EFFECT OF CHEMICAL WEED CONTROL AND INTRA-ROW SPACING ON THE GROWTH AND YIELD OF POPCORN (*Zea mays L. Var. everta)* IN THE NORTHERN GUINEA SAVANNA OF NIGERIA

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 before in any previous application for a higher degree.

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The above declaration is confirmed.

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CERTIFICATION

This thesis entitled "EFFECT OF CHEMICAL WEED CONTROL AND INTRA-ROW SPACING ON THE GROWTH AND YIELD OF POPCORN (*Zea mays L. Var. everta*) IN THE NORTHERN GUINEA SAVANNA OF NIGERIA" meets the regulations governing the degree of master of Science of Ahmadu Bellow University, Zaria, and is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

This work is dedicated to the Author of Success who is JESUS for His divine protection and promise for me throughout the course of this study.

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– A. K. Gana (1997).

ABSTRACT

Field trials were conducted at the Institute for Agricultural Research Farm, Samaru (11° 11 N.07° 38'E) in the northern Guinea Savanna Ecological Zone of Nigeria to study the effect of chemical weed control and intra-row spacing on the growth and yield of popcorn (*Zea. mays L. Var. everta)* in 1995 and 1996 wet seasons.

The treatments tested consisted of eight pre-mergence herbicides supplemented with one hoe-weeding at 7 weeks after sowing (WAS). These were compared with three hoe-weedings at 3, 6 and 9 WAS and a weedy check. These were tested under spacings of 15, 30 and 45cm. The treatments were laid out in a split plot design with three replications.

In both years of experimentation, the use of herbicides (except metolachlor + metobromuron at 1.0 + 1.0kg a.i./ha) and hoe-weeding consistently resulted in significantly lower weed cover score, weed dry matter production and higher popcorn grain yield than the weedy check. However, the most promising herbicide treatments were pro-emergence app]ication of metolachlor at 2.0 kg a. i./ha and its combination with atrazine at 1.0 + 1.0 kg a.i./ha and 1.25 + 1.25 kg a.i./ha each followed by supplementary hoe-weeding at 7 WAS. These treatments resulted in effective weed control and higher popcorn grain yields than other herbicide treatments.

In both years, crop planted at intra-row spacing of 15cm on 75 cm ridges resulted in significantly lower weed cover score than those of 30 and 45cm spacings at 6 and 9 WAS. Crop vigour and number of leaves per plant at 6 WAS, plant height and leaf area index at 6 and 9 WAS, total dry matter production per plant at harvest, cob weight, number of cobs per plot, cob yield and grain yield (kg/ha) in both years also increased with decrease in intra-row spacing.

The Interaction between weed control treatments and intra-row spacing on weed cover score at 9 WAS, weed dry matter production, cob yield and grain yield in both years were significant. In this, interaction mixture of metolachlor plus atrazine at 1.0 + 1.0 kg a.i./ha applied pre-emergonce under the intra-row spacing of 30cm combined effective weed control with high pop-corn grain yield comparable to the hoe-weeded control. Unrestricted weed growth throughout the crop life cycle resulted in 83.8 and 72.9% reduction in popcorn grain yield compared to the maximum obtained in each trial in 1995 and 1996 wet. seasons, respectLvely.

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Chapter 1

INTRODUCTION

1.1 Popcorn Production and Economic Importance

Popcorn (*Zea mays* var. everta) is an important cereal crop grown in different parts of the world with an annual production of about 253,329.8 metric tons over an area of about 253,329 hectares of land (Judyenheimer, 1976). The major commercial production centres of this crop are located primarily in nine States of America including Iowa, Indiana, Nebraska, Illinois, Ohio, Kansas, Kentucky, Missouri and Michigan where it is grown on contract basis (Obajimi and Oyekan, 1985). Its spread to other parts of the world including Nigeria was probably due to American travellers and /or explorers.

Popcorn is fast becoming a very important domestic and industrial crop in Nigerian savanna particularly in places like Kaduna (Zaria), Kwara and Plateau States where it is often referred to as "Money maker". Obajimi and Oyekan (1985) reported that popcorn contains about 67.78 percent carbohydrates, 8.34 percent protein, and 3.46 percent fat. Freshly popped corn (guguru) alone or mixed with groundnut is a popular snack in many parks, markets, homes and even social functions. It is used for porridge, and also for confectioneries. The by-products of corn industries also include gluten, feed, oil cake, oil meal and corn sugar molasses used for livestock feed (Judyenheimer, 1976).

1.2 Climatic and Agronomic Requirements.

In Nigeria, corn in general, has been adapted to latitude 6^0N in the rain forest Zone and 12^0N in deep savanna Zones of the North. The crop does well on a fertile soil rich in organic matter. Where the soil is less fertile, the plant normally respond to major plant nutrients such as *nitrogen, phosphorus and potassium* (Samuel, 1970). It requires a rainfall of 76.2cm and is generally planted with early rainfall to enable the crop to benefit from early release of nitrates in the soil (Joseph, 1962). Corn requires a pH range of 5.0 to 8.0 (Judyenheimer, 1976). The crop is planted at intra- row spacing of 20-40cm and inter-row of 60 - 91.44cm. Single superphosphate is applied at the rate of 60kg/ha for the Northern States and it is applied before planting, while nitrogen is applied at the rate of 120kg N/ha at two split doses (at three and six weeks after planting) (Eldredge and Thomas, 1972).

Crop rotation is important for popcorn as a means of reducing pests and disease incidence and also as part of weed management strategy (Sobulo et al., 1975). As much as possible in rotation, popcorn should not follow field corn because volunteer field corn may arise in the field resulting in dent ears in the popcorn thereby affecting popping quality (Eldredge and Thomas, 1972)

1.3 Limitation to Popcorn Production in Nigeria

Although popcorn has great potential both as a domestic and commercial crop in Nigeria, its yield on farmer's field is often very low (hardly up to 1000 kg/ha). Sobulo et al. (1975) observed that inadequate knowledge of some of the necessary cultural practices such as adequate spacing, nutrient requirements, pests and diseases as well as weed management problems might have contributed to low popcorn yield obtained on farmer's field in Nigeria. According to Agboola (1969) the rainfall pattern, popcorn variety, low soil fertility, land tenure system and lack of fertilizer could also be responsible for poor yield of popcorn in Nigeria.

1.4 Weeds and their Control in Popcorn

Weed interference constitute a serious bottle-neck in the production of popcorn. Popcorn is very sensitive to weed competition during its early stages of growth because it does not completely cover the ground until two to three months after sowing (Akobundu, 1977). During this period, weeds compete with the crop for nutrients, water, light and space and when these growth factors fall below that of the crop requirement, yield may correspondingly decline (Akobundu, 1987).

Apart from their direct effect on crop growth and yield, weed also cause great losses to popcorn by hosting harmful insects which feed, live and multiply on weed and the crop. Yield reduction ranging from 69 to 87% due to unrestricted weed growth in corn has been reported by Lagoke (1978).

Traditionally in Nigeria, weed is controlled by the use of simple hand tools particularly the hand-hoe. This method is very inadequate as it is expensive, labour intensive, strenuous and effective in small scale production only. It also causes mechanical damage to the roots of the growing crop and also results in stand losses if the implements are not carefully used (Harika and Bains, 1985). Therefore, this method is not desirable at the advance growth stage when the roots of the crop have spread out. In addition to high cost, labour availability is uncertain especially at the peak period of cropping season thus making precission of weeding difficult to attain (Lagoke et al., 1981). Many rhizomatous grasses such as Imperata cylindrica and certain noxious weeds including Portulaca species are difficult to control by hand weeding because of their potential ability to reproduce from fragmented stem left inside soil (Akobundu, 1987).

Herbicides have been reported to be more profitable than hoe-weeding in the production of various crops in Nigeria (Lagoke et al., 1987, Ogungbile et al., 1982). Selective chemical weed control in corn had been reported by (Akobundu,1987). The herbicide treatments, however were not consistent in giving season long weed control and often required supplementary weed control which further increased the cost of production.

A number of studies (Weber and Staniform, 1957, Haisel and Harper, 1973) have shown that crop densities will decrease the magnitude of competition that crop will suffer from weeds. Weber and Staniform (1957) found that soybean (Glycine max (L) Merr) yield losses from weed competition were dependent largely on the stands of soybean present.

Street et al. (1981) reported decreased weed dry matter production with increased cotton density. It is expected that corn planted in closer spacing should not only yield higher but give effective weed suppression due to early canopy closure particularly when moderately persistent herbicides are used.

Under such condition the need for post-emergence herbicide application or supplementary hoe-weeding may not be necessary.

1.5 Objectives of the study

There is need for adequate information on cultural practices for popcorn production that the existing and prospective growers in Nigeria could use in order to boost production and obtain optimize profit. This study was therefore undertaken with the following objectives:-

i. To determine optimum intra-row spacing for popcorn production.

ii. To evaluate the effects of intra-row spacing on the performance of various herbicides for weed management in pop-corn.

Chapter 2

LITERATURE REVIEW

2.1 Losses due to weed competition

Corn like many other cereals is very sensitive to competition from weeds because it does not completely cover the ground until two to three months after sowing (Akobundu 1987). Earlier workers agreed that corn is most sensitive to weed competition during the first month after sowing. Weed growth before 10 days or after 30 to 40 days appears to have less effect (Okigbo, 965).

In India Mani et al., (1969) reported between 30 and 70% loss in grain yield due to weed infestation throughout the crop growth. Ciorlaus (1979) reported grain yields of 1.54t/ha without weed control and 3.62 and 3.87t/ha when kept free of weeds up to the 4 to 5 leaf and knee high stages, respectively.

In Rhodesia, Labrada (1979) reported that season-long overall infestation of Cyprus esculentus (L.) established before sowing corn reduced grain yield by 17.2%.

In South Africa, Pivar et al. (1975) reported that yield reduction in corn was proportional to weed dry matter production, but yield advantage of weed-free crops increased as fertilizer application increased.

Ciorlaus (1979) and Remison (1979) reported yield losses of 54 and 50% in the forest zone of Ghana.

In Nigeria, losses of up to 50 - 87% have been attributed to unchecked weeds growth throughout the crop cycle (Lagoke, 1978).

Agboola (1969) also reported that by not weeding early corn, grain yields was reduce by about 60% compare to that obtained from weeded plots. Two weedings (3 and 6 WAS) seem desirable for high yield of early corn. Cutlassing or hoeing early corn field resulted in similar grain yield.

In Samaru, Nigeria, uncontrolled weeds resulted in 87% loss in corn grain yields (Lagoke et al., 1986). Similarly, Yahaya (1983) reported that unchecked weed growth caused about 76% reduction in corn yield when this crop was intercropped with okra.

2.2 Chemical weed control in corn

Economic losses due to weed competition are now recognized as a major bottle neck in crop production. In many developing countries, half of the effort devoted to crop production is spent on weed control (Kasassian, 1971). Improving the growing conditions for crops through the use of fertilizers and irrigation often intensifies the weed problem since they too respond to the improved conditions. The high cost of labour for hoe-weeding and their unavailability at the time of need in corn production as well as the difficulty in weeding and the injury that may occur during the operation has further generated the desire for the use of herbicides by the producer (Moreland, 1967).

The use of herbicides is a recent crop production technology in Nigeria which can be employed to maximum advantage for corn production. Metolachlor, atrazine, terbutryne and metobromuron are some of the herbicides that have been found suitable for selective weed control in corn when applied pre-emergence to weeds (Akobundu, 1987, Lagoke *et al*., 1981).

2.2.1 **Amides**

All the members of the group are derived from reactions in which the hydroxyl portion of a carboxyl acid group of an acid has been replaced by an amino group ($-NH_2$). Amide herbicides take the name of acid represented by the R group. Thus depending on the acid group, the herbicide could be an acetamide, propinamide, benzamide etc. If one of the hydrogens of the ammonium group is replaced by a phenoxyl group, the resultant herbicide is known as an analide (Akobundu, 1987).

A major subdivision of the amide class of herbicides is the chloroacetamides. They have a monochlorinated methyl ($CL-CH_2$) in the R-1 position. Members include alachlor, (2-chloro-2, 6-diethyl-N-(methoxymethyl) acetamide) diphennamid (N, N-dimethyl-2, 2-diphenyl acetamide), and metolachlor (2-chloro-N-(2-ethyl-6 methylphenyl)-N-(2-methoxyl 1-ethyl acetamide. The chemical structure of the remaining amide herbicides have little in common except for the central amide structure although most have a hydrogen substitution in the R-position (Akobundu, 1987).

There is indication that an alphachlorine must be present and that the two hydrogen atoms attached to nitrogen in the acetamide structure must be replaced in order to obtain herbicidal activity (Hamm, 1974).

They are mostly used as selective herbicides in vegetable and field crops for the control of grasses although they have activities on broad leaved weeds and sedges (Ashton and Crafts, 1981).

Chloroacetamides are readily absorbed by plants primarily by seeds and first node of germinating seedling and appear to be translocated in the apoplast but symplastic movement may also occur. These herbicides are readily taken up by susceptible and resistant species (Akobundu, 1987).

The degree of susceptibility of various weeds to chloroacetamide required to initiate the metabolism of these chemicals. Chloroacetamide influence nitrogen metabolism due to the influences 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 soil-applied amides inhibit root enlogation (Akobundu, 1987).

2.2.1.1 Metolachlor

Metolachlor (2-chloro-N-(2-ethyl-6 methyl Phenyl-N-(2-methoxyl-ethyl) acetamide is used pre-emergence for the selective control of weeds in field crops like maize, cowpea, soybean, cotton, yam and groundnut (Akobundu, 1987). It is white to tan odorless liquid normally formulated as emulsifiable concentrate either alone or in mixture with other less soluble chemicals (wettable powder or flowable) to improve the spectrum of weed control (Klingman and Ashton, 1975). It has a solubility of 530 ppm in water at 20^{0}C and acute oral LD50 of 2,535mg/kg. Soil moisture is necessary for its absorption hence adequate rain fall or irrigation especially when not incorporated (Crafts,1975). Like other chloroacetamides, is a growth inhibitor especially that of root elongation (Akobundu, 1987). It has also been observed to cause some significant reduction in plant height of some corn hybrids though yields were not affected (Khan and Saghir 1987).

According to Swain (1976) in Australia, metolachlor at 1.5kg a.i./ha gave good pre-emergence control of Echinochloa crus-galli (L.) P. Beauv, Setaria species Digitaria singularis (L) (Retz.) Koch. but the addition of atrazine at 1.2kg a.i./ha was required for adequate control of broadleaved weeds. Ciorlaus (1979) reported that metolachlor at 1.0 kg. a.i./ha incorporated before sowing corn and followed with post-emergence application of atrazine controlled weeds better than three weedings and resulted in a yield increase of 6% above hoe-weedings. Application of metolachlor at 1.5 kg a.i./ha pre-emergence gave a selective control of grasses with corn grain yield comparable to three hoe-weedings (Klingman and Ashton, 1975).

