TOLERANCE OF SOYABEAN (*Glycine max* (L.)Merr.), COWPEA (*Vigna unreuiculata* (L.) Walp.), GROUNDNUT (*Arachis hypogaea* L.) AND **BAMBARANUT** (*Voandzeia subterranea* (L.) Thou.) TO IMAZETHAPYR

BY

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A Thesis submitted to the Postgraduate School, Ahmadu Bello University, in partial fulfillment of the requirements for the degree of Master of Science in Agronomy,

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22ND JUNE, 1994

DECLARATION

I hereby declare that this thesis entitled "Tolerance of soyabean (Glycine max (L.) Merr.), cowpea (Vigna unguiculata (L.) Walp.), groundnut (Arachis hypogaea L.) and bambaranut (Voandzeia subterranea (L.) Thou.) to imazethapyr" 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 "Tolerance of soyabean (Glycine max (L.) Merr.), cowpea (Vigna unguiculata (L.) Walp.), groundnut (Arachis hypogaea L.) and bambaranut (Voandzeia subterranea (L.) Thou.) to imazethapyr" by ISRAEL KWAME DZOMEKU meets the regulations governing the award of the degree of Master of Science (Agronomy) of Ahmadu Bello University, Zaria and it is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

To my beloved wife Mabel, and to my children Peter and Paul for all their love, tolerance and support during my stay in the Federal Republic of Nigeria.

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In conclusion I wish to thank The Lord Jesus Christ for his guidance and protection through the course of study and particularly for his salvation.

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ABSTRACT

The tolerance of selected leguminous crops namely: SJoyabean (Glycine max (L.) Merr., Var, Samsoy-2)$_f$ cowpea (Vigna unguiculatq. (L.) Walp., Var. Sampea-7), groundnut (Arachis hypogaea L., Var. Samnut-8) and bambaranut (Voandzeia subterranea (L.) Thou., Var. "Gurjiya")to pre-emergence application of imaze thapyr ((+ **)-5-ethyl-2-** (4~isopropyl-4-methyl-5-oxo-2-imidazolin-2-yl) nicotinic acid) was studied in the screenhouse and field at Samaru (11^o , 11^o N; 7^o, 38'E) in the northern Guinea savanna zone of Nigeria, during the 1992 wet season. The soil was of sandy loam texture, having a pH of 4.7 and *0.54%* organic carbon.

Imazethapyr at **0.15** - 1.00kg a.i/ha in the screenhouse and 0.05 - 0.60kg a.i/ha in the field did not affect crop emergence and establishment. Rates of 0.05 - 0.23kg a.i/ha were the most tolerated treatments and resulted in greater yields than higher rates. While the herbicide was moderately tolerated at 0.30 - 0.45 kg a.i/ha, 0.50 - 1.0kg a.i/ha caused severe injury in the legumes.

The crops exhibited differential response to imazethapyr. Soyabean and groundnut were more sensitive to lower rates of imazethapyr than cowpea and bambaranut. While the performance of the ollcrops-soyabean and groundnut-became significantly depressed by imazethapyr at 0.35kg a.i/ha and above. Significant depression in the performance of the non-oilcrops-cowpea **and** bambaranut- occurred at 0.45kg a.i/ha and above

However, the maximum tolerance level of imazethapyr for groundnut, soyabean, cowpea and bambaranut were obtained at 0.18, 0.19, 0.19 and 0.24 kg a.i/ha, respectively. The most sensitive parameter in soyabean and cowpea was days to 50% flowering, while those of groundnut and bambaranut were grain yield and crop vigour score at 20 DAS, respectively.

Grain yield of soyabean, groundnut and bambaranut were negatively correlated with herbicide injury score and number of days to *50%* flowering and positively correlated with crop vigour score, shoot dry weight, pod yield and 100-grain/seed weight.

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CHAPTER 1:

INTRODUCTION

Legumes such as soyabean (Glycine max (L.) Merr.), cowpea (Vigna unguiculata (L.) Walp.), groundnut (Arachis hypogaea L.) and bambaranut (Voandzeia subterranea (L.) Thou.) contribute substantially to the protein intake in the less humid tropics (Cobley and Steele, 1976). The biological values of their protein are high, because they contain considerably high amounts of essential amino acids such as lycine and tryptophan (Kineshear et al., 1985). In addition, they are useful sources of thiamine, niacin and calcium.

Soyabean production in Nigeria in 1980 amounted to 77,000 metric tonnes, being the highest in Africa (Anonymous, 1982). Cowpea is the most important pulse crop in Nigeria from where over 77% of the world's output was produced on 4.5 million ha in 1975 (FAO, 1976). Until the late 70's, groundnut was the main cash and export crop of the savanna zone of Nigeria (Lagoke et al., 1981). About half of the world's production of bambaranut comes from West Africa (Sellschop, 1962) where it is well adapted to soils with low fertility status (Doku and Karikari, 1971). These grain legumes provide good economic returns to growers and are suitable for rotation with cereals grown in the Guinea savanna zone.

In view of the importance of these crops, there is the need to increase farmers yields. This could be achieved through the use of viable seeds, good seedbed preparation, timely planting, adequate fertilization, insect and disease control and the elimination of weed competition. It has been observed that under the prevailing tropical conditions, weeds constitute the greatest biological contraint to agricultural production (Lagoke et al., 1981; Akobundu 1982). Work done at Samaru in the northern Guinea savanna of Nigeria has shown that uncontrolled weeds resulted in yield losses of 68% in soyabean (Shebayan and Lagoke 1988), 74.4% in cowpea (Lagoke et al, 1981), 78.6% in groundnut (Lagoke et al., 1991a), and 75.2% in bambaranut (Shebayan, 1988).

The most common weed control methods in grain legumes are hoe-weeding (Lagoke et al., 1981), cultivation, mulching, and intercropping (Robles and Fabro, 1979). Some of these operations cause plant, pod and root injuries resulting in yield reductions (Lagoke et al., 1981). These practices are highly labour-intensive, expensive and time-consuming. African farmers therefore on the average spend 40% of their time removing weeds from crops (Lagoke et al., 1991b).

To reduce the reliance on manual weed control, the use of herbicides was advocated. Indeed, herbicides have resulted in dramatic increases in grain production over the past thirty years (Newhouse et al., 1991).

Imazethapyr is an imidazolinone herbicide recently developed for broad-spectrum weed control in a number of crops including the grain legumes (Cantwell et al., 1989; Lagoke et al., 1991a). It possesses both soil and foliar activity, thus allowing flexibility in timing of its application.

Information on the relative susceptibilities of the major legumes grown in Nigeria to imazethapyr is limited. The investigations conducted earlier at Samaru by Buhari (1990), Mgbemena (1990), and Lagoke et al., (1991a), have provided some valuable reports on crop sensitivity to imazethapyr. However, it is necessary to determine relative susceptibility of these legumes to higher than recommended rates of imazethapyr. This is important because: (1) there is the possibility of careless handling of the herbicide under field conditions; (2) of different soil characteristics that may warrant the use of higher than the recommended rates and (3) differential crop response to the herbicide may result in crop injury at higher rates.

The study was therefore initiated with the objective of evaluating the relative tolerance of soyabean, cowpea, groundnut and bambaranut to imazethapyr applied pre-emergence.

CHAPTER 2.

LITERATURE REVIEW

2.1 Characteristics of Imazethapyr

Imazethapyr ((±) - 5 - ethyl - 2 - (4-isopropyl- 4-methyl - 5 - oxo - 2 - imidazolin - 2 - yl) nicotinic acid) is a broadspectrum systemic imidazoline herbicide developed for use in various leguminous crops (Malefyt et al., 1984). Some of these crops are soyabean, peas, broadbeans, seedling and established alfalfa and clover, peanuts and lupins (Peoples et al., 1985).

The herbicide is off-white to tan solid in colour with a slightly pungent odour and a solubility of 0.14g/100ml water. Various formulations of the herbicide are available including that of an ammonium salt. The ammonium salt is formulated as aqueous solutions of different acid equivalent concentrations depending upon geographical region (Wang et al., 1985). The formulation marketed in Nigeria is 100g a.e/L.

2.1.1 Mode of action

Imazethapyr kills weeds by reducing the levels of three branched - chain aliphatic amino acids, isoleucine, leucine and valine through the inhibition of acetohydroxyacid synthase (AHAS) (Wang et al., 1985).

It has been observed that the enzyme is common to the biosynthetic pathway of these amino acids. Its inhibition therefore causes disruption in the protein synthesis, which in turn leads to an interference in DNA synthesis and cell growth (Wang et al., 1985).

Roots and foliage of plants readily absorb imazethapyr, and translocate the herbicide through the apoplastic and symplastic systems and accumulate it at the growing points (American Cyanamid Company, 1987). Pre-emergence and pre-plant incorporated applications have shown that, susceptible weeds may germinate and emerge; however, normal growth stops at the cotyledon stage in broad-leave weeds and before the 2-leaf stage in grasses. Such adversely affected weeds would no longer be competitive with the crop. Growth and competition of susceptible weeds stop soon after post-emergence application with death occuring within 4 to 8 weeks (American Cyanamid Company, 1987). The first sign of herbicidal activity is a purple colouration or chlorosis of the youngest leaves, leading to necrotic apical meristems and stunted growth or death. The earliness of signs of herbicidal activity following treatment varies with the species and environmental conditions (American Cyanamid Company, 1987). Under optimum growth

conditions of favourable temperature and moisture, a marked increase in herbicidal activity has been observed in the field (American Cyanamid Company, 1987).

Wang et al. (1985) reported that the selectivity of imazethapyr in crops is the result of the rapid metabolism of the herbicide by the crop. Susceptible crops either cannot metabolise the herbicide or do so too slowly for detoxification.

2.2 Crop Tolerance to Imazethapyr

The tolerance of imazethapyr has been evaluated in some leguminous crops under different ecological zones. Trial results on some of the crops have been reviewed.

2.2.1 Soyabean (Glycine max.)

Determinate and indeterminate varieties of soyabeans have shown tolerance to imazethapyr applied pre-plant incorporated, pre-emergence at cracking, or post-emergence (Wang et al., 1985). Vanwinkel et al. (1987), Wilson and Hines (1989), Cole et al. (1989) and Steckel et al. (1990) reported the tolerance of soyabean to imazethapyr applied at 0.072, 0.09, 0.14 and 0.30kg a.i/ha respectively.

In Nigeria, Buhari (1990) reported that pre-emergence application imazethapyr at 0.025, 0.05 and 0.075kg a.i/ha was tolerated by soyabean with resultant high grain yields comparable to the hoe-weeded check.

Crop injury may occur as a result of imazethapyr treatment. Mills and Witt (1989) reported that pre-emergence applications of the herbicide at 0.015 to 0.140kg a.i/ha caused slight injuries to the vegetative phase of soyabeans although grain yields were not reduced. Similarly, Wang et al. (1985) observed that post-emergence applications of 0.12kg a.i/ha or more at the unifoliate to the third trifoliate stage of soyabeans have occassionally produced slightly shortened internodes, temporary leaf crinkling or/and interveinal chlorosis. However, soyabeans recovered rapidly and yields were not affected.

2.2.2 Cowpea (Vigna unguiculata).

In the Northern Guinea Savanna, at Samaru, Mgbemena (1990) reported the tolerance of cowpea to imazethapyr at 0.025 to 0.075kg a.i/ha. The results indicated that imazethapyr provided upto 70% control of weeds.

2.2.3 Groundnut (Arachis hypogaea)

The selectivity of imazethapyr in groundnuts at rates of 0.13 to 0.30kg a.i/ha at all application timings has been observed (American Cyanamid Company, 1987). At Samaru, in Nigeria, Lagoke et al. (1991a) reported the safe use of imazethapyr at 0.05 to 0.075kg a.i/ha and indicated that season-long weed control was obtained, resulting in high pod yields.

2.3 Weed susceptibility to imazethapyr

Field trials conducted in some African countries by Peoples et al. (1985) and Wilson and Hines (1988), have shown that pre-emergence application of imazethapyr at 0.03 to 0.08kg a.i/ha gave better and more consistent control of Amaranthus spinosus Linn., Chenopodium album var. centrorubrum Makino, Portulaca oleracea Linn., Ipomoea eriocarpa R. Br., Panicum maximum Jacq., Setaria barbata (Lam.) Kunth, Digitaria horizontalis Willd. Cyperus rotundus Linn., and Echinochloa crus-galli (L.) P. Beauv. than post- emergence treatments.

CHAPTER 3.

MATERIALS AND METHODS

3.1 Experimental sites

The study was conducted in the screenhouse and field under weed-free conditions during the 1992 wet season at the Institute for Agricultural Research, Samaru, Zaria (11°, 11' N; 7°, 38'E) in the northern Guinea savanna of Nigeria. The field trial was conducted at the research farm at a site where the soil is sandy-loam, well-drained but low in organic matter, total nitrogen, available phosphorus, exchangeable potassium and cation exchange capacity (Table 1). A total of 801.6mm of rainfall was recorded during the period of field experimentation (Table 2) from July 1 to November 20, 1992.

3.2 Treatments and Experimental Design and Plot size

Different rates of imazethapyr were applied on four leguminous crop plants viz: soyabean (Var. Samsoy-2), cowpea (Var. Sampea-7), groundnut (Var. Samnut-8) and bambaranut (local variety).

In the screenhouse eight rates of imazethapyr were factorially combined with the four crops. The pots were laid out in the screenhouse in a randomised complete block design in three replicates.

Table 1: Selected physico-chemical properties of the soil at the experimental site, Samaru, (1992 wet season.)

Characteristics	Value (Depth 0 - 30cm)
Physical properties	
Sand %	50.0
Silt %	38.0
Clay %	12.0
Textural class	Sandy loam.
Chemical properties	
pH 1: 2.5 H_2O	4.7
pH $Cacl_2$ (0.01m)	4.5
Organic carbon %	0.54
Total nitrogen %	0.04
Available phosphorus (Bray 1) ppm	1.79
Exchangeable cations (Meq/100g soil)	
Ca	0.37
Mg	0.21
K	0.30
Na	0.05
C.E.C	6.1

Table 2: Rainfall, temperature, relative humidity and sunshine distribution at Samaru during the period July - November,(1992 wet season.)

Month	Period Days	Rainfall (mm)	Temperature Max. °C	Temperature Min. °C	Relative Humidity %	Sunshine (hours) per day
July	1-10	74.0	28.7	19.5	67.3	6.5
	11-20	130.9	28.1	19.9	82.4	4.9
	21-31	38.4	31.3	22.0	74.5	6.2
Aug.	1-10	150.8	27.8	19.8	68.3	6.2
	11-20	56.2	27.6	20.4	73.3	6.6
	21-31	80.4	29.8	21.8	83.3	7.4
Sept.	1-10	72.9	28.6	17.9	81.6	8.4
	11-20	124.2	29.0	19.3	63.5	6.6
	21-30	32.6	30.8	19.5	73.5	8.1
Oct.	1-10	3.4	30.8	18.8	54.2	7.9
	11-20	35.2	31.5	19.4	51.1	7.0
	21-31	Nil	35.3	16.7	32.7	10.2
Nov.	1-10	2.6	29.2	21.0	46.5	8.8
	11-20	Nil	28.7	17.7	28.9	9.3

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

In the field the experiment was laid out in a split-plot design consisting of twelve rates of imazethapyr and a hoe-weeded check and the four crops in three replicates. The thirteen (13) weed control treatments constituted the main plot. The sub-plot treatments were the four varieties of the crops used. The gross size of the main plot was $60.8m^2$. The size of the gross and net sub-plot were 13.5^2 and $9.0m^2$ respectively.

3.2.1 Screenhouse operations.

Ninety-six plastic pots, each having a diameter of 10cm and a volume of 1.7L, were filled with about 1.0kg of soil obtained from the field experimental site. The soil was thoroughly mixed with compound fertilizer NPK 15: 15: 15 and single superphosphate (SSP) to give an equivalent of 20kg N, 60kg P_2O_5 and 20kg K_2O per hectare, before watering to field capacity.

Five seeds of each crop were sown in 24 labelled pots. The pre-emergence application of imazethapyr was done with a knapsack-sprayer, in about 220L/ha spray liquid volume, using a green deflector nozzle, at a pressure of $2.1kg/cm^2$.

After spraying the pots were transferred to the screenhouse bench. The pots were watered twice daily, in the morning and evening to field capacity. At fourteen days after sowing (DAS), the plants were thinned to two plants per pot.

3.3 Field Trial

3.3.1 Cultural practices and management

a). Land preparation.

The land was ploughed and later harrowed and rigded at 75cm apart.

b). Planting

The trial was established on July 7, 1992. Three seeds per hole of each crop were sown manually using a pair of marked planting ropes to reflect the desired intra-row spacing for each crop. Both cowpea and groundnut were planted at an intra-row spacing of 20cm while bambaranut and soyabean were each spaced at 15cm and 5cm respectively. This resulted in plant population of 266,660; 66,665; 66,665 and 88,887 plant/ha for soyabean, cowpea, groundnut and bambaranut respectively. At 14 DAS, crops were thinned to one plant per stand.

c). Fertilizer application

The mixture of compound fertilizer NPK 15:15:15 and single superphosphate was side-dressed, one week after sowing (WAS) to give 20kg N, 60kg P_2O_5 and 20kg K_2O per hectare.

d). Weed control

In order to determine crop tolerance to imazethapyr without weed interference, all herbicide treated plots were kept relatively weed-free throughout the period of crop growth by three hoe-weedings at 35, 56 and 77 DAS. Control plots were hoe-weeded five times, starting from 14 DAS.

3.3.2 Herbicide application

All herbicide treatments were applied pre-emergence 1 DAS using CP3 Knapsack sprayer with a deflector nozzle at a pressure of 2.1kg/cm^2 to deliver 220L/ha of spray solution. The application was done early in the morning to avoid high wind speed and resultant drift.

3.3.3 Crop protection

Insect pests were controlled with a mixture of Cymbush (cypermethrin) 10 E.C. and Rogor (dimethoate) 40 E.C. at the rate of 500ml plus 500ml in 100 litres of water per hectare using CP3 knapsack sprayer. Spraying of all plots started 4 WAS when insect infestation was observed on cowpea. Spraying continued fortnightly up to flowering period. During flowering and podding the crops were sprayed at weekly interval using the same rates up to 12 WAS.

In controlling fungal infection, Benlate plus Dithane M45 were used at the rate of 0.60kg plus 1.25kg per 200 litres of water per hectare, starting from 4 WAS and continued at two weeks interval until crop maturity.

3.3.4 Harvesting and Threshing

Pods were only harvested from soyabean, groundnut and bambaranut at full maturity as determined by various maturity indices. Cowpea could not produce pods because of scab (a fungal disease caused by Sphaceoloma sp.) infection at podding. Soyabean was harvested when pods and leaves turned yellow-brown to brown. Groundnut and bambaranut were harvested when the leaves were almost completely dried. Soyabean was harvested by cutting the stem at the base with a cutlass, sun-dried and threshed later. Groundnut and bambaranut were dug up with a hoe and sun-dried, picked, threshed and shelled later.

