EFFECTS OF NITROGEN, PERIOD OF WEED INTERFERENCE AND HERBICIDES ON THE PERFORMANCE OF KENAF (Hibiscus caimahinus L.) IN THE NORTHERN GUINEA SAVANNA OF NIGERIA

BY

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A Dissertation submitted to the Postgraduate School, Ahmadu Bello University in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Agronomy

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MAY, 1998

DECLARATION

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

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CERTIFICATION

This thesis entitled **"EFFECT OF NITROGEN, PERIOD OF WEED INTERFERENCE AND HERBICIDE ON THE PERFORMANCE OF KENAF (Hibiscus cannabinus L.) IN THE NORTHERN GUINEA SAVANNA OF NIGERIA"** by November Chiroma Kuchinda meets the regulations governing the degree of Doctor of Philosophy of Ahmadu Bello University, Zaria, and is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

This work is dedicated to late Mal. Kuchinda Chiroma and Mrs. Zenuka Kuchinda for their foresight, sacrifice and support that have earned me the academic status.

ACKNOWLEDGEMENT

I wish to express my sincere gratitude to Dr. W.B. Ndahi (Chairman, Supervisory Team) for his invaluable assistance, useful suggestions and guidance during the conduct of the experiments and preparation of this manuscript. The same sincere gratitude goes to Prof. S.T.O. Lagoke and Prof. M.K. Ahmed (Supervisors) for their outstanding contribution to the success of this study and preparation of the manuscript. I gratefully acknowledge Dr. Y. Yusuf, a member of the supervisory team at the preliminary stages of the project.

My profound appreciation is also extended to Dr. E.B. Amans, the Head of Agronomy Department who, in various ways contributed to the success of this work. I very much appreciate the efforts of the immediate past Programme Leader, Prof. V.B. Ogunlela and Director of the Institute for Agricultural Research, Samaru, in allowing the project to be conducted under the Fibre Research Programme of the Institute.

I am grateful to Mr. G. Ritkangnga who assisted in data collection and to Mr. S. Mutdin who also assisted in the collection of data during the first year of trials. I am also grateful to Mr. John Ajegenea for printing the manuscript of this thesis. I acknowledge the encouragement by all the staff of Agronomy Department.

I am greatly indebted to my wife, Ladi; daughter, Tamana and senior brother; Mr. Iliya and mother and late father for their patience, love, understanding and moral support during the period of my study.

Above all, I am eternally grateful to the Almighty God who upholds everything and makes all good things possible through his Love and Grace.

ABSTRACT

Field experimenfewere conducted during the 1993 to 1995 wet seasons to study the effects of period of weed interference and herbicides on the yield performance of kenaf (Hibiscus cannabinus L.) grown under varying N levels at the Institute for Agricultura Research, Samaru (11° ll'N; 07° 38'E).

The results showed that N application significantly increased wood, fibre and seed yields of kenaf. This was as a result of the increase in growth parameters, viz crop vigour score, plant height and butt diameter. Nitrogen fertilizer application also caused early flowering in kenaf. Application of 90 kg N/ha at 12 WAS in 1994 and 45 and 90 kg N/ha at 9 WAS in 1995 in the weed control trials caused singificant reduction of weed cover score in the crop.

Initial weed infestation for 6 WAS and beyond depressed crop growth and yields compared to the weed-free control. The growth and yields of the crop kept weed-free for 6 WAS and beyond were however comparable to the maximum in the trial and the weed-free control. The critical period of weed competition in kenaf was between 3 and 6 WAS.

Metolachlor and alachlor each at 1.50 kg and the mixtures with ametryne at 1.0 + 1.0 kg consistently depressed weed cover score. Similar results were obtained by fusilade at 0.75 kg and its mixture with ametryne at 0.50 + 1.0 kg, although the treatments were fairly phytotoxic to the crop. The weed control treatments with exception of metolachlor in 1995 and fusilade in 1994 and 1995 resulted in greater crop vigour score than the weedy check at 6-12 WAS in 1993 and 1995 and 9-12 WAS in 1994. Alachlor and its mixture with ametryne increased wood yield over the weedy check and was comparable to hoe-

weeding at 3 and 6 WAS in 1995. A similar result on ribbon yield was obtained by the mixture with fusilade in 1993. Alachlor and mixtures containing metolaehlor and alachlor increased fibre yield in 1995. Alachlor + ametryne and fluazifop-butyl (fusilade) in 1993, mixture with alachlor and metolaehlor alone in 1994 and fusilade + ametryne in 1995 increased the number of capsules per plant. Weed infestation throughout the crop growth cycle caused 28.2% to 53.0% wood yield, 26.5% to 55.3% fibre yield and 21.9% to 63.8% seed yield reductions compared to the highest yields obtained in 1993, 1994 and 1995, respectively.

Seed and fibre weights per plant were positively correlated with crop vigour score, plant height, butt diameter and number of capsules per plant. Seed weight was positively correlated with 100-seed weight. *Seed* and fibre yields were however, negatively correlated with the number of days to first flowering, weed cover score and weed dry weight. Wood yield was a major contributor to fibre yield, while butt diameter was a major contributor to seed yield.

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CHAPTER ONE

1. INTRODUCTION

1.1 Importance, Uses and Production of Kenaf

Kenaf (Hibiscus cannabinus L.), a leading substitute to jute, is often superior to jute for most important applications. The commercial production of kenaf has been stepped up greatly during recent years in many tropical and sub-tropical countries in order to replace the use of jute, save the cost of jute importation, create new industries and ensure self-sufficiency. It is also in line with this that kenaf production in Nigeria is being encouraged to meet the demands of the agro-allied factories.

The fibre is comparable to jute in lustre, although it is coarse, less supple and resistant to rottening. The cordage fibre is used in sacks, mats, carpets, ropes, roofing and canvass. The stalk is used as paper pulp. The seeds contain about 20% oil (Purseglove, 1968) which is extracted and used as lubricant and for illumination, soaps, paints and varnishes. The leaf contains about 25% crude protein (Killinger, 1965) and is used in human diets and animal feeds.

Kenaf is grown within a wide geographical range (Lat. 45° N - 30° S). Although there is no clear statistics on kenaf, the world's average jute and jute-like fibre production was put at 4.44 million metric tonnes per annum for the years 1991-1993 (FAO, 1994). Of this amount, Asia produced 3.34m tonnes; India being the leading producer with an average of 1.57m tonnes. Africa produced only 0.02m tonnes during the same period. However, Nigeria's production, approximated at 367t fell far short of domestic

requirement of the Badagry and Jos processing factories (Anon, 1971). Other world producers of kenaf include the former Soviet Union, China, South Africa, Egypt, Mexico and Cuba. The world's average yields in 1991-1993 were put at 1.61 t/ha, with Vietnam having the highest average yield of 2.39 t/ha, while Africa produced only 0.82 t/ha (FAO, 1994). The potential fibre yield of kenaf in the Nigeria's savanna has been estimated at 1.50 - 2.50 t/ha (Kumar et al., 1985).

1.2 Constraints to Kenaf Production in Nigeria

The generally low production of kenaf in Nigeria is due in part, to the limited usage of its products. Most farmers cultivate the crop mainly for local consumption, and so its production has remained at a subsistent level. In addition to this, the actual fibre yields obtained from the farmers' plots are far below the potential yield estimates of 1.50 - 2.50 t/ha. A number of factors are responsible for the low yields. There is poor knowledge of the necessary cultural practices such as plant density, nutrient requirement as well as pests, disease and weed management. Other problems may include the use of low yielding varieties and adverse environmental stresses during the growing season.

Kenaf production in the northern Guinea savanna of Nigeria is limited by nitrogen because the soils are inherently low in native N and P (Heathcote and Stockinger, 1970; Mokwunye, 1979). Although no report is available, Idem (1977) did not observe any response to N by the crop in the southern Guinea savanna. There is therefore the need to conduct an indepth study on the response of the crop to N application in the northern Guinea savanna of Nigeria.

1.3 Effect of Weeds on Kenaf

Weed infestation is one of the major constraints to crop production, especially in the tropics where environmental conditions are conducive for their proliferation. Mayer (1976) observed that in developing countries of the humid tropics, weed problems are very serious and weeding consumes more than 50% of the labour required to produce a crop. Weeds compete with the crop plants for water, light, nutrients and space; and this directly affects the crop yield. Kenaf is susceptible to weed infestation, especially during the early growth stages. This is due to its slow initial growth rate. Reports have indicated that unchecked weed infestation could reduce fibre yield by 31-59% (Baker, 1970; Lagoke et al., 1981; Kuchinda et al., 1991). Apart from the problem of yield reduction, weeds may also hamper the harvesting operation (Nieto et al., 1968) and contaminate the crop produce. Weeds may also serve as alternate hosts of crop pests and diseases.

The most susceptible period of crop growth to weed interference has been described as the critical period of weed competition. It is ofen the first quarter of the crop growth cycle (Nieto et al., 1968). In most crops, the damage at this critical period is irreversible. If such damage is avoided during this period, initial or subsequent weed competition is not likely to have significant effect on yield. Factors such as relative growth of the crop and weeds, plant density, crop variety and time of moisture and nutrients stresses have been reported to influence the precise time and duration of maximum competition (Shadbolt and Holm, 1956). Studying the various weed control measures without assessing the critical period of weed competition may not be adequate in evolving an optimum control package.

There is therefore the need to investigate the critical period of weed competition for kenaf in the northern guinea savanna of Nigeria.

1.4 Current Control Methods and their Limitations

Kenaf production is still at a subsistent level in Nigeria and the traditional methods of checking weeds are generally applied just as in all the other crops that are produced by peasant farmers. These methods are mainly hoe-weeding and hand-pulling. The mannual methods are labour-intensive, strenuous and limited to small scale production. Hoe-weeding is likely to cause mechanical damage to the crop plants (Olunuga and Akobundu, 1980), especially with respect to a closely spaced crop such as kenaf. Labour is not readily available around farm locations, and when available, it is usually expensive (Chinaka and Enyinnia, 1981). Similarly, the uncertainty of labour availability often makes timely weeding to be unpracticable (Lagoke et al., 1981). There is therefore the need to consider a more efficient and cost-effective alternative measure to manual weeding in kenaf.

1.5 The Use of Herbicides

Although the use of herbicides is a new introduction in tropical Africa (Chinaka and Enyinnia, 1981), it is generally considered to be more efficient than the manual methods since it reduces labour requirement with its attendant cost (Ogungbile and Lagoke, 1986; Lagoke and Shebayan, 1988). The use of herbicides also helps to address the problem of labour availability especially on farms that are remote from human settlements. The use of herbicides minimizes soil erosion and displacement of plant nutrients since it does not

disturb the soil. Herbicides reduces the drudgery of hand-weeding and the time spent on the operation could be devoted to other farming operations. The use of herbicides is however more viable under commercial crop production than the traditional hand weeding. There is the need to evaluate herbicides for selective weed control in kenaf.

1.6 Objective of the Study

The objectives of this investigation are therefore:-

(i) to evaluate the effect of period of weed interference on kenaf fibre yield under varying nitrogen levels.

(ii) to evaluate the effect of some herbicides and herbicide mixtures on kenaf fibre yield under varying nitrogen levels.

CHAPTER TWO

2 REVIEW OF LITERATURE

2.1 Effect of Nitrogen on Kenaf

Nitrogen is an essential macro elements for plant growth and development. Nitrogen metabolism in plants results in the synthesis of soluble N-compounds, proteins, alkaloids, chloroplyll and other complex substances which are necessary for promoting aerial growth as well as formation of fruits and seeds (Olson et al., 1970). Unlike in most other crops, response of kenaf to nitrogen has not been consistent (White et al., 1970; Massey, 1974). Some positive responses have however been reported in Florida (Karbassi and Willinger, 1966), Western Nigeria (Baker, 1970) Ghana (Amankwatia and Takyi, 1975), Sudan (Salih, 1977) and Uzbekistan (Tsygankova, 1977). Joyner et al. (1964) reported that nitrogen significantly increased fresh weight and green stalk yield on a sandy soil. Whereas there was a significant response of kenaf to N in the savanna zone, none was observed in the forest zones of Nigeria (Baker, 1970) and Ghana (Amankwatia and Takyi, 1975). Tsygankova and Safagaraeva (1977) observed that N application increased stem yield of kenaf by 3.61 - 4.23 t/ha. Applying 50 kg N/ha before sowing and two top dressings, each at 75 kg N/ha gave the highest yield (Tsygankova, 1977).

Plant height and fibre length increased with increase in N rate, but no significant effect was observed on butt diameter and dry matter yield (Idem, 1977). Plant height, butt diamter and fibre yield were increased by N, and splitting the application of N gave higher yields than the same amount applied in a single dose (Adamson et al., 1979).

Lakshminarayana et al. (1980) observed that the fibre yield increased as N rates increased from 0-80 kg N/ha. Bhangoo et al. (1986) reported that applying N at 135 and 180 kg/ha resulted in 71% and 83.5% increase in yields over the no N control, respectively. Dry ribbon yield of kenaf increased from 4.95t with no N application to 5.93 and 6.10t with 43 and 86 kg N/ha, respectively (Salih, 1983). The root growth also increased with N rates upto 80 Kg N/ha, but was depressed at 180 kg N/ha (Bhangoo et al., 1986). Lyons et al. (1991) reported that 240 kg N/ha was required for maximum stem yield and the application of N did not influence the yield except where the initial soil N was low.

Amon (1966) and de Geus (1973) have earlier recommended 51.5 and 60 kg N/ha for kenaf, respectively. Optimum fibre yield was obtained by 100 kg N/ha or slightly higher (Amankwatia and Takyi, 1975; Gutteridge, 1985). In the southern guinea ecological zone of Nigeria, Idem (1985) did not observe any significant response to N. A similar observation was earlier reported in Nebraska (Williams, 1966).

Increasing N rates increased N but reduced P and K contents in whole plants (Adamson et al., 1979; Bhangoo et al., 1986) and a high N supply reduced bast fibre strength and increased its coarseness (Joyner, 1964). Singh et al. (1988) also reported that high N rates increased fibre length and fineness but also decreased fibre strength.

2.2 Effect of Nitrogen on Weed Interference and Control

Both the crop plants and weeds respond to nitrogen fertilization, although the response may vary from place to place, as well as from one plant species to the other. Blackman and Templeman (1938) revealed that in a normal rainfall year, low growing weeds species compete for N and so recommended high N rates as a means of suppressing

moderate weed populations. On a weed infested field that was low in native N, wheat showed a greater response to applied N than on its weed-free counterpart (Buchanan and Mclaughin, 1975). At lower N levels, a wheat crop that was infested by weeds showed higher response to the element than the weed-free crop (Hawkins and Blackman, 1958). Dotzenko et al. (1969) observed that the rate and time of N fertilization affected weed population and the number of weed species that emerged. Buchanan and Burns (1970) have observed that the magnitude of interference by grasses and broad leaf weeds on cotton was not altered by variation in N rates upto 100 kg N/ha. Adejonwo (1988) reported that only broadleaf weed dry matter production responded to the applied N because they emerged later in the season; and that increasing N level from 0-150 kg N/ha resulted in lower okra fruit number in plots kept weed-infested for 3 WAS compared with those kept weed-free throughut the crop life-cycle.

Charles (1968) reported that the N level necessary to obtain maximum yield potential can itself act as a weed control measure. It has been reported that application of N enhanced the efficacies

of some herbicides on certain crops (Buchanan and Melaughin, 1975; Khalilov, 1975 and Dadari, 1983). The phytotoxic effect of diuron on cotton was reduced and susceptibility of weeds to the herbicide was increased by N application (Buchanan and Mclaughin, 1975). Pre-emergence application of fluometuron with N was observed to enhance the phytotoxicity of the chemical on weeds (Khalilov, 1975). Dadari (1983) reported that at 60 kg N/ha, weed weight was lower in cotton plots treated with high rate of fluridone plus ametryne. However, there is limited work done to evaluate the influence of N on weed

interference and control in kenaf.

2.3. Losses Due to Weed Competition in Kenaf

Weeds constitute a serious problem in crop production, especially under rain-fed conditions in the Nigeria's savanna. Kenaf is susceptible to weed infestation at the early growth stages since it has a slow rate of growth initially (Lagoke et al., 1981). Therefore a good kenaf yield performance may not be attained where the weeds are left unchecked, especially during the early growth stages. Baker (1970) observed a 14-31% increase in fibre yield in the hoe-weeded plots as compared with those that were left weedy. However, hoe-weeding should be discontinued as soon as the crop is 60-90cm tall (Kirby, 1963). This is to avoid injuries to the roots of the plants. Lagoke et al. (1981) reported a fibre yield loss of upto 59% due to unchecked weeds throughout the crop life-cycle. Kuchinda et al. (1991) also observed that weeds resulted in the reduction of 47.2% and 30% fibre and capsules yields respectively, as compared with the best weed control treatments in the trial.

2.4 Critical Period for Weed Interference in Kenaf

The critical period of weed interference is the period when the crop is most susceptible to weed competition (Nieto et al., 1968). In most annual crops, the final yields are not affected by the presence of weeds up to a certain stage of growth if the weeds are subsequently removed and the crop is kept weed free thereafter. Conversely, if the crop is kept weed-free upto a certain growth stage, subsequent weed infestation would not affect

the yield. In between these stages is the critical period, during which the weeds must be removed, otherwise there will be significant yield reduction. Nieto et al. (1968) observed that in most vegetable crops the greatest losses in yield due to weed interference occurs during this critical period.

The precise time and duration of period for maximum competition depends on many factors such as relative rate of growth of the crop and weeds, weed flora, crop population and variety, and times of moisture and nutrient stresses. For most crops, it has been estimated to be the first quarter of the crop growth cycle. However, Kasasian and Seeyave (1969) reported that for most vegetable crops, the first third of the crop growth cycle has to be kept weed-free if adverse effect of weeds on yield is to be avoided. Lagoke et al. (1981) estimated the critical period for weed competition on kenaf to be between 3-4 weeks after sowing (WAS). Concise information on the critical period for kenaf is still limiting, particularly in the northern guinea savanna of Nigeria.

2.5 Weed Control in Kenaf

Weed control has been identified as one of the most important crop production practices. The problems associated with manual weed control can be addressed by the use of herbicides which have been found to lower production cost. In Nigeria, the use of herbicides have been reported to be more profitable than hoe-weeding (Bakut, 1985; Sinha et al., 1982; Ogungbile and Lagoke, 1986; Lagoke and Shebayan, 1988; Adigun, 1991). The feasibility of chemical weed control on kenaf has been reported by a number of workers. The promising herbicides on kenaf include alachlor, metolachlor and ametryne

(Boulanger et al., 1973; Michieka et al.; 1977; Lagoke et al., 1981; Kuchinda et al., 1991). Kuchinda et al. (1991) have observed that ametryne in mixture with either alachlor or metolachlor performed better than when the individual herbicides were each applied alone. Fluazifop-butyl has also been reported to control weeds and increase seed yield per plant of kenaf, although it was found to be moderately phytotoxic to the crop (Kuchinda, et al., 1991).

Herbicides act by influencing some metabolic processes within the susceptible plants. The major targets for the action of the herbicides are the metabolic pathways such as biosynthesis, photosynthesis and regulation of cell division (Fedtke and Trebst, 1986).

2.5.1 Chloroacetamides

Chloroacetamides are substituted acid amides which have monochlorinated methyl [Cl-CH_2] in the R1 position. Members of this group include alachlor, metolachlor metazachlor, among others. They are mostly used as selective herbicides in vegetables and field crops for the control of grasses, some broad leaf weeds and sedges (Ashton and Crafts, 1981). Chloroacetamides are readily absorbed by plants, primarily by seeds and the first node of germinating seedlings; and appear to be translocated in the apoplast system, although symplastic movement may occur. These herbicides are readily taken up by both susceptible and resistant species, but appear to be more rapidly degraded in the resistant species (Jaworski, 1975). Lethal concentrations accumulate in those plants with low rate of metabolism of the chemical, and this gives the basis for selectivity. Members inhibit mitochondrial phosphorylation and reduce cell division in the primary meristem

(Audus, 1976). They also affect protein metabolism. The soil applied-amides inhibit seed germination and root elongation, while the foliar applied results in localized or general necrosis (Audus, 1976).

1. Alachlor

Alachlor [(α C-chloro-2, 6-diethyl-N-(methoxymethyl) acetanilide] is applied pre-emergence or early post-emergence for the control of grasses, yellow nutsedge and certain broad leaved weeds in broad leaved crops like cowpea, soyabeans, sunflower, cotton and some vegetables. Boulanger et al. (1973) observed that alachlor at rates exceeding 1.50 kg a.i/ha reduced fibre yield of kenaf by 15-20% in the Republic of Benin. However, of the eighteen herbicides tried, Michieka et al. (1977) observed that alachlor at 2.4 kg a.i/ha was the safest on kenaf. In India, Saraswat and Mitra (1977) reported that pre-emergence application of alachlor at 1.2 kg gave effective weed control in the crop., In the southern guinea zone of Nigeria, Lagoke et al. (1981) reported that treatments with alachlor at 1-2 kg resulted in higher fibre yields compared with the weedy control. A similar observation has been made in the northern guinea zone of Nigeria (Kuchinda et al., 1991). In Brazil, alachlor at 2.4 kg gave selective weed control in kenaf (Deuber et al., 1982). A fibre yield increase of up to 45% over the weedy control was achieved by applying alachlor at 2.00 kg (Kuchinda et al., 1991). Application of alachlor plus ametryne at 2 + 1 kg a.i/ha followed by supplementary hoe-weeding at 6 WAS resulted in a season-long weed control and increased okro pod yield over two and three hoe-weedings (Lagoke et al., 1986; Adejonwo et al., 1987).

2. Metolachlor

Metolachlor [α C-chloro-6-ethyl-N-(2-methoxy-1-Methylethyl)-0-aceto-toluidide] has a solubility of 530 mg/kg at 20°C. It is applied pre-emergence and it inhibits seedling emergence. The primary mode of action of metolachlor is inhibition of protein synthesis in seedlings (Anon., 1979). Metolachlor is mainly active on grasses and sedges at the rates of 1.0-2.5 kg, depending on soil type and climatic conditions (Martin and Worthing, 1977). Cornelius et al. (1976) observed that pre-emergence application of metolachlor at 3.36 kg effectively controlled Cyperus esculentus in transplanted tomato. The control of broad leaved weeds was enhanced when metolachlor was applied together with other herbicides (Peak, 1980, Lagoke et al., 1982). Metolachlor at 2.16 kg gave a good selectivity on kenaf (Deuber et al., 1982). Lagoke et al. (1981) and Kuchinda et al. (1991) reported that metolachlor at 1.5-2.16 kg gave selective weed control as well as increased fibre and seed yields in kenaf in the southern and northern guinea agroecological zones of Nigeria, respectively.

2.5.2 Triazines

Triazines are heterocyclic nitrogen derivatives and the heterocyclic ring is composed of three nitrogen and three carbon atoms (Klingman and Ashton, 1975). Members of this group are either symmetrical-s-triazines or assymmetrical, depending on whether the three N atoms in the heterocyclic benzene ring are symmetrically arranged or lack the symmetry. The S-triazines are divided into three sub-groups which include chloro

diamino-, methoxy diamino- and methyl thio diamino-s-triazines, and these have common names that end with -zine, -tone and -tryne, respectively (Akobundu, 1987). The sub-groups are similar in activity (Holly, 1968). The uptake of this group of herbicides is mainly through the roots, although foliar absorption occurs with the methylthio diamino-s-triazines such as ametryne and prometryne (Kearney and Kaufman, 1975). From the roots translocation takes place in the apoplastic system to other parts of the plant (Glenn et al., 1975).

Triazines inhibit photosythesis in susceptible plants by blocking the Hill reaction associated with photosystem II, and so the site of action is the chloroplast (Moreland and Hill 1963). The mode of action is the displacement of the natural plastoquinone electron acceptor in the Hill reaction (Fedtke and Trebst, 1986). Tolerant plants rapidly detoxicate the herbicide through modification of the active molecule into inactive form by hydroxylation dechlorination, demethoxylation, dealkylation or demethylation, depending on the parent substitution (Kearney and Kaufman, 1975) and by the production of peptide conjugate (Audus, 1976). The triazines are most widely used in field crops for the control of grass seedlings and broad leaf weeds. The characteristic symptom is foliar chlorosis followed by necrosis. Selectivity of these herbicides is mainly due to differential rate of metabolism in the plant (Jachetta and Radosevich, 1981). Resistant species metabolise the herbicide faster and the susceptible species, slower.

1. Ametryne

Ametryne (4-ethylamino-6-isopropyl amino-2-methyl thio-1,3,5-triazine) has pre-emergence and post-emergence activities on plants. It is the least persistent in the family and shows some degree of selectivity in many crops. It is mainly used in mixture with other herbicides (Michieka et al., 1977; Lagoke et al., 1986; Adejonwo et al., 1987). Ametryne controls broad leaved weeds and some grasses. Although gesatan, a formulation of ametryne and prometryne at rates exceeding 1.5+2.00 kg was observed to reduce kenaf fibre yield by 15-20% (Michieka et al., 1977), it was however reported that a selective weed control was enhanced by the use of ametryne in mixture with norfluorozone at 0.5 + 1.0 kg (Lagoke et al., 1981). However, norflurozone has been suggested to be too persistent in the soil (Lagoke, personal communication). Lagoke et al. (1981) further reported that despite the initial weed control by ametryne at 1.5 kg, there was a reduction in fibre yield due to phytotoxic effect of the chemical. Ametryne plus metolachlor was observed to check weeds for 8 WAS on a yam/maize mixture (Lagoke et al., 1986). Ametryne in mixtures with alachlor, metolachlor and metazachlor have been observed to selectively control weeds in kenaf and result in fibre and seed yields that were comparable to the hoe-weeded check (Kuchinda et al., 1991).

2.5.3 Pyridinyl oxy-phenyl carboxylic acid

1. Fluazifop-butyl

Fluazifop-butyl (±-butyl [5-(trifluoro methyl)-2-pyridinyl) oxy] phenoxy] propanoate) is a light straw coloured, odourless liquid with a water solubility of 2ppm at

ambient temperature (Anon., 1983). It has an oral LD_{50} of 4350 mg/kg for rats. Fusilade, a formulation of fluazifop-butyl is a selective post-emergence herbicide which has excellent activity on annual and perennial grasses in broad leaved crops (Plowman et al., 1980; Anderson, 1982; Nalewaja et al., 1982). However, it is not effective against Cyperus spp (Roy et al., 1988). It is also applied pre-emergence, but requiring 2-4 times the normal post-emergence rate (ICI, 1981). Its soil activity is also reported by Buhler and Burnside (1984). Fusilade is quickly absorbed through the leaves and it is transported in both the xylem and the phoem (Plowman et al., 1980). It accumulates at growing points in plants thereby affecting the meristamatic tissues of nodes and buds (ICI, 1981). Fusilade interferes with Adenosine triphosphate (ATP) production (Plowman et al., 1980). Symptoms become visible within 48 hours of application when growth ceases. Nodes and growing points become necrotic, young leaves show chlorosis followed by necrosis and there is a general loss of vigour (Plowman et al., 1980). Death usually occurs 3-5 weeks after application. Fusilade is rapidly degraded in moist soil in which it has a half life of less than 9 weeks. Cold and dry conditions prolong its persistence in the soil.

Fusilade has been reported to control grasses in cotton, groundnuts, soyabean and cowpea (Knott, 1982, Lagoke et al., 1985; Kavani et al., 1986). Selectivity is due to rapid degradation followed by conjugate formation in broad leaved plants (Plowman et al., 1980). Fusilade at rates of 0.125-0.50 and 0.5-2.0 kg are required for the control of annual and perennial grasses, respectively (Plowman et al., 1980). It gave a season long control of Sorghum halepense following initial application of fluometryn (Vidrine et al., 1983), and its mixture with diuron controlled Cynodon dactylon, Rottboelia

cochinchinerisis, Digitaria ciliaris and Vernonia galamensis in cowpea (Anon., 1984). Fusilade at 0.25 and 0.37 kg/ha followed by inter-row cultivation 40-45-DAS, improved cowpea pod yield (Kavani et al., 1986). On cotton, fusilade in combination with diuron at 1.0+0.8 kg/ha increased cotton yield appreciably (Lagoke et al., 1985). Prusty et al. (1988) reported that fusilade gave jute fibre yield of 2.09 t/ha which was comparable with the 2.54 t/ha obtained from a hoe-weeded check. Although fusilade was found to improve crop vigour and seed yield per plant of kenaf, its phytotoxicity to the crop resulted in high stand losses (Kuchinda et al., 1991).

CHAPTER THREE

3 MATERIALS AND METHODS

3.1 Description of the Experimental Site

The field trials were conducted during the wet seasons of 1993-1995 on the farm of the Institute for Agricultural Research, Ahmadu Bello University, Samaru (Lat. 11° 11'N; Long. 7° 38'; 686m above mean sea level) in the northern guinea savanna ecological zone of Nigeria. The soil of the area is characterized by ferrugenious tropical group of soils. Details of the physico-chemical properties of the soil of the experimental sites are presented on Appendix 1 and the meteorological data on Appendices 2-4.

3.2 Cultural Practices

3.2.1 Land prepration

At the on set of each rainy season, the site of the trials was ploughed and disc-harrowed a week after, to get a fine tilth before sowing. Raised seed beds of 2.0m by 2.0m were prepared using hand hoes. The spaces allowed between the beds were 0.50m along and across the beds. Each bed constituted the gross treatment plot.

3.2.2 Seed sowing

Several seeds of kenaf (Cv. Cuba 108) were sown on flat in the beds immediately after land preparation on June 30, July 7 and July 6 in 1993, 1994 and 1995, respectively. Four to six seeds were sown per hill at intra-row and inter row spacings of 20cm and 25cm, respectively; and thinned to one plant per stand at 10 days after sowing (10 DAS).

3.2.3 Fertilizer application

In the trials involving different levels of nitrogen as treatments (N x herbicides and N x period of weed interference), single superphosphate and muriate of potash were broadcast prior to second harrowing operation to give 26kg P/ha and 40kg K_2O/ha, respectively in all the cropping seasons. For the nitrogen treatments, calcium ammonium nitrate (26% N) was applied appropriately to individual plots immediately after thinning to give the required N rates.

3.2.4 Herbicide application

In the N x herbicide trial, metolachlor and alachlor and their mixtures with ametryne were applied pre-emergence; while fluazitop-butyl and its mixtures with ametryne were applied post-emergence. The herbicides were applied using a CP3 Knapsack sprayer with a green deflector nozzle at a pressure of about 2.1 kg/cm^2, with a discharge rate of 200 l/ha. The pre-emergence herbicides were applied immediately after sowing, while the post-emergence treatments were applied at four weeks after sowing (4 WAS).

3.2.5 Weed control

Plots were hoe-weeded according to the treatments. Before any hoe-weeding was done, weed samples were collected from each plot in the N x period of weed interference trial.

3.2.6 Pest control

The only pest that was considered serious in the three years of trials was flee-beetle which feeds on kenaf leaves. Cypermethrin as Cymbush 10EC was used to control the pest at the rate of 100g a.i/ha (100 L/ha).

3.3 Physico-Chemical Properties of the Soil

In each year and prior to the establishment of each trial, a composite soil sample was taken from a depth of 0-15cm. The samples were air-dried, thoroughly mixed, ground and then passed through a 2mm sieve for the physical and chemical laboratory analysis.

Particle size distribution was determined by the Hydrometer method as described by Day (1965). Soil pH was determined using pH meter (Black, 1965). Organic carbon was estimated by the Walky-Black method (Jackson, 1958). Total N was estimated by the Micro Kjeldahl method (Bremner, 1965). Cation exchange capacity (CEC) and Exchangeable Bases (K, Na, Ca and Mg) were estimated by ammonium acetate extraction and distillation as described by Chapman (1965): Na and K in the extracts were determined by an EEL flame photometer, while Ca and Mg were determined by a Perkin Elmer, Model 290B atomic absorption spectrophotometer. Available P was estimated according to Bray 1 sulphuric acid reduction method
as described by Trough (1930).

3.4 Meteorological Data

Data on temperature, rainfall, relative humidity and sunshine hours during the periods of the investigation were obtained from the IAR Meteorological Unit, Samaru.

