EFFECTS OF PERIODS OF WEED INTERFERENCE AND WEED CONTROL ON GINGER (*Zingiber officinale* Roscoe.)

BY

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DECLARATION

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

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CERTIFICATION

This thesis entitled "EFFECTS OF PERIODS OF WEED INTERFERENCE AND WEED CONTROL ON GINGER (Zingiber Officinale Roscoe.)" by Mrs Marilyatu Mojishola **Olorukooba** meets the regulations governing the degree of Master of Science of Ahmadu Bello University, Zaria and is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

This work is dedicated to my daughter
RUQUAYAT

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ABSTRACT

Two field experiments were conducted during the 1986 wet season at Samaru in the northern Guinea savanna ecological zone of Nigeria to study the effects of mulching, periods of weed interference and chemical weed control ginger (Zingiber officinale Roscoe).

In the weed interference trial, the use of grass mulch resulted in lower weed infestation and vigorous growth of ginger compared with the unmulched plots. Mean dry rhizome yield in mulched plots was about 37% higher than that of the unmulched situation. Mulching also resulted in lower weed dry matter production compared with no mulching due to the effect of grass mulch which suppressed weed growth through smothering. It was also apparent in this trial that weed infestation for 4 weeks after planting (WAP) did not adversely affect crop growth due to initial slow growth of the crop. Maximum rhizome yield could be obtained even when the crop is allowed to be infested up to 12 WAP due to lack of crop injury which usually occurs during weed removal at early stages of growth. Probably the critical period of weed competition in the crop is between 12 and 16 WAP.

It was apparent that all the herbicide treatments consistently controlled weeds effectively both before and after one supplementary weeding. Among the weed control treatments, mixtures of metolachlor with chlorbromuron and prometryne, each at 1.0 + 1.0 kg a.i/ha, terbutryne at 1.33 + 0.67 kg a.i./ha metribuzin at 1.0 to 0.25 kg a.i./ha, fluometuron and ametryne,

each at 1.0 + 1.0 and 1.5 + 1.5 kg a.i./ha and with diuron at 1.0 + 0.4 and 1.5 + 0.8 kg a.i./ha, all followed by supplementary hoe-weeding at 13 weeks after planting, resulted in significantly higher rhizome yield and effective season-long weed reduction compared with the unweeded control .

Except the mixtures of metolachlor with fluometuron, ametryne and diuron, high rates of the other herbicide mixtures did not differ significantly in rhizome yield from the unweeded check, thus indicating possible detrimental effect of increasing the rates of these mixtures for weed control in the crop. It was apparent that atrazine-containing mixture was not tolerated by this crop, since both rates resulted in poor crop vigour and low rhizome yield comparable to the unweeded control.

In this trial, unchecked weed growth throughout the crop life cycle significantly depressed crop vigour, leaf, stem and shoot dry weight and number of leaves per plant. It also reduced rhizome yield by 50.3% and 63.0% compared with the appropriate best treatments in the weed interference and chemical weed control trials, respectively.

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Chapter 1

INTRODUCTION

1.1 Production Trend and Importance

Ginger, (Zingiber officinale, Roscoe), a member of the family Zingiberaceae, is grown in almost all the tropical regions of the world. The important producing countries are China, India, Japan, Ghana, Sierra Leone, Austria, The Malay Achipelago, Puerto Rico, Hawaii and Jamaica (Akamine, 1962). It has since been grown in Nigeria for domestic use before efforts were made to increase the production in the southern districts of Zaria province as a cash crop in 1929 (Momber, 1942).

According to Gibbon (1953), about 100 tons of fresh ginger was provided for internal trade in 1927 in Nigeria. The figure rose to 1,502.8 tonnes in 1959. Purseglove (1972) puts Nigeria's export figure at 1,500 tons while India exported 5,000 tons. India, which at present is the largest exporter of the crop, produced over 20,000 tons of dry ginger from 21,000 ha in 1973 (Muralidharam and Kamalam, 1973). Jamaica, Sierra Leone and Mauritius also exported about 750 to 1,000 tons each.

A survey of Kaduna State Agriculture carried out by Abalu et al. (1979) indicated that ginger production efficiency and rating were very low. It was put at 13% and minimum rating of Grade E with a potential yield estimate of 5 tonnes per hectare of fresh ginger.

The low productivity : indicated, suggests that considerable improvements are needed if adequate quantities of raw materials are to be forthcoming for new agro-related industries. Karikari and Musa (1985) observed that data on current production is not even available because the Government is not aware of how much is being produced or traded although ginger is one of the export crops. National Export Promotion Council reports however indicated that overseas markets have been found for Nigerian ginger which is of little importance in the domestic market (Anonymous, 1986).

The economic value of ginger centres on its use in the preparation of medicines, food and in the manufacture of beverages and perfumes. In both local and international trade, it is available as whole rhizome or in the split and ground forms. It has distinctively aromatic, spicy, sweet, pungent flavour (Lester, 1956). Its aromatic and pungent characters are derived from the oleoresin which is extracted with volatile solvents in a highly concentrated form from the crop. The volatile oil of ginger, obtained by distillation, is also used for flavouring (Anonymous, 1962). The dried ginger, which is brittle, contains approximately 50% starch, 3 to 5% crude fibre, about 3% oleoresin and the rest ash (Rodriquez, 1971).

For beverages, ginger is incorporated into drinks like Ginger Ale and beer. Ground ginger is used for pasteries such as ginger bread, pies, cookies, cakes and biscuits.

It is used in meat processing and in spice blends including curry powder. Split ginger is used in mixed pickling spice (Lester, 1956; Akamine, 1962). Ginger is used for medicinal purposes in pharmaceutical and veterinary preparations of a digestive stimulant (Rodriquez, 1971). Ginger tea was regarded by ancients as a carminative to ease an ailing stomach (Lester, 1956). The odour of the oil which is lasting is often blended with other types of oils used in the manufacture of perfumes to impart a lasting and oriental tone (Rodriquez, 1971).

1.2 Climatic and Agronomic Requirements

In Kerala State of India, Paulosa (1972) reported that ginger is grown under an annual rainfall of 3,000 mm with a rainy period of eight to ten months and temperatures ranging from 28°C to 35°C. This condition probably accounted for the yield of 15 to 24 t/ha of fresh ginger obtained compared with 5 to 12.5 t/ha in Southern Zaria of Nigeria which has a shorter rainy season of five to seven months with a maximum of 1,500 mm precipitation annually. Ginger thrives well in well-drained soils with good tilth, in order to produce good shaped rhizomes (Rodriquez, 1971).

The crop is always propagated vegetatively through its underground rhizome which has at least one bud as growing point. Ratoon crops may also be taken as practised in Jamaica, India and Nigeria (Anonymous, 1962, Paulosa; 1972).

The three varieties of ginger grown in the main producing areas of the country are the more common 'Tafin-Giwa' with plump rhizomes, and 'Yatsun-Biri' with small rhizomes, both of which are common and the less common 'Turawa'. 'Taffin-Giwa' is however the most popular variety because of its acceptable physical qualities such as plumpiness, pale yellow coloration and high yielding potential. It also has the ability of curing more quickly, needing about half the number of washings required by the 'Yatsun-Biri' with corresponding reduction in labour and the risk of excessive leaching (Anonymous, 1947). Planting is usually done on raised beds, while irrigated ginger is usually planted on flat beds of convenient size or on ridges (Paulosa, 1972).

Recommended spacing varies with the tradition of the ginger growing areas of the world. Purseglove (1972) recommended spacing of 23 to 30 cm by 15 to 23 cm. Spacing of about 38.1 by 38.1 cm corresponding to 68,888 plants/ha was recommended in Mauritius (Owadally et al. 1981). In Nigeria, it has been indicated that close spacings gives the highest yield (Anonymous, 1967). It is recommended that the crop be planted on the flat at a spacing of 10 cm and 15 cm within and between rows respectively (Anonymous, 1981). Planting of the 'seed' is done in shallow pits about 4 to 10 cm deep.

Ginger is often grown under shade and mulches are provided. It can however be grown without mulch.

About 250 kg/ha of sulphate of ammonia split applied in two equal doses at three months and four and half months after planting has been recommended for ginger (Anonymous, 1981). However, it has been indicated earlier that the principal mineral elements removed from the soil by ginger are calcium and phosphorus, and this should be replaced from time to time (Anonymous, 1962).

Harvesting is done when the leaves begin to yellow and the stem lodge. Jayachandran et al. (1980) reported that yields of green ginger/plant were highest at seven months when the percentage contents of oleoresin and volatile oils were also highest. However, the highest yield of dry ginger was obtained at eight months when starch content was maximal and crude fibre content minimal.

1.3 Weeds and their Control in Ginger

There is paucity of information on the extent of yield reduction caused by weed interference in ginger in Nigeria and other growing areas despite its numerous domestic uses and economic importance. But like most vegetable and tuber crops, it is known to have problems of weed competition. Gupta and Lamba (1978) reported that most vegetables are initially slow-growing crops incapable of offering any competition to the aggressive weeds. Roots of vegetables are malformed in the presence of weeds because of underground competition for space. Hammerton (1974) in west Indies identified the major weeds associated with ginger as Achyranthes indica, Euphorbia spp., Cyperus

rotundus, Phyllanthus amarus, Sorghum verticilliforum, Kallstoemia maxima, Chloris radiata.

Generally, handpulling or hand-weeding are the most common methods of weed control in ginger. Because of the close spacing of the crop, this operation is usually time-consuming and labour-intensive, and would distrupt the mulch and probably hamper tuber formations. As a result, farmers in Southern Zaria hardly weed their plots and rather prefer the use of mulch, thereby ignoring the effect of weed competition. This partially contributes to the reported low yields.

Vale (1971), Collinham and Higgins (1973), Lagoke et al. (1981) all concluded that manual weed control is very unsatisfactory as it is expensive, high labour-demanding, strenuous and limited to small-scale production. It would be advisable to employ less laborious methods of weed control. The use of herbicide has been reported to reduce cost of weed contr hence cost of production and subsequently increased profitability in field and vegetable crops (Sinha et al., 1982, Ogunbile and Lagoke, 1986). The spared labour could be utilized more effectively for bringing additional land under cultivation thus enhancing overall production in the country (Gupta and Lamba, 1978).

1.4 Objectives

The objectives of this study are therefore:

i) To study the effect of mulching on the response of ginger crop to various periods of weed interference.

ii) To evaluate the performance of some pre-emergence herbicide treatments in ginger crop.

Chapter 2 LITERATURE REVIEW

2.1 Effect of Mulching on Ginger

Mulching after planting which, is one of the most important cultural practices in the cultivation of ginger (Kennan and Nair, 1965), has been reported to improve the performance of various crops through conservation of soil moisture, moderation of soil temperatures for germination and early root development, increasing nutrient availability and suppression of weeds. It has been reported to improve soil condition by reducing soil compaction thus resulting in better aeration (Edmond et al., 1959; Sheldrake, 1967; Paulosa, 1972; Anon., 1981; Suleiman, 1985). Common mulches include crop residues, cut and placed on the soil surface, stubble left standing after harvest, vegetation (banana leaves, grasses, etc.) carried from elsewhere and black plastic polythene sheet (Giddens, et al., 1969; Mohanty, 1977; Owadally, et al., 1981). In a trial conducted by Mohanty (1977) using different mulch materials in ginger, the best results with regard to rhizome sprouting, yield, suppression of weeds and prevention of soil erosion were obtained with banana leaves. In this trial, rhizome yield obtained with banana leaves, grasses, soil materials and the control were 31.1, 23.8, 17.8 and 18.0 tonnes per hectare, respectively. Owadally et al. (1981) also reported that mulching with cane trash or rice straw was generally beneficial in ginger. Mohanty and Sarma (1978) similarly reported that mulching with green leaves at 15 t/ha at planting followed by two mulches at 7.5 t/ha, 45 and 90 days after planting resulted in high rhizome yield of ginger.

2.2 Effect of Period of Weed Interference on Ginger and Related Crops

Weeds constitute a major constraint to efficient ginger production. At least three hand pullings of weeds are required for season-long weed control in the crop (Duka et al., 1986). There is paucity of information on the effect of weed interference on ginger.

Weed competition was reported to have suppressed growth of onion to the maximum when Sinapsis arvensis, L. Polygonum convolvulus L. Chenopodium album L. and Stachys arvensis L. competed with the crop (Vorobior and Vasetskii, 1981). Nelson and Thoreson (1981) reported that weed competition reduced both the size and number of tubers of potato (Solanum tuberosum) tubers but had little effect on the specific gravity of the tubers. In some instances, the reduction in tuber size by weeds reduced the percent of marketable tubers. Yields obtained from unweeded potato plants were reduced by 58% (Saghir and Markoullis, 1974). In studies of three potato cultivars competing with Amaranthus retroflexus L., Chenopodium album, L. and Cyperus esculentus, yields were not significantly reduced by the broad-leaved species. 'Hudson' variety competed very well with Cyperus esculentus. (Yip et al., 1974). Purple nutsedge competing with various vegetables throughout the growing season was found to reduce the yield of garlic by 89% and the yields of two carrot cultivars 'Kurodo' and 'Nantes' by 39% and 50%. respectively (William and Warren, 1974).