3.3.5 Observation and Data Collection

3.3.5.1 Crop growth parameters

a). Stand count

Stand count was taken at emergence (at 7 DAS for soyabean and cowpea and 12 DAS for groundnut and bambaranut) in the screenhouse and field and also at 20 and 50 DAS and at harvest in the field. Observations were taken from the net plot in order to assess the effect of the herbicide treatments on crop establishment. A stand which consisted of one plant, was counted as one, the figure obtained was expressed as percentage of the expected total number of stands per net plot.

b). Herbicide phytotoxicity score

Herbicide phytotoxicity score was taken at emergence in the field and also at 20 and 50 DAS in the field and screenhouse. A scale of 0 - 10 was used, where 0 and 10 represented no injury and seriously injured plants respectively (Appendix 1).

c). Crop vigour score

The vigour was assessed at 50 DAS and at 20 and 50 DAS in the screenhouse and field respectively. A scale of 0 - 10 was used, where 0 was taken for the plot with completely killed plants while 10 was for the plot with the most vigorous and healthy plants (Appendix 2).

d). Plant height

Plant height reading was taken at 35 and 50 DAS in the screenhouse. In each plot of soyabean, cowpea and groundnut, five plants were tagged at random and measured from ground level to the tip of the stem.

e). Days to 50% flowering

Days to 50% flowering were recorded from the time of sowing to when at least 50% of the plants in each plot had flowered in the field.

f). Nodulation

Root nodule count was taken at 42, 49, 56 and 56 DAS for cowpea, soyabean, groundnut and bambaranut respectively. Nodule count for groundnut and bambaranut was taken at 50 DAS in the screenhouse.

Two plants were sampled (from the net plots in the field) and the number of fresh nodules per plant was counted.

g). Shoot and total dry matter production

Shoot dry matter production was determined in the field by harvesting the top portion of five plants selected at random and cut to the ground level, from the discard area at 28 and 56 DAS and from the net ridges at 84 DAS. At 50 DAS, the total dry matter production per plant was determined in the screenhouse. The samples were oven-dried for 72 hours at 70°C to constant weight to determine dry matter production.

3.3.5.2 Yield and yield components

Data collected on the yield and yield components, in the field, include pod and grain weight per plot and 100-grain weight.

3.3.6 Statistical analysis of data

All data collected were subjected to analysis of variance for test significance and treatment means were compared using Duncan's Multiple Range Test (Duncan, 1955) at 5% level of probability. The relationship between various crop parameters and yield and yield components were also determined in a correlation coefficient analysis. Some vegetative and yield parameters, (Figures 1-7), of treatments as percentage of the untreated was obtained using the following equation: $A = (B - C)/C \times 100$ where A = percent of the untreated check; B = parameter of the appropriate herbicide treatment and C=untreated check.

CHAPTER 4.

RESULTS

4.1 General Observation

Crop growth and performance were generally not adversely affected by imazethapyr at 0.05 to 0.15kg a.i/ha.

The test crops viz: soyabean, cowpea, groundnut and bambaranut exhibited interveinal chlorosis, epinasty and shortening of internodes, 20 DAS, at 0.15 and 0.20kg a.i/ha and above in the screenhouse and field respectively. The symptoms decreased and completely disappeared at 0.15 and upto 0.25kg a.i/ha in the screenhouse and field respectively. The symptoms persisted more in the screenhouse than field. Results of the parameters measured are presented.

4.2 Screenhouse experiment

The effect of imazethapyr on crop emergence, crop injury, crop vigour, plant height, nodulation and total dry weight are presented in Tables 3 to 11.

4.2.1 Emergence count

Emergence of the crops was not significantly affected by imazethapyr treatments. Crops, however, differed significantly in emergence percentage (Table 3).

Cowpea had significantly higher emergence percentage than the other test crops which were similar. The interaction of imazethapyr rates and crops on emergence percentage was not significant in the trial.

Table 3: Effect of rate of imazethapyr and crop type on emergence, phytotoxicity score and crop vigour score in soyabean, cowpea, groundnut and bambaranut in the screenhouse at Samaru, 1992 wet season.

Imazethapyr rate (H) (kg a.i/ha)	Emergence	Phytotoxicity score[2]			Crop vigour score[3]
		20 DAS[1]	35 DAS	50 DAS	50 DAS
0.00	77.8	0.0f	0.0g	0.0g	10.00a
0.15	86.1	0.5e	1.0f	0.0g	9.96a
0.30	70.8	1.1d	1.9e	0.8f	9.25b
0.45	70.8	1.3d	2.3e	1.5e	8.54c
0.60	64.6	1.5cd	3.4d	3.3d	6.88d
0.75	79.9	1.8c	4.0c	4.5c	6.71d
0.90	76.4	2.8b	5.9b	6.8b	2.96e
1.00	77.8	4.6a	7.8a	8.1a	2.67e
S.E ±	5.41	0.15	0.17	1.11	0.15
Crop (C)					
Soyabean	76.4b	1.7b	3.5b	3.6a	6.85b
Cowpea	88.9a	1.3c	3.0c	2.7b	7.40a
Groundnut	69.4b	2.7a	4.0a	4.0a	6.79b
Bambaranut	67.4b	1.1c	2.8c	2.4b	7.44a
S.E (±)	3.83	0.29	0.12	0.08	0.10
Interaction H x C	NS	**	**	**	**

1. DAS = DAS after sowing. NS = Not significant;
   ** = Significant at P = 0.01
2. Phytotoxicity score (0-10 scale); 0 = No injury; 10 = dead crop.
3. Crop vigour score (0-10 scale); 0 = dead crop; 10 = most vigorous and healthy crop.

Within factor means followed by same letter(s) within a column are not significantly different at P=0.05 using DMRT.

4.2.2. Crop phytotoxicity score

Crop phytotoxicity scores were significantly affected by imazethapyr rates. Similarly, test crops differed significantly in phytotoxicity scores in the trial (Table 3).

Generally, crop phytotoxicity score increased with herbicide rate. While the phytotoxicity generally was more intensified at 35 DAS compared with 20 DAS, the effect was less pronounced with rates of 0.15 to 0.45kg a.i/ha at 50 DAS. With higher rates of imazethapyr, phytotoxicity score of 4.58 observed with 1.00kg a.i/ha at 20 DAS was observed with 0.75kg a.i/ha at 50 DAS.

At 20 and 35 DAS, groundnut exhibited the highest phytotoxicity scores while cowpea and bambaranut exhibited the least. At 50 DAS, the phytotoxicity scores on groundnut and soyabean were similar but significantly higher than those of cowpea and bambaranut which were also similar.

The interaction of the crops and imazethapyr treatments on phytotoxicity scores was significant at the three stages of crop growth (Tables 4 - 6). At 20 DAS, the highest phytotoxicity score was obtained on groundnut treated with imazethapyr at 1.00kg a.i/ha. Phytotoxic score of 5.00 obtained on the same crop treated with imazethapyr at 0.90kg a.i/ha was comparable to imazethapyr at 1.00kg a.i/ha on

Table 4: Interaction of soyabean, cowpea, groundnut and bambaranut with imazethapyr on phytotoxicity score at 20 DAS[1], in the screenhouse, at Samaru 1992 wet season.

Imazethapyr rate (kg a.i/ha)	Phytotoxicity score[2]			
	Soyabean	Cowpea	Groundnut	Bambaranut
0.00	0.0j	0.0j	0.0j	0.0j
0.15	0.5ij	0.5ij	0.5ij	0.5ij
0.30	1.3ghi	0.8ij	1.7fgh	0.7ij
0.45	1.3ghi	1.0ghi	2.0fg	0.8hij
0.60	1.3ghi	1.0ghi	3.0de	1.0hi
0.75	1.7fg	1.0ghi	3.7cd	1.7fgh
0.90	2.3ef	2.0fg	5.0b	3.0de
S.E (±)	0.29 For comparison within crops and herbicide rates.			

1. DAS = Days after sowing; 2. Phytotoxicity score (0 - 10 scale); 0 = No injury; 10 = dead crop.

Interaction means within each crop followed by same letter(s) are not significantly different at P= 0.05 using DMRT.

Table 5: Interaction of soyabean, cowpea, groundnut and bambaranut with imazethapyr on phytoxicity score at 35 DAS[1] in the screenhouse at Samaru, 1992 wet season.

Imazethapyr rate (kg a.i/ha)	Phytotoxicity score[2]			
	Soyabean	Cowpea	Groundnut	Bambaranut
0.00	0.0j	0.0j	0.0j	0.0j
0.15	1.0i	1.0i	1.0i	1.0i
0.30	2.3fg	1.7hi	2.7fgh	1.0i
0.45	2.7fg	2.0gh	2.7fgh	2.0gh
0.60	3.0efg	3.2ef	5.0d	2.3fgh
0.75	3.0efg	3.3ef	5.7cd	4.0e
0.90	6.7b	5.3d	6.3bc	5.3d
1.00	8.2a	7.2b	8.7a	7.0b

S.E (±) 0.35 For comparison within crops and herbicide rates.

1. DAS = Days after sowing.
2. Phytotoxicity score (0-10 scale); 0 = No injury. 10= dead crop.

Interaction means within each crop followed by same letter(s) are not significantly different at P= 0.05 using DMRT.

Table 6: Interaction of soyabean, cowpea, groundnut and bambaranut with imazethapyr on phytotoxicity score at 50 DAS[1], in the screenhouse at Samaru, 1992 wet season.

Imazethapyr rate (H) (kg a.i/ha)	Phytotoxicity score[2]			
	Soyabean	Cowpea	Groundnut	Bambaranut
0.00	0.0 l	0.0 1	0.0 1	0.0 1
0.15	0.0 1	0.0 1	0.0 1	0.0 1
0.30	1.7j	0.0 1	0.7j	0.0 1
0.45	2.0ij	1.0k	2.5i	0.7k
0.60	4.0g	2.5i	4.7f	2.0ij
0.75	5.0f	4.0g	6.0de	3.3h
0.90	7.3c	6.3d	8.0b	5.7e
1.00	8.7a	7.3c	9.0a	7.3c

S.E (±) 0.22 For comparison within crops and herbicide rates.

1. DAS = Days after sowing.
2. Phytotoxicity score (0 = 10 scale); 0=No injury
   10 = dead crop.

   Interaction means within each crop followed by same letter(s) are not significantly different at P = 0.05 using DMRT.

soyabean. Similarly, the score of 3.67 observed on groundnut treated with 0.75kg a.i/ha was comparable to that of cowpea treated with 1.00kg a.i/ha. Score of 3.00 on bambaranut treated with 1.00kg a.i/ha was comparable to groundnut treated with 0.60kg a.i/ha. Application of imazethapyr at 0.15kg a.i/ha on soyabean and groundnut, 0.15 and 0.30kg a.i/ha on cowpea and 0.15 to 0.60kg a.i/ha on bambaranut still resulted in phytotoxicity scores comparable to those of the corresponding untreated controls. Phytotoxicity scores for bambaranut were lower than those of groundnut at 0.30 to 1.0kg a.i/ha, cowpea and soyabean at 0.60 to 1.00kg a.i/ha. At 35 DAS, both soyabean and groundnut had highest phytotoxicity score at 1.00kg a.i/ha. Application of imazethapyr at 0.90kg a.i/ha on those crops resulted in scores comparable to 1.00kg a.i/ha on cowpea and bambaranut. In cowpea and bambaranut 0.15 and 0.30kg a.i/ha had similar scores. In soyabean, scores were similar for 0.30 to 0.75kg a.i/ha. At rates of 0.60 and 0.75kg a.i/ha, soyabean, cowpea and bambaranut had lower scores than groundnut. At 0.90 and 1.00kg a.i/ha, cowpea and bambaranut had lower scores than soyabean and groundnut. Higher phytotoxicity than the control was obtained at 0.30kg a.i/ha and above with soyabean and groundnut but at 0.45kg a.i/ha and above with cowpea and bambaranut. The highest phytotoxicity scores of 8.67 and 9.00 were observed on soyabean and groundnut

treated with imazethapyr at 1.00kg a.i/ha respectively. Phytotoxicity scores on cowpea and bambaranut treated with 1.00kg a.i/ha were comparable to that of soyabean treated with 0.90kg a.i/ha. At 0.30 and 0.45kg a.i/ha, cowpeas and bambaranut had lower scores than soyabean and groundnut while at higher rates, i.e. 0.60 to 0.90kg a.i/ha, all the other crops were lower than groundnut.

4.2.3 Crop vigour score

Crop vigour score was significantly affected by imazethapyr rates at 50 DAS. The test crops also differed significantly in vigour (Table 3).

Crop vigour generally decreased with herbicide rate, except between 0.60 and 0.75kg a.i/ha as well as 0.90 and 1.00kg a.i/ha. Crop vigour score with imazethapyr at 0.15kg a.i/ha was comparable to that of the untreated control.

The vigour scores of cowpea and bambaranut were similar but higher than those of soyabean and groundnut which were also similar.

The interaction of crops and imazethapyr rates on crop vigour score was significant at 50 DAS (Table 7). Compared with the control no significant reduction in vigour was observed on cowpea and bambaranut treated with imazethapyr at 0.15 and 0.30kg a.i/ha and soyabean and groundnut treated with 0.15kg a.i/ha.

Table 7: Interaction of soyabean, cowpea, groundnut and bambaranut with imazethapyr on crop vigour score at 50 DAS[1], in the screenhouse at Samaru, 1992 wet season.

Imazethapyr rate (H) (kg a.i/ha)	Crop vigour score[2]			
	Soyabean	Cowpea	Groundnut	Bambaranut
0.00	10.00a	10.00a	10.00a	10.00a
0.15	10.00a	10.00a	9.83ah	10.00a
0.30	9.00bcd	10.00a	8.67cd	9.33abc
0.45	8.17d	8.67cd	8.33d	9.00bcd
0.60	6.67e	7.00e	6.83e	7.00e
0.75	6.67e	6.83e	6.67e	6.67e
0.90	2.33g	3.33f	2.17g	4.00f
1.00	2.00g	3.33f	1.83g	3.50f

S.E ± 0.29 For comparison within crops and herbicide rates.

1. DAS = Days after sowing. 2. Crop vigour score (0 - 10 scale); 0 = dead crop. 10= most vigorous and healthy crop.

Interaction means within each crop followed by unlike letter(s) are significantly different at P=0.05 using DMRT.

At 0.30kg a.i/ha higher vigour score was observed in cowpea than in soyabean and groundnut. At 0.90 and 1.00kg a.i/ha both cowpea and bambaranut had higher scores than groundnut and soyabean.

4.2.4 Plant height

The effect of imazethapyr on plant heights of soyabean, cowpea and groundnut was significant at 35 and 50 DAS. Significant differences in plant height were also obtained among the crops (Table 8).

Plant height was significantly depressed by imazethapyr at 0.90 and 0.60kg a.i/ha and above at 35 and 50 DAS respectively, compared with the untreated control. At the two stages of growth, imazethapyr at 1.00kg a.i/ha significantly depressed plant height compared with all the other rates. At 50 DAS, application of imazethapyr at 0.30 and 0.45kg a.i/ha resulted in taller plants than the untreated control.

At the two stages of growth, plant height of the crops was in the order soyabean - cowpea - groundnut.

The interaction of imazethapyr rates and crops was significant on plant height at 35 and 50 DAS (Tables 9 and 10). At 35 DAS, only the plant height of soyabean was significantly influenced by imazethapyr rates with 1.00kg a.i/ha resulting in significantly shorter plant than the untreated control.

Table 8: Effect of rates of imazethapyr and crop type on nodulation, plant height and total dry matter production in soyabean, cowpea, groundnut and bambaranut in the screenhouse at Samaru, 1992 wet season.

Imazethapyr rate (H) (kg a.i/ha)	Plant height		No. of nodules	Total dry weight
	35 DAS[1]	50 DAS	per plant	g/plant(50 DAS)
0.00	14.23a	29.69b	13.4b	1.10b
0.15	14.48a	31.11ab	18.5a	1.34ä
0.30	14.46a	33.36a	10.8bc	1.20ab
0.45	14.10a	32.17a	9.2cd	1.09b
0.60	12.84ab	22.28c	7.1de	0.95c
0.75	12.79ab	21.89c	5.5e	0.94c
0.90	11.92b	20.58c	4.2e	0.81c
1.00	9.28c	11.08d	0.3f	0.64d
S.E ±	0.71	1.54	1.12	0.04
Crop (C)				
Soyabean	21.44a	48.79a	3.3c	0.95b
Cowpea	12.22b	16.41b	7.5b	1.11a
Groundnut	5.38c	10.61c	16.0a	0.92b
Bambaranut	-	-	7.7b	1.12a
S.E ±	0.43	0.94	0.79	0.04
Interaction H x C	**	**	**	N.S

1. DAS = Days after sowing. 2. - = Data not taken.
N.S. = Not significant; * = Significant at P = 0.05;
** = Significant at P=0.01.

Within factor means followed by the same letter(s) in the same column are not significantly different at P = 0.05 using DMRT.

Table 9: Interaction of soyabean, cowpea and groundnut with imazethapyr on plant height at 35 DAS[1], in the screenhouse at Samaru, 1992 wet season.

Imazethapyr rate (kg a.i/ha)	Plant height (cm)		
	Soyabean	Cowpea	Groundnut
0.00	23.0ab	13.0c	6.7d
0.15	23.6ab	13.2c	6.6d
0.30	24.7a	13.1c	5.6d
0.45	24.4a	12.4c	5.4d
0.60	21.3ab	11.8c	5.4d
0.75	21.2ab	11.8c	5.4d
0.90	20.2b	11.5c	4.1d
1.00	12.9c	11.2c	3.8d
S.E ±	1.23	For comparison within crops and herbicide rates.	

1. DAS = Days after sowing.

Interaction means within each crop followed by the same letter(s) are not significantly different at P = 0.05 using DMRT.

Table 10: Interaction of soyabean, cowpea and groundnut with imazethapyr on plant height at 50 DAS[1], in the screenhouse at Samaru, 1992 wet season.

Imazethapyr rate (H) (kg a.i/ha)	Plant height (cm)		
	Soyabean	Cowpea	Groundnut
0.00	56.7b	16.9d	15.5de
0.15	62.7ab	17.7d	13.0def
0.30	70.2a	17.6d	12.3def
0.35	69.3a	16.5d	10.7def
0.60	40.0c	16.3d	10.5def
0.75	39.5c	16.2d	10.0def
0.90	38.7c	15.8de	7.3ef
1.00	13.3def	14.3def	5.7f
S.E ±	2.67 For comparison within crops and herbicide rates.		

1. DAS = Days after sowing.

Interaction means within each crop followed by same letter(s) are not significant at P = 0.05 using DMRT.

Imazethapyr at 0.30 and 0.45kg a.i/ha also resulted in taller plants than 0.90kg a.i/ha. At 50 DAS, 0.60 to 1.00kg a.i/ha. At 50 DAS, 0.60 to 1.00kg a.i/ha depressed plant height significantly compared with untreated control, while 0.30 and 0.45kg a.i/ha was stimulatory. Both soyabean and cowpea treated with imazethapyr at 1.00kg a.i/ha had heights similar to all rates in groundnuts.