3.5 Treatments

The experiment consisted of two trials carried out during each wet season as follows:

3.5.1 Effect of nitrogen and period of weed interference

The treatments consisted of three levels of N (0, 45 and 90 kg N/ha) factorially combined with ten periods of weed interference. The weed interference periods (Appendix 2) were in two sets: in the first set, plots were initially kept weed-free by hoe-weeding for 3, 6, 9 and 12 WAS and left weed-infested thereafter. In the other set, plots were left weed-infested initially for the corresponding periods and kept weed-free thereafter. The other two treatments consisted of plots that were kept weed-free and those left weed-infested throughout the crop growth period and these two served as checks. There were 30 treatments in this experiment.

3.5.2 Effect of nitrogen and herbicides

Prior to the commencement of this experiment, a preliminary screening of pre-emergence and post-emergence herbicides was carried out in 1991. Some promising pre-emergence herbicides and fluazifop-butyl (although relatively phytotoxic) were selected for use in this investigation.

The treatments consisted of three levels of N (0, 45 and 90 kg N/ha) factorially combined with nine weed control treatments (metolachlor, Metolachlor plus ametryne, alachlor, alachlor plus ametryne, fluazifop-butyl, fluazifop-butyl plus ametryne, hoe-weeded at 4 WAS, hoe-weeded at 3 and 6 WAS and a weedy check). Details of the

herbicide treatments are contained in Appendix 3. There were 27 treatments in this experiment.

3.5.3 Experimental design and plot size

In each trial, the factorial combinations were laid out in a randomized complete block design with three replications. The plot size was 2m x 2m = $4m^2$, while the net plot size was 1.5m x 1.2m = $1.8m^2$.

3.6 Observation and Data Collection

3.6.1 Weed parameters

1. Weed cover score

The weed cover score was taken at 3, 6, 9 and 12 WAS using a scale of 0-10, where scale 0 indicates plots without any weeds and scale 10 stands for plots completely covered by weeds.

2. Cummulative weed weight

In the weed interference study, samples of fresh weeds were taken from an area of $0.25m^2$ on each plot before any weeding operation and from all the plots at seed harvest. A square metal frame (0.5m by 0.5m) was used to mark out the sampling area on each plot. The weed samples were cleaned free of soil, oven dried at 65°C for 48 hours and then weighed. The cummulative dry weed weight per plot was determined by adding up the respective weights taken at the various weeding operations and at harvest.

3.6.2 Crop growth and yield parameters

1. Emergence score

Seedling emergence score was taken at 10 DAS using a scale of 0 (zero emergence) to 10 (100% emergence). The scoring was done just before thinning operation.

2. Crop vigour score

This parameter was also taken at 3, 6, 9 and 12 WAS. The assessment for crop vigour was based on a scale of 0-10; where scale 0 was assigned to plots with plants which were unhealthy and dying, and scale 10 assigned to plots with very healthy and vigorously growing crop. In the visual assessment, plant height, stem thickness, foliage greenness and canopy spread were taken into consideration.

3. Plant height

This was taken at 4, 8 and 12 WAS. Ten plants were taken from outside the net rows on each plot and their individual heights measured using a meter rule. The measurement was done from the ground level to the tip of the terminal bud of the plant. The average height was then computed.

4. Butt diameter

This was also taken at 4, 8 and 12 WAS. Ten plants were also taken from outside the net rows and cut at the ground level. The butt diameters across the cut surfaces were measured using Vernier Calipher and the average was computed for each plot.

5. Wood and ribbon dry weights and yields

Ten plants from the net plots were used at 12 WAS for the wood and ribbon dry weights and yields determination. The plants were cut and left on the field for several days to ease the removal of leaves and reproductive structures. The sticks were peeled to separate the ribbon from the stalks. They were later dried to constant weights at 65°C and then weighed. The average weights of wood and ribbon per plant were determined and yields per hectare computed.

6. Fibre yield

For fibre yield determination, ten plants were cut from the net plots at 12 WAS. The plants were left on the field for several days (to shed their leaves) and later retted in a slow flowing stream for two weeks. This permitted the rottening of the mass covering the fibre strands, which was then washed off. Retting also facilitates the separation of the fibre from the wood stalks. The fibre was sun-dried to constant weight and then weighed. Fibre weight per plant and average yield were computed.

7. Number of days to first and 50% flowering

Daily inspection of plants on each plot to determine the number of days to floral initiation and attainment of 50% flowering (in 1994 and 1995 only) was carried out appropriately.

8. Number of capsules per plant

Ten plants from the net plots were used at seed harvest. The capsules on them were counted and the average number of capsules per plant appropriately determined.

9. *Seed yield*

The capsules indicated above were sun-dried, threshed and the seeds weighed. The seed weight per plant and average yield were computed appropriately.

10. 100-seed weight

One hundred seeds were taken from the net yields of the respective plots and weighed to determined their weight.

3.7 Statistical Analysis

The data collected were subjected to analysis of variance using the 'F' Test to determine significant differences in the treatment means as described by Snedecor and Cochran (1967). Multiple comparison of treatment means was done using the Duncan's Multiple Range Test (Duncan, 1955); and the magnitude of association and relationship between some growth and yield characters were assessed through simple correlation (Little and Hills, 1978). Path coefficient analysis was carried out to determine the direct and indirect contributions as well as percent contributions of some parameter to fibre and seed yields as described by Dewey and Lu (1959). Regression analysis was also carried out to estimate the effect of the period of weed interference on fibre and seed yields as described by Steel and Torie (1984).

CHAPTER FOUR

4 RESULTS

4.1 Effects of Nitrogen and Period of Weed Interference on the Growth of Kenaf

The effects of nitrogen and period of weed interference on the growth of kenaf are shown in Tables 1-15.

4.1.1 Crop vigour score

The application of N significantly influenced the crop vigour score of kenaf in all the years of investigation (Tables 1-3). In each year and at each sampling, crop vigour increased with increasing N level from 0-90 kg N/ha.

The period of weed interference (P) had significant effect on crop vigour score from 6 wAS in the three years of trials. In all the years, with the exception of 12 WAS in 1993, the crop vigour score of plots kept weed-free for 6 WAS and more and that initially weed-infested for 3 WAS only, were similar and significantly higher than those of plots kept weed-free for 3 WAS only. At 12 WAS in 1993, the plot kept weed-free for 12 WAS and that initially infested for 3 WAS produced more vigorous plants than that kept weed-free for 3 WAS only. The vigour score of kenaf plants kept weed-free for 3 WAS was comparable to those of plants weed-infested for 6 WAS and more in all cases in 1993 and 1994 and at 6 WAS only in 1995. However, in 1995, the vigour score of plants kept weed-free for 3 WAS only was also significantly lower than those weed-infested for 6 WAS at 9 WAS and 9 WAS and more at 12 WAS.

Table 1: Effects of nitrogen and period of weed interference on crop vigour score of kenaf during the 1993 wet season at Samru

Treatment	Crop vigour score		
Nitrogen level (kg N/ha)	6 WAS	9 WAS	12 WAS
0	4.39c	5.18c	4.45c
45	6.91b	7.35b	6.59b
90	8.28a	8.85a	7.67a
SE ±	0.236	0.220	0.220
Period of weed interference (P)			
Weed-free for 3 WAS	5.67c	6.22c	5.78bc
Weed-free for 6 WAS	7.44a	7.89ab	6.78ab
Weed-free for 9 WAS	-	7.56ab	6.56ab
Weed-free for 12 WAS	-	-	7.33a
Weed-free until Harvest	-	-	-
Weed-infested for 3 WAS	6.89ab	8.11a	7.44a
Weeded-infested for 6 WAS	6.11c	6.89bc	6.33ab
Weed-infested for 9 WAS	-	6.11c	4.67c
Weeded-infested for 12 WAS	-	-	5.00c
Weed-infested until harvest	-	-	-
SE ±	0.433	0.402	0.401
Interaction			
N x P	*	NS	NS

Means followed by the same letter(s) within the same column of any treatment group are not significantly different at 5% level of probability (DMRT)

WAS = Weeks after sowing

NS = Not significant at 5% level of probability

* = Significant at 5% level of probability

\- = Not completely applied at the time of observation

Table 2: Effects of nitrogen and period of weed interference on crop vigour score of kenaf during the 1994 wet season at Samru

Treatment	Crop vigour score		
Nitrogen level (kg N/ha)	6 WAS	9 WAS	12 WAS
0	3.81c	4.05c	4.13c
45	6.99b	6.47b	6.17b
90	7.70a	8.11a	7.09a
SE ±	0.225	0.214	0.272
Period of weed interference (P)			
Weed-free for 3 WAS	5.83ab	5.17b	4.94cd
Weed-free for 6 WAS	7.00a	6.9a	6.83a
Weed-free for 9 WAS	-	7.83a	7.33a
Weed-free for 12 WAS	-	-	6.78a
Weed-free until harvest	-	-	-
Weed-infested for 3 WAS	6.89a	7.06a	6.56ab
Weeded-infested for 6 WAS	4.94c	5.33b	5.28bc
Weeded-infested for 9 WAS	-	4.94b	4.89cd
Weed-infested for 12 WAS	-	-	3.78d
Weed-infested until harvest	-	-	-
SE ±	0.412	0.391	0.497
Interaction			
N x P	NS	NS	NS

Means followed by the same letter(s) within the same column of any treatment group are not significantly different at 5% level of probability (DMRT)

WAS = Weeks after sowing

NS = Not significant at 5% level of probability

* = Significant at 5% level of probability

\- = Not completely applied at the time of observation

Table 3: Effects of nitrogen and period of weed interference on crop vigour score of kenaf during the 1995 wet season at Samaru

Treatment	Crop vigour score		
Nitrogen level (kg N/ha)	6 WAS	9 WAS	12 WAS
0	3.41c	3.92c	4.21c
45	5.67b	5.66b	5.68b
90	6.75a	7.00a	7.07a
SE ±	0.170	0.169	0.180
Period of weed interference (P)			
Weed-free for 3 WAS	3.83b	3.56c	3.11d
Weed-free for 6 WAS	6.61a	7.00a	7.00a
Weed-free for 9 WAS	-	7.00a	6.83a
Weed-free for 12 WAS	-	-	7.17a
Weed-free until harvest	-	-	-
Weed-infested for 3 WAS	6.44a	6.61a	6.72a
Weeded-infested for 6 WAS	4.22b	5.11b	5.39b
Weeded-infested for 9 WAS	-	3.89c	4.89bc
Weed-infested for 12 WAS	-	-	4.11c
Weed-infested until harvest	-	-	-
SE ±	0.310	0.308	0.329
Interaction			
N x P	NS	NS	NS

Means followed by the same letter(s) within the same column of any treatment group are not significantly different at 5% level of probability (DMRT)

WAS = Weeks after sowing

NS = Not significant at 5% level of probability

\- = Not completely applied at the time of observation

There was a significant interaction of N and period of weed interference on crop vigour score at 6 WAS in 1993 (Table 4). Without the application of N, no weed interference treatment had crop vigour that was comparable to the maximum in the trial. Plots kept weed-free for 3 WAS only had the least crop vigour than all the other treatments at the N level. With 45 kg N/ha, plots kept weed-free for 6 WAS and that weed-infested for 3 WAS only had higher crop vigour than the least and comparable to the maximum. At the N level, plot kept weed-free for 3 WAS only had higher crop vigour while that weed-infested for 6 WAS had comparable crop vigour with the least. With 90 kg N/ha, all the treatments had higher crop vigour than the least. At the N level, plots kept weed-free for 6 WAS and those infested for 3 and 6 WAS had maximum crop vigour. With 45 and 90 kg N/ha, plots kept weed-free for 3 and 6 WAS and that weed-infested for 3 WAS only had more vigorous plants than the corresponding plots without N. Without N and at 45 kg N/ha, plots weed-infested for 6 WAS had similar crop vigour that was significantly lower than those with 90 kg N/ha.

4.1.2 Plant height

Nitrogen had significant effect on plant height at 8 and 12 WAS in 1993 and 1994, and during all the sampling periods in 1995 (Tables 5-7). In all the cases, plant height of kenaf increased significantly with N levels, except at 12 WAS in 1993 when the heights of plants were similar with the application of 45 and 90 kg N/ha.

Table 4: Interaction of nitrogen and period of weed interference on crop vigour score of kenaf at 6 WAS during the 1993 wet season at Samaru

	Crop vigour score at 6 WAS		
	Nitrogen level (kg N/ha)		
Period of weed interference	0	45	90
Weed-free for 3 WAS	4.00e	6.67cd	7.33bc
Weed-free for 6 WAS	5.33de	8.00a-c	9.00a
Weed-free for 9 WAS	-	-	-
Weed-free for 12 WAS	-	-	-
Weed-free until harvest	-	-	-
Weed-infested for 3 WAS	4.67e	7.67a-c	8.33ab
Weed-infested for 6 WAS	4.67e	5.33de	8.33ab
Weed-infested for 9 WAS	-	-	-
Weed-infested for 12 WAS	-	-	-
Weed infested until harvest	-	-	-
SE ±	0.527		

Means followed by the same letter(s) are not significantly different at 5% level of probability (DMRT)

WAS = Weeks after sowing

\- = Not completely applied at the time of observation

Table 5: Effects of nitrogen and period of weed interference on plant height of kenaf during the 1993 wet season at Samaru

Treatment	Plant height (m)		
Nitrogen level (kg N/ha)	4 WAS	8 WAS	12 WAS
0	0.34	1.53c	2.25b
45	0.33	1.87b	2.50a
90	0.34	1.98a	2.54a
SE ±	0.006	0.036	0.105
Period of weed interference (P)			
Weed-free for 3 WAS	0.34	1.72bc	2.22d
Weed-free for 6 WAS	-	1.93a	2.53ab
Weed-free for 9 WAS	-	-	2.58a
Weed-free for 12 WAS	-	-	2.53a-c
Weed-free until harvest	-	-	-
Weed-infested for 3 WAS	0.33	1.89ab	2.73a
Weeded-infested for 6 WAS	-	1.64c	2.27c-d
Weeded-infested for 9 WAS	-	-	2.42b-d
Weed-infested for 12 WAS	-	-	2.19d
Weed-infested until harvest	-	-	-
SE ±	0.102	0.067	0.096
Interaction			
N x P	NS	*	NS

Means followed by the same letter(s) within the same column of any treatment group are not significantly different at 5% level of probability (DMRT)

WAS = Weeks after sowing

NS = Not significant at 5% level of probability

* = Significant at 5% level of probability

- = Not completely applied at the time of observation

Table 6: Effects of nitrogen and period of weed interference on plant height of kenaf during the 1994 wet season at Samaru

Treatment	Plant height (m)		
Nitrogen level (kg N/ha)	4 WAS	8 WAS	12 WAS
0	0.33	1.40c	1.89c
45	0.32	1.86b	2.32b
90	0.33	2.09a	2.69a
SE ±	0.006	0.036	0.045
Period of weed interference (P)			
Weed-free for 3 WAS	0.33	1.64b	2.16b
Weed-free for 6 WAS	-	1.95a	2.5a
Weed-free for 9 WAS	-	-	2.66a
Weed-free for 12 WAS	-	-	-
Weed-free until harvest	0.32	1.92a	2.47a
Weed-infested for 3 WAS	-	1.63b	2.22b
Weeded-infested for 6 WAS	-	-	2.00bc
Weeded-infested for 9 WAS	-	-	1.89c
Weed-infested for 12 WAS	-	-	-
Weed-infested until harvest	0.100	0.066	0.820
SE ±			
Interaction			
N x P	NS	NS	*

Means followed by the same letter(s) within the same column of any treatment group are not significantly different at 5% level of probability (DMRT)

WAS = Weeks after sowing

NS = Not significant at 5% level of probability

* = Significant at 5% level of probability

- = Not completely applied at the time of observation

Table 7: Effects of nitrogen and period of weed interference on plant height of kenaf during the 1995 wet season at Samaru

Treatment	Plant height (m)		
Nitrogen level (kg N/ha)	4 WAS	8 WAS	12 WAS
0	0.33c	1.11c	1.54c
45	0.36b	1.51b	1.84b
90	0.38a	1.67a	1.05a
SE ±	0.007	0.039	0.041
Period of weed interference (P)			
Weed-free for 3 WAS	0.38	1.14c	1.37c
Weed-free for 6 WAS	-	1.75a	2.07a
Weed-free for 9 WAS	-	-	2.06a
Weed-free for 12 WAS	-	-	2.11a
Weed-free until harvest	-	-	-
Weed-infested for 3 WAS	0.34	1.51bc	1.93a
Weeded-infested for 6 WAS	-	1.33bc	1.65b
Weeded-infested for 9 WAS	-	-	1.65bc
Weed-infested for 12 WAS	-	-	1.57bc
Weed-infested until harvest	-	-	-
SE ±	0.013	0.071	0.075
Interaction			
N x P	NS	NS	NS

Means followed by the same letter(s) within the same column of any treatment group are not significantly different at 5% level of probability (DMRT)

WAS = Weeks after sowing

NS = Not significant at 5% level of probability

* = Significant at 5% level of probability

- = Not completely applied at the time of observation

The period of weed interference had significant effect on plant height from 8 WAS in each year. At 8 WAS the kenaf plants kept weed-free for 6 WAS and those weed-infested for 3 WAS only were significantly taller than those kept weed-free for 3 WAS only in 1994 and 1995 and those weed-infested for 6 WAS in 1993 and 1994. At 12 WAS, plants kept weed-free for 6 WAS and more and those initially infested for 3 WAS only were significantly taller than those of the other treatments in 1994 and 1995. In 1993, the tallest plants occured on the plot kept weed-free for 9 WAS and those weed-infested initially for 3 WAS only. In this year, plants weed-free for 3 WAS only had similar height with those weed-infested for 6 WAS and more. However, the plants kept weed-free for 3 WAS only were taller than the shortest ones obtained from the plots weed-infested for 12 WAS in 1994, but shorter than those weed-infested for 6 and 9 WAS in 1995.

There were significant interactions of N and period of weed interference on plant height at 8 and 12 WAS in 1993 and 1994, respectively (Tables 8 and 9). In 1993, without the application of N, only plots left infested for 6 WAS had taller plants than the least and comparable to the maximum. With 45 and 90 kg N/ha, plots kept weed-free for 3 and 6 WAS and that weed-infested for 3 WAS only had taller plants than the corresponding treatments without N and comparable to the tallest plants. However, kenaf plants given 45 and 90 kg N/ha and left infested for 6 WAs had shorter plants than the tallest. Without N, plot kept weed-free for 3 WAS only had the shortest plants. In 1994,

Table 8: Interaction of nitrogen and period of weed interference on plant height of kenaf at 8 WAS during the 1993 wet season at Samaru

	Plant height at 8 WAS		
	Nitrogen level (kg N/ha)		
Period of weed interference	0	45	90
Weed-free for 3 WAS	1.19d	1.95a	2.00a
Weed-free for 6 WAS	1.59bc	2.05a	2.14a
Weed-free for 9 WAS	-	-	-
Weed-free for 12 WAS	-	-	-
Weed-free until harvest	-	-	-
Weed-infested for 3 WAS	1.58c	1.94ab	2.14a
Weed-infested for 6 WAS	1.79a-c	1.57bc	1.55c
Weed-infested for 9 WAS	-	-	-
Weed-infested for 12 WAS	-	-	-
Weed infested until harvest	-	-	-
SE ±	0.117		

Means followed by the same letter(s) are not significantly different at 5% level of probability (DMRT)

WAS = Weeks after sowing

\- = Not completely applied at the time of observation

Table 9: Interaction of nitrogen and period of weed interference on plant height of kenaf at 12 WAS during the 1994 wet season at Samaru

	Plant height at 12 WAS		
	Nitrogen level (kg N/ha)		
Period of weed interference	0	45	90
Weed-free for 3 WAS	1.82h-j	1.93g-j	2.74b-d
Weed-free for 6 WAS	2.13f-g	2.72b-d	2.67b-e
Weed-free for 9 WAS	2.25e-g	2.80b-d	02.94ab
Weed-free for 12 WAS	1.94g-j	2.75b-d	2.83a-c
Weed-free until harvest	-	-	-
Weed-infested for 3 WAS	1.93g-j	2.25ef	3.24a
Weed-infested for 6 WAS	1.84g-j	2.39d-f	2.42c-f
Weed-infested for 9 WAS	1.52j	1.95g-i	2.53b-f
Weed-infested for 12 WAS	1.70h-j	1.81h-j	2.14f-h
Weed infested until harvest	-	-	-
SE ±		0.140	

Means followed by the same letter(s) are not significantly different at 5% level of probability (DMRT)

WAS = Weeks after sowing

without N and with 45 kg N/ha application, no weed interference treatment had comparable plant height to the maximum. However, at the same N treatments, plants kept weed-free for 6 and 9 WAS were taller than the shortest plants obtained from those weed-infested initially for 9 WAS. With the application of 45 kg N/ha, plants kept weed-free initially for 3 WAS only and those weed-infested for 12 WAS had similar heights which were comparable to the least. With 90 kg N/ha, plants initially weed-infested for 3 WAS only had maximum plant height which was comparable to those of the plants kept weed-free for 9 and 12 WAS. Under this N rate, all the plants were taller than the shortest plants obtained in the trial. The plants given 45 and 90 kg N/ha and kept weed-free for 6-12 WAS or left weedy for 6 WAS were correspondingly similar in height, and taller than those without N. However, plants given 45 kg N/ha and left weed-infested for 3-9 WAS and those given 90 kg N/ha and left weed-infested for 6-12 WAS had comparable plant heights with those kept weed-free for 6 and 9 WAS but given no N.

4.1.3 Butt diameter

Application of N significantly influenced the stem butt diameter of kenaf plants at 8 and 12 WAS in 1993 and 4 to 12 WAS in 1994 and 1995 (Tables 10-12). The butt diameter increased with increasing N rate in the three years, except at 12, 4 and 8 WAS in 1993, 1994 and 1995, respectively, when the difference between 45 and 90 kg N/ha was not significant, although the two rates resulted in greater butt diameters than the no N control.

Table 10: Effects of nitrogen and period of weed interference on butt diameter of kenaf during the 1993 wet season at Samaru

Treatment	Butt diameter (cm)	
Nitrogen level (kg N/ha)	8 WAS	12 WAS
0	0.96c	1.12b
45	1.25b	1.29a
90	1.39a	1.33a
SE ±	0.036	0.031
Period of weed interference (P)		
Weed-free for 3 WAS	1.08b	1.14bc
Weed-free for 6 WAS	1.23ab	1.30ab
Weed-free for 9 WAS	-	1.31a
Weed-free for 12 WAS	-	1.31a
Weed-free until harvest	-	-
Weed-infested for 3 WAS	1.34a	1.38a
Weeded-infested for 6 WAS	1.14b	1.23a-c
Weeded-infested for 9 WAS	-	1.22a-c
Weed-infested for 12 WAS	-	1.08c
Weed-infested until harvest	-	-
SE ±	0.065	0.055
Interaction		
N x P	NS	NS

Means followed by the same letter(s) within the same column of any treatment group are not significantly different at 5% level of probability (DMRT)

WAS = Weeks after sowing

NS = Not significant at 5% level of probability

\- = Not completely applied at the time of observation

Table 11: Effects of nitrogen and period of weed interference on butt diameter of kenaf during the 1994 wet season at Samaru

Treatment	Plant height (m)		
Nitrogen level (kg N/ha)	4 WAS	8 WAS	12 WAS
0	0.50b	0.85c	1.03c
45	0.68a	1.15b	1.23b
90	0.70a	1.35a	1.44a
SE ±	0.013	0.024	0.026
Period of weed interference (P)			
Weed-free for 3 WAS	0.65	1.04b	1.21bc
Weed-free for 6 WAS	-	1.18a	1.26b
Weed-free for 9 WAS	-	-	1.41a
Weed-free for 12 WAS	-	-	1.26b
Weed-free until harvest	-	-	-
Weed-infested for 3 WAS	0.60	1.20a	1.34ab
Weeded-infested for 6 WAS	-	1.04b	1.26b
Weeded-infested for 9 WAS	-	-	1.08cd
Weed-infested for 12 WAS	-	-	1.04d
Weed-infested until harvest	-	-	-
SE ±	0.023	0.044	0.046
Interaction			
N x P	NS	NS	*

Means followed by the same letter(s) within the same column of any treatment group are not significantly different at 5% level of probability (DMRT)

WAS = Weeks after sowing

NS = Not significant at 5% level of probability

* = Significant at 5% level of probability

- = Not completely applied at the time of observation

Table 12: Effects of nitrogen and period of weed interference on butt diameter of kenaf stem during the 1995 wet season at Samaru

Treatment	Butt diameter (m)		
	4 WAS	8 WAS	12 WAS
Nitrogen level (kg N/ha)			
0	0.47c	0.66b	0.77c
45	0.62b	0.95a	0.98b
90	0.68a	1.02a	1.14a
SE ±	0.015	0.031	0.027
Period of weed interference (P)			
Weed-free for 3 WAS	0.55	0.69c	070c
Weed-free for 6 WAS	-	1.03a	1.13a
Weed-free for 9 WAS	-	-	1.13a
Weed-free for 12 WAS	-	-	1.11a
Weed-free until harvest	-	-	-
Weed-infested for 3 WAS	0.63	0.97ab	1.07a
Weed-infested for 6 WAS	-	0.81bc	0.86b
Weed-infested for 9 WAS	-	-	0.83bc
Weed-infested for 12 WAS	-	-	0.84bc
Weed-infested until harvest	-	-	-
SE ±	0.028	0.055	0.048
Interaction			
N x P	NS	NS	NS

Means followed by the same letter(s) within the same column of any treatment group are not significantly different at 5% level of probability (DMRT)

WAS = Weeks after sowing

NS = Not significant at 5% level of probability

\- = Not completely applied at the time of observation

The period of weed interference significantly influenced the butt diameter of kenaf plants at 8 and 12 WAS in the three years of trials. At 8 WAS, plants kept weed-free for 6 WAS and those infested for 3 WAS only had greater butt diameters than those kept weed-free for 3 WAS only and those initially weed-infested for 6 WAS in 1994. At this period, plants initially weed-infested for 3 WAS only in 1993 and those kept weed free for 6 WAS in 1995 had greater butt diameter than those kept weed-free for 3 WAS only and those weed-infested for 6 WAS, respectively. At 12 WAS plants kept weed-free for 6 WAS and more and those infested for 3 WAS only had greater butt diameter than those weed-infested for 12 WAS in 1993, 9-12 WAS in 1994 and 6-12 WAS in 1995. At this period, plants initially weed-free for 3 WAS had comparable butt diameter to the appropriate least in 1993 and 1995.

There was significant interaction of N and period of weed interference on butt diameter at 12 WAS in 1994 (Table 13). In this case, without the application of N, plants kept weed-free for 9 WAS and those weed-infested for 3 WAS only had larger butt diameters than the least obtained from plants kept weed-free for 3 WAS only. With 45 kg N/ha, only plants initially kept weed-free for 3 WAS only and those weed-infested for 9 and 12 WAS had butt diameters comparable to the least, while with 90 kg N/ha, no plant was comparable to the least. While no plant without N could compare well with the maximum butt diameter, those with 45 kg N/ha which were kept weed-free for 9 and 12 WAS had comparable butt diameters to the maximum. With 90 kg N/ha, the maximum

Table 13: Interaction of nitrogen and period of weed interference on butt diameter of kenaf stem at 12 WAS during the 1993 wet season at Samaru

	Butt diameter at 12 WAS		
	Nitrogen level (kg N/ha)		
Period of weed interference	0	45	90
Weed-free for 3 WAS	0.88g	1.12d-g	1.66a
Weed-free for 6 WAS	1.06d-g	1.23c-e	1.50ab
Weed-free for 9 WAS	1.24c-e	1.47a-c	1.52ab
Weed-free for 12 WAS	0.90g	1.47a-c	1.45a-c
Weed-free until harvest	-	-	-
Weed-infested for 3 WAS	1.29b-d	1.17d-f	1.58a
Weed-infested for 6 WAS	1.07d-g	1.19d-e	1.50ab
Weed-infested for 9 WAS	0.94f-g	1.06d-g	1.25c-e
Weed-infested for 12 WAS	0.92g	1.03e-g	1.17d-f
Weed infested until harvest	-	-	-
SE ±	0.081		

Means followed by the same letter(s) are not significantly different at 5% level of probability (DMRT)

WAS = Weeks after sowing

\- = Not applied at the time of observation

butt diameter was obtained on plants kept weed-free or weed-infested for 3 WAS and this was comparable to all the other treatments, except those weed-infested for 9-12 WAS. With zero and 45 kg N/ha, the butt diameter of plants kept weed-free for 3 and 6 WAS and those initially weed infested for the same periods were correspondingly similar and less than those of the plants given 90 kg N/ha. With each N rate, plants kept weed-free for 3 WAS only and those weed-infested for 9 and 12 WAS had lower butt diameters than their maxima, except those supplied with 90 kg N/ha and kept weed-free for 3 WAS only.

4.1.4 Number of days to first flowering

It took less number of days for plants to start flowering in 1993 than in 1994 (Table 14). Although the number of days to first flowering was less in 1995 than in 1994, the difference was not significant.

Nitrogen application and period of weed interference significantly affected the number of days to first flowering of kenaf crop in all the years of trials. The number of days to first flowering decreased with increasing N rate in the three years.

In all the years, plants of the plots kept weed-free for 3 WAS only and those weed-infested for 9 and 12 WAS took more number of days to first flowering than the appropriate least. In 1993, keeping the plots weed-free for 6 and 12 WAS or initially infested for 6 WAS significantly reduced the number of days to first flower formation compared with weed infestation for 12 WAS. In 1994, the

Table 14: Effects of nitrogen and period of weed interference on number of days to first flowering of kenaf during the 1993-1995 wet seasons at Samaru

Treatment	No. of days to first flowering		
	1993	1994	1995
Nitrogen level (kg N/ha)			
0	73.4a	77.4a	74.5a
45	71.2b	71.8b	71.7b
90	68.1c	69.8c	69.1c
SE ±	0.508	0.537	0.721
Period of weed interference (P)			
Weed-free for 3 WAS	72.2ab	74.6a	74.6a
Weed-free for 6 WAS	68.9c	72.2ab	69.6b
Weed-free for 9 WAS	70.7a-c	72.7ab	68.2b
Weed-free for 12 WAS	69.3c	72.3ab	69.4b
Weed-free until harvest	-	-	-
Weed-infested for 3 WAS	70.7a-c	70.9b	69.9b
Weed-infested for 6 WAS	69.7bc	72.0ab	73.6a
Weed-infested for 9 WAS	72.3ab	74.7a	73.8a
Weed-infested for 12 WAS	73.2a	74.7a	74.6a
Weed-infested until harvest	-	-	-
SE ±	0.926	0.979	0.721
Interaction			
N x P	NS	NS	NS
Mean	70.9b	73.0a	71.8ab

Means followed by the same letter(s) within the same column of any treatment group are not significantly different at 5% level of probability (DMRT)

NS = Not significant at 5% level of probability
- = Not completely applied at the time of observation

plots weed-infested for 3 WAS only had less number of days to first flowering than those kept weed-free initially for 3 WAS only and those weed-infested for 9 and 12 WAS. In 1995, the plants kept weed-free for 6 WAS and more and those initially weed-infested for 3 WAS only had shorter periods to first flowering than the corresponding weed-free and weed-infestation periods, respectively.

The interaction of N and period of weed interference on the number of days to first flowering was not singificant during the three years of this study.

4.1.5 Number of days to 50% flowering

There was no significant difference in the number of days to 50% flowering between 1994 and 1995 (Table 15), while no data was available for 1993.

Nitrogen and period of weed interference significantly affected the number of days to 50% flowering in 1994 and 1995. The number of days to 50% flowering also decreased with increase in N rate from 0-90 kg N/ha in the two years of trials.