In trials in the Lebanon, yield and quality of potatoes grown under season long weed-free conditions were compared with those from plots weeded at 3, 6, 9, or 12 weeks after planting and from unweeded control plots. Weed competition had no significant effect on potato yields before the 9th week after planting but reduced yield by 31.1% between the 9th and 12th week (Saghir and Markoullis, 1974). Nelson and Thoreson (1981) indicated that the mixtures of annual weeds emerging one week after the emergence of potatoes and subsequently competing with the crop until harvest reduced the yield of tubers by 54%. Thakval et al. (1985) compared weeding at 2, 4, 6, 8 or 10 weeks after planting with weed-free condition (weeding at 15-day intervals) and weedy condition (control). The weed population increased up to 6 weeks after planting (WAP) and then decreased sharply in two years of experimentation. Dry weight of weeds was maximum in the weedy control followed by weeding at 10 WAP. However, the most critical period for crop competition was 4 to 6 WAP. Tuber yield was highest under the weedfree condition followed by weeding at 4 and 6 WAP. In the weedy control, the yield was decreased by 40 to 43%. Winter and Wiese (1976) reported that late emerging weeds in sugar beet field did not greatly influence the yield when the crop was kept weedfree for six weeks after crop emergence. The control of early weeds within six weeks after sugar beet emergence nearly eliminated weed competition in the crop until eighty days after planting. Studies carried out with purple nutsedge and various vegetable

crops indicated that the critical periods of purple nutsedge competition occurred between three and thirteen weeks for garlic, three and seven weeks for the carrot cultivar 'Nantes' and three and five weeks after crop emergence for the carrot cultivar 'Kuroda' (William and Warren, 1974). In bulb onion and red beet, Hewson (1971) reported that final crop yield was unaffected when weeds were allowed to compete up to four to four and half and four to six and half weeks respectively after 50% crop emergence, provided the plots were kept clean subsequently. The critical period for onions in this study occurred during development of the 3rd true leaf which was about 5 to 7 weeks after emergence. Loss of yield was mainly through decrease in bulb size. In a field experiment conducted at Samaru, the potato varieties '87906-1' and 'Greta' were most critically affected by weed interference between 3 and 6 weeks after planting (WAP) and 6 and 9 WAP, respectively. Weed infestation for the first 3 weeks after planting did not have any adverse effect on the two potato varieties. It was required to keep variety 'Greta' weed-free throughout it's life-cycle and '87906-1' weed-free until 50 days after planting in order to obtain maximum tuber yields (Bulus, 1986).

2.3 Chemical Weed Control in Ginger

The herbicides that have been evaluated for selective control of weeds in ginger included ametryne (2-ethylamine-4-(isopropyl amino)-0-(methylthio)-5-triazine, atrazine

(2-chloro-4-ethylamino-6-130-propylamino-1, 3, 5-triazine), chlorbromuron (N-bromo-3-chlorophyenyl)-N-methoxy-N-methyl Urea), diuron (3-3, 4-dichlorophenyl)-1, 1-dimethylurea), metobromuron (3-(4-bromophenyl-1 methoxy-1-methylurea), prometryne (4, 6-Bi-iso-propyl amino-2-methythio-1, 3, 5-triazine) and terbutryne (2- (tert-butylamino-4-(ethyl-amino) -6-methylthio-5-triazine). These herbicides were applied pre-emergence to the crop (Arakeri, 1957; Kasasian, 1968; Kasasian and Seeyave, 1970; Hammerton, 1974; Lee, 1978; Lee, et al., 1981).

Fluometuron (1,1-dimethyl-3-(a,a,a-trifluoro-m-tolyl) urea) chlorbromuron, atrazine, metobromuron, terbutryne, diuron, ametryne, prometryne and metribuzin (4-amino-6-tert-butyl-3 (methylthio)-1,2,4- triazine -5(4H) one) have all been mixed with metolachlor for broadspectrum weed control in various crops in the Guinea Savanna ecological zone of Nigeria successfully (Lagoke et al., 1981; 1982; 1983; Adigun et al., 1986, Choudhary and Lagoke, 1985; Bulus, 1986; Lagoke et al., 1986a; 1986b).

2.3.1 Triazines

Structurally, the triazines are heterocyclic nitrogen derivatives. The heterocyclic ring is composed of three nitrogen and three carbon atoms (Klingman and Ashton, 1975). Absorption of triazine herbicides is usually by roots and translocation takes place through the apoplastic system to the shoots of susceptible plants (Glen. et al., 1975).

They appear to concentrate first at the veins then in the interveinal areas and finally around the margins of the leaves. There is virtually no symplastic movement out of leaves and the waxy leaf surfaces are often a barrier to uptake (Audus, 1976). Wax and Behrens (1965) and Vostral et al. (1970) have shown that the rate of absorption and translocation of triazine herbicides from the root to shoot is proportional to the amount of water absorbed and/or the transpiration rate.

Triazine herbicides are powerful inhibitors of photosynthesis in plants by interrupting the light-driven flow of electrons from water to nicotinamide adenine dinucleotide phosphate (NADP)(Kearney and Kaufman, 1975). The action centre is the chloroplast where they inhibit Hill reaction (Moreland, 1969).

The usual phytotoxic symptom of the triazine herbicides is foliar chlorosis followed by necrosis. However, the first effect is the reduction of the amount of glucose, fructose and/or sucrose in plants (Audus, 1976). Very low concentrations of the herbicide in the leaves causes increased greening due to increase in the chlorophyll content of the leaves while high concentrations causes chlorosis and necrosis. The rate of degradation of the triazine herbicides in higher plants varies greatly with different species (Ashton and Craft, 1973). In resistant species, they are rapidly degraded while in susceptible species, the herbicides degrade slowly, thus, the rate of degradation appears to be the primary basis of

selectivity. This process occurs by hydroxylation, dechlorination, demethoxylation, demethythiolation depending on the parent substitution. Dealkylation of the alkyl side chains also occurs (Kearney and Kaufman, 1975).

Ametryne which has a water solubility of 185 ppm at 20°C and acute oral LD_{50} of 1110 mg/kg body weight (Ashton and Klingman, 1975; Anon. 1983) is usually used as a selective pre-emergence herbicide in many arable crops for the control of annual grasses and broadleaved weeds (Moreland, 1969). It has been used effectively for the control of weeds in cotton, bananas, yam, maize, grape-fruit, oranges, pineapples, sugar cane and potatoes (Anon. 1983; Lagoke et al. 1986a; Sambo, 1986; Bulus, 1986).). It may be applied post-emergence due to its foliar activity (Glenn et al., 1975). Kasasian (1962) and Kasasian and Seeyave (1970). concluded that ginger tolerated ametryne at rates that controlled weeds effectively. Similarly, Hammerton (1974) reported that ametryne at 2.2 kg a.i./ha applied to yellow ginger grown in the shade of established Samanea saman trees gave satisfactory control of the weeds present for nine weeks.

Atrazine is a white crystalline solid with a water solubility of 33 ppm at 20 °C and acute oral LD_{50} of 3080 mg/kg body weight (Ashton and Klingman, 1975). Atrazine is widely used selectively for the control of broadleaved weeds and grasses in maize, sorghum, millet, sugar cane, pineapple turf grass sod and potatoes (Choudhary and Lagoke, 1985; Anon., 1983; Bulus, 1986; Lagoke et al., 1986b, Sambo, 1986).

Atrazine at the rate of 2.2 kg a.i./ha has been reported to control weeds in ginger (Hammerton, 1974). Kasasian (1962) also reported that ginger tolerated atrazine at rates that controlled weeds effectively when applied pre-emergence both to crop and the weeds.

Prometryne is a white crystalline solid with water solubility of 48 ppm at 20 °C and an acute oral LD_{50} of 3750 mg/kg body weight. It is being used as pre-emergence herbicide for the selective control of broadleaved weeds and some grasses in cotton, okra, potatoes, onion, carrot, sunflower, yam, soybeans, cowpea, groundnut, millet, maize and melon (Lagoke et al., 1981; 1983; Chaudhary and Lagoke, 1985; Adejonwo et al., 1986; Bulus, 1986; Lagoke et al., 1986b; 1986c; Sambo, 1986; Lagoke et al., 1987b).

In Jamaica, prometryne at 1.6 kg a.i./ha applied to yellow ginger gave satisfactory control of the weeds for nine weeks (Hammerton, 1974). Kasasian (1962) also used prometryne as a pre-emergence treatment in ginger at rates that controlled weeds effectively.

Terbutryne, a white crystalline solid with a water solubility of 25 ppm at 20 °C and an acute oral LD_{50} of 2400 - 2980 mg/kg body weight (Ashton and Klingman, 1975; Anon., 1983), may be applied either pre-emergence or post-emergence at rates of 1 to 2 kg a.i./ha for the selective control of broadleaved weeds in wheat, barley, sorghum, sunflower, potatoes, peas, okra, groundnut, maize, cotton,

yam, soyabean and a variety of vegetables (Martin and Worthing 1977 ; Anon., 1983; Lagoke et al., 1983; Adejonwo et al., 1986; Sambo, 1986). Lagoke et al., 1983, reported that metolachlor plus terbutryne at 1.33 + 0.67 and 2.0 + 1.0 kg a.i./ha resulted in similar okra yield to two or three hoe-weedings. Mixtures of metolachlor plus terbutryne at 1.33 + 0.67 kg a.i./ha among other herbicide mixtures, produced potato tuber number and yield that were comparable in values to the hoe-weeded check in a trial conducted at Samaru in the Northern Guinea Savanna ecological zone of Nigeria during the 1986 wet season (Sambo, 1986).

Metribuzin, which is a white crystalline solid with a water solubility of 1200 ppm at 20 ^{o}C and acute oral LD_{50} of 1937 - 1986 mg/kg body weight,is an assymetrical triazine. Metribuzin is normally applied pre-emergence at the rate of 0.25 to 1.0 kg a.i./ha for the effective control of annual grasses and numerous broadleaved weeds including deep rooted weeds in soybean, yam, potatoes, sugar canes and transplanted tomatoes (Sinha and Lagoke, 1982; Lagoke et al., 1983; Tijani, 1985; Bulus, 1986, Sambo, 1986. Lagoke et al., 1986b). In a herbicide evaluation study in irrigated okra at Galma, metribuzin at 0.25 kg a.i./ha gave high okra pod yield that was comparable to that of the hoe-weeded control while 0.5 kg a.i./ha reduced pod yield significantly (Lagoke et al., 1983). In a trial conducted to evaluate herbicide mixtures

for weed control in Irish potato (Solanum tuberosum L.) variety 'Greta' higher tuber yields and season-long weed control were obtained with metolachlor plus metribuzin at 1.00 + 0.25 kg a.i./ha. (Bulus, 1986).

2.3.2 Chloroacetamides

The amide herbicides comprise a diverse group of chemicals. A major subdivision of the amide class of herbicides is the chloroacetamides. They have a mono-chlorinated methyl ($Cl-CH_2$) in the R-1 and include metolachlor and propachlor. The chemical structure of the remaining amide herbicides have little in common except for the central amide structure although most have a hydrogen substitution (H) in RO3 position (Ashton and Klingman, 1975). They are most exclusively used as selective herbicides in vegetable and field crops mainly for the control of grasses although it may have activities on broadleaved weeds and sedges (Ashton and Floyd, 1981).

Chloroacetamides are readily absorbed by susceptible plants primarily by seeds and first node of germinating seedling and appear to be translocated primarily in the apoplast but symplastic movement occurs (Ashton and Floyd, 1981). The degree of susceptibility of various weeds to chloroacetamides could be directly related to the length of time required to initiate the metabolism of these chemicals. Those species that are able to metabolize the chemical as soon as it is absorbed or within a short time thereafter have only small amount of the chemical present internally at any time. On the

other hand, those species with delayed or slow metabolic capabilities accumulate relatively higher and therefore lethal concentrations. The basis for selectivity of the chloroacetamide herbicides could therefore be attributed to the ability of resistant plants to metabolize them at a rate sufficient to keep cellular levels below that required for growth inhibition in the leaves (Kearney and Kaufman, 1975). They inhibit mitochondrial phosphorylation and reduce cell divison in primary meristems (Audus, 1976). They influence nitrogen metabolism due to the influence they have on nucleic acid and/or protein metabolism.

Foliage applied amide damage takes the form of localized or general necrosis, depending on the dose applied while the soil-applied amides inhibit root elongation (Audus, 1976).

Metolachlor, a white, colorless liquid with water solubility of 530 ppm at 20 ^{o}C (Anonymous, 1983), is used as pre-emergence herbicide for the effective control of grasses, sedges and some broadleaved weeds at rates ranging from 1.00 to 1.8 kg a.i./ha in field crops like cowpea, cotton, yam, maize, soyabean, some horticultural crops such as pepper and various crop mixtures (Sinha and Lagoke, 1982; Bakut, 1985; Adigun et al., 1986; Lagoke et al., 1987b; Lagoke et al., 1987a). Recent studies suggest that the mode of action of metolachlor involves disruption of the integrity of plant cell membranes, resulting in leakage of certain key constituents. It also acts as an inhibitor of lipid synthesis (Anon. 1983). A broader spectrum of weed control to include

broadleaved species is possible if metolachlor is combined with other herbicides (Dill and Dumford, 1978; Lagoke et al., 1982; Bulus, 1986; Lagoke et al., 1986a and 1986b). Musa (1985) reported that metolachlor was already being used for weed control in ginger in Southern Zaria.

2.3.3 Substituted Urea derivatives

The structural formula of substituted urea derivatives is derived by substituting three of the hydrogen atoms of urea with other common groups such as phenyl, methyl and methoxyl groups. The phenyl group often has one or two chlorine substitutions and occassionally a bromine substitution (Ashton and Klingman, 1975).

Most of the urea herbicides are readily absorbed by roots and rapidly translocated to the upper plant parts through the apoplast. The actual amount absorbed and translocated from roots to shoot varies greatly with various compounds (Ashton and Crafts, 1975).

The members of this group, like the triazines are also photosynthetic inhibitors. The primary site of action of the urea herbicides is the inhibition of the Hill reaction. They influence nitrogen metabolism (Overbeek, 1964; Ashton and Floyd, 1981). Urea herbicides are subjected to degradation by higher plants and various species are degraded at different rates. This primary detoxification mechanism is demethylation. Demethoxylation also occurs in those compounds containing methoxy group and it is the simplest process taking place before other

processes. Following dealkylation, dealkoxylation, aniline formation occurs with stepwise demethylation followed by hydrolysis. The aniline may be subjected to oxidation to yield the corresponding nitrite or conjugate with normal cellular constituents (Ashton and Craft, 1973).

Diuron is a white crystalline solid with water solubility of 42 ppm at 25°C and an acute oral LD_{50} of 3400 mg/kg body weight (Anon. 1983). Diuron is used for selective weed control as pre-emergence herbicide at low rates to control germinating broadleaved weeds and grasses in crops such as cotton, sugar cane, cowpea, pineapple, grapes, apples, pears, maize and okra mixtures, yam (Lagoke, et al., 1981; Anon., 1983; Lagoke et al., 1986 a; Adejonwo et al., 1987).

