Zn level in 1986 was lower than that of 1987, probably due to the lower soil Zn level in 1986. The higher leaf and seed Zn in 1987 compared to 1986 resulted from higher soil Zn level in 1987 compared to 1986 (Table 1).

5.11.7 MANGANESE (Mn)

The decline in leaf maganese (Mn) level from 4 to 6 WAE occurred at the period of rapid growth of soybean plant. This was probably due to redistribution of the element to the stem and apical meristem or it may be due to growth dilution resulting from rapid plant growth. Similar finding was reported by Romney and Toth (1954). By the 8 WAE, the growth of the plant has reduced drastically. The high Mn level from 8 WAE was probably due to increased absorption of soil Mn for seed-filling, as a result the level of leaf Mn was increased concomitantly with that of the seed as seen in the high seed Mn at 4 WAF. Furthermore the increase in leaf Mn showed little or no redistribution of Mn from the leaf to the seed similar to calcium.

However, the slight increase in leaf Mn from the 8 to 12 WAE was similar to the report of Peterson et al. (1974) on Oat. They reported a rise in Mn level from 67 days after planting. Generally soybean seed Mn level declined from the 4 WAF till maturity in both years. Probably due to cellular

expansion and dilution during growth, and accumulation of the biomolecules. While this report was similar to the findings of Peterson et al. (1974) on Oat, it was contrary to that of Sale and Campbell (1980) on soybean.

The lower seed manganese level in the unweeded plots might have been due to reduced uptake from the soil as a result of competition with weeds for the element. This could have greatly reduced the soil maganese by the time flowering began in the plant. Thus the higher seed Mn in the plants on metolachlor + metobromuron treated plots could have been due to reduced weed number and weed competition on those plots.

5.11.8 CONCLUSION ON MINERAL ELEMENTS

The significant increase in the leaf and seed levels of P and K seed Mn and leaf Fe due to metolachlor + metobromuron treatment was similar to the report of Simeonova and Stoimenova (1984) that application of atrazine + metolachlor or alachlor or ethafluralin pre-emergence, slightly increased the content of N, P, Mg, K, Ca, Na, Mn, Cu, Zn, and Fe in Maize leaves. However the slightly lower level of leaf calcium and magnesium and seed Zn in plants on the herbicide treated plots, observed in this study was similar to the report of Ellis et al. (1983), that 14-day exposure of maize to 10^{-6}M metolachlor caused a decrease in the accumulation of Ca, Mg, K and P.

5.12 GENERAL DISCUSSION

The effective weed control by metolachlor + metobromuron treatment, especially 2, 3 and 4 kg a.i/ha prevented the weeds from competng with the soybean plants. This enhanced the growth of the plant as shown in terms of plant height and leaf area which ultimately brought about the high seed yield observed especially among the plants on 2kg a.i/ha metolachlor + metobromuron treated plots. However the enhanced growth of plants on 3 and 4kg a.i/ha metolachlor + metobromuron treated plots was not manifested in terms of high seed yield, due to the injury and death caused them, thereby reducing plant stands and subsequent yield. This enhanced growth was probably due to little or no interplant competition among the plants that survived these herbicide rates, since they were fewer in number compared to that of other plots.

The metolachlor + metobromuron treatment increased leaf NRA, nodules number, leaf area and seed ash. It also increased leaf P, K, Fe, Zn, Seed P, Mg, and Fe seed carbohydrate. However, these increase was not proportionally enhanced by the use of higher metolachlor - metobromuron rates. This was why in most cases with the exception of leaf area, seed ash and leaf potassium, the correlation of these parameters with metolachlor - metobromuron levels was low (Tables 26 and 27). These showed that, the use of higher metolachlor + metobromuron

rates had no additional advantage of increasing these parameters.