In 1994, the plants kept weed-free for 6 and 12 WAS and those weed-infested initially for 3 and 6 WAS had less number of days to 50% flowering than the plants left weedy for 12 WAS. Keeping the plants weed-free for 3 and 9 WAS or weed-infested for 9 WAS resulted in comparable number of days to those infested for 12 WAS. In 1995, plants kept weed-free for 6 WAS and more had less number of days to 50% flowering than those left weedy for the corresponding periods. The plants weed-infested initially for 3

Table 15: Effects of nitrogen and period of weed interference on number of days to 50% flowering of kenaf during the 1993-1995 wet seasons at Samaru

Treatment	No. of days to 50% flowering	
	1994	1995
Nitrogen level (kg N/ha)		
0	84.6a	81.1a
45	79.0b	78.6b
90	76.8c	75.8c
SE ±	0.542	0.751
Period of weed interference (P)		
Weed-free for 3 WAS	81.21a-c	82.0a
Weed-free for 6 WAS	78.9c	76.1c
Weed-free for 9 WAS	79.9a-c	75.3c
Weed-free for 12 WAS	79.1bc	76.1c
Weed-free until harvest	-	-
Weed-infested for 3 WAS	78.3c	76.6bc
Weed-infested for 6 WAS	79.0c	80.4ab
Weed-infested for 9 WAS	82.0ab	80.7ab
Weed-infested for 12 WAS	82.6a	80.9a
Weed-infested until harvest	-	-
SE ±	0.991	1.373
Interaction		
N x P	NS	NS
Mean	80.1	78.5

Means followed by the same letter(s) within the same column of any treatment group are not significantly different at 5% level of probability (DMRT)
NS = Not significant at 5% level of probability
- = Not completely applied at the time of observation

WAS only had comparable number of days to those weed-infested for 6 and 9 WAS, but less than of the plants weed-infested for 12 WAS and the corresponding, weed-free situation.

The interaction of N and period of weed interference on the number of days to 50% flowering was not siginficant in the two years of trials.

4.2 Effects of Nitrogen and Period of Weed Interference on Weeds

The effects of nitrogen and period of weed interference on weeds are presented in Tables 16-21. The weed species found at the sites of the trials are presented on Appendix 5.

4.2.1 Weed cover score

The effect of N on weed cover score was significant at 6-9 WAS in 1993, 6 WAS in 1994 and 6-12 WAS in 1995 (Tables 16-18). In 1993, 90 kg N rate increased weed cover score at 6 and 9 WAS compared with no N treatment. In 1994 and 1995, 45 and 90 kg N rate similarly increased weed cover score at 6 WAS. A similar result was obtained at 9 WAS in 1995. At 12 WAS in 1995, only 45 kg N/ha increased the weed cover score compared with the no N control.

There was significant effect of period of weed interference on weed cover score from 6 WAS in the three years of study. In this case, plots kept weed-free for 6 WAS and more and that initially weed-infested for 3 WAS only had singificantly lower weed cover score than that kept weed-free for 3 WAS only. The weed cover score on the plots kept

Table 16: Effects of nitrogen and period of weed interference on weed cover score during the 1993 wet season at Samaru

Treatment	Weed cover score		
	6 WAS	9 WAS	12 WAS
Nitrogen level (kg N/ha)			
0	2.89b	2.25b	1.84
45	3.06ab	2.32b	1.86
90	3.45a	2.85a	1.95
SE ±	0.119	0.134	0.106
Period of weed interference (P)			
Weed-free for 3 WAS	6.33a	6.22a	6.00a
Weed-free for 6 WAS	0.10b	0.41c	0.41c
Weed-free for 9 WAS	-	0.10c	0.53c
Weed-free for 12 WAS	-	-	1.27b
Weed-free until harvest	-	-	-
Weed-infested for 3 WAS	0.10b	0.10c	0.31c
Weed-infested for 6 WAS	6.00a	2.03b	0.31c
Weed-infested for 9 WAS	-	6.00a	0.10c
Weed-infested for 12 WAS	-	-	6.11a
Weed-infested until harvest	-	-	-
SE ±	0.216	0.245	0.194
Interaction			
N x P	*	NS	NS

Means followed by the same letter(s) within the same column of any treatment group are not significantly different at 5% level of probability (DMRT)
WAS = Weeks after sowing
NS = Not significant at 5% level of probability
* = Significant at 5% level of probability
- = Not completely applied at the time of observation

Table 17: Effects of nitrogen and period of weed interference on weed cover score during the 1994 wet season at Samaru

Treatment	Weed cover score		
	6 WAS	9 WAS	12 WAS
Nitrogen level (kg N/ha)			
0	2.15b	2.90	2.52
45	3.04a	3.35	2.53
90	3.35a	2.81	2.35
SE ±	0.192	0.215	0.116
Period of weed interference (P)			
Weed-free for 3 WAS	4.17b	5.94b	6.28b
Weed-free for 6 WAS	0.24c	2.00c	2.22c
Weed-free for 9 WAS	-	0.68d	1.47cd
Weed-free for 12 WAS	-	-	0.29e
Weed-free until harvest	-	-	-
Weed-infested for 3 WAS	0.97c	0.56d	0.56e
Weed-infested for 6 WAS	6.00a-c	0.73d	0.98de
Weed-infested for 9 WAS	-	8.20a	0.58de
Weed-infested for 12 WAS	-	-	7.41a
Weed-infested until harvest	-	-	-
SE ±	0.351	0.392	0.299
Interaction			
N x P	NS	NS	NS

Means followed by the same letter(s) within the same column of any treatment group are not significantly different at 5% level of probability (DMRT)

WAS = Weeks after sowing
NS = Not significant at 5% level of probability
- = Not completely applied at the time of observation

Table 18: Effects of nitrogen and period of weed interference on weed cover score during the 1995 wet season at Samaru

Treatment	Weed cover score		
	6 WAS	9 WAS	12 WAS
Nitrogen level (kg N/ha)			
0	3.67b	3.38b	2.94b
45	5.35a	4.25a	3.69a
90	5.65a	4.28a	3.23b
SE ±	0.185	0.144	0.164
Period of weed interference (P)			
Weed-free for 3 WAS	9.00a	9.72a	10.00a
Weed-free for 6 WAS	1.06b	2.39b	2.94b
Weed-free for 9 WAS	-	2.11b	2.52b
Weed-free for 12 WAS	-	-	0.88c
Weed-free until harvest	-	-	-
Weed-infested for 3 WAS	1.00b	0.34c	0.23c
Weed-infested for 6 WAS	8.50a	0.20c	0.27c
Weed-infested for 9 WAS	-	9.06a	0.20c
Weed-infested for 12 WAS	-	-	9.22a
Weed-infested until harvest	-	-	-
SE ±	0.337	0.264	0.300
Interaction			
N x P	NS	NS	NS

Means followed by the same letter(s) within the same column of any treatment group are not significantly different at 5% level of probability (DMRT)

WAS = Weeks after sowing
NS = Not significant at 5% level of probability
- = Not completely applied at the time of observation

weed-free for 3 WAS only was similar to those obtained on plots weed-infested for 6 WAS and more during the corresponding periods in 1993 and 1995. At 12 WAS, plot kept weed-free for 9 WAS had comparable weed score to those weed-infested for the same periods in 1993 and 1994.

The interaction of N and period of weed interference on weed cover score was significant at 6 WAS in 1993 (Table 19). With each of the N levels, plot kept weed-free for 6 WAS and those initially weed-infested for 3 WAS only had the least weed cover score. The plot kept weed-free for 3 WAS only and given 0-9 kg N/ha had comparable weed cover score to the maximum obtained from that given 45 kg N/ha and left infested for 6 WAS. Without N, the weed cover score on plot weed-infested for 6 WAS was also comparable to the maximum and greater than the least in the trial. However, with 90 kg N/ha, the plot left weedy for 6 WAS had greater weed cover score than the least, but lower than the maximum.

4.2.2 Cummulative weed dry weight

The cummulative weed dry weight obtained in 1993 was greater than in 1995, which in turn was greater than that obtained in 1994 (Table 20).

Application of N had significant effect on the cummulative weed dry weight in 1995 only. In this year, N application increased cummulative weed dry weight over the no N control, while no significant difference was observed between 45 and 90 kg N/ha treatments.

Table 19: Interaction of nitrogen and period of weed interference on weed cover score at 6 WAS during the 1993 wet season at Samaru

	Weed cover score at 6 WAS		
	Nitrogen level (kg N/ha)		
Period of weed interference	0	45	90
Weed-free for 3 WAS	6.33a	6.33a	6.33a
Weed-free for 6 WAS	0.10c	0.10c	0.10c
Weed-free for 9 WAS	-	-	-
Weed-free for 12 WAS	-	-	-
Weed-free until harvest	-	-	-
Weed-infested for 3 WAS	0.10c	0.10c	0.10c
Weed-infested for 6 WAS	6.00ab	7.00a	5.00b
Weed-infested for 9 WAS	-	-	-
Weed-infested for 12 WAS	-	-	-
Weed infested until harvest	-	-	-
SE ±		0.381	

Means followed by the same letter(s) are not significantly different at 5% level of probability (DMRT)

WAS = Weeks after sowing

\- = Not completely applied at the time of observation

Table 20: Effects of nitrogen and period of weed interference on cummulative weed dry weight during the 1993-1995 wet seasons at Samaru

Treatment	Cummulative weed dry weight (t/ha)		
	1993	1994	1995
Nitrogen level (kg N/ha)			
0	8.33	2.23	3.04c
45	11.21	2.57	4.86a
90	9.27	2.29	4.59ab
SE ±	0.605	0.223	0.37
Period of weed interference (P)			
Weed-free for 3 WAS	15.24b	3.66b	4.04c
Weed-free for 6 WAS	6.00c	0.05d	1.73de
Weed-free for 9 WAS	4.27cd	0.05d	0.40c
Weed-free for 12 WAS	2.73cd	0.05d	0.12e
Weed-free until harvest	2.43d	0.05d	0.08e
Weed-infested for 3 WAS	3.92cd	1.76c	0.19e
Weed-infested for 6 WAS	5.02cd	4.06b	3.61cd
Weed-infested for 9 WAS	20.43a	3.63b	9.72b
Weed-infested for 12 WAS	19.69a	5.63a	11.86a
Weed-infested until harvest	16.23b	4.65ab	9.91b
SE ±	1.100	0.406	0.12
Interaction			
N x P	*	NS	NS
Mean	9.60a	2.36c	4.16b

Means followed by the same letter(s) within the same column of any treatment group are not significantly different at 5% level of probability (DMRT)

WAS = Weeks after sowing
NS = Not significant at 5% level of probability
* = Significant at 5% level of probability

The period of weed interference also significantly influenced weed dry weight in the three years of study. In 1993, plots kept weed-free for 6 WAS and more and those weed-infested for 3 and 6 WAS had less weed dry weight than that kept weed-free for 3 WAS only and those weed-infested for 9 and 12 WAS. In 1994, plots kept weed-free for 6 WAS and more had less weed dry weight than that initially infested for 3 WAS only, which in turn was singificantly less than those infested for 6 WAS and more and that kept weed-free for 3 WAS. In 1995, plots kept weed-free for 9 WAS and more and that weed-infested for 3 WAS only had less weed dry weight than those weed-infested for 6 WAS and more. In this year, keeping the plot weed free for 3 WAS only resulted in comparable weed dry weight to that obtained from the weed-infested plot for 6 WAS, but less than those infested for 9 WAS and more. The cummulative weed dry weight of plot weed-infested throughout the crop life-cycle was less than that obtained from plots weed-infested for 9 WAS 1993 and 1994.

There was significant interaction of N and period of weed interference on cummulative weed dry weight in 1993 (Table 21). In all the N levels, plots kept weed-free for 6 WAS and more and those infested for 3 and 6 WAS had lower weed dry weight than all other treatments except that with 90 kg N/ha kept weed-free for 3 WAS. Without N, plot kept weed-free for 3 WAS only and those weed-infested for 9 WAS and more had lower weed dry weight than the maximum in the trial, but greater than the least. With 45 kg N/ha, plot kept weed-free for 3 WAS and that weed-infested for 12

Table 21: Interaction of nitrogen and period of weed interference on cummulative weed dry weight during the 1993 wet season at Samaru

	Cummulative weed dry weight (t/ha)		
	Nitrogen level (kg N/ha)		
Period of weed interference	0	45	90
Weed-free for 3 WAS	18.7b-d	23.08ab	3.96e
Weed-free for 6 WAS	2.52e	2.45e	2.81e
Weed-free for 9 WAS	2.25e	3.13e	1.88e
Weed-free for 12 WAS	6.04e	3.44e	3.33e
Weed-free until harvest	1.98e	2.81e	3.33e
Weed-infested for 3 WAS	2.34e	3.91e	5.51e
Weed-infested for 6 WAS	5.26e	7.24e	2.55e
Weed-infested for 9 WAS	13.59d	27.5a	20.21bc
Weed-infested for 12 WAS	14.27d	23.86ab	20.31bc
Weed infested until harvest	15.83c-d	14.06d	18.80b-d
SE ±	0.90		

Means followed by the same letter(s) are not significantly different at 5% level of probability (DMRT)

WAS had comparable weed dry weight to the maximum obtained from weed infestation for 9 WAS, under the same N rate. Nitrogen application increased weed dry weight over the no N control on plots left weedy for 9 and 12 WAS. With 90 kg N/ha, plot kept weed-free for 3 WAS had comparable weed dry weight to the least and less than those without N and 45 kg N/ha.

4.3 Effects of Nitrogen and Period of Weed Interference on Wood, Fibre and Seed Yields of Kenaf

The effects of N and period of weed interference on wood fibre and seed yields of kenaf are shown on Tables 22-33.

4.3.1 Wood weight per plant and yield

The wood weight and wood yield were higher in 1993 than in 1995, being the least in the three years of investigation (Tables 22 and 23). The influence of N application and period of weed interference on wood weight and yield was significant in the three years of study. The effect of N on wood weight per plant and yield was similar in the three years of trials. In both cases, wood weight and yield increased with increasing N level from 0-90 kg N/ha.

In all the years, plot kept weed-free for 3 WAS only and those weed-infested for 9 WAS and more produced significantly lower wood weight and yield than the appropriate maxima. Similarly, plots kept weed-free for 6 WAS and more and that left weed-infested for 3 WAS only produced significantly more wood weight and yield than the appropriate leasts obtained from plots left-infested for 9 WAS

Table 22: Effects of nitrogen and period of weed interference on wood dry weight per plant of kenaf during the 1993-1995 wet season at Samaru

Treatment	Weed weight (g/plant)		
	1993	1994	1995
Nitrogen level (kg N/ha)			
0	8.95c	6.24c	6.57c
45	18.59b	16.83b	13.39b
90	24.55a	22.99a	19.42a
SE ±	0.895	0.931	0.951
Period of weed interference (P)			
Weed-free for 3 WAS	15.42bc	12.21cd	8.97de
Weed-free for 6 WAS	20.60a	19.23ab	17.41ab
Weed-free for 9 WAS	21.22a	22.67a	15.64bc
Weed-free for 12 WAS	18.49ab	16.94b	21.18a
Weed-free until harvest	19.73a	19.42ab	18.04ab
Weed-infested for 3 WAS	18.58ab	19.98ab	13.20b-d
Weed-infested for 6 WAS	17.07a-c	12.99cd	11.29c-e
Weed-infested for 9 WAS	12.89c	10.77d	7.06e
Weed-infested for 12 WAS	14.42bc	8.84d	8.16de
Weed-infested until harvest	15.24bc	10.49d	10.30c-e
SE ±	1.63	1.70	1.736
Interaction			
N x P	NS	NS	NS
Mean	17.37a	15.35ab	13.13b

Means followed by the same letter(s) within the same column of any treatment group are not significantly different at 5% level of probability (DMRT)

NS = Not significant at 5% level of probability

Table 23: Effects of nitrogen and period of weed interference on wood yield of kenaf during the 1993-1995 wet season at Samaru

Treatment	Wood yield (kg/ha)		
	1993	1994	1995
Nitrogen level (kg N/ha)			
0	1790c	1264c	1257c
45	3718b	3366b	2773b
90	4910a	4598a	3775a
SE ±	179.0	185.7	181.5
Period of weed interference (P)			
Weed-free for 3 WAS	3084c	2442cd	1793cd
Weed-free for 6 WAS	4120a	3846ab	3616ab
Weed-free for 9 WAS	4244a	4534a	3150ab
Weed-free for 12 WAS	3698ab	3411b	3754a
Weed-free until harvest	3946a	3832ab	3607ab
Weed-infested for 3 WAS	3716ab	3993ab	2641bc
Weed-infested for 6 WAS	3414a-c	2596cd	2068cd
Weed-infested for 9 WAS	2578c	2156d	1412d
Weed-infested for 12 WAS	2884bc	1768d	1951cd
Weed-infested until harvest	3048bc	2132d	2024cd
SE ±	326.0	339.0	331.4
Interaction			
N x P	NS	NS	NS
Mean	3473a	3073ab	2602b

Means followed by the same letter(s) within the same column of any treatment group are not significantly different at 5% level of probability (DMRT)

NS = Not significant at 5% level of probability

in 1993 and 1995 and 9 WAS and more in 1994. The plots infested for 6 WAS in 1994 and 3 and 6 WAS in 1995 also produced less wood weight than the appropriate maxima. Weed infestation throughout the crop life-cycle caused 28.2%, 53.0% and 46.1% reductions in wood yield compared to the maximum yields in 1993, 1994 and 1995, respectively.

The interaction of N and period of weed interference on wood weight and yield were not significant in the three years of study.

4.3.2 Ribbon weight per plant

The ribbon weight per plant of kenaf was greater in 1993 than in 1994 and 1995 (Table 24).

Nitrogen application and period of weed interference had significant effects on ribbon yield per plant of kenaf in the three years of trials. The yield tended to increase with increasing N level in the three years.

In 1993, plot kept weed-free for 3 WAS only and those weed-infested for 6 WAS and more produced significantly less ribbon than the maximum obtained from plots kept weed-free for 9 WAS. In this year, the plots kept weed-free for 6 WAS and more and that weed-infested for 3 WAS only produced ribbon yields comparable to the maximum and higher than the least obtained from those weed-infested for 9 WAS. In 1994, plots kept weed-free for 6 WAS and more and that infested for 3 WAS only resulted in higher ribbon yield than plot kept weed-free for 3 WAS only and those weed-infested for 6 WAS and more. In 1995, plots kept weed-free for 6 WAS and throughout the crop life-cycle

Table 24: Effects of nitrogen and period of weed interference on ribbon weight per plant of kenaf during the 1993-1995 wet seasons at Samaru

Treatment	Ribbon weight (g/plant)		
	1993	1994	1995
Nitrogen level (kg N/ha)			
0	6.06c	4.05c	3.71c
45	12.32b	9.17b	7.31b
90	15.79a	12.71a	9.90a
SE ±	0.595	0.474	0.470
Period of weed interference (P)			
Weed-free for 3 WAS	10.04b-d	6.90c	4.05e
Weed-free for 6 WAS	12.87a-c	10.80ab	9.97ab
Weed-free for 9 WAS	14.02a	12.77a	8.02bc
Weed-free for 12 WAS	12.22a-c	10.03b	10.78a
Weed-free until harvest	13.43ab	10.46a-b	9.54ab
Weed-infested for 3 WAS	12.73a-c	10.67ab	6.98cd
Weed-infested for 6 WAS	10.60b-d	7.32c	6.20c-e
Weed-infested for 9 WAS	8.13d	6.44c	3.90e
Weed-infested for 12 WAS	9.53cd	4.85c	4.86de
Weed-infested until harvest	10.31b-d	6.19c	5.44c-e
SE ±	1.081	0.864	0.858
Interaction			
N x P	NS	NS	NS
Mean	11.39a	8.64b	6.97b

Means followed by the same letter(s) within the same column of any treatment group are not significantly different at 5% level of probability (DMRT)

NS = Not significant at 5% level of probability

produced ribbon yield comparable to the maximum obtained from that kept weed-free for 12 WAS. These were also higher than that of plot kept weed-free for 3 WAS only and those infested for 3 WAS and more. Yields of ribbon from plot kept weed-free for 9 WAS and that weed-infested for 3 WAS only were similar and however higher than the least obtained from plot weed-infested for 9 wAS and that kept weed-free for 3 WAS. Unchecked weed infestation throughout the crop life-cycle caused 26.5%, 51.5% and 49.5% reductions in ribbon weight per plant compared to the appropriate maxima in 1993, 1994 and 1995, respectively.

There was no significant interaction of N and period of weed interference on ribbon weight per plant of kenaf during the three years of investigation.

4.3.3 Ribbon yield

Nitrogen application and period of weed interference significantly influenced ribbon yield of kenaf in 1993 when the data was only available (Table 25). The ribbon yield increased with increasing N level.

The plots kept weed-free for 6 WAS and more and those weed-infested for 3 WAS only produced ribbon yields comparable to the maximum obtained from plot kept weed-free for 9 WAS and greater than the least obtained from plot weed-infested for the same period. The yields obtained from plots weed-infested for 3, 6 and 12 WAS, and until harvest were comparable to those kept weed-free for the corresponding periods.

Table 25: Effects of nitrogen and period of weed interference on ribbon yield of kenaf during the 1993 wet season at Samaru

Treatment	Ribbon yield (kg/ha)
	1993
Nitrogen level (kg N/ha)	
0	1212c
45	2464b
90	3158a
SE ±	119.0
Period of weed interference (P)	
Weed-free for 3 WAS	2008b-d
Weed-free for 6 WAS	2574a-c
Weed-free for 9 WAS	2804a
Weed-free for 12 WAS	2444a-c
Weed-free until harvest	2686ab
Weed-infested for 3 WAS	2546a-c
Weed-infested for 6 WAS	2120b-d
Weed-infested for 9 WAS	1628d
Weed-infested for 12 WAS	1906cd
Weed-infested until harvest	2062b-d
SE ±	216.2
Interaction	
N x P	NS
Mean	2278

Means followed by the same letter(s) within the same column of any treatment group are not significantly different at 5% level of probability (DMRT)

NA = Data not available
NS = Not significant at 5% level of probability

The interaction of N and period of weed interference on ribbon yield of kenaf was not significant in the year of trial.

4.3.4 Fibre weight per plant and yield

The fibre production of kenaf was higher in 1994 than in 1995 (Tables 26 and 27), while data was not available for 1993.

Effects of N and period of weed interference on fibre weight per plant and yield of kenaf were significant in 1994 and 1995. The effects on the two parameters were similar. Fibre production increased with N rate upto 90 kg N/ha in the two years.

Plots kept weed-free for 6 WAS and more and those infested for 3 WAS only produced high fibre yield than that kept weed-free for 3 WAS only and those weed-infested for 6 WAS and more in 1994 and 9 WAS and more in 1995. The fibre production on plots weed-infested for 6 WAS and more and that kept weed-free for 3 WAS only were similar and significantly lower than their maxima and comparable to the least yield in the two years of trials. Unchecked weed growth caused 41.4% and 55.3% fibre yield reductions compared to the maximum yields in 1994 and 1995, respectively.

The interaction of N and period of weed interference on fibre production was significant in 1994 (Tables 28 and 29). The interaction on the fibre weight per plant and yield was similar. Without the application of N, fibre yields of all the weed interference treatments did not differ. The yields were also comparable to the least obtained on plots left weedy for 9 WAS and more. With application of 45 kg N/ha, plots kept weed-free for

Table 26: Effects of nitrogen and period of weed interference on fibre weight per plant of kenaf during the 1994-1995 wet seasons at Samaru

Treatment	Fibre weight (g/plant)		
	1993	1994	1995
Nitrogen level (kg N/ha)			
0	NA	2.30c	2.18c
45	NA	5.84b	4.53b
90	NA	7.61a	6.05a
SE ±	-	0.299	0.337
Period of weed interference (P)			
Weed-free for 3 WAS	NA	4.11c	2.36c
Weed-free for 6 WAS	NA	6.60b	6.05a
Weed-free for 9 WAS	NA	8.77a	4.88ab
Weed-free for 12 WAS	NA	6.11b	6.68a
Weed-free until harvest	NA	6.12b	5.87a
Weed-infested for 3 WAS	NA	6.08b	4.84ab
Weed-infested for 6 WAS	NA	4.29c	3.68bc
Weed-infested for 9 WAS	NA	3.90c	2.31c
Weed-infested for 12 WAS	NA	2.86c	2.88c
Weed-infested until harvest	NA	3.68c	2.98c
SE ±		0.546	0.616
Interaction			
N x P		*	NS
Mean		5.25a	4.25

Means followed by the same letter(s) within the same column of any treatment group are not significantly different at 5% level of probability (DMRT)

NA = Data not available
NS = Not significant at 5% level of probability
* = Significant at 5% level of probability

Table 27: Effects of nitrogen and period of weed interference on fibre yield of kenaf during the 1994-1995 wet seasons at Samaru

Treatment	Fibre yield (kg/ha)		
	1993	1994	1995
Nitrogen level (kg N/ha)			
0	NA	461c	436c
45	NA	1168b	904b
90	NA	1509a	1210a
SE ±	-	60.1	67.3
Period of weed interference (P)			
Weed-free for 3 WAS	NA	823c	472c
Weed-free for 6 WAS	NA	1274b	1211a
Weed-free for 9 WAS	NA	1256a	966ab
Weed-free for 12 WAS	NA	1224b	1336a
Weed-free until harvest	NA	1226b	1174a
Weed-infested for 3 WAS	NA	1214b	968ab
Weed-infested for 6 WAS	NA	858c	736bc
Weed-infested for 9 WAS	NA	778c	462c
Weed-infested for 12 WAS	NA	572c	576c
Weed-infested until harvest	NA	736c	597c
SE ±	-	109.7	122.9
Interaction			
N x P	-	*	NS
Mean	-	1046a	850b

Means followed by the same letter(s) within the same column of any treatment group are not significantly different at 5% level of probability (DMRT)

NA = Data not available
NS = Not significant at 5% level of probability

Table 28: Interaction of nitrogen and period of weed interference on fibre weight per plant of kenaf during the 1994 wet season at Samaru

Period of weed interference	Fibre weight (g/plant) Nitrogen level (kg N/ha) 0	45	90
Weed-free for 3 WAS	2.041m	4.38g-m	5.91e-j
Weed-free for 6 WAS	2.391m	6.28e-h	11.14ab
Weed-free for 9 WAS	3.60h-m	12.24a	10.46a-c
Weed-free for 12 WAS	2.66k-m	7.03d-g	8.66b-e
Weed-free until harvest	2.551m	8.13c-f	7.69c-f
Weed-infested for 3 WAS	2.91j-m	5.80e-j	9.52a-d
Weed-infested for 6 WAS	2.101m	5.06f-l	5.73e-k
Weed-infested for 9 WAS	1.44m	3.65h-m	6.60d-g
Weed-infested for 12 WAS	1.53m	2.71k-m	4.34g-m
Weed infested until harvest	1.82m	3.14i-m	6.08e-i
SE ±		0.945	

Means followed by the same letter(s) are not significantly different at 5% level of probability (DMRT)

Table 29: Interaction of nitrogen and period of weed interference on fibre yield of kenaf during the 1994 wet season at Samaru

	Fibre yield (kg/ha)		
	Nitrogen level (kg N/ha)		
Period of weed interference	0	45	90
Weed-free for 3 WAS	408lm	876g-m	1182e-j
Weed-free for 6 WAS	478lm	1256e-h	2228ab
Weed-free for 9 WAS	720h-m	2448a	2092a-c
Weed-free for 12 WAS	532k-l	1406d-g	1732b-e
Weed-free until harvest	510lm	1626c-f	1538c-f
Weed-infested for 3 WAS	582j-m	1160e-j	1904a-d
Weed-infested for 6 WAS	420lm	10I2f-l	1146e-k
Weed-infested for 9 WAS	288m	730h-m	1320d-g
Weed-infested for 12 WAS	306m	542k-m	868g-m
Weed infested until harvest	364m	628i-m	1216e-i
SE ±		189.0	

Means followed by the same letter(s) are not significantly different at 5% level of probability (DMRT)

9 WAS had the maximum fibre yield, while yields from plots weed-infested for 9 wAS and more and that kept weed-free for 3 WAS only were comparable to the least in the trial. In the N level, plots kept weed-free for 6 WAS and more produced higher fibre than the least, while at 90 kg N rate, only the plots weed-infested for 12 WAS produced comparable fibre yield to the least. Also at 90 kg N/ha, plots kept weed-free for 6 and 9 WAS and that weed-infested for 3 WAS only produced fibre yields that were comparable to the maximum in the trial. With the application of 45 and 90 kg N/ha, fibre production on the plots kept weed-free for 9 WAS and more were correspondingly similar and greater than those without N. Fibre yield increased with N level in plot kept weed-free for 6 WAS. The fibre yields from plots kept weed-free for 3 WAS only and those weed-infested for 12 WAS and until harvest and given 45 kg N/ha were similar to the corresponding treatments with 90 kg N/ha.