4.2.5 Nodulation

The effect of imazethapyr on root nodulation at 50 DAS was significant. The crops also differed significantly in nodulation (Table 8).

Imazethapyr at 0.15kg a.i/ha resulted in significantly higher number of nodules than all the other rates including the untreated control. Among all the rates, only 0.30kg a.i/ha resulted in similar nodule count to the untreated control. 0.30kg a.i/ha was, however, higher than 0.60kg a.i/ha to 1.00kg a.i/ha. 1.00kg a.i/ha resulted in lower nodulation than all the other rates of imazethapyr.

Differences in the crops with respect to nodulation was in the order groundnut ≥ cowpea = bambaranut ≥ soyabean.

The interaction of imazethapyr rates and crops on nodulation was significant (Table 11). Application of imazethapyr at 0.15kg a.i/ha stimulated nodulation in cowpea and groundnut although the effect was only significant on the latter crop. In soyabean, nodulation although was not significantly affected by all rates of the herbicide compared with the appropriate untreated control, it was depressed by 0.90 and 1.00kg a.i/ha in cowpea and bambaranut. In groundnut, 0.15kg a.i/ha resulted in higher nodulation than all other treatments including the untreated control. With the application of 0.45 to 0.75kg a.i/ha, nodulation was generally higher in groundnut than soyabean and also in soyabean and cowpea with application of 0.90kg a.i/ha.

4.2.6 Total dry matter production

Total dry matter production was significantly affected by imazethapyr at 50 DAS. Crops also differed significantly in total dry matter production (Table 8).

Imazethapyr at 0.60kg a.i/ha and above caused significant reduction in total dry matter, compared with the untreated control and other lower rates. Imazethapyr at 1.00kg a.i/ha also resulted in lower total dry weight than all the other rates tested.

Table 11: Interaction of soyabean, cowpea, groundnut and bambaranut with imazethapyr on nodulation in the screenhouse at Samaru, 1992 wet season.

Imazethapyr rate (kg a.i/ha)	Number of nodules per plant (50 DAS[1])			
	Soyabean	Cowpea	Groundnut	Bambaranut
0.00	7.0d-i	12.6c-e	22.0b	11.8c-f
0.15	7.3d-i	18.0bc	37.0a	11.7c-f
0.30	6.0e-i	69.0d-h	18.0bc	10.6d-g
0.45	5.7e-i	6.8d-i	14.2cd	10.2d-g
0.60	0.2i	5.9e-i	14.0e	8.4d-h
0.75	0.0i	5.7e-i	11.5c-f	4.7f-i
0.90	0.0i	1.7hi	11.2e-g	3.8ghi
1.00	0.0i	0.5i	0.3i	0.5i

S.E ± 2.24 For comparison within crops and herbicides rates.

1. DAS = Days after sowing.

Interaction means within a crop followed by same letter(s) are not significantly different at P = 0.05 using DMRT.

The total dry matter produced by cowpea and bambaranut were similar and significantly higher than the similar productions of soyabean and groundnut.

The interaction of imazethapyr rates and crops on total dry matter production at 50 DAS was not significant.

4.3 Field experiment

The effect of imazethapyr on crop emergence and establishment, phytotoxicity score, crop vigour score, number of 50% flowering, nodulation, shoot dry weight, pod yield, 100-grain weight and grain yield of the crops are presented in Tables 12 to 32 and Figures 1 to 7.

4.3.1 Crop emergence and establishment

Stand count of crops was not significantly affected by imazethapyr at emergence, 20 and 50 DAS and at harvest. However, significant differences in stand count were observed among crops at all the stages of sampling (Table 12).

The highest and lowest stand count were observed on soyabean and bambaranut respectively, throughout crop life-cycle, while those of cowpea and groundnut were similar.

The interaction of imazethapyr rates and crops on emergence and establishment of crops was not significant.

Table 12: Effect of rates of imazethapyr and crop type on emergence and establishment of soyabean, cowpea, groundnut and bambaranut at Samaru, 1992 wet season.

Imazethapyr rate (H)[1] kg a.i/ha.	Emergence	Establishment		
		20 DAS[2]	50 DAS	Harvest
0.00	92.0	90.4	86.3	86.3
0.05	94.1	90.8	89.4	88.9
0.10	91.5	91.0	90.8	90.8
0.15	89.1	87.3	85.1	85.1
0.20	92.9	91.5	90.3	90.3
0.25	87.5	86.0	84.5	84.5
0.30	91.1	90.6	89.5	89.5
0.35	95.2	92.6	92.0	92.0
0.40	93.1	91.0	89.9	89.9
0.45	91.8	90.3	89.9	89.9
0.50	94.4	91.3	91.1	91.1
0.55	92.4	90.7	89.9	89.9
0.60	92.3	90.6	90.2	90.1
S.E ±	1.74	1.93	2.05	2.06
Crop (C)				
Soyabean	99.9a	98.3a	98.0a	98.0a
Cowpea	95.3b	92.4b	90.9b	90.9b
Groundnut	93.0b	91.0b	89.7b	89.7b
Bambaranut	80.2c	79.5c	78.0c	77.8c
S.E ±	0.97	1.04	1.15	1.15
Interaction H x C	NS	NS	NS	NS

1. All plots were hoe-weeded. 2. DAS = Days after sowing.
NS = Not significant.
Within factor means followed by same letter in a column are not significantly different at P=0.05 using DMRT.

4.3.2 Crop phytotoxicity score

The herbicide treatments had significant effect on crop phytotoxicity scores at 20 and 50 DAS. Significant differences were observed among the crops in their phytotoxic response to imazethapyr (Table 13).

Phytotoxicity occurred at rates 0.20 and 0.30kg a.i/ha and above at 20 DAS and 50 DAS respectively compared with the untreated control. Phytotoxicity increased with increased herbicide rate.

At the two stages of growth, the degree of phytotoxicity exhibited by the crops followed the order *groundnut - soyabean* - cowpea - bambaranut.

The interaction of herbicide rates with crops was significant on crop phytotoxicity score at 20 and 50 DAS (Tables 14 and 15). At 20 DAS, while in soyabean, cowpea and groundnut rates of 0.20kg a.i/ha and above were phytotoxic, bambaranut was only injured by 0.30kg a.i/ha and above, Phytotoxicity increased with rates above 0.20kg a.i/ha up to 0.50kg a.i/ha in soyabean and groundnut and upto 0.55kg a.i/ha in cowpea and bambaranut. At 50 DAS, herbicide rates of 0.30kg a.i/ha and above were phytotoxic to soyabean and groundnut, Similarly, the rates of 0.35 and 0.40kg a.i/ha and above were respectively injurious to cowpea and bambaranut compared with the appropriate untreated control. Phytotoxicity increased with rate above 0.30kg a.i/ha up to 0.60kg a.i/ha and

Table 13: Effect of various rates of imazethapyr and crop type on the phytotoxicity and crop vigour score in soyabean, cowpea, groundnut and bambaranut at Samaru, 1992 wet season.

Imazethapyr rate (H)[1] (kg a.i/ha)	Phytotoxicity score[3]		Crop vigour score[4]	
	20 DAS[2]	50 DAS	20 DAS	50 DAS
0.00	0.0h	0.0h	10.00a	8.17ab
0.05	0.0h	0.0h	9.42b	8.50a
0.10	0.0h	0.0h	8.83bc	8.42a
0.15	0.0h	0.0h	8.75bc	8.38a
0.20	0.8g	0.0h	8.42cd	7.33bc
0.25	1.4f	0.0h	8.08de	7.21bc
0.30	1.8e	1.1g	7.75e	6.93cd
0.35	2.0e	2.3f	7.17f	6.63cd
0.40	2.4d	2.6e	6.83f	6.13de
0.45	2.8c	3.3d	6.64g	5.46ef
0.50	3.4b	4.5c	5.83h	5.13f
0.55	3.9a	5.0b	5.42h	4.54fg
0.60	4.0a	5.3a	5.42h	3.75g
S.E (±)	0.12	0.05	0.148	0.318
Crop (C)				
Soyabean	1.8b	2.6b	7.86c	6.19c
Cowpea	1.4c	1.1c	8.16b	6.91b
Groundnut	3.1a	3.2a	6.82c	6.09c
Bambaranut	0.6d	0.5d	8.62a	7.44a
S.E (±)	0.06	0.03	0.086	0.083
Interaction	**	**	**	**

1. All plots were hoe-weeded.
2. DAS = Days after sowing; ** = Significant at P=0.01.
3. Phytotoxicity score (0-10 scale); 0 = No injury; 10 = dead crop.
4. Crop vigour score (0-10 scale); 0 = dead crop; 10 = most vigorous and healthy crop.

Within factor means followed by the same letter(s) within a column are not significantly different at P=0.05 using DMRT.

Table 14: Interaction of soyabean, cowpea, groundnut and bambaranut with imazethapyr on phytotoxicity score at 20 DAS[1], at Samaru, 1992 wet season.

Imazethapyr rate (H)[2] (kg a.i/ha)	Phytotoxicity score[3]			
	Soyabean	Cowpea	Groundnut	Bambaranut
0.00	0.0 1	0.0 1	0.0 1	0.0 1
0.05	0.0 1	0.0 1	0.0 1	0.0 1
0.10	0.0 1	0.0 1	0.0 1	0.0 1
0.15	0.0 1	0.0 1	0.0 1	0.0 1
0.20	0.5k	0.5k	2.2ghi	0.0 1
0.25	1.7hi	1.5ij	2.5fg	0.0 1
0.30	2.0ghi	1.5ij	3.2de	0.5k
0.35	2.0gh	1.8ghi	3.7cd	0.5k
0.40	2.3gh	1.8ghi	4.3bc	1.0jk
0.45	3.2de	2.3gh	4.6b	1.0jk
0.50	3.8c	2.3gh	6.5a	1.0jk
0.55	4.2bc	3.0ef	6.8a	1.5ij
0.60	4.2bc	3.0ef	7.0a	2.0ghi

S.E (±) 0.22 For comparison within crop and herbicide rates.

1. DAS = Days after sowing. 2. All plots were hoe-weeded.

3. Phytotoxicity score (0-10 scale); 0= No injury.

Interaction means within each crop followed by the same letter(s) are not significantly different at P = 0.05 using DMRT.

Table 15: Interaction of soyabean, cowpea, groundnut and bambaranut with imazethapyr on phytotoxicity score at 50 DAS[1], at Samaru, 1992 wet season.

Imazethapyr rate (H)[2] (kg a.i/ha)	Phytotoxicity score[3]			
	Soyabean	Cowpea	Groundnut	Bambaranut
0.00	0.0 1	0.0 1	0.0 1	0.0 1
0.05	0.0 1	0.0 1	0.0 1	0.0 1
0.10	0.0 1	0.0 1	0.0 1	0.0 1
0.15	0.0 1	0.0 1	0.0 1	0.0 1
0.20	0.0 1	0.0 1	0.0 1	0.0 1
0.25	0.0 1	0.0 1	0.0 1	0.0 1
0.30	1.0j	0.0 1	3.0g	0.0 1
0.35	3.0g	1.0j	5.0g	0.0 1
0.40	3.7f	1.5j	5.3a	1.0j
0.45	4.7e	2.0h	5.7d	1.0j
0.50	6.2c	3.0g	7.0b	2.0h
0.55	7.0b	3.0g	8.0a	2.0h
0.60	8.0a	3.0g	8.0a	2.0h

S.E (±) 0.10 For comparison within crop and herbicide rates.

1. DAS = Days after sowing.
2. All plots were hoe-weeded
3. Phytotoxicity score (0-10 scale); 0 = No injury; 10 = dead crop.

Interaction means within each crop followed by same letter(s) are not significantly different at P = 0.05 using DMRT.

0.55kg a.i/ha in soyabean and groundnut respectively. In cowpea and bambaranut at the respective rates of 0.35 and 0.40kg a.i/ha up to 0.50kg a.i/ha phytotoxicity increased when compared with the appropriate control.

4.3.3. Crop vigour score

Herbicide treatment had significant effect on crop vigour score at 20 and 50 DAS. The crops also differed significantly in vigour at the two stages of growth (Table 13).

At 20 DAS, all the herbicide rates evaluated resulted in significantly lower crop vigour scores compared with the untreated control. In general, crop vigour score decreased with increasing rate of herbicide (Table 13 and Figure 1). At 50 DAS, imazethapyr at 0.30kg a.i/ha and above significantly depressed crop vigour score compared with the untreated control (Table 13 and Figure 2). At the rates of 0.05 to 0.15kg a.i/ha,,the herbicide resulted in more vigorous crop than the other higher rates.

Both at 20 and 50 DAS, the vigour scores of the crops followed the order bambaranut ≥ cowpea≥groundnut ≥ soyabean.

The interaction of herbicide and crop on vigour score was significant at 20 and 50 DAS (Tables 16 and 17 and Figures 1 and 2). At 20 DAS, crop vigour

Table 16: Interaction of soyabean, cowpea, groundnut and bambaranut with imazethapyr on crop vigour score at 20 DAS[2], at Samaru, 1992 wet season.

Imazethapyr rate (H)[1] (kg a.i/ha)	Crop vigour score[3]			
	Soyabean	Cowpea	Groundnut	Bambaranut
0.00	10.00a	10.00a	10.00a	10.00a
0.05	9.00bc	10.00a	8.67bcd	10.00a
0.10	9.17abc	9.17abc	8.67bcd	9.33ab
0.15	8.67bcd	9.00bc	8.67bcd	9.00bc
0.20	8.67bcd	8.67bcd	8.67bcd	9.00bc
0.25	8.33cde	8.67bcd	7.67efg	9.00bc
0.30	7.67efg	8.67bcd	7.00ghi	9.00bc
0.35	7.33fgh	8.00def	7.00ghi	8.67bcd
0.40	7.33fgh	7.33fgh	6.00jk	8.00def
0.45	7.00g	7.33fgh	5.00 1	7.67efg
0.50	6.67hi	7.25fghi	5.00 1	7.00ghi
0.55	6.67hi	6.33ijk	3.33m	7.00ghi
0.60	5.67kl	5.67kl	3.00m	7.33fgh

S.E (±) 0.308 For comparison within crops and herbicide rates.

1. All plots were hoe-weeded.
2. DAS = Days after sowing
3. Crop vigour score (0 - 10 scale); 0= No injury 10 = dead crops; 10 = most vigorous and healthy crop.

Interaction means within each crop followed by same letter(s) are not significantly different at P = 0.05 using DMRT.

Table 17: Interaction of soyabean, cowpea, groundnut and bambaranut with imazethapyr on crop vigour score at 50 DAS[2] at Samaru, 1992 wet season.

Imazethapyr rate (H)[1] (kg a.i/ha)	Crop vigour score[3]			
	Soyabean	Cowpea	Groundnut	Bambaranut
0.00	8.17a-d	8.17a-d	8.17a-d	8.17a-d
0.05	8.33abc	8.50abc	8.83a	8.33abc
0.10	8.67ab	7.83a-f	8.67ab	8.50abc
0.15	8.00a-e	8.50abc	8.67ab	8.33abc
0.20	7.50b-g	7.33c-h	7.00d-i	7.50b-g
0.25	7.00d-i	7.33c-h	7.00d-i	7.50b-g
0.30	6.67f-i	7.00d-i	6.53f-i	7.50b-g
0.35	6.00h-k	7.00d-i	6.00h-k	7.50b-g
0.40	5.67i-l	6.33e-i	5.00jkl	7.50b-g
0.45	4.33mno	6.33e-i	4.33mno	6.83e-i
0.50	4.00mno	6.17g-i	3.8m-p	6.50ghi
0.55	3.67nop	4.83k-n	3.17opq	6.50ghi
0.60	2.50pq	4.50imn	2.00q	6.00h-k
S.E ±	0.410 For comparison within crop and herbicide rates			

1. All plots were hoe-weeded. 2. DAS[2] = Days after sowing.

3. Crop vigour score (0 - 10 scale); 0= dead crop; 10 = most vigorous and healthy crop.

Interaction means within each crop followed by the same letter(s) are significantly not different at P = 0.05 using DMRT.

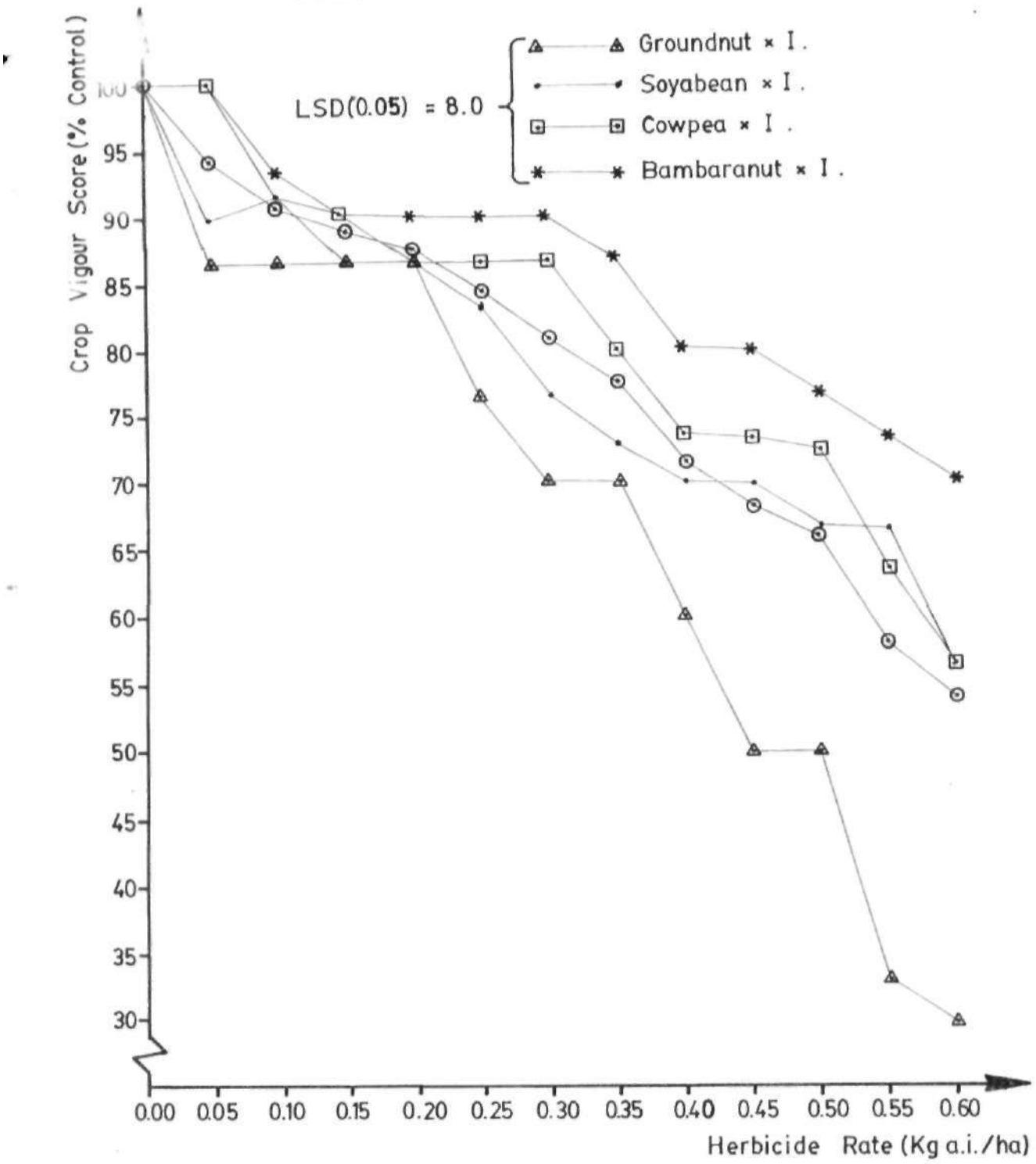


FIGURE 1: CROP VIGOUR RESPONSE TO IMAZETHAPYR RATES IN GROUNDNUTS, SOYABEAN, COWPEA, AND BAMBARANUT UNDER FIELD CONDITIONS AT 20 DAS.
(SAMARU, 1992 WET SEASON).

scores at the rates of 0.05 and 0.10kg a.i/ha for cowpea and bambaranut were similar to the appropriate untreated control while that of soyabean was comparable only at 0.10kg a.i/ha. All the rates of imazethapyr evaluated resulted in significantly lower vigour scores in groundnut compared with the appropriate untreated control. The herbicide at 0.60kg a.i/ha resulted in the lowest crop vigour score in soyabean while the lowest values in cowpea, groundnut and bambaranut vigour were attained with the application of 0.55kg a.i/ha compared with the appropriate untreated control. At 50 DAS, imazethapyr at 0.30kg a,i/ha and above significantly depressed vigour in soyabean and groundnut, while at 0.40 and 0.45kg a.i/ha and above respectively, cowpea and bambaranut vigour declined compared with the appropriate untreated control. The herbicide at low rates of 0.05 to 0.15kg a.i/ha was stimulatory on crop vigour, especially in groundnut and bambaranut, although not significant, compared with the appropriate untreated control (Figure 2). The lowest crop vigour in soyabean, cowpea and groundnut was obtained at 0.55kg a.i/ha and in bambaranut at 0.50kg a.i/ha.