Broader spectrum of weed control have been reported by many workers when metolachlor was mixed with atrazine (Spanil, 1983). Better weed control was obtained up to six weeks when metolachlor was mixed with atrazine than when used alone (Akobundu, 1987). Ciorlaus (1979) recommended application of metolachlor plus atrazine for weed control which are very competitive during 6 weeks after sowing.

Metolachlor was also noticed to be more compatible with atrazine than other herbicides in their mixtures (Ogo et al., 1988). In Ibadan, Nigeria, Akobundu (1977) reported that broadest spectrum weed control and high grain yield were obtained with a mixture of metolachlor plus atrazine at 1.25 + 1.25 kg a.i./ha applied pre-emergence. When metolachlor is used alone, it is said to be effective in controlling annual grasses and yellownut sedges (Hasmmerton, 1972). Adejonwo (1982) reported that mixture of metolachlor with atrazine at 1.33 + 0.67 kg a.i./ha applied pre-emergence gave persistent weed control up to 9 weeks after sowing in corn. In Samaru, Nigeria,Yahaya (1983) reported that mixture of metolachlor with metobromuron at 1.0 + 0.5 kg a.i./ha and followed by supplementary hoe-weeding at 6 weeks after sowing combined effective weed control till 10 weeks after sowing with high corn grain yield comparable to the hoe weeded control.

2.2.2 **Substituted urea**

The substituted urea herbicides are soil-residual in action and are absorbed by roots of plants in nutrients and water into the xylem systems through which they are transported to the leaves. The main site of action of this group of herbicides is the interference with photolysis of water during photosynthesis and nitrogen metabolism in susceptible plants ?(Ashton and Crafts, 1981).

2.2.2.1 **Metobromuron**

Metobromuron (2-4(4- bromophenol)-4-methoxy-1-methyl-urea) is formulated singly as patoran, a wettable powder. It is also commonly formulated in mixture with metolachlor as "Galex" an emulsifiable concentrate. It has a water solubility of 330 ppm and an acute oral LD50 of 300 mg/kg for rate (Klingman and Ashton, 1975). Metobromuron is mainly used as pre-emergence or in mixture with other herbicides for season-long weed control of may annual grasses and certain broadleaved weeds in crops like maize, potato, cowpea, sorghum, ginger, pepper and tomato (Ashton, 1978; Labrada, 1979; Lagoke et al., 1981; Adigun, 1984). Metobronmuron plus metolachlor was reported to give the best weed control best weed control in corn, groundnut and cotton (Chandra and Singh, 1982). Metobromuron at 2-6kg a.i./ha gave a good control of grass weeds and evaluated to be best pre-emergence treatment of its 30 days for control of weeds in corn (Uriate and Garcial, 1971). Spasic et al. (1983) reported that metobromuron controls the following weeds:- Amaranthus retroflexus L., Ageratum convzoides L., Digitaria singularis L., Klousine indica L. According to them metobromuron applied pre-emergence at 3kg a.i./ha to Phaseolus vulgaris gave good weed control. Lyuvenor (1968) discovered that even when metobromuron was applied at twice the normal rate to sandy loam and humic loam sown to corn it did not impair germination. Metobromuron with metolachlor at 3 + 3 kg a.i./ha applied pre-emergence to corn interplanted with phaseolus beans gave a good weed control of many annual grasses and broadleaved weeds (Akobundu, 1977).

In Samaru, Nigeria, Yahaya (1983) reported that mixture of metolachlor with metobromuron at 1.0 + 0.5 kg a.i./ha followed by supplementary hoe-weeding at 6 weeks after sowing combined effective weed control with high corn grain yield comparable to the hoe-weeded control.

2.2.3 **Triazines**

Chemically, the triazines are heterocyclic nitrogen derivatives. The heterocyclic ring is composed of three nitrogen and three carbon atoms (Klingman and Ashton, 1975). Triazine herbicides are symmetrical or assymetrical depending on whether the three nitrogen atoms in the heterocyclic benzene ring of their chemical structure are symmetrically arranged or lack that symmetry. The S-triazines are divided into three sub-groups that consist of the chloro-diamino, methyldiamino-and methylthiodiamino-S-triazines and these have common names that end with - zine, -tone and -tryne, respectively (Akobundu, 1987). While uptake of all herbicides in this groups is mainly through plant roots, foliage uptake occurs with the more soluble methythio-diamino-S-triazines such as prometryne and terbutryne (Klingman and Ashton, 1975). Absorption of triazine herbicides is usually by roots and translocation takes place through the apoplastic system to the shoots of plant (Akobundu, 1987).

Triazine herbicides are well known inhibitors of photosynthesis in plants. The sites of action is the chloroplast and the mechanism of this inhibition involves blocking of the Hill reaction associated with photosynthesis II (Moreland, 1967).

The triazines are the most widely used herbicides in food crop production in the tropics (Akobundu, 1987). The usual 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 cause increase in chlorophyll content of the leaves while high concentrations cause chlorosis and necrosis. Selectivity of these herbicides is mainly due to differential rate of metabolism in parts of the crop plants (Moreland, 1967). Most of the crop plants which tolerate the triazine herbicides rapidly detoxify the triazines by modification of the active molecule to inactive forms. This process occurs by hydroxylation dechlorination, dimethoxylation depending on the parent substitution. Dealkylation of the alkyl side chain also occurs (Akobundu, 1987, Moreland, 1967).

2.2.3.1 Atrazine

Atrazine(2-chloro-4(ethylamino)-6-(Isopropylamino-S-triazine) is a white crystalline solid with a water solubility of 33 ppm at 20^{0}C and acute oral LD50 of 3.080 mg/kg body weight (Ashton and Craft, 1975). Atrazine is widely used selectivity for the control of broadleaved weeds and grasses in corn, sorghum, pineapples and sugarcane (Akobundu, 1987). It is used as pre-planting, pre-emergence and early post-emergence weed control in corn. When applied pre-emergence at 1.0 kg a.i./ha It resulted in high grain yields equivalent to those from hand weeded control plots (Akobundu, 1977). The yields were further increased when the herbicide was combined with metolachlor at 1.0kg a.i./ha (Harika and Bains, 1985). Hasmmerton,(1972) reported very effective control of grasses and sedges except Cyprus rotundus (L.) when atrizine at 3.3 kg a.i./ha was applied as pre-emergence to corn grown on clay loam soil.

Ciorlaus (1979) after a four year trial reported that atrazine at 2.8 and 3.6 kg a.i./ha applied as pre-emergence to corn effectively controlled grasses and broadleaved weeds. Khan and Saghir (1987) after their respective three years trials obtained the most consistent wide spectrum weed control with atrazine.

Very good weed control especially of Cyprus species and other sedges have been reported by some workers with atrazine alone and its mixture with metolachlor. Debrovodsky (1980) reported that a mixture of atrazine plus metolachlor at 1.20 + 1.20 kg a.i./ha applied pre-emergence effectively controlled most annual grasses and broad-leaved weeds especially on sites with high soil moisture content. Ogo et al. (1988) reported weed control in corn cultivar FARZ 27 comparable to that of weed free period plots with atrazine plus metolachlor at 1.25 + 1.25 kg a.i./ha and better control than either pre-emergence atrazine at 3.0 kg a.i/ha and two hoe-weedings. However all the treatments did not differ in corn grain yields (2.7-3t/ha). Pre-emergence application of atrazine plus metobromuron at 2.2 + 2.2 kg a.i./ha when compared with hand weeded controls on the yield of corn indicated that the lowest grain yield was recorded from unweeded control plots. Handweeding produced the highest grain yield although this was not significantly different from treatments of atrazine, diuron and cynazine (Olunuga, 1976).

In Nigeria, atrazine at 2kg a.i./ha gave better corn yield as compared with 1.0 kg a.i./ha. However the yield obtained with 2.0 kg a.i./ha was not always comparable to two hoe weedings (Hasmmerton, 1972). Similarly season long weed control was obtained with atrazine plus metolachlor at 2.0 + 2.0 kg a.i./ha (Dobrovodisky, 1980).

2.2.3.2 **Terbutryne**

Terbutryne 2-(tert-butylamino)-4-(ethylamino)-6-(methyl-thio)-S- trazine is a white crystaline solid with a solubility of 58 ppm formulated as wettable powder and also as flowable. It is a traizine being used as selective pre-emergence herbicide for the control of annual braod-leaved weeds and grasses in barley, wheat, sorghum, potatoes, beans, groundnut and non-crop areas (Akobundu, 1987). It is a systemic herbicide which is absorbed by roots and translocated via the apoplastic system to the roots (Akobundu, 1987). The basis for its selectivity resides in its rapid and slow degradation in resistant and susceptible crops respectively (Ashton and Crafts, 1981). The basis for its selectivity resides in its rapid and slow degradation in resistant and susceptible crops respectively

(Ashton and Crafts, 1981) Terbutryne mainly inhibits photosynthesis by preventing the transfer of electron from water to the quinones. The influence of light in this process has been found to be indispensable for the development of morphological and physiological symptom of toxicity (Ashton and Crafts, 1981). Its physiological effect on plants is similar to those of ametryne and promatryne at 3.0 kg a.i./ha. At 3kg a.i./ha it was effective in weed control but caused slight growth in inhibition of corn (Bandel, 1969). Bansa and Sharma (1989) reported that at 4.0 - 6- kg a.i./ha of terbutryne gave a good control of several broad leaved weeds and annual grasses including Setaria species. Terbutryne at 1 to 20 ppm did not affect seed germination of corn though had different effects on seedling growth. Seedling growth increased with increasing terbutryne concentration with both pre- and post-emergence on plants. However, It was phytotoxic to Echinochloa colonum (L.) Seedling growth and lethal at concentration of 20 ppm (Bansa and Sharma, 1989). Igran combi, is a commercial formulation of terbutryne plus metolachlor in 1:1 ratio. It is found to delay the appearance of broad leaved weeds in groundnut which helped in improving yield (Choudhary, 1981). Metolachlor plus terbutryne at 1.5 kg a.i./ha delayed the appearance of broad leaved as compared to metolachlor alone, only effective on grasses when used at comparable ratio (Choudhary, 1981). Swain (1978) reported that weed cover with metolachlor plus terbutryne at 1.4 + 1.4 kg a.i./ha at 45 days after treatment application was 30% as compared to

37% without weeding.

In Nigeria, Lagoke (1978) reported that metolachlor plus terbytryne at 1.0 + 0.5 kg a.i./ha applied pre-emergence controlled weeds better than metolachlor alone in corn. Lagoke et al. (1986) also at Samaru, Nigeria, reported that metolachlor plus terbutryne at 2.0 + 1.0 kg a.i./ha applied pre-emergence gave effective weed control within ground nut with pod yield comparable to hoe-weeded control and significantly high than the untreated control.

2.3.1 **Effect of intra-row spacing on weed control in corn**

Studies have shown that weed control can be improved and crop yields increased by reducing row spacing (Burnside and Colville, 1964, Stickler and Anderson, 1964).

Samuel (1970) reported that close spacing captures sunlight more effectively and utilizes soil moisture better as long as soil surface is moist but in drought periods corn in narrow spacing suffers. According to him, heavy planting rate helps in weed control indicating that smaller intra-row spacings generate earlier canopy shading within rows with consequent suppression of weed growth.

Haisel and Harper (1973) proposed that shading of weed by the quickly formed canopy of corn planted in narrow rows accounted for more effective weed control than in wide row.

Wax and Pendleton (1968) noted an increase in soybean of 10, 18 and 20% for 76, 51, and 25cm rows when compared to 102cm rows. They noted that broadleaved weeds unaffected by trifluralin made sufficient growth to cause yield reduction in wide rows but not in narrow rows.

Peter et al. (1965) observed that when herbicides were used soybean in 50 and 60cm rows usually needed no more than one cultivation while those in 80 and 100cm rows needed at least one cultivation for good weed control and high yields. Soybean in narrow rows always equalled and sometimes produced higher yields than those in wide rows. They also reported that soybean covered the ground more rapidly in narrow rows than in wide rows so that when herbicides suppressed early weed, growth less weeds were produced in closer spacings than wider spacings.

Gascho and Shih (1978) also reported that sugarcane yields and weed control increased as row spacing decreased. It was further observed that lower rates of diuron were required for comparable weed control as row spacing decreased.

2.3.2 Effect of Intra-row Spacing on Growth and Yield of Corn

The effect of plant spacing on the growth and yield of crops is of great importance (Haisel and Harper,1973).

In Iowa, United States of America many popcorn grower plant four seeds every 71.12 or 73.66cm in rows of 101.6cm apart. But experiments have shown that on fertile soil and in a year with normal rainfall, one kernel can be planted every 17.78 - 20.23cm (Eldredge and Thomas, 1972).

Shafshak et al. (1984) got the highest grain yield of 4000kg./ha from the closest plant spacing of 15cm. Filho et al. (1988) reported that high plant population in corn led to the development of stalk lodging because of steady decrease in stalk diameter with increasing population. They also observed that growing popcorn at 80,000 - 24,000 plants per hectare led to decrease in 1000 seed weight from 135 to 80 gram and one ear per plant. Plant density up to 74,000 per hectare produced leaf area index as high as 1.8 to 4.9 depending on the hybrid, soil fertility and season

Hayes and Sayre, (1956) reported that popcorn grown at intra-row spacings ranging from 21 to 28cm resulted in decreased grain weight per ear when compared with 35cm intra-row spacing. However, Halsel and Harper (1973) reported that the largest weight per ear was between 22 and 40cm compared with 12 and 15cm intra-row spacing.

Shafshak et al. (1984) planted corn at 70cm and 30cm within rows and got yield of 140 and 148 g/ear. However, when they planted one plant per hill at 15 and 20, 25 and 30 days after sowing, the yield increased to 188 and 211 g/ear.

From the foregoing, it can be deduced that optimum and maximum yield could be attained with intra-row spacing ranging from 15 and 22cm.

Chapter 3

MATERIALS AND METHODS

3.1 Experimental Sites

Field trials were carried out to study the effect of chemical weed control and intra-row spacing in pop corn during the rainy seasons of 1995 and 1996 at the Institute for Agricultural Research Farm, Samaru (11^0 $11'$N; 07^0 $38'$E; 686m above sea level) in the Northern Guinea Savanna ecological zone of Nigeria. The soils of the experimental sites were deep freely-drained sandy loam with low organic matter content. Details of the physico-chemical characteristics of the soils, rainfall distribution, temperature and relative humidity recorded during the periods of experimentation are presented in Tables 1, 2 and 3 respectively. The common weed species observed at the experimental sites are grasses, broad leaved weeds and sedges as indicated in table 4.