Diuron at the rate of 1.6 kg a.i./ha was reported to have selectively controlled weeds present in ginger for nine weeks (Hammerton, 1974). In an experiment conducted in Malaysia to evaluate the selectivity of herbicide in ginger, weed control was achieved by means of single application of diuron at 2 kg a.i./ha prior to crop emergence, and spot treatment of weeds appearing after emergence with paraquat (Lee et al., 1981). Whiley (1974) however reported the extensive use of diuron at the rate of 4.5 kg a.i./ha for weed control in ginger in Queensland. The rate of active ingredient used varied with soil type. On sandy soils, lower rates were adequate while higher rates were required on clay loams. Kasasian (1962) also reported that ginger tolerated diuron at rates that controlled weeds effectively.

1983). It is applied pre-emergence and as directed post-emergence herbicide in such crops as cotton, sugar cane, yam, maize and okra mixture (Lagoke et al., 1986a, 1986b; Adejonwo et al., 1987) for selective control of most annual grass and broadleaved weeds.

Mixtures of metolachlor with fluometuron at 1.0 + 1.0 kg a.i./ha followed by supplementary hoe-weeding resulted in effective weed control till 10 WAS with high okra pod and maize grain yield that were comparable to that of the hoe-weeded control and higher than the untreated check in a field trial conducted at Samaru, during the 1983 wet season to evaluate pre-emergence mixtures for selective weed control in maize and okra mixture.(Adejonwo et al., 1987).

Chlorbromuron, a white crystalline solid having a water solubility of 50 ppm with acute oral LD_{50} 3700 mg/kg, is used as pre-emergence herbicide treatment to control many annual grasses and broadleaved weeds in crops such as onion potatoes, vegetable crops, maize and okra mixture (Deuber et al., 1977; Sambo, 1986; Adejonwo et al., 1987).

Adejonwo et al. (1987) reported that mixtures of metolachlor with chlorbromuron at 1.0 + 1.0 kg a.i./ha followed by supplementary hoe-weeding combined effective weed control till 10 weeks after sowing with high okra pod and maize grain yield that were comparable to that of the hoe-weeded control and higher than the untreated check, in a field trial conducted at Samaru during 1983 wet season.

Chapter 3

MATERIALS AND METHODS

3.1 Description of Experimental Site

Two field experiments were conducted during the 1986 wet season on the Institute for Agricultural Research farm Samaru ($11^{0}11'N$, $7^{o}38'E$) in the northern Guinea Savanna ecological zone of Nigeria. The experimental site was cropped to soyabean during the 1985 wet season.

In the first experiment (weed interference trial), the response of ginger to periods of weed interference under mulched and unmulched situations was investigated while in the second experiment (weed control trial), pre-emergence herbicide mixtures were evaluated for weed control in the crop. Details of the physico-chemical characteristics of the soil at the experimental site are contained in Table 1. Both sites had a loam soil. The annual rainfall received on the experimental station during the crop growth period was 962.5 mm. Details of the pattern of distribution of rainfall, mean relative humidity, shunshine hours and temperature at 10-day interval during the period of the trial are contained in Table 2. The most prevalent weed species observed at the site of the trial were broad leaved weeds, especially at the later stage of crop growth. Grasses and sedges were also present especially at the early stage of crop growth and in low-lying areas,

Table 1: Physico-chemical analysis of soil of the experimental site at Samaru during the 1986 wet season.

Soil Composition	
Soil fraction	%
Sand	37.00
Silt	50.00
Clay	13.00
Soil textural class	Loam
Soil pH	
In water (1:2.5)	5.30
In $CaCl_2$ (0.01M)	4.30
Organic carbon C %	0.40
Total Nitrogen, N %	0.042
Available P (ppm)	6.30
Exchangeable Bases (Meq/100g soil)	
Calcium, Ca	3.20
Magnesium, Mg	0.76
Sodium, Na	0.06
Potassium, K	0.98
Cation Exchange capacity (meq/100g soil)	7.40

Table 2: Total rainfall, mean temperature, relative humidity, at ten-day interval during the period of the trial, 1986 wet season.

Month	Days	Total Rainfall (mm)	Mean Temperature °C		Relative Humidity %		Sun-shine (hours
			max.	min.	A.M.	P.M.	
June	11-20	22.6	30.2	20.6	74.3	55.8	9.1
	21-30	24.1	30.0	20.1	75.3	59.0	7.4
July	1-10	52.9	29.0	20.0	79.8	62.1	7.0
	11-20	49.4	27.8	19.5	83.4	67.3	6.5
	21-31	175.0	27.0	19.6	83.1	73.1	5.2
August	1-10	50.6	28.1	19.3	83.0	76.9	5.8
	11-20	94.9	28.5	19.7	84.3	66.0	7.1
	21-31	173.3	29.1	19.4	78.3	70.5	7.7
September	1-10	56.4	28.0	19.5	77.5	68.9	7.1
	11-20	81.2	29.3	18.6	72.6	64.2	8.6
	21-30	75.3	29.3	19.1	76.4	69.2	7.8
October	1-10	0.0	30.4	19.1	67.5	56.3	7.9
	11-20	0.0	31.5	15.8	45.4	45.3	9.6
	21-31	0.0	31.4	17.9	57.4	48.4	8.1
November	1-10	0.0	33.0	17.8	49.8	31.0	9.0
	11-20	0.0	30.0	12.0	24.9	22.4	8.5
	21-30	0.0	31.1	13.9	33.7	25.8	78.1
December	1-10	0.0	26.4	13.0	28.6	22.7	56.7
	11-20	0.0	27.0	12.4	24.3	20.4	86.0
	21-30	0.0	27.6	12.4	22.4	22.5	66.5
January	1-10	0.0	28.0	11.7	21.8	19.2	8.5

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

respectively. Table 3 shows the common weed species and their levels of infestation at the site of the trials.

3.2 Details of Treatments and Experimental Designs

Both trials were laid out, in a randomized complete block design and replicated three times. The gross plot was a slightly raised bed of 2.5 m long by 0.9m wide and the net plot was 2.5 m long by 0.6 m wide. The weed interference trial consisted of 20 treatments in two by ten factorial combinations. The treatment combinations were mulched and unmulched with various periods of weed interference as shown in Table 4. In the weed control experiment, eighteen herbicide mixtures applied pre-emergence were compared with a hand-weeded control and an untreated check.

3.3 Cultural Practices

3.3.1 Land Preparation and planting

The experimental site was disc-ploughed and harrowed on 14 June, 1986, when the rains were well established. Basal dose of fertilizers at the rates of 50 kg P/ha and 100 kg K/ha using single super phosphate and muriate of potash, respectively, were broadcast on 18th June, 1986, before the second harrowing. This was done to ensure effective incorporation of the fertilizers. Plots were marked out and prepared into slightly raised beds using hand hoes. Beds were separated by 0.5 m paths in either direction. The rhizome setts (Var. Taffin

Table 3: List of common weed species at the experimental site, Samaru, 1986 wet season during the period of growth.

Types of Weeds	Level of weed infestation
GRASSES	
Andropogon gayanus Kunth	++
Chloris pilosa Schumach	++
Dactyloctenium aegyptium (Linn)	+
Eleusine indica (Linn) Gaerth	++
Eragrostis ciliaris (Linn) R.B.	+
Eragrostis gangetica (Roxb) Steud	
Eragrostis tremala Hochst	+
Pennisetum polystachion (Linn) schlt	+
BROADLEAVED WEEDS	
Ageratum conyzoides L	++
Alternanthera nodiflora (L) R. Br	++
Amaranthus spinosus (L)	+
Jacquimontia taminifolia L	++
Leucas martinicensis R. Br	++
Polygata petitiana	+
Solanum nodiflora (L)	+
Spermacoce radiata (DC) Sieberex Hiem	++
Stachytarpheta angustifolia	++
Vernonia ambigue	++
Vernonia galamensis (Cass) Less	+
SEDGE	
Kyllinga safuamulata	++

Key

\+ Minor infestation

++ Major infestation

Table 4 Details of treatment for the weed interference trial in ginger at Samaru, 1986 wet season.

Treatments	Code
Mulching	
Mulched	
Unmulched	
Period of weed interference	
Weed-free for 4 WAP*	+
Weed-free for 8 WAP	+
Weed-free for 12 WAP	+
Weed-free for 16 WAP	+
Weed-free till harvest	+
Weed-infested for 4 WAP	++
Weed-infested for 8 WAP	++
Weed-infested for 12 WAP	++
Weed-infested for 16 WAP	++
Weed-infested till harvest	++

* Weeks after planting

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

++ Allowed to be weed-infested for various periods and subsequently kept weed-free until harvest.

Giwa) with 3-5 buds of about 4 cm length were dressed with Benomyl (as Benlate) and planted in shallow pits of about 5 cm depth at inter-row and intra-row spacings of 15 cm on 19 June, 1986. Nitrogen fertilizer was split-applied at 5, 9 and 12 weeks after planting (WAP) at the rates of 50, 80 and 20 kg N/ha, respectively, using calcium ammonium nitrate (Musa, 1986).

3.3.2 Mulching

Dried grasses were used as mulching material in the two experiments. The mulches were spread uniformly at a thickness of about 5 cm on the appropriate plots soon after planting. Mulching was done after planting in the weed interference experiment while all the plots in the weed control trial were mulched after herbicide application. The appropriate plots were again mulched at 14 WAP to protect the rhizomes from exposure.

3.3.3 Crop protection

In the weed interference experiment, weed removal was done by handpulling with the aid of cutlass which was used to keep the plot weed-free according to the treatments (Table 4). All the herbicide treated plots were supplementarily hand-weeded at 13 WAP in the weed control experiment and the weeded control plots were weeded at 4, 8 and 12 weeks, respectively. Benomyl (as Benlate) was sprayed at 12 WAP at the rate of 0.5 kg a.i./ha to further protect the crop against fungal attack.

3.3.4 Harvesting

In the two experiments, harvesting of rhizomes was done on 7 January, 1987, about 27 weeks after planting, after the leaves had dried.

3.4 Herbicide Application

In the weed control experiment, the herbicide mixtures which are all metolachlor-based were applied, pre-emergence, one day after planting with a knapsack sprayer in about 254 l/ha spray volume, at a pressure of 2.1 kg/cm^2 using a deflector nozzle.

3.5 Data Collection

3.5.1 Weed infestation

Weed cover score: Observations were taken visually at 4, 8, 12, 16 WAP and at harvest. A scale of 0 to 10 was used to assess the level of infestation, where 0 represented no weed cover and 10 represented complete weed cover.

Weed dry matter production: Weeding was carried out by hand-pulling with the aid of cutlass which was used to dig out the weeds on each plot at the specified period (Tables 4 and 5) and at harvest. The samples were cleaned free of soil and weighed fresh and oven-dried at 70^{o}C to constant weight for dry matter determination. Cummulative weed dry matter production per plot in the weed interference experiment was determined by adding up all the weed dry weights at each weeding and at harvest.

Table 5: Details of herbicide treatments for the weed control trial in ginger at Samaru, 1986 wet season.

Treatment	Rate kg a.i./ha
Metolachlor + metobromuron	1.0 + 1.0
"	1.5 + 1.5
Metolachlor + terbutryne	1.33+0.67
"	2.0 + 1.0
Metolachlor + atrazine	1.33 + 0.67
"	2.0 + 1.0
Metolachlor + metribuzin	1.0 + 0.25
"	1.5 + 0.5
Metolachlor + prometryne	1.0 + 1.0
"	1.5 + 1.5
Metolachlor + fluometuron	1.0 + 1.0
"	1.5 + 1.5
Metolachlor + diuron	1.0 + 0.4
"	1.5 + 0.8
Metolachlor + ametryne	1.0 + 1.0
"	1.5 + 1.5
Metolachlor + chlorbromuron	1.0 + 1.0
"	1.5 + 1.5
Hand-weeding at 4, 8 and 12 WAP	
Unweeded check	

3.5.2 Crop growth parameters

Crop stand count was taken at 6 WAP in order to assess the effect of treatment on the crop establishment.

Crop vigour score: Crop vigour score was taken at 4, 8, 12, 16 WAP and at harvest, using a scale of 0 to 10, where 0, represented completely dead plant and 10 represented the most vigorous plant. Parameters taken into consideration in vigour score included plant height, number and width of leaves per plant and plant coloration among others.

Crop dry matter production: Using systematic random sampling, two plants per plot were dug out with hand trowel at 8, 12, 16 and 20 WAP, cleaned and separated into leaves, shoot and rhizome, they were oven-dried for about 48 hours at 70°C to constant weights for the determination of dry matter production. Plant height, was obtained by measuring the main shoot of the sampled plants from the ground level.

3.6 Analysis of Data

All the data collected were subjected to analysis of variance and the treatment means compared using new Duncan Multiple Range Test (DMRT) (Duncan, 1955). Correlation coefficient analyses were also done in appropriate parameters when necessary.

Chapter 4

RESULTS

4.1 Effects of Mulching and Period of Weed Interference on the Growth and Yield of Ginger

The effects of mulching and periods of weed interference on various growth parameters viz, crop vigour score, plant height, leaf dry matter production, stem dry weight, shoot dry weight, rhizome dry weight and rhizome yield are shown in Tables 6 to 10. In the trial, none of the interactions between mulching and periods of weed interference were not significant in all cases.

4.1.1 Crop vigour score

At 8 and 12 WAP, significantly higher crop vigour scores were obtained on the mulched plots compared with the unmulched (Table 6)

The effect of period of weed interference on crop vigour score was significant at 8, 12 and 16 WAP. At 8 WAP, crop weed-infested until 4 WAP had comparable vigour score to that kept weedfree until 8 WAP. Vigour score of the crop weed-infested until 8 WAP was however significantly lower. At 12 and 16 WAP, crops weed-infested for 4 and 8 WAP did not differ significantly in vigour score. Similarly, those kept weedfree for 4 and 8 WAP had comparable vigour scores. At 12 WAP, crops kept weedfree throughout that period

Table 6 Effects of mulching and period of weed interference on crop vigour score of ginger at Samaru in 1986 wet season.