4.3.4 Number of days to 50% flowering

Imazethapyr significantly affected the number of days to 50% flowering of the test crops. The crops differed significantly in the number of days to 50% flowering (Table 18).

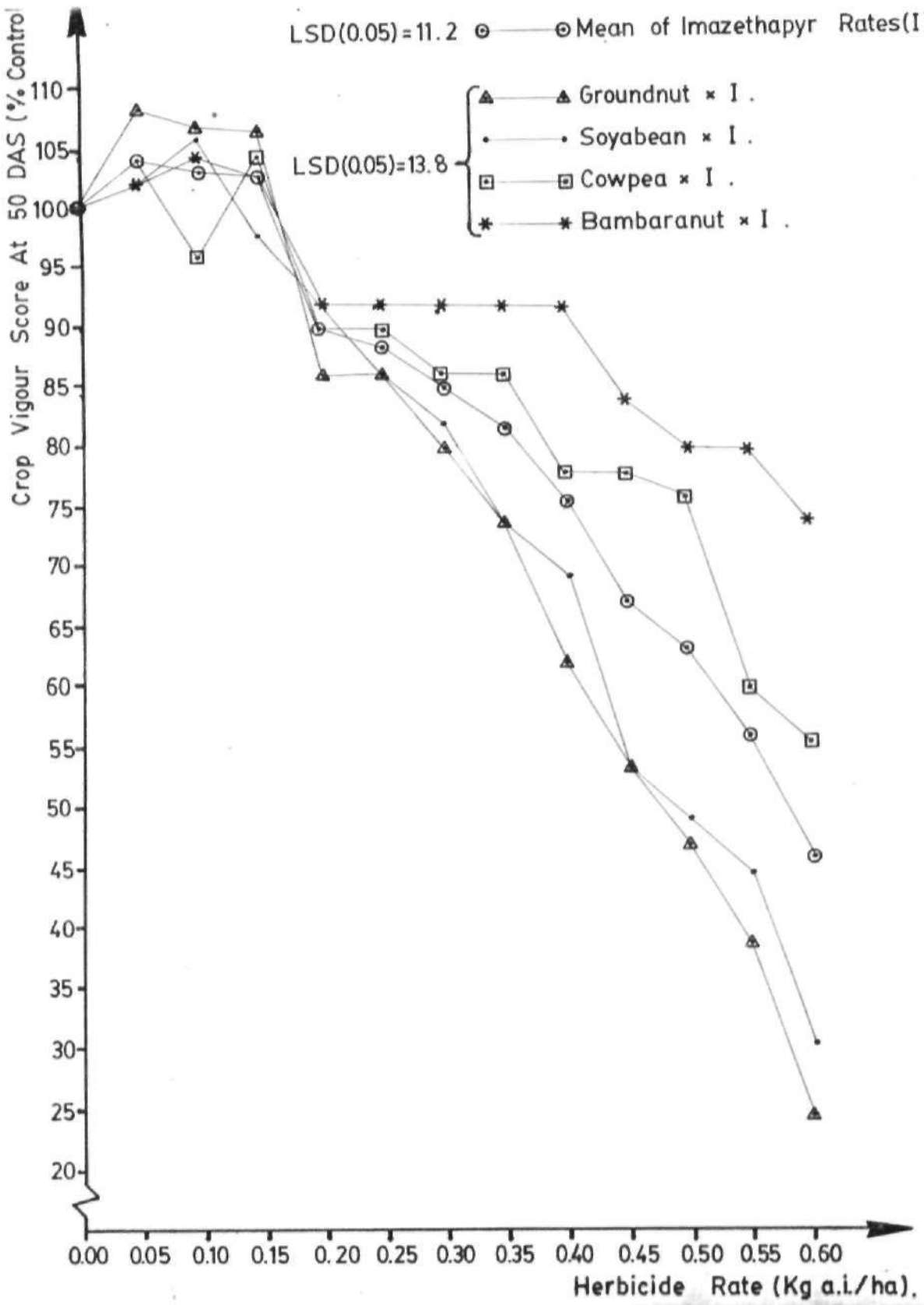


FIGURE 2: CROP VIGOUR RESPONSE TO IMAZETHAPYR RATES IN GROUNDNUT, SOYABEAN, COWPEA, AND BAMBARANUT UNDER FIELD CONDITIONS AT 50 DAS.

(Samaru, 1992 Wet Season)

Table 18: Effect of rates of imazethapyr and crop type on nodulation and number of days to 50% flowering in soyabean, cowpea, groundnut and bambaranut at Samaru, 1992 wet season.

Imazethapyr rate (H)[1] (kg a.i/ha)	Days to 50% flowering	Number of nodules/plant
0.00	43.4fg	139.2ab
0.05	43.3g	120.2abc
0.10	43.4fg	127.9ab
0.15	43.4fg	143.0a
0.20	43.8ef	114.3abc
0.25	43.6efg	112.3bcd
0.30	44.0e	102.3bcd
0.35	44.5d	81.3cd
0.40	45.0c	66.4de
0.45	45.3bc	43.6ef
0.50	45.6ab	36.0ef
0.55	45.8a	30.2ef
0.60	46.1a	21.7f
Crop (C)		
Soyabean	50.8a	27.1c
Cowpea	49.6b	57.0b
Groundnut	33.1d	213.9a
Bambaranut	44.1c	37.0c
S.E ±	0.09	7.00
Interaction	**	**

1. All plots were hoe-weeded.

** = Significant at P = 0.01.

Within factor means followed by same letter(s) within a a column are not significantly different at P=0.05 using DMRT.

Number of days to 50% flowering was significantly increased by rates of 0.30 to 0.60kg a.i/ha compared with the untreated control. No difference in days to flowering was observed from 0.50 to 0.60kg a.i/ha.

The difference in days to 50% flowering of the test crops followed the order groundnut < bambaranut < cowpea < soyabean.

The interaction of imazethapyr rates and crops on the number of days to 50% flowering differed significantly (Table 19). Herbicide rates of 0.05 to 0.30kg a.i/ha in soyabean, 0.05 to 0.25kg a.i/ha in groundnut and 0.05 to 0.35 in bambaranut did not affect the number of days to 50% flowering compared with the untreated control. In cowpea only rates of 0.40kg a.i/ha and above resulted in more days to flowering than the untreated control.

4.3.5 Nodulation

Nodulation of the legumes at sampling time was significantly affected by imazethapyr. Significant differences also occurred among the test crops (Table 18).

Imazethapyr at 0.35kg a.i/ha and above significantly depressed nodulation compared with the untreated control. Imazethapyr at 0.60kg a.i/ha resulted in the least nodule count. Nodulation at 0.45kg a.i/ha to 0.55kg a.i/ha did not differ significantly from that of 0.60kg a.i/ha.

Table 19: Interaction of soyabean, cowpea, groundnut and bambaranut with imazethapyr on number of days to 50% flowering at Samaru, 1992 wet season.

Imazethapyr rate (H)[1] (kg a.i/ha)	Number of days to 50% flowering			
	Soyabean	Cowpea	Groundnut	Bambaranut
0.00	50.0ef	49.0gh	31.7h	43.0k
0.05	50.0ef	48.0i	31.7n	43.3k
0.10	50.0ef	48.3ghi	31.8mn	43.3k
0.15	50.0ef	48.0i	32.3mn	43.3k
0.20	50.7cde	48.7ghi	32.3mn	43.3k
0.25	50.3de	48.0i	32.3mn	43.7k
0.30	50.7cde	49.0gh	32.7m	43.7k
0.35	51.0cd	49.3fg	34.0 1	43.7k
0.40	51.0cd	50.0ef	34.0 1	45.0j
0.45	51.0cd	51.0cd	34.0 1	45.0j
0.50	52.0ab	51.3bc	34.0 1	45.0j
0.55	52.0ab	52.0ab	34.3 1	45.0j
0.60	52.0ab	52.7a	34.7 1	45.0j

S.E ± 0.30 For comparison within crops and herbicide rates.

1. All plots were hoe-weeded.

Interaction means within each crop followed by the same letter(s) are not significantly different at P = 0.05 using DMRT.

Nodulation in the crops followed the order groundnut > cowpea > soyabean = bambaranut.

The interaction of herbicide and crops on nodulation was significant (Table 20). Among the herbicide rates, there were no significant differences in nodulation of soyabean and bambaranut compared with the appropriate untreated control. In cowpea imazethapyr at 0.55 and 0.60kg a.i/ha significantly depressed nodulation compared with the untreated control while depression was caused in groundnut by rates of 0.30 to 0.60kg a.i/ha. In groundnut, imazethapyr at 0.45kg a.i/ha and above further depressed nodulation compared with lower rates.

4.3.6 Shoot dry matter production

The herbicide treatments had significant effect on shoot dry matter production at 28, 56 and 84 DAS. Dry matter accumulations differed among the four crops at the three stages of growth (Table 21).

At 28 DAS, among the herbicide rates of imazethapyr tested, only 0.05 and 0.10kg a.i/ha resulted in shoot dry weights that were comparable to the untreated control. Shoot dry matter accumulation decreased with increased herbicide rate upto 0.55kg a.i/ha (Table 2[illegible] and Figure 3). At 56 DAS, imazethapyr at 0.10kg a.i/ha resulted in higher dry matter production than the untreated control while significant depression occurred with 0.25kg a.i/ha

Table 20: Interaction of soyabean, cowpea, groundnut and bambaranut within imazethapyr on nodulation at Samaru, 1992 wet season.

Imazethapyr rates (H)[1] (kg a.i/ha)	Number of nodules/plant			
	Soyabean	Cowpea	Groundnut	Bambaranut
0.00	43.8g-1	97.3fg	389.7a	35.0g-1
0.05	34.7h-1	53.7g-1	339.7ab	52·7g-1
0.10	36.3g-1	62.5f-1	335.0ab	77.7f-1
0.15	69.0k-j	115.5ef	322.5ab	65.0f-1
0.20	35.7g-1	63.8f-1	318.4ab	37.2g-1
0.25	35.0h-1	63.2f-1	315.8ab	35.8g-1
0.30	24.7i-1	59.3f-1	293.0b	32.2h-1
0.35	20.3i-1	47.7g-1	222.0c	34.8h-1
0.40	15.3j-1	44.8g-1	169.0d	36.3g-1
0.45	16.7i-1	40.8g-1	93.3f-h	23.5i-1
0.50	10.0k1	39.3g-1	73.3f-i	21.3i-1
0.55	6.5 1	33.8h-1	62.0f-1	18.3i-1
0.60	3.7 1	16.8i-1	55.5g-1	10.7k1

S.E (±) 25.04 For comparison within crops and herbicide rates.

1. All plots were hoe-weeded.
2. Interaction means within each crop followed by the same letter(s) are not significantly different at P = 0.05 using DMRT.

Table 21: Effect of various rates of imazethapyr and crop type on shoot dry weight in soyabean, cowpea, groundnut and bambaranut at Samaru, 1992 wet season.

Imazethapyr rate (H)[1] (kg a.i/ha)	Shoot dry weight		
	28 DAS[2]	56 DAS	84 DAS
	kg/ha		
0.00	425.8a	1669bc	4574ab
0.05	393.0a	1632bcd	4559ab
0.10	374.5ab	2053a	4917a
0.15	328.4bc	1774b	5031a
0.20	307.0c	1441c-e	4130abc
0.25	282.2cd	1385d	3865bcd
0.30	271.0cde	1317ef	3736cd
0.35	233.6def	1183efg	3229d
0.40	217.2ef	1097fg	2181e
0.45	191.0fg	919gh	1956e
0.50	185.8fg	758hi	1546ef
0.55	149.6gh	647i	1191f
0.60	117.7a	576i	880f
S.E (±)	18.63	82.4	227.9
Crop (C)			
Soyabean	438.9n	1624a	5540a
Cowpea	222.3c	1314c	2991b
Groundnut	115.3d	750d	1900d
Bambaranut	193.2b	1273b	2594c
S.E (±)	8.08	41.6	120.2
Interaction	**	**	**

1. All plots were hoe-weeded
2. DAS = Days after sowing. ** = Significant at P=0.01.

Within factor means followed by the same letter(s) within a column are not significantly different at P = 0.05 using DMRT.

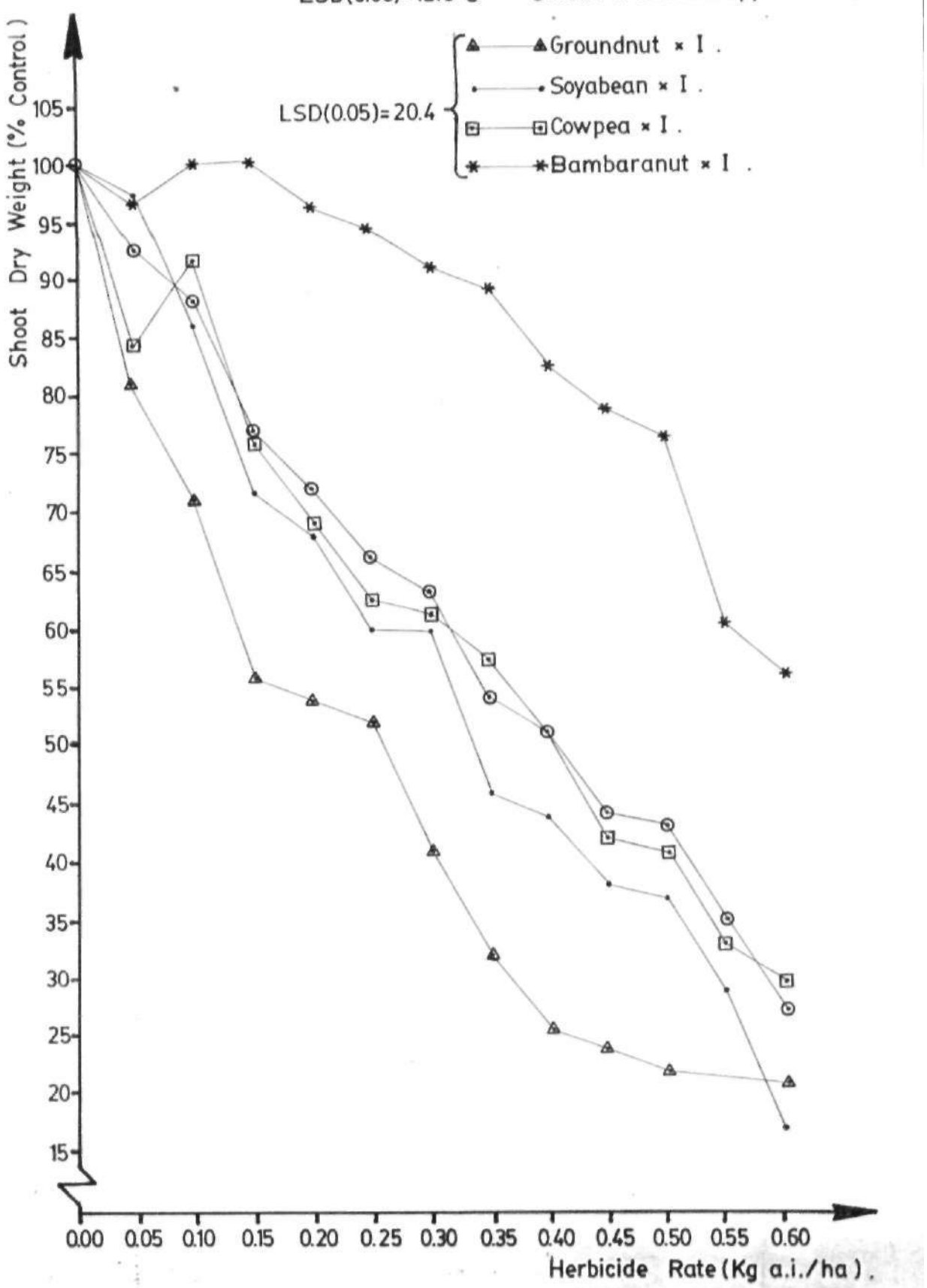


FIGURE 3 : SHOOT DRY WEIGHT RESPONSE TO IMAZETHAPYR RATES IN GROUNDNUT, SOYABEAN, COWPEA, AND BAMBARANUT UNDER FIELD CONDITIONS AT 28 DAS .
(Samaru , 1992 Wet Season).

and above. In general, shoot dry matter accumulation decreased with herbicide rate at 0.20kg a.i/ha and above at 56 and 84 DAS (Figures 4 and 5). Imazethapyr at 0.50 to 0.60kg a.i/ha caused the least shoot dry matter production at 56 and 84 DAS.

While shoot dry matter production at 28 and 56 DAS followed the order soyabean > bambaranut > cowpea > groundnut; the order at 84 DAS, was soyabean > cowpea > bambaranut > groundnut.