3.2 Treatments, Experimental Design and Plot size

The treatments tested consisted of three intra-row spacings 15, 30 and 45cm, and eight pre-emergence herbicdes supplemented with hoe-weeeding at 7 WAS were compared with hoe-weeded control and a weedy check in a factorial arrangement laid out in a split plot design replicated three times. The main plots were the weed control treatments while the sub plots were the intra-row

Table 1: Physico-chemical characteristics of soil taken from experimental sites

Soil Properties 0-15cm depth	Samaru	
	1995	1996
<u>Physical properties</u>		
Sand (%)	59.5	56.0
Silt (%)	34.0	36.0
Clay (%)	6.0	8.0
Textural class	Sandyloam	Sandyloam
<u>Chemical properties</u>		
pH in water	5.0	5.20
pH in 0.01CaCl$_2$	4.9	4.00
Organic carbon (%)	0.30	0.52
Total Nitrogen (%)	0.033	0.170
Available P$_{(ppm)}$	8.37	3.50
<u>Exchangeable cations Meq/100g soil)</u>		
K	0.104	0.280
Mg	0.317	0.890
Ca	1.798	2.130
Na	0.065	0.160
CEC(meq/100g of soil	5.5	6.600

Table 2: Total rainfall distribution at 10 days intervals during the period of experimentation at Samaru in 1995 and 1996 wet seasons

Month	Days	Rainfall distribution (mm)	
		1995	1996
June	21 - 30		18.4
July	1 - 10	36.8	99.8
	11 - 30	52.3	65.4
	21 - 30	67.9	69.5
August	1 - 10	88.1	30.8
	11 - 20	73.6	115.6
	21 - 31	96.7	120.6
September	1 - 10	39.3	79.8
	11 - 20	80.5	59.7
	21 - 30	39.3	34.2
October	1 - 10	32.5	28.7

Source: Meteorological Unit, IAR, Samaru.

Table 3: Mean monthly air temperature (Maximum and minimum) relative humidity at 10 days intervals during the period of experimentation at Samaru in 1995 and 1996 wet seasons

		Mean air temperature (°C)				Relative humidity (%)			
		1995		1996		1995		1996	
Month	Days	Max.	Min.	Max.	Min.	10.00a.m	4.00p.m	10.00a.m	4.00p.m
June	21-30			29.8	18.4			75.7	61.3
July	1-10	29.0	21.8	28.4	19.3	79.6	59.6	78.4	55.6
	11-20	30.2	22.7	27.6	16.4	79.4	66.9	74.4	57.1
	21-31	30.3	20.8	27.3	19.4	82.2	73.4	77.3	74.9
August	1-10	28.7	19.9	28.4	20.0	84.4	75.3	80.1	70.6
	10-20	29.1	19.5	26.9	19.0	82.8	73.1	83.4	76.6
	21-31	28.5	21.0	28.0	19.7	78.6	87.6	82.2	66.8
September	1-10	29.5	23.9	29.4	21.0	81.9	78.1	82.6	70.0
	11-20	29.4	18.9	30.2	19.3	81.6	58.7	81.9	69.6
	21-30	28.1	18.6	30.4	19.7	80.5	63.5	80.3	69.6
October	1-10	31.1	20.1	31.6	20.0	77.9	68.7	78.1	60.2

Source: Meteorological Unit. IAR, Samaru.

spacings of 15, 30 and 45 cm. All the treatments were laid out in a split-plot design replicated three times. The gross plot size was 4.50 x 2.25m (10.13m^2) while the net plot was 4.50 x .75m (3.38m^2)

3.3 Cultural Practices

3.3.1 Land Preparation

The experimental fields were ploughed, disc harrowed and ridged 0.75m apart at two days before marking out the plots. Each plot was separated from its neighbours by an unplanted border measuring one meter.

3.3.2 Variety

The popcorn variety used for the trials was obtained from IAR Samaru (SAM 1). It is a pearl variety that has rounded grains with deep yellow colour.

3.3.3 Planting

The seeds were dressed with Apron-plus, a sachet to 1kg seed before planting. Sowing were done on ridges at intra-row spacings of 15, 30 and 45 cm on 1st July, 1995 and 26th June, 1996 at the rate of three seeds per hole and in a depth of 4cm and later thinned down to two seedlings per hole three weeks after sowing.

3.3.4 Herbicide application

The pre-emergence herbicides were applied one day after sowing with a CP3 knapsack sprayer in a spray volume of 250L/ha using a deflector nozzle at a swath width of 75cm and a pressure of about 2.1kg /cm2.

3.3.5 Fertilizer Application

In both trials, fertilizers were applied at the rate of 120kg N./ha. P and K 60kg/ha each. The first dose of 60 kgN/ha, 30kg/ha of P and K each was applied by side dressing at 3 WAS while the second dose of 60 kgN/ha, 30kg /ha of P and K each was applied at 6 WAS using a compound fertilizer N.P.K. (20.10.10).

3.3.6 Crop protection

Cymbus at rate of 1 litre/ha was applied on 27th August, 1995 and 7th July, 1996 to control stemborers on the popcorn. Furadan 5G at rate of 25kg/ha was also applied through the plant funnel at four weeks after sowing in 1996 to control stem borer.

3.3.7 Harvesting

The crop was harvested on 10th October 1995 and 1996 at 15 weeks after maturing.The number of cobs per plot and
weight of cob per plot were taken.

3.4 Observations and Data Collection

The following observations were taken:-

3.4.1 Weed infestation

3.4.1.1 Weed cover score

Weed cover score was taken at 3, 6 and 9 weeks after sowing by visual observation using a scale 0 to 10, where 0 was assigned to plots without any weed and 10 assigned to plots with full weed cover.

3.4.1.2 *Weed count*

Samples of fresh weeds were taken from $1m^2$ quardrat in

each net plot at 7 WAS during the supplementary weeding. The weeds were cleaned, free of soil, classified into grasses, broad leaves and sedges, and were finally counted.

3.4.1.3 Weed dry matter production

The samples of fresh weeds taken from $1m^2$ quadrat in each net plot at 7 WAS were oven dried at 70°C for 48 hours to constant weight before recording the final dry weight.

3.4.2 Crop growth paratmeters

3.4.2.1 Crop stand count

Crop stand count was taken at 3, 6 WAS and at harvest within the net plots in order to assess the effect of treatments on crop establishment.

3.4.2.2 Crop vigour score

Crop vigour score was taken at 3, 6 WAS and at harvest in order to assess the vigour of crop growth using the scale of 0 to 10 . Where 0 was to those with complete crop kill and 10 was assigned to plots with fully healthy crop. The crop vigour scores were taken by visual observation taking into consideration plant height, greeness of foliage and the spread of the plant canopy.

3.4.2.3 Number of leaves per plant

Number of leaves from five randomly tagged plants from each net plot was counted and averaged for each plant was recorded at the various stages of crop growth at 3, 6 and 9 WAS.

3.4.2.4 Plant height (cm)

Five tagged plants selected randomly from each net plot was measured from the ground level

to the tip of the innermost leaf. Average height for each plant was recorded at the various stages of crop growth at 3, 6 WAS and at harvest.

3.4.2.5 Leaf area index (LAI)

The length and breath of each leaf from the widest point was taken with a ruler from five tagged plants. The product was multiplied by 0.75 (a factor) for the leaf area. The leaf area obtained from individual leaves was added and divided by the number of plants sampled, and the leaf area per plant was multiplied by the number of plants/m^2 and divided by the land area.

3.4.2.6 Total dry matter production per plant(g) (above ground level)

Total dry matter production per plant was determined at harvesting by sampling five plants and oven-drying to a constant weight at 70^{0}C for 48 hours.

3.4.2.7 Number of days to 50% tasseling

This was taken when 50% of the crop have tasselled.

3.4.2.8 Number of days to 50% silking

This was taken when 50% of the crop have silked.

3.4.3 Yield parameters

3.4.3.1. Number of ears per plant

Five plants were randomly sampled and number of cobs that reached maturity was counted and the average count/plot was recorded.

3.4.3.2 Weight of ear per plant (g)

Five randomly selected cobs from each plot were weighed. The average weight per cob was recorded.

3.4.3.3 Number of cobs per plot

Cob from each plot were counted and recorded.

3.4.3.4 Cob yield (kg/ha)

Cobs from each plot were weighed and expressed in kilogram per hectare.

3.4.3.5 Grain yield (kg/ha)

The harvested cobs from each plot were threshed and the clean seeds were weighed and expressed in kilogram per hectare.

3.4.3.6 1000 grain weight (g)

1000 seeds were randomly picked and weighed.

3.4.4 Analysis of data

All data obtained during the experiment were subjected to statistical analysis to test the treatment effects for significance using the 'F' test as described by Snedecor and Cochran (1967). Where the 'F' test showed significance, the means were compared using Duncan Multiple Range Test (DMRT). Correlation coefficient was also done on appropriate parameters to determine the association and relationship between the grain yield and plant characters.

Table 4: List of common weed species present at the experimental sites and their level of occurrence.

Weed species	Weed occurrence	
	Wet season 1995	Wet season 1996
4(a) Annual grasses		
Cynodon dactylon (L.) per	++	+++
Eleusin indica (L.)	++	+
Dactyloctenium aegyptium (L.)	++	+
Digitaria ciliaris (Retz) Kock	++	+
Rottboellia cochinchinensis (L.)	++	-
4(b) Broad leaved weeds		
Commelina benghalensis (L.)	+++	++
Ageratum conyzoides (L.)	++	+++
Fallopia convolvulus (L.)	+++	++
Acanthospermum hispidum (L.)	++	+
Ipomea aquatica (L.)	+++	++
4(c) Sedges		
Cyperus rotundus (L).	+++	++
Cyperus esculentus (L.	++	+

Key:- +++ = high occurrence

++ = Moderate occurrence

+ = Minor occurrence

- = Nil (Presence not noticeable)

Chapter 4

4.0 RESULTS

4.1 Effect of Chemical Weed Control and Intra-row Spacing on Growth and Yield of Popcorn

The effect of chemical weed control and intra-row spacing on weed cover score, weed count, weed dry production, crop stand count, crop vigour score, number of leaves per plant, plant height, leaf area index, number of days to 50% tasseling and silking, total dry matter production per plant, number of ears per plant, weight per cob, number of cobs per plot, cob yield, grain yield and 1000 seed weight are shown in tables 5 to 33.

4.1.1 Effect of Herbicide Treatments and Intra-row Spacing on Weeds

4.1.2 Weed cover score

In both years of the experiment, all the herbicide treatments had similar weed cover score which were significantly lower than those of the weedy check and hoe-weeded control at 3 WAS (Table 5). At 6 WAS in 1995 and 1996 application of metolachlor plus metobromuron at 1.0 + 1.0kg a.i./ha resulted in similar weed cover score to that of the weedy check. All other herbicide treatments resulted in significantly lower weed cover score than the weedy check but similar to the hoe-weeded control. Similarly, at 9 WAS, application of various herbicide treatments except metolachlor plus metobromuron at 1.0 +

1.0 kg a.i./ha resulted in significantly lower weed cover score than the weedy check in both years of the experiment (Table 5).

Similarly, in both years of experimentation , intra-row spacing did not have any significant effect on weed cover score at 3 WAS (Table 5). At 6 and 9 WAS, however, the closest intra-row spacing of 15cm resulted in significantly lower weed cover score than 30 and 45cm (Table 5).

Table 5: Effect of chemical weed control and intra-row spacing on weed cover score in popcorn at Samaru grown in 1995 and 1996 wet seasons

Treatments		Weed cover score[3]					
		3 WAS[1]		6 WAS		9 WAS	
		1995	1996	1995	1996	1995	1996
Herbicides (H)	**Rate(kg a.i./ha)**						
Metolachlor + Metobromuron	1.0 + 1.0	3.67b	2.35b	5.23a	3.00a	7.00a	6.00a
Metolachlor + Metobromuron	1.5 + 1.5	3.55b	2.30b	2.99b	1.66b	4.00cd	3.66c
Metolachlor	1.5	3.44b	2.35b	2.55b	1.68b	6.00b	5.00b
Metolachlor	2.0	3.55b	2.31b	2.97b	1.66b	3.77cde	3.66c
Metolachlor + atrazine	1.0 + 1.0	3.44b	2.30b	2.66b	1.77b	3.33de	2.77d
Metolachlor + atrazine	1.25 + 1.25	3.41b	2.30b	2.55b	1.33b	3.22de	2.55d
Metolachlor + terbutryne	1.0 + 1.0	3.44b	2.34b	2.99b	1.55b	6.00b	5.00b
Metolachlor + terbutryne	1.25 + 1.25	3.44b	2.30b	2.98b	1.44b	4.00cd	3.83c
Hoe-weeded(3,6 & 9 WAS)		4.00a	3.00a	2.22b	1.11c	2.66e	4.00e
Weedy check		4.11a	3.00a	6.33a	3.55a	7.99a	6.89a
SE (±)		0.09	0.08	0.44	0.20	0.38	0.22
		*	*	**	**	**	**
Intra-row spacing (S)							
15cm		3.43	2.85	3.00c	1.43c	3.80c	3.43c
30cm		3.44	2.86	3.73c	1.76b	4.33b	4.00b
45cm		3.44	2.86	4.90a	2.20a	5.83a	4.96a
SE(±)		0.25	0.08	0.09	0.09	0.12	0.14
		NS	NS	**	**	**	**
Interaction							
H x S		NS[2]	NS	NS	NS	*	*

1. WAS = Weeks after sowing 2. NS = Non significant 3. Weed cover score at scale of 0-10 where 0 signifies no weed and 10 represents full weed cover.

* = Significant at 5% * * = Highly significant at 1%

Means followed by the same letter (S) within the same column and treatment are not significantly different at 5% level of probability.

The interaction between weed control treatments and intra-row spacing on weed cover score was only significant at 9 WAS in 1995 and 1996 wet seasons (Table 5). In both years, the weedy check resulted in significantly higher weed cover score than all herbicide treatments including the hoe-weeded control (Tables 6 & 7). When metolachlor at 1.5 kg a.i./ha and its mixtures with metobromuron at 1.0 + 1.0 kg a.i./ha and terbutryne at 1.0+1.0 kg i.a./ha were applied at 30 and 45cm intra-row spacings, they resulted in significantly higher weed cover score than when applied at intra-row spacing of 15cm (Tables 6 & 7). However, when metolachlor at 2.0 kg a.i/ha and its mixture with metobromuron at 1.5 + 1.5 kg a.i./ha, atrazine at 1.0 + 1.0 kg a.i./ha and 1.25 + 1.25 kg a.i./ha, and terbutryne at 1.25 + 1.25 kg a.i./ha were applied, no significant difference was observed in weed cover score among the various intra-row spacings. On the other hand, at 30 and 45cm intra-row spacings, application of metolachlor at 1.5 kg a.i./ha and its mixtures with metobromuron at 1.0 + 1.0 kg a.i./ha and terbutryne at 1.0 + 1.0 kg a.i./ha resulted in significantly higher weed cover score than all other herbicide treatments. Though with all intra-row spacings, the hoe-weeded control resulted in lower weed cover score than the application of various herbicide treatments (Tables 6 & 7).