Treatments	Crop Vigour Score[4] at 8 WAP[1]	12 WAP	16 WAP
Mulching (M)			
Mulched	5.17a[2]	5.03a	5.93
Unmulched	2.57b	3.83b	5.10
SE ±	0.618	0.455	0.477
Period of weed interference (P)			
Weed-free for 4 WAP	3.33bc	3.67de	4.17c
Weed-free for 8 WAP	5.17a	4.17cd	4.83c
Weed-free for 12 WAP	-[3]	5.67a	7.67a
Weed-free for 16 WAP	-	-	7.33ab
Weed-free until harvest	-	-	-
Weed-infested for 4 WAP	4.50ab	5.33ab	7.33ab
Weed-infested for 8 WAP	2.83c	4.67bc	6.00b
Weed-infested for 12 WAP	-	3.17e	3.33d
Weed-infested for 16 WAP	-	-	3.33d
Weed-infested until harvest	-	-	-
SE ±	0.460	0.450	0.480
SE± (MxP: Comparison within the same mulching treatment)	0.873_{NS}	0.750_{NS}	0.790_{NS}
SE± (MxP: Mulching with any other interaction)	0.650NS	0.629NS	0.675NS

[1]Weeks after planting.

[2]Means followed by the same letter(s) within the same column are not significantly different from each other using DMRT.

[3]Dash(-)indicates that treatments had not been applied at the time of observation.

[4]Crop vigour score taken using a scale of 0 to 10, where 0 represented completely dead plant and 10 represented the most vigorous crop.

had significantly higher vigour score than those kept weed-free for 4 and 8 WAP, and those weed-infested for 8 and 12 WAP. Weed infestation until 12 WAP also resulted in lower vigour score compared with those infested for 4 and 8 WAP. At 16 WAP, the crop weed-infested for 8, 12 and 16 WAP and those kept weed-free for 4 and 8 WAP resulted in significantly less vigorous plants compared with the maximum obtained with that kept weed-free for 12 WAP. Weed infestation until 12 and 16 WAP resulted in lower vigour score compared with infestation for 4 and 8 WAP.

4.1.2 Plant height

The mulched plots had significantly taller plants of ginger until 16 WAP than the unmulched plots at all sampling periods. (Table 7). No significant difference in plant height was obtained between periods of weed interference at 8 WAP. However, at 12 WAP, plots weed-infested for various period up to 12 WAP and those kept weed-free for 4 WAP had significantly shorter plants compared with the tallest obtained with those kept weedfree for 8 WAP. At 16 WAP, plots weed-infested until 8 WAP and more had significantly shorter plants than the tallest obtained on plots kept weedfree until 12 and 16 WAP.

4.1.3 Leaf production

The effect of mulching and period of weed interference on number and dry weight of leaves per plants are shown in

Table 7 Effects of mulching and period of weed interference on plant height (cm) of ginger at Samaru in 1986 wet seasom.

Treatments	Plant Height (cm)		
	8 WAP[1]	12 WAP	16 WAP
Mulching (M)			
Mulched	43.6a[3]	99.0a	167.1a
Unmulched	28.3b	61.9b	120.1b
SE ±	1.513	5.749	12.735
Period of Weed Interference (P)			
Weed free for 4 WAP	42.49	75.2b	135.3ab
Weed-free for 8 WAP	38.8	106.3a	161.3ab
Weed-free for 12 WAP	-[2]	86.9ab	188.0a
Weed-free for 16 WAP	-	-	190.7a
Weed-free until harvest	-	-	-
Weed-infested for 4 WAP	35.C	76.2b	160.5ab
Weed-infested for 8 WAP	37.7	76.1b	126.3bc
Weed-infested for 12 WAP	-	66.4b	84.2c
Weed-infested for 16 WAP	-	-	116.7bc
Weed-infested until harvest	-	-	-
SE ±	5.18	10.23	18.50
SE±(MxP: Comparison within the same mulching treatment)	7.106 NS	14.884 NS	27.885 NS
SE±(MxP: Comparison of any other interactions)	7.32	14.48NS	26.16NS

[1]Weeks after planting

[2]Treatments had not been applied at the time of observation.

[3]Means followed by the same letter(s) within the same column are not significantly different from each other using DMRT.

Table 8. The mulched plots consistently had higher number and dry weight of leaves per plant than the unmulched plots (Table 8).

The effect of period of weed interference was significant on dry weight of leaves per plant at 12 and 16 WAP and on number of leaves per plant at 16 WAP. At 12 WAP, crop weed-infested until 8 WAP had significantly lower dry weight of leaves per plant compared with the maximum obtained with those kept weed-free for 4 and 8 WAP. At 16 WAP, crop weed-infested for 12 and 16 WAP and that kept weed-free until 4 WAP had significantly lower number and dry weight of leaves per plant compared with the appropriate maximum obtained. In addition, weed infestation until 8 WAP also resulted in lower leaf number per plant compared with the maximum of 65.3 obtained in the trial. Crop weed-infested for 12 and 16 WAP had significantly lower number of leaves per plant compared with that infested for 4 WAP.

4.1.4 Stem and Shoot dry matter production

The effect of mulching was significant on stem dry weight per plant at 8 and 12 WAP and shoot weight per plant at 8 WAP with mulching resulting in higher values than no-mulching (Table 9). The effect of period of weed interference was significant on stem and shoot dry weight per plant at 12 and 16 WAP. At 12 WAP, plots infested until 8 WAP had lower stem and shoot weight than the maximum obtained. As observed with leaf dry matter production at 16 WAP, plots weed-infested

Table 8 Effects of mulching and period of weed interference on leaf dry matter production of ginger at Samaru in 1986 wet season.

Treatments	Leaf Dry Weight/Plant (g)			Numbers of Leaves/Plant		
	8 WAP[1]	12WAP	16 WAP	8 WAP	12 WAP	16 WAP
Mulching (M)						
Mulched	1.31a[2]	2.30	3.73a	24.5	41.3a	55.7
Unmulched	0.75b	2.19	2.92b	21.7	32.8b	44.3
SE ±	0.077	0.135 NS	0.433	3.01 NS	1.35	4.65
Period of Weed interference (P)						
Weed-free for 4 WAP	1.22	2.94a	2.67bc	21.8	38.7	43.7bc
Weed-free for 8 WAP	1.10	2.95a	3.17abc	20.7	48.3	50.8abc
Weed-free for 12 WAP	-[3]	2.17ab	4.39ab	-	35.5	65.3a
Weed-free for 16 WAP	-	-	4.27ab	-	-	61.3ab
Weed-free until harvest	-	-	-	-	-	-
Weed-infested for 4 WAP	0.93	2.42ab	4.57a	22.0	36.0	59.2ab
Weed-infested for 8 WAP	0.90	1.75b	2.85abc	27.7	36.3	46.0bc
Weed-infested for 12 WAP	-	2.05ab	1.91c	-	35.5	31.3c
Weed-infested for 16 WAP	-	-	2.37c	-	-	38.8c
Weed-infested until harvest	-	-	-	-	-	-
SE±	0.183	0.346	0.573	3.196	4.342	5.820
SE± (MxP: Comparison within the same mulching treatment)	0.257 NS	0.483 NS	0.882 NS	5.240 NS	5.980 NS	9.122 NS
SE± (MxP: Comparison of any other interaction)	0.259NS	0.489NS	0.810NS	4.53 NS	6.15 NS	8.33 NS

[1]Weeks after planting. [2]Means followed by the same letter(s) within the same column are not significantly different using DMRT. [3] Treatments had not been applied at the time of observation.

Table 9 Effects of mulching and period of weed interference on stem and shoot dry matter production of ginger at Samaru in 1986 wet season.

Treatments	Leaf dry weight/plant (g)			Shoot dry weight/plant (g)		
	8 WAP[1]	12 WAP	16 WAP	8 WAP	12 WAP	16WAP
Mulching (M)						
Mulched	0.76a[2]	1.43a	3.88	2.07a	3.73	7.6
Unmulched	0.43b	1.15b	2.89	1.18b	3.24	5.8
SE ±	0.198	0.063	0.509 NS	0.138	0.198NS	0.930 NS
Period of weed interference (P)						
Weed-free for 4 WAP	0.59	1.36a	2.75bc	1.91	4.29ab	5.42bc
Weed-free for 8 WAP	0.49	1.88a	4.13abc	1.59	4.82a	7.30abc
Weed-free for 12 WAP	-[3]	1.35a	4.76a	-	3.52ab	9.16a
Weed-free for 16 WAP	-	-	4.39ab	-	-	8.66ab
Weed-free until harvest	-	-	-	-	-	-
Weed-infested for 4 WAP	0.61	1.74a	3.93abc	1.54	4.16ab	8.50ab
Weed-infested for 8 WAP	0.54	0.89b	2.99abc	1.43	2.65b	5.84abc
Weed-infested for 12 WAP	-	1.16a	2.79abc	-	3.21ab	4.69c
Weed-infested for 16 WAP	-	-	2.07c	-	-	4.44c
Weed-infested until harvest	-	-	-	-	-	-
SE ±	0.820	0.270	0.112	0.966	0.569	1.030
SE± (MxP: Comparison within the same mulching treatment)	0.165NS	0.369NS	0.967NS	0.374NS	0.789NS	1.665NS
SE± (MxP: Mulching with any other interaction)	0.159NS	0.383NS	0.866NS	0.367NS	0.805NS	1.457NS

[1]Weeks after planting. [2]Means followed by the same letter(s) within the same column are not significantly different using DMRT. [3]Dash indicates that treatments had not been applied at the time of observation.

for 12 and 16 WAP and those kept weed-free for 4 WAP had significantly lower stem and shoot dry weight per plant compared with the appropriate maximum obtained.

4.1.6 Rhizome dry weight and rhizome yield

Mulching resulted in significantly higher rhizome dry weight per plant at 8 and 12 WAP and at harvest, compared with no mulching.

Periods of weed interference had significant effect on rhizome dry weight per plant at 16 WAP and rhizome yield at harvest (Table 10).

At 16 WAP, plots weed-infested for 12 and 16 WAP had significantly lower rhizome dry weight per plant compared with the maximum obtained with crop kept weed-free for 8 and 12 WAP. Only plots weed-infested for 16 WAP resulted in lower rhizome yield than the maximum obtained in the trial. With crop kept weed-free initially rhizome yield tend to decrease as the weed-free period increased until 16 WAP, while no definite trend was observed with crop weed-infested initially.

4.1.6 Weed cover score and weed dry matter production

As shown in Table 11, mulching did not have significant effect on broadleaved weeds while grass weed cover and total weed dry matter production were significantly higher at both 8 and 12 WAP on the unmulched plots compared with the mulched. At 8 WAP, crop kept weed-free for 8 WAP and those infested for 4 WAP had significantly lower score compared with

Table 10 Effects of mulching and period of weed interference on rhizome dry matter production and yield of ginger at Samaru in 1986 wet season.

Treatments	Rhizome dry weight/plant (g)			Rhizome Yield (kg/ha)
	8WAP[1]	12WAP	16WAP	
Mulching (M)				
Mulched	0.71a[2]	2.10a	5.57	533a
Unmulched	0.46b	1.56b	3.63	409b
SE ±	0.022	0.129	0.627 NS	38.2
Period of weed interference (P)				
Weed-free for 4 WAP	0.72	1.95	4.34ab	555a
Weed-free for 8 WAP	0.54	2.47	6.39a	509ab
Weed-free for 12 WAP	-[3]	2.05	6.15a	477ab
Weed-free for 16 WAP	-	-	4.9a	408ab
Weed-free until harvest	-	-	-	596a
Weed-infested for 4 WAP	0.58	1.60	4.97ab	468ab
Weed-infested for 8 WAP	0.53	1.93	4.31ab	385ab
Weed-infested for 12 WAP	-	2.12	2.95b	594a
Weed-infested for 16 WAP	-	-	3.01b	296b
Weed-infested until harvest	-	-	-	428ab
SE ±	0.097	0.390	0.732	75.5
SE± (MxP: Comparison within the same mulching treatment)	0.130 NS	0.538NS	1.160NS	108.3 NS
SE± (MxP: Comparison of any other interactions)	0.137NS	0.551NS	1.165NS	110.0NS

[1]Weeks after planting

[2]Means followed by the same letter(s) within the same column are not significantly different from each other using DMRT.

[3]Treatments had not been applied at the time of observation.

Table 11 Effects of mulching and period of weed interference on weed cover score and dry matter production of ginger at Samaru in 1986 wet season.

Treatments	Weed Cover Score [2] (Broadleaved)			(Grasses)			Total weed dry matter production (kg/ha)
	8 WAP[1]	12 WAP	16 WAP	8 WAP	12 WAP	16 WAP	
Mulching (M)							
Mulched	1.50a[3]	1.15	2.86	0.82b	2.57b	1.95	848b
Unmulched	1.00b	0.95	2.80	2.99a	3.41a	2.52	1979a
SE±	0.127	0.235NS	0.132NS	0.529	0.622	0.890NS	383.3
Period of weed interference(P)							
Weed-free for 4 WAP	1.75ab	1.33ab	2.92ab	1.92b	5.83a	3.00b	820bcd
Weed-free for 8 WAP	1.08bc	0.50b	2.17ab	0.50b	3.67a	1.83b	1956ab
Weed-free for 12 WAP	-[4]	0.25b	3.00ab	-	0.42c	0.08c	1546abcd
Weed-free for 16 WAP	-	-	2.93ab	-	-	1.67b	1193bcd
Weed-free until harvest	-	-	-	-	-	-	1241bcd
Weed-infested for 4 WAP	0.42c	0.42b	3.50ab	0.42b	0.08c	0.50b	1854abc
Weed-infested for 8 WAP	2.42a	0.42b	4.12a	4.08a	0.33c	1.75b	2409a
Weed-infested for 12 WAP	-	2.33a	2.00ab	-	7.17a	0.33b	1908ab
Weed-infested for 16 WAP	-	-	1.92b	-	-	6.50a	649cd
Weed-infested until harvest	-	-	-	-	-	-	558d
SE ±	0.330	0.414	0.730	0.544	0.936	0.936	329.8
SE ±(MxP: Comparison within the same mulching treatment)	0.462 NS	0.602 NS	0.988 NS	0.900 NS	1.400 NS	1.439 NS	644.7 NS
SE±(MxP: Mulching with any other interactions)	0.469NS	0.585NS	1.032NS	0.769NS	1.323NS	1.323NS	537.12NS

[1]Weeks after planting. [2]Weed Score taken where 0 represented the no weed cover and 10 represented complete weed cover. [3]Means followed by the same letter(s) within the same column are not significantly different using DMRT. [4]Treatments had not been applied at the time of observation.

those infested for 8 WAP. At 12 WAP, crop weed-infested for 4 and 8 WAP and those kept weed-free for 8 and 12 WAP had lower score compared with those weed-infested for 12 WAP for both broadleaved and grass weeds.