Interaction of herbicide rates and crops on shoot dry matter production was significant at 28, 56 and 84 DAS (Tables 22 - 24). At 28 DAS, within the same crop at varying herbicide rates, the rates of 0.05kg a.i/ha in soyabean, 0.05 and 0.10kg a.i/ha in groundnut, 0.05 to 0.15kg a.i/ha in cowpea and 0.05 to 0.50kg a.i/ha in bambaranut resulted in shoot dry matter production comparable to those the appropriate controls. In soyabean, 0.55 and 0.60kg a.i/ha resulted in the least shoot dry matter while there was no difference in the shoot dry weights of cowpea, groundnut and bambaranut at 0.40 to 0.60kg a.i/ha, 0.15 to 0.60kg a.i/ha and 0.40 to 0.60kg a.i/ha respectively. At 56 and 84 DAS, shoot dry matter productions of soyabean and groundnut at 0.05 to 0.30kg a.i/ha and cowpea and bambaranut at 0.05 to 0.40kg a.i/ha were comparable to those of the appropriate untreated controls. At 56 DAS, imazethapyr

Table 22: Interaction of soyabean, cowpeay groundnut and bambaranut within imazethapyr on shoot dry weight at 28 DAS[1], at Samaru, 1992 wet season.

Imazethapyr rate (H)[2] (kg a.i/ha)	Shoot dry weight (kg/ha)			
	Soyabean	Cowpea	Groundnut	Bambaranut
0.00	753.3a	360.8d	250.7e-k	338.2de
0.05	734.7ab	305.1d-h	203.8h-o	328.4def
0.10	650.2b	331.1def	178.0j-p	338.8de
0.15	540.9c	275.9d-j	142.1m-r	354.6de
0.20	513.8c	249.7e-l	136.9m-r	327.6def
0.25	453.8c	225.7f-m	130.5m-r	318.7d-g
0.30	453.3c	220.8g-m	102.1 opqr	307.8d-h
0.35	346.2de	207.4h-o	80.6pqr	300.9d-h
0.40	338.2de	186.3i-o	64.8qr	279.4d-j
0.45	288.4d-i	150.7k-q	60.4qr	264.4d-j
0.50	280.0d-i	149.1 l-q	56.4qr	257.5h-o
0.55	221.3g-n	118.9n-r	53.4qr	204.7i-o
0.60	192.0m-r	108.8n-r	39.7r	190.1

S.E(±) 31.35 For comparison within crops and herbicide rates.

1. DAS = Days after sowing.
2. All plots were hoe-weeded.

Interaction means within each crop followed by the same letter(s) are not significantly different at P = 0.05 using DMRT.

Table 23: Interaction of soyabean, cowpea, groundnut and bambaranut within imazethapyr on shoot dry weight at 56 DAS[1], at Samaru, 1992 wet season.

Imazethapyr rate (H)[2] (kg a.i/ha)	Shoot dry weight (kg/ha)			
	Soyabean	Cowpea	Groundnut	Bambaranut
0.00	2155ab	1761b-e	1206g-q	1552c-k
0.05	2056abc	1685b-i	1224fg	1564c-k
0.10	2353a	1695b-h	1295d-p	1572c-k
0.15	2481a	1800bcd	1173h-r	1640c-k
0.20	1790bcd	1435d-n	1005 1-t	1532d-1
0.25	1749bcdef	1421d-o	966n-t	1402d-o
0.30	1706b-g	1391d-o	927n-w	1245e-q
0.35	1644c-j	1372d-p	551t-z	1165i-r
0.40	1487d-m	1305d-p	451w-z	1145j-r
0.45	1214g-q	1123j-s	297w-z	1042 1-s
0.50	1106k-s	726q-y	271x-z	930n-w
0.55	764q-x	685r-y	234y-z	906o-w
0.60	611s-z	684e-y	158z	850p-w

S.E (±) 153.9 For comparison within crops and herbicide rates.

1. DAS = Days after sowing.
2. All plots were hoe-weeded

Interaction means within each crop followed by the same letter(s) are not significantly defferent at P=0.05 using DMRT.

Table 24: Interaction of soyabean, cowpea, groundnut and bambaranut with imazethapyr on shoot dry weight at 84 DAS[1], at Samaru, 1992 wet season.

Imazethapyr rate (H)[2] (kg a.i/ha)	Shoot dry weight (kg/ha)			
	Soyabean	Cowpea	Groundnut	Bambaranut
0.00	7800ab	3813d-h	3227e-j	3427d-j
0.05	7595ab	4165c-g	3259e-j	3217e-k
0.10	8327a	4651cde	3264e-j	3424d-j
0.15	8418a	4824cd	2699g-p	4184c-f
0.20	7606ab	3519d-i	2229i-r	3167f-l
0.25	7068ab	3256e-j	2085i-s	3052f-k
0.30	6854b	3097f-m	1956j-s	3037f-n
0.35	5245c	2976g-q	1740k-s	2955g-n
0.40	4468c-f	2575n-g	1679 l-s	2141i-r
0.45	3052f-m	2034i-s	1119q-t	1618m-s
0.50	2554h-q	1559n-t	735rst	1334 o-t
0.55	1741k-s	1297p-t	575st	1152q-t
0.60	1290p-t	1112q-t	101t	1017r-t

S.E(±) 439.1 For comparison within crops and herbicde rates.

1. DAS = Days after sowing.
2. All plots were hoe-weeded

Interaction means within each crop followed by the same letter(s) are not significantly different at P = 0.05 using DMRT.

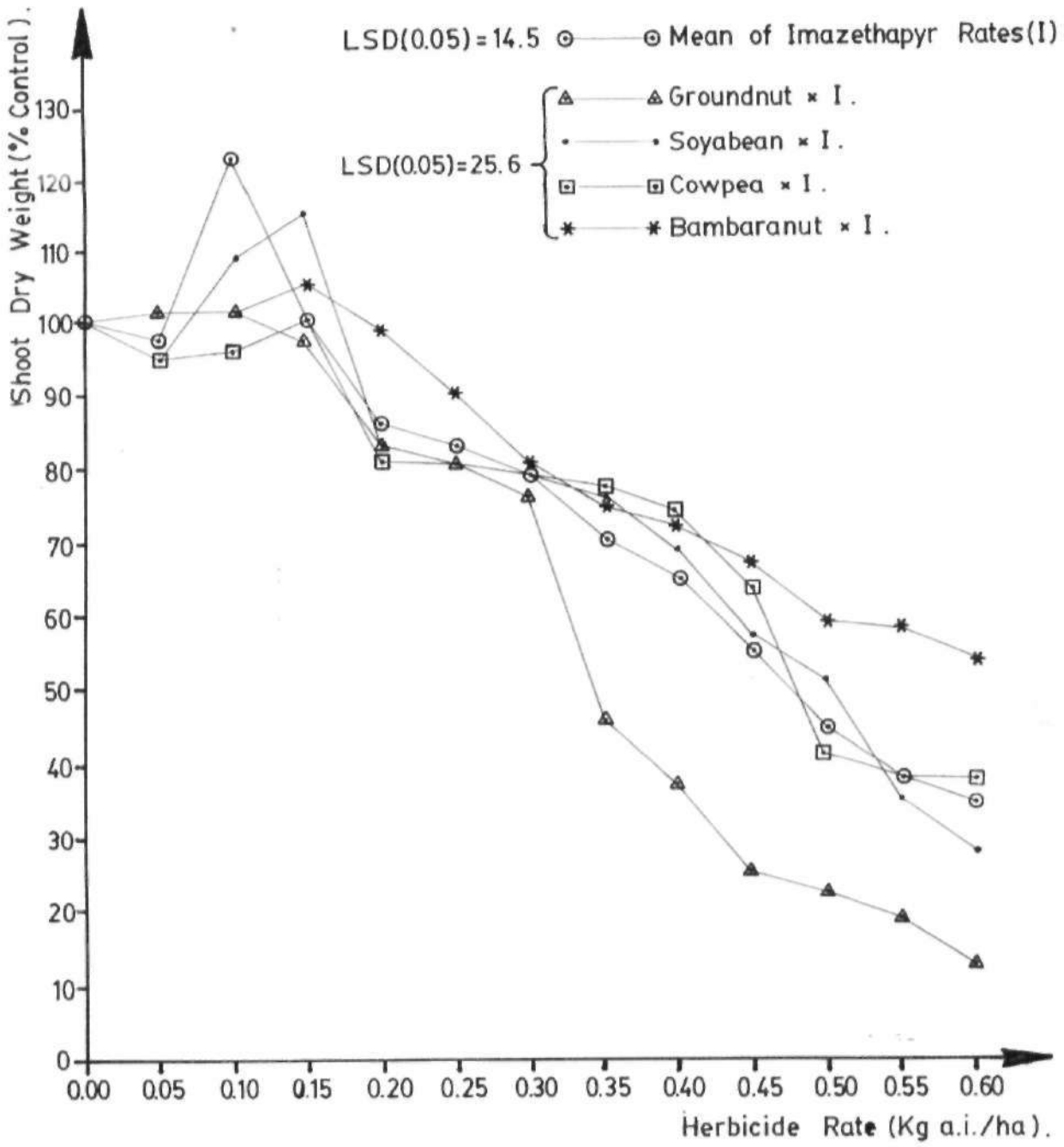


FIGURE 4 : SHOOT DRY WEIGHT RESPONSE TO IMAZETHAPYR RATES IN GROUNDNUT, SOYABEAN, COWPEA, AND BAMBARANUT UNDER FIELD CONDITIONS AT 56 DAS. (Samaru, 1992 Wet Season).

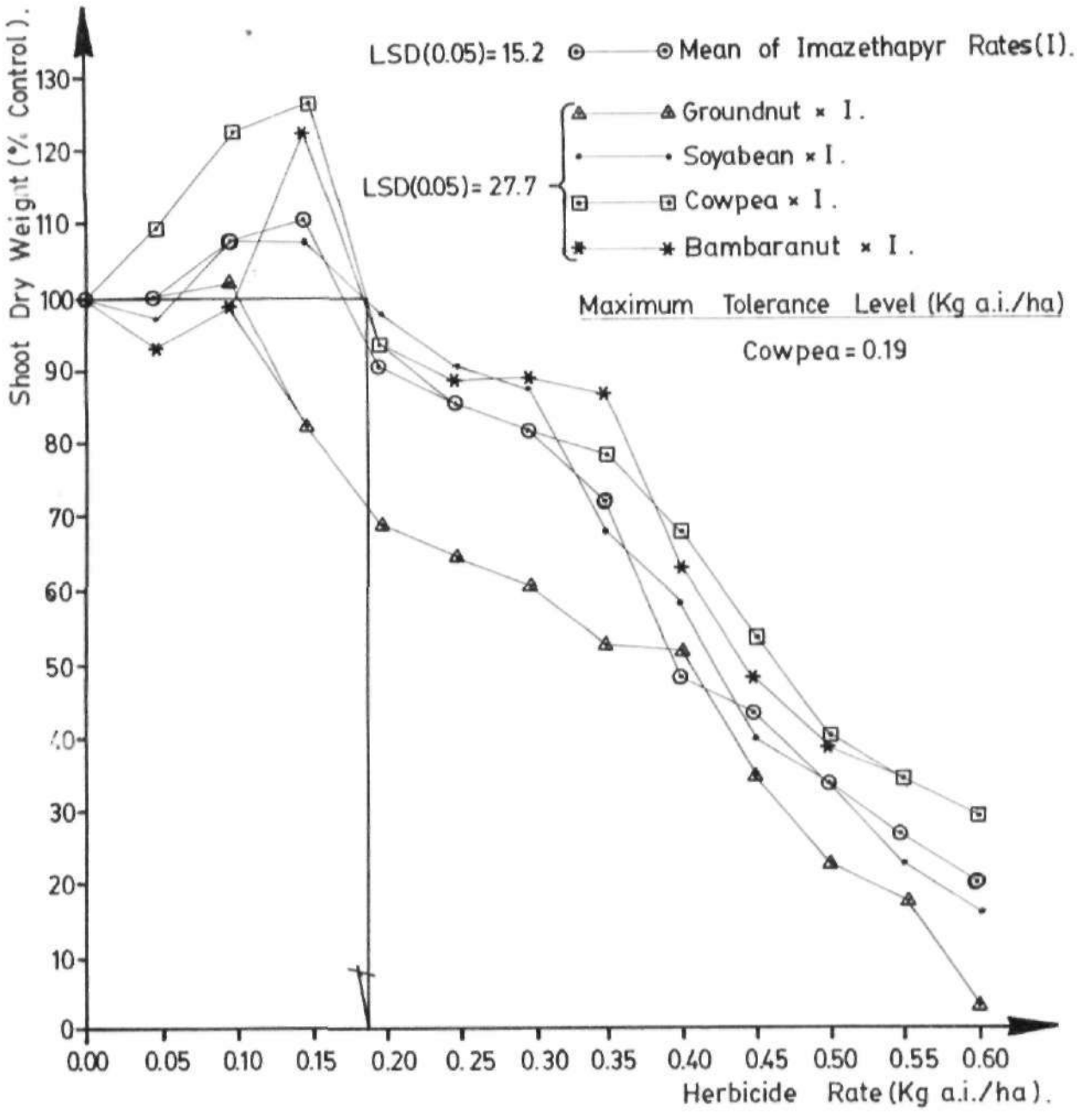


FIGURE 5: SHOOT DRY WEIGHT RESPONSES TO IMAZETHAPYR RATES IN GROUNDNUT, SOYABEAN, COWPEA, AND BAMBARANUT UNDER FIELD CONDITIONS AT 84 DAS.
(Samaru, 1992 Wet Season).

rates of 0.50kg a.i/ha, 0.45kg a.i/ha, 0.35kg a.i/ha and 0.30kg a.i/ha and above resulted in the least soyabean, cowpea, groundnut and bambaranut shoot dry weight respectively. At 84 DAS, however, the least shoot dry matter of soyabean, cowpea, groundnut and bambaranut were respectively observed on 0.50 to 0.60kg a.i/ha, 0.35 to 0.60kg a.i/ha, 0.45 to 0.60kg a.i/ha and 0.40 to 0.60kg a.i/ha treated plots. In general, at 56 and 84 DAS, imazethapyr rates of 0.05 to 0.15kg a.i/ha stimulated the shoot dry matter accumulation of the test crops although the effect was not significant when compared with the appropriate untreated control (Figures 4 and 5) maximum tolerance level of cowpea was 0.19kg a.i/ha.

4.3.7 Pod yield

The herbicide treatments had significant effect on pod yields of soyabean, groundnut and bambaranut. The crops also differed significantly in pod yield (Table 25).

Significant reduction in pod yield compared with the untreated control was observed with the application of 0.30kg a.i/ha and above with the least values occurring with 0.55 and 0.60kg a.i/ha (Figure 6).

Difference among crops in respect of pod yield was in the order bambaranut > ground > soyabean.

Table 25: Effect of various rates of imazethapyr and crop type on pod yield, 100-grain weight and grain yield in soyabean, groundnut and bambaranut at Samaru, 1992 wet season.

Imazethapyr rate (H) (kg a.i/ha)	Pod yield (kg/ha)	100-grain weight (g)	Grain yield kg/ha
0.00	2282a	60.16ab	1650b
0.05	2302a	59.96ab	1850ab
0.10	2296a	60.70a	1955a
0.15	2465a	60.52a	1835ab
0.20	2209a	60.63a	1613bc
0.25	2074ab	59.21b	1577bc
0.30	1824b	57.34c	1340c
0.35	1428c	57.06c	1047d
0.40	1116cd	57.02c	810de
0.45	865d	48.98d	688e
0.50	760de	41.78e	571ef
0.55	410ef	41.20e	351fg
0.60	269f	41.46e	239g
S.E (±)	120.5	0.967	92.9
Crop (C)			
Soyabean	1481b	13.17c	1097b
Groundnut	1346b	28.76b	926c
Bambaranut	1962a	121.00a	1560a
S.E (±)	53.5	0.471	38.3
Interaction	**	**	**

1. All plots were hoe-weeded. ** - Significant at P≤0.01.

Within factor means followed by the same letter(s) within a column are not significantly different at P = 0.05 using DMRT.

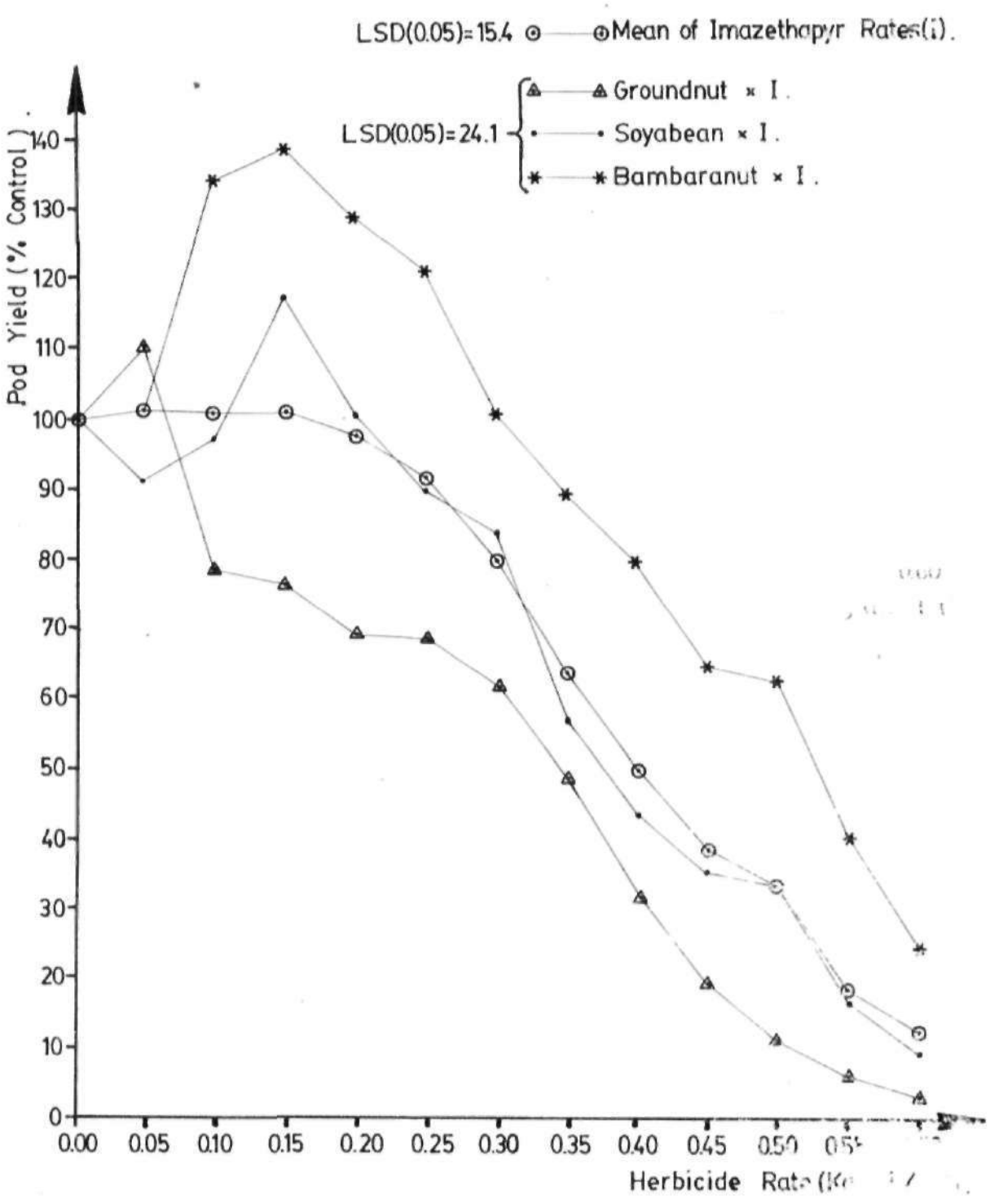


FIGURE 6: POD YIELD RESPONSE TO IMAZETHAPYR RATES IN GROUNDNUT, SOYABEAN, AND BAMBARANUT UNDER FIELD CONDITIONS.
(Samaru, 1992 Wet Season).