Figures 1- 3 show curves of predicted values of kenaf ribbon yields as affected by period of weed interference. In 1993 for 10, 20 and 50% reductions in the potential ribbon yield, initial weed-free periods of 54.9, 45.5 and 22.54 days after sowing (DAS) were required respectively (Fig. 1). For similar reductions in the yield, initial weed-infestation of 11.2, 18.9 and 37.1 DAS were required respectively. In 1994, weed-free periods of 42.7, 35.7 and 19.6 DAS or initial weed infestation of 9.1, 21.0 and 53.2 DAS were required to cause 10, 20 and 50% reductions in the potential fibre yield, respectively (Fig. 2). In 1995, for 10, 20 and 50% reductions in the potential fibre yield, the crop had to be

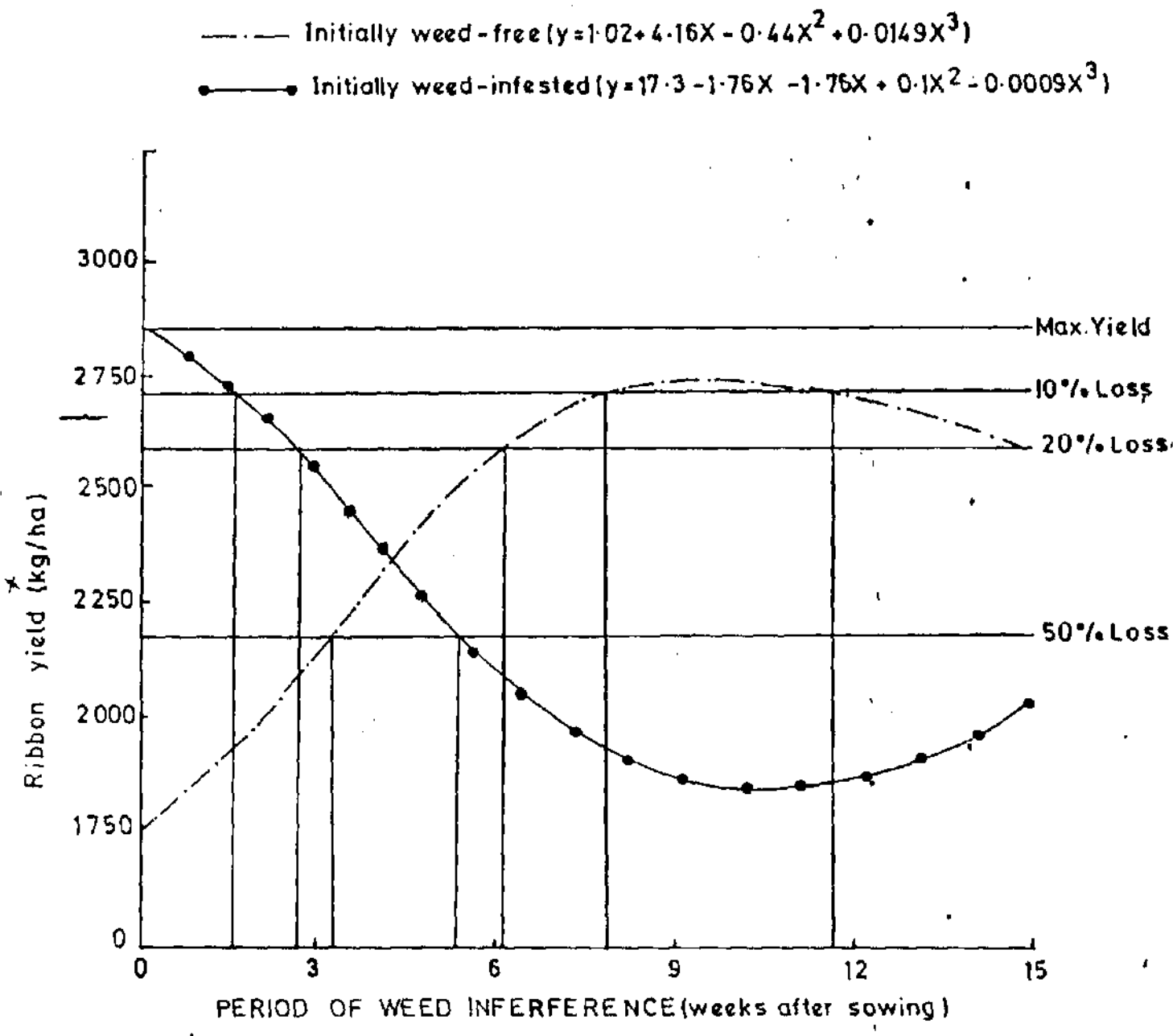


Fig.1: Ribbon yield of kenaf as affected by period of weed interference during the 1993 wet season at Samaru

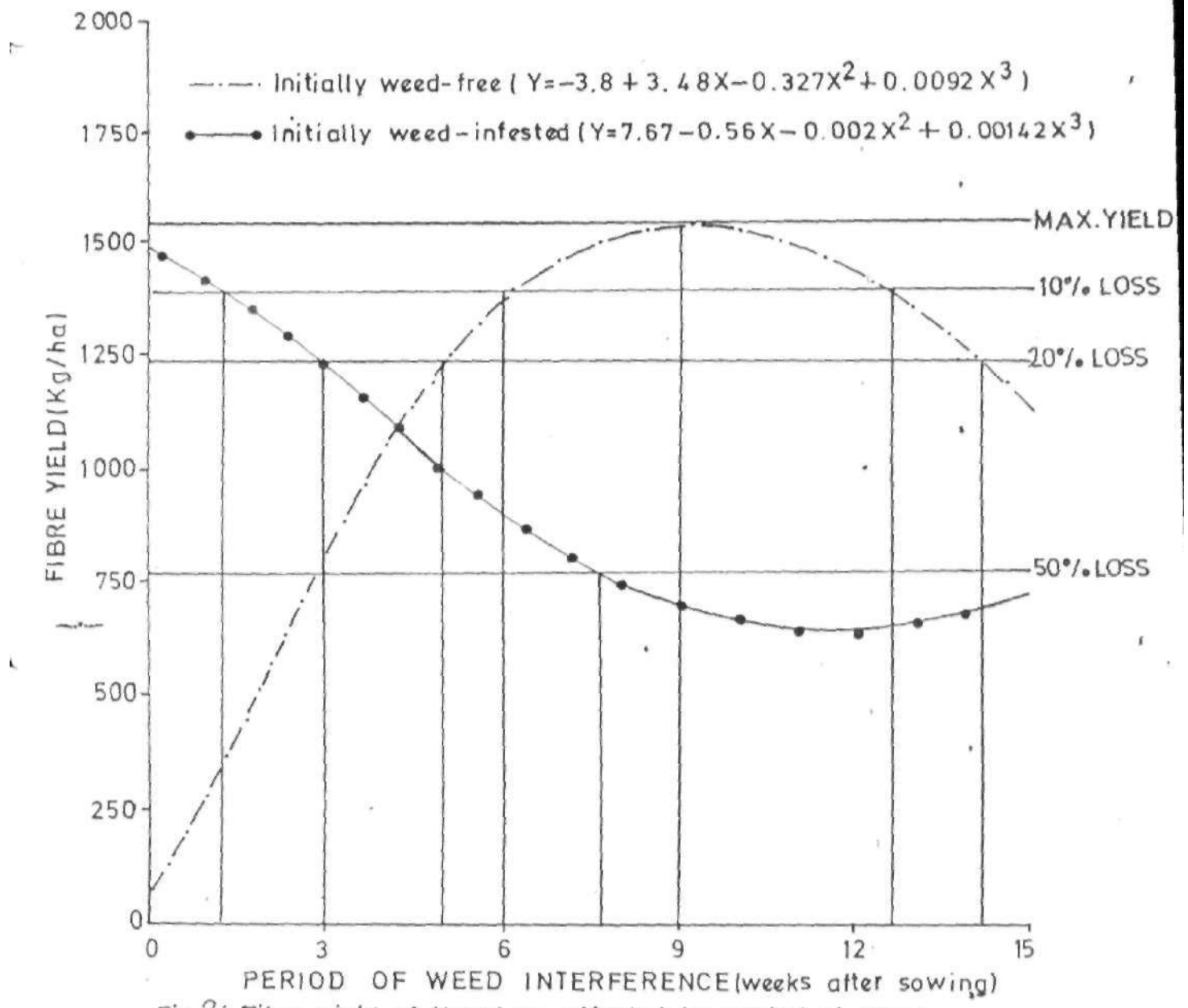


Fig.2: Fibre yield of Kenaf as affected by period of weed interference during the 1994 wet season at Samaru

kept weed-free for 61.6, 46.9 and 23.8 DAS, respectively (Fig. 3). On the other hand, for similar reductions in the yield, weed-infestation of 7.7, 15.4 and 46.9 DAS were required, respectively.

4.3.5 Number of capsules per plant

The number of capsules per plant of kenaf was higher in 1993 than in 1994 and 1995 (Table 30).

The number of capsules per plant was singificantly influenced by N and period of weed interference during the three years of trials. Capsules number generally increased with N rates, except in 1993 when both 45 and 90 kg N/ha similarly increased the number of capsules compared with the no N treatment.

In 1993, the plants kept weed-free through out the crop life-cycle and those initially weed-infested for 3 WAS only produced the maximum number of capsules per plant, while the least was produced by those weed-infested for 12 WAS. The number of capsules of the plants kept weed-free for 3-9 WAS and those weed-infested for 6 WAS and more were however comparable to the least in the trial. In 1994, plants kept weed-free for 9 WAS had significantly higher number of capsules than those kept weed-free for 3 WAS only as well as those weed-infested for 6 WAS and more. The plants kept weed-free until harvest had higher number of capsules than the least obtained from those weed-infested for 12 WAS and more, and those kept weed-free for 3 WAS only. The plants kept weed-free for 6 WAS and those infested for 3 WAS resulted in the number of capsules that were also comparable to the maximum and greater than the least. In 1995, plants kept weed-free for

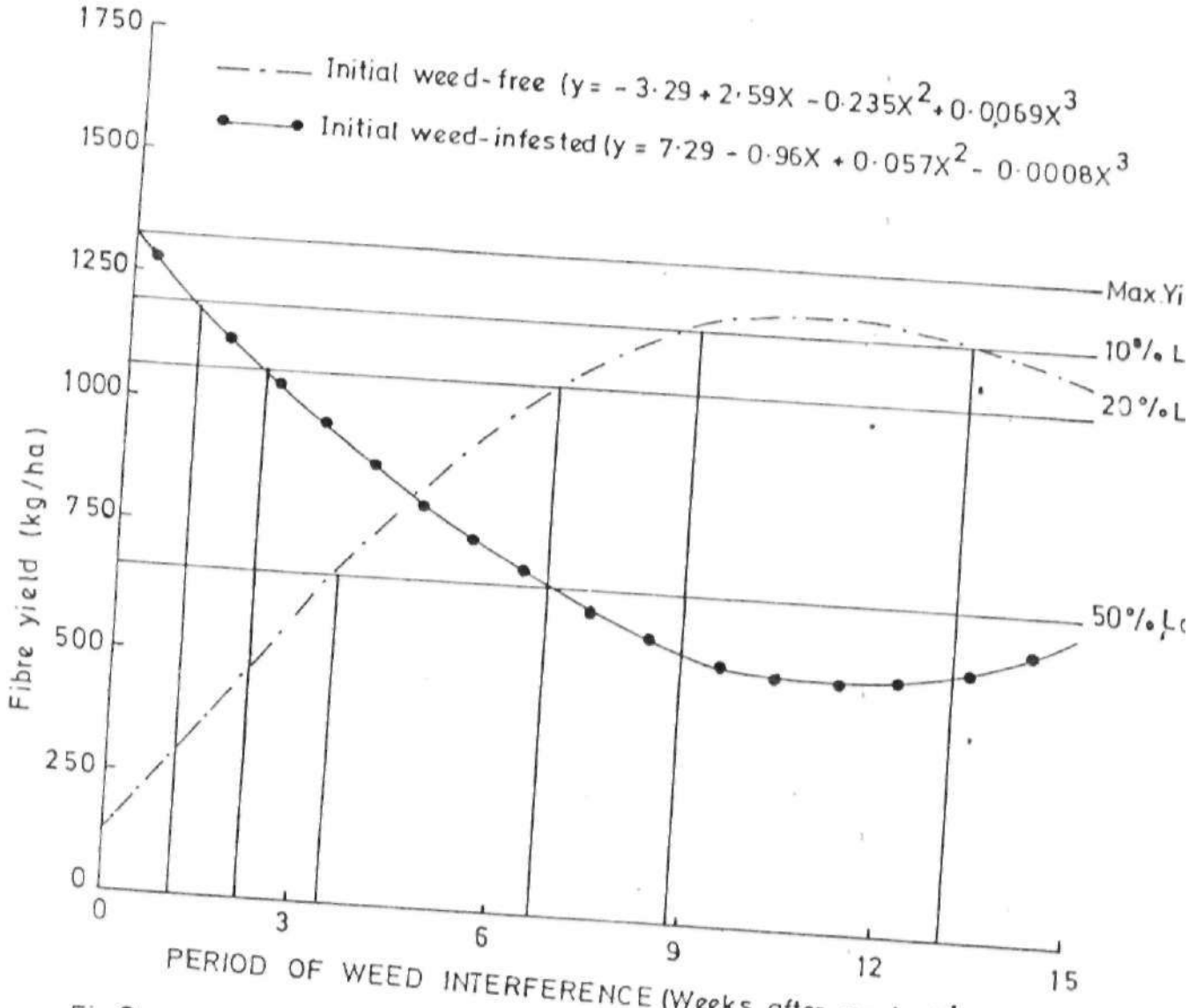


Fig.3: Fibre yield of kenaf as affected by period of weed interference during the 1995 wet season at Samaru.

Table 30: Effects of nitrogen and period of weed interference on the number of capsules per plant of kenaf during the 1993-1995 wet seasons at Samaru

Treatment	Number of capsules per plant		
	1993	1994	1995
Nitrogen level (kg N/ha)			
0	13.18b	10.61c	7.81c
45	19.13a	14.31b	10.10b
90	19.19a	17.68a	14.37a
SE ±	1.156	0.912	0.747
Period of weed interference (P)			
Weed-free for 3 WAS	13.27bc	9.60e	4.60f
Weed-free for 6 WAS	16.82a-c	16.27a-c	12.36ab
Weed-free for 9 WAS	17.27a-c	20.87a	13.60ab
Weed-free for 12 WAS	19.13ab	14.83b-d	16.36a
Weed-free until harvest	20.11a	18.18ab	16.09a
Weed-infested for 3 WAS	21.38a	16.66a-c	11.73bc
Weed-infested for 6 WAS	17.27a-c	11.77b-e	10.49b-d
Weed-infested for 9 WAS	17.42a-c	13.72b-c	9.22c-e
Weed-infested for 12 WAS	11.47c	10.86de	7.26d-f
Weed-infested until harvest	17.50a-c	9.28e	5.87ef
SE ±	2.145	1.665	1.364
Interaction			
N x P	NS	NS	NS
Mean	17.17a	14.20b	10.77b

Means followed by the same letter(s) within the same column of any treatment group are not significantly different at 5% level of probability (DMRT)

NS = Not significant at 5% level of probability

3 WAS and those weed-infested initially for 3 WAS and more produced lower number of capsules than the maximum obtained with those kept weed-free for 12 WAS and until harvest. Plants kept weed-free for 6 and 9 WAS produced capsules numbers comparable to the maximum in the trial. The plants weed-infested initially for 3 and 6 WAS produced number of capsules comparable to those kept weed-free for 6 and 9 WAS. Plants kept weed-free for 3 WAS only and those weed-infested for 12 WAS and more produced the least capsules.

There was no significant interaction of N and period of weed interference on the number of capsules per plant of kenaf in the three years of study.

4.3.6 Seed production

The kenaf crop produced more seeds in 1993 and 1994 than in 1995. Both nitrogen and period of weed interference had significant effects on seed weight per plant and seed yield (Tables 31 and 32). The effects of these factors on the two parameters were similar in the three years of trials. Seed production increased with N level in the three years.

In 1993, the plants kept weed-free for 6 and 12 WAS and those weed-infested for 3 WAS only had maximum seed production, which was greater than the least obtained from those weed-infested for 9 and 12 WAS. However, the plants kept weed-free for 3 and 9 WAS and until harvest had seed yields comparable to the maximum in the trial. In 1994, plants kept weed-free for 3 WAS only and those

Table 31: Effects of nitrogen and period of weed interference on seed wieght per plant of kenaf during the 1993-1995 wet seasons at Samaru

Treatment	Seed weight (g/plant)		
	1993	1994	1995
Nitrogen level (kg N/ha)			
0	4.11c	3.79c	2.57c
45	5.57b	4.88b	3.48b
90	7.10a	6.29a	4.81a
SE ±	0.314	0.347	0.272
Period of weed interference (P)			
Weed-free for 3 WAS	5.68ab	3.17e	1.39f
Weed-free for 6 WAS	6.22a	5.63a-d	4.62a-d
Weed-free for 9 WAS	5.76ab	6.91a	4.85a-c
Weed-free for 12 WAS	6.70a	5.56a-d	5.32ab
Weed-free until harvest	6.05ab	6.28ab	5.77a
Weed-infested for 3 WAS	6.51a	6.03a-c	4.01b-d
Weed-infested for 6 WAS	5.45a-c	4.05de	3.67c-d
Weed-infested for 9 WAS	4.66bc	4.76b-e	3.13de
Weed-infested for 12 WAS	3.77c	4.13c-e	1.37f
Weed-infested until harvest	5.17a-c	3.36e	2.09ef
SE ±	0.574	0.634	0.272
Interaction			
N x P	NS	NS	NS
Mean	5.60a	4.99a	3.63b

Means followed by the same letter(s) within the same column of any treatment group are not significantly different at 5% level of probability (DMRT)

NS = Not significant at 5% level of probability

Table 32: Effects of nitrogen and period of weed interference on seed yjeld of kenaf during the 1993-1995 wet seasons at Samaru

Treatment	Seed yield(kg/ha)		
	1993	1994	1995
Nitrogen level (kg N/ha)			
0	822c	755c	507c
45	1114b	978b	697b
90	1420a	1260a	962a
SE ±	62.8	70.0	54.5
Period of weed interference (P)			
Weed-free for 3 WAS	1136ab	634e	279f
Weed-free for 6 WAS	1244a	1126a-d	902a-d
Weed-free for 9 WAS	1152ab	1382a	970b-c
Weed-free for 12 WAS	1340a	1112a-d	1065ab
Weed-free until harvest	1210ab	1256ab	1153a
Weed-infested for 3 WAS	1302a	1206a-c	803b-d
Weed-infested for 6 WAS	1090a-c	810de	733c-e
Weed-infested for 9 WAS	932bc	952b-e	626de
Weed-infested for 12 WAS	754c	826c-e	273f
Weed-infested until harvest	1034a-c	672e	415ef
SE ±	114.7	127	99.5
Interaction			
N x P	NS	NS	NS
Mean	1119a	998a	722b

Means followed by the same letter(s) within the same column of any treatment group are not significantly different at 5% level of probability (DMRT)

NS = Not significant at 5% level of probability

weed-infested for 6 WAS and more had lower seed production than the maximum obtained from those kept weed-free for 9 WAS. The plants kept weed-free for 6 wAS and more and those initially infested for 3 WAS only produced seed yield comparable to the maximum and higher than the least in the trial. Plants kept weed-free for 3 WAS only and those weed-infested throughout the crop life-cycle produced the least seeds. In 1995, plants kept weed-free for 3 WAS only and those weed-infested for 3 WAS and more produced lower seed yields than the maximum obtained from those kept weed-free throughout the crop life-cycle. The plants kept weed free for 6 to 12 WAS produced yields comparable to the maximum and higher than the least obtained from plants weed-infested for 12 WAS and more, as well as those kept weed-free initially for 3 WAS. The plants initially weed-infested for 3 WAS only produced seed yield comparable to those kept weed-free for 6-12 WAS. Unchecked weed growth resulted in 16.9%, 51.4% and 63.8% reductions in seed yield compared to the maximum obtained in the respective years of experimentation.

There was no significant interaction of N and period of weed interference on seed production of kenaf in the three years of trials.

The predicted values of kenaf seed yields as affected by period of weed interference are shown on figures 4-6. In 1993, for a 10% reduction in the potential seed yield, the crop had to be kept weed-free for 28 DAS only (Fig. 4). For 10 and 20% reductions in the potential yield, weed-infested periods of 40.6 and 52.5 DAS were required, respectively. In 1994, for 10, 20 and 50% reductions in potential seed yield, the crop

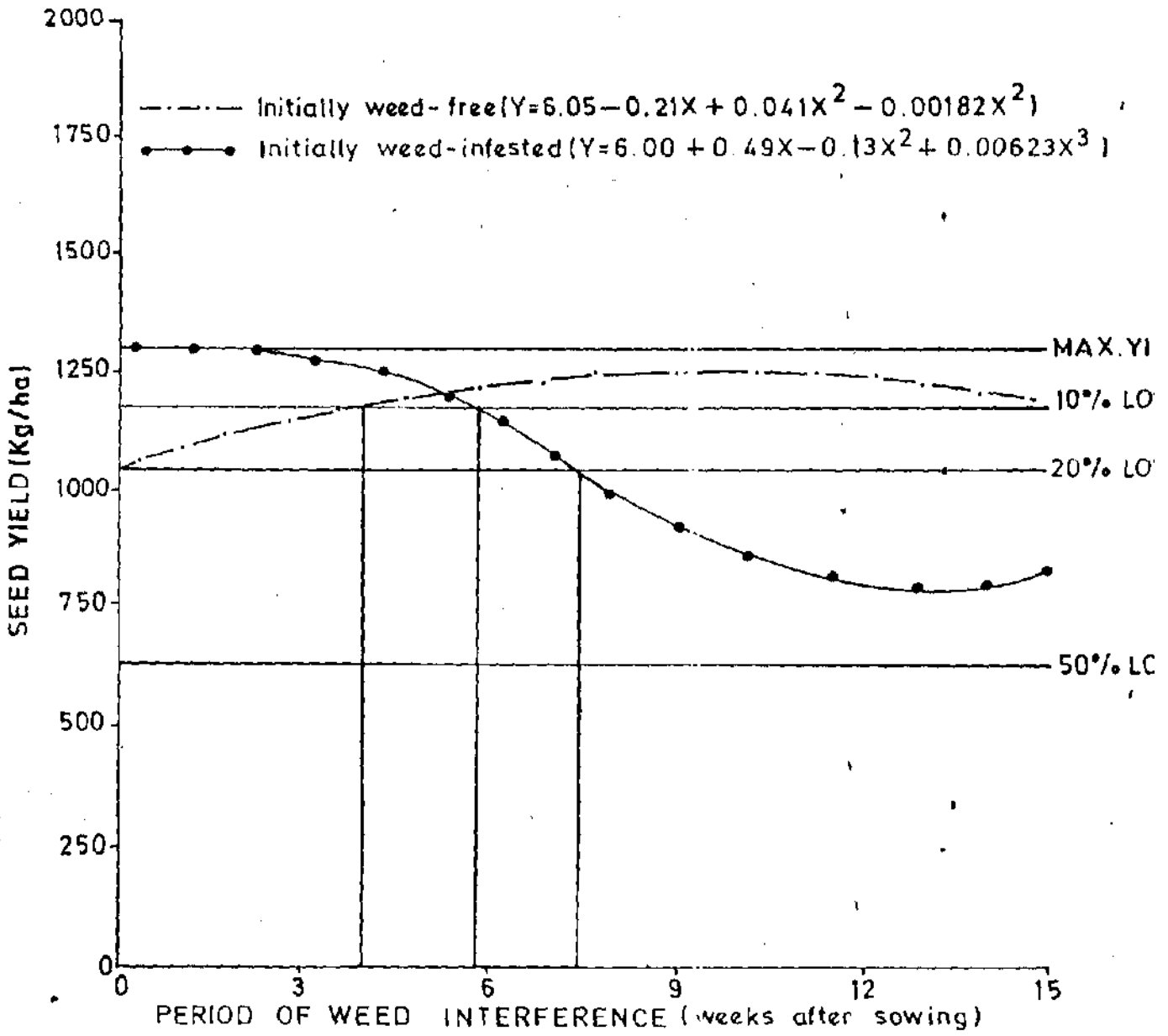


Fig. 4. Seed yield of Kenaf as affected by period of weed interference during the 1993 wet season at Samaru

had to be initially weed-infested for 3.5, 9.1 and 49.7 DAS, respectively (Fig. 5). An initial weed-free period of 25.9 DAS was required for 50% reduction in the yield in this year. In 1995, for 10, 20 and 50% reductions in the yield, weed-free periods of 51.1, 44.1 and 28.7 DAS were required, respectively (Fig. 6). However for a 50% reduction in yield, weed infestation period of 65.8 DAS was required.

4.3.7 100-seed weight

The 100-seed weight of kenaf was higher in 1994 than in 1995, while no data was available for 1993 (Table 33).

Both N application and period of weed interference had significant effects on 100-seed weight in 1995. Application of N increased 100-seed weight compared to no N treatment in this case. The difference between 45 and 90 kg N/ha treatments was not significant.

In 1994 plants left weed-infested for 12 WAS resulted in the maximum 100-seed weight in the trial. Comparable seed weights to the maximum were obtained from plants kept weed-free for 9 WAS. The least weights were obtained from plants kept weed-free for 3 WAS only and those weed-infested throughout the crop life-cycle. The 100-seed weight of plants weed-infested for 3 and 6 WAS and those weed-free for 6 and 12 WAS were comparable to the least. In 1995, plants kept weed-free for 9 WAS and more and those infested for 3-9 WAS had greater seed weights than those of plants kept weed-free

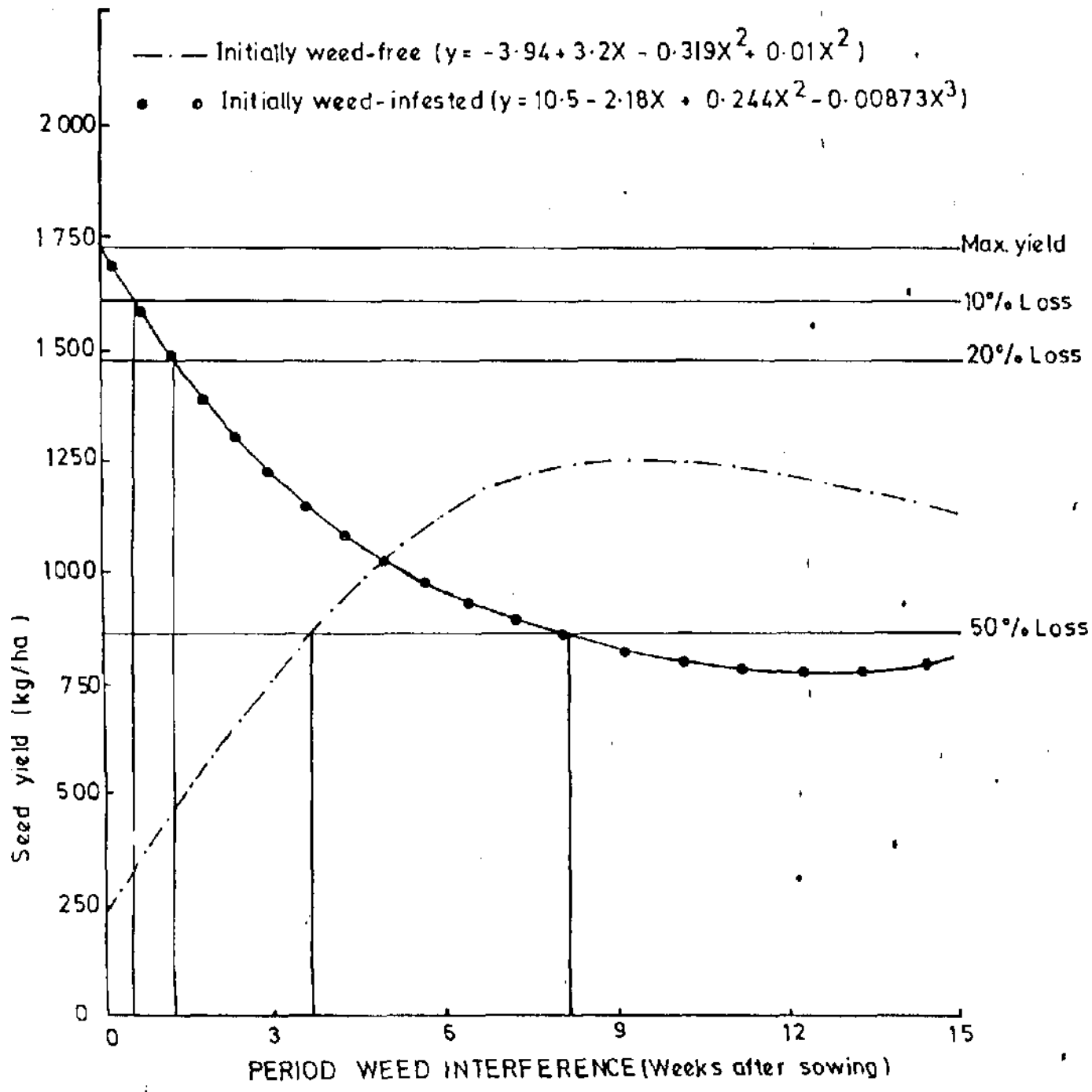


Fig.5: Seed yield of kenaf as affected by period of weed interference during the 1994 wet season at Samaru.

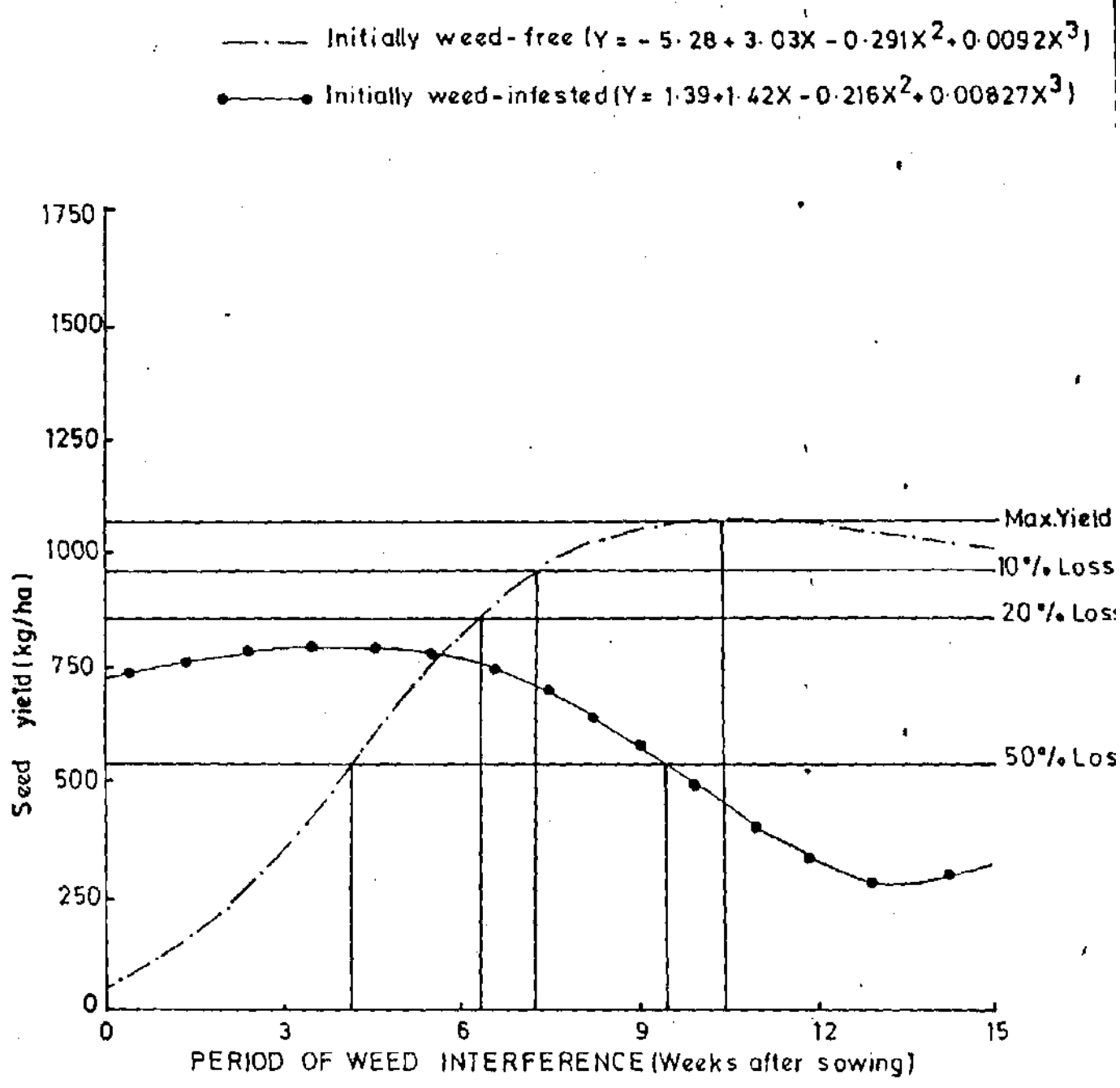


Fig. 6: Seed yield of kenaf as affected by period of weed interference during the 1995 wet season at Samaru.

Table 33: Effects of nitrogen and period of weed interference on 100-seed weight of kenaf during the 1993-1995 wet seasons at Samaru

Treatment	100-Seed weight (g)		
	1993	1994	1995
Nitrogen level (kg N/ha)			
0	NA	2.65	2.30b
45	NA	2.63	2.41a
90	NA	2.64	2.39ab
SE ±	-	0.033	0.33
Period of weed interference			
Weed-free for 3 WAS	NA	2.47d	2.20c
Weed-free for 6 WAS	NA	2.60b-d	2.26bc
Weed-free for 9 WAS	NA	2.69a-c	2.44ab
Weed-free for 12 WAS	NA	2.63b-d	2.52a
Weed-free until harvest	NA	2.76ab	2.48a
Weed-infested for 3 WAS	NA	2.63b-d	2.38ab
Weed-infested for 6 WAS	NA	2.57cd	2.51a
Weed-infested for 9 WAS	NA	2.77ab	2.43ab
Weed-infested for 12 WAS	NA	2.82a	2.16c
Weed-infested until harvest	NA	2.45d	2.27bc
SE ±		0.059	0.061
Interactions			
N x P		NS	NS
Mean		2.64a	2.37b

Means followed by the same letter(s) within the same column of any treatment group are not significantly different at 5% level of probability (DMRT)

NA = Data not available
NS = Not significant at 5% level of probability

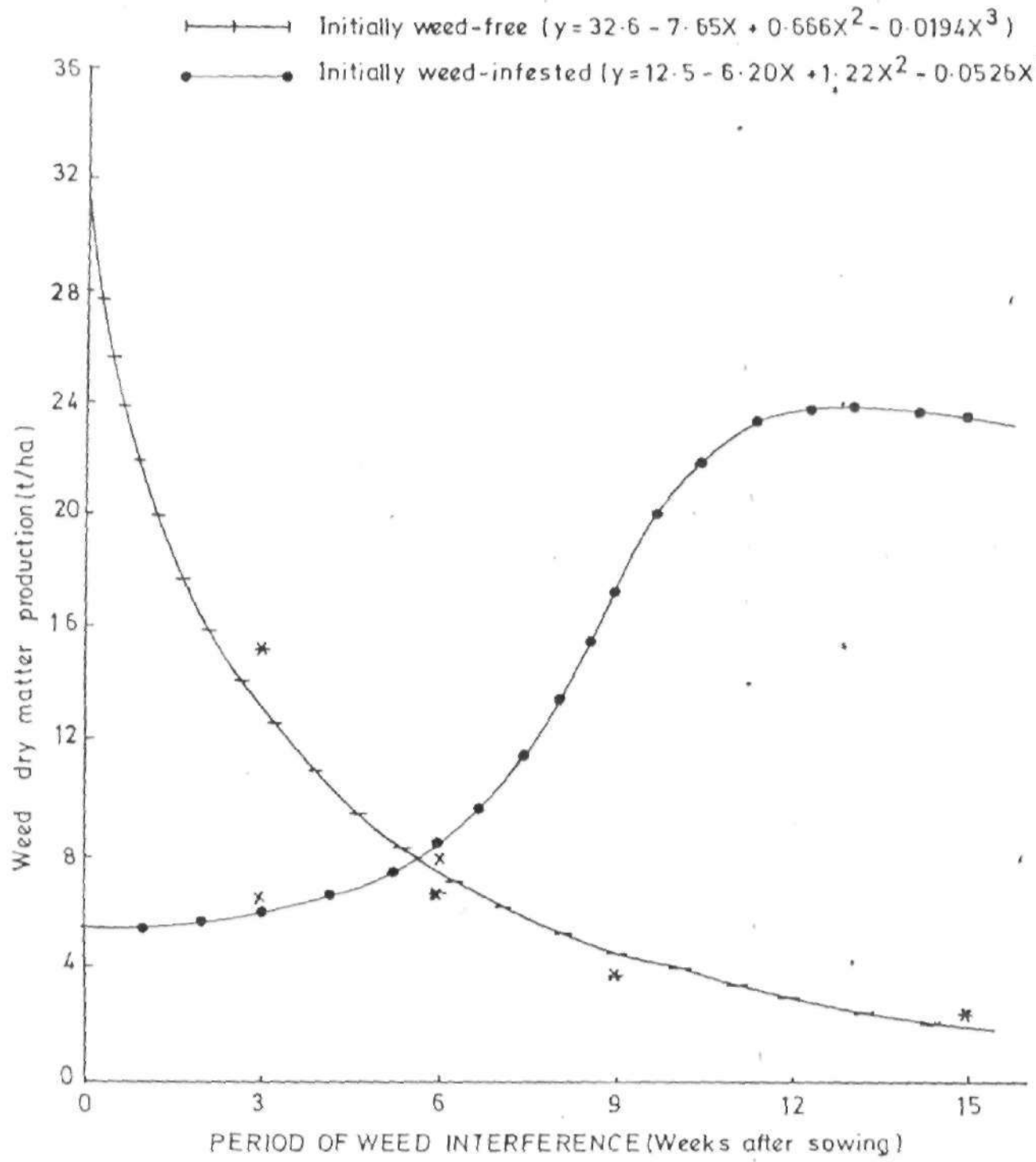


Fig. 7: Weed dry matter production as affected by period of weed interference during the 1993 wet season at Samaru.