Cummulative total weed dry weight was obtained by sampling each plot before any weeding was conducted and at harvest. At 20 WAP and at harvest most of the weeds had completed their life-cycle and senesced, leaving the plots almost bare. The mulched plots had significantly lower total weed dry matter production compared with the unmulched plots. The plots kept weed free for 8 WAP and those weed-infested for 8 and 12 WAP had significantly higher weed dry matter production compared with those weed-infested until harvest.

4.1.7 Relationship between various parameters and rhizome yield of ginger in the weed interference studies

Among the observations taken, stem dry weight, plant height and crop vigour score at 8 WAP were significantly positively correlated with rhizome yield at harvest (Table 12). Similarly, at 12 WAP, the rhizome yield was positively correlated with rhizome weight, leaf weight and crop vigour score at 16 WAP It was however negatively correlated with weed cover score at 8 WAP.

Table 12: Relationship between various parameters and rhizome yield of ginger in the weed interference studies at Samaru, in 1986 wet season.

Parameters	r - value
Stem dry weight at 8 WAP	0.434**
Plant height at 8 WAP	0.306*
Crop vigour score at 8 WAP	0.379**
Weed cover score (grasses) at 8 WAP	-0.345**
Crop vigour score at 12 WAP	0.332**
Rhizome weight at 12 WAP	0.265*
Leaf weight at 12 WAP	0.252*
Crop vigour score at 16 WAP	0.303*
Weed cover score (grasses) at 16 WAP	-0.412**
Weed cover score (broadleaves) at 16 WAP	-0.295**

* r value = 0.256 significant at 5% level

**r value = 0.331 significant at 1% level

4.2 Effect of Weed Control Treatments on Weeds, Growth and Yield of Ginger

The effect of weed control treatments on weeds is shown in Table 13, while the effects on growth and yield of ginger are shown in Table 14 to 18.

4.2.1 Weed cover score

As shown in Table 13 the weed control treatments had significant effects on weed cover scores at 8, 12 and 16 WAP in the trial. At 8 WAP, all the herbicide treatments except mixtures of metolachlor with metobromuron at 1.0 + 1.0 kg a.i./ha and with diuron at 1.5 + 0.8 kg a.i./ha resulted in significantly lower weed cover score than the unweeded check but comparable to the hand-weeded control.

At 12 WAP, all the herbicide treatments resulted in lower weed score than the unweeded check; among the herbicide treatments, mixtures of metolachlor with metobromuron at 1.0 + 1.0 kg a.i./ha and with prometryne at 1.5 + 1.5 kg a.i./ha had significantly higher weed score compared with the hand-weeded control. The weed score taken at 16 WAP, i.e. three weeks after the supplementary weeding showed that all the herbicide treatments gave lower score than the hand-weeded control and the unweeded check although the hand-weeded control however had lower weed cover score compared with the unweeded check. Between 93 and 100% weed control were obtained at thirteen weeks, as reflected in the weed cover score (Table 13).

Table 13: Effect of weed control treatments on weed infestation of ginger at Samaru, in 1986 wet season.

Treatments Herbicides +[1]	Rate kg a.i./ha	Weed Cover Score[2] at 8WAP[3]	12WAP	16WAP	Weed dry matter production at 13 WAP (kg/ha)
Metolachlor+metobromuron	1.0+1.0	2.3ab[4]	4.7b	0.00c	89.42bc
Metolachlor+metobromuron	1.5+1.5	1.5bcd	3.3bc	0.16c	58.79bc
Metolachlor+terbutryne	1.33+0.67	0.5d	2.3bc	0.30c	59.95bc
Metolachlor+terbutryne	2.0+1.0	0.5d	3.0bc	0.50c	92.37bc
Metolachlor+atrazine	1.33+0.67	0.8d	3.0bc	0.30c	85.46bc
Metolachlor+atrazine	2.0+1.0	0.3d	3.0bc	0.16c	76.39bc
Metolachlor+metribuzin	1.0+0.25	0.3d	1.7bc	0.16c	70.66bc
Metolachlor+metribuzin	1.5+0.5	0.0d	1.7bc	0.30c	83.81bc
Metolachlor+prometryne	1.0+1.0	0.8d	2.3bc	0.00c	51.46bc
Metolachlor+prometryne	1.5+1.5	0.7d	4.7b	0.16c	92.37bc
Metolachlor+flumeturon	1.0+1.0	0.3d	1.0c	0.16c	67.47bc
Metolachlor+flumeturon	1.5+1.5	1.0cd	3.3bc	0.16c	98.10bc
Metolachlor+ametryne	1.0+1.0	0.5d	3.0bc	0.16c	61.65bc
Metolachlor+ametryne	1.5+1.5	0.7d	2.3bc	0.16c	41.10bc
Metolachlor+diuron	1.0+0.4	0.7d	2.3bc	0.16c	48.98bc
Metolachlor+diuron	1.5+0.8	2.0ab	3.0bc	0.16c	51.13bc
Metolachlor+chlorbromuron	1.0+1.0	0.5d	3.3bc	0.16c	48.13bc
Metolachlor+chlorbromuron	1.5+1.5	1.3bcd	3.3bc	0.16c	73.60bc
Weeded check at 4, 8,12 WAP		0.8d	0.16c	1.30b	53.00bc
Unweeded control		3.0a	8.6a	7.30a	768.39a
SE ±		0.350	0.940	0.240	25.880

+1 All the herbicide treated plots were supplementarily weeded at 13 WAP.

[1] All the herbicide treatments were applied pre-emergence one day after planting.

[2] weed cover score, where 0 represented no weed cover and 10 represented complete weed cover.

[3] WAP= Weeks after planting. [4] Means followed by the same letter(s) within a column are not significantly different from each other using DMRT

4.2.2 Weed dry matter production

At 13 WAP, all the weed control treatments resulted in significantly lower weed dry matter production compared with the unweeded check. The weed control treatments did not however differ significantly among themselves in weed dry matter production.

4.2.3 Crop stand count and vigour score

The weed control treatments did not have any significant effect on crop stand count at 6 WAP while the effect was significant on crop vigour at 8, 12, 16 and 20 WAP (Table 14). The highest crop vigour scores recorded at the various stages of growth were 7.0 at 8 WAP, 6.7 at 12 WAP, 8.0 at 16 WAP, and 4.3 at 20 WAP. Plots treated with mixtures of metolachlor with metobromuron at 1.5 + 1.5 kg a.i./ha, terbutryne at 1.33 + 0.67 kg a.i./ha, metribuzin at 1.0 + 0.25 kg a.i./ha, prometryne and ametryne each at 1.0 + 1.0 kg a.i./ha had comparable crop vigour score to the highest at each stage of growth, throughout the crop life-cycle. In addition to those indicated, mixtures of metolachlor with fluometuron at 1.0 + 1.0 kg a.i./ha and chlorbromuron at 1.5 + 1.5 kg a.i./ha also had comparable vigour to the highest until 16 WAP. At 8 WAP, it was apparent that high rate of mixtures of metolachlor with atrazine and ametryne resulted in significantly lower crop vigour scores compared with the low rates. A similar trend also occured with metolachlor plus chlorbromuron at 16 WAP

Table 14: Effect of weed control treatments on crop vigour score and stand count of ginger at Samaru, 1986

Treatment Herbicides +[1]	Rate kg a.i/ha	Crop Vigour Score[2] at 8WAP[3]	12WAP	16WAP	20WAP	Stand count at 6 WAP
Metolachlor+metobromuron	1.0+1.0	4.7 bcdef[4]	5.3 abcd	7.3 abc	4.0 ab	71.3
Metolachlor+metobromuron	1.5+1.5	6.0 abcd	6.0 ab	7.3 abc	3.3 abc	71.3
Metolachlor+terbutryne	1.33+0.67	5.7 abcde	5.7 abc	7.0 abc	4.0 ab	61.3
Metolachlor+terbutryne	2.0+1.0	4.3 cdef	4.3 cd	5.3 de	2.7 bcde	45.0
Metolachlor+atrazine	1.33+0.67	5.6 abcde	5.3 abcd	6.7 bcd	2.3 de	45.3
Metolachlor+atrazine	2.0+1.0	3.0 f	5.0 bcd	6.0 de	2.3 de	50.0
Metolachlor+metribuzin	1.0+0.25	6.0 abcd	5.7 abc	7.0 abc	3.0 abcd	61.7
Metolachlor+metribuzin	1.5+0.5	5.7 abcde	5.3 abcd	6.7 bcd	2.7 bcde	53.0
Metolachlor+prometryne	1.0+1.0	6.7 ab	6.3 ab	7.3 abc	3.0 abcd	63.7
Metolachlor+prometryne	1.5+1.5	4.7 bcdef	5.7 abc	7.3 abc	2.3 de	61.0
Metolachlor+flumeturon	1.0+1.0	6.0 abcd	6.3 ab	8.0 a	2.7 bcde	63.0
Metolachlor+flumeturon	1.5+1.5	4.7 bcdef	5.3 abcd	7.7 abc	2.0 de	51.7
Metolachlor+ametryne	1.0+1.0	6.3 abc	6.7 a	8.0 a	3.0 abcd	67.3
Metolachlor+ametryne	1.5+1.5	4.0 ef	5.7 abc	7.3 abc	3.0 abcd	52.3
Metolachlor+diuron	1.0+0.4	5.3 bcde	6.0 ab	7.7 ab	3.3 abc	59.3
Metolachlor+diuron	1.5+0.8	5.0 bcde	5.3 abcd	6.3 bcd	2.7 bcde	67.0
Metolachlor+chlorbromuron	1.0+1.0	6.0 abcd	6.0 ab	6.7 bcd	4.3 a	55.7
Metolachlor+chlorbromuron	1.5+1.5	6.0 abcd	5.7 abc	7.0 abc	2.7 bcde	65.7
Weeded check at 4,8,12 WAP		7.0 a	6.3 ab	6.7 bcd	1.7 d	77.3
Unweeded control		4.0 ef	4.0 e	4.0 e	1.0 e	74.0
SE ±		0.52	0.46	0.67	0.45	7.15

+All the herbicide treated plots were supplementarily weeded at 13 WAP.

[1]All herbicide treatments were applied pre-emergence one day after planting.

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

[3]WAP = Weeks after planting

[4]Means followed by the same letter(s) within a column are not significantly different from each other using DMRT.

At 12 WAP, among the weed control treatments, only mixtures of metolachlor with atrazine and terbutryne each at 2.0 + 1.0 kg a.i./ha resulted in lower vigour score than the highest obtained with metolachlor plus ametryne at 1.0 + 1.0 kg a.i./ha.

4.2.4 Leaf production

The weed control treatments had significant effect on the number of leaves per plant at 8 and 20 WAP and leaf dry weight per plant at 16 and 20 WAP (Table 15).

At 8 WAP, mixtures of metolachlor with atrazine and terbutryne, each at 1.33 + 0.67 kg a.i./ha and 2.0 + 1.0 kg a.i./ha, prometryne at 1.0 + 1.0 and 1.5 + 1.5 kg a.i./ha, metribuzin at 1.5 + 0.5 kg a.i./ha, ametryne and chlorbromuron each at 1.5 + 1.5 kg a.i./ha, resulted in significantly lower number of leaves per plant compared with the highest obtained with metolachlor plus diuron at 1.0 + 0.4 kg a.i./ha. At 20 WAP, both rates of metolachlor plus atrazine still resulted in lower number of leaves per plant compared with the highest obtained with metolachlor plus ametryne at 1.0 + 1.0 kg a.i./ha At this stage of crop growth, plots treated with mixtures of metolachlor with metobromuron and flumeturon each at 1.0 + 1.0 kg a.i./ha and 1.5 + 1.5 kg a.i./ha, terbutryne at 1.33 + 0.67 and 2.0 + 1.0 kg a.i./ha, metribuzin at 1.0 + 0.25 and 1.5 + 0.5 kg a.i./ha, prometryne at 1.5 + 1.5 kg a.i./ha and

Table 15 Effect of weed control treatments on leaf production of ginger at Samaru in 1986 wet season

Treatment Herbicide +[1]	Rate kg a.i/ha	Number of leaves/plant at 8 WAP[2]	12 WAP	16 WAP	20 WAP	Leaf dry weight/ at 8 WAP	12 WAP	16 WA
Metolachlor+metobromuron	1.0+1.0	22.0abcd[3]	47.7a	48.0	24.33bc	0.96	2.88	3.14a
Metolachlor+metobromuron	1.5+1.5	24.0ab	19.7a	53.7	31.00bcd	1.16	2.60	3.11a
Metolachlor+terbutryne	1.33+0.67	18.7bcd	46.0a	62.7	43.00abc	0.89	3.18	4.11a
Metolachlor+terbutryne	2.0+1.0	17.0bcd	33.0a	39.0	29.33bcd	0.65	1.76	2.28c
Metolachlor+atrazine	2.0+1.0	12.7d	46.7a	45.0	22.66bcd	0.52	3.73	2.03d
Metolachlor+atrazine	2.0+1.0	16.7bcd	58.7a	70.0	21.00bcd	0.74	5.06	3.12a
Metolachlor+metribuzin	1.0+0.25	23.0abc	51.0a	51.0	14.00d	1.46	4.31	3.38a
Metolachlor+metribuzin	1.5+0.5	15.0cd	44.7a	43.7	24.66bcd	0.46	2.43	2.97a
Metolachlor+prometryne	1.0+1.0	16.3bcd	42.0a	44.7	41.00abcd	0.44	3.38	3.83a
Metolachlor+prometryne	1.5+1.5	13.3d	33.0a	45.7	22.33bcd	0.72	2.51	2.58b
Metolachlor+flumeturon	1.0+1.0	23.0abc	34.7a	63.0	24.00bcd	0.99	2.97	3.06a
Metolachlor+flumeturon	1.5+1.5	22.0abcd	37.3a	64.7	19.66bcd	0.87	3.12	5.09a
Metolachlor+ametryne	1.0+1.0	23.7ab	43.3a	67.0	57.00a	1.60	4.17	5.53a
Metolachlor+ametryne	1.5+1.5	19.7bcd	33.7a	51.3	32.66abcd	0.71	1.81	2.16d
Metolachlor+diuron	1.0+0.4	30.3c	41.3a	64.3	46.66ab	0.97	3.31	5.64a
Metolachlor+diuron	1.5+0.8	21.3abcd	52.0abc	46.3	22.66bcd	0.98	2.71	3.41a
Metolachlor+chlorbromuron	1.0+1.0	23.0abc	41.3a	78.0	48.33ab	1.01	3.50	6.34a
Metolachlor+chlorbromuron	1.5+1.5	20.0bcd	39.0a	68.3	36.00abcd	0.74	2.57	4.61a
Weeded check at 4,8,12 WAP		24.7ab	57.3a	65.0	23.33bcd	1.41	3.08	4.26a
Unweeded control		21.3abcd	36.7a	45.0a	16.00cd	0.55	2.35	1.16c
SE ±		2.850	6.97	10.04	8.530	0.250	0.670	0.960

+All the herbicide treated plots were supplementarily weeded at 13 WAP

[1]All herbicide treatments were applied pre-emergence, one day after planting. [2]WAP=Weeks after plant

[3]Means followed by the same letter(s) within a column are not significantly different from each other

diuron at 1.5 + 0.8 kg a.i./ha as well as the hand-weeded and the unweeded controls had significantly lower number of leaves per plant than the maximum obtained. Leaf dry weight per plant at 16 WAP was significantly lower with mixtures of metolachlor with terbutryne at 2.0 + 1.0 kg a.i./ha, prometryne and ametryne each at 1.5 + 1.5 kg a.i./ha, as well as the unweeded control compared with the highest obtained with metolachlor plus chlorbromuron at 1.0 + 1.0 kg a.i./ha. At 20 WAP, the herbicide treatments that resulted in comparable leaf weight per plant to the highest obtained included mixtures of metolachlor with metobromuron at 1.5 + 1.5 kg a.i./ha, prometryne at 1.0 + 1.0 kg a.i./ha and ametryne at both rates. All the other herbicide treatments including the unweeded control resulted in lower leaf weight per plant.