The interaction of herbicide rates and crops was significant on pod yield of soyabean groundnut and bambaranut (Table 26). Imazethapyr rates of 0.05 to 0.30kg ai/ha applied to soyabean and groundnut and 0.05 to 0.40kg a.i/ha on bambaranut resulted in pod yields comparable to the appropriate untreated control. Imazethapyr at 0.05kg a.i/ha in groundnut and 0.10 and 0.15kg a.i/ha in bambaranut resulted in significantly higher pod yields than the appropriate control. The least pod yield for soyabean and groundnut were obtained with imazethapyr at0.45 to 0.60kg a.i/ha and for bambaranut with imazethapyr at 0.55 and 0.60kg a.i/ha.

4.3.8 100-grain weight.

100-grain weight was significantly affected by herbicide rate. Significant differences in 100-grain weights of the crops were also observed (Table 25).

100-grain weights of crops treated with imazethapyr at 0.05 to 0.25kg a.i/ha were comparable to that of the untreated control, while the higher rates caused significant depression. Imazethapyr at 0.50 to 0.60kg a.i/ha resulted in the least 100-grain weight in the trial.

100-grain weights of the test crops followed the order bambaranut > groundnut > soyabean.

Table 26: Interaction of soyabean, groundnut and bambaranut with imazethapyr on pod yield at Samaru, 1992 wet season.

Imazethapyr rate (H)[1] (kg a.i/ha)	Pod yield (kg/ha)		
	Soyabean	Groundnut	Bambaranut
0.00	2215a-f	2582c-f	2049c-f
0.05	2005c-f	2832a	2069c-f
0.10	2141b-f	1998f-g	2749ab
0.15	2584a-d	1978f-g	2833a
0.20	2213a-f	1779f-g	2635abc
0.25	1977d-f	1767f-g	2478a-d
0.30	1855e-g	1561f-h	2055c-f
0.35	1243g-i	1215g-i	1826e-g
0.40	942h-j	791i-k	1614fg
0.45	776i-l	499j-m	1320g-i
0.50	740i-l	267k-m	1272g-i
0.55	356j-m	139 lm	736 i-l
0.60	200k-m	86m	520j-m

S.E (±) 198.3 For comparison within crops and herbicide rates.

1. All plots were hoe-weeded.

Interaction means within each crop followed by the same letter(s) are significantly not different at P = 0.05 using DMRT.

The interaction of imazethapyr and crops significantly affected 100-grain weight (Table 27). Within the same crop at varying herbicide rates, significant differences in 100-grain weights were obtained for only groundnut and bambaranut. Significant reduction in 100-grain weights of bambaranut and groundnuts was obtained with the application of imazethapyr at 0.40 to 0.60kg a.i/ha.

4.3.8 Grain yield

The effect of imazethapyr on grain yield of the crops was significant. Crops also differed significantly in grain yield (Table 25).

As observed with the pod yields, imazethapyr at 0.05 to 0.25kg a.i/ha resulted in grain yields that were not significantly lower than the untreated control. Significantly higher yield was obtained with imazethapyr at 0.10kg a.i/ha compared with the untreated control. At 0.30 to 0.60kg a.i/ha, grain yield generally decline with increasing rate of imazethapyr, with the rates of 0.55 and 0.60 resulting in the least yields.

Grain yield production of the crops was in the order bambaranut > soyabean > groundnut.

Interaction of imazethapyr rates and crops significantly influenced grain yield (Table 28).

Table 27: Interaction of soyabean, groundnut and bambaranut with imazethapyr on 100-grain weight at Samaru, 1992 wet season.

Imazethapyr rate (H)[1] (kg a.i/ha)	100-grain weight (g)		
	Soyabean	Groundnut	Bambaranut
0.00	13.47g	33.63d	133.37a
0.05	13.40g	34.10d	132.07a
0.10	13.40g	34.63d	134.07a
0.15	13.43g	34.27d	133.87a
0.20	13.47g	34.40d	134.03a
0.25	13.33g	33.03d	131.27a
0.30	13.30g	29.23d	129.50a
0.35	13.33g	29.27d	128.95a
0.40	13.23g	29.23d	128.60a
0.45	13.17g	24.00e	109.67b
0.50	12.90g	20.80e	91.63c
0.55	12.73g	18.63f	92.23c
0.60	12.03g	18.57f	92.77c

S.E(±) 1.690 For comparison within crops and herbicide rates.

1. All plots were hoe-weeded.

Interaction means within each crop followed by same letter(s) are not significantly different at P = 0.05 using DMRT.

Table 28: Interaction of soyabean, groundnut and bambaranut with imazethapyr on grain yield at Samaru, 1992 wet season.

Imazethapyr rate (H)[1] (kg a.i/ha)	Grain yield (kg/ha)		
	Soyabean	Groundnut	Bambaranut
0.00	1621a-g	1413e-i	1915a-d
0.05	1613a-g	1907a-d	2030abc
0.10	1774a-g	2046ab	2045ab
0.15	1866a-d	1548c-f	2091a
0.20	1552c-f	1301g-j	1985abc
0.25	1549c-f	1292g-j	1891a-d
0.30	1388f-i	1025i-l	1608a-g
0.35	875k-m	684k-n	1582b-h
0.40	638 l-p	353 nop	1439 d-i
0.45	530 m-p	186 op	1349g-i
0.50	488 m-p	106p	1119 h-k
0.55	247 nop	96 p	710k-n
0.60	126 p	80 p	510 m-p

S.E.(±) 145.9 For comparison within crops and herbicide rates.

1. All plots were hoe-weeded

Interaction means within each crop followed by the same letter(s) are not significantly different at P = 0.05 using DMRT.

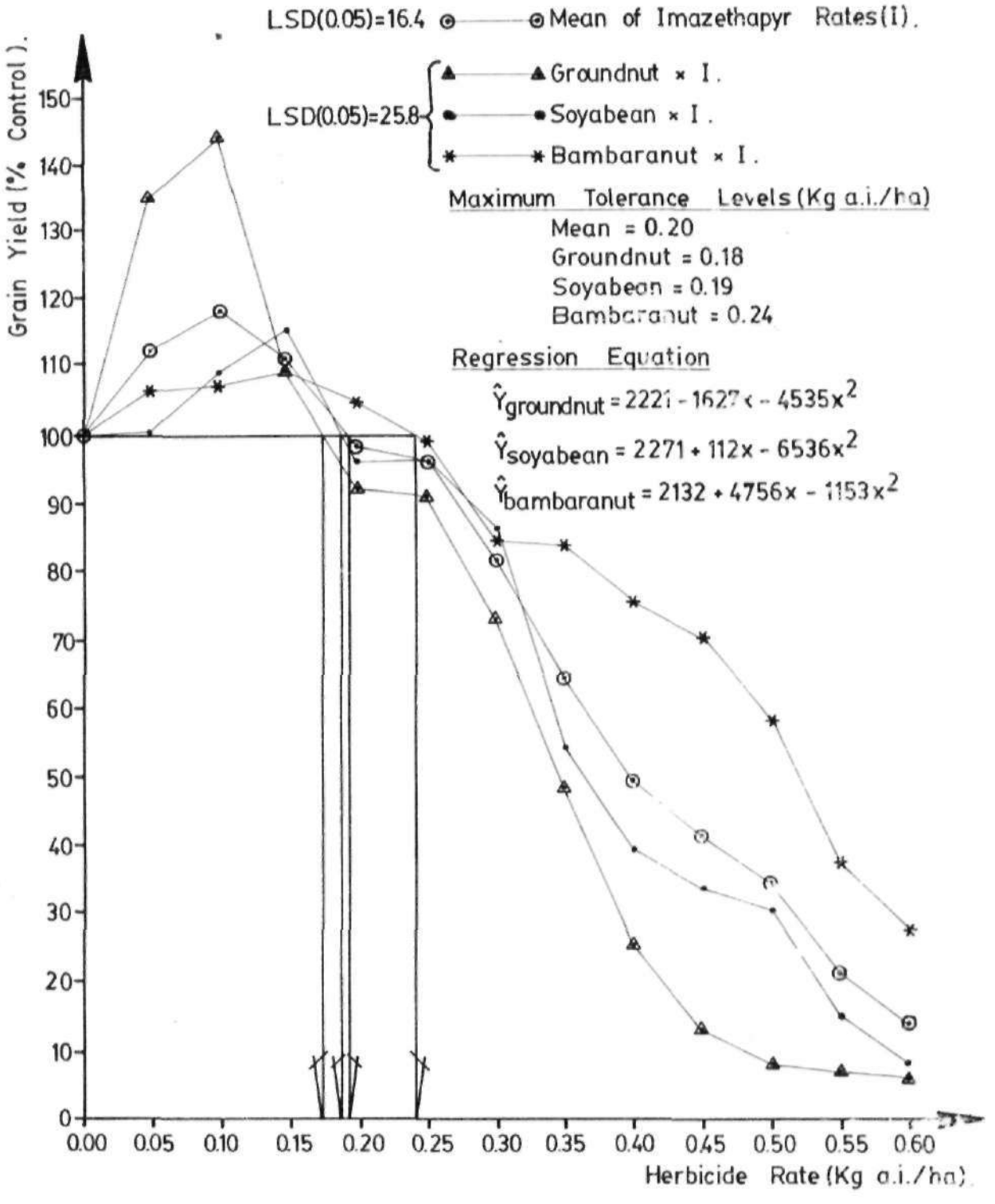


FIGURE 7: GRAIN YIELD RESPONSE TO IMAZETHAPYR RATES IN GROUNDNUT, SOYABEAN, AND BAMBARANUT UNDER FIELD CONDITIONS.
(Samaru, 1992 Wet Season).

Table 29: Correlation of various parameters with soyabean grain yield at Samaru, 1992 w[illegible] season.

	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	S_{11}	S_{12}	S_{13}	S_{14}
S_1	1.000													
S_2	0.938**	1.000												
S_3	0.148	0.043	1.000											
S_4	-0.148	-0.029	-0.762**	1.000										
S_5	-0.169	-0.072	-0.731**	0.930**	1.000									
S_6	0.163	0.090	0.668**	-0.872**	-0.852**	1.000								
S_7	0.258	0.177	0.715**	0.902**	-0.900**	0.894**	1.000							
S_8	-0.225	-0.118	-0.746**	0.898**	0.908**	-0.805**	-0.826**	1.000						
S_9	0.190	0.069	0.618**	-0.839**	-0.804**	0.855**	0.804**	-0.793**	1.000					
S_{10}	0.123	0.017	0.630**	-0.767**	-0.775**	0.685**	0.703**	-0.710**	0.631**	1.000				
S_{11}	0.147	0.059	0.693**	-0.830**	-0.811**	0.733**	0.743**	-0.786**	0.625**	0.823**	1.000			
S_{12}	0.135	0.026	0.759**	-0.888**	-0.924**	0.800**	0.892**	-0.831**	0.734**	0.749**	0.753**	1.000		
S_{13}	0.084	0.017	0.572**	-0.733**	-0.819**	0.684**	0.717**	-0.757**	0.640**	0.684**	0.764**	0.749**	1.000	
S_{14}	0.133	0.023	0.758**	-0.885**	-0.922**	0.803**	0.895**	-0.825**	0.738**	0.753**	0.752**	0.997**	0.751**	1.000

S_1 = Stand count at 20 DAS
S_2 = Stand count at harvest
S_3 = Nodulation at 49 DAS
S_4 = Herbicide injury score at 20 DAS
S_5 = Herbicide injury score at 50 DAS
S_6 = Crop vigour score at 20 DAS
S_7 = Crop vigour score at 50 DAS
S_8 = Days to 50% flowering
S_9 = Shoot dry matter production at 28 DAS
S_{10} = Shoot dry matter production at 56 DAS
S_{11} = Shoot dry matter production at 84 DAS
S_{12} = Pod yield.
S_{13} = 100-grain weight
S_{14} = Grain yield.

DAS = Days after sowing; * (0.312) = Significant at 5% level of probability.
** (0.408) = Significant at 1% level of probability.

Table 30: Correlation of various parameters with groundnut grain yield at Samaru, 1992 wet season.

	G_1	G_2	G_3	G_4	G_5	G_6	G_7	G_8	G_9	G_{10}	G_{11}	G_{12}	G_{13}	G_{14}
G_1	1.000													
G_2	0.915**	1.000												
G_3	-0.059	-0.151	1.000											
G_4	0.072	0.134	-0.817**	1.000										
G_5	0.026	0.082	-0.759**	0.929**	1.000									
G_6	0.004	-0.084	0.785**	-0.919**	-0.917**	1.000								
G_7	-0.234	-0.188	0.294	-0.318*	-0.283	0.284								
G_8	0.056	0.156	-0.801**	0.862**	0.867**	-0.843**	-0.243	1.000						
G_9	-0.45	-0.136	0.674**	-0.809**	-0.788**	0.790**	0.107	-0.856**	1.000					
G_{10}	-0.062	-0.165	0.753**	-0.853**	-0.918**	0.872**	0.192	-0.820**	0.765**	1.000				
G_{11}	0.053	0.006	0.744**	-0.866**	-0.792**	0.816**	0.316*	-0.811**	0.784**	0.701**	1.000			
G_{12}	0.013	-0.023	0.679**	-0.856**	-0.888**	0.837**	0.364*	-0.703**	0.703**	0.817**	0.804**	1.000		
G_{13}	-0.042	-0.092	0.772**	-0.925**	-0.948**	0.938**	0.279	-0.802**	0.739**	0.876**	0.782**	0.847**	1.000	
G_{14}	0.016	-0.020	0.686**	-0.854**	-0.886**	0.832**	0.360*	-0.705**	0.708**	0.816**	0.805**	0.999**	0.843**	1.000

G_1 = Stand count at 20 DAS
G_2 = Stand count at harvest
G_3 = Nodulation at 56 DAS
G_4 = Herbicide injury score at 20 DAS
G_5 = Herbicide injury score at 50 DAS
G_6 = Crop vigour score at 20 DAS
G_7 = Crop vigour score at 50 DAS
G_8 = Days to 50 % flowering
G_9 = Shoot dry matter production at 28 DAS
G_{10} = Shoot dry matter production at 56 DAS.
G_{11} = Shoot dry matter production at 84 DAS
G_{12} = Pod yield
G_{13} = 100-grain weight
G_{14} = Grain yield.

DAS = Days after sowing; * (0.312) = Significant at 5% level of probability.
** (0.408) = Significant at 1% level of probability.

Table 31: Correlation of various parameters with bambaranut grain yield at Samaru, 1992 wet season.

	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8	B_9	B_{10}	B_{11}	B_{12}	B_{13}	B_{14}
B_1	1.000													
B_2	0.961**	1.000												
B_3	0.166	-0.178	1.000											
B_4	0.046	0.132	-0.592**	1.000										
B_5	0.050	0.125	-0.538**	0.843**	1.000									
B_6	-0.049	-0.141	0.559**	-0.851**	-0.755**	1.000								
B_7	0.141	-0.139	0.488**	-0.603**	-0.631**	0.429**	1.000							
B_8	0.192	0.282	-0.468**	0.793**	0.631**	-0.797**	-0.493**	1.000						
B_9	0.076	0.027	0.320*	-0.580**	-0.674**	0.517**	0.326*	-0.407*	1.000					
B_{10}	-0.230	-0.165	0.306	-0.292	-0.248	0.246	0.514**	-0.375*	0.315*	1.000				
B_{11}	-0.283	-0.357*	0.259	-0.595**	-0.579**	0.416**	0.534**	-0.509**	0.468**	0.251	1.000			
B_{12}	-0.255	-0.184	-0.196	0.449**	-0.773**	-0.565**	0.647**	-0.578**	0.585**	0.294	0.551**	1.000		
B_{13}	-0.128	-0.202	0.581**	-0.906**	-0.905**	0.827**	0.592**	-0.753**	0.529**	0.253	0.599**	0.735**	1.000	
B_{14}	-0.165	-0.182	0.450**	-0.797**	-0.749**	0.585**	0.684**	-0.594**	0.583**	0.309	0.582**	0.991**	0.752**	1.000

B_1 = Stand count at 20 DAS
B_2 = Stand count at harvest
B_3 = Nodulation at 56 DAS
B_4 = Herbicide injury at 20 DAS
B_5 = Herbicide injury at 50 DAS
B_6 = Crop vigour score at 20 DAS
B_7 = Crop vigour at 50 DAS
B_8 = Days to 50 % flowering
B_9 = Shoot dry matter production at 28 DAS
B_{10} = Shoot dry matter production at 56 DAS
B_{11} = Shoot dry matter production at 84 DAS
B_{12} = Pod yield.
B_{13} = 100-grain weight
B_{14} = Grain yield.

DAS = Days after sowing. *(0.312) = Significant at 5% level of probability.
** (0.408) = Significant at 1% level of probability.

Crop vigour scores of soyabean at 20 and 50 DAS were positively correlated with nodulation (r = 0.668) and (r = 0.715), respectively. Crop vigour score at 50 DAS was negatively correlated with herbicide injury at 20 DAS (r = - 0.902) and 50 DAS (r = - 0.900).

Significant negative correlation was obtained between nodulation at 49 DAS and herbicide injury score at 20 DAS (r = - 0.762) and 50 DAS (r= - 0.731).

Grain yield of groundnut was positively correlated with nodulation at 56 DAS (r=0.686), crop vigour score at 20 and 50 DAS (r = 0.832 and r = 0.360 respectively), shoot dry matter production at 28, 56 and 84 DAS (r= 0.708, r = 0.816 and r = 0.805 respectively), pod yield (r= 0.999) and 100-grain weight (r= 0.843). It was also negatively correlated with herbicide injury at 20 and 50 DAS (r =-0.854 and r = - 0.886 respectively) and days to 50% flowering (r = 0.705).

The crop vigour score at 20 was positively correlated with nodulation (r = 0.785), but negatively correlated with herbicide injury score at 20 and 50 DAS (r = - 0.919, r = - 0.917 and r = - 0.318, respectively).

Significant and negative correlation was obtained between nodulation at 42 DAS and herbicide injury score at 20 (r = - 0.817) and 50 DAS (r=-0.759).

There were significant positive correlations between grain yield of bambaranut and nodulation at 56 DAS (r = 0.450), crop vigour score at 20 and 50 DAS (r = 0.585 and r = 0.684 respectively, shoot dry matter production at 28 and 84 DAS (r=0.583 and r = 0.582 respectively), pod yield (r = 0.991) and 100-grain weight (r= 0.752). Significant negative correlations were observed between grain herbicide injury scores at 20 and 50 DAS (r = - 0.797 and r = - 0.749 respectively) and days to 50% flowering (r = - 0.594).