The highest rate of metolachlor + metobromuron (4kg a.i/ha) used in this investigation induced the highest level of seed ash, seed P, Mg, and Fe, leaf area, leaf nitrate and leaf manganese. These could have been as a result of reduced competition for these elements and other essential elements due to reduced weeds and soybean plant stands. These high values obtained in plants on plots with this treatment could have been counted as advantages for its use, except for the toxic action of high nitrate level to man's health and the destruction of the seedlings, thereby reducing the plant stand and consequently the seed yield.

Conversely, the plants on 2kg a.i/ha metolachlor - metobromuron treated plots had the highest leaf NRA, nodule number, leaf P, K and Zn as well as seed protein, seed Ca and Fe, and seed yield. The metolachlor + metobromuron treatment at this rate, had an effective control of weeds in a comparable manner to 4kg a.i/ha metolachlor - metobromuron treatment. As a result of this, weed number and competition for water, mineral nutrient and space was reduced. This enhanced the growth and probably the physiological activities of plants on the plots treated with this herbicide rate.

In both years the leaf and seed mineral elements except Ca, were at high concentration at the early stages of growth. This was probably because these elements were very

crucial for the physiological processes of both the whole plant, as well as the seed. As the rate of uptake of these nutrients from the soil is usually proportional to the concentration in the soil, it is also likely that their translocation from the shoot parts to the seeds followed the same pattern.

The decrease in level of all the mineral elements in the seed with seed maturity was probably due to growth dilution in the seed as it accumulated more dry weight. While the decline in the level of these elements in the leaf with maturity was probably due to their translocation to the stem or due to cellular dilution as a result of growth. The further decline in their levels after flowering was probably due to their translocation to the seeds. However, calcium was an exception, as it increased in the leaf up till the 12 WAE. This probably showed that it is highly immobile and its absorption and accumulation in the plant is high and continuous throughout the growth season. Similar to this, was the pattern shown by leaf iron and manganese as they increased at the later part of the sampling period.

The seed had higher content of P and K compared to the level of these element in the leaves. This could have been made possible through remobilization of these elements from the leaves to the seeds, along with those being absorbed by the plant from the soil during seed development. This also showed that these elemets are highly mobile in the plant.

On the other hand, the leaf had higher content of nitrate, calcium, magnesium, Iron, Mn and Zn compared to the seed. These might have been the result of their accumulation at the early stage of growth, when the elements were probably still high in the soil. The reduction in soil level of these elements could have resulted in low absorption into the plants during seed development. On the other hand, the phenomenon can be an indication of low mobility of the elements (except nitrate) in the plant.

Table 26: Correlation of the parameters analyzed in soybean leaves with metolachlor + metobromuron treatment levels

Plant/leaf parameters	Correlation (r) values
Plant height	+0.04
Plant dry matter	-0.16
Plant Ash	-0.21
Nodule number	+0.18
Leaf area	+0.64
Leaf NR activity	+0.10
Leaf Chlorophyll a	+0.04
Leaf Chlorophyll b	-0.17
Leaf total chlorophyll	-0.07
Leaf nitrate	+0.10
Leaf nitrogen	+0.31
Leaf phosphorus	+0.25
Leaf potassium	+0.35
Leaf calcium	-0.11
Leaf magnesium	-0.52
Leaf Iron	+0.16
Leaf Zinc	-0.12
Leaf Manganese	+0.02

Table 27: Correlation of the parameters analysed in soybean seeds with metolachlor + metobromuron treatment levels.

Seed parameters	Correlation (r) values
Protein	+0.02
Lipids	+0.13
Carbohydrate	-0.01
Nitrogen	+0.02
Phosphorus	+0.29
Potassium	+0.15
Calcium	-0.11
Magnesium	+0.12
Zinc	-0.03
Iron	+0.01
Maganese	+0.24
Ash	+0.38
Nitrate	-0.08
Yield	-0.03

5.13 SUMMARY AND CONCLUSION

Maturity affected soybean plants growth and chemical compositions that were investigated in various ways. With the advancement in age of soybean plants, the number of root nodules, plant height, leaf area, dry matter and chlorophyll a, b and total content of the leaf increased. This increase in most cases was generally rapid from the 2 and 8 WAE (but dry matter increase was extended till the 12 WAE. However, the leaf area, and leaf chlorophyll b content, decreased with soybean maturity. The seed lipid also decreased slightly towards the ripening of the soybean seed.