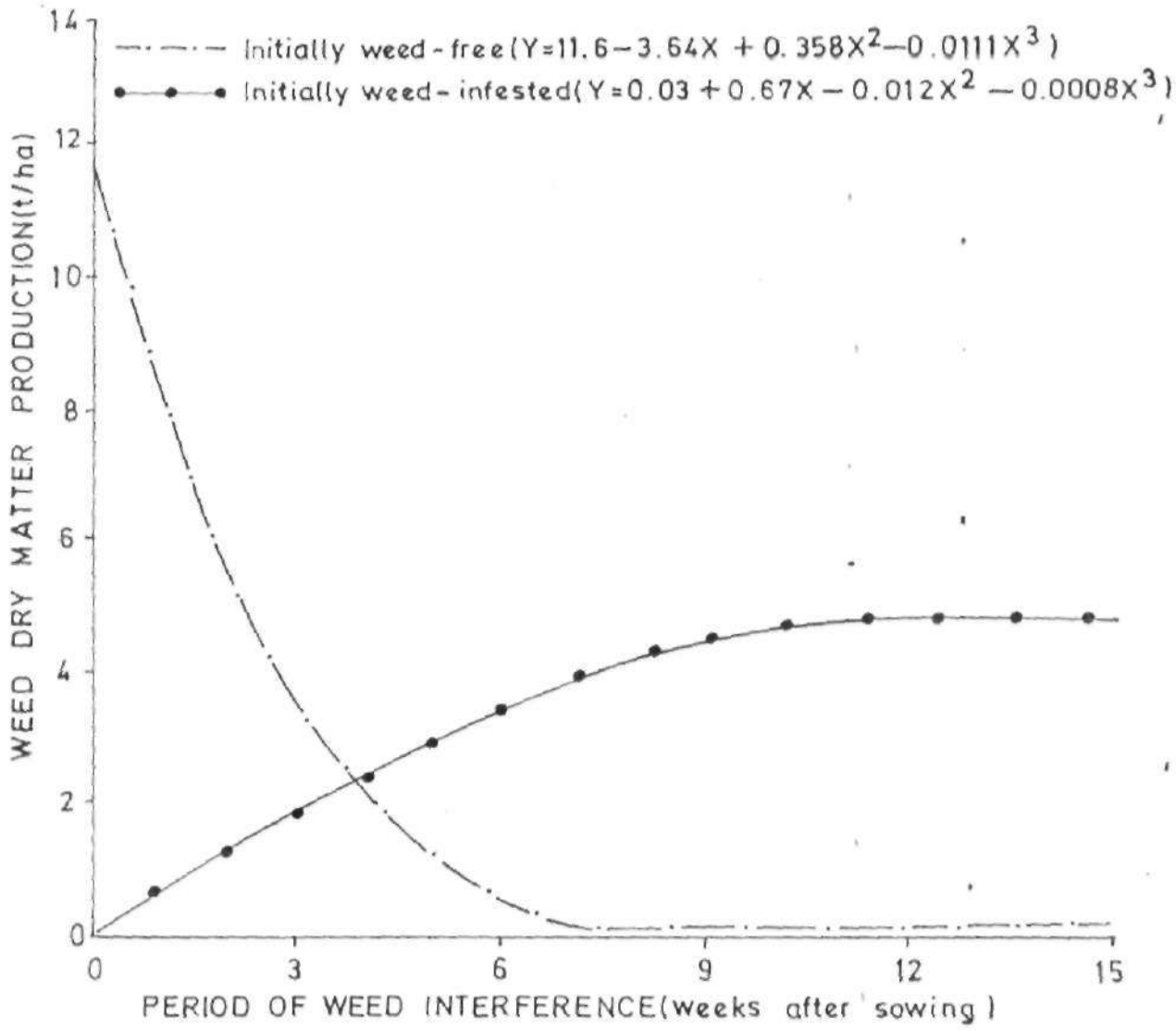


Fig. 8. Weed dry matter production as affected by period of weed interference during the 1994 weet season at Samaru

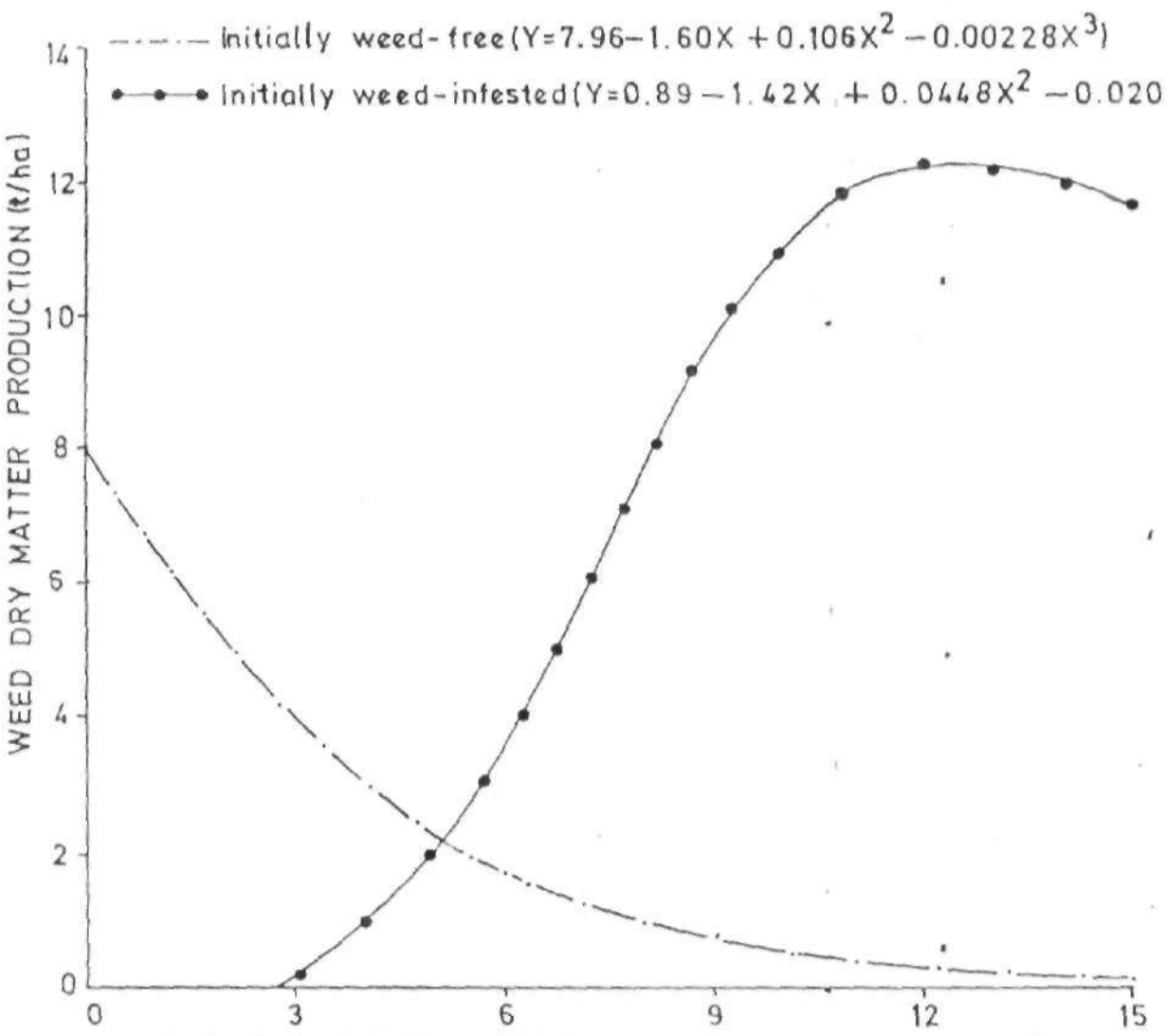


Fig. 9. Weed dry matter production as affected by period of weed interference during the 1995 wet season at Samaru

for 3 WAS only and those weed-infested for 12 WAS, being the least in the trial. Plants kept weed-free for 6 WAS and those weed-infested throughout the life-cycle also produced 100-seed weights that were comparable to the least.

The interaction of N and period of weed interference on 100-seed weight was not significant in the two years of study.

4.4 Correlation and Path Coefficient Analysis

The coefficient of correlation between seed and fibre yields and some crop growth and weed characters in the weed interference study are presented on Tables 34-36. There was a strong and positive correlation between the seed yield and number of capsules per plant, fibre yield and wood weight as well as crop vigour score, plant height and butt diameter at 6 WAS in the three years of trials; and 100-seed weight in 1994 and 1995. The seed yield was strongly and negatively correlated with the number of days to first flowering in the three years, and weed cover score and cummulative weed dry weight in 1994 and 1995. The correlations with weed cover score and dry weight were moderate and also negative in 1993. Fibre yield of kenaf was strongly and positively correlated with number of capsules per plant, weed dry weight, crop vigour score, plant height and butt diameter in the three years of trials. Fibre yield was however negatively correlated with number of days to first flowering and weed cover score in the three years and cummulative weed dry weight in 1994 and 1995. Wood dry weight was significantly and positively correlated with number of capsules per plant, crop vigour score, plant height and butt

Table 34: Mattrix of correlation coefficient between the various kenaf yields, yield characters, weed cover score and cummulative weed weight as affected by nitrogen and period of weed interference during the 1993 wet season at Samaru

	1	2	3	4	5	6	7	8	9	10
1. Seed yield/plant	1.00									
2. No of capsules/plant	0.44**	1.00								
3. Fibre weight/plant	0.59**	0.37**	1.00							
4. Wood - weight/plant	0.62**	0.34*	0.98**	1.00						
5. No of days to first flowering	-0.66**	-0.33*	-0.47**	-0.50**	1.00					
6. Crop vigour score at 6 WAS	0.65**	0.33**	0.76**	0.80**	-0.60**	1.00				
7. Plant height at 6 WAS	0.49**	0.21	0.77**	0.80**	-0.36**	0.77**	1.00			
8. Butt diameter at 6 WAS	0.54**	0.34**	0.85**	0.86**	-0.43**	0.72**	0.79**	1.00		
9. Weed cover score at 6 WAS	-0.27*	-0.19	-0.26*	-0.24	0.36**	-0.27*	-0.28*	0.24	1.00	
10. Cummulative weed dry weight	-0.30*	-0.20	-0.23	0.23	0.28*	-0.22	-0.21	-0.19	0.71**	1.00

* Significant at 5% level of probability (r = 0.26)
** Significant at 1% level of probability (r = 0.35)

Table 35: Mattrix of correlation coefficient between the various kenaf yields, yield characters, weed cover score and cummulative weed weight as affected by nitrogen and period of weed interference during the 1994 wet season at Samaru

	1	2	3	4	5	6	7	8	9	10	11
1. Seed yield/plant	1.00										
2. 100-Seed weight/plant	0.36**	1.00									
3. No of capsules/plant	0.96**	0.33*	1.00								
4. Fibre weight/plant	0.70**	0.07	0.73**	1.00							
5. Wood weight/plant	0.71**	0.11	0.74**	0.92**	1.00						
6. No of days to first flowering	-0.49**	-0.05	-0.50**	-0.69**	-0.74**	1.00					
7. Crop vigour score at 6 WAS	0.67**	0.17	0.71**	0.81**	0.85**	-0.76**	1.00				
8. Plant height at 6 WAS	0.66**	0.11	0.68**	0.88**	0.93**	-0.77**	0.86**	1.00			
9. Butt diameter at 6 WAS	0.68**	0.10	0.68**	0.88**	0.90**	-0.76**	0.87**	0.92**	1.00		
10. Weed cover score at 6 WAS	-0.40**	-0.17	-0.42**	-0.38**	-0.37**	0.12	-0.36**	-0.40**	-0.33*	1.00	
11. Cummulative weed dry weight	-0.40**	-0.14	-0.45**	-0.43**	-0.38**	0.24	-0.44**	-0.41**	-0.37**	0.82**	1.00

* Significant at 5% level of probability (r = 0.26)
** Significant at 1% level of probability (r = 0.35)

Table 36: Mattrix of correlation coefficient between the various kenaf yields, yield characters, weed cover score and cummulative weed weight as affected by nitrogen and period of weed interference during the 1995 wet season at Samaru

	1	2	3	4	5	6	7	8	9	10	11
1. Seed yield/plant	1.00										
2. 100-Seed weight/plant	0.45**	1.00									
3. No of capsules/plant	0.89**	0.36**	1.00								
4. Fibre weight/plant	0.68**	0.24	0.75**	1.00							
5. Wood weight/plant	0.69**	0.25*	0.73**	0.91**	1.00						
6. No of days to first flowering	-0.55**	-0.08	-0.64**	-0.63**	-0.63**	1.00					
7. Crop vigour score at 6 WAS	0.68**	0.27*	0.72**	0.80**	0.79**	-0.70**	1.00				
8. Plant height at 6 WAS	0.69**	0.29*	0.72**	0.81**	0.80**	-0.66**	0.88**	1.00			
9. Butt diameter at 6 WAS	0.68**	0.23	0.67**	0.81**	0.79**	-0.62**	0.88**	0.92**	1.00		
10. Weed cover score at 6 WAS	-0.40**	-0.65**	-0.37**	-0.33*	0.41**	0.35**	-0.32*	-0.30*	-0.28*	1.00	
11. Cummulative weed dry weight	-0.46**	-0.25	-0.39**	-0.34*	-0.36**	0.34*	-0.26*	-0.26*	-0.26*	0.76**	1.00

* Significant at 5% level of probability (r = 0.26)
** Significant at 1% level of probability (r = 0.35)

diameter; but negatively correlated with number of days to first flowering in the three years, and weed cover score and cummulative weed dry weight in 1994 and 1995. Crop vigour score, plant height and butt diamter were strongly and positively correlated with one another. These three parameters were strongly and negatively correlated with number of days to first flowering in the three years of study, and weed cover score and dry weight in 1994 and 1995. The number of days to first flowering was positively correlated with weed cover score and weed dry weight in 1993 and 1994.

The direct and indirect effects of some crop parameters on fibre and seed yields are presented in Tables 37 and 38 and the path coefficient between the yields and the parameters are presented in figures 10 and 11. Out of a total contribution of 75% by plant height to fibre yield, the direct contribution via wood yield was 65.0%. The indirect contributions via butt diameter and seed yield were small (1.7 and 1.2% respectively). Of the total contribution of 72% by butt diameter only 2.4% was directly contributed to fibre yield, while the indirect contributions via wood weight, plant height and seed yield were 63.3, 5.7 and 1.4%, respectively. Wood weight contributed a total of 94.8% to fibre yield with 85.5% as direct and 6.2, 1.8 and 1.3% as indirect contributions, via plant height, butt diameter and seed yield, respectively. Out of a total contribution of 56.6% by seed, the direct contribution was only 2.4%, while the indirect contributions via wood yield, plant height and butt diameter were 48.7, 4.0 and 1.5%, respectively.

Table 37: The direct and indirect effects of some crop parameters on ribbon yield of kenaf during the 1993-1995 wet seasons (combined analysis) at Samaru

Crop parameter	Effect through:				
	Plant height (cm)	Butt diameter (mm)	Wood weight (g)	Seed yield (g)	Total correlation
Plant height (cm)	0.082(a)	0.017	0.650	0.012	0.750
Butt diameter (mm)	0.057	0.024	0.633	0.014	0.720
Wood weight (g)	0.062	0.018	0.855	0.013	0.948
Seed yield (g)	0.040	0.015	0.487	0.024	0.566

(a) = Direct effect underlined

Table 38: The direct and indirect effects of some growth characters on kenaf seed yield during the 1993-1995 wet seasons (combined analysis) at Samaru

Crop parameter	Effect through:				
	Plant height (cm)	Butt diameter (mm)	Wood weight (g)	Ribbon yield (g)	Total correlation
Plant height (cm)	-0.021(a)	0.281	0.125	0.095	0.490
Butt diameter (mm)	0.015	0.401	0.122	0.092	0.600
Wood weight (g)	0.016	0.297	0.165	0.120	0.566
Ribbon yield (g)	0.289	0.289	0.155	0.127	0.564

a) = Direct effect underlined

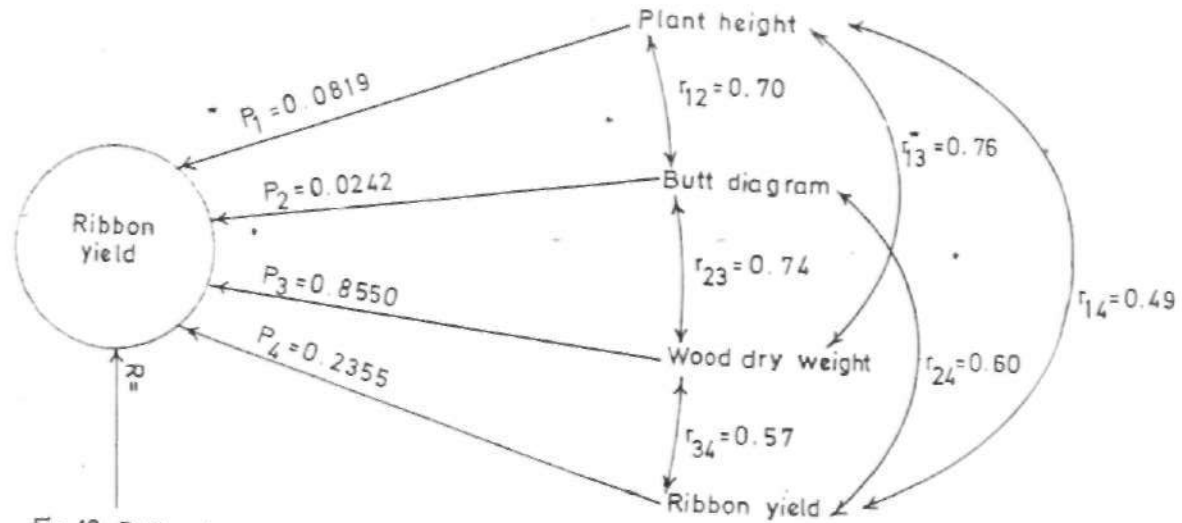


Fig.10. Path diagram showing interrelations of ribbon yield per plant and some crop parameters during the 1993–1995 wet seasons (combined analysis) at Samaru

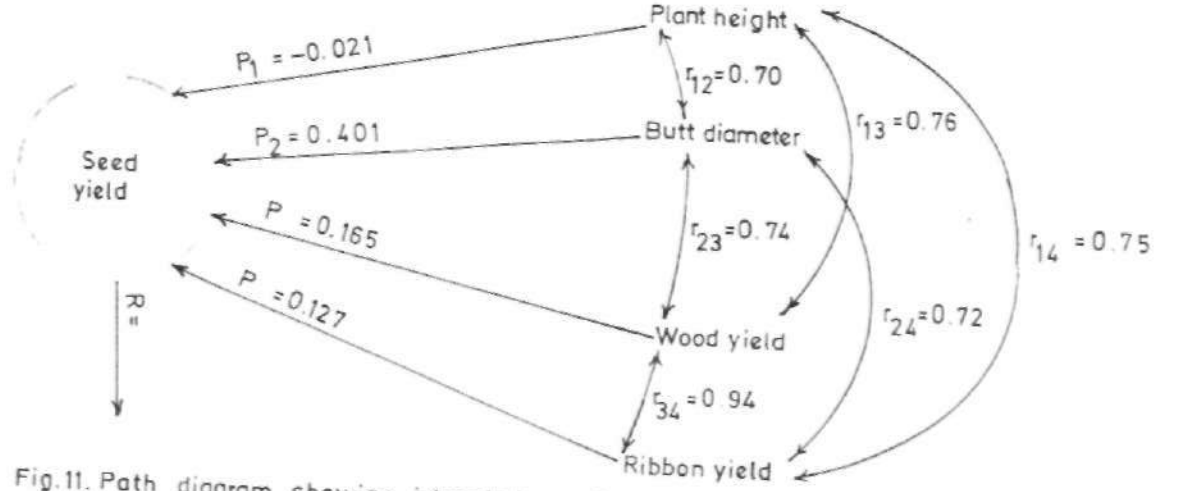


Fig.11. Path diagram showing interrelations of seed yield per plant and some growth characters of Kenaf during the 1993–1995 wet seasons (combined analysis) at Samaru

The total contribution of plant height to seed yield was 49.0%. The direct contribution was small and negative (-2.1%) and the indirect contributions via butt diameter, wood weight and fibre yield were 28.1, 12.5 and 9.5%, respectively. Butt diameter contributed 40% directly to seed yield and 12.2% and 9.2% indirectly via wood and fibre yields, respectively. Its indirect contribution via plant height was however small and negative (-1.5%). The total contribution by this parameter was 60%. The direct contribution by wood weight was 16.5%, while the indirect contributions via butt diameter, fibre yield and plant height were 29.7, 12.0 and -1.6%, respectively. The total contribution was 57.0%. Out of a total contribution of 56.0% to seed production, fibre yield contributed 12.7% directly, while its indirect contribution via butt diameter, wood weight and plant height were 28.9, 15.5 and -1.6%, respectively.

The percentage contribution by individual factors as well as combinations of the factors to fibre yield (Tabe 39) revealed that the greatest contribution was made by wood weight (73.01%), while contributions by the other factors was very small (0.06-0.67%). Wood weight in combination with plant height, butt diameter and seed yield contributed 10.64%, 3.06% and 2.30%, respectively, while contributions by the other combinations was very low (0.07-0.28%). The individual percentage contributions of some growth characters to seed yield was also considered (Table 40). Butt diameter, wood and fibre yields contributed 16.08%, 2.72% and 1.62%, respectively, to seed yield. The contribtuions of plant height in combination with the other factors were low and negative. However, butt diameter in combination with wood and fibre yields contributed 9.79% and 7.35%, respetively, while wood and fibre yields together contributed 3.95%. The remaining unaccounted residual effect was 60.56.

Table 39: The percentage contributions of some crop paremeters to fibre yield of kenaf during the 1993-1995 wet seasons (combined analysis) at Samaru

Crop parameter	Contribution (%)
Individual factor	
Plant height	0.67
Butt diameter	0.06
Wood dry weight	73.10
Seed yield	0.06
Combined factors	
Plant height and butt diameter	0.28
Plant height and wood weight	10.64
Plant height and seed weight	0.19
Butt diameter and wood weight	3.06
Butt diameter and seed weight	0.07
Wood weight and seed weight	2.30
Residual effect	9.85
Total	100.00

Table 40: The percentage contributions of some growth characters to kenaf seed yield during the 1993-1995 wet seasons (combined analysis) at Samaru

Crop parameter	Contribution (%)
Individual factors	
Plant height	0.04
Butt diameter	16.08
Wood weight	2.72
Seed yield	1.62
Combined factors	
Plant height and butt diameter	-1.18
Plant height and wood weight	-0.53
Plant height and seed weight	-0.40
Butt diameter and wood weight	9.79
Butt diameter and seed weight	7.35
Wood weight and seed weight	3.95
Residual effect	60.56
Total	100.00

4.5 Effects of Nitrogen and Herbicides on the Growth of Kenaf

The effects of nitrogen and herbicides on the growth of kenaf are shown on Tables 41-53.

4.5.1 Seedling emergence

Neither N nor weed control treatments had significant effect on seedling emergence score in the three years of investigation. The interaction of the two factors was also not significant in all the years of trials.

4.5.2 Crop vigour score

Nitrogen application and weed control treatments significantly influenced crop vigour score during the three years of study (Tables 41-43). The crop vigour score increased with N rate at 6 to 12 WAS in 1993 and 1994 and at 9 WAS in 1995. At 6 and 12 WAS in 1995, N application also increased crop vigour compared with the no N control and the difference between 45 and 90 kg N/ha was not singificant.

At 6 and 9 WAS in 1993, all the weed control treatments resulted in significantly higher crop vigour score compared with the weedy check (Table 41). Metolachlor plus ametryne at 1.0 + 1.0 kg a.i/ha and alachlor at 1.50 kg/ha however resulted in vigour score comparable to the weedy check at 12 WAS. Fluazifop-butyl plus ametryne at 0.50 + 1.0 kg a.i/ha at 6, 9 and 12 WAS, fluzifop-butyl at 0.75 kg at 9 and 12 WAS, metolachlor at 1.50 kg at 6 WAS and alachlor

Table 41: Effects of nitrogen and weed control treatments on crop vigour score of kenaf during the 1993 wet season at Samaru

Treatment		Crop vigour score		
Nitrogen level (kg N/ha)		6 WAS	9 WAS	12 WAS
0		5.56c	5.56c	5.30c
45		7.15b	6.67b	6.48b
90		8.26a	8.22a	7.96a
SE ±		0.263	0.275	0.308
Herbicides	Rate			
Metolachlor	1.50	7.11a-c	6.22b	6.11c
Metolachlor+Ametryne	1.00+1.00	6.78bc	6.44b	5.89cd
Alachlor	1.50	6.89bc	6.33b	5.78cd
Alachlor+Ametryne	1.00+1.00	6.67c	7.00ab	6.44bc
Fluazitop-butyl	0.75	6.33c	7.22ab	7.78ab
Fluaztop-butyl+Ametryne	0.50+1.00	7.56a-c	7.00ab	6.72a-c
Hoe-weeded at 4 WAS		8.44a	8.11a	8.11a
Hoe-weeded at 3 and 6 WAS		8.11ab	8.11a	8.00ab
Unweeded check		5.00d	4.89c	4.33d
SE ±		0.456	0.477	0.533
Interaction				
N x Herbicides		NS	*	NS

Means followed by the same letter(s) within the same column of any treatment group are not significantly different at 5% level of probability (DMRT)

WAS = Weeks after sowing

NS = Not significant at 5% level of probability

* = Significant at 5% level of probability

plus ametryne at 1.0 + 1.0 kg at 9 WAS resulted in crop vigour that was comparable to hoe-weeding at 4 WAS in 1993. Crop vigour score with fluazifop-butyl alone at 0.75 kg a.i/ha and alachlor plus ametryne at 1.0 + 1.0 kg at 6 WAS, metolachlor containing treatments and alachlor alone at 9 and 12 WAS were also significantly lower than those of two hoe-weeding at 3 and 6 WAS. The two hoe-weeding treatments did not differ significantly in crop vigour score in 1993. In 1994, crop vigour score at 6 WAS was only significantly depressed by hoe-weeding at 4 WAS and post-emergence application of fluazifop-butyl at 0.75 kg a.i/ha compared with the maximum obtained with metolachlor plus ametryne (Table 42). However at 9 WAS, all the herbicide treatments except fluazifop-butyl alone resutled in higher crop vigour score than the weedy check and comparable to the hoe-weeded controls. At 12 WAS, the herbicide treatments, except the application of fluzifop-butyl and alachlor each alone resulted in higher crop vigour score than the weedy check. At this period, mixtures of ametryne with alachlor and fluazifop-butyl resulted in higher crop vigour score than their corresponding single herbicide treatments. In 1995, only alachlor and mixture of alachlor and ametryne at 6 and 9 WAS resulted in higher crop vigour score than the weedy check and comparable to the maximum score obtained by hoe-weeding at 3 and 6 WAS (Table 43). At 12 WAS, application of metolachlor plus ametryne and hoe-weeding at 4 WAS resulted in crop vigour score comparable to the maximum obtained by hoe-weeding at 3 and 6 WAS and alachlor and its mixture with ametryne, although not significantly higher than of the weedy check.

Table 42: Effects of nitrogen and weed control treatments on crop vigour score of kenaf during the 1994 wet season at Samaru

Treatment		Crop vigour score		
Nitrogen level (kg N/ha)		6 WAS	9 WAS	12 WAS
0		3.24c	2.89c	2.46c
45		5.94b	5.44b	4.43b
90		6.72a	7.83a	7.02a
SE ±		0.201	0.166	0.277
Herbicides	Rate			
Metolachlor	1.50	5.78ab	5.67a	4.83ab
Metolachlor+Ametryne	1.00+1.00	5.89a	5.78a	4.89ab
Alachlor	1.50	5.33ab	5.33a	4.17bc
Alachlor+Ametryne	1.00+1.00	5.78ab	5.78a	5.17a
Fluazitop-butyl	0.75	4.72bc	4.39b	3.83c
Fluaztop-butyl+Ametryne	0.50+1.00	5.67ab	5.72a	4.94ab
Hoe-weeded at 4 WAS		4.22c	5.44a	4.83ab
Hoe-weeded at 3 and 6 WAS		5.44ab	5.89a	5.39a
Unweeded check		4.89ac	4.50b	3.67c
SE ±		0.348	0.287	0.60
Interaction				
N x Herbicides		NS	NS	NS

Means followed by the same letter(s) within the same column of any treatment group are not significantly different at 5% level of probability (DMRT)

WAS = Weeks after sowing

NS = Not significant at 5% level of probability

Table 43: Effects of nitrogen and weed control treatments on crop vigour score of kenaf during the 1995 wet season at Samaru

Treatment		Crop vigour score		
Nitrogen level (kg N/ha)		6 WAS	9 WAS	12 WAS
0		4.54b	4.71c	6.46b
45		6.78a	7.04b	6.78a
90		7.33a	7.59a	7.30a
SE ±		0.259	0.270	0.227
Herbicides	Rate			
Metolachlor	1.50	5.89bc	5.89b-d	5.28bc
Metolachlor+Ametryne	1.00+1.00	6.17bc	6.50a-d	6.36ab
Alachlor	1.50	6.83ab	7.00ab	6.94a
Alachlor+Ametryne	1.00+1.00	7.22ab	7.28ab	7.28a
Fluazitop-butyl	0.75	5.00c	5.33d	5.00c
Fluaztop-butyl+Ametryne	0.50+1.00	5.33c	5.83a-c	5.67bc
Hoe-weeded at 4 WAS		6.11bc	6.01b-d	6.33ab
Hoe-weeded at 3 and 6 WAS		7.94a	7.78a	7.44a
Unweeded check		5.44c	5.39cd	5.28bc
SE ±		0.448	0.468	0.393
Interaction				
N x Herbicides		NS	NS	NS

Means followed by the same letter(s) within the same column of any treatment group are not significantly different at 5% level of probability (DMRT)

WAS = Weeks after sowing

NS = Not significant at 5% level of probability

There was significant interaction of N and weed control treatments on crop vigour score at 9 WAS in 1993 (Table 44). Without N application, only fluazifop-butyl applied alone resulted in a crop vigour score that was comparable to the maximum obtained with hoe-weeding at 4 WAS under 90 kg N/ha in the trial, while with 45 kg N/ha application, mixtures containing alachlor and fluazifop-butyl as well as the two hoe-weeded checks were comparable. With the application of 90 kg N/ha, all the other weed control treatments including the weedy check were comparable to the maximum and greater than the least from the weedy check under no nitrogen application.