Crop vigour scores of bambaranut at 20 and 50 DAS were positively correlated with nodulation at 56 DAS (r = 0.559 and r = 0.488), but negatively correlated with herbicide injury score at 20 DAS (r = - 0.851 and r = - 0.603 respectively) and 50 DAS (r = - 0.755 and r = - 0.631 respectively).

There were significant and negative correlations between nodulation and herbicide injury scores at 20 and 50 DAS (r = - 0.592 and r = - 0.538).

CHAPTER 5.

DISCUSSION

5.1 Introduction

The results obtained showed significant differences in crop growth, yield and yield attributes as a result of changes in the rates of imazethapyr. As reflected in most parameters the growth and yield of the legumes tested were not adversely affected by imazethapyr at rates 0.05 to 0.15kg a.i/ha compared with other treatments. However, substantial reduction in growth and yield generally occurred as herbicide rate increased from 0.20kg a.i/ha due to phytotoxicity of lethal concentrations of imazethapyr as also reported for several other herbicides (Wiedman and Appleby, 1972. Salazar and Appleby, 1982 .) and imazethapyr (Wang et al., 1985). These findings are consistent with earlier reports that imazethapyr at recommended rates of upto 0.15kg a.i/ha did not adversely affect crop growth and development (Wang et al., 1985; Vanwinkel et al., 1989; Buhari, 1980; Mgbemena, 1990; Lagoke et al., 1991a).

5.2 Effect of imazethapyr on the legumes

The study showed no significant influence of various rates of imazethapyr on emergence and establishment of the leguminous crops. Similar results were obtained by Buhari (1990) and Lagoke et al. (1991a)

when imazethapyr was applied at 0.025 to 0.075kg a.i/ha to soyabean and groundnut, respectively. However, phytotoxicity score, crop vigour score, plant height, days to 50% flowering, nodulation, dry matter production, pod yield, 100-grain weight and grain yield were significantly affected by the herbicide at rates in excess of the recommended rate.

Visual assessment of phytotoxicity indicated that imazethapyr rates of 0.15kg a.i/ha in the screenhouse and 0.20kg a.i/ha in the field resulted in crop injury at the early stages of growth. Injury symptoms of interveinal chlorosis, epinasty and shortening of internodes declined with age at low rates but the severity increased with increasing rate from 0.30kg a.i/ha as reflected by phytotoxicity score. In a study of tolerance of some grain legumes to imazethapyr, Wang et al. (1985) observed that the herbicide at 0.25 to 0.30kg a.i/ha resulted in phytotoxicity to soyabean and groundnut.

The significant differences in crop vigour scores were observed at 20 and 50 DAS. Crop vigour score generally decreased with increasing rate of herbicide at 20 DAS, with the least scores occuring at 0.90kg a.i/ha and 0.55kg a.i/ha in the screenhouse and field, respectively. But the initial low vigour as a result of imazethapyr application at the rates of 0.05 to 0.25kg a.i/ha did not persist till 50 DAS, as crop vigour was comparable with the untreated control.

This is in line with the observations of several workers fof imazethapyr and other herbicides on some leguminous crops including soyabean and groundnuts, that the adverse herbicide effect at the early stages of growth may not persist till harvest (Hagood et al., 1980; Wang et al., 1985; Mills and Witt, 1989). The lower crop vigour observed at 0.30kg a.i/ha and above compared with the untreated control throughout the life cycle of the legumes could be attributed herbicide phytotoxicity, probably as a result of the disruption in physiological functions of the crops leading to the reduction of the levels of branch-chain aliphatic amino acids as reported by Wang et al.(1985) and Shaner and Mallipudi (1991). Furthermore, a slight stimulation of crop vigour was obtained at 0.05 to 0.15kg a.i/ha at 50 DAS in the field. This agrees with earlier reports on imazethapyr and several other herbicides that at sublethal concentrations, plant growth was enhanced (Wiedman and Appleby, 1972, Salazar and Appleby 1982, Helms and Halvorson, 1991). Also data presented by Lagoke et al. (1991a) on imazethapyr at 0.025 and 0.075kg a.i/ha indicated the stimulation of groundnut vigour by 48 and 20.5% respectively.

Imazethapyr significantly depressed plant height at 0.90kg a.i/ha and above at 20 DAS, with the effect persisting to 50 DAS, at which stage shorter plants were also noted at 0.60kg a.i/ha and above. The high herbicide injury score of 33 to 81% observed at 0.60 to 1.00kg a.i/ha 50 DAS, propably resulted in slow rate of imazethapyr metabolism (Wang et al., 1985) with the resultant adverse effect on plant height. Similarly, Obilana and Lagoke (1979) observed a reduction in plant height as a result of the application of a mixture of atrazine and pendimethalin.

Days to 50% flowering was not significantly affected by imazethapyr at 0.05 to 0.25kg a.i/ha while 0.30kg a.i/ha and above delayed flowering compared with the untreated control. Imazethapyr rates of 0.50 to 0.60kg a.i/ha resulted in the longest days to flowering probably as a result of high herbicide injury. Imazethapyr rates of 0.05 to 0.30kg a.i/ha favoured root nodulation in the field. However, at 0.35kg a.i/ha and above the herbicide had a depressive influence on nodulation with the rates of 0.45kg a.i/ha and 1.00kg a.i/ha resulting in the least number of nodules in the field and screenhouse, respectively, probably as a result of phytotoxicity. In the screenhouse, imazethapyr at 0.15kg a.i/ha, however, stimulated nodulation in the plants compared with untreated control.

Although the response of crop vigour score of the plant to imazethapyr in each sampling was similar to that of shoot dry matter, the latter parameter was more adversely affected at the early stages of growth. At 28 DAS, imazethapyr at 0.15kg a.i/ha and above caused significant reduction in shoot dry matter production compared with the untreated control. This effect did not, however, persist to 56 DAS at which stage only 0.30kg a.i/ha and above reduced shoot production, compared with the untreated control. The application of 0.55 and 0.60kg a.i/ha, at 28 DAS and 0.50 to 0.60kg a.i/ha at 56 and 84 DAS resulted in the least shoot dry weights. Total dry matter was not adversely affected by rates of 0.15 to 0.45kg a.i/ha in the screenhouse. The results obtained were a reflection of the effect of the herbicide treatments on crop vigour and phytotoxicity scores.

Similar to crop vigour score and shoot dry matter production, pod yields at the rates 0.05 to 0.25kg a.i/ha were not significantly different compared with the untreated control. At 0.30kg a.i/ha and above a significant reduction in pod yields per unit area were observed with the rates of 0.55 and 0.60kg a.i/ha resulting in the least values. Similarly, using the herbicide rates of 0.025 to 0.075kg a.i/ha Buhari (1990) and Lagoke et al. (1991a) did not observe any

significant influence of imazethapyr on pod yields of soyabean and groundnut at Samaru. Increasing imazethapyr rates from 0.05 to 0.25kg a.i/ha did not adversely affect 100-grain weight of the legumes while at 0.30kg a.i/ha and above a significant reduction in 100-grain weight occurred, with the least results obtained at 0.50 to 0.60kg a.i/ha.

Imazethapyr at the rates of 0.05 to 0.25kg a.i/ha resulted in comparable grain yields to that of the untreated control. However at 0.30 to 0.60kg a.i/ha, grain yields were significantly reduced compared with the untreated control. Among the herbicide rates, only 0.10kg a.i/ha resulted in improved production of grain yield. The favourable influence of imazethapyr at low rates of up to 0.25kg a.i/ha on grain yield could be attributed to low phytotoxicity score, which apparently did not adversely affect vegetative growth, days to flowering, nodulation, shoot dry matter production at 56 and 84 DAS and also the yield attributes of pod and 100-grain weights. On the contrary, the decline in grain yields at imazethapyr rates far in excess of the recommended was a reflection of high phytotoxicity scores. The application of imazethapyr at commercial use rates resulted in good grain yields in soyabean (Buhari, 1990; Helms and Halvorson, 1991) and groundnuts (Wilcut et al. 1991; Lagoke et al., 1991a).

5.3 Performance of the legume crops.

The results obtained from the overall effects of imazethapyr rates on the test crops indicated significant differences among the crops with respect to the parameters measured. Cowpea had better emergence than soyabean, groundnut and bambaranut in the screenhouse. However, soyabean had the highest emergence and stand count and bambaranut the least, while those of cowpea and groundnut were similar throughout the growing season. The varieties of the crops tested, in the exception of bambaranut are recommended varieties in Nigeria. However, the total dry matter production of cowpea and bambaranut were higher than those of soyabean and groundnut which were also similar.

In the trial, groundnut was the most susceptible to herbicide injury followed by soyabean. Bambaranut and cowpea were equally sensitive to imazethapyr in the screenhouse but bambaranut showed more tolerance in the field.

Plants of bambaranut and cowpea were more vigorous than those of soyabean and groundnut in the screenhouse. However, in the field, although soyabean and groundnut were the least vigorous, bambaranut had better vigour than cowpea. Cowpea was taller than groundnut while soyabean produced the tallest plants. Soyabean had the highest shoot dry

weight while groundnut produced the least in the trial. Shoot dry matter production of cowpea was higher than that of bambaranut at 84 DAS, but less at 28 and 56 DAS.

Groundnut reached 50% flowering at about 11, 17 and 18 days earlier than bambaranut, cowpea and soyabean respectively. Nodulation was highest in groundnut and least in soyabean and bambaranut.

Bambaranut produced the highest pod yield, 100-grain weight and grain yield than soyabean and groundnut. The advantage in mean performance of bambaranut in seed weight, pod and grain yields at all rates of imazethapyr could be attributed to its genetic tolerance to the herbicide.

5.4 Interaction of crops and imazethapyr rates on growth, yield and yield components.

The interaction of imazethapyr rates and crops was significant on phytotoxicity score, crop vigour score, plant height, days to 50% flowering, nodulation, shoot dry matter production and yield and yield components.

Cowpea and bambaranut apparently tolerated imazethapyr more than soyabean and groundnut. In general, parameters recorded on cowpea and bambaranut treated with imazethapyr up to 0.30kg a.i/ha

and 0.35kg a.i/ha did not differ significantly from that of the untreated control while those of soyabean and groundnut were only comparable at up to 0.25kg a.i/ha.

In the trial, groundnut and soyabean were the most susceptible crops to herbicide injury while bambaranut was the least. Groundnut was the most sensitive legume to imazethapyr at higher rates of 0.30 to 0.60kg a.i/ha as indicated by the average phytotoxicity scores of 60, 48, 19 and 11% to groundnuts, soyabean, cowpea and bambaranut respectively, 50 DAS. The crops, however, overcame the initial phytotoxic effect of imazethapyr rates of 0.25kg a.i/ha, 0.25kg a.i/ha, 0.30kg a.i/ha and 0.35kg a.i/ha on groundnut, soyabean, cowpea and bambaranut respectively as reflected in similar phytotoxicity score to the appropriate control at 50 DAS. The herbicide has been earlier reported to cause phytotoxicity at the early stage of growth on soyabean, groundnut and beans (Wang et al., 1985; Mills and Witt, 1989; Helms and Halvorson, 1991; Blackshaw and Esau, 1991. Wilcut et al.,1991), but plants recover with age.

In response to imazethapyr treatments only cowpea and bambaranut had comparable vigour to the appropriate untreated control at 0.10kg a.i/ha, 20 DAS. Despite the low phytotoxicity scores, all the herbicide treatments depressed crop vigour in groundnuts and soyabean.

However, groundnut and soyabean vigour were not adversely affected at 0.05 to 0.25kg a.i/ha, neither those of cowpea and bambaranut at 0.05 to 0.35kg a.i/ha and 0.05 to 0.40kg a.i/ha respectively. In spite of 10% and 15% phytotoxicity on bambaranut and cowpea at 0.40kg a.i/ha and 0.35kg a.i/ha, growth was not reduced compared with the untreated control due to insufficient injury. The crops overcame the initial depressive effects of lower rates of imazethapyr on vigour score at 20 DAS.

Plant heights of only soyabean were sensitive to imazethapyr at 35 DAS, with the height at 0.90kg a.i/ha comparable to the untreated control. Also at 50 DAS, plant heights of only soyabean and groundnut were sensitive to imazethapyr treatment with soyabean and groundnut heights greater than or comparable to the appropriate untreated control at 0.35kg a.i/ha and 0.90kg a.i/ha. At commercial use rates, soyabean height was not sensitive to imazethapyr treatment (Buhari, 1990; Helms and Halvorson, 1991).

Days to flowering was not affected by imazethapyr at 0.05 to 0.25kg a.i/ha, o.05 to 0.30kg a.i/ha in groundnut and soyabean respectively, as well as 0.05 to 0.35kg a.i/ha in cowpea and bambaranut. Higher rates than indicated for the crops, increased days to flowering. This confirms the sensitivity of days to

flowering to imazethapyr treatment. The sensitivity was more magnified in cowpea and soyabean whose pods are carried well above the ground level. Higher rates of 0.50 to 0.60kg a.i/ha increased days to 50% flowering than the lower rates in the two crops. Nodulation of soyabean was not significantly depressed by imazethapyr although plants treated with 0.60 to 1.00kg a.i/ha did not form nodules. Nodule formation at rates up to 0.30kg a.i/ha in groundnuts and 0.75kg a.i/ha in cowpea and bambaranut were comparable to the appropriate untreated control in the screenhouse. However, in the field, imazethapyr at rates up to 0.25kg a.i/ha and 0.50kg a.i/ha resulted in favourable nodulation in groundnut and cowpea respectively. Soyabean and bambaranut nodule formation was not sensitive to the herbicide treatments in spite of high phytotoxicity scores. The reason for the non-significant depression in soyabean and bambaranut could be attributed to low nodulation by the two crops compared with cowpea and groundnut and further confounded by the effect of imazethapyr. This probably has little to do with tolerance in the crops and may not be a critical index.

Shoot dry matter production of soyabean, groundnut, cowpea and bambaranut at rates up to 0.05kg a.i/ha, 0.10kg a.i/ha , 0.15kg a.i/ha and 0.50kg a.i/ha were comparable with the appropriate untreated control

at 28 DAS. The phytotoxicity at 20 DAS, appeared to have influenced shoot dry matter production and the low injury scores at 0.30 to 0.50kg a.i/ha on bambaranut did not adversely affect the parameter. Imazethapyr at 0.05 to 0.30kg a.i/ha in groundnut and soyabean and 0.05 to 0.40kg a.i/ha resulted in shoot dry matter compared with the appropriate untreated control. Significant reduction in shoot dry matter production occurred at higher rates than quoted for the legumes as a result of high phytotoxicity.

Results of the phytotoxicity score, crop vigour score and shoot dry matter production had a good measure of influence on yield and yield components, resulting in substantial reduction in the parameters at high imazethapyr rates. Pod yields of soyabean and groundnut at the rates of 0.05 to 0.30kg a.i/ha, bambaranut at 0.05 to 0.40kg a.i/ha, slightly improved or compared with the appropriate untreated control. Significant depression in the pod yield production of the crops occurred when the herbicide rates increased to 0.35kg a.i/ha for soyabean and groundnut and 0.45kg a.i/ha for bambaranut.

100-grain weight of soyabean was not sensitive to imazethapyr at 0.05 to 0.60kg a.i/ha while in groundnut and bambaranut, rates up to 0.40kg a.i/ha resulted in comparable weights to the untreated control. The inherently larger grain size of groundnut and bambaranut compared with soyabean probably confounded the effect of imazethapyr on soyabean seed.

Similar to the results obtained for yield attributes of pod yield and 100-grain weight, grain yields of soyabean, groundnut and bambaranut were respectively reduced at 0.35kg a.i/ha, 0.35kg a.i/ha and 0.45kg a.i/ha and above compared with the appropriate untreated control. Despite 10 to 30% phytotoxicity at 0.30kg a.i/ha on soyabean and groundnut and at 0.40kg a.i/ha on bambaranut at 50 DAS, grain yields were not reduced. This could be due to substantial recovery by the crop at later stages of growth as earlier reported for some grain legumes including beans, soyabean and groundnut (Wang et al., 1985; Helms and Halvorson, 1991, Wilcut et al., 1991).

Results of the trial further showed that the parameter most sensitive in soyabean and cowpea was days to 50% flowering, while those of groundnut and bambaranutwere grain yield and crop vigour score at 20 DAS respectively. The high oil content of groundnut which probably influenced its sensitivity to the herbicide and also the pre-emergence application of the herbicide could be an added factor which pronounced the severity of injury in this crop which burries its pods below the ground level. In spite of the good tolerance of bambaranut to imazethapyr, the severe depression of its growth vigour at the early stage of growth could be attributed to time required for the necessary physiological biodegradation of the herbicide (Sharner et al., 1984) to non-toxic forms.

The physiological basis of selectivity of imazethapyr in leguminous crops have been reported (Sharner et al., 1984; Wang et al., 1985; Sharner and Mallipudi, 1991). Sharner et al, (1984) and Wang et al. (1985) observed that imazethapyr sensitive plants are killed by the inhibition of acetohydroxyacid synthase, which catalyses the first step in the biosynthesis of the branch-chain amino acids, valine, leucine and isoleucine. Sharner and Mallipudi (1991) noted that the predominant mechanism of selectivity of imazethapyr is differential rates of metabolism followed by conjugation to glucose. However, they maintained that the real detoxification step of imazethapyr is the conjugation of the hydroxylated metabolite to glucose. Comparing the response of imazethapyr-sensitive corn to imazethapyr-tolerant soyabean, Sharner and Mallipudi (1991) observed that the difference in the metabolism of imazethapyr between the two species is that soyabean plants rapidly conjugate the hydroxylated imazethapyr with glucose while corn plants do not.

In this trial, the two crops viz: groundnut and soyabean most susceptible to imazethapyr are oil-seed legumes compared with the other two pulses. Imazethapyr has inhibitory effect on amino acid synthesis. High amino acid biodegradation therefore overwhelmed the growth and development of the oil-seed crops more, relative to the other

dry-seed pulses, which appear less sensitive to inhibition of acetohydroxyacid synthase. This may be responsible for the differential tolerance of the crops in the trial. Furthermore, Miflin and Cave (1972) observed in vitro assays of corn plants that acetohydroxyacid synthase activity in plants is normally feed back regulated by valine and leucine. Also, that the feedback regulation by valine and leucine appear normal for the herbicide-resistant crops.