4.2.5 Stem and shoot dry matter production

Both the stem and shoot dry weight per plant were significantly affected by the weed control treatments at 16 and 20 WAP. In both cases, the highest weights were obtained with metolachlor plus chlorbromuron at 1.0 + 1.0 kg a.i./ha (Table 16). At 16 WAP, mixtures of metolachlor with fluometuron and chlorbromuron each at 1.5 + 1.5 kg a.i./ha, ametryne at 1.0 + 1.0 kg a.i./ha and diuron at 1.0 + 0.4 kg a.i./ha, and the hand-weeded control resulted in comparable stem and shoot weight to the highest. In addition, mixture of metolachlor

Table 16 Effect of weed control treatments on stem and shoot dry matter production of ginger at Samar 1986 wet season.

Treatment Herbicides +[1]	Rate kg a.i/ha	Stem dry weight/plant(g) at 8WAP[2]	12WAP	16WAP	20WAP	Shoot dry weight/p at 8WAP	12WAP	16WAP
Metolachlor+metobromuron	1.0+1.0	0.41	3.20	3.40defg[3]	3.82abcde	1.37a	6.08	5.42bcd
Metolachlor+metobromuron	1.5+1.5	0.36	1.89	3.11defg	4.17abcde	1.77a	4.49	5.35bcd
Metolachlor+terbutryne	1.33+0.67	0.29	1.60	4.11abcdef	3.52abcde	1.19a	4.78	7.31abcd
Metolachlor+terbutryne	2.0+1.0	0.13	1.09	2.28efgh	2.66bcde	0.78a	2.85	3.66cd
Metolachlor+atrazine	1.33+0.67	0.18	2.54	2.03gh	3.71abcde	0.70a	6.28	3.76cd
Metolachlor+atrazine	2.0+1.0	0.28	3.19	3.12defg	2.59cde	1.02a	8.25	5.08bcd
Metolachlor+metribuzin	1.0+0.25	0.20	1.70	3.38cdefg	3.33bcde	1.68a	6.00	6.48abcd
Metolachlor+metribuzin	1.5+0.5	0.18	2.58	2.97defgh	2.68cde	0.62a	5.00	4.97bcd
Metolachlor+prometryne	1.0+1.0	0.22	2.89	3.83bcdef	3.27bcde	0.94a	6.37	6.34abcd
Metolachlor+prometryne	1.5+1.5	0.13	1.59	2.58efgh	3.74abcde	0.60a	4.00	4.00bcd
Metolachlor+flumeturon	1.0+1.0	0.36	2.34	3.06defg	6.25ab	1.36a	5.32	6.17bcd
Metolachlor+flumeturon	1.5+1.5	0.42	1.98	5.09abc	2.86cde	1.29a	5.09	8.24abc
Metolachlor+ametryne	1.0+1.0	0.41	2.77	5.53ab	5.38abcd	2.00a	6.94	9.05ab
Metolachlor+ametryne	1.5+1.5	0.24	2.04	2.16fgh	5.58abc	0.95a	3.85	3.74cd
Metolachlor+diuron	1.0+0.4	0.20	2.59	5.64ab	3.82abcde	1.17a	3.90	9.82ab
Metolachlor+diuron	1.5+0.8	0.31	2.03	3.41cdefg	2.40de	1.28a	6.75	5.30bcd
Metolachlor+chlorbromuron	1.0+1.0	0.36	2.51	6.34a	6.59a	1.38a	6.01	11.27a
Metolachlor+chlorbromuron	1.5+1.5	0.27	2.22	4.61abcd	3.17bcde	1.01a	4.79	8.11abc
Weeded check at 4, 8, 12 WAP		0.30	2.52	4.26abcde	3.66abcde	1.47a	5.59	7.53abcd
Unweeded control		0.25	1.53	1.16h	1.45e	0.80a	3.89	2.9abcd
SE ±		0.790 NS	0.480 NS	0.570	0.920	0.300	0.980 NS	1.40

+All the herbicide treated were supplementarily weeded at 13 WAP.

[1]All herbicide treatments were applied pre-emergence, one day after planting. [2]WAP=Weeks after plant

[3]Means followed by the same letter(s) within a column are not significantly different from each other

with terbutryne at 1.33 + 0.67 kg a.i./ha, metribuzin at 1.0 + 0.25 kg a.i./ha and prometryne at 1.0 + 1.0 kg a.i./ha also resulted in comparable shoot weight to the highest obtained at this stage of growth. High rates of mixtures of metolachlor with ametryne and diuron caused significantly lower stem weight per plant than the low rates. High rates of mixtures containing metribuzin, prometryne, and ametrune also resulted in comparable stem weight to the unweeded check. At 20 WAP, mixtures of metolachlor with ametryne at 1.0 + 1.0 and 1.5 + 1.5 kg a.i./ha metobromuron at 1.5 + 1.5 kg a.i./ha and diuron at 1.0 + 0.4 kg a.i./ha resulted in comparable stem and shoot weight per plant to the highest obtained. In addition, metolachlor mixture with metobromuron and fluometuron each at 1.0 + 1.0 kg a.i./ha, atrazine and terbutryne each at 1.33 + 0.67 kg a.i./ha, prometryne at 1.5 + 1.5 kg a.i./ha and the hand-weeded control resulted in comparable stem weight per plant to the highest at this stage of growth. Among the herbicide treatments, in addition to the best treatments, only mixture of metolachlor with prometryne at 1.5 + 1.5 kg a.i./ha and ametryne at both rates caused significantly higher stem dry weight per plant compared with the unweeded check. Shoot weight with prometryne at 1.0 + 1.0 kg a.i./ha was also comparable to the highest the herbicide treatment in addition to those of mixtures of metolachlor with fluometuron at 1.0 + 1.0 kg a.i./ha and ametryne at both rates were significantly higher than that of the unweeded check at 10 WAP.

4.2.6 Plant height

The weed control treatments resulted in significantly taller plants at 16 and 20 WAP compared with the unweeded check (Table 17). At 8 WAP, herbicide treatments that resulted in comparable plant height to the hand-weeded control were mixtures of metolachlor with metobromuron at 1.0 + 1.0 kg a.i./ha and fluometuron at 1.5 + 1.5 kg a.i./ha. At 12 WAP, it was apparent that among the weed control treatments, mixtures of metolachlor with diuron at both rates, prometryne at 1.0 + 1.0 kg a.i./ha and terbutryne at 1.33 + 0.67 kg a.i./ha were comparable to the tallest plants obtained with metolachlor plus prometryne at 1.5 + 1.5 kg a.i./ha. At 16 WAP, mixtures of metolachlor with terbutryne at 2.0 + 1.0 kg a.i./ha, metribuzin at 1.5 + 0.5 kg a.i./ha, ametryne at 1.5 + 1.5 kg a.i./ha resulted in shorter plants compared with the tallest plants and those of the plots treated with metolachlor plus chlorbromuron at 1.0 + 1.0 kg a.i./ha. Weed control treatments comparable with the best treatment obtained with metolachlor plus chlorbromuron at 1.0 + 1.0 kg a.i./ha at 20 WAP, were mixtures of metolachlor with metobromuron, and ametryne each at 1.0 + 1.0 and 1.5 + 1.5 kg a.i./ha, fluometuron at 1.0 + 1.0 kg a.i./ha and diuron at 1.0 + 0.4 kg a.i./ha.

Table 17: Effect of weed control treatments on plant height of ginger at Samaru, in 1986 wet season.

Treatments Herbicides +[1]	Rate kg a.i/ha	Plant height (cm) at 8WAP[2]	12 WAP	16WAP	20 WAP
Metolachlor+metobromuron	1.0+1.0	20.8	75.5	103.7abc[3]	175.0ab
Metolachlor+metobromuron	1.5+1.5	18.9	37.7	129.7abc	147.3abc
Metolachlor+terbutryne	1.33+0.67	18.4	90.0	144.0abc	133.3abcde
Metolachlor+terbutryne	2.0+1.0	11.9	68.8	74.0bc	112.7abcde
Metolachlor+atrazine	1.33+0.67	12.9	83.3	98.7abc	104.3bcde
Metolachlor+atrazine	2.0+1.0	14.9	73.6	149.0abc	51.3de
Metolachlor+metribuzin	1.0+0.25	19.2	87.2	102.7abc	83.7bcde
Metolachlor+metribuzin	1.5+0.5	13.0	87.5	86.3bc	107.7bcde
Metolachlor+prometryne	1.0+1.0	12.6	98.7	119.0abc	139.0abcd
Metolachlor+prometryne	1.5+1.5	11.3	108.2	97.2abc	125.7abcde
Metolachlor+flumeturon	1.0+1.0	15.3	60.8	120.5abc	144.0abc
Metolachlor+flumeturon	1.5+1.5	20.1	78.3	124.7abc	103.7bcde
Metolachlor+ametryne	1.0+1.0	19.8	84.3	166.0abc	143.0abc
Metolachlor+ametryne	1.5+1.5	12.8	78.0	80.7bc	131.0abc
Metolachlor+diuron	1.0+0.4	16.8	93.0	157.0abc	140.7abc
Metolachlor+diuron	1.5+0.8	14.0	99.4	102.0abc	97.7bcde
Metolachlor+chlorbromuron	1.0+1.0	16.3	81.7	183.7a	201.0a
Metolachlor+chlorbromuron	1.5+1.5	16.8	50.3	123.2abc	119.3abcde
Weeded check at 4,8,12 WAP		23.5	59.3	177.8a	104.0bcde
Unweeded control		17.5	89.2	116.7abc	48.7de
SE ±		3.44NS	17.27NS	25.36	26.06

+All the herbicide treated plots were supplementarily weeded at 13 WAP.

[1]All herbicide treatments were applied pre-emergence one day after planting.

[2]WAP = weeks after planting

[3]Means followed by the same letter(s) within a column are not significantly different from each other using DMRT

4.2.7 Rhizome dry matter production and yield

The effect of weed control treatments on rhizome dry matter production per plant and yield are shown in Table 18. The weed control treatments significantly affected rhizome dry matter production per plant at 16 and 20 WAP and rhizome yield at harvest. At 16 WAP, mixtures of metolachlor with metobromuron and chlorbromuron, each at 1.5 + 1.5 kg a.i./ha, prometryne and ametryne each at 1.0 + 1.0 kg a.i./ha, fluometuron at 1.0 + 1.0 and 1.5 + 1.5 kg a.i./ha, diuron at 1.0 + 0.4 and 1.5 + 0.8 kg a.i./ha and the hand-weeded check resulted in comparable rhizome dry matter production per plant to the harvest obtained with metolachlor with chlorbromuron at 1.0 + 1.0 kg a.i./ha. Similarly, at 20 WAP, mixtures of metolachlor with metobromuron and fluometuron each at 1.0 + 1.0 kg a.i./ha, and ametryne at 1.0 + 1.0 and 1.5 + 1.5 kg a.i./ha were also comparable to the highest rhizome weight per plant obtained.

Weed control treatments with rhizome yield that were comparable in value to the best obtained with metolachlor plus metribuzin at 1.0 + 0.25 kg a.i./ha are mixtures of metolachlor with metobromuron, prometryne, fluometuron, chlorbromuron each at the rate of 1.0 + 1.0 kg a.i./ha, terbutryne at 1.33 + 0.67 kg a.i./ha, ametryne at 1.0 + 1.0 and 1.5 + 1.5 kg a.i./ha and diuron at 1.0 + 0.4 and 1.5 + 0.8 kg a.i./ha.

Table 18: Effect of weed control treatments on rhziome dry matter production and yield of ginger at Samaru, .