4.1.1.2 **Weed count**

All the herbicide treatments resulted in significantly lower weed count of grasses, broadleaved weeds and sedges than the weedy check in both years (Table 8). The application of metolachlor plus atrazine at 1.0 +1.0 and 1.25 +1.25 kg a.i./ha resulted in significantly lower

number of grasses and sedges than those of the other herbicide treatments in both trials. However, application of metolachlor alone at 1.5 and 2.0 kg a.i./ha resulted in significantly higher number of broadleaved weeds than all the herbicide treatments and the hoe weeded control (Table 8).

Intra-row spacing of 15cm resulted in significantly lower weed count of grasses, broadleaved weeds and sedges than 30 and 45cm in both years (Table 8). In both years of the experiment the interaction between chemical weed control and intra-row spacing on weed count was not significant (Table 8).

4.1.1.3 Weed dry matter production

In both years, weed control treatment had significant effect on weed dry matter production (Table 9). All the herbicide treatments applied resulted in significantly lower weed dry matter production than the weedy check in the two trials. though none of the herbicide treatments resulted in significantly lower weed dry matter production than the hoe-weeded control (Table 9). In both years, application of metolachlor at 2.0kg a.i./ha and its mixtures with metobromuron at 1.5 + 1.5 kg a.i/ha, atrazine at 1.0 +1.0 and 1.25 + 1.25kg a.i./ha and metolachlor plus terbutryne at 1.25 + 1.25kg a.i./ha resulted in significantly lower weed dry matter production than application of all other herbicide treatments (Table 9).

Intra-row spacing of 15cm had significantly lower weed dry matter production than 30 and 45 cm in both years (Table 9).

The interaction between weed control treatments and inra-row spacing on weed dry matter production was significant in both years (Table 9). In both years, the weedy check resulted significantly in higher weed dry matter production than all the herbicide treatments including the hoe-weeded control at the 15, 30 and 45cm intra-row (Tables 10 & 11). In both years, application of herbicides at their various rates did not cause any significant difference in weed dry matter production at all intra-row spacing except metolachlor plus metobromuron at 1.0 + 1.0 kg a.i./ha which gave significantly higher weed dry matter production at 30 and 45 cm intra-row spacing than 15cm (Tables 10 & 11). When the crops were planted at a row of 15cm intra-row spacing, there was no significant difference in the weight of weed dry matter production within all the herbicide treatments, but at 30 and 45cm application of metolachlor plus metobromuron at 1.0 + 1.0kg a.i./ha significantly gave higher weed dry matter production than all the herbicide treatments. Though with all intra-row spacings, the hoe-weeded control significantly resulted in lower weed dry matter production than all the herbicide treatments in both years (Tables 10 & 11).

Table 6: Interaction between chemical weed control and intra-row spacing on weed cover score at (9 WAS) at Samaru in 1995 wet season

Weed control treatments	Rate (kg a.i./ha)	Weed cover score (9 WAS[1]) Intra-row spacing (cm)		
		15	30	45
Metolachlor + Metobromuron	1.0 + 1.0	4.33fghi	7.00c	7.00c
Metolachlor + Metobromuron	1.5 + 1.5	3.66hijk	4.00ghij	4.66efgh
Metolachlor	1.5	4.33fghi	6.00d	6.77cd
Metolachlor	2.0	3.33ijk	4.33fghi	4.33fghi
Metolachlor + atrazine	1.0 + 1.0	4.00ghij	3.30ghij	4.00ghij
Metolachlor + atrazine	1.25 + 1.25	3.00kjk	3.33ijk	3.33ijk
Metolachlor + terbutryne	1.0 + 1.0	3.33ijk	7.00c	7.00c
Metolachlor + terbutryne	1.25 + 1.25	3.00ijk	4.00ghij	4.00ghij
Hoe-weeded(3,6 & 9 WAS)		2.33m	2.66mn	2.77mn
Weedy check		8.00ab	8.33ab	8.66a
SE (±)		0.38		

1. WAS = Weeks after sowing.

Means followed by the same letter(s) in both row and column are not significantly different at 5% level of probability.

Table 7: Interaction between chemical weed control and intra-row spacing on weed cover score at (9 WAS) at Samaru in 1996 wet season

Weed control treatments	Rate (kg a.i./ha)	Weed cover score (9 WAS[1]) Intra-row spacing (cm) 15	30	45
Metolachlor + Metobromuron	1.0 + 1.0	3.33de	6.00b	6.00b
Metolachlor + Metobromuron	1.5 + 1.5	3.33de	3.66de	4.00de
Metolachlor	1.5	3.33de	6.00b	6.00b
Metolachlor	2.0	3.33de	4.00de	4.33cd
Metolachlor + atrazine	1.0 + 1.0	3.00ef	3.33de	3.66de
Metolachlor + atrazine	1.25 + 1.25	2.26ef	3.00ef	3.00ef
Metolachlor + terbutryne	1.0 + 1.0	3.33de	6.00b	6.00b
Metolachlor + terbutryne	1.25 + 1.25	3.33de	3.66de	3.66de
Hoe-weeded(3,6 & 9 WAS)		1.00g	1.00g	1.00g
Weedy check		7.44a	7.44a	7.66a
SE (±)		0.02		

1. WAS = Weeks after sowing.

Means followed by the same letter(s) in both row and column are not significantly different at 5% level of probability.

Table 8: Effect of chemical weed control and intra-row spacing on the weed count (grasses, broadleaves and sedges) in popcorn at Samaru grown in 1995 and 1996 wet seasons

Treatments	Rates(kg a.i./ha)	Weed count: Grasses 1995	Grasses 1996	Broadleaves 1995	Broadleaves 1996	Sedges 1995	Sedges 1996
Herbicides							
Metolachlor + Metobromuron	1.0 + 1.0	12.44b	10.33b	10.66c	9.77c	11.23b	9.66b
Metolachlor + Metobromuron	1.5 + 1.5	5.71b	4.66bc	9.66c	8.55c	10.00b	7.60bc
Metolachlor	1.5	6.80b	5.22bc	23.00d	22.55b	9.34bc	6.99bc
Metolachlor	2.0	4.00b	2.22bc	20.80d	21.99b	6.31c	4.22cd
Metolachlor + atrazine	1.0 + 1.0	1.51c	1.43d	5.71b	4.11b	1.77d	1.00e
Metolachlor + atrazine	1.25 + 1.25	1.44c	1.33d	2.55b	2.33b	1.55d	1.00e
Metolachlor + terbutryne	1.0 + 1.0	6.00b	4.22bc	3.34b	5.44b	10.11d	8.33bc
Metolachlor + terbutryne	1.25 + 1.25	4.81b	2.88bc	6.47b	3.00b	6.00c	3.00c
Hoe-weeded(3, 6 & 9 WAS)		1.33c	1.31d	1.33a	1.66b	1.11d	0.55e
Weedy check		30.44a	36.30a	56.60a	53.33a	39.00a	20.77a
SE (±)		2.90 **	2.89 **	3.99 **	3.93 **	1.01 *	0.09 *
Intra-row spacing (S)							
15cm		8.11b	4.36b	11.13b	9.13b	23.00b	4.83c
30cm		12.21a	7.00a	13.31a	10.90a	27.91a	5.80b
45cm		13.13a	11.36a	14.11a	12.00a	29.12a	7.80a
SE(±)		0.84 *	1.02 *	1.45 *	1.17 *	1.02 *	0.08 *
Interaction H x S		NS[1]	NS	NS	NS	NS	NS

1. NS = Non significant ** = Highly significant at 1%

* = Significant at 5%

Means followed by the same letter (S) within the same column and treatment are not significantly different at 5% level of probability.

Table 9: Effect of chemical weed control and intra-row spacing on weed dry matter production in popcorn at Samaru grown in 1995 and 1996 wet seasons

Treatments		Weed dry matter production (kg/ha)	
Herbicides	Rate(kga.i/ha)	7 WAS[1]	
		1995	1996
Herbicides (H)	Rate (kg a.i./ha)		
Metolachlor + Metobromuron	1.0 + 1.0	188.91c	181.40c
Metolachlor + Metobromuron	1.5 + 1.5	75.04d	62.84ef
Metolachlor	1.5	227.04b	214.90b
Metolachlor	2.0	81.71d	62.52ef
Metolachlor + atrazine	1.0 + 1.0	65.59d	55.73ef
Metolachlor + atrazine	1.25 + 1.25	55.61d	45.64fg
Metolachlor + terbutryne	1.0 + 1.0	185.21c	157.90d
Metolachlor + terbutryne	1.25 + 1.25	77.23d	63.12ef
Hoe-weeded(3,6 & 9 WAS)		35.12e	25.98h
Weedy check		416.56a	389.20a
SE (±)		7.48 **	6.75 **
Intra-row spacing (S)			
15cm		103.52c	93.28c
30cm		148.55b	133.85b
45cm		170.55a	155.38a
SE (±)		0.19 **	4.54 **
Interaction			
H x S		*	*

1. WAS = Weeks after sowing

* = Significant at 5%

* * = Highly significant at 1%

Means followed by the same letter (S) within the same column and treatment are not significantly different at 5% level of probability.

Table 10: Interaction between chemical weed control and intra-row spacing on weed weight dry matter production (kg/ha) at Samaru during the wet season of 1995

Weed control treatments	Rate (kg a.i./ha)	Weed dry matter production (kg/ha) Intra-row spacing (cm)		
		15	30	45
Metolachlor + Metobromuron	1.0 + 1.0	146.33ef	222.66d	268.00cd
Metolachlor + Metobromuron	1.5 + 1.5	71.33fgh	78.33fgh	79.33fg
Metolachlor	1.5	140.66ef	159.33ef	185.00ef
Metolachlor	2.0	78.66fgh	82.33fgh	87.33fgh
Metolachlor + atrazine	1.0 + 1.0	54.33fgh	66.33fgh	75.33fgh
Metolachlor + atrazine	1.25 + 1.25	50.66fgh	61.33fgh	66.66fgh
Metolachlor + terbutryne	1.0 + 1.0	99.66fg	158.33ef	160.00ef
Metolachlor + terbutryne	1.25 + 1.25	74.66fgh	78.33fgh	83.00fgh
Hoe-weeded(3,6 & 9 WAS)		43.99i	42.33i	49.00i
Weedy check		337.33b	446.00a	486.71a
SE (±)		16.64		

Means followed by the same letter(s) in both row and column are not significantly different at 5% level of probability.

Table 11: Interaction between chemical weed control and intra-row spacing on weed weight dry matter production (kg/ha) at Samaru during the wet season of 1996

Weed control treatments	Rate (kg a.i./ha)	Weed dry matter production (kg/ha) Intra-row spacing (cm)		
		15	30	45
Metolachlor + Metobromuron	1.0 + 1.0	149.33d	164.52c	180.33c
Metolachlor + Metobromuron	1.5 + 1.5	56.23ef	65.81f	111.33ef
Metolachlor	1.5	99.74ef	115.00ef	109.03ef
Metolachlor	2.0	99.74ef	115.00ef	109.03ef
Metolachlor + atrazine	1.0 + 1.0	47.05f	55.61f	68.49f
Metolachlor + atrazine	1.25 + 1.25	30.27f	50.33f	55.94f
Metolachlor + terbutryne	1.0 + 1.0	88.53ef	100.33ef	111.00ef
Metolachlor + terbutryne	1.25 + 1.25	65.56f	68.78f	99.10ef
Hoe-weeded(3,6 & 9 WAS)		23.03g	27.97g	29.94g
Weedy check		307.68ab	400.07a	459.72a
SE (±)		14.36		

Means followed by the same letter(s) in both row and column are not significantly different at 5% level of probability.

4.2 Effect of herbicide treatments and intra-row spacing on growth of popcorn

4.2.1 Crop stand count

In both years of experimentation weed control treatments had no significant effect on crop stand count (Table 12). In both years, 15cm intra-row spacing had significantly higher number of stand count than 30 and 45cm intra-row (Table 12).

The interaction between chemical weed control and intra-row spacing on crop stand count was not significant in both years (Table 12).

4.2.2 Crop vigour score

Weed control treatments had significant effect on crop vigour score at 6 and 9 WAS in both 1995 and 1996, but no significant difference were observed at 3 WAS after sowing (Table 13). In both years, all herbicide treatments resulted in significantly higher crop vigour at 6 and 9 WAS compared with the weedy check.

At 6 WAS in both years, application of metolachlor at 2.0kg a.i./ha and its mixture with atrazine at 1.0 + 1.0 kg a.i./ha and 1.25 + 1.25 kg a.i./ha resulted significantly in higher crop vigour compared with rest herbicide treatments, but having similar value with the hoe-weeded control. While at 9 WAS in 1995, all herbicide treatments resulted significantly in lower crop vigour score than the hoe-weeded control, and at 9 WAS in 1996, except the application of metolachlor plus metobromuron at 1.0 + 1.0

kg a.i./ha and metolachlor plus terbutryne at 1.0 + 1.0 kg a.i./ha all herbicide treatments resulted significantly in higher, but similar crop vigour to the hoe-weeded control (Table 13).

Intra-row spacing only had significant effect on crop vigour at 6 WAS in both 1995 and 1996 in which the closest intra-row spacing of 15cm resulted in significantly higher crop vigour score than 30 and 45cm (Table 13).

The interaction between weed control treatments and intra-row spacing on crop vigour score was significant at 9 WAS in both 1995 and 1996 (Table 13). In both years, application of all the herbicide treatments at intra-row spacing of 15cm resulted significantly in better crop vigour than 30 and 45cm (Table 14 & 15). However, the hoe-weeded control resulted in significantly better crop vigour than all the herbicide treatments at all intra-row spacings of 15, 30 and 45cm (Table 14 & 15).

4.2.3 Number of leaves per plant.

Weed control treatments only caused significant effect on number of leaves per plant at 6 and 9 WAS 1995 and 1996 but not at 3 WAS (Table 16). In both years, application of all herbicide treatments at 6 and 9 WAS resulted in significantly higher number of leaves per plant than the weedy check. At 6 WAS in both years, application of all herbicide treatments including the hoe-weeded control resulted in similar number of leaves per plant. While at 9 WAS in both years of experimentation, all herbicide treatments applied significantly caused lower number of leaves per plant than the hoe-weeded control (Table 16).

At 6 WAS both 15 and 30cm intra-row spacings caused significantly higher leaf production than 45cm in both 1995 and 1996 (Table 16).

The interaction between chemical weed control and intra-row spacing on number of leaves per plant was not significant in both years (Table 16).