Application of imazethapyr at 0.15kg a.i/ha was stimulatory on cowpea and groundnuts heights while soyabean height improved at 0.30kg a.i/ha and 0.45kg a.i/ha over the untreated control in the screenhouse, although this parameter appears not to be a critical index in this trial. In the field crop growth was slightly stimulated by imazethapyr rates of 0.05 and 0.10kg a.i/ha in soyabean and 0.05 to 0.15kg a.i/ha in cowpea, groundnut and bambaranut. Similar results of improved growth were obtained at 0.075kg a.i/ha in soyabean (Buhari, 1990) and in groundnuts (Lagoke et al. 1991a). Imazethapyr rates of 0.10 and 0.15kg a.i/ha, 0.05 to 0.15kg a.i/ha, 0.05 to 0.10kg a.i/ha and 0.10 and 0.15kg a.i/ha had stimulatory effects on soyabean, cowpea, groundnut and bambaranut respectively. Pod yield production was enhanced by the rates of 0.05 [illegible] and 0.10kg a.i/ha and 0.15kg a.i/ha in groundnut and bambaranut respectively. Groundnut plots which received the

herbicide treatments at 0.05 and 0.10kg a.i/ha produced slightly improved grain yields compared with the untreated control Lagoke et al. (1991a) and Helms and Halvorson (1991) reported slightly higher groundnut yield with 0.075kg a.i/ha at Samaru and soyabean yield at 0.14kg a.i/ha of imazethapyr respectively compared with the control. The enhancement effect of low rates could be attributed to the sublethal concentrations of the herbicide as reported for several other herbicides (Wiedman and Appleby 1972; Salazar and Appleby, 1982).

5.5 Correlation matrix.

The negative correlation between grain yields of soyabean, groundnut and bambaranut and herbicide injury scores indicates that the imazethapyr rates used in the trial can reduce the grain yields drastically if the herbicide rate at which it is applied is not properly selected.

The positive correlation observed between grain yield of the crops and crop vigour score, nodulation, shoot dry weight, pod yield and 100-grain weight revealed these parameters as important determinants of grain yield of the test crops. These results partly agree with the findings of previous workers for soyabean (Chiezey 1989; Yev 1990) and groundnuts (Gworgwor 1985) who reported a positive and significant correlation between crop vigour, pod yield

and 100-seed weight. It is possible that vigorous vegetative growth of soyabean, groundnuts and bambaranut provided more nodes for floral production for the photosynthate which is required for pod filling. Fisher (1980), Olufajo et al, (1984) and Chiezey et al, (1992) also observed a positive and significant relationship between soyabean grain yield and nodulation although this was contrary to the observations of (Kang, 1975).

CHAPTER 6

SUMMARY AND CONCLUSION

Field and screenhouse studies were conducted at Samaru in the Northern Guinea Savanna Zone of Nigeria to observe the tolerance of soyabean variety Samsoy-2, cowpea variety Sampea-7, groundnut variety Samnut-8, and a local variety of bambaranut to various rates of imazethapyr applied pre-emergence under weed-free conditions.

In the screenhouse, the four varieties with eight imazethapyr rates were laid out in a randomized complete block design in three replications. The herbicide rates were 0.15, 0.30, 0.45, 0.60, 0.75, 0.90 and 1.00kg a.i/ha. Untreated pots were included as controls. In the field the same varieties were tested with thirteen imazethapyr rates. The treatments were completely randomized, replicated three times and laid out in a split-plot design with the herbicide being allocated to the main plot, while the varieties were allocated to the sub-plot. The herbicide rates consisted of 0.00, 0.05,0.10, 0.15, 0.20, 0.25, 0.30, 0.35, 0.40, 0.45, 0.50, 0.55 and 0.60kg a.i/ha.

The results of the studies showed that imazethapyr applied at 0.15 to 1.00kg a.i/ha caused interveinal chlorosis, epinasty and shortening of internodes but symptoms and retardation in early growth was temporary at 0.15 to 0.25kg a.i/ha.

Growth and yield was therefore not adversely affected by imazethapyr at 0.05 to 0.25kg a.i/ha; and from 0.05 to 0.15kg a.i/ha stimulatory action was observed. Increase in herbicide rate above 0.25kg a.i/ha generally resulted in poor growth and reduction in yield and yield components.

There were significant differences among the test legumes in the parameters measured. Soyabean had better establishment in the field than cowpea and groundnut, while bambaranut had the least. Phytotoxicity score in the screenhouse and field were of the respective order groundnut > soyabean > cowpea = bambaranut and groundnut > soyabean > cowpea > bambaranut. Crop vigour score in the field was of the order bambaranut - cowpea - groundnut = soyabean. Shoot dry matter production was of the order soyabean - cowpea - bambaranut - groundnut. Bambaranut had higher pod yield than soyabean and groundnut, while the grain yield of bambaranut was the highest with groundnut the least.

Interactions of crops with imazethapyr rates in most cases were significant suggesting differential response of the test legumes to imazethapyr rates. Soyabean and groundnut were the most sensitive to high rates of imazethapyr with significant decreases in shoot dry matter production and grain yield at 0.35kg a.i/ha and above. Cowpea and bambaranut were adversely affected by imazethapyr at 0.45 a.i/ha and

above with significant depression in shoot dry matter and/or grain yield production. Soyabean and groundnut tolerated imazethapyr at rates upto 0.30kg a.i/ha while bambaranut and cowpea upto 0.40kg a.i/ha, The most severe depression on grain yield of soyabean, groundnut and bambaranut were obtained at 0.40, 0.40 and 0.55 kg a.i/ha respectively. The highest grain yield was obtained for soyabean, groundnut and bambaranut at the rate of 0.15kg a.i/ha, 0.10kg a.i/ha and 0.15kg a.i/ha respectively, while the highest shoot dry matter production of cowpea was obtained at 0.15kg a.i/ha.

Crop growth was generally related to phytotoxicity score with the results indicating toxicity of imazethapyr at high rates to soyabean, groundnut, cowpea and bambaranut. The differential responses of the crops to imazethapyr as shown by reduced shoot dry matter production and/or grain yields were a carry-over of the same reactions at the vegetative growth phases to the yield.

Grain yield of soyabean, groundnut and bambaranut was negatively correlated with herbicide injury score and number of days to 50% flowering while it was positively correlated with crop vigour score, shoot dry weight, pod yield and 100-grain weight.

In conclusion, the results of the trials indicated that increasing rates of imazethapyr resulted in decrease tolerance and that soyabean, and groundnut could tolerate upto 0.30kg a.i/ha. Imazethapyr at 0.40kg a.i/ha would also be safe on cowpea and bambaranut. However, maximum tolerance level for groundnut, soyabean, cowpea and bambaranut were observed at 0.18, 0.19, 0.19 and 0.24kg a.i/ha, respectively. The most sensitive parameter in soyabean and cowpea was days to 50% flowering, while those of groundnut and bambaranut were grain yield and crop vigour score at 20 DAS, respectively.

The results have also shown that care should to taken in the usage of imazethapyr to ensure an injury-free crop in the field. Furthermore, the data could be used as a basis for logical formulation of imazethapyr recommendation for these four crops when grown in mixture; which hopefully will provide both optimum weed control and crop tolerance. Nevertheless, proper care should be taken in calibration of sprayer equipment, application of the solution and the selection of the cultivars of the species tested.

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Appendix 1: Phytotoxicity score.

10 = Dead crop.

9 = Moribund

8 = Only few green tissues

7 = Definite growth reduction and severe toxicity symptoms and less likely to survive.

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

5 = Distinguishable inhibition of growth and other injury symptoms.

4 = Distinguishable inhibition of growth and slight discolouration/other injury symptoms.

3 = Distinguishable inhibition of growth.

2 = Slight discolouration and lower vigour/discolouration and necrotic spots.

1 = Slight discolouration or low vigour

0 = No herbicide injury to crop.

Appendix 2: Crop vigour score.

10 = Most vigorous and healthy crop in the whole experiment.

9 = Slight discolouration or lower vigour.

8 = Slight discolouration and low vigour/discolouration and necrotic spots.

7 = Distinquishable inhibition of growth.

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

5 = Distinguishable inhibition of growth and other injury symptoms.

4 = Detinite growth reduction and severe toxicity symptoms but apparantly still making some growth.

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

2 = Only few green tissues present.

1 = Moribund.

0 = No injury.

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Appendix 3: Mean squares from analysis of variance for germination percentage as affected by imazethapyr rates and crops in the screenhouse at Samaru, 1992 wet season.

Source	D.F	M.S	F.
Replication	2	631.5	-
Herbicide	7	531.7	2.1NS
Error (a)	14	253.7	-
Crop	3	2263.5	5.95**
Herbicide x crop	21	248.1	0.65NS
Error (b)	48	380.0	-
Total	95	-	-

NS = Not significant at 5% level of probability.
** = Significant at 1% level of probability.

Appendix 4: Mean squares from analysis of variance for herbicide injury score at 20 DAS as affected by imazethapyr rates and crops in the screenhouse at Samaru, 1992 wet season.

Source	D.F	M.S	F.
Replication	2	0.289	-
Herbicide	7	24.491	76.81**
Error (a)	14	0.319	-
Crop	3	12.801	52.85**
Herbicide x crop	21	1.156	4.77**
Error (b)	48	0.242	-
Total	95	-	-

** = Significant at 1% level of probability.

Appendix 5: Mean squares from analysis of variance for phytotoxicity score at 35 DAS as affected by imazethapyr rates and crops in the screenhouse at Samaru, 1992 wet season.

Source	D.F	M.S	F.
Replication	2	0.010	-
Herbicide	7	81.590	383.36**
Error (a)	14	0.213	-
Crop	3	6.489	16.98**
Herbicide x crop	21	1.191	3.11**
Error (b)	48	0.392	-
Total	95	-	-

** = Significant at 1% level of probability.

Appendix 6: Mean squares from analysis of variance for phytotoxicity score at 50 DAS as affected by imazethapyr rates and crops in the screenhouse at Samaru, 1992 wet season.

Source	D.F	M.S	F.
Replication	2	0.167	-
Herbicide	7	116.191	976.0**
Error (a)	14	0.119	-
Crop	3	13.840	90.59**
Herbicide x crop	21	0.775	5.07**
Error (b)	48	0.153	-
Total	95	-	-

** = Significant at 1% level of probability.

Appendix 7: Mean squares from analysis of variance for crop vigour score at 50 DAS as affected by imazethapyr rates and crops in the screenhouse at Samaru, 1992 wet season.

Source	D.F	M.S	F.
Replication	2	0.211	-
Herbicide	7	105.678	395.08**
Error (a)	14	0.268	-
Crop	3	2.447	9.78**
Herbicide x crop	21	1.17	4.68**
Error (b)	48	0.25	-
Total	95	-	-

** = Significant at 1% level of probability.

Appendix 8: Mean squares from analysis of variance for nodulation as affected by imazethapyr rates and crops in the screenhouse at Samaru, 1992 wet season.

Source	D.F	M.S	F.
Replication	2	18.60	-
Herbicide	7	294.61	26.70**
Error (a)	14	11.03	-
Crop	3	597.22	48.09**
Herbicide x crop	21	67.04	5.39**
Error (b)	48	12.42	-
Total	95	-	-

** = Significant at 1% level of probability.

Appendix 9: Mean squares from analysis of variance for total dry matter production as affected by imazethapyr rates and crops in the screenhouse at Samaru, 1992 wet season.

Source	D.F	M.S	F.
Replication	2	0.008	-
Herbicide	7	0.530	24.56**
Error (a)	14	0.022	-
Crop	3	0.280	7.44**
Herbicide x crop	21	0.0614	1.63NS
Error (b)	48	0.055	-
Total	95	-	-

NS = Not significant at 5% level of probability

** = Significant at 1% level of probability.

Appendix 10: Mean squares from analysis of variance for stand count at emergence as affected by imazethapyr rates and crops at Samaru, 1992 wet season.

Source	D.F	M.S	F.
Replication	2	196.54	-
Herbicide	12	52.68	1.44N.S
Error (a)	24	36.46	-
Crop	3	2794.37	76.24**
Herbicide x crop	36	31.51	0.86 NS
Error (b)	78	36.65	-
Total	155	-	-

NS = Not significant at 5% level of probability.

** = Significant at 1% level of probability.

Appendix 11: Mean squares from analysis of variance for stand count at 20 DAS as affected by imazethapyr rates and crops at Samaru, 1992 wet season.

Source	D.F	M.S	F.
Replication	2	374.19	-
Herbicide	12	36.84	0.82NS
Error (a)	24	44.49	-
Crop	3	2420.55	57.23**
Herbicide x crop	36	34.71	0.82NS
Error (b)	78	42.29	-
Total	155	-	

N.S = Not significant at 5% level of probability.

** = Significant at 1% level of probability.

Appendix 12: Mean squares from analysis of variance for stand count at 50 DAS as affected by imazethapyr rates and crops at Samaru, 1992 wet season.

Source	D.F	M.S	F.
Replication	2	456.38	-
Herbicide	12	64.87	1.29NS
Error (a)	24	55.15	-
Crop	3	2691.71	52.33**
Herbicide x crop	36	47.45	0.92NS
Error (b)	78	51.43	
Total	155	-	

NS = Not significant at 5% level of probability.
** = Significant at 1% level of probability.

Appendix 13: Mean squares from analysis of variance for stand count at harvest as affected by imazethapyr rates and crops at Samaru, 1992 wet season.

Source	D.F	M.S	F.
Replication	2	461.31	-
Herbicide	12	64.91	1.27NS
Error (a)	24	50.79	-
Crop	3	2724.66	52.75**
Herbicide x crop	36	46.80	0.90NS
Error (b)	78	51.65	-
Total	155	-	-

NS = Not significant at 5% level of probability.
** = Significant at 1% level of probability.

Appendix 14: Mean squares for analysis of variance for days to 50% flowering as affected by imazethapyr rates and crops at Samaru, 1992 wet season.

Source	D.F	M.S	F
Replication	2	1.43	-
Herbicide	12	13.65	53.36**
Error (a)	24	0.26	-
Crop	3	2593.43	9022.71**
Herbicide x crop	36	0.9412	3.28**
Error (b)	78	0.2863	-
Total	155	-	-

** = Significant at 1% level of probability.

Appendix 15: Mean squares for analysis of variance for nodulation per plant as affected by imazethapyr rates and crops at Samaru, 1992 wet season.

Source	D.F	M.S	F.
Replication	2	3937	-
Herbicide	12	18301	10.21**
Error (a)	24	1792	-
Crop	3	212206	111.11**
Herbicide x crop	36	5795	3.03**
Error (b)	78	1910	-
Total	155	-	-

** = Significant at 1% level of probability.

Appendix 16: Mean squares from analysis of variance for phytotoxicity score at 20 DAS as affected by imazethapyr rates and crops at Samaru, 1992 wet season.

Source	D.F	M.S	F.
Replication	2	0.200	-
Herbicide	12	27.342	173.37**
Error (a)	24	0.157	-
Crop	3	44.880	311.95**
Herbicide x crop	36	2.394	16.64**
Error (b)	78	0.144	-
Total	155	-	-

** = Significant at 1% level of probability.

Appendix 17: Mean squares from analysis of variance for phytotoxicity score at 50 DAS as affected by imazethapyr rates and crops at Samaru, 1992 wet season.

Source	D.F	M.S	F.
Replication	2	0.034	-
Herbicide	12	52.749	1974.91**
Error (a)	24	0.027	-
Crop	3	61.784	2267.82**
Herbicide x crop	36	5.287	194.06**
Error (b)	78	0.027	-
Total	155	-	-

** = Significant at 1% level of probability.

Appendix 18: Mean squares from analysis of variance for crop vigour score at 20 DAS as affected by imazethapyr rates and crops at Samaru, 1992 wet season.

Source	D.F	M.S	F.
Replication	2	0.468	-
Herbicide	12	23.707	90.37**
Error (a)	24	0.262	-
Crop	3	22.626	77.53**
Herbicide x crop	36	1.148	3.93**
Error (b)	78	0.292	-
Total	155	-	-

** = Significant at 1% level of probability.

Appendix 19: Mean squares from analysis of variance for crop vigour score at 50 DAS as affected by imazethapyr rates and crops at Samaru, 1992 wet season.

Source	D.F	M.S	F.
Replication	2	1.043	-
Herbicide	12	26.381	21.80**
Error (a)	24	1.209	-
Crop	3	12.403	45.97**
Herbicide x crop	36	2.016	7.47**
Error (b)	78	0.270	-
Total	155	-	-

** = Significant at 1% level of probability.

Appendix 20: Mean squares from analysis of variance for shoot dry matter production at 28 DAS as affected by imazethapyr rates and crops at Samaru, 1992 wet season.

Source	D.F	M.S	F.
Replication	2	7641	-
Herbicide	12	99629	23.91**
Error (a)	24	4166	-
Crop	3	718136	282.62**
Herbicide x crop	36	18130	7.13**
Error (b)	78	2541	-
Total	155	-	-

** = Significant at 1% level of probability.

Appendix 21: Mean squares from analysis of variance for shoot dry matter production at 56 DAS as affected by imazethapyr rates and crops at Samaru, 1992 wet season.

Source	D.F	M.S	F.
Replication	2	363298	-
Herbicide	12	1251568	15.37**
Error (a)	24	81403	-
Crop	3	5994314	88.67**
Herbicide x crop	36	231480	3.42**
Error (b)	78	67598	-
Total	155	-	-

** = Significant at 1% level of probability.

Appendix 22: Mean squares from analysis of variance for shoot dry matter production at 84 DAS as affected by imazethapyr rates and crops at Samaru, 1992 wet season.

Source	D.F	M.S	F.
Replication	2	515990	-
Herbicide	12	18853720	30.24**
Error (a)	24	623314	-
Crop	3	125660456	222.96**
Herbicide x crop	36	2530940	4.49**
Error (b)	78	563600	-
Total	155	754292160	-

** = Significant at 1% level of probability.

Appendix 23: Mean squares from analysis of variance for pod yield production as affected by imazethapyr rates and crops at Samaru, 1992 wet season.

Source	D.F	M.S	F.
Replication	2	6261.0	-
Herbicide	12	14695.1	29.64**
Error (a)	24	495 .1	-
Crop	2	14239.4	65.42**
Herbicide x crop	24	805.6	3.70**
Error 6	52	217.6	-
Total	116	-	-

** = Significant at 1% level of probability.

Appendix 24: Mean squares from analysis of variance for 100-grain weight as affected by imazethapyr rates and crops at Samaru, 1992 wet season.

Source	D.F	M.S	F.
Replication	2	9.453	-
Herbicide	12	557.778	66.24**
Error (a)	24	8.420	-
Crop	2	127631.086	14741.05**
Herbicide x crop	24	223.275	25.78**
Error (b)	52	8.658	-
Total	116	-	-

** = Significant at 1% level of probability.

Appendix 25: Mean squares from analysis of variance for grain yield as affected by imazethapyr rates and crops at Samaru, 1992 wet season.

Source	D.F	M.S	F.
Replication	2	57282	-
Herbicide	12	2789075	35.87**
Error (a)	24	77753	-
Crop	2	5279304	92.59**
Herbicide x crop	24	172427	3.02**
Error (b)	52	57018	-
Total	116	-	-

** = Significant at 1% level of probability.

Appendix 26: Common and chemical names of herbicides mentioned in the test.

Atrazine - 2 - Chloro-4-(ethylamine) - 6 - (isopropylamine)-5-triazine.

Imazethapyr ((+) - 6 - ethyl-2-(4 - isopropyl-4-methyl-5-Oxo-2-imidazolin-2-yl) nicotinic acid).

Pendimethalin - N - (1-ethylpropyl) 2, 6 - dinitro-3, 4-xylidine.

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