On the other hand seed protein decreased with maturity of soybean plant in both years. Similar to the ash content of the whole soybean plant and the seed, the following mineral elements also decreased with maturity in both the leaf and the seed, phosphorus, and magnesium. However the leaf iron and manganese first decreased, but later increased towards the end of the sampling period. The leaf iron decreased up to the 10 WAE, before it increased in the 12 WAE, manganese also decreased from 2 to 6 WAE, but increased from 8 - 12 WAE. Conversely, leaf Zinc content increased from the 2 - 4 WAE, and leaf K from 2-6 WAE, but decreased subsequently. However, leaf calcium increased throughout the sampling period. On the other hand the seed Iron, Manganese, Zinc and calcium content decreased with seed maturity.

The 1kg a.i/ha metolachlor + metobromuron treatment was not effective in weed control, since the commencement of weed growth and weed population on it was almost the same as that of the unweeded control. (based on visual observation). On the other hand the 2, 3 and 4kg a.i/ha metolachlor + metobromuron treatments were effective in weed control, since weed growth started late and the weed population was very low in these treatments. However, the death of soybean plants on 3 and 4kg a.i./ha metolachlor + metobromuron treated plots makes it adviseable not to use them for weed control in soybean farms.

The herbicide treatments significantly increased soybean plant height and leaf area but slightly increased soybean leaf NRA, nodule number, seed protein and seed ash content. With the exception of the plants on 4kg a.i/ha metolachlor + metobromuron treated plots, the herbicide treatment also increased the yield slightly, especially the 2kg a.i/ha metolachlor + metobromuron treatment which had the highest seed yield. The herbicide treatments also increased leaf and seed phosphorus, potassium and Iron content. The 4kg a.i/ha metolachlor + metobromuron treatment increased both the leaf and seed nitate-nitrogen contents.

The herbicide treatment, however, decreased soybean dry matter, leaf magnesium and calcium and seed Zinc. The plants on 2kg.a.i/ha metolachlor + metobromuron treated plots had the highest yield, whereas the lowest yield was obtained

from the plants on 4kg a.i/ha metolachlor + metobromuron treated plots.

The leaf area, leaf nitrogen and potassium, and seed ash had a fairly high postive correlation with the metolachlor + metobromuron treatment levels (Tables 26 and 27). Conversely the soybean leaf magnesium, had a strong negative correlation with the herbicide treatment levels. All other parameters had low correlation coefficient with the herbicide treatment levels.

Finally,metolachlor + metobromuron treatments increased the seed protein and most of the essential mineral elements in the seed, which are very much needed by Nigerian populace. Secondly, the control of weeds for the first four to six weeks after emergence of soybean seedlings enabled the soybean plants to form canopy above the few scattered weeds among them. However, the 3 and 4kg a.i/ha metolachlor + metobromuron treatments did not have any advantage in weed control over the 2kg a.i/ha treatment. Furthermore both treatments (3 and 4kg a.i/ha) caused the injury and death of soybean seedlings. The 2kg a.i/ha metolachlor + metobromuron treatment in its effect on soybean plant and composition was comparable with that of the 3 and 4kg a.i/ha metolachlor - metobromuron treatment and it did not cause injury on soybean seedlings. Thirdly, the high seed protein and seed yield which are the most coveted aspect of soybean by the farmers was not adversely affected but comparable with the values obtained from hoe-weeded soybean plants. Therefore the use of 3 and 4kg a.i/ha metolachlor + metobromuron

treatments is an economic wastage, and it should be avoided. It is therefore recommended that the 2kg a.i/ha metolachlor + metobromuron rate can be used in soybean fields.

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