Treatments Herbicides +[1]	Rate kg a.i/ha	Rhizome dry weight per plant (g) at 8WAP[2]	12WAP	16WAP	20WAP	Rhizome yield at harvest (kg/ha)
Metolachlor +metobromuron	1.0+1.0	0.42	2.56	3.87bc[3]	8.89ab	935. ab
Metolachlor+metobromuron	1.5+1.5	0.49	1.91	5.83abc	5.34bcde	705. abc
Metolachlor+terbutryne	1.33+0.67	0.28	1.87	5.87abc	6.42bcd	888. ab
Metolachlor+terbutryne	2.0+1.0	0.30	1.40	2.57c	6.04bcde	685. abc
Metolachlor+atrazine	1.33+0.67	0.19	2.39	2.52c	4.50cde	470. abc
Metolachlor+atrazine	2.0+1.0	0.27	0.28	3.00bc	2.66de	535. abc
Metolachlor+metribuzin	1.0+0.25	0.35	3.81	2.98bc	6.43bcd	990. a
Metolachlor+metribuzin	1.5+0.5	0.19	2.61	3.65bc	4.97bcde	609. abc
Metolachlor+prometryne	1.0+1.0	0.20	2.58	5.90abc	6.35bcde	931. ab
Metolachlor+prometryne	1.5+1.5	0.19	1.48	2.65c	5.27bcde	717. abc
Metolachlor+flumeturon	1.0+1.0	0.25	2.78	5.44abc	7.75abcd	890. ab
Metolachlor+flumeturon	1.5+1.5	0.27	1.16	6.14abc	5.34bcde	881. ab
Metolachlor+ametryne	1.0+1.0	0.26	1.65	1.73c	7.52abc	948. ab
Metolachlor+ametryne	1.5+1.5	0.26	1.65	1.83c	7.52abc	881. ab
Metolachlor+diuron	1.0+0.4	0.33	2.54	6.43abc	6.50bcd	825. ab
Metolachlor+diuron	1.5+0.8	0.24	1.38	3.62ab	5.08bcde	787. ab
Metolachlor+chlorbromuron	1.0+1.0	0.29	2.25	9.74a	11.04c	929. ab
Metolachlor+chlorbromuron	1.5+1.5	0.26	2.21	7.85ab	5.92bcde	579. abc
Weeded check at 4,8,12 WAP		0.38	2.10	6.60ab	4.85bcde	684. abc
Unweeded check		0.21	1.48	4.03bc	2.23e	240. c
SE ±		0.077NS	0.532NS	1.520	1.230	145.04

*All the herbicide treated plots were supplementary weeded at 13 WAP.

[1]All herbicide treatments were applied pre-emergence one day after planting.

[2]WAP=weeks after planting

[3]Means followed by the same letter(s) within a column are not significantly different from each other using DMRT

Relationship between various parameters and rhizome yield of ginger in the weed control studies at Samaru, 1986.

As shown in Table 19, rhizome yield at harvest was significantly positively correlated with crop vigour score, plant height at 16 and 20 WAP, leaf, stem and rhizome weight per plant all at 20 WAP. Weed cover score at 16 WAP and total weed weight at 13 WAP were however negatively correlated with rhizome yield.

Table 19 Relationship between various parameters and rhizome yield of ginger in the weed control studies at Samaru, 1in 1986 wet season.

Parameters	r-value
Crop vigour score at 12 WAP	0.412**
Weed cover score (broadleaved) at 16 WAP	-0.349**
Crop vigour score at 16 WAP	0.547**
Plant height at 16 WAP	0.425**
Rhizome weight at 20 WAP	0.301*
Leaf weight at 20 WAP	0.261*
Plant height at 20 WAP	0.431**
Stem weight at 20 WAP	0.332**
Crop vigour score at 20 WAP	0.325*
Total weed weight at 13 WAP	-0.343**

* r value = 0.256 significant at 5% level

** r value = 0.331 significant at 1% level

Chapter 5

DISCUSSION

The maximum yield of dry ginger rhizome of 990 kilograms per hectare obtained in the weed control trial during the study compared favourably with an average yield of 952 kilogram per hectare obtained in part of India(Muralidharam and Kamalam, 1973), despite the lower total annual precipitation of 962.5 mm and distributed over 4 months in Zaria compared with an average of 3,000 mm in part of India distributed over 8 to 10 months in India (Paulosa, 1972). The yield obtained in the study is however low compared with 1,568 to 2,016 kilogram per hectare reported in Jamaica (Prentice, 1959) which has an annual rainfall of 1,800 mm and mean temperature of 21°C. The difference in yield could also be attributed to the higher mean temperature of 24.4°C at Zaria(Table 2) which probably encouraged more vegetative growth to the detriment of rhizome formation and development. Similar observation have been reported in potato by various workers (Beukema and Vander,1979; Harmsworth and Albert,1980; Mbah, 1985; Bulus, 1986). In spite of this limitation, it is possible that with adequate fertilizer application, and other management practices which include appropriate spacing, timely planting mulching and proper weed control method, very high yield similar to that of India, the largest producer of ginger, could also be obtained in Zaria, in the northern Guinea savanna of Nigeria.

In the weed interference trial, the maximum yield of dry ginger rhizome was 596 kilogramme per hectare obtained with the crop kept weed-free until harvest. The low yield could be attributed to crop disturbances during frequent handpulling of weeds in order to keep the plots weed-free while no weeding was done on the herbicide treated plots in the weed control trials until 13 WAP. The differences in yield were also reflected in the vegetative growth with the plants in the weed control experiment appearing more vigorous generally than those of the weed interference trials. Furthermore, the weeds left with the crops until 13 weeks after planting when supplementary weeding was done in the herbicide-treated plots, provided shade without necessarily competing with the crop seriously. These weeds only infested the crop after it had become established, since the herbicide treatments prevented this infestation initially. The yield of the weed interference trial was a mean of mulched and unmulched plots, and this would have contributed to its low value.

5.1 Effects of Mulching and Period of Weed interference on the Growth and Yield of Ginger

In the weed interference trial, the use of grass mulch resulted in lower weed infestation and vigorous growth of ginger plant as reflected in the weed cover score, plant height, leaf dry weight, number of leaves/plant, stem dry weight,

shoot dry weight and rhizome dry weight at 8, 12 and 16 WAP compared with the unmulched crop. Rhizome production was initiated earlier on the mulched plots as observed at 8 WAP when rhizome dry weights were 0.71 g/plant and 0.46 g/plant for the mulched and unmulched crops, respectively. Mean dry rhizome yield on mulched plots was about 37% higher than that of the unmulched situations. This result agrees with that of Joachin and Pieris (1934), who observed that a mulch of straw was definitely beneficial to ginger, resulting in 12.2% higher mean yield on the mulched plots compared with the unmulched. Similarly, Appadurai (1967), Mohanty (1977) in India and Owadally et al. (1981) in Mauratius, all reported that mulching, through effective weed suppression, conservation of soil moisture and prevention of soil erosion resulted in high rhizome yield, respectively. Sheldrake (1967) has also associated higher yield of crop on mulched plots with reduced fertilizer leaching, improved microbial activity in the soil, reduced water evaporation and more carbon dioxide availability to the plants.

It was apparent in this trial that weed infestation for 4 WAP did not adversely affect crop growth as reflected in the crop vigour score, plant height, leaf, stem and shoot weight (Table, 6, 7, 8 and 9). In contrast, results on vigour score at 12 and 16 WAP and plant height at 16 WAP, showed that weed infestation until eight weeks and more depressed vegetative growth of the crop significantly.

Although not significant, leaf, number, shoot and stem dry weight of these treatments were also low compared with those of the plots infested for four weeks only. Rhizome dry matter production was only lower with infestation for 16 WAP compared with the crop weed-infested for 4 WAP. This could be attributed to the fact that the crop which had not commenced active growth was also exposed to very low weed infestation as at 4 WAP. Subsequent infestation until 16 WAP were however detrimental to the growth and yield of ginger resulting in significantly lower vigour score, leaf, stem and shoot weight, plant height, rhizome dry matter production and yield (Table 6, 7, 8, 9 and 10).

Except where the crop was kept weed-free throughout, rhizome yield decreased as the initial weed-free period increased (Table 10). Regular removal of weeds in the closely spaced crop which probably resulted in crop injury and removal of shade essential for good ginger crop growth and yield (Hammerton, 1974) was probably responsible for this trend in rhizome yield. It was also observed that after each weeding, plant exhibited signs of moisture stress, with consequent loss of some stands (Table 10). Similar observation on crop injury with consequent yield reduction in closely spaced onion was observed at Samaru by Sinha and Lagoke (1982). It was however observed that plot weed-infested until 12 WAP, even though initially

disturbed by weeding resulted in higher rhizome yield compared with those weed-infested till 16 WAP. It was probable that the shade provided by infesting weeds until 12 WAP enhanced rhizome production and reduce possible rhizome losses due to weed competition for available resources, viz. nutrient and moisture.

In this trial, weed association with the crop until 16 WAP resulted in 50.33% reduction in total rhizome yield compared with the best obtained with the crop kept weed-free throughout (Table 10). Similarly, in bulb onion and red beet, Hewson (1971) reported that final crop yeidl was unaffected when weeds were allowed to compete up to four to four and half and four to six and half weeks, respectively after 50% crop emergence, provided the plots were kept clean subsequently. It was also apparent that maximum rhizome yield could be obtained even if the crop is weed-infested until 12 WAP. Probably the critical period of weed competition in the crop is between 12 and 16 WAP. This further emphasizes the importance of crop injury caused by hand-pulling relative to shade removal during weeding in influencing rhizome yield. In effect, any method which would preclude the need for weed removal during this early stage of growth would definitely enhance rhizome yield as was observed with herbicide treatments in the weed control experiment.

In this trial, mulching resulted in lower weed dry matter production compared with no-mulching. This obviously was due to the effect of grass mulches which suppressed weed growth through smothering. The effect on grasses was also significant since major weed infestation at the early stage was grasses with the broadleaved weeds infesting the plots later

when the mulch might have decayed. Plots weed-infested for 8 WAP gave the maximum weed dry matter of 2,409 kilogram per hectare compared to the minimum of 558 kilogram per hectare obtained with those weed-infested until harvest. This could be due to the rapid growth of weed from planting until about 20 WAP when most of the weeds had completed their life-cycle and senesced leaving the plots almost bare.

5.2 Effects of Weed Control Treatments on Weeds and the Crop

It was apparent that all the herbicide treatments consistently controlled weeds effectively both before and after one supplementary weeding. All the herbicide treated plots had even lower weed infestation than the hand-weeded control plots three weeks after the supplementary weeding. In effect the pre-emergence herbicide treatments successfully substituted the first two hand-weedings done on the hand-weeded plots (Table 14). Bakut (1985), Gworgwor (1985), Adejonwo et al., (1987) and Bulus (1987) have all reported the effectiveness of single supplementary weeding to pre-emergence herbicides for season long weed control in maize-okra, maize-pepper, sorghum-groundnut mixtures and potato, respectively, at Samaru.

However, prior to supplementary weeding, plots treated with metolachlor plus metobromuron at 1.0 + 1.0 kg a.i./ha consistently had higher weed score than those hand-weeded twice until 12 WAP, thus confirming the relative weakness of the treatment on weeds as reported earlier by Bulus (1987) in

potato at Samaru. Inspite of the high weed cover and low crop vigour score at 8 WAP obtained with the mixture, which might be a consequence of the poor weed control, the treatment still resulted in high rhizome yield when supplementarily weeded at 13 WAP. In this trial, mixtures of metolachlor with ametryne and chlorbromuron at 1.0 + 1.0 kg a.i./ha combined effective weed control with good crop growth throughout the crop life-cycle,resulting in high rhizome yield. These treatments resulted in crop vigour score that were comparable to those of the best treatment at 8, 12, 16 WAP and significantly higher than the unweeded check. In addition, the treatments resulted in high leaf number, leaf, stem and shoot dry weight, plant height and rhizome yield comparable to the appropriate best treatments and significantly higher than the unweeded control throughout the crop life cycle (Table 15 to 19). Similarly, it has been reported in West Indies that ginger tolerated ametryne at rates that controlled weeds effectively. (Kasasian, 1962; Kasasian and Seeyave, 1970; Hamerton, 1974). Sambo(1986) and Adejonwo et al.,(1987) reported that mixtures of metolachlor with chlorbromuron at 1.0 + 1.0 kg a.i./ha followed by supplementary hoe-weeding combined effective weed control with high okra pod and maize grain yield and potato yield that were comparable to that of the hoe-weeded control and higher than the unweeded check at Samaru. The beneficial effect of metolachlor plus diuron at 1.0 + 0.4 kg a.i./ha

was manifested on the crop at the later stage of growth and harvest when crop vigour score, stem, shoot, leaf and rhizome dry weights and leaf number at 20 WAP of the treatment were comparable to the best and significantly higher than the unweeded check. Crop vigour score and leaf, stem and shoot dry weights at 16 WAP with the herbicide treatments were also comparable to those of the best treatments and higher than the untreated check. Similarly, mixtures of metolachlor plus fluometuron at 1.0 + 1.0 kg a.i./ha resulted in stem, shoot and rhizome dry weight at 20 WAP and rhizome yield at harvest that were comparable to those of the best treatments and significantly higher than those of the unweeded check. Inspite of the fact that the growth of the crop was not comparable to the best treatment with mixtures of terbutryne at 1.33 + 0.67 kg a.i./ha, metribuzin at 1.0 + 0.25 kg a.i./ha and prometryne at 1.0 + 1.0 kg a.i./ha, the treatments also resulted in high rhizome yield at harvest probably due to supplementary hand-weeding which enhanced effective rhizome formation. The highest rhizome yield of 990 kg per hectare was obtained with mixtures of metolachlor with metribuzin at 1.0 + 0.25 kg a.i./ha. Diuron, when used alone, has been reported to give selective control of weeds in ginger in West Indies (Kasasian, 1962) and in Queensland, Australia (Whiley, 1974). At Samaru, Nigeria, mixtures of metolachlor with fluometuron has been reported to control weeds effectively in various crops viz, cotton, yam, maize-okra mixtures, especially when supplemented by hoe-weeding (Lagoke et al., 1986a; 1986b; Adejowno et al., 1987). For weed control in

potato, using variety 'Greta' the highest tuber yields and season-long weed control were obtained with metolachlor plus metribuzin at 1.00+0.25 kg a.i./ha when compared with the other treatments at Samaru, Nigeria (Bulus, 1986). In Jamaica, prometryne at 1.6 kg a.i./ha applied to yellow ginger gave satisfactory control of weeds for nine weeks (Hammerton, 1974) Kasasian (1962) also used prometryne as pre-emergence treatment in ginger at rates that controlled weeds effectively. Mixtures of metolachlor plus terbutryne at 1.33 + 0.67 kg a.i./ha produced comparable potato tuber yield to the hoe-weeded check in a trial conducted at Samaru (Sambo, 1986).