4.2.4 Plant height

Application of all herbicide treatments significantly produce taller plants compared with the weedy check at 6 and 9 WAS (Table 17). At 6 WAS in 1995, application of metolachlor plus atrazine at 1.0 + 1.0 and 1.25 + 1.25 kg a.i./ha resulted significantly in taller plants than all the other herbicide treatments, but significantly shorter than the hoe-weeded control. While at 6 WAS in 1996 application of mixture of metolachlor plus atrazine at 1.0 + 1.0 and 1.25 + 1.25 kg a.i./ha including the hoe-weeded control produced significantly taller plants than all the other herbicide treatments (Table 17). At 9 WAS in 1995 also, application of metolachlor plus atrazine at 1.0 + 1.0 and 1.25 + 1.25 kg a.i./ha significantly produced taller plants than the application of all other herbicide treatments. However, at 9 WAS in 1996, application of metolachlor plus atrazine at 1.25+ 1.25kg a.i./ha produced significantly taller plants than application of metolachlor+ metobromuron at 1.0 + 1.0 and 1.5 + 1.5 kg a.i./ha and metolachlor plus terbutryne at 1.0 + 1.0 kg a.i./ha (Table 17).

Similarly, in both 1995 and 1996, the closest intra-row spacing of 15cm significantly produced taller plants than 30 and 45cm at 6 and 9 WAS while no significant was observed at 3 WAS (Table 17).

The interaction between chemical weed control and intra-row spacing on plant height was not significant in both years (Table 17).

4.2.5 Leaf area index

Weed control treatments had significant effect on leaf area index at 6 and 9 WAS in 1995 and 1996 (Table 18). In both years, at 6 and 9 WAS, application of all herbicide treatments including the hoe-weeded control resulted significantly in greater leaf area index than the weedy check. However, application of metolachlor at 2.0 and mixture of metolachlor plus atrazine at 1.0 +1.0 and 1.25 + 1.25 kg a.i./ha including the hoe-weeded control at 6 and 9 WAS resulted in significantly greater leaf area index than all other herbicide treatments(Table 18).

In both years, at 6 and 9 WAS 15cm intra-row spacing had significantly higher leaf area index than 30 and 45cm (Table 18).

The interaction between chemical weed control and intra-row spacing on leaf area index was not significant in both years (Table 18).

4.2.6 Number of days to 50% tasseling

Weed control treatments including the hoe-weeded control significantly had about one and half days earlier to 50% tasseling than the weedy check (Table 19).

Neither the intra-row spacing and interaction between herbicide and intra-row spacing had any significant effect on number of days to 50% tasseling in both years of experimentation (Table 19). 15cm intra-row spacing had shorter number of days to 50% tasseling than 40 and 45cm in both years (Table 19)

4.2.7 Number of days to 50% silking

Application of all herbicide treatments including the hoe-weeded control resulted in significantly shorter number of days to 50% silking than the weedy check in both years (Table 20).

Neither the intra-row spacing and interaction between herbicide and intra-row spacing had any significant effect on number of days to 50% silking in both years (Table 20). 15cm intra-row spacing resulted in shorter number of days to 50% silking than 30 and 45cm (Table 20)

4.2.8 Total dry matter production per plant

Weed control treatments had significant effect on the total dry matter production in both 1995 and 1996 (Table 21). In both years, application of all herbicide treatments including the hoe- weeded control had significantly higher total dry matter production than the weedy check. However, application of metolachlor at 2.0kg a.i./ha and its mixture with atrazine at 1.0 + 1.0 and 1.25 + 1.25kg a.i./ha including the hoe-weeded control resulted significantly in greater total dry matter production than application of all other herbicide treatments. (Table 21)

Similarly in both years, intra-row spacing of 15 and

30cm significantly had higher total dry matter production per plant than 45cm (Table 21)

The interaction between chemical weed control and intra-row spacing on total dry matter production per plant was not significant in both years (Table 21).

Table 12: Effect of chemical weed control and intra-row spacing on stand count of popcorn at Samaru grown in 1995 and 1996 wet seasons

Treatments		Stand count					
		3 WAS[1]		6 WAS		Harvest	
		1995	1996	1995	1996	1995	1996
Herbicide (H)	Rate(kg a.i./ha)						
Metolachlor + Metobromuron	1.0 + 1.0	44.44	57.22	44.22	57.11	37.00	49.11
Metolachlor + Metobromuron	1.5 + 1.5	44.00	56.66	45.89	56.33	42.22	50.33
Metolachlor	1.5	40.78	56.11	44.50	56.11	40.88	49.55
Metolachlor	2.0	43.44	55.88	47.50	56.11	42.22	52.22
Metolachlor + atrazine	1.0 + 1.0	45.90	55.44	50.22	56.44	44.77	52.66
Metolachlor + atrazine	1.25 + 1.25	45.90	56.88	51.67	57.00	49.22	53.33
Metolachlor + terbutryne	1.0 + 1.0	43.22	55.55	46.67	55.55	40.66	51.22
Metolachlor + terbutryne	1.25 + 1.25	44.00	57.11	48.67	56.33	40.77	51.55
Hoe-weeded(3,6 & 9 WAS)		44.00	55.88	50.00	55.88	48.88	53.88
Weedy check		45.67	55.11	49.11	58.88	46.11	56.66
SE (±)		2.85	0.77	2.62	0.74	2.62	1.13
		NS	NS	NS	NS	NS	NS
Intra-row spacing (S)							
15cm		77.80a	89.46a	72.63a	89.16a	57.66a	77.66a
30cm		40.93b	46.63a	41.73a	46.63b	38.76b	44.10b
45cm		27.17c	32.76c	29.40c	32.76c	25.36c	37.77c
SE(±)		1.59	0.32	1.85	0.33	1.85	0.72
		**	**	**	**	**	**
Interaction							
H x S		NS[2]	NS	NS	NS	NS	NS

1. WAS = Weeks after sowing 2. NS = Non significant

* * = Highly significant at 1%

Means followed by the same letter (S) within the same column and treatment are not significantly different at 5% level of probability.

Table 13: Effect of chemical weed control and intra-row spacing on crop vigour of popcorn at Samaru grown in 1995 and 1996 wet seasons

Treatments		Crop vigour[3]					
		3 WAS[1]		6 WAS		9 WAS	
		1995	1996	1995	1996	1995	1996
Herbicides (H)	Rate (kg a.i./ha)						
Metolachlor + Metobromuron	1.0 + 1.0	6.43	8.76	7.00b	9.22b	6.88bc	7.99d
Metolachlor + Metobromuron	1.5 + 1.5	6.43	8.77	7.33b	9.22b	7.00bc	8.77abc
Metolachlor	1.5	6.41	8.77	7.33b	9.22b	6.88bc	8.77abc
Metolachlor	2.0	6.41	8.77	7.99a	9.85a	7.44bc	8.77abc
Metolachlor + atrazine	1.0 + 1.0	6.33	8.77	8.00a	9.86a	7.44bc	8.97abc
Metolachlor + atrazine	1.25 + 1.25	6.46	8.77	8.11a	9.88a	7.55b	9.00ab
Metolachlor + terbutryne	1.0 + 1.0	6.44	8.77	7.22b	9.44b	7.00bc	7.99d
Metolachlor + terbutryne	1.25 + 1.25	6.42	8.77	7.66b	9.66b	7.44bc	8.67abc
Hoe-weeded(3,6 & 9 WAS)		6.43	8.77	8.11a	9.88a	9.44a	9.66a
Weedy check		6.44	8.77	6.55c	7.11c	3.88d	5.00e
SE (±)		0.51	0.11	0.20	0.11	0.13	0.29
		NS	NS	*	*	*	**
Intra-row spacing (S)							
15cm		6.96	8.85	8.00a	9.80a	6.99	8.44
30cm		6.96	8.84	7.33b	9.46b	7.00	8.40
45cm		6.96	8.84	7.00c	9.21c	7.33	8.66
SE(±)		0.99	0.37	0.16	0.11	0.12	0.15
		NS	NS	**	**	NS	NS
Interaction							
H x S		NS[2]	NS	NS	NS	*	*

1. WAS = Weeks after sowing 2. NS = Non significant 3. Crop vigour score at scale of 0-10 where 0 represents completely killed plants and 10 represents fully healthy crop.

* = *Significant at 5%* ** = Highly significant at 1%

Means followed by the same letter (S) within the same column and treatment are not significantly different at 5% level of probability.

Table 14: Interaction between chemical weed control and intra-row spacing on crop vigour score (at 9 WAS) at Samaru during the wet season of 1995

Weed control treatments	Rate (kga.i/ha)	Crop vigour score (at 9 W A S[1]) Intra-row spacing (cm) 15	30	45
Metolachlor + Metobromuron	1.0 + 1.0	7.66b	6.88cd	6.00de
Metolachlor + Metobromuron	1.5 + 1.5	7.66b	7.00c	6.66cde
Metolachlor	1.5	7.66b	7.00c	6.66cde
Metolachlor	2.0	7.66b	7.00c	6.66cde
Metolachlor + atrazine	1.0 + 1.0	7.66b	7.00c	6.66cde
Metolachlor + atrazine	1.25 + 1.25	7.66b	7.00c	6.66cde
Metolachlor + terbutryne	1.0 + 1.0	7.66b	7.00c	6.66cde
Metolachlor + terbutryne	1.25 + 1.25	7.66b	7.00c	6.66cde
Hoe-weeded(3,6 & 9 WAS)		8.66a	8.66a	8.66a
Weedy check		4.00f	4.00f	4.00f
SE (±)		0.39		

1. WAS = Weeks after sowing.

Means followed by the same letter(s) in both row and column **are not significantly different** at 5% level of probability.

Table 15: Interaction between chemical weed control and intra-row spacing on crop vigour score (at 9 WAS) at Samaru during the wet season of 1996

Weed control treatments	Rate (kg a.i./ha)	Crop vigour score (at 9 W A S[1]) Intra-row spacing (cm) 15	30	45
Metolachlor + Metobromuron	1.0 + 1.0	8.33b	7.22cd	6.88de
Metolachlor + Metobromuron	1.5 + 1.5	8.33b	7.62c	7.00cde
Metolachlor	1.5	8.33b	7.63c	7.00cde
Metolachlor	2.0	8.44b	7.63c	7.00cde
Metolachlor + atrazine	1.0 + 1.0	8.44b	7.63c	7.00cde
Metolachlor + atrazine	1.25 + 1.25	8.44b	7.63c	7.00cde
Metolachlor + terbutryne	1.0 + 1.0	8.33b	7.63c	7.00cde
Metolachlor + terbutryne	1.25 + 1.25	8.33b	7.63c	7.00cde
Hoe-weeded(3,6 & 9 WAS)	-	9.00a	9.00a	9.00a
Weedy check		5.33f	5.22f	5.22f
SE (±)		0.34		

1. WAS = Weeks after sowing.

Means followed by the same letter(s) in both row and column are not significantly different at 5% level of probability.

Table 16. Effect of chemical weed control and intra-row spacing on number of leaves/plant of popcorn at Samaru grown in 1995 and 1996 wet seasons

Treatments		Leaf count					
		3 WAS[1]		6 WAS		9 WAS	
		1995	1996	1995	1996	1995	1996
Herbicides (H)	Rate (kg a.i./ha)						
Metolachlor + Metobromuron	1.0 + 1.0	5.33	7.42	10.00a	10.66a	10.66b	11.33b
Metolachlor + Metobromuron	1.5 + 1.5	5.33	7.43	10.00a	10.77a	10.66b	11.44b
Metolachlor	1.5	5.33	7.41	10.00a	10.77a	10.55b	11.55b
Metolachlor	2.0	5.33	7.44	10.22a	10.88a	10.77b	11.55b
Metolachlor + atrazine	1.0 + 1.0	5.32	7.44	10.33a	10.99a	10.99b	11.66b
Metolachlor + atrazine	1.25 + 1.25	5.33	7.44	10.33a	10.99a	10.99b	11.66b
Metolachlor + terbutryne	1.0 + 1.0	5.32	7.44	10.22a	10.88a	10.77b	11.33b
Metolachlor + terbutryne	1.25 + 1.25	5.33	7.44	10.33a	10.88a	10.77b	11.55b
Hoe-weeded (3, 6 & 9 WAS)		5.32	7.44	10.44a	10.99a	11.33a	11.77a
Weedy check		5.33	7.44	9.66b	10.00b	9.88c	10.00c
SE (±)		0.31	0.16	0.38	0.21	0.40	0.35
		NS	NS	*	*	*	*
Intra-row spacing (S)							
15cm		3.73	7.30	10.20a	10.80a	10.93	11.73
30cm		5.72	7.33	10.00a	10.76a	10.93	11.63
45cm		5.71	7.30	9.46b	10.10b	10.78	11.60
SE (±)		0.20	0.12	0.19	0.19	0.17	0.13
		NS	NS	*	*	NS	NS
Interaction							
H x S		NS[2]	NS	NS	NS	NS	NS

1. WAS = Weeks after sowing 2. NS = Non significant * = Significant at 5%

Means followed by the same letter(s) in both row and column are not significantly different at 5% level of probability.

Table 17: **Effect of chemical weed control and intra-row spacing on plant height of popcorn at Samaru grown in 1995 and 1996 wet seasons**

Treatments	Rate (kg a.i./ha)	Plant height (cm) 3 WAS[1] 1995	3 WAS[1] 1996	6 WAS 1995	6 WAS 1996	9 WAS 1995	9 WAS 1996
Herbicides (H)							
Metolachlor + Metobromuron	1.0 + 1.0	26.10	29.40	111.11e	110.56bc	134.10g	139.77c
Metolachlor + Metobromuron	1.5 + 1.5	26.11	29.41	111.13e	112.55bc	145.21f	135.99c
Metolachlor	1.5	26.10	29.40	111.11e	112.77bc	146.10e	150.77abc
Metolachlor	2.0	26.11	29.40	114.12d	116.20bc	152.11c	153.00abc
Metolachlor + atrazine	1.0 + 1.0	26.10	29.41	131.13b	132.81a	157.11b	155.77abc
Metolachlor + atrazine	1.25 + 1.25	26.11	29.40	131.14b	134.77a	157.11b	169.44ab
Metolachlor + terbutryne	1.0 + 1.0	26.11	29.41	113.82d	115.78bc	142.11h	146.33c
Metolachlor + terbutryne	1.25 + 1.25	26.10	29.39	120.12c	121.10bc	150.11d	152.22abc
Hoe-weeded(3, 6 & 9 WAS)		26.10	29.40	135.13a	142.11a	165.11a	172.22a
Weedy check		26.10	29.41	91.14f	110.88d	118.13h	120.11d
SE (±)		0.61	0.77	0.05	5.22	0.06	7.04
		NS	NS	*	*	*	*
Intra-row spacing (S)							
15cm		26.46	29.73	127.10a	139.35a	149.00a	157.26a
30cm		26.45	29.73	113.12b	125.70b	134.10b	151.68b
45cm		26.45	29.73	107.10c	119.80c	130.00c	148.10b
SE(±)		6.21	0.21	0.02	2.73	0.03	3.003
		NS	NS	**	**	*	*
Interaction							
H x S		NS	NS	NS	NS	NS	NS

1. WAS = Weeks after sowing 2. NS = Non significant

* = Significant at 5% * * = Highly significant at 1%

Means followed by the same letter (S) within the same column and treatment are not significantly different at 5% level of probability.