4.5.3 Plant height

The effect of N application on plant height of kenaf was significant at 8 WAS in 1993 and 8 and 12 WAS in 1994 and 1995 (Tables 45-47). In all cases, plant height increased with N level upto 90 kg N/ha except at 12 WAS in 1995 when the difference between 45 and 90 kg N/ha treatments was not significant.

The effect of weed control treatments on plant height was also significant at 8 WAS only in 1993 and at 8 and 12 WAS in 1995. In 1993, only the two hoe-weeded checks produced significantly taller plants than the weedy control (Table 45). Among the herbicides treatments, only fluazifop-butyl plus ametryne resulted in plant height comparable to the maximum in the trial. At 8 WAS none of the herbicide treatments resulted in plant height comparable to the maximum obtained with hoe-weeding at 3 and 6 WAS in 1995 (Table 47). However, alachlor applied alone

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Table 44: Interaction of nitrogen and weed control treatments on crop vigour score of kenaf at 9 WAS during the 1993 wet season at Samaru

Treatment		Crop vigour score at 9 WAS		
		Nitrogen level (kg N/ha)		
Herbicides	Rate kg a.i N/ha	0	45	90
Metolachlor	1.50	3.33e-h	6.67d-h	6.67a-e
Metolachlor Ametryne	1.00+1.00	4.33g-i	7.00b-g	8.00a-d
Alachlor	1.50	4.67g-i	6.33c-h	8.00a-d
Alachlor+Ametryne	1.00+1.00	5.67d-h	7.76a-e	7.67a-e
Fluazifop-butyl	0.75	8.33a-c	4.00hi	9.33ab
Fluazifop-butyl+Ametryne	0.50+1.00	5.67d-h	8.00a-d	7.33a-f
Hoe-Weeded at 4 WAS		7.33d-h	7.33a-f	9.67a
Hoe-weeded at 3 and 6 WAS		6.00c-h	9.00ab	9.33ab
Unweeded check		2.67i	5.00f-i	7.00b-g
SE ±		0.825		

Means followed by the same letter(s) are not significantly different at 5% level of probability (DMRT)

WAS = Weeks after sowing

Table 45: Effects of nitrogen and weed control treatments on plant height of kenaf during the 1993 wet season at Samaru

Treatment		Plant height (m)		
Nitrogen level (kg N/ha)		4 WAS	8 WAS	12 WAS
0		0.32	1.69c	2.29
45		0.34	1.87b	2.48
90		0.33	2.00a	2.39
SE ±		0.021	0.039	0.050
Herbicides	Rate			
Metolachlor	1.50	0.34	1.83bc	2.29
Metolachlor+Ametryne	1.00+1.00	0.32	1.84bc	2.44
Alachlor	1.50	0.33	1.84bc	2.37
Alachlor+Ametryne	1.00+1.00	0.33	1.73c	2.30
Fluazitop-butyl	0.75	0.34	1.79c	2.41
Fluaztop-butyl+Ametryne	0.50+1.00	0.32	1.90a-c	2.57
Hoe-weeded at 4 WAS		0.34	2.01ab	2.20
Hoe-weeded at 3 and 6 WAS		0.34	2.05a	2.70
Unweeded check		0.33	1.71c	2.20
SE ±		0.008	0.067	0.860
Interaction				
N x Herbicides		NS	NS	NS

Means followed by the same letter(s) within the same column of any treatment group are not significantly different at 5% level of probability (DMRT)

WAS = Weeks after sowing

NS = Not significant at 5% level of probability

Table 46: Effects of nitrogen and weed control treatments on plant height of kenaf during the 1994 wet season at Samaru

Treatment		Plant height (m)		
Nitrogen level (kg N/ha)		4 WAS	8 WAS	12 WAS
0		0.29	1.26c	1.69c
45		0.30	1.71b	2.30b
90		0.30	2.07a	2.54a
SE ±		0.007	0.046	0.057
Herbicides	Rate			
Metolachlor	1.50	0.31	1.72	2.16
Metolachlor+Ametryne	1.00+1.00	0.30	1.75	2.33
Alachlor	1.50	0.28	1.73	2.24
Alachlor+Ametryne	1.00+1.00	0.30	1.66	2.28
Fluazitop-butyl	0.75	0.29	1.55	2.07
Fluaztop-butyl+Ametryne	0.50+1.00	0.31	1.72	2.24
Hoe-weeded at 4 WAS		0.29	1.67	2.02
Hoe-weeded at 3 and 6 WAS		0.29	1.73	2.27
Unweeded check		0.29	1.58	2.02
SE ±		0.0128	0.080	0.099
Interaction				
N x Herbicides		NS	NS	NS

Means followed by the same letter(s) within the same column of any treatment group are not significantly different at 5% level of probability (DMRT)

WAS = Weeks after sowing

NS = Not significant at 5% level of probability

Table 47: Effects of nitrogen and weed control treatments on plant height of kenaf during the 1995 wet season at Samaru

Treatment		Plant height (m)		
Nitrogen level (kg N/ha)		4 WAS	8 WAS	12 WAS
0		0.34	1.41c	1.78b
45		0.38	1.70b	2.12a
90		0.37	1.93a	2.17a
SE ±		0.011	0.024	0.037
Herbicides	Rate			
Metolachlor	1.50	0.36	1.57c	1.79c
Metolachlor+Ametryne	1.00+1.00	0.35	1.43d	2.02b-d
Alachlor	1.50	0.38	1.72b	1.97b-e
Alachlor+Ametryne	1.00+1.00	0.37	1.64bc	2.12ab
Fluazitop-butyl	0.75	0.38	1.51cd	1.87de
Fluaztop-butyl+Ametryne	0.50+1.00	0.33	1.59c	2.16ab
Hoe-weeded at 4 WAS		0.38	1.60b	2.07bc
Hoe-weeded at 3 and 6 WAS		0.39	1.99a	2.28a
Unweeded check		0.37	1.52cd	1.91c-e
SE ±		0.019	0.041	0.065
Interaction				
N x Herbicides		NS	*	NS

Means followed by the same letter(s) within the same column of any treatment group are not significantly different at 5% level of probability (DMRT)

WAS = Weeks after sowing

NS = Not significant at 5% level of probability

* = Significant at 5% level of probability

as well as hoe-weeding at 4 WAS resulted in taller plants than the weedy check. Kenaf plants treated with metolachlor plus ametryne were shorter than those treated with metolachlor alone at this stage of growth. At 12 WAS, mixtures of ametryne with alachor and fluazifop-butyl resulted in kenaf plant height comparable to the maximum with hoe-weeding at 3 and 6 WAS and better than the weedy check. At this stage of growth mixtures of ametryne with metolachlor and fluazifop-butyl resulted in taller plants than the corresponding single herbicide treatments. In the trial, hoe-weeding at 3 and 6 WAS resulted in taller plants than hoe-weeding at 4 WAS.

There was a significant N and weed control interaction on plant height at 8 WAS in 1993 (Table 48). Without N application, no weed control treatment resulted in plant height comparable to the maximum obtained with hoe-weeding at 3 and 6 WAS and treatment with 90 kg N/ha. With the application of 45 kg N/ha, only the weedy check resulted in plant height comparable to the maximum. However, with the application of 90 kg N/ha, metolachlor plus ametryne; alachlor and hoe-weeding at 4 WAS resulted in plant heights which were comparable to the maximum.

4.5.4 Butt diameter

The effect of N on butt diameter was significant at 8 WAS only in 1993 and at 4, 8 and 12 WAS in 1994 and 1995 (Tables 49-51). The butt diameter increased with N level at 8 WAS in 1993 and 4, 8 and 12 WAS in 1994. At 4-12 WAS in 1995, N application increased butt diameter

Table 48: Interaction of nitrogen and period of weed control treatments on plant height at 8 WAS during the 1993 wet season at Samaru

Treatment		Plant height at 8 WAS (M)		
		Nitrogen level (kg N/ha)		
Herbicides	Rate kg a.i N/ha	0	45	90
Metolachlor	1.50	1.31i-k	1.65d-g	1.74c-f
Metolachlor+Ametryne	1.00+1.00	1.48g-j	1.74c-f	2.07a
Alachlor	1.50	1.22j-k	1.84b-d	2.11a
Alachlor+Ametryne	1.00+1.00	1.48g-i	1.61d-h	1.84b-d
Fluazifop-butyl	0.75	1.35i-k	1.56e-h	1.62d-h
Fluazifop-butyl+Ametryne	0.50+1.00	1.52f-i	1.47g-i	1.77c-e
Hoe-Weeded at 4 WAS		1.39h-j	1.40h-j	2.01ab
Hoe-Weeded at 3 and 6 WAS		1.76c-e	2.11a	2.10a
Unweeded check		1.15k	1.96a-c	2.10a
SE ±		0.074		

Means followed by the same letter(s) are not significantly different at 5% level of probability (DMRT)

WAS = Weeks after sowing

Table 49: Effects of nitrogen and weed control treatments on butt diameter of kenaf during the 1993 wet season at Samaru

Treatment		Butt dieamter (cm)		
Nitrogen level (kg N/ha)		4 WAS	8 WAS	12 WAS
0		NA	1.05c	1.17
45		NA	1.17b	1.26
90		NA	1.30a	1.29
SE ±			0.042	0.038
Herbicides	Rate			
Metolachlor	1.50	NA	1.13	1.26
Metolachlor+Ametryne	1.00+1.00	NA	1.13	1.22
Alachlor	1.50	NA	1.23	1.21
Alachlor+Ametryne	1.00+1.00	NA	1.06	1.16
Fluazitop-butyl	0.75	NA	1.15	1.30
Fluaztop-butyl+Ametryne	0.50+1.00	NA	1.10	1.25
Hoe-weeded at 4 WAS		NA	1.28	1.32
Hoe-weeded at 3 and 6 WAS		NA	1.29	1.33
Unweeded check		NA	1.11	1.11
SE ±			0.073	0.066
Interaction				
N x Herbicides		NS	NS	NS

Means followed by the same letter(s) within the same column of any treatment group are not significantly different at 5% level of probability (DMRT)

WAS = Weeks after sowing

NA = Not available

NS = Not significant at 5% level of probability

compared with the no N control and there was no significant difference between 45 and 90 kg N treatments on this parameter.

The influence of weed control treatments on butt diameter was significant only at 4 and 8 WAS in 1994 and at 8 and 12 WAS in 1995. In 1994, application of metolachlor alone resulted in significantly thicker stems than the weedy check at 4 and 8 WAS (Table 50). A similar result was obtained at 4 WAS from plants treated with mixtures of ametryne with alachlor and fluazifop-butyl. At 8 and 12 WAS in 1995, alachlor plus ametryne at 1.0 + 1.0 kg a.i./ha and hoe-weeding at 3 and 6 WAS caused thicker plant stem production than the weedy check (Table 51). Application of fluazifop-butyl plus ametryne also resulted in greater butt diameter than the weedy check at 12 WAS in the year.

There was no significant N and weed control interaction on butt diameter during the three years of investigation.

4.5.5 Number of days to first flowering

Kenaf plants started flowering earlier in 1993 and 1995 than in 1994 (Table 52).

Nitrogen application significantly influenced the number of days to first flowering in the three years of trials. The number of days to first flowering reduced with increasing N rate from 0-90 kg N/ha in 1993 and 1994. In 1995, N reduced the number of days to flowering and there was no significant difference between the effects of 45 and 90 kg N/ha treatments.

Table 50: Effects of nitrogen and weed control treatments on butt diameter of kenaf during the 1994 wet season at Samaru

Treatment		Butt dieamter (cm)		
Nitrogen level (kg N/ha)		4 WAS	8 WAS	12 WAS
0		0.54c	0.79c	0.93c
45		0.68b	1.06b	1.18b
90		0.74a	1.23a	1.33a
SE ±		0.017	0.025	0.032
Herbicides	Rate			
Metolachlor	1.50	0.74a	1.19a	1.26
Metolachlor+Ametryne	1.00+1.00	0.67a-c	1.04b	1.19
Alachlor	1.50	0.60b-d	0.99b	1.05
Alachlor+Ametryne	1.00+1.00	0.71a	1.04b	1.10
Fluazitop-butyl	0.75	0.58d	0.95b	1.03
Fluaztop-butyl+Ametryne	0.50+1.00	0.68ab	1.04b	1.20
Hoe-weeded at 4 WAS		0.61b-d	1.04b	1.13
Hoe-weeded at 3 and 6 WAS		0.68a-c	1.04b	1.15
Unweeded check		0.59cd	0.93b	1.19
SE ±		0.029	0.049	0.056
Interaction				
N x Herbicides		NS	NS	NS

Means followed by the same letter(s) within the same column of any treatment group are not significantly different at 5% level of probability (DMRT)

WAS = Weeks after sowing

NS = Not significant at 5% level of probability

Table 51: Effects of nitrogen and weed control treatments on butt diameter of kenaf during the 1995 wet season at Samaru

Treatment		Butt dieamter (cm)		
Nitrogen level (kg N/ha)		4 WAS	8 WAS	12 WAS
0		0.54b	0.80b	0.96b
45		0.64a	1.04a	1.22a
90		0.66a	1.09a	1.23a
SE ±		0.017	0.031	0.024
Herbicides	Rate			
Metolachlor	1.50	0.65	0.87c	1.02c
Metolachlor+Ametryne	1.00+1.00	0.62	1.00bc	1.3bc
Alachlor	1.50	0.65	0.98bc	1.13b
Alachlor+Ametryne	1.00+1.00	0.64	1.13ab	1.24ab
Fluazitop-butyl	0.75	0.55	0.83c	1.03c
Fluaztop-butyl+Ametryne	0.50+1.00	0.52	0.97bc	1.26a
Hoe-weeded at 4 WAS		0.60	0.95c	1.13bc
Hoe-weeded at 3 and 6 WAS		0.68	1.19a	1.24ab
Unweeded check		0.61	0.87c	1.03c
SE ±		0.030	0.055	0.042
Interaction				
N x Herbicides		NS	NS	NS

Means followed by the same letter(s) within the same column of any treatment group are not significantly different at 5% level of probability (DMRT)

WAS = Weeks after sowing

NS = Not significant at 5% level of probability

Table 52: Effects of nitrogen and weed control treatments on the number of days to first flowering of kenaf during the 1993-1995 wet seasons at Samaru

Treatment		No of days to first flowering		
Nitrogen level (kg N/ha)		1993	1994	1995
0		71.96a	76.67a	71.63a
45		70.26b	71.26b	69.19b
90		67.07c	67.70c	67.70b
SE ±		0.499	0.487	0.516
Herbicides	Rate			
Metolachlor	1.50	71.33ab	70.89	70.67
Metolachlor+Ametryne	1.00+1.00	69.78b	72.11	69.67
Alachlor	1.50	69.67b	72.67	68.56
Alachlor+Ametryne	1.00+1.00	70.67b	71.44	68.89
Fluazitop-butyl	0.75	69.00b	73.56	69.78
Fluaztop-butyl+Ametryne	0.50+1.00	68.89b	70.89	70.11
Hoe-weeded at 4 WAS		65.89b	72.44	70.11
Hoe-weeded at 3 and 6 WAS		69.00b	70.00	67.89
Unweeded check		73.67a	72.89	71.56
SE ±		0.864	0.844	0.894
Interaction				
N x Herbicides		NS	NS	NS

Means followed by the same letter(s) within the same column of any treatment group are not significantly different at 5% level of probability (DMRT)

NS = Not significant at 5% level of probability

The influence of herbicides on the number of days to first flowering was significant only in 1993 when all the weed control treatments except metolachlor at 1.50 kg caused early flowering of kenaf plants than the weedy check. Hoe-weeding at 4 WAS also resulted in shorter days to first flowering than all the other weed control treatments.

There was no significant interaction of N and weed control treatments on the number of days to first flowering in the three years of trials.

4.5.6 Number of days to 50% flowering

It took a longer period for kenaf plants to attain 50% flowering in 1995 than in 1995, when data was available (Table 53).

Application of N significantly affected the number of days to 50% flowering in 1994 and 1995. In this case, the number of days taken by plants to attain 50% flowering decreased with increasing N levels.

The effect of herbicides on the number of days to 50% flowering was only significant in 1994. In this year, the application of metolachlor and mixture of fluazifop-butyl and ametryne as well as hoe-weeding at 3 and 6 WAS significantly reduced the number of days to 50% flowering. Although all the other treatments had fairly less number of days than the weedy check, the differences were not quite significant.

There was significant interaction of N and weed control treatments on the number of days to 50% flowering in 1994 (Table 54). Plants treated with metolachlor plus ametryne and given 90 kg N/ha took the least number of days to attain 50% flowering in the trial. However, all the other weed control treatments with the N level had comparable number of days to the least, while no treatment without N was comparable. With 45 kg N/ha, metolachlor alone and hoe-weeding at 3 and 6 WAS were also comparable to the least number of days. Without N, alachlor treatments and the weedy check had the maximum number of days to 50% flowering, and these were greater

Table 53: Effects of nitrogen and weed control treatments on the number of days to first flowering of kenaf during the 1994-1995 wet seasons at Samaru

Treatment		No of days to 50% flowering		
Nitrogen level (kg N/ha)		1993	1994	1995
0		NA	83.22a	79.07a
45		NA	78.56b	76.56b
90		NA	74.67c	74.78c
SE ±		-	0.422	0.636
Herbicides	Rate			
Metolachlor	1.50	NA	77.78b	78.00
Metolachlor+Ametryne	1.00+1.00	NA	78.44ab	76.89
Alachlor	1.50	NA	79.78ab	76.11
Alachlor+Ametryne	1.00+1.00	NA	79.33ab	76.56
Fluazitop-butyl	0.75	NA	79.67ab	76.78
Fluaztop-butyl+Ametryne	0.50+1.00	NA	77.67b	77.11
Hoe-weeded at 4 WAS		NA	78.56ab	76.22
Hoe-weeded at 3 and 6 WAS		NA	77.44b	75.22
Unweeded check		NA	80.67a	78.33
SE ±			0.730	1.102
Interaction				
N x Herbicides			*	NS
Mean			78.83a	76.80b

Means followed by the same letter(s) within the same column of any treatment group are not significantly different at 5% level of probability (DMRT)

NA = Not available

NS = Not significant at 5% level of probability

* = Significant at 5% level of probability

Table 54: Interaction of nitrogen and period of weed control treatments on the number of days to 50% flowering of kenaf during the 1993 wet season at Samaru

Treatment		No. of days to 50% flowering		
		Nitrogen level (kg N/ha)		
Herbicides	Rate kg a.i N/ha	0	45	90
Metolachlor	1.50	83.0a-d	76.0h-l	74.3k-l
Metolachlor+Ametryne	1.00+1.00	84.0a-c	78.3e-j	72.7l
Alachlor	1.50	85.7ab	79.0d-i	74.7j-l
Alachlor+Ametryne	1.00+1.00	86.31a	77.3f-k	74.3k-l
Fluazifop-butyl	0.75	83.00a-d	82.0b-e	74.0k-l
Fluazifop-butyl+Ametryne	0.50+1.00	79.7d-h	79.3d-i	74.0k-l
Hoe-Weeded at 4 WAS		80.31d-g	79.0d-i	76.3g-l
Hoe-Weeded at 3 and 6 WAS		81.00c-f	76.0h-l	75.3i-l
Unweeded check		85.7ab	80.0d-h	76.3g-l
SE ±		1.266		

Means followed by the same letter(s) are not significantly different at 5% level of probability (DMRT)

than the two hoe-weeded checks, as well as mixture with fluazifop-butyl. With 45 and 90 kg N/ha, all treatments including the weedy check had comparable number of days to hoe-weeding, except fluazifop-butyl at 45 kg N/ha.

4.6 Effects of Nitrogen and Weed Control Treatments on Weeds

The major weed species identified at the sites of the trials and the levels of infestation during the three years of study are shown on Appendix 7. Most of the weeds started occuring earlier than 6 WAS, except the later emerging weeds such as Rottboelia spp, Euphorbia hetrophylla, Crotolaria retusa, Solanum nigrum, Portulaca oleraceae and Vernonia spp. In the three years, the sites were generally infested with Acanthospermum hispidum, Vernonia galamensis, Cyperus spp, Ageratum conyzoides, Euphorbia sp, Rottboelia cochinchinerisis and Crotalaria retusa. Other more serious weeds were Cynodon dactylon, Dactyloctenium aegyptium and Ipomea aquatica in 1993 and Echinochloa colona in 1995.

4.6.1 Weed cover score

Appliction of N significantly influenced the weed cover score at 6 WAS in 1993, 6, 9 and 12 WAS in 1994 and 9 WAS in 1995 (Tables 55-57). At 6 WAS in 1993, 90 kg N/ha increased weed cover score compared with no N treatment. In 1994, 45 and 90 kg N/ha increased the weed cover score at 6 wAS but only 45 kg N/ha increased it at 9 WAS. Weed cover score was significantly reduced by 90 kg N/ha at 12 WAS in 1994 and 9 WAS in 1995, and 45 kg N/ha at 9 WAS in 1995.

The effect of weed control treatments on weed cover score at 6 to 12 WAS was significant in the three years of study. In the trials, all the weed control treatments with the exception of fluazifop-butyl and its mixture with ametryne at 6 WAS in 1994 and fluazifop-butyl applied alone at 6 and 12 WAS in 1995, suppresed weeds compared to the weedy check. Generally, hoe-weeding at 3 and 6 WAS and at 4 WAS resulted in the least weed score in the three years of trials. However, at 12 WAS in 1993, alachlor and fluazifop-butyl as well as mixtures of ametryne with alachlor and metolachlor resulted in weed suppression comparable to hoe-weeding at 4 WAS. In 1994, no herbicide treatment caused weed suppression comparable to two hoe-weeding controls at 6 to 12 WAS. However in 1995, comparable weed suppression to hoe-weeding was achieved at 6 WAS with fluazifop-butyl plus ametryne. At 12 WAS in this year, alachlor and mixtures of ametryne with alachlor and fluazifop-butyl resulted in weed suppression comparable to hoe-weeding at 4 WAS.

There was significant interaction of N and weed control treatments on weed cover score at 6 WAS in 1995 (Table 58).

Table 55: Effects of nitrogen and weed control treatments on weed cover score during the 1993 wet season at Samary

Treatment		Weed cover score		
Nitrogen level (kg N/ha)		6 WAS	9 WAS	12 WAS
0		3.70b	3.41	3.49
45		4.30ab	4.16	4.16
90		5.17a	3.75	3.49
SE ±		0.350	0.344	0.340
Herbicides	Rate			
Metolachlor	1.50	6.11a	4.11b	4.33b
Metolachlor+Ametryne	1.00+1.00	4.28c	4.22b	3.78bc
Alachlor	1.50	5.28bc	4.22b	3.89bc
Alachlor+Ametryne	1.00+1.00	4.78bc	4.00b	3.89bc
Fluazitop-butyl	0.75	2.48d	3.78b	4.11bc
Fluaztop-butyl+Ametryne	0.50+1.00	5.56bc	4.56b	4.44b
Hoe-weeded at 4 WAS		1.48d	2.11c	2.33c
Hoe-weeded at 3 and 6 WAS		1.42d	0.29d	0.41d
Unweeded check		8.17a	6.67a	6.22a
SE ±		0.606	0.596	0.589
Interaction				
N x Herbicides		NS	NS	NS

Means followed by the same letter(s) within the same column of any treatment group are not significantly different at 5% level of probability (DMRT)

WAS = Weeks after sowing

NS = Not significant at 5% level of probability

Table 56 Effects of nitrogen and weed control treatments on weed cover score during the 1994 wet season at Samaru

Treatment		Weed cover score		
Nitrogen level (kg N/ha)		6 WAS	9 WAS	12 WAS
0		1.73b	2.88b	4.03a
45		2.73a	4.87a	4.60a
90		2.95a	2.78b	2.60b
SE ±		0.262	0.276	0.268
Herbicides	Rate			
Metolachlor	1.50	2.44bc	3.89cd	4.33bc
Metolachlor+Ametryne	1.00+1.00	1.83c	3.22cd	3.44c
Alachlor	1.50	2.83c	4.67bc	5.44b
Alachlor+Ametryne	1.00+1.00	2.50bc	3.06d	3.56c
Fluazitop-butyl	0.75	4.44a	5.44b	5.17b
Fluaztop-butyl+Ametryne	0.50+1.00	3.67ab	3.11d	3.22c
Hoe-weeded at 4 WAS		0.10d	0.470e	0.67d
Hoe-weeded at 3 and 6 WAS		0.10d	0.84e	0.96d
Unweeded check		4.30a	0.89a	6.89a
SE ±		0.453	0.479	0.464
Interaction				
N x Herbicides		NS	NS	NS

Means followed by the same letter(s) within the same column of any treatment group are not significantly different at 5% level of probability (DMRT)

WAS = Weeks after sowing

NS = Not significant at 5% level of probability

Table 57 Effects of nitrogen and weed control treatments on weed cover score during the 1995 wet season at Samaru

Treatment		Weed cover score		
Nitrogen level (kg N/ha)		6 WAS	9 WAS	12 WAS
0		3.64	5.26a	4.59
45		3.83	4.08b	4.20
90		3.37	3.48b	3.77
SE ±		0.34	0.285	0.331
Herbicides	Rate			
Metolachlor	1.50	6.44b	7.61b	7.50b
Metolachlor+Ametryne	1.00+1.00	2.89c	2.94c	3.28c
Alachlor	1.50	2.72c	3.63c	2.72cd
Alachlor+Ametryne	1.00+1.00	2.44c	2.56c	2.39cd
Fluazitop-butyl	0.75	7.28ab	8.17b	8.11ab
Fluaztop-butyl+Ametryne	0.50+1.00	1.22cd	3.17c	2.74cd
Hoe-weeded at 4 WAS		0.50d	0.48d	1.13de
Hoe-weeded at 3 and 6 WAS		0.67d	0.20d	0.53e
Unweeded check		8.36a	9.72a	9.28a
SE ±		0.587	0.494	0.573
Interaction				
N x Herbicides		*	NS	NS

Means followed by the same letter(s) within the same column of any treatment group are not significantly different at 5% level of probability (DMRT)

WAS = Weeks after sowing

NS = Not significant at 5% level of probability

* = Significant at 5% level of probability

Table 58: Interaction of nitrogen and weed control treatments on weed cover score at 6 WAS during the 1995 wet season at Samaru

Treatment		Weed cover score at 6 WAS		
		Nitrogen level (kg.N/ha)		
Herbicides	Rate kg a.i N/ha	0	45	90
Metolachlor	1.50	7.33a-d	7.67a-c	4.33d-g
Metolachlor+Ametryne	1.00+1.00	3.83e-h	3.83e-h	1.00h-i
Alachlor	1.50	4.67c-f	2.17f-i	1.33g-i
Alachlor+Ametryne	1.00+1.00	2.17f-i	2.17f-i	3.00f-i
Fluaziop-butyl	0.75	6.67b-e	6.67b-e	8.50ab
Fluazifop-butyl+Ametryne	0.50+1.00	2.00f-i	0.83h-i	0.83h-i
Hoe-Weeded at 4 WAS		0.50i	0.50i	0.50i
Hoe-Weeded at 3 and 6 WAS		0.50i	0.67h-i	0.83h-i
Unweeded check		5.07c-f	10.00a	10.00a
SE ±		0.587		

Means followed by the same letter(s) are not significantly different at 5% level of probability (DMRT)

WAS = Weeks after sowing

Without the application of N, mixtures of ametryne with fluazifop-butyl and alachlor resulted in weed cover score that was comparable to the least obtained with hoe-weeding at 3 and 6 WAS. With 45 kg N/ha, the two treatments and alachlor applied alone resulted in weed cover scores that were also comparable to the least. With the exception of metolachlor and fluazifop-butyl each applied alone and the weedy check, all the other treatments caused weed suppression comparable to hoe weeding when 90 kg N/dha was applied. The maximum weed score was observed on the weedy check with 45 and 90 kg N/ha treatments.

4.7 Effects of Nitrogen and Weed Control Treatments on Wood, Fibre and Seed Yields of Kenaf

The effect of N and weed control treatments on wood, fibre and seed yields of kenaf are contained in Tables 59-68.

4.7.1 Wood weight per plant

Wood dry weight per plant of kenaf was greatest in 1993 and least in 1994 (Table 59).

Nitrogen application significantly influenced wood weight per plant of kenaf in the three years of trials. Kenaf wood weight increased with N levels in the three years.

The influence of weed control treatment on wood weight per plant was significant in 1993 and 1995. In 1993, the plots treated with fluazifop-butyl at 0.75 kg a.i/a and its mixture with ametryne at 0.5 + 1.0 kg produced significantly higher wood weight than the weedy check and comparable to the hoe-weeded controls. Plots

Table 59 Effects of nitrogen and weed control treatments on wood weight per plant of kenaf during the 1993-1995 wet seasons at Samaru

Treatment		Wood weight (g/plant)		
Nitrogen level (kg N/ha)		1993	1994	1995
0		12.29c	5.74c	7.88c
45		19.20b	12.63b	15.86b
90		26.39a	19.73a	19.60a
SE ±		1.570	0.921	1.261
Herbicides	Rate			
Metolachlor	1.50	19.07a-c	14.81	10.21c
Metolachlor+Ametryne	1.00+1.00	16.52bc	15.54	14.71bc
Alachlor	1.50	16.18bc	10.96	16.17a-c
Alachlor+Ametryne	1.00+1.00	16.37bc	12.46	15.47bc
Fluazitop-butyl	0.75	21.28ab	10.68	9.39c
Fluaztop-butyl+Ametryne	0.50+1.00	21.67ab	13.27	18.41ab
Hoe-weeded at 4 WAS		25.49a	12.68	13.13bc
Hoe-weeded at 3 and 6 WAS		25.20a	13.36	22.20a
Unweeded check		11.88c	10.56	10.33c
SE ±		2.715	1.595	2.184
Interaction				
N x Herbicides		NS	NS	NS
Mean		19.29a	12.70c	14.45b

Means followed by the same letter(s) within the same column of any treatment group are not significantly different at 5% level of probability (DMRT)

NS = Not significant at 5% level of probability

treated with metolachlor at 1.50 kg had wood weight comparable to both the hoe-weeded controls and the weedy check. In 1995, mixture of fluazifop-butyl with ametryne resulted in higher wood dry weight than the weedy check and comparable to hoe-weeding at 3 and 6 WAS. The plots treated with alachlor alone produced wood weight comparable to both hoe-weedings at 3 and 6 WAs and the weedy checks.

There was no significant interaction of N and weed control treatments on wood weight per plant of kenaf in the three years of trials.

4.7.2 Wood yield

There was no significant difference in wood yield of kenaf between 1994 and 1995 (Table 60).

Nitrogen application significantly influenced wood yield in 1994 and 1995 when data was available. In each year, wood yield increased with N levels.

The effect of weed control treatments on kenaf wood yield was significant in 1995 only, when alachlor and the mixture with ametryne resulted in higher wood yield than the weedy check and comparable to the maximum with hoe-weedings at 3 and 6 WAS. Unchecked weed growth caused 32.1% and 44.7% wood yield reductions compared to the maximum yields obtained in 1994 and 1995, respectivley.

There was no significant interaction of N and weed control treatments on wood yield of kenaf in the two years of trials.

Table 60: Effects of nitrogen and weed control treatments on wood yield of kenaf during the 1994 and 1995 wet seasons at Samaru

Treatment		Wood yield (kg/ha)		
Nitrogen level (kg N/ha)		1993	1994	1995
0		NA	1091c	1538c
45		NA	2527b	2749b
90		NA	3947a	3544a
SE ±		-	185.1	211.7
Herbicides	Rate			
Metolachlor	1.50	NA	2793	2299bc
Metolachlor+Ametryne	1.00+1.00	NA	3109	2941b
Alachlor	1.50	NA	2192	3234ab
Alachlor+Ametryne	1.00+1.00	NA	2492	3106ab
Fluazitop-butyl	0.75	NA	2136	1775c
Fluaztop-butyl+Ametryne	0.50+1.00	NA	2651	1609c
Hoe-weeded at 4 WAS		NA	2537	2634bc
Hoe-weeded at 3 and 6 WAS		NA	2672	4108a
Unweeded check		NA	2112	1788c
SE ±		-	320.7	366.6
Interaction				
N x Herbicides		NS	NS	NS
Mean		-	2522	2610

Means followed by the same letter(s) within the same column of any treatment group are not significantly different at 5% level of probability (DMRT)

NA = Data not available

NS = Not significant at 5% level of probability

4.7.3 Ribbon weight per plant

Ribbon weight per plant of kenaf was highest in 1993 and least in 1994 (Table 61).