Except the mixtures of metolachlor with fluometuron, ametryne and diuron, high rates of the other herbicide mixtures did not differ significantly in rhizome yield from the unweeded check, thus indicating possible detrimental effect of increasing the rate of these mixtures for more effective weed control in the crop. However, low rate of mixtures containing ametryne and diuron had significantly higher shoot weight at 16 and 20 WAP, than the unweeded check.

It was apparent that atrazine-containing mixture was not tolerated by this crop since both rates resulted in comparable yield to the unweeded check, thus indicating a depression in yield inspite of its effective control of

weeds. This effect was mainly manifested in crop vigour score at 16 and 20 WAP where both rates resulted in lower vigour score than the best treatments.

Unchecked weed growth throughout the crop life cycle resulted in 63% loss in yield compared with the best treatment.

5.3 Relationship between various Parameter, and Rhizome Yield of Ginger in the Weed Interference and Weed Control Studies at Samaru

Among the observations taken, stem dry weight, plant height and crop vigour score at 8 WAP were positively correlated with rhizome yield at harvest in the weed interference studies and negative correlation was obtained with weed cover score of broad leaved weeds and grasses at 16 WAP (Table 12).

Similarly, in Table 19 rhizome yield at harvest was significantly positively correlated with crop vigour score and plant height at 16 and 20 WAP and leaf, stem and rhizome weight at 20 WAP in the weed control experiment. Most of the vegetative growth were strongly correlated with yield at 16 and 20 WAP probably due to the fact that active vegetative growth and rhizome formation commenced at about 12 WAP, thus active transportation of photosynthates from source to sink for rhizome formation could be observed at 16 and 20 WAP. Bulus (1986) also observed that potato yield correlated positively with crop dry matter production.

Chapter 6

SUMMARY AND CONCLUSIONS

Two field experiments were conducted during the 1986 wet season at Samaru in the northern Guinea savanna ecological zone of Nigeria to study the effects of mulching practice, and period of weed interference on ginger (*Zingiber officinale* Roscoe) and evaluate pre-emergence herbicide mixtures in the crop.

In the weed interference study, a factorial combination of mulching and no-mulching with ten periods of weed interference were laid out in a randomized complete block design in three replicates. One set of the treatments consisted of plots kept weed-free initially for 4, 8, 12 and 16 weeks after planting and subsequently weed-infested until harvest, while, the other set consisted of plots kept weedy initially for 4, 8, 12 and 16 weeks after planting and subsequently weed-free until harvest. Two treatments of weed-free and weed-infestation throughout the crop life-cycle were also included as controls. Weeding was carried out by hand-pulling and with cutlass.

In the weed control study, eighteen herbicide treatments of nine metolachlor-based mixtures at two rates each were compared with one hand-weeded control at 4, 8 and 12 weeks after planting and an unweeded control. These treatments were laid out in a randomized complete block design and replicated three times.

In the weed interference trial, the use of grass mulch resulted in lower weed infestation and vigorous growth of ginger plant as reflected in the weed cover score, plant height, number of leaves, leaf, stem and shoot dry weights per plant, and rhizome dry weight at 8, 12 and 16 WAP compared with the unmulched plot. Mean dry rhizome yield on mulched plots was about 37% higher than that of the unmulched situation. Mulching also resulted in lower weed dry matter production compared with no mulching due to the effect of grass mulch which suppressed weed growth through smothering. It was apparent in this trial that weed infestation for 4WAP did not adversely affect crop growth due to initial slow growth of the crop. Maximum rhizome yield could be obtained even when allowed to be weed infested up to 12 WAP due to lack of crop injury which usually occured during weed removal. Probably the critical period of weed competition in the crop is between 12 and 16 WAP. In effect, any method which preclude the need for weed removal during the early growth stage of the crop would definitely enhance rhizome yield, as observed with herbicide treatments in the weed control experiment.

It was apparent that all the herbicide treatments consistently controlled weeds effectively both before and after one supplementary weeding. The treatments also resulted in lower weed infestation than three hand-weedings after they were supplementarily hoe-weeded. Among the herbicide treatments, mixture of metolachlor with chlobromuron, and ametryne, each at the rate of 1.0 + 1.0 kg a.i./ha, diuron at 1.0+ 0.4 kg a.i./ha resulted in significantly lower weed scores at 8, 12 and 16 WAP, weed dry matter production at 13 WAP,

higher crop vigour score at 8, 12, 16 and 20 WAP, stem and shoot weight at 16 and 20 WAP and rhizome yield compared with the unweeded check. Similarly mixtures of metolachlor plus fluometuron at 1.0 + 1.0 kg a.i./ha resulted in crop growth at 20 WAP and yield at harvest that were comparable to those of the best treatment. Inspite of the fact that the growth of the crop were not comparable to the best with mixtures of terbutryne at 1.33 + 0.67 kg a.i./ha, metribuzin at 1.0 + 0.25 kg a.i./ha and prometryne at 1.0 + 1.0 kg a.i./ha, the treatments also resulted in high rhizome yield at harvest. The best rhizome yield in the trial was obtained with metolachlor + metribuzin at 1.0 + 0.25 a kg a.i./ha. Excepting the mixtures of metolachlor with fluometuron, ametryne, and diuron higher rates of the other herbicide mixtures did not differ significantly in rhizome yield from the unweeded check, thus indicating possible detrimental effect of increasing the rates of these mixtures for more effective weed control in this crop. It was apparent that atrazine containing mixture were not tolerated by this crop since both rates appear phytotoxic with noticeable symptoms of depressed growth in crop vigour at 16 and 20 WAP compared with the best treatments.

In this trial, unchecked weed growth throughout the crop life cycle significantly depressed crop vigour, leaf, stem and shoot dry weight and numbers of leave per plant. It also reduced rhizome yield by 50.3% and 63.0% compared with the appropriate best treatments in the weed interference and chemical weed control trials, respectively.

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Appendix 1 Means squares from analysis of variance for weed cover score (grasses) as affected by period of weed interference at Samaru in 1986 wet season.

Source of Variation	Df	Weed Cover Score (Grasses) at 8 WAP	12 WAP	16 WAP
Replication	1	0.65	12.46	18.65
Mulch	1	71.06**	10.66	4.81
Treatment	9	17.47**	53.22**	29.36**
Treat x Mulch	9	8.89**	3.46	7.23
Residuals	38	2.12	5.61	6.23
Total	59			

Appendix 2 Mean squares from analysis of variance for weed cover score (broadleaves) and weed dry matter production as affected by period of weed interference at Samaru in 1986 wet season.

Source of Variation	Df	Weed Cover score (broad-leaves) at: 8 WAP	12 WAP	16 WAP	Weed dry matter production
Replication	2	3.23	2.96	71.54	4088177
Mulch	1	3.75**	0.60	0.05	19197505**
Treatment	9	4.35**	4.69**	3.13	2325351*
Treatment x Mulch	9	0.12	0.53	4.66	964501
Residuals	38	0.65	1.05	3.05	1051839.8
Total	59				

* F value significant at 5% level of probability

** F value significant at 1% level of probability

WAP = weeks after planting

Appendix 3 Mean squares from analysis of variance for leaves dry matter production as affected by period of weed interference at Samaru in 1986 wet season.

Sources of variation	Df	Leaves dry weight (g) at: 8 WAP	12 WAP	16 WAP	Number of leaves at: 8WAP	12WAP	16WAP
Replication	2	0.75	0.20	1.45	496.95	76.60	321.3
Mulch	1	4.76**	0.65	9.76**	117.60	1083.80**	1938.0**
Treatment	9	0.26	1.48	5.54**	51.04	111.80	898.4**
Treatment x Mulch	9	0.37	1.16	1.26	57.90	224.70	419.3
Residuals	38	0.19	0.70	2.16	72.46	110.13	227.5
Total	59						

Appendix 4 Mean squares from analysis of variance for stem and shoot dry matter production as affected by period of weed interference at Samaru in 1986 wet season.

Source of variation	Df	Stem dry weight (g) at 8WAP	12WAP	16WAP	Shoot dry weight(g)at 8WAP	12WAP	16WAP
Replication	2	0.42	0.10	9.01	2.29	0.21	17.70
Mulch	1	1.59	1.15	14.65**	11.89	3.55	48.33
Treatment	9	0.19*	0.77	5.11	0.83	3.93	21.15
Treatment x Mulch	9	0.07	0.59	1.83	0.71	3.09	4.44
Residuals	38	0.07	0.42	2.54	0.41	1.90	7.39
Total	59						

* F values significant at 5% level of probability

** F values significant at 1% level of probability

WAP = Weeks after planting.

Appendix 5 Mean squares from analysis of variance for crop vigour scores as affected by period of weed interference at Samaru in 1986 wet season.

Source of variation	Df	Crop vigour score at 8WAP	12 WAP	16 WAP
Replication	2	11.71	2.06	10.61
Mulch	1	101.40**	21.60*	10.41**
Treatment	9	3.43	7.85**	22.76**
Treatment x Mulch	9	0.51	1.23	1.56
Residual	38	1.80	1.45	1.65
Total	59			

Appendix 6 Mean squares from analysis of variance for rhizome dry matter production and rhizome yield at harvest as affected by period of weed interference at Samaru in 1986 wet season.

Source of variation	Df	Rhizome dry matter production at: 8 WAP	12 WAP	16 WAP	Rhizome yield at harvest (kg/ha)
Replication	2	0.27	0.21	1.75	0.08
Mulch	1	0.95**	4.41**	56.49**	0.22**
Treatment	9	0.16**	0.32	11.28**	0.05
Treatment x Mulch	9	0.04	1.08	3.07	0.03
Residual	38	0.05	0.08	3.66	0.03
Total	59				

* F value significant at 5% level of probability

** F values significant at 1% level of probability

WAP = Weeks after planting

Appendix 7 Mean squares from analysis of variance for plant height of ginger as affected by period of weed interference at Samaru in 1986 wet season.

Source of variation	Df	Plant height per plant (cm) at 8WAP	12WAP	16 WAP
Replication	2	709.8	448.1	2022
Mulch	1	3611.5**	20694.4**	33182**
Treatment	9	112.7	718.2	8446*
Treatment x Mulch	9	136.7	1399.3	2015
Residuals	38	155.87	647.46	2200.2
Total	59			

Appendix 8 Mean squares from analysis of variance for crop vigour score as affected by weed control treatments at Samaru in 1986 wet season

Source of variation	Df	Crop Vigour Score at 8 WAP	12 WAP	16 WAP	20 WAP
Replication	2	4.32	2.60	17.12	0.60
Treatment	19	3.09**	1.28*	2.65*	1.87**
Residual	38	0.84	0.65	1.33	0.60
Total	59				

* F value significant at 5% level of probability

** F value significant at 1% level of probability

WAP = Weeks after planting.

Appendix 9 Mean squares from analysis of variance for stem dry matter production as affected by weed control treatments at Samaru in 1986 wet season.

Source of variation	Df	Stem dry matter production/plant (g) at 8WAP	12WAP	16WAP	20 WAP
Replication	2	2.23×10^{-3}	1.37	0.84	2.83
Treatment	19	2.45×10^{-2}	0.98	2.86***	5.50*
Residual	38	0.018	0.701	0.97	2.56
Total	59				

Appendix 10 Mean squares from analysis of variance for shoot dry matter production as affected by weed control treatments at Samaru in 1986 wet season.

Source of variation	Df	Shoot dry matter production/plant(g) at: 8WAP	12WAP	16WAP	20WAP
Replication	2	0.41	7.08	10.51	4.12
Treatment	19	0.44	4.49	15.28**	11.24*
Residual	38	0.27	2.88	5.84	4.81
Total	59				

* F value significant at 5% level of probability

** F value significant at 1% level of probability

WAP = weeks after planting

Appendix 11 Mean squares from analysis of variance for numbers of leaves as affected by weed control treatments at Samaru in 1986 wet season.

Source of variation	Df	Numbers of leaves/plant at: 8WAP	12WAP	16WAP	20WAP
Replication	2	14.52	59.62	258.22	529.62
Treatment	19	55.62**	255.22	378.86	414.40*
Residual	38	24.32	145.62	302.22	218.48
Total	59				

Appendix 12 Mean squares from analysis of variance for leaves dry matter production as affected by weed control treatments at Samaru in 1986 wet season.

Source of variation	Df	Leaves dry matter production/plant (g) at 8WAP	12WAP	16WAP	20WAP
Replication	2	0.35	2.25	5.41	0.32
Treatment	19	0.32	2.00	5.38*	1.82
Residual	38	0.18	1.35	2.76	0.89
Total19	59				

* F value significant at 5% level of probability

** F value significant at 1% level of probability

WAP = Weeks after planting

Appendix 13 Mean squares from analysis of variance for plant height as affected by weed control treatments at Samaru in 1986 wet season.

Source of variation	Df	Plant height/plant (cm) at 8WAP	12WAP	16WAP	20WAP
Replication	2	15.09	3.46	1424.78	2379.66
Treatment	19	34.79	895.66	2990.98	3970.37*
Residual	38	35.63	894.42	1929.72	2037.40
Total	59				

Appendix 14 Mean squares from analysis of variance for rhizome dry matter production and yield as affected by weed control treatments at Samaru in 1986 wet season.

Source of variation	Df	Rhizome dry matter production (g) at 8WAP	12WAP	16WAP	20WAP	Rhizome yield (kg/ha) at harvest
Replication	2	4.18×10^{-3}	1.69	21.18	0.34	0.54
Treatment	19	2.29×10^{-2}	1.37	14.11*	12.28**	0.15*
Residual	38	0.017	0.85	6.96	4.54	0.065
Total	59					

* F value significant at 5% level of probability

**F value significant at 1% level of probability

WAP = Weeks after planting

Appendix 15 Mean squares from analysis of variance for weed cover score and weed dry matter production as affected by weed control treatments at Samaru in 1986 wet season.

Source of variation	Df	Weed Cover Score at: 8WAP	12WAP	16WAP	Weed dry matter production at 13WAP (kg/ha)
Replication	2	0.65	7.92×10^{-2}	0.24	5182.06
Treatment	19	1.71**	8.76**	7.78*	7016.88**
Residual	38	0.37	2.65	0.176	2009.66
Total	59				

* F value significant at 5% level of probability

** F value significant at 1% level of probability

WAP = Weeks after planting

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Ahmadu Bello University, Samaru Zaria	1977	1981	B.Sc (Agric)

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