Table 18: Effect of chemical weed control and intra-row spacing on leaf area index of popcorn at Samaru grown in 1995 and 1996 wet seasons

Treatments	Rate (kg a.i./ha)	Leaf area index 6WAS[1] 1995	Leaf area index 6WAS[1] 1996	Leaf area index 9WAS 1995	Leaf area index 9WAS 1996
Herbicides (H)					
Metolachlor + Metobromuron	1.0 + 1.0	2.24b	2.62bc	3.15b	3.21b
Metolachlor + Metobromuron	1.5 + 1.5	2.32b	2.68bc	3.16b	3.31b
Metolachlor	1.5	2.30b	2.62bc	3.17b	3.37b
Metolachlor	2.0	2.68a	2.91a	3.38a	3.71a
Metolachlor + atrazine	1.0 + 1.0	2.77a	2.92a	3.39a	3.75a
Metolachlor + atrazine	1.25 + 1.25	2.82a	2.97a	3.42a	3.77a
Metolachlor + terbutryne	1.0 + 1.0	2.44b	2.62bc	3.14b	3.21b
Metolachlor + terbutryne	1.25 + 1.25	2.78a	2.70bc	3.15b	3.31b
Hoe-weeded(3,6 & 9 WAS)		2.94a	2.97a	3.43a	3.78a
Weedy check		2.10c	2.39d	2.32c	2.83c
SE (±)		0.09	0.07	0.08	0.08
		*	*	*	**
Intra-row spacing (S)					
15cm		2.75a	2.85a	3.29a	3.66a
30cm		2.51b	2.61b	3.21b	3.59b
45cm		2.40c	2.50c	3.10c	3.50c
SE(±)		0.07	0.04	0.07	0.04
		*	*	*	*
Interaction					
H x S		NS[2]	NS	NS	NS

1. WAS = Weeks after sowing   2. NS = Non significant

* = Significant at 5%   * * = Highly significant at 1%

Means followed by the same letter (S) within the same column and treatment are not significantly different at 5% level of probability.

Table 19: Effect of chemical weed control and intra-row spacing on number of days to 50% tasseling of popcorn at Samaru grown in 1995 and 1996 wet seasons

Treatments		No. of days to 50% tasseling	
		1995	1996
Herbicides (H)	Rate (kg a.i./ha)		
Metolachlor + Metobromuro	1.0 + 1.0	56.44b	55.48b
Metolachlor + Metobromuron	1.5 + 1.5	56.44b	55.48b
Metolachlor	1.5	56.44b	55.48b
Metolachlor	2.0	56.33b	55.40b
Metolachlor + atrazine	1.0 + 1.0	56.33b	55.22b
Metolachlor + atrazine	1.25 + 1.25	56.33b	55.22b
Metolachlor + terbutryne	1.0 + 1.0	56.44b	55.48b
Metolachlor + terbutryne	1.25 + 1.25	56.33b	55.48b
Hoe-weeded(3,6 & 9 WAS)		56.22b	55.22b
Weedy check		57.66a	56.88a
SE (±)		0.09	0.09
		*	*
Intra-row spacing (S)			
15cm		55.20	54.56a
30cm		57.16	56.60
15cm		57.73	56.73
SE(±)		0.41 NS	0.61 NS
Interaction			
H x S		NS[1]	NS

1. NS = Non significant

* = Significant at 5%

Means followed by the same letter (S) within the same column and treatment are not significantly different at 5% level of probability.

Table 20: Effect of chemical weed control and intra-row spacing on number of days to 50% silking of popcorn at Samaru grown in 1995 and 1996 wet seasons

Treatments		No. of days to 50% silking	
		1995	1996
Herbicides (H)	Rate (kg a.i./ha)		
Metolachlor + Metobromuron	1.0 + 1.0	68.22b	66.44b
Metolachlor + Metobromuron	1.5 + 1.5	68.11b	66.33b
Metolachlor	1.5	68.11b	66.33b
Metolachlor	2.0	68.11b	66.00b
Metolachlor + atrazine	1.0 + 1.0	68.00b	66.00b
Metolachlor + atrazine	1.25 + 1.25	68.00b	64.44b
Metolachlor + terbutryne	1.0 + 1.0	68.22b	66.44b
Metolachlor + terbutryne	1.25 + 1.25	68.22b	66.33b
Hoe-weeded(3,6 & 9 WAS)		68.20b	66.33b
Weedy check		72.22a	69.22a
SE (±)		0.34	0.16
		*	*
Intra-row spacing (S)			
15cm		67.90	66.90
30cm		68.26	67.63
45cm		68.46	67.60
SE(±)		0.19 NS	0.14 NS
C Interaction			
H x S		NS[1]	NS

1. NS = Non significant

* = Significant at 5%

Means followed by the same letter (S) within the same column and treatment are not significantly different at 5% level of probability.

Table 21: Effect of chemical weed control and intra-row spacing on total dry matter production per plant of popcorn at Samaru grown in 1995 and 1996 wet seasons

Treatments		Total dry matter production per plant at harvest (g)	
		1995	1996
Herbicides (H)	Rate (kg a.i./ha)		
Metolachlor + Metobromuron	1.0 + 1.0	100.88b	105.67c
Metolachlor + Metobromuron	1.5 + 1.5	102.89b	106.89c
Metolachlor	1.5	102.98b	106.90c
Metolachlor	2.0	121.23a	122.89ab
Metolachlor + atrazine	1.0 + 1.0	122.78a	123.11ab
Metolachlor + atrazine	1.25 + 1.25	124.22a	126.22a
Metolachlor + terbutryne	1.0 + 1.0	102.44b	105.78c
Metolachlor + terbutryne	1.25 + 1.25	103.77b	106.89c
Hoe-weeded(3,6 & 9 WAS)		127.88a	129.00a
Weedy check		50.77c	53.00d
SE (±)		5.17	1.2148
		*	*
Intra-row spacing (S)			
15cm		100.40a	103.00a
30cm		100.24a	102.70a
45cm		97.29b	100.00b
SE(±)		0.06	0.54
		*	*
Interaction			
H x S		NS[1]	NS

1. NS = Non significant

   * = Significant at 5%

   Means followed by the same letter (S) within the same column and treatment are not significantly different at 5% level of probability.

4.3 Effect of herbicide treatments and intra-row spacing on yield and yield attributes

4.3.1 Number of ears per plant

In both years, application of all herbicide treatments including hoe-weeded control had significantly greater number of ears per plant than the weedy check (Table 22).

Intra- row spacing had no significant effect on number of ears per plant in both 1995 and 1996 (Table 22).

The interaction between chemical weed control and intra-row spacing on number of ears per plant was not significant in both years (Table 22).

4.3.2 Weight per cob

Weed control treatments had significant effect on the weight per cob of popcorn in both 1995 and 1996 (Table 23). All the herbicide treatments had significantly greater weight per cob than the weedy check in both years. In 1995, application of metolachlor at 2.0kg a.i./ha and mixtures of metolachlor plus atrazine at 1.0 + 1.0kg a.i./ha and 1.25 + 1.25kg a.i./ha, and metolachlor plus terbutryne at 1.25 + 1.25kt a.i./ha including the hoe-weeded control had weight per cob significantly greater than all other herbicide treatments. While in 1996, all herbicide treatments including the hoe-weeded control had similar weight per cob (Table 23).

In both years, 15cm intra-row spacing had significantly greater weight per cob than 30 and 45cm (Table 23).

The interaction between chemical weed control and intra-row spacing on weight per cob was not significant in both years (Table 23).

4.3.3 Number of cobs per plot

Weed control treatment had significant effect on number of cobs per plot in both 1995 and 1996 (Table 24). In both years, except application of metolachlor at 1.5 kg a.i./ha and its mixtures with metobromuron at 1.0 + 1.0 kg a.i./ha and terbutryne at 1.0 + 1.0 kg a.i./ha and 1.25 +1.25 kg a.i./ha all other herbicide treatments had greater number of cobs per plot than the weedy check. However, in 1995 none of the herbicide treatments had number of cobs per plot significantly greater than the hoe-weeded control. While in 1996, application of metolachlor at 2.0 kg a.i./ha and its mixture with atrazine at 1.0 + 1.0 kg a.i./ha and 1.25 + 1.25 kg a.i./ha gave similar number of cobs per plot with the hoe-weeded control (Table 24).

In both 1995 and 1996, 15cm intra-row spacing had significantly greater number of cobs per plot than 30 and 45cm (Table 24).

The interaction between chemical weed control and intra-row spacing *on* number of cobs per plot was not significant in both years (Table 24).

4.3.4 Cob yield

All herbicide treatments gave significantly higher cob yield than weedy check in both 1995 and 1996 (Table 25). In both years, application of metolachlor at 2.0 kg a.i./ha and its mixture with atrazine at 1.0 + 1.0 kg a.i./ha and

1.25+1.25kg a.i./ha produced cob yield similar to the hoe-weeded control but significanctly greater than all other herbicide treatments (Table 25).

In both years of experimentation, 15cm intra-row spacing had higher cob yield than 30 and 45cm (Table 25).

The interaction between weed control treatments and intra-row spacing on cob yield kilogram per hectare was significant in both 1995 and 1996 (Table 25). In both years of experimentation, the weedy check resulted in significantly lower cob yield than all herbicide treatments including the hoe-weeded control (Tables 26 & 27). In both years, the hoe-weeded plot gave significantly higher cob yield than all the herbicide treatments at 15 and 30cm intra-row spacing.

In 1995, all herbicide treatments applied at 15cm intra-row spacing gave significantly higher cob yield than at 30 and 45cm (Table 26). While in 1996, application of metolachlor at 1.5 and 2.0kg a.i./ha and its mixtures with metobromuron at 1.0 + 1.0 and 1.5 + k1. kg a.i./ha and terbutryne at 1.0 + 1.0 kg a.i./ha at 15 and 30cm intra-row spacing gave significantly higher cob yield than at 45cm (Table 27).

4.3.5 Grain yield

In both years of experimentation all the herbicde treatments resulted in significantly higher grain yield than the weedy check (Table 28). Though none of the herbicide treatments resulted in significantly greater grain yield than the hoe-weeded control (Table 28).

Among the herbicide treatments tested, application of metolachlor at 2.0 kg a.i./ha and it mixture with atrazine at 1.0 + 1.0 kg a.i./ha and 1.25+ 1.25kg a.i./ha resulted in significantly higher grain yield than all the other herbicde treatments (Table 28).

Similarly intra-row spacidng of 15cm resulted in significantly higher grain yield than 30 and 45cm in both 1995 and 1996 (Table 28).

The interaction between weed control treatments and intra-row spacing on grain yield weight was significant in both 1995 and 1996 (Table 28). The hoe-weeded plot gave significantly higher grain yield than all the herbicide treatments and the weedy check at all intra-row spacings in both years (Tables 29 & 30). Also among the herbicide treatments the application of metolachlor at 2.0 kg a.i./ha and mixtures with metobromuron at 1.5 + 1.5 kg a.i./ha, with atrazine at 1.25+ 1.25kg a.i./ha, and terbutryne at 1.25 + 1.25 kg a.i./ha at intra-row spacing of 15cm resulted in significntly higher grain yield than at intra-row spacing of 30cm which was also significantly higher than 45cm intra-row spacing. However, application of metolachlor plus metobromuron at 1.0 + 1.0 kg a.i./ha at intra-row spacing of 15cm, resulted in significantly higher grain yield than all other row spacings of 30 and 45cm (Tables 29 & 30).

On the other hand, the hoe-weeded control resulted in significantly higher grain yield than metolachlor plus atrazine at 1.0 + 1.0 kg a.i./ha and 1.25+1.25.kg a.i./ha which also resulted in significantly higher yield than all other herbicide treatments at all intra-row spacings in both years.

4.3.6 1000 grain weight

In both years, all the herbicide treatments including the hoe-weeded control had significantly greater 1000 grain weight than the weedy check (Table 31). However, among the herbicide treatments application of metolachlor at 2.0 kg i.a./ha and its mixture with atrazine at 1.0 + 1.0 and 1.25 + 1.25kg a.i./ha significantly had greater 1000 seed weight than all other herbicide treatments (Table 31).

There was no significant effect of intra-row spacing on 1000 grain weight in both 1995 and 1996 (Table 31).

The interaction between chemical weed control and intra-row spacing in both years was not significant (Table 31)

Table 22: Effect of chemical weed control and intra-row spacing on number of ears per plant of popcorn (at 12 WAS[1]) at Samaru grown in 1995 and 1996 wet seasons

Treatments		Number of ears per plant	
		1995	1996
Herbicides (H)	Rate (kg a.i./ha)		
Metolachlor + Metobromuron	1.0 + 1.0	1.00a	1.11a
Metolachlor + Metobromuron	1.5 + 1.5	1.11a	1.22a
Metolachlor	1.5	1.11a	1.22a
Metolachlor	2.0	1.22a	1.33a
Metolachlor + atrazine	1.0 + 1.0	1.33a	1.44a
Metolachlor + atrazine	1.25 + 1.25	1.33a	1.44a
Metolachlor + terbutryne	1.0 + 1.0	1.11a	1.11a
Metolachlor + terbutryne	1.25 + 1.25	1.22a	1.33a
Hoe-weeded(3,6 & 9 WAS)		1.44a	1.55a
Weedy check		0.99b	1.00b
SE (±)		0.17	0.01
		*	*
Intra-row spacing (S)			
15cm		1.37	1.40
30cm		1.36	1.38
45cm		1.35	1.37
SE(±)		1.35 NS	1.37 NS
Interaction			
H x S		NS[2]	NS

1. WAS = Weeks after sowing
2. NS = Non significant

* = Significant at 5%

Means followed by the same letter (S) within the same column and treatment are not significantly different at 5% level of probability.