Nitrogen application significantly influenced ribbon weight per plant in the three years of trials. The ribbon weight increased significantly with N levels in the three years.

The effect of herbicides on ribbon weight per plant was significant in 1993 and 1995. In 1993, metolachlor and fluazifop-butyl, each applied alone and a mixture of the latter with ametryne out yielded the weedy check and produced ribbon weights comparable to the two hoe-weeded controls. In 1995, only fluazifop-butyl plus ametryne resulted in significantly higher ribbon weight than the weedy check and comparable to the maximum obtained with hoe-weedings at 3 and 6 WAS. Alachlor applied alone and in mixture with ametryne however, resulted in ribbon weights that were comparable to both hoe-weedings at 3 and 6 WAS and the weedy check. Unchecked weed growth resulted in 57.1, 25.5 and 51.9% reductions in wood weight per plant compared with the maximum in 1993, 1994 and 1995, respectively.

There was no significant N and weed control interaction on ribbon weight per plant of kenaf during the three years of study.

4.7.4 Ribbon yield

The data on this parameter were taken in 1993 only to replace the fibre yield that is not available for the year. In this case, the ribbon yield increased with N rate (Table 62).

Table 61: Effects of nitrogen and weed control treatments on ribbon weight per plant of kenaf during the 1993-1995 wet seasons at Samaru

Treatment		Ribbon weight (g/plant)		
Nitrogen level (kg N/ha)		1993	1994	1995
0		8.61c	3.51c	5.00c
45		13.44b	6.83b	8.88b
90		16.61a	11.71ab	10.68ac
SE ±		0.955	0.541	0.651
Herbicides	Rate			
Metolachlor	1.50	12.60a-c	8.27	6.25cd
Metolachlor+Ametryne	1.00+1.00	11.02b-d	8.60	8.47a-d
Alachlor	1.50	11.91b-d	6.22	9.04a-c
Alachlor+Ametryne	1.00+1.00	10.54cd	7.17	9.10a-c
Fluazitop-butyl	0.75	17.22a	6.21	5.16d
Fluaztop-butyl+Ametryne	0.50+1.00	13.85a-c	8.77	10.39ab
Hoe-weeded at 4 WAS		15.94ab	7.12	7.36b-d
Hoe-weeded at 3 and 6 WAS		15.57a-c	7.74	12.11a
Unweeded check		7.39d	6.05	5.82cd
SE ±		1.655	0.937	1.129
Interaction				
N x Herbicides		NS	NS	NS
Mean		12.89a	7.35c	8.19b

Means followed by the same letter(s) within the same column of any treatment group are not significantly different at 5% level of probability (DMRT)

NS = Not significant at 5% level of probability

Table 62: Effects of nitrogen and weed control treatments on ribbon yield of kenaf during the 1993 wet season at,Samaru

Treatment		Ribbon yield (kg/ha)		
Nitrogen level (kg N/ha)		1993	1994	1995
0		1122c	NA	NA
45		1711b	NA	NA
90		2356a	NA	NA
SE ±		147.2	-	-
Herbicides	Rate			
Metolachlor	1.50	1633a-d	NA	NA
Metolachlor+Ametryne	1.00+1.00	1744a-d	NA	NA
Alachlor	1.50	1889a-d	NA	NA
Alachlor+Ametryne	1.00+1.00	1389b-d	NA	NA
Fluazitop-butyl	0.75	1233d	NA	NA
Fluaztop-butyl+Ametryne	0.50+1.00	2156ab	NA	NA
Hoe-weeded at 4 WAS		2044a-c	NA	NA
Hoe-weeded at 3 and 6 WAS		2211a	NA	NA
Unweeded check		1289cd	NA	NA
SE ±		254.5	-	-
Interaction				
N x Herbicides		NS	-	-
Mean		1729.7		

Means followed by the same letter(s) within the same column of any treatment group are not significantly different at 5% level of probability (DMRT)

NA = Data not available

NS = Not significant at 5% level of probability

The weed control treatments also had significant effect on ribbon yield of kenaf. Application of fluazifop-butyl plus ametryne increased ribbon yield compared with the weedy check. The treatment also resulted in ribbon yields comparable to two hoe-weeding at 3 and 6 WAS. Metolachlor and alachlor, each applied alone, mixture of the former with ametryne and hoe-weeding at 4 WAS however resulted in ribbon yields that were comparable to the maximum with hoe-weeding at 3 and 6 WAS and the weedy check.

The interaction of N and weed control treatments on ribbon yield was not significant in the year of trial.

4.7.5 Fibre weight per plant

The fibre weight per plant of kenaf was higher in 1995 than in 1994 when data was available (Table 63). Application of N significantly influenced the fibre weight per plant in 1994 and 1995. In each year, the fibre weight increased with N levels.

The effect of the weed control treatments on fibre weight was significant in 1995. In the trial, fluazifop-butyl plus ametryne resulted in fibre weight that was comparable to hoe-weeding at 3 and 6 WAS and significantly higher than the weedy check. Hoe-weeding at 4 WAS resulted in significantly lower fibre weight per plant than hoe-weeding at 3 and 6 WAS.

There was no singificant interaction of N and weed control treatments on fibre weight per plant of kenaf in the two years of trials.

Table 63: Effects of nitrogen and weed control treatments on fibre weight per plant of kenaf during the 1994 and 1995 wet seasons at Samaru

Treatment		Fibre weight (g/plant)		
Nitrogen level (kg N/ha)		1993	1994	1995
0		NA	2.08c	3.14c
45		NA	4.04b	5.37b
90		NA	6.79a	6.53a
SE ±		-	0.318	0.393
Herbicides	Rate			
Metolachlor	1.50	NA	5.06	4.00b-d
Metolachlor+Ametryne	1.00+1.00	NA	5.21	3.25bc
Alachlor	1.50	NA	3.69	5.55bc
Alachlor+Ametryne	1.00+1.00	NA	4.11	5.34bc
Fluazitop-butyl	0.75	NA	3.45	3.15d
Fluaztop-butyl+Ametryne	0.50+1.00	NA	5.21	6.12ab
Hoe-weeded at 4 WAS		NA	4.12	4.54b-d
Hoe-weeded at 3 and 6 WAS		NA	4.73	7.53a
Unweeded check		NA	3.71	3.63cd
SE ±		-	0.55	0.680
Interaction				
N x Herbicides		NS	NS	NS
Mean		-	4.37b	5.01a

Means followed by the same letter(s) within the same column of any treatment group are not significantly different at 5% level of probability (DMRT)

NA = Data not available

NS = Not significant at 5% level of probability

4.7.6 Fibre yield

The fibre yields of kenaf were similar for 1994 and 1995 when data was available (Table 64). Fibre yield increased significantly with N levels in the two years of trials.

The effect of weed control treatments was significant only in 1995. In this case, all the herbicide treatments and hoe-weeding at 4 WAS resulted in significantly lower fibre yield than the maximum obtained with hoe-weeding at 3 and 6 WAS. Alachlor applied alone and in mixture with ametryne and metolachlor plus ametryne resulted in higher fibre yields than the weedy check. Mixture of metolachlor with ametryne resulted in higher fibre yield than metolachlor applied alone. Unchecked weed growth resulted in 28.9 and 51.4% reductions in fibre yield compared to the maximum yields obtained in 1994 and 1995, respectively.

The interaction of N and weed control treatments on fibre yield of kenaf was not significant in the two years of study.

4.7.7 Number of capsules per plant

The number of capsules per plant of kenaf was higher in 1993 than in 1994 and 1995 (Table 65).

Nitrogen application had singificant effect on the number of capsules per plant in the three years of study. The application of 90 kg N/ha in 1993 and 45 and 90 kg N/ha in 1995 significantly increased the number of capsules per plant of kenaf compared with the no N treatment. The number of capsules however increased with N rate in 1994.

Table 64: Effects of nitrogen and weed control treatments on fibre yield of kenaf during the 1994 and 1995 wet seasons at Samaru

Treatment		Fibre yield (kg/ha)		
Nitrogen level (kg N/ha)		1993	1994	1995
0		NA	417c	374c
45		NA	809b	932b
90		NA	1395a	1242a
SE ±		-	63.78	64.40
Herbicides	Rate			
Metolachlor	1.50	NA	1013	700cd
Metolachlor+Ametryne	1.00+1.00	NA	1043	1056b
Alachlor	1.50	NA	738	1111b
Alachlor+Ametryne	1.00+1.00	NA	822	1067b
Fluazitop-butyl	0.75	NA	690	555d
Fluaztop-butyl+Ametryne	0.50+1.00	NA	1042	630cd
Hoe-weeded at 4 WAS		NA	826	907bc
Hoe-weeded at 3 and 6 WAS		NA	947	1493a
Unweeded check		NA	742	725cd
SE ±		-	110.5	111.5
Interaction				
N x Herbicides		NS	NS	NS
Mean		-	874	416

Means followed by the same letter(s) within the same column of any treatment group are not significantly different at 5% level of probability (DMRT)

NA = Data not available

NS = Not significant at 5% level of probability

Table 65: Effects of nitrogen and weed control treatments on the number of capsules per plant of kenaf during the 1993-1995 wet seasons at Samaru

Treatment		Number of capsules per plant		
Nitrogen level (kg N/ha)		1993	1994	1995
0		13.79b	6.96c	7.07b
45		15.75ab	10.42b	12.79a
90		17.65a	16.43a	12.10a
SE ±		1.05	0.697	0.696
Herbicides	Rate			
Metolachlor	1.50	11.33cd	12.63a	7.16d
Metolachlor+Ametryne	1.00+1.00	15.56a-d	12.52ab	8.44cd
Alachlor	1.50	14.08b-d	9.03bc	10.62cd
Alachlor+Ametryne	1.00+1.00	16.87a-c	12.63a	10.47cd
Fluazitop-butyl	0.75	20.53a	8.34c	7.56d
Fluaztop-butyl+Ametryne	0.50+1.00	15.08a-d	10.80a-c	17.90a
Hoe-weeded at 4 WAS		19.56ab	13.13a	11.49bc
Hoe-weeded at 3 and 6 WAS		18.25ab	13.49a	14.31b
Unweeded check		10.31d	8.81c	7.91cd
SE ±		1.82	1.207	1.205
Interaction				
N x Herbicides		NS	NS	NS
Mean		15.73a	11.27b	10.65b

Means followed by the same letter(s) within the same column of any treatment group are not significantly different at 5% level of probability (DMRT)

NS = Not significant at 5% level of probability

The influence of the weed control treatments on the number of capsules per plant was also significant in the three years of study. In 1993, fluazifop-butyl at 0.75 kg a.i./ha resulted in the maximum number of capsules per plant of kenaf. The two hoe-weeding contols and alachlor plus ametryne resulted in the number of capsules comparable to the maximum and higher than the least obtained with the weedy check. Mixtures of ametryne with metolachlor and fluazifop-butyl however caused number of capsules comparable to the maximum and the least in the trial. In 1994, metolachlor and mixtures of ametryne with metolachlor and alachlor resulted in higher capsules production than the weedy check, and comparable to the two hoe-weeding controls. The number of capsules of plant treated with fluazifop-butyl plus ametryne was comparable to the maximum, although not significantly higher than the least with the weedy check. In 1995, fluazifop-butyl plus ametryne resulted in the maximum number of capsules per plant. Hoe-weeding at 3 and 6 WAS resulted in higher number of capsules than the weedy check, although lower than the maximum.

There was no significant interaction of N and weed control treatments on the number of capsules per plant of kenaf during the three years of trials.

4.7.8 Seed weight per plant

The weight of seeds per plant of kenaf was significantly lower in 1995 than in 1993 and 1994 (Table 66).

The effect of N on seed weight per plant was significant in the three years of study. In 1993 and 1995, application of N increased seed weight, although the difference between no N and 45 kg N/ha treatments was not significant in 1993. In 1994, seed weight per plant increased with the N levels.

The effect of weed control treatments was also significant on seed weight per plant of kenaf

Table 66: Effects of nitrogen and weed control treatments on seed yield per plant of capsules per plant of kenaf during the 1993-1995 wet seasons at Samaru

Treatment		Seed weight g/plant		
Nitrogen level (kg N/ha)		1993	1994	1995
0		3.87b	2.33c	2.43b
45		4.67ab	3.30b	4.13a
90		5.33a	6.16a	4.04a
SE ±		0.295	0.233	0.325
Herbicides	Rate			
Metolachlor	1.50	4.41a-c	4.43ab	2.01d
Metolachlor+Ametryne	1.00+1.00	5.58ab	4.31a-c	2.60cd
Alachlor	1.50	4.20a-c	3.15c	3.09cd
Alachlor+Ametryne	1.00+1.00	4.13bc	4.25a-c	3.30b-d
Fluazitop-butyl	0.75	2.90c	3.08c	2.29cd
Fluaztop-butyl+Ametryne	0.50+1.00	5.24ab	3.61a-c	7.12a
Hoe-weeded at 4 WAS		5.88a	4.53ab	4.01bc
Hoe-weeded at 3 and 6 WAS		4.94ab	4.74a	4.84b
Unweeded check		4.32a-c	3.31bc	2.54cd
SE ±		0.511	0.404	0.562
Interaction				
N x Herbicides		NS	NS	NS
Mean		3.93a	3.93a	3.53b

Means followed by the same letter(s) within the same column of any treatment group are not significantly different at 5% level of probability (DMRT)

NS = Not significant at 5% level of probability

in all the three years of study. In 1993, none of the weed control treatments out yielded the weedy check. Hoe-weeding at 4 WAS resulted in the highest seed weight per plant but this was not significantly higher than the weedy control. In 1994, hoe-weeding at 3 and 6 wAS resulted in higher weight than the weedy check. Metolachlor, mixtures of ametryne with metolachlor and fluazifop-butyl and hoe-weeding at 4 WAS resulted in comparable seed weights to the maximum, although these were not significantly higher than with the weedy check. In 1995, fluazifop-butyl plus ametryne resulted in the maximum seed weight per plant which was greater than with the other weed control treatments, including the hoe-weeded controls. Hoe-weeding at 3 and 6 wAS resulted in higher seed weight than the weedy check.

The interaction of N and weed control treatments on seed weight per plant of kenaf was not significant in the three years of trials.

4.7.9 100-seed weight

The kenaf 100-seed weight was higher in 1994 than in 1995 when data was available (Table 67).

Nitrogen application significantly increased the 100-seed weight compared to the no N control in 1994. The difference between 45 and 90 kg N/ha was however not significant in this case.

The effect of weed control treatments on 100-seed weight was not significant in the two years of trials.

The interaction of N and weed control treatments on 100-seed weight was also not significant in the two years.

4.7.10 Seed yield

The seed yield of kenaf was maximum in 1994 (Table 68). The yield in 1993 was comparable to the maximum and the least obtained in 1995.

Nitrogen application significantly influenced the seed yield of kenaf in the three years of study. Application of N increased seed yield over the no N control and the response was almost linear with N rate in 1994.

The effect of weed control treatments was significant in 1993 and 1994. In 1993, metolachlor plus ametryne resulted in the maximum seed yield. Fluazifop-butyl plus ametryne as well as the hoe-weeding controls and the weedy check however, resulted in seed yields comparable to the maximum. In 1994, hoe-weeding at 3 and 6 WAS resulted in the maximum seed yield, which was higher than the yield with the weedy check. Metolachlor and mixtures of ametryne

Table 67: Effects of nitrogen and weed control treatments on 100-seed weight of kenaf during the 1993-1995 wet seasons at Samaru

Treatment		100-Seed weight (g)		
Nitrogen level (kg N/ha)		1993	1994	1995
0		NA	2.67a	2.42
45		NA	2.57b	2.49
90		NA	2.57b	2.46
SE ±		-	0.033	0.048
Herbicides	Rate			
Metolachlor	1.50	NA	2.54	2.35
Metolachlor+Ametryne	1.00+1.00	NA	2.59	2.50
Alachlor	1.50	NA	2.54	2.43
Alachlor+Ametryne	1.00+1.00	NA	2.58	2.49
Fluazitop-butyl	0.75	NA	2.65	2.50
Fluaztop-butyl+Ametryne	0.50+1.00	NA	2.63	2.54
Hoe-weeded at 4 WAS		NA	2.69	2.48
Hoe-weeded at 3 and 6 WAS		NA	2.64	2.45
Unweeded check		NA	2.57	2.42
SE ±		-	0.056	0.083
Interaction				
N x Herbicides		NS	NS	NS
Mean		-	2.60a	2.46b

Means followed by the same letter(s) within the same column of any treatment group are not significantly different at 5% level of probability (DMRT)

NA = Data not available

NS = Not significant at 5% level of probability

Table 68: Effects of nitrogen and weed control treatments on seed yield per hectare of kenaf during the 1993-1995 wet seasons at Samaru

Treatment		Seed yield (kg/ha)		
Nitrogen level (kg N/ha)		1993	1994	1995
0		484.46	466c	423b
45		706.7a	631b	702a
90		814.4a	1233a	670a
SE ±		49.46	46.74	68.60
Herbicides	Rate			
Metolachlor	1.50	644.4bc	886ab	401
Metolachlor+Ametryne	1.00+1.00	913.3a	861a-c	520
Alachlor	1.50	633.3bc	629c	618
Alachlor+Ametryne	1.00+1.00	500.0c	849a-c	660
Fluazitop-butyl	0.75	242.2d	617c	407
Fluaztop-butyl+Ametryne	0.50+1.00	860.0a-b	721a-c	612
Hoe-weeded at 4 WAS		780.0ab	906ab	802
Hoe-weeded at 3 and 6 WAS		728.9a-c	950a	857
Unweeded check		713.3a-c	660bc	508
SE ±		85.55	80.89	118.8
Interaction				
N x Herbicides		NS	NS	NS
Mean		669ab	776a	598b

Means followed by the same letter(s) within the same column of any treatment group are not significantly different at 5% level of probability (DMRT)

NS = Not significant at 5% level of probability

with metolachlor, alachlor and flauzifop-butyl resulted in yields comparable to the maximum, although none was significantly greater than with the weedy check. Unchecked weed growth resulted in 21.9, 30.1 and 40.7% reductions in kenaf seed yield compared to maximum yields obtained in 1993, 1994 and 1995, respectively.

There was no significant interaction of N and weed control treatments on seed yield of kenaf in the three years of study.

4.8 Correlation

The coefficient of correlation amongst some growth characters, fibre and seed yield attributes and weed cover score in the weed control trials are presented on Tables 69-71. The seed yield was strongly and positively correlated with crop vigour score and plant height in the three years of trials, and butt diameter, wood weight, fibre yield and number of capsules per plant in 1994 and 1995. The correlation with butt diameter and wood weight was moderate in 1993. Seed yield was strongly and negatively correlated with number of days to first flowering in the three years, and weed cover in 1995. The fibre yield was strongly and positively correlated with wood weight, crop vigour score, plant height, butt diameter and number of capsules per plant; but negatively correlated with number of days to first flowering in the three years and weed cover score in 1993 and 1995. Similarly, wood dry weight was strongly and positively correlated with crop vigour score, plant height, butt diameter and number of capsules per plant; but negatively correlated with the number of days to first

Table 69: Matrix of correlation coefficient between the various kenaf yields, yield characters and weed cover score as affected by nitrogen and herbicides during the 1993 wet season at Samaru

	1	2	3	4	5	6	7	8	9
1. Seed weight/plant	1.00								
2. Number of capsules/plant	0.18	1.00							
3. Ribbon weight/plant	0.23	0.45**	1.00						
4. Wood weight/plant	0.28*	0.42**	0.92**	1.00					
5. No. of days to first flowering	-0.40**	-0.50**	-0.63**	-0.63**	1.00				
6. Crop vigour score at 6 WAS	0.48**	0.51**	0.57**	0.63**	-0.71**	1.00			
7. Plant height at 6 WAS	0.46**	0.44**	0.76**	0.82**	-0.68**	0.78**	1.00		
8. Butt diameter at 6 WAS	0.34*	0.42**	0.68**	0.71**	-0.52**	0.58**	0.76**	1.00	
9. Weed cover score at 6 WAS	-0.03	-0.43**	-0.37**	0.35**	0.37**	-0.30*	-0.36**	-0.29*	1.00

* Significant at 5% level of probability (r = 27)
** Significant at 1% level of probability (r = 35)

Table 70 Matrix of correlation coefficient between the various kenaf yields, yield characters and weed cover score as affected by nitrogen and herbicides during the 1994 wet season at Samaru

	1	2	3	4	5	6	7	8	9	10
1. Seed weight/plant	1.00									
2. 100-seed weight	0.01	1.00								
3. Number of capsules/plant	0.95**	0.03	1.00							
4. Fibre weight/plant	0.69**	-0.22	0.64**	1.00						
5. Wood weight/plant	0.70**	-0.17	0.66**	0.92**	1.00					
6. No of days to first flowering	-0.69**	0.29*	-0.63**	-0.74**	-0.74**	1.00				
7. Crop vigour score at 6 WAS	0.63**	0.19	0.62**	0.67**	0.72**	-0.79**	1.00			
8. Plant height at 6 WAS	0.69**	0.18	0.64**	0.78**	0.83**	-0.82**	0.79**	1.00		
9. Butt diameter at 6 WAS	0.67**	0.13	0.67**	0.78**	0.82**	-0.76**	0.74**	0.83**	1.00	
10. Weed cover score at 6 WAS	-0.05	-0.24	-0.05	-0.04	-0.02	0.17	0.22	-0.14	0.06	1.00

* Significant at 5% level of probability (r = 27)
** Significant at 1% level of probability (r = 35)

Table 71 Matrix of correlation coefficient between the various kenaf yields, yield characters and weed cover score as affected by nitrogen and herbicides during the 1995 wet season at Samaru

	1	2	3	4	5	6	7	8	9	10
1. Seed weight/plant	1.00									
2. 100-seed weight	0.25	1.00								
3. Number of capsules/plant	0.84**	0.37**	1.00							
4. Fibre weight/plant	0.49**	0.21	0.56**	1.00						
5. Wood weight/plant	0.50**	0.23	0.59**	0.97**	1.00					
6. No of days to first flowering	-0.39**	-0.17	-0.45**	-0.58**	-0.58**	1.00				
7. Crop vigour score at 6 WAS	0.39**	0.15	0.51**	0.69**	0.69**	-0.70**	1.00			
8. Plant height at 6 WAS	0.28*	0.22	0.39**	0.74**	0.72**	-0.60**	0.72**	1.00		
9. Butt diameter at 6 WAS	0.62**	0.23	0.73**	0.66**	0.66**	-0.65**	0.74**	0.58**	1.00	
10. Weed cover score at 6 WAS	-0.41**	-0.07	-0.38**	-0.41**	-0.42**	0.58**	-0.23	-0.21	-0.34*	1.00

* Significant at 5% level of probability (r = 27)
** Significant at 1% level of probability (r = 35)

flowering in the three years of study and weed cover score in 1993 and 1995. Crop vigour score, plant height and butt diameter were strongly and positively correlated with one another in the three years of trials. These parameters were strongly and negatively correlated with the number of days to first flowering. Weed cover score was negatively correlated with butt diameter in 1993 and 1994, and crop vigour score and plant height in 1995. The number of days to first flowering was positively correlated with weed cover score in 1993 and 1995.

CHAPTER FIVE

5 DISCUSSION

In the weed interference study, it was observed that fibre/ribbon was generally higher in 1993 than in the other years, while wood and seed yields were generally higher in 1993 and 1994 than in 1995. Fibre yield was higher in 1994 than in 1995 by about 19%. In the weed control trial, although maximum wood and ribbon dry weights per plant were obtained in 1993 and least in 1994, there was no significant difference between the yields in 1994 and 1995 when data was available. Seed yield was however, higher in 1994 than in 1995. The variation in the yield trend between the two trials could be due to differential effect of fusilade on the crop in the weed control study. The herbicide was most phytotoxic to kenaf in 1993 and least in 1994. The higher ribbon and seed yields in 1993 could be due to higher precipitation and better distribution of rainfall during the active crop growth period in the year compared with the other years (Appendix 2 - 4). During the active stage, the plants required adequate moisture for rapid vegetative growth. The moisture condition in 1993 might have been conducive for kenaf growth and consequently wood production, a major attribute of fibre/ribbon yields (Table 34-36). The response of kenaf to periods of weed interference was reported to be influenced by variation in moisture condition during the crop growth-cycle (Shadbolt and Holm, 1956). In addition to favourable moisture condition of the soil, the fairly higher level of native phosphorus at the trial site in 1993 (Appendix 1) could have also favoured the vegetative growth of the crop, which is necessary for wood and fibre production. Although a basal dressing with 30 kg P/ha was made, there was no consideration of the native P level of the soil prior to application. Thus the higher residual P in the soil in this year must have augmented the applied element more in 1993 than in subsequent years. Hari et al. (1978) and Negi et al (1982) have observed that phosphorus promotes root growth and development and consequently, facilitates nutrients uptake for greater plant growth and development.

5.1. Effects of Nitrogen on Weeds and Kenaf

In the weed interference and control trials, application of nitrogen consistently promoted the growth of kenaf as reflected in plant height, butt diameter and crop vigour and consequently increased wood, fibre/ribbon and seed yields of the crop compared with no nitrogen control. In most cases, the growth parameters as well as the yields and yield attributes increased with N rates. It is apparent that the effect of N on the growth characters was directly responsible for the response of various yield parameters, viz wood, fibre and seed. The increase in the number of capsules per plant as a result of N application was also responsible for similar response by seed yield. In the study, N also enhanced early floral initiation in the three years and 50% flowering in 1994 and 1995. Favourable responses to N by kenaf have been reported (Amankwatia and Takyi, 1975; Salih, 1977; Lakshminarayana et al., 1980; Bhangoo et al., 1986; Lyons et al., 1991). Where as Lakshminarayan et al., (1980) reported that fibre yield increased with N rate from 0-80 kg N/ha, Bhangoo et al. (1986) reported that there were 71% and 83% fibre yield increase when 135 and 180 kg N/ha were applied, respectively. Lyons et al. (1991) observed that kenaf wood yield responded to as high as 240 kg N/ha. Kenaf was earlier observed to be a heavy feeder and soil depleting crop (Darmsey, 1964). The positive response of kenaf to N is expected since it is essential for the synthesis of various N related compounds which are required for plant growth and development. Olson et al. (1970) have observed that N promotes aerial growth and seed formation in most plants. Nitrogen was however found to reduce the number of days to first and 50% flowering, and these parameters tended to decrease with N level. This trend is not usual. Nitrogen is generally known to prolong vegetative phase of most plants of the Malvaceae family. However, in the three years of investigation, plants that were given no N and left weed-infested throughout their growth-cycle had extremely poor growth and took a very long period to initiate floral buds. Indeed some of the plants with these treatments could hardly attain 50% flowering. The plants in this case were submerged in weeds and the effect of the weeds tended to decrease with N-level. It is thus the extra long period taken by the plants with these treatments to start flowering and to attain 50% flowering that tended to reverse the general

trend. Takahachi et al. (1979) have however reported that nitrogen enhanced early flowering in garden egg, and attributed the trend to ability of the element to promote rapid growth and physiological maturity.

The influence of N on weed cover score was less consistent. In the weed interference study, application of N, especially 90 kg N/ha increased weed cover score and commulative weed dry weight in most cases. However, while similar trend was observed at 6 WAS in the weed control studies, 90 kg N/ha seemed to reduce weed cover score. Nitrogen had no influence on cummulative weed dry weight, except in 1995 when it increased with N rate. Buchanan and Mclaughin (1975) have observed that the competitive relationship of some weeds with cotton was not altered by variation in fertilizer rates up to 100 kg N/ha; while Adejonwo (1988) reported that only broad leaved weeds responded to the applied N due to their late emergence in the cropping season.

The results suggest that weed competition in kenaf is more important at lower than at high soil N level inspite of increase growth of weeds with N level. The greater response to higher N rates by kenaf than by the weeds indicates that higher N levels are more beneficial to the crop than the weeds, probably due to additional smothering effect of kenaf by a dense canopy at later stage of growth. Thus higher N doses can be used to enhance rapid crop growth and canopy formation required to smother the weeds and therefore suppress their growth. Blackman and Templeman (1938) have earlier recommended high N rates as a means of suppressing moderate weed populations in annual crops. Some reports have indicated the differential effect of fertilizer on the competitiveness of weeds with crops. Fusyunov (1969) and Lagoke (1978) have observed that increased fertilizer application could benefited both the crop and the weeds, and the former was more responsive.

5.2 Effect of Weed Interference on Kenaf

In the three years of trials, initial weed infestation for 3 WAS only did not have any serious effect on any of the crop growth characters and fibre and seed yields provided the weeds were subsequently removed. In contrast, the growth parameters and yields of kenaf kept weed-free initially for 3 WAS only

were significantly depressed by subsequent weed infestation for the remaining part of the crop growth cycle. The young and tender grasses and few broad leaved weeds with rudimentary root systems and few leaves could not compete effectively with the kenaf plants to cause any remarkable adverse effect on the growth and yield of the crop. In addition, at the initial stages of crop establishment, both the weeds and the kenaf plants were small and the soil nutrients and moisture contents as well as the solar radiation were still adequate to meet their combined requirements. In the Nigerian savanna, several workers have also reported that initial weed infestation for 3 WAS did not affect the growth and yield of crops such as pepper (Lagoke et al., 1988; Adigun et al., 1991), cotton (Dadari, 1983), potato (Bulus, 1986), okra (Adejonwo, 1988), maize (Magani, 1990) and tomato (Adigun, 1991). However, initial weed infestation for 6 WAS and more resulted in the depression of growth characters such as crop vigour score, plant height and stem butt diameter, as well as wood and fibre yields compared to the crop kept weed-free for 6 WAS and beyond. In order to obtain yields that were comparable to the weed-free check, a weed-free environment of 6 WAS and more was required. Once the crop is kept weed-free upto this period, subsequent infestation did not have significant effect on its growth and fibre yield. Although seed yield was depressed by initial weed infestation for 9 and 12 WAS in 1993, and 6 WAS and beyond in 1994 and 1995 compared to their appropriate maxima, data on the parameter were generally less consistent. For instance, in 1993, the yield obtained from the weedy control was comparable to the maximum yield in the year. Similarly, weed infestation for 6-12 WAS resulted in comparable yields to those obtained from plots kept weed-free for 6 and 12 WAS in 1994. Seed production apparently is more adversely affected by the growth of the weeds at the later stage of growth. At this stage, adequate canopy produced by kenaf plants would have smothered the weeds and reduced their effect on seed production. Thus the period between 3 and 9 WAS is particularly crucial in the crop growth cycle in relation to weed infestation. A number of workers have emphasized the importance of early weed control in vegetable crops (Sinha and Lagoke, 1984, Adigun, 1984, Bakut, 1985, Adigun et al., 1991). Lagoke et al. (1981) have reported that kenaf is more susceptible to weed interference at the early growth stages because of its slow initial growth rate.

At the later growth stages, the crop had formed a continuous canopy which could smother the weeds below it, and so depress their growth and dry matter production. However, keeping the crop weed-free for 3 WAS only was not enough to obviate its growth and yield depressions by the weeds because at this stage the crop had not formed the canopy required to suppress subsequent weed growth. Thus there was unabated resurgence of weeds which competed adversely with kenaf plant and consequently depressed the growth and yield of the crop. The rapid increase in weed growth from 3 WAS to 6 WAS and more as reflected in the weed cover scores in the three years of study further substantiates the explanation (Tables 16-18 and 55-57). Similarly, there was a sharp increase in weed dry matter accummulation on the weed infested plots from 3 to 6 WAS in the three years of study (Fig. 7-9). However, weeding the plots at 12 WAS and beyond appeared to have negative effect on the yields (Figs. 1-6). Hoe-weeding at an advanced stage of growth can cause injury to roots, stems and tender shoots, resulting in serious yield reductions. Olunuga and Akobundu (1980) have observed that apart from the various limitations associated with hoe-weeding, the physical damage caused to the crop plants may result in the depression of yields. Kirby (1963) has earlier indicated that hoe-weeding of kenaf should discontinue as soon as the crop is 60 to 90cm tall.