Table 23: Effect of chemical weed control and intra-row spacing on weight per cob of popcorn (at 15 WAS[1]) at Samaru grown in 1995 and 1996 wet seasons

Treatments		Weight per cob (g)	
		1995	1996
Herbicides (H)	Rate (kg a.i./ha)		
Metolachlor + Metobromuron	1.0 + 1.0	45.55c	47.50a
Metolachlor + Metobromuron	1.5 + 1.5	51.55b	53.14a
Metolachlor	1.5	51.11b	53.17a
Metolachlor	2.0	54.40a	56.11a
Metolachlor + atrazine	1.0 + 1.0	54.51a	56.14a
Metolachlor + atrazine	1.25 + 1.25	54.66a	56.48a
Metolachlor + terbutryne	1.0 + 1.0	54.88a	56.80a
Metolachlor + terbutryne	1.25 + 1.25	51.00b	53.14a
Hoe-weeded(3,6 & 9 WAS)		54.38a	55.88a
Weedy check		37.22d	32.31b
SE (±)		0.57	3.54
		**	**
Intra-row spacing (S)			
15cm		56.77a	58.70a
30cm		53.64b	55.10b
45cm		50.26c	53.17c
SE(±)		0.43 *	0.33 **
Interaction			
H x S		NS[2]	NS

1. WAS = Weeks after sowing
2. NS = Non significant

* = Significant at 5%

* * = Highly significant at 1%

Means followed by the same letter (S) within the same column and treatment are not significantly different at 5% level of probability.

Table 24: Effect of chemical weed control and intra-row spacing on number of cobs per plot of popcorn at Samaru grown in 1995 and 1996 wet seasons

Treatments		Number of cobs per plot	
		1995	1996
Herbicides (H)	Rate (kg a.i./ha)		
Metolachlor + Metobromuron	1.0 + 1.0	29.90e	51.98c
Metolachlor + Metobromuron	1.5 + 1.5	42.44c	52.37c
Metolachlor	1.5	35.22d	52.44c
Metolachlor	2.0	46.22bc	55.55ab
Metolachlor + atrazine	1.0 + 1.0	46.88bc	55.66ab
Metolachlor + atrazine	1.25 + 1.25	52.55b	61.33ab
Metolachlor + terbutryne	1.0 + 1.0	41.97cd	51.55c
Metolachlor + terbutryne	1.25 + 1.25	42.57cd	53.33c
Hoe-weeded(3,6 & 9 WAS)		59.55a	68.00a
Weedy check		28.55de	49.98c
SE (±)		1.7475	4.99
		**	*
Intra-row spacing (S)			
15cm		57.80a	90.40a
30cm		47.23b	46.77b
45cm		26.36c	38.43c
SE(±)		0.75	1.93
		**	**
Interaction			
H x S		NS[1]	NS

1. NS = Non significant
   * = Significant at 5%
   * * = Highly significant at 1%
   Means followed by the same letter (S) within the same column and treatment are not significantly different at 5% level of probability.

Table 25: Effect of chemical weed control and intra-row spacing on cob yield (kg/ha) of popcorn at Samaru grown in 1995 and 1996 wet seasons

Treatments		Cob yield (kg/ha)	
		1995	1996
Herbicides (H)	Rate (kg a.i./ha)		
Metolachlor + Metobromuron	1.0 + 1.0	1300.22c	1870.77c
Metolachlor + Metobromuron	1.5 + 1.5	1669.38b	2393.50b
Metolachlor	1.5	1753.88b	2341.91b
Metolachlor	2.0	1857.75a	2633.14a
Metolachlor + atrazine	1.0 + 1.0	1864.43a	2723.93a
Metolachlor + atrazine	1.25 + 1.25	1873.43a	2760.93a
Metolachlor + terbutryne	1.0 + 1.0	1660.11b	2340.00b
Metolachlor + terbutryne	1.25 + 1.25	1807.18b	2399.44b
Hoe-weeded(3,6 & 9 WAS)		2323.34a	3211.00a
Weedy check		647.156c	940.44d
SE (±)		97.695	26.84
		**	**
Intra-row spacing (S)			
15cm		2078.86a	3174.65a
30cm		1642.32b	2919.67b
45cm		1368.51c	2052.42c
SE(±)		51.56 **	52.94 **
Interaction			
H x S		**	**

* * = Highly significant at 1%

Means followed by the same letter (S) within the same column and treatment are not significantly different at 5% level of probability.

Table 26: Interaction between chemical weed control and intra-row spacing on weed weight of cobs (kg/ha) at Samaru during the wet season of 1995

Weed control treatments	Rate (kg a.i./ha)	Cob Yield (kg/ha) Intra-row spacing (cm)		
		15	30	45
Metolachlor + Metobromuron	1.0 + 1.0	1844.70c	1071.00d	1030.00d
Metolachlor + Metobromuron	1.5 + 1.5	2190.73b	170.30cd	1636.33cd
Metolachlor	1.5	2196.46b	1910.33c	1640.90cd
Metolachlor	2.0	2582.73b	2930.41c	1686.60cd
Metolachlor + atrazine	1.0 + 1.0	2582.73b	1994.10c	1900.70c
Metolachlor + atrazine	1.25 + 1.25	2482.44b	2000.13c	1911.80c
Metolachlor + terbutryne	1.0 + 1.0	2192.46b	1700.10cd	1510.00cd
Metolachlor + terbutryne	1.25 + 1.25	2435.33b	1899.20c	1711.00cd
Hoe-weeded(3,6 & 9 WAS)		3242.20a	2443.33b	2339.44b
Weedy check		852.00e	690.00e	401.10f
SE (±)		163.04		

Means followed by the same letter(s) in both row and column are not significantly different at 5% level of probability.

Table 27: Interaction between chemical weed control and intra-row spacing on weight of cobs (kg/ha) at Samaru during the wet season of 1996

Weed control treatments	Rate (kg a.i./ha)	Cob Yield (kg/ha) Intra-row spacing (cm)		
		15	30	45
Metolachlor + Metobromuron	1.0 + 1.0	2970.00def	2707.00fg	1736.00i
Metolachlor + Metobromuron	1.5 + 1.5	2970.00def	2811.00f	2000.00k
Metolachlor	1.5	2917.00cf	2890.00f	1999.00k
Metolachlor	2.0	3400.00bc	3100.00de	2299.00hi
Metolachlor + atrazine	1.0 + 1.0	3440.00bc	3100.00de	2310.00hi
Metolachlor + atrazine	1.25 + 1.25	3453.00b	3120.00de	2280.00hi
Metolachlor + terbutryne	1.0 + 1.0	2957.00def	2910.00ef	2033.00jk
Metolachlor + terbutryne	1.25 + 1.25	3493.00b	2967.00def	2093.00jk
Hoe-weeded(3,6 & 9 WAS)		4757.00a	3420.00bc	2500.00gh
Weedy check		1480.00L	1433.00L	1233.00m
SE (±)		94.89		

Means followed by the same letter(s) in both row and column are not significantly different at 5% level of probability.

Table 28: Effect of chemical weed control and intra-row spacing on grain yield (kg/ha) of popcorn at Samaru grown in 1995 and 1996 wet seasons

Treatments		Grain yield (kg/ha)	
		1995	1996
Herbicides (H)	Rate (kg a.i./ha)		
Metolachlor + Metobromuron	1.0 + 1.0	925.38f	1591.86e
Metolachlor + Metobromuron	1.5 + 1.5	1290.10d	2007.43d
Metolachlor	1.5	1017.91e	2009.65d
Metolachlor	2.0	1535.60b	2375.11b
Metolachlor + atrazine	1.0 + 1.0	1601.41b	2387.45b
Metolachlor + atrazine	1.25 + 1.25	1621.00b	2395.91b
Metolachlor + terbutryne	1.0 + 1.0	1045.10e	1999.28d
Metolachlor + terbutryne	1.25 + 1.25	1399.10c	2100.77c
Hoe-weeded(3,6 & 9 WAS)		2040.13a	2992.21a
Weedy check		329.06g	610.88g
SE (±)		34.39	11.13
		**	**
Intra-row spacing (S)			
15cm		1618.81a	2702.00a
30cm		1341.76b	2449.00b
45cm		1001.34c	1637.00c
SE(±)		17.65 **	6.23 **
Interaction			
H x S		**	**

* * = Highly significant at 1%

Means followed by the same letter (S) within the same column and treatment are not significantly different at 5% level of probability.

Table 29: Interaction between chemical weed control and intra-row spacing on grain yield at Samaru during the wet season of 1995

Weed control treatments	Rate (kg a.i./ha)	Grain Yield (kg/ha) Intra-row spacing (cm)		
		15	30	45
Metolachlor + Metobromuron	1.0 + 1.0	1107.00i	721.00j	720.00j
Metolachlor + Metobromuron	1.5 + 1.5	1507.00e	1300.00gh	1100.00i
Metolachlor	1.5	1401.00f	1345.00gh	1100.00i
Metolachlor	2.0	1945.00b	1551.00e	1259.00h
Metolachlor + atrazine	1.0 + 1.0	1977.00b	1731.00cd	1679.00d
Metolachlor + atrazine	1.25 + 1.25	1992.00b	1752.00c	1691.00d
Metolachlor + terbutryne	1.0 + 1.0	1413.00f	1300.00gh	1031.00i
Metolachlor + terbutryne	1.25 + 1.25	1800.00c	1534.00e	1410.00f
Hoe-weeded(3, 6 & 9 WAS)		2810.00a	2001.00b	1981.00b
Weedy check		543.00k	3701.00L	298.00m
SE (±)		20.35		

Means followed by the same letter(s) in both row and column are not significantly different at 5% level of probability.

Table 30: Interaction between chemical weed control and intra-row spacing on grain yield at Samaru during the wet season of 1996

Weed control treatments	Rate (kg a.i./ha)	Grain Yield (kg/ha) Intra-row spacing (cm)		
		15	30	45
Metolachlor + Metobromuron	1.0 + 1.0	2600.00e	2390.00kg	1381.00q
Metolachlor + Metobromuron	1.5 + 1.5	2607.00ef	2412.00jk	1603.00q
Metolachlor	1.5	2505.00hi	2470.00ij	1588.00q
Metolachlor	2.0	3000.00b	2660.00e	1885.00n
Metolachlor + atrazine	1.0 + 1.0	2987.00b	2820.00d	1895.00mn
Metolachlor + atrazine	1.25 + 1.25	3000.00b	2840.00cd	1947.00m
Metolachlor + terbutryne	1.0 + 1.0	2570.00fg	2521.0ghi	1600.00p
Metolachlor + terbutryne	1.25 + 1.25	2890.00c	2527.00ghi	1700.00o
Hoe-weeded(3, 6 & 9 WAS)		3990.00a	2983.00b	2104.00L
Weedy check		1033.00r	733.00s	667.00t
SE (±)		19.71		

Means followed by the same letter(s) in both row and column are not significantly different at 5% level of probability.

Table 31: *Effect of chemical weed control and intra-row spacing on 1000 grain weight of popcorn at Samaru grown in 1995 and 1996 wet seasons*

Treatments		1000 grain weight	
		1995	1996
Herbicides (H)	Rate (kg a.i./ha)		
Metolachlor + Metobromuron	1.0 + 1.0	92.46b	93.20b
Metolachlor + Metobromuron	1.5 + 1.5	92.76b	93.37b
Metolachlor	1.5	92.47b	93.34b
Metolachlor	2.0	93.65a	94.61a
Metolachlor + atrazine	1.0 + 1.0	93.68a	94.71a
Metolachlor + atrazine	1.25 + 1.25	93.77a	94.80a
Metolachlor + terbutryne	1.0 + 1.0	92.36b	93.41b
Metolachlor + terbutryne	1.25 + 1.25	92.40b	93 80b
Hoe-weeded(3,6 & 9 WAS)		93.85a	94.90a
Weedy check		73.40c	74.33c
SE (±)		0.21	0.48
		*	*
Intra-row spacing (S)			
15cm		93.90	94.90
30cm		93.70	94.88
45cm		93.64	94.80
SE(±)		0.07 NS	1.17 NS
Interaction			
H x S		NS[1]	NS

1. NS = Non significant

* = Significant at 5%

Means followed by the same letter (S) within the same column and treatment are not significantly different at 5% level of probability.

4.4 Relationship between various parameters and popcorn grain yield

A number of correlations between the grain yield and other parameters have been observed at Samaru during the wet seasons of 1995 and 1996 and pop-corn grain yield was significantly and positively correlated with crop stand count at harvest, plant height at 9 WAS, crop vigour at 9 WAS, leaf area index at 9 WAS, cob yield kilogram per hectare, 1000 grain weight and total dry matter production at harvest (r = o.471 and 0.482, 0.427 and 0.605, 0.457 and 0.452, 0.377 and 0.970, 0.352 and 0.371, 0.534 and 0.613) in 1995 and 1996, respectively (Tables 32 and 33). Also in 1995 and 1996 grain yield was significantly and negatively correlated with weed cover score at 6 and 9 WAS, weed dry matter production and number of days to 50% silking (r = -0.583 and -0.689, -0.662 and -0.703, -0.680 and -0.747, -0.413 and -0.742, respectively) (Tables 32 and 33). Grain yield, however was not significantly correlated with leaf count at 9 WAS (r = 0.444 and 0.588) in both years (Tables 32 & 33).

Table 32: Correlation matrix (r) between grain yield and various parameters as affected by chemical weed control and intra-row spacing at Samaru in 1995 wet season

		Grain yield	Stand count harvest	Leaf area index 9WAS	No. of days to 50% silking	Total dry matter production/plant	1000 grain weight	Cob yield kg/ha	Weed dry matter production	Weed cover score 6 WAS	Weed cover score 9 WAS	Crop vigour score 9 WAS	Leaf count 9WAS
		1	2	3	4	5	6	7	8	9	10	11	12
Grain yield	1	1.000	0.471**	0.343*	-0.413**	0.534**	0.352*	0.377**	-0.680**	-0.583**	-0.662**	0.457**	0.444**
Stand count at harvest	2		1.000	-0.410**	-0.413**	-0.520**	-0.262*	0.556**	-0.231*	-0.293*	-0.154*	-0.281*	0.142
Leaf area index at 9 WAS	3			1.000	-0.579**	0.468**	0.434**	0.332*	-0.466**	-0.286*	-0.321*	0.559**	0.278*
No.of days to 50% silking	4				1.000	-0.324*	-0.348*	-0.391*	0.505**	0.418**	-0.408**	-0.276*	-0.479*
Total dry matter production/plant	5					1.000	0.436**	0.670**	-0.307*	-0.245*	-0.218*	0.562**	0.282*
1000 grain weight	6						1.000	0.179	-0.524**	-0.498**	-0.479**	0.641**	0.284*
Cob kg/ha	7							1.000	-0.618**	-0.525**	-0.618*	0.463**	0.431**
Weed dry matter production	8								1.000	0.597**	0.804**	-0.681**	-0.498**
Weed cover score at 6 WAS	9									1.000	0.760**	-0.543**	-0.431**
Weed cover score at 9 WAS	10										1.000	-0.447**	-0.447**
Crop vigour score at 9 WAS	11											1.000	0.444**
Leaf count at 9 WAS	12												1.000
Plant height at 9 WAS	13												

* = Significant at 5% level of probability.

** = Significant at 1% level of probability.

WAS = Weeks after sowing.

Table 33: Correlation matrix (r) between grain yield and various parameters as affected by chemical weed control and intra-row spacing at Samurai in 1996 wet season

		Grain yield 1	Stand count ha-vest 2	Leaf area index wA 3	No. of days to 50% silking 4	Total dry matter pro-duction/plant 5	1000 grain weight 6	Cob yield kg/ha 7	Weed dry matter producti on 8	Weed cover score 6WAS 9	Weed cover score 9WAS 10	Crop vigour score 9 WAS 11	Leaf count 9WAS 12
Grain yield	1	1.000	0.482**	0.452**	-0.742**	0.613**	0.371**	0.970**	-0.747**	-0.689**	-0.703**	0.513**	0.588**
Stand count at harvest	2		1.000	-0.506**	-0.410**	-0.460**	-0.089	0.599**	-0.200*	-0.265*	-0.192*	-0.269*	0.256*
Leaf area index at 9 WAS	3			1.000	-0.479**	0.734**	0.587**	0.389**	-0.645**	-0.451**	-0.511**	0.667**	0.319*
No.of days to 50% silking	4				1.000	-0.614**	0.468**	0.683**	0.683**	0.670**	-0.629**	-0.376*	0.466**
Total dry matter production/plant	5					1.000	0.587**	0.540**	-0.776**	-0.567**	-0.610**	0.729**	0.417**
1000 grain weight	6						1.000	0.296*	-0.534**	-0.375*	-0.460**	0.631**	0.285*
Cob kg/ha	7							1.000	-0.684**	-0.621**	-0.665**	0.337*	0.555**
Weed dry matter production	8								1.000	0.710**	0.810**	-0.644**	-0.554**
Weed cover score at 6 WAS	9									1.000	0.694**	-0.644**	-0.513**
Weed cover score at 9 WAS	10										1.000	-0.437**	-0.475**
Crop vigour score at 9 WAS	11											1.000	0.292*
Leaf count at 9 WAS	12												1.000
Plant height at 9 WAS	13												

* = Significant at 5% level of probability.

** = Significant at 1% level of probability.

WAS = Weeks after sowing.

Chapter 5

DISCUSSION

In this study, it was observed that yield obtained from 1995 wet season was generally lower with (about 31.7%) than that obtained in 1996. The low yield in 1995 was probably due to late establishment of rainfall which led to late planting (Table 2), and high infestation of streak virus (MSV) caused by Locris maculatus and corn stem borer Busseola fusca which led to loss of many plant stands at the later stage of crop life cycle.

Fajemisin (1985) recorded 50% yield loss due to early infection of corn by streak virus through poor grain formation and barrenness. In the same year 1995, weed growth and competition was more serious. This must have caused reduction in crop growth and subsequent yield.

5.1 Effect of herbicide treatments on weeds and pop-corn growth and yield

In spite heavy weed infestation at the sites of experiment, a good measure weed was obtained with a number of herbicide treatments such as metolachlor alone at 1.5 and 2.0 kg a.i./ha and mixtures of metolachlor plus metobromuron at 1.0 + 1.0 kg a.i./ha and 1.5 + 1.5 kg a.i./ha could, atrazine at 1.0 + 1.0 kg a.i./ha and 1.25 + 1.25 kg a.i./ha, terbutryne 1.0 + 1.0 kg a.i./ha and 1.25 + 1.25 kg a.i./ha as reflected in weed cover score and weed dry matter production.

Metolachlor alone at 1.5 and 2.0 kg a.i./ha and mixtures of metolachlor plus metobromuron at 1.0 + 1.0 kg a.i./ha and 1.5+1.5 kg a.i./ha could not give a better weed control of broadleaved weeds as compared to other herbicide treatments. Martin and Wothing (1977) reported that metolachlor is mainly active on grasses and sedges at the rate of 1.0 to 2.0 kg a.i./ha depending on the soil and climatic conditions. However, broad spectrum of weed control to include broad leaved species is possible if metolachlor is combined with other herbicide (Lagoke et al, 1983). Mixture of metolachlor plus terbutryne at 1.0 + 1.0 kg a.i./ha and 1.25 + 1.25 kg a.i./ha resulted in high crop vigour, plant height, leaf area index and grain yield. Metolachlor plus metobromuron at 1.0 + 1.0 kg a.i./ha gave the least performance on the growth parameters and yield when compared to mixtures of metolachlor plus atrazine at 1.0 + 1.0 kg a.i./ha and 1.25 + 1.25 kg a.i./ha. Lagoke (1978) reported yield of maize of 1991 kg./ha with metolachlor plus metobromuron at 1.0 + 1.0 kg a.i./ha when compared to the highest yield of 2,750kg/ha of corn obtained with mixtures of metolachlor plus atrazine at 1.5 + 1.5 kg a.i./ha.

In this study, mixtures of metolachlor plus atrazine at 1.0 + 1.0 kg a.i./ha and 1.25 + 1.25 kg a.i./ha combined effective weed control with high popcorn grain yield better than metolachlor at 1.5kg a.i./ha and mixtures of metolachlor plus metobromuron at 1.0 + 1.0 kg a.i./ha and 1.5 + 1.5 kg a.i./ha and metolachlor plus terbutryne at 1.0 + 1.0 kg a.i./ha and 1.25 + 1.25 kg a.i./ha. This result is similar to those obtained by Lagoke, et al. 1986, Akobandu

1987 and Ogungbile et al 1982 who obtained higher maize grain yield similar to the hoe-weeded control with pre-emergence application of metolachlor plus atrazine.

5.2 Effect of intra- row spacing on weeds and popcorn growth and yield

Spacing had significant effect on weed cover score. The closest intra-row spacing of 15cm resulted in significantly lower weed cover score, weed count (of grasses, broadleaved and sedges) and weed dry matter production than 30 and 45cm in 1995 and 1996 respectively. The significant reduction in weed cover score, weed count and weed dry matter production obtained with the 15 intra-row spacing compared with the 30 and 45cm could be attributed to better canopy production hence smothering of weeds. Both leaf production and plant height of 15cm were also higher than those of wider spacings in this study and these probably facilitated effective canopy formation for weed control. Kust and Smith (1969) similarly observed that weed control increased with narrower spacing in soyabean and corn Dougherty (1969) and Samuel (1970) has earlier reported that the shading effect of quickly formed canopy of soyabean and corn in narrow rows accounted for more effective weed control in narrow rows than in wider rows.

Plant spacing is one of the agronomic practices reported by Haisel and Harper (1973) to influence the growth and development of any given crop. Shaf Shak et al. (1984) suggested that closer spacing may be needed to optimize the yields of corn.

The significant increase in plant height, number of leaves per plant and crop vigour score with decreasing spacing in this study, confirms the work done by Shune et al. (1989) who reported increase in internode growth, number of leaves per plant, plant height and crop vigour with density. The significant increase also in the total dry matter production with decreased intra-row is in conformity with what was reported by Shune et al. (1989). The increase in leaf area index with decreased in spacing is due to more number of plants per area. Decreasing in intra-row had been attributed to improve leaf area index and consequently increasing grain yield (Olson and Sander, 1988). The significant increase in cob yield obtained by decreasing spacing could be attributed to increase in either leave area index or increased population. Samuel (1970) observed that increase in leaf area index resulted in increased ear yield of corn. While Machul (1988) attributed increased yield to greater population density.

In this study, it was observed that intra-row spacing significantly affected corn grain yield in 1995 and 1996. In both years, intra-row spacing of 15cm resulted in higher grain yield (10 to 61.7% than that of 30 and 45cm spacings. There were two obvious advantages in the close spacing. First, there was better and early leaf canopy formation coupled with higher population density This observation is in agreement with that of Shaf Shak et al. (1984) who reported increased corn yield at close spacing of 15cm.

5.3 Interaction effect between weed control treatments and intra-row spacing popcorn growth and yield

Significant interactions between weed control treatments and intra-row spacing were observed in terms of weed cover score at 9 WAS and weed dry matter production in 1995 and 1996 wet seasons. In each of these interactions, all interactions of herbicides and spacing resulted in lower weed cover score and weed dry matter production than the interactions of spacing and weedy check. Though greater weed cover score and weed dry matter production resulted from the interactions of herbicides and spacing than interaction of spacing and hoe-weeded control.

Interaction of weed control treatments and spacing on crop vigour score at 9 WAS in 1995 and 1996 was significant. At 15cm spacing higher crop vigour was recorded than that of 30 and 45cm spacings in both years. The observed better crop growth at 15cm spacing may be due to early canopy formation which enhanced good weed control to the advantage of the crop. In addition, the interaction of weed control treatments and spacing on cob yield kilogram per hectare and grain yield kilogram per hectare in 1995 and 1996 were significant. At 15cm spacing higher cob count was recorded than 30 and 45cm. The higher number of cobs in 15cm spacing due to higher number of stand count, led to higher cob and grain yield. In contrast at wider spacing less was the number of crop stand which led to lower cob and grain yield.

5.4 Relationship between various parameters and popcorn grain yield

The significant positive correlation in 1995 and 1996 between popcorn grain yield and growth characters such as crop vigour, plant height and leaf area index may be attributed to the fact that those parameters determined the grain yield. Weed cover score at 6 and 9 WAS, and weed dry matter production was also negatively correlated with corn grain yield in this study (Tables 30 and 31). Bakut (1985) reported similar significantly positive correlation between grain yield and vegetative growth as well as negative correlation between grain yield and weed cover score at 6 and 9 WAS, and weed dry matter production.

The highly significant positive correlation between the yield attributes viz weight of cobs and total dry matter production with grain yield in 1995 and 1996 revealed those as important yield components and critical determinant of pop-corn grain yield.

Chapter 6

SUMMARY AND CONCLUSION

Field trials were conducted to study the effect of chemical weed control and intra-row spacing in popcorn (Zea mays L. Var. everta) during the rainy season of 1995 and 1996 at the Institute for Agricultural Research Farm, Samaru.

The treatments tested consisted of eight pre-emergence herbicides supplemented with hoe-weeding at 7 WAS were compared with three hoe weeding plots at 3, 6 and 9 WAS and weedy check, and three intra-row spacings 15, 30 and 45cm. Each treatment was replicated three times laid in a split plot design.

The use of herbicide supplemented once with hoe-weeding resulted in significantly lower weed cover score, weed count and weed dry matter production, and also resulted to increase in growth and yield parameters over the weedy check in 1995 and 1996.

In this study, it was shown that at least three hoe weedings are required for optimum yields of popcorn. Also metolachlor at 2.0kg a.i./ha and a mixture of metolachlor plus atrazine at 1.0 + 1.0 kg a.i./ha and 1.25 + 1.25 kg a.i./ha combined effective weed control with high popcorn grain yields comparable to the hoe-weeded control. Also herbicide mixtures are to be more preferred to single herbicides in popcorn because grasses, broadleaved weeds and sedges are equally important.

Hence, it is necessary to use herbicides that have a wide spectrum of weed control especially in the Northern

Guinea Savanna.

Unchecked weed growth throughout the crop life cycle resulted in 83.8 and 72.9% reduction in grain yield during 1995 and 1996 wet season respectively.

In the study in 1995 and 1996, intra-row spacing had no significant effect on number of leaves per plant, number of days to 50% tasseling and silking, number of ears per plant and 1000 seed weight. While weed cover score at 6 and 9 WAS, weed count, weed dry matter production, plant height at 6 and 9 WAS, number of leaves per plant at 6 WAS, total dry matter production per plant, stand count at 6 and 9 WAS and at harvest, weight per cob, number of cobs per plant, cob yield kilogram per hectare, and grain yield kilogram per hectare were however significantly influenced by the intra-row spacing in 1995 and 1996 respectively.

Grain yield were significantly and positively correlated with crop vigour, plant height, leaf are index and stand count at harvest, and negatively correlated with weed cover score at 6 and 9 WAS, and weed dry matter production (r= 0.457 and 0.513, 0.427 and 0.605, 0.343 and 0.452, 0.471 and 0.482, -0.583 and -0689, -0.662 and -0.703) in 1995 and 1996 wet seasons (Tables 31 & 32).

Based on the results obtained from this study, the application of metolachlor at 2.0kg a.i./ha and its mixture with atrazine at 1.0 + 1.0 and 1.25 + 1.25kg a.i./ha, and the closet intra-row spacing of 15cm resulted in better weed control and higher popcorn grain yield which can be recommended for optimum popcorn production.

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Appendix 1: Common and Chemical names of herbicides mentioned in the text.

Common Names	Chemical Names
Metolachlor	2-Chloro-N-(2-ethyl-6-methyl C-Phenyl)-N-(2-methoxyl-1-methyl) acetamide.
Atrazine	2-Chloro-4(ethylamino)-6 (Isopropylamine-S-triazine).
Terbutryne	2(tert-butylumino)-4-(ethylamino)-6-(methyl-thio-S-triazine).
Metobromuron	2-(4-bromophenyl)-N-Methoxy-N-methyl Urea.

Appendix 2a: Anova tables for weed dry matter production in 1995 and 1996

1995

Source	Degree of Freedom	Sum of Square	Mean Square	F Value	Probability
Replication	2	2534.422	1267.211	2.5139	0.1089
Factor A	9	1142042.278	126893.586	251.7354	0.0000
Error	18	9073.356	504.075		
Factor B	2	75473.356	37736.678	45.3763	0.0000
AB	18	76332.422	4240.690	5.0992	0.0000
Error	40	33265.556	831.639		
Total	89	1338721.39			

1996

Source	Degree of Freedom	Sum of Square	Mean Square	F Value	Probability
Replication	2	1101.571	550.785	1.3393	0.2869
Factor A	9	1013463.063	112607.007	273.8257	0.000
Error	18	7402.285	411.237		
Factor B	2	59659.313	29829.657	548.1684	0.000
AB	18	60336.057	3352.003	0035.4128	0.000
Error	40	24771.118	619.278		
Total	89	1166733.397			

Appendix 2b: Anova tables for grain yield in 1995 and 1996.

1995

Source	Degree of Freedom	Sum of Square	Mean Square	F Value	Probability
Replication	2	15650.906	7825.453	0.7349	
Factor A	9	18923501.358	2102611.262	147.4698	0.0000
Error	18	191659.7946	10647.764		
Factor B	2	10240313.543	5120156.772	547.4516	0.0000
AB	18	5977377.861	332076.548	35.5056	0.0000
Error	40	374108.476	9352.712		
Total	89	35722611.893			

1996

Source	Degree of Freedom	Sum of Square	Mean Square	F Value	Probability
Replication	2	1769.907	884.953	0.7349	
Factor A	9	26660771.423	2962307.941	2656.0582	0.0000
Error	18	20075.442	1115.302		
Factor B	2	18561940.942	9280920.471	7963.0039	0.0000
AB	18	2283831.595	126879.533	108.86178	0.0000
Error	40	46620.449	1165.511		
Total	89	47575009.907			

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