Maximum wood and ribbon/fibre yields were obtained from plots kept weed-free for 9 WAS in 1993 and 1994 and 12 WAS in 1995 (Tables 22-27). The difference in the weed-free period requirement for maximum wood and fibre yields in 1993 and 1994 compared with 1995 could be attributed to variation in the weather conditions in the years of investigation. For example, the amounts of rainfall received in 1993 and 1994 were generally higher than in 1995 (Appendix 2-4). The amount and distribution of the rains in the two years might have favoured early crop growth more than in the later season. The ribbon/fibre yield reduction from the potential yields as a result of weed infestation throughout the crop life-cycle were 26%, 58% and 55% in 1993, 1994 and 1995, respectively (Tales 25 and 27). Similarly, maximum seed yields were obtained from plots kept weed-free for 12 WAS in 1993, 9 WAS in 1994 and until harvest in 1995 (Table 32). The seed yield reductions from the potential yields as a result of

unchecked weed growth were 23%, 51% and 64% in 1993, 1994 and 1995 respectively. The longer weed-free period requirement for seed production indicates that later weed infestation is more important in seed production than fibre yield. Fibre yield reductions of 59.0% and 47.2% from the potential yields as a result of weed infestation in kenaf were also reported by Lagoke et al. (1981) and Kuchinda et al. (1991), respectively. Capsules yield reduction of 30% compared with the maximum obtained in a trial was also observed by Kuchinda et al. (1991). Reductions in both the ribbon and seed yields were least in 1993 than in subsequent years. This could be due to the adequate rainfall and soil P which might have enhanced rapid crop growth required to suppress the weeds in this year than in subsequent years. Shadbolt and Holm (1956) have earlier indicated that the precise time, duration and magnitude of weed competition depended on the time of moisture and nutrients stresses, among other factors.

5.3 Critical Period of Weed Competition

Figures 1-6 show that the critical period of weed competition in kenaf was between 3 and 6 WAS. Nieto et al. (1968) have earlier indicated that the critical period of weed competition in most crops is often the first quarter of the crop life-cycle; and for most vegetable crops, Kasasian and Seeyave (1969) observed that the first one third of a crop life-cycle needs to be kept weed-free if adverse effect of weeds is to be avoided. Lagoke et al. (1982) have estimated the critical period of weed competition for kenaf to be between 3 and 4 WAS. This is the period when the crop plants are most susceptible to weed competition. This period coincided with the time of maximum weed dry matter production (Figs. 7-9) and competition with kenaf plants. Hence, leaving the weeds unchecked upto 6 WAS and beyond will have adverse and irreversible effect on the crop despite subsequent removal of the weeds. In the trials, weed infestation for 6 WAS and beyond significantly reduced wood and ribbon/fibre yields in the three years and seed yield in 1994 and 1995 compared to yields obtained from the crop kept weed-free throughout its life-cycle. In this study, unchecked weed growth for 6 WAS

resulted in 30-37% and 36% fibre and seed yields reductions, respectivley, compared to yields of the crop kept weed-free throughout its life-cycle. Similarly, unchecked weed growth for 6 WAS resulted in 33-39% and 12-28% fibre and seed yields reductions, respectively, compared to yields of the crop kept weed-free for the same period. On the other hand, the crop initially kept weed-free for 3 WAS only resulted in 33-60% and 6-76% fibre and seed yields reductions, respectively, compared to the weed-free check. In the same vein, the crop initially kept weed-free for 3 WAS only resulted in 32-51% and 13-65% reductions in fibre and seed yields, respectively, compared to weed infestation for the same period.

5.4 Effect of Weed Control Treatments

Weed infestations at 9 and 12 WAS as observed on the weedy check were generally higher in 1995 than in 1993 and 1994. During the period of study, alachlor, metolachlor and their mixtures with ametryne resulted in weed suppression during the sampling periods as reflected on weed cover score (Tables 41-43). These treatments also suppressed sedges. Fluazifop-butyl (fusilade) and its mixture with ametryne had similar effects from 6 WAS in 1993 and 9 WAS in 1994 and 1995. However, fusilade resulted in the emergence and proliferation of Cyperus spp. There were corresponding positive effects of alachlor and metolachlor as well as their mixtures with ametryne on crop vigour score from 6 WAs in 1993 and 9 WAS in 1994. In 1995, alachlor and its mixture with ametryne also improved crop vigour from 6 WAS. Weed suppression by fusilade was significant from 6 WAS in 1993 and its mixture with ametryne from 9 WAS in 1994. Although only few of the herbicides resulted in weed suppression comparable to the hoe-weeded controls most of them gave vigorous crop comparable to the controls.

The higher weed cover in 1995 could also be attributed to inadequate and uneven rainfall distribution during the season; compared to that obtained in 1993 and 1994 (Appendix 2-4). This might have affected crop growth and canopy development required to smother the weeds and suppress their growth. The weeds are more hardy and can thrive better under moisture stress conditions than the crop

lants. Another explanation to the trend could be the proliferation of late emerging weeds such as Rottboelia cochinchinensis, Acanthospermum hispidium, Euphorbia hetrophylla and Vernonia galamensis on the trial site in 1995 than in the other years (Appendix 5). Crop vigour improvement by the weed control treatments could be a reflection of their effect on weeds. Weed suppression and consequently, enhancement of crop vigour by alachlor and metolachlor have also been reported earlier by a number of workers (Michieka et al., 1977; Lagoke et al., 1981; Kuchinda et al., 1991). Ashton and Crafts (1981) have reported that some members of the chloroacetamides gave selective control of grasses, some broad leaved weeds as well as sedges in vegetable crops. Cyperus spp were observed to be controlled by metolachlor (Cornelius, 1976; Choudhary, 1980). Mixtures of alachlor and metolachlor each with ametryne gave similar results as the individual herbicides. Peak (1980) and Lagoke et al. (1981) have reported that broadleaved weeds were controlled by metolachlor applied in mixture with other suitable herbicides. However, the performance of fusilade was not quite promising probably due to its delayed application (applied post-emergence). Fusilade was also phytotoxic on kenaf plants and resulted in late proliferation of Cyperus spp. Fusilade has been reported to be non-effective on sedges (Roy et al., 1988) and plytotoxic to kenaf plants (Kuchinda et al., 1991).

The effects of all the weed control treatments were not consistent on the various yield and yield components of kenaf. The wood and fibre yields were increased by alachlor and mixtures of alachlor and metolachlor, each with ametryne when compared with the weedy control in 1995. Although there was similar effect by fusilade and its mixture with ametryne on wood and fibre weights per plant in some trials, the effect was not reflected on the yields. This is probably due to stand loss as a result of its phytotoxicity on the crop. Reports on the effect of herbicides on kenaf have not been consistent. For instance, where as alachlor at 2.5 kg reduced fibre yield by 15-20% (Boulanger et al., 1973), fibre yield was significantly increased by the herbicide at rates that range from 1.5 to 2.4 kg (Lagoke et al., 1981; Deuber et al., 1982; Kuchinda et al., 1991). Kuchinda et al. (1991) reported that a fibre yield increase

of 45% was achieved with alachlor at 2.0 kg. Positive yield responses to application of metolachlor have also been reported (Lagoke et al. 1981; Kuchinda et al., 1991). Although the influence of herbicides on seed yield was generally inconsistent, the effect of fusilade appears to be more promising inspite of its adverse effect on the crop plants. This may be due to the high number of capsules per plant on plots treated with the herbicide. Capsules number is a major component of seed yield of kenaf. Higher number of capsules and consequently, higher seed dry weight per plant could have compensated for the stand losses as a result of the herbicide effect.

The effect of hoe-weeding on kenaf yields and yield parameters was also not consistent, except on the number of capsules per plant, which was increased by hoe-weeding at 3 and 6 WAS during the three years of investigation. Wood and ribbon dry weights per plant was increased by hoe-weeding at 3 and 6 WAS in 1994 and 1995. Similar results were obtained by one hoe-weeding at 4 WAS on wood yield, capsules number and seed yield in 1994. Hoe-weeding however consistently gave effective weed control and also resulted in correspondingly more vigorous crop than the weedy check. The possible explanation to the inconsistent effect of hoe-weeding on yields and yield attributes of kenaf despite effective weed control may be attributed to the fact that fibre and seed yields were influenced by other environmental factors other than by weed infestation alone. Martin and Worthing (1977) have observed that the influence of weed control treatments on kenaf depended on the soil and weather conditions under which the crop was grown. Generally, the effect of hoe-weeding at 3 and 6 WAS resulted in better and more consistent yield performance than the herbicide treatments. Various reasons may be attributed to this observation. In all the years, none of the herbicide treatments resulted in weed cover depression comparable to hoe weeding at 3 and 6 WAS. Also, there was late emergence of A. hispidium, R. cochinchinensis, V. galamensis, Ageratum conygoides and Crotolaria juncea at the sites of trials (Appendix 5) on plots treated with alachlor and metolachlor. These weeds might have also affected the yields, especially of seeds which is observed to require a longer weed-free period than fibre production.

In the same vein, apart from the phytotoxicity of fusilade to kenaf plants, the herbicide was applied post emergence at about 4 WAS. Thus period falls within the critical period of weed competition. This indicates that the effect of the herbicides on weeds started at the time the crop had already suffered from weed infestation. Thus yield depression especially of fibre was not ameliorated by fusilade.

5.5 Interactions

There was significant N and period of weed interference interactions on crop vigour score at 6 WAS in 1993, plant height at 8 wAS in 1993 and 12 WAS in 1994 and butt diameter at 12 WAS and fibre yield in 1994. The interactions on weed cover score at 6 WAS and cummulative weed dry weight in 1993 were also significant. Maximum crop vigour was obtained from plots treated with 90 kg N/ha and kept weed-free for 6 WAS in 1993. The least vigour was from weed interference treatments without N. Maximum plant height was obtained from plots dressed with 45 and 90 kg N/ha and kept weed-free for 3 WAS and longer and those given 90 kg N/ha and left weedy for 3 WAS only in 1993. In 1994, maximum plant height was obtained on plots dressed with 90 kg N/ha and left weedy for 3 WAS only. With a few exceptions in the trial, plant height increased with N; and plots kept weed-free for 6 WAS and more had taller plants than those weed-infested for the same period under the 45 and 90 kg N rates. Similarly, at 12 WAS in 1994, the maximum butt diameter was obtained from plants given 90 kg N/ha and either kept weed-free or weed-infested for 3 WAS only. Generally, plots given 45 kg N/ha and kept weed free for 9 WAS and longer and those given 90 kg N/ha and either kept weed-free for 6 wAS and more or left weedy for 3-6 WAS resulted in butt diameters comparable to the maximum in the trial. The trend indicates that for better growth, the crop had to be supplied with 90 kg N/ha and left weedy initially for 3 WAS only. At the N level, weed infestation for 9 WAS and more would reduce butt diameter, a major component of fibre yield. At all the N levels in 1993, plots kept weed-free for 6 WAS and that weed-infested for 3 WAS only resulted in lower weed cover score than those weed-infested and weed-free

for the respective periods. This shows that weed growth is not necessarily influenced by N at 6 WAS. Similarly, at all the N levels, plots kept weed-free for 6 WAS and longer and those weed-infested for 6 WAS and less produced weed dry matter comparable to the least. With 90 kg N/ha, plot kept weed-free for 3 WAS only also had comparable weed dry matter to the least. Maximum weed dry matter production was obtained on plots dressed with 45 kg N/ha and either kept weed-free for 3 WAS only or left weedy for 9-12 WAS. The results indicate that weed dry matter production in kenaf is less influenced by N application if the crop is initially kept weed-free for 6 WAS and more or weed-infested for 6 WAS and less. However, keeping a kenaf crop weed-free for at least 6 WAS and leaving it weedy for a maximum of 6 WAS would result in weed dry matter depression comparable to the crop that is kept weed-free throughout its life-cycle; whether N is applied or not. With 90 kg N/ha the plots can be kept weed-free initially for 3 WAS only for it to give comparable weed dry matter depression. However, application of N may stimulate weed dry matter production if the weeds are left unchecked for 9 wAS and more, and this is more so with 45 kg N/ha. At the moderate N rate it was found that weed infestation for 9-12 WAS resulted in greater weed dry matter accummulation than infestation through out the crop life-cycle. This may be attributed to the fact that at 9 WAS, maximum weed dry matter has formed and therefore subsequent weeding would clear the ground to allow the emergence of new species which may not grow substantially but would add to the final weed dry weight at seed harvest.

The N and period of weed interference interaction show that maximum fibre yield was obtained from plots with 45 kg N/ha which were weed-free for 9 WAS. Plots with 90 Kg N/ha either weed-free for 6 and 9 WAS or weed-infested for 3 WAS only gave comparable fibre yields to the maximum. Whereas all the weed interference treatments without N resutled in comparable fibre yield to the least, only those weed-infested for 12 WAS were comparable with 90 kg N/ha. With 0 kg N/ha plot kept weed-free for 3 WAS only and those weed-infested for 6 WAS and more had comparable yields to the corresponding plots with 45 kg N/ha. The results indicate that a good fibre yield requires that the crop

be supplied with either 45 kg N/ha and kept weed-free for 9 WAS or be given 90 kg N/ha and kept weed-free for 6 to 9 WAS. With 90 kg N/ha, a good fibre yield can still be obtained if the crop is weed-infested for 3 WAS only. However, fibre yield reduction by weed infestation for 6 WAS and more may not be ameliorated by N application. Since weed dry matter was least on plots kept weed-free for 6 WAS and more and those weed-infested for 3-6 WAS, the positive response of kenaf to 90 kg N/ha and to a lesser extent, 45 kg N/ha shows that the element was a limiting factor, among others.

The N and weed control treatments interactions were significant on crop vigour score at 9 WAS and plant height at 8 wAS in 1993, number of days to 50% flowering in 1994 and weed cover score in 1995. With 0 kg N/ha, fusilade at 0.75 kg resulted in comparable crop vigour to the maximum at 9 WAS in 1993. With 45 kg N level, mixtures of fusilade and alachlor with ametryne and the hoe-weeded checks resulted in crop vigour that was comparable to the maximum. With 90 kg N level, all the weed control treatments had crop vigour similar to the maximum obtained by the hoe-weeded checks, except the weedy control. With the N rate, alachlor and mixture of metolachlor and ametryne as well as the hoe-weeded checks and the weedy control had more vigourous plants than the corresponding treatments without N. The favourable effects of alachlor and metolachlor plus ametryne on crop vigour at higher N rate reveals that the treatments can favourably substitute manual hoe-weeding of kenaf crop under appropriate N fertilization. However, the comparable effect of fusilade at lower N level may be attributed to stand losses which left fewer plants to make use of the avilable nutrients. Plant height was increased by mixtures of ametryne with metolachlor, alachlor and fusilade with 0 kg N/ha at 8 WAS in the same year. However, with 45 and 90 kg N levels < no weed control treatment had taller plants than the weedy check. Indeed most of the treatments had shorter plants than the check. The positive effects of some of the herbicide mixtures on kenaf at zero N level may be due to weed suppression which reduced their competition effect on the crop plants compared to the weedy control. The plants were able to make use of the limited nutrients in the soil which enhanced their growth. However, the comparable plant height

by the weedy check to the maximum at 45 and 90 kg N/ha indicates that rather than the nutrient element alone, light was a limiting factor for crop growth. Weeds were generally more aggresive and grew faster than the crop plants. Thus kenaf plants exhibited etiolation and spindle growth to meet their light requirement amidst the weeds. These plants were taller but had thinner stems than those kept weed-free. The general increase in plant height with N rate shows that the parameter is favoured by N, whether the weeds are controlled or not. Fusilade plus ametryne and the hoe weeded controls resulted in less number of days to 50% flowering than the unweeded check at 0 Kg N/ha. However, at 45 and 90 kg N/ha, all the treatments including the weedy control resulted in less number of days to 50% flowering than the maximum in the trial. This result shows that crop maturation is hasten by N, not withstanding the weed control measure adopted. However, without application of N, fusilade plus ametryne and the two hoe-weeding treatments will hasten crop maturation. With 0 Kg N/ha, the hoe-weeded controls were found to suppress weed cover at 6 WAS in 1995. However, with 45 and 90 kg N/ha, all the weed control treatments suppressed weed cover score compared with the weedy check. The effect of the herbicides at the N levels were comparable to those of the hoe-weeded controls, except metolachlor and fusilade each applied alone. Weed cover score was favoured by N only when the plots were left weedy throughout the crop life-cycle. This observation shows that alachlor and mixtures of ametryne with alachlor, metolachlor and fusilade can give comparable weed suppression to hoe-weeding provided 45 kg N/ha or more is applied. At zero N level, only hoe-weeding effectively suppressed weeds and application of N encouraged weed growth when no control measure was taken. The phytotoxicity of some of the herbicide on weeds have been observed to be enhanced by N (Buchanan and Mclaughin, 1975, Khalilov, 1975). Improvement in the efficiency of herbicides at higher N rate could be attributed to the enhanced rapid crop growth in relation to early emerging weeds, which were mostly grasses. Thus the crop was able to suppress the grasses and the emerging broadleaved weeds at the later stage of crop growth.

5.6 Correlation and Path Co-efficient Analysis

In the study, fibre and seed yields were positively correlated with crop vigour score, plant height, butt diameter and capsules number (Tables 34-46 and 69-71). The fibre and seed yields were however negatively correlated with the number of days to first flowering, weed cover score and cummulative weed dry weight in the study. In addition, seed yield was positively correlated with 100-seed weight. Positive correlations between ribbon yield and plant height, butt diameter and wood yield of kenaf have also been reported by Lagoke et al. (1981) and Kumar et al. (1985). Similarly, relationships between yield and growth characters of okra and tomato were observed by Adejonwo (1988) and Adigun (1991), respectively. The positive relationships indicate that vigorous growth and thick stems favour fibre and seed yields of kenaf. Fibre production is also linked with seed yield. Also, rapid growth and maturation of kenaf favour fibre and seed production. Damsey (1964) have earlier reported that rapid maturation of kenaf led to flower concentration which in turn, resulted in high seed yield. However, weed cover score and cummulative weed dry weight had negative effects on fibre and seed yields. This could be attributed to the fact that rapid weed growth and dry matter production resulted in adverse competition with the crop plants for the various growth factors, and this directly affected their growth and development and thus, the yields.

Considering the percent contributions of the various factors to fibre yield, it was observed that the most important contributing factor was wood dry weight, which contributed about 73.1% (Table 39). Its combined contributions with the other parameters were also high. Wood dry weight also had high direct (85.5%) and total (94.8%) contributions to fibre yield (Table 37). Although its indirect contributions were generally low, the indirect contribution of the other factors via wood dry weight were high. Kumar et al. (1985) have also observed that wood yield of kenaf had the highest contribution of 42.3 to ribbon yield. Thus breeding work on kenaf should aim at improving wood dry matter production. When the percent contributions of some growth characters to seed yield were also considered (Table 40), butt

diameter had the maximum contribution of 16.1% followed by wood dry weight with 2.7%. The contributions of butt diameter in combinations with the other factors were also high, except with plant height. The direct (40%) and total (60%) contributions of butt diameter to seed yield were also high (Table 38). The percent contribution of plant height was negligible, while its combined contributions with the other factors were negative. The direct contribution by plant height was also negative (-2.1%). The findings also indicate that thick stems of kenaf plants with adequate wood dry matter favour seed production. On the other hand, plants that grow relatively tall tend to produce less seeds. This may be due to the fact that there is competition for the photosynthate partitioning between the vegetative and reproductive sinks. Breeding kenaf for seed production should therefore aim at producing plants with thick stems and of medium height.

CHAPTER SIX

6. SUMMARY AND CONCLUSION

The trials were conducted during the wet seasons of 1993-1993 on the farm of the Institute for Agricultural Research, Samaru (11° 11'N, 7° 38'E; 686 above mean sea level) in the northern Guinea savanna of Nigeria.

In the weed interference study, the treatments consisted of three levels of nitrogen (0, 45 and 90 kg N/ha) factorially combined with ten periods of weed interference. The weed interference periods were in two sets: in one set, the crop was kept weed-free initially for 3, 6, 9 and 12 WAS and subsequently left unweeded until harvest; in the other set, the crop was left weed-infested initially for the corresponding periods and subsequently kept weed-free until harvest. Two treatments consisting of weed-free and weed-infested crop throughout its growth-cycle were used as controls. In the weed management study, three nitrogen levels (0, 45 and 90 kg N/ha) were factorially combined with nine weed control treatments (metolachlor at 1.50 kg a.i./ha, metolachlor plus ametryne at 1.00 + 1.00 kg a.i./ha, alachlor at 1.50 kg, alachlor plus ametryne at 1.00 + 1.00 kg, fluazifop-butyl (fusilade) at 0.75 kg, fusilade + ametryne at 0.50 + 1.00 kg, hoe-weeding at 4 WAS, hoe-weeding at 3 and 6 WAS and and unweeded/weedy control). The factorial combinations in each trial were laid out in a randomized complete block design and replicated thrice.

In both experiments, nitrogen significantly increased crop vigour score and fibre and seed yields as well as their attributes during the period of investigation. Most of these parameters increased with N level from 0-90 kg N/ha. Nitrogen also caused early floral initiation and attainment of 50% flowering. Weed cover score was reduced by 90kgN/ha at 12 WAS in 1994 and 45 and 90kgN/ha at 9 WAS in 1995.

Initial weed infestation for 3 WAS only did not have any significant effect on crop vigour score, plant height, butt diameter and wood production. Similar results were obtained on ribbo

and fibre yields. However, weed infestation for 6 WAS and beyond significantly depressed the various crop growth parameters and wood production compared to the crop kept weed-free throughout its life-cycle. A similar trend was observed on ribbon, fibre and seed yields in 1994 and 1995. The fibre and seed yields of the crop kept weed-free for 6 WAS and beyond were comparable to their maxima and those of the weed-free control. The plots kept weed-free for 6 WAS and beyond and that weed-infested for 3 WAS only resulted in significantly lower weed dry matter production than the weed-infested and weed-free situations for the respective periods.

The use of herbicides and hoe-weeding consistently resulted in significantly lower weed-cover score than the weedy check. However, non of the herbicide treatments resulted in weed cover depression comparable to the two hoe-weeded controls. All the weed control treatments with the exception of metolachlor alone in 1995 and fusilade alone in 1994 and 1995, resulted in better crop vigour than the weedy check at 6-12 WAS in 1993 and 1995 and 9-12 WAS in 1994. In most of the cases, the crop vigour score by the use of herbicides was comparable to hoe-weeding at 3 and 6 WAS. Metolachlor and fusilade and mixture of the latter with ametryne resulted in greater ribbon weight than the weedy check and comparable to the two hoe-weeded controls in 1993. A similar result was obtained by the mixture in 1995. Alachlor and its mixture with a ametryne increased wood yield over the weedy check and was comparable to hoe weeding at 3 and 6 WAS. Mixtures of ametryne with metolachlor and alachlor, and alachlor alone resulted in great er fibre yield than the weedy check in 1995. Although fusilade plus ametryne resulted in significantly greater seed weight per plant than the weedy control in 1995, this was however not reflected on yield. This was probably due to stand losses as a result of the adverse effect of fusilade on kenaf plants.

Although the herbicide mixtures with ametryne resulted in comparable seed dry weight and yield to their maxima obtained by hoe-weedings at 3 and 6 WAS, non was superior to the weedy check.

Seed and fibre yields were positively correlated with crop vigour score, plant height, butt diameter and capsules number. In addition, seed yield was positively correlated with 100-seed weight. The seed and fibre yields were however negatively associated with the number of days to floral initiation, weed cover score and cummulative weed weight. Wood weight was found to be a major direct contributor to fibre yield while butt diameter was a major direct contributor to seed yield. Plant height however had a slight but negative direct contribution to seed yield.

The findings in this study revealed that incremental nitrogen application upto 90 kg N/ha is beneficial to kenaf crop growth and yields. Further studies with N beyond this level is required with respect to integrated weed management in kenaf.

Initial weed infestation in kenaf for 3 WAS does not have significant effect on the growth and yields of kenaf provided the weeds are subsequently removed. On the other hand, crop growth and yield depressions are not alleviated by keeping the crop weed-free initially for 3 WAS only, if it is subsequently left unweeded. In order to obtain comparable yields to the weed-free control, it is required to keep the crop weed-free for 6 WAS and beyond. On the other hand, crop growth and yields reductions are not redeemed by subsequent weeding if it is weed-infested initially for 6 WAS and beyond. This implies that the period between 3 and 6 WAS of weed infestation is critical for kenaf. Thus the crop should be kept weed-free within this period if reasonable yields are expected. For maximum yield, the crop requires a weed-free environment of 9 WAS and beyond.

The use of alachlor and metolachlor at low rates (1.50 kg) and their mixtures with ametryne (1.00 + 1.00 kg) are selective on kenaf in the northern Guinea of Nigeria. The treatment suppressed weed growth and enhanced vigorous crop growth. However, higher rates of the herbicides need to be tried since non of the rates used resulted in weed suppression comparable to the maximum by the two hoe-weeded controls. Non of the weed control treatments wa

consistently effective in giving acceptable kenaf yields, except hoe-weeding at 3 and 6 WAS. There is the need to try the herbicides along with supplementary hoe-weeding in order to enhance a more effective and season-long weed control in the crop. Weed infestation throughout the crop growth-cycle caused 28.2% to 53.0% wood yield, 26.5% to 55.3% fibre yield and 21.9% to 63.8% seed yield reductions compared to the highest yields obtained in 1993, 1994 and 1995, respectively.

The positive association between crop vigour score, plant height and butt diameter on one hand and fibre and seed yields on the other hand shows that these parameters are important attributes of the yields. Fibre yields, capsules number and 100-seed weight are also important components of seed yield. The negative association between weed cover score and weed dry weight indicates the detrimental effect of weeds on the crop. Path coefficient analysis revealed that wood production and butt diameter are major contributors to fibre and seed yields, respectively; while plant height may contribute negatively to the latter. Breeding work for fibre and seed production should aim at improving wood production and stem thickness, respectively. And for seed production, plants should be of moderate height.

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APPENDICES

Appendix 1: Physical and chemical properties of the soil of the experimental sites in 1993-1995 at Samaru

Property	1993	1994	1995
Particle size distribution (g/kg)			
Sand	40	46	46
Silt	44	34	36
Clay	16	20	18
Textural class	Loam	Loam	Loam
Chemical characteristics			
pH in water (1:2.5)	6.43	6.93	6.25
pH in 0.01M $CaCl_2$ (1:2.5)	5.92	6.53	5.95
Organic carbon (g/kg)	0.46	0.69	0.56
Total nitrogen (g/kg)	0.11	0.11	0.10
Available phosphorus (mg/kg)	3.1	1.6	2.2
Exchangeable bases (Cmol/Kg)			
Ca	0.20	0.33	0.39
Mg	0.34	0.55	0.65
K	0.21	0.31	0.37
Na	0.36	0.23	0.17
CEC	3.1	2.9	3.4
EC	0.07		0.11

Appendix 2: Details of treatments for the weed interference study in kenaf during the 1993 to 1995 wet seasons at Samaru

Treatments	Code
Periods of weed interference	
Weed free for 3 WAS	*
Weed free for 6 WAS	*
Weed free for 9 WAS	*
Weed free for 12 WAS	*
Weed-free until harvest	*
Weed-infested for 3 WAS	**
Weed-infested for 6 WAS	**
Weed-infested for 9 WAS	**
Weed-infested for 12 WAS	**
Weed-infested unitl harvest	**

WAS = Weeks after sowing

* = Plots kept weed-free for the given period and subsequently left unweeded until harvest.

** = Plots left weed-infested for the given period and subsequently kept weed-free until harvest.

Appendix 3: Details of herbicide treatments for the weed control study in kenaf during the 1993 to 1994 wet seasons at Samaru

Treatment	Rate (Kg a.i./ha)
Metolachlor	1.50
Metolachlor + Ametryne	1.00 + 1.00
Alachlor	1.50
Alachlor + Ametryne	1.00 + 1.00
Fluazifop-butyl	0.75
Fluazifop-butyl + Ametryne	0.50 + 1.00
Hoe-weeded at 4 WAS	
Hoe-weeded at 3 and 6 WAS	
Weedy/unweeded check	

WAS = Weeks after sowing

Appendix 4: Meteorological data showing air temperature, relative humidity, rainfall and sunshine hours durinp the 1993 wet season at Samaru

Date	Temperature (°C)		Relative Humidity (%)		Rainfall	Sunshine
	Max.	Min.	am	pm	(mm)	(Hours)
May						
1-10	35.2	20.0	56.8	36.3	22.8	6.8
11-20	35.3	22.3	60.1	44.3	12.2	7.8
21-31	33.1	22.5	69.7	53.6	78.6	8.8
June						
1-10	30.8	20.5	72.6	49.7	72.2	7.8
11-20	31.9	21.3	72.1	47.6	60.1	7.7
21-30	32.3	20.9	73.8	53.0	77.5	7.2
July						
1-10	20.1	29.7	77.6	49.9	42.2	7.3
11-20	20.5	29.5	78.7	57.5	47.7	6.6
21-31	19.9	29.2	79.2	62.1	179.1	7.1
August						
1-10	28.6	19.6	82.7	53.3	53.4	5.8
11-20	28.6	20.0	80.0	61.6	137.3	7.2
21-31	28.0	18.4	84.5	70.5	109.9	2.4
September						
1-10	29.6	19.5	77.4	58.2	101.7	6.5
11-20	30.2	19.8	78.8	60.4	65.0	6.6
21-30	30.9	20.3	73.5	55.9	15.1	8.5
October						
1-10	32.3	20.4	70.1	55.9	4.0	8.2
11-20	33.2	18.1	56.0	52.1	24.4	7.5
21-31	33.5	18.3	-NA	-NA	4.0	9.4

NA : Not available
Source: Meteorological data at the Institute for Agricultural Research, Samaru, Zaria

Appendix 5: Meteorological data showing air temperature, relative humidity, rainfall and sunshine hours during the 1994 wet season at Samaru

Date	Temperature (°C)		Relative Humidity (%)		Rainfall	Sunshine
	Max.	Min.	am	pm	(mm)	(Hours)
May						
1-10	33.0	22.5	69.7	32.4	36.7	5.8
11-20	34.1	22.1	71.1	48.1	16.7	7.6
21-31	33.4	21.3	73.1	41.7	66.7	7.4
June						
1-10	31.8	20.8	74.0	31.2	24.9	7.2
11-20	30.4	20.0	76.6	64.0	88.4	7.8
21-30	30.5	20.2	79.7	60.8	118.6	7.5
July						
1-10	28.8	20.2	85.7	62.0	53.9	5.9
11-20	29.3	20.4	84.0	57.7	61.5	6.4
21-31	30.5	20.5	83.4	71.5	52.71	6.3
August						
1-10	26.6	20.1	88.7	74.3	94.1	3.2
11-20	27.4	19.5	82.7	77.0	67.5	3.4
21-31	28.1	21.9	83.8	74.5	54.39	4.6
September						
1-10	28.2	19.4	86.6	69.2	21.67	4.1
11-20	28.6	19.5	84.1	61.3	57.5	5.1
21-30	30.5	19.6	77.5	77.9	3.41	6.28
October						
1-10	30.1	19.2	78.0	72.9	0	5.4
11-20	30.6	18.6	77.8	67.2	0	7.1
21-31	31.0	19.2	73.1	56.4	0	8.8

Source: Meteorological data at the Institute for Agricultural Research, Samaru, Zaria

Appendix 6: Meteorological data showing air temperature, relative humidity, rainfall and sunshine hours during the 1995 wet season at Samaru

Date	Temperature (°C)		Relative Humidity (%)		Rainfall	Sunshine
	Max.	Min.	am	pm	(mm)	(Hours)
May						
1-10	32.5	16.8	75.0	52.8	30.5	NA
11-20	34.3	18.0	71.8	44.0	0	NA
21-31	35.7	16.5	65.0	36.6	13.8	NA
June						
1-10	NA	NA	NA	NA	39.4	NA
11-20	32.4	15.6	77.4	46.6	66.4	NA
21-30	29.9	18.8	78.6	56.6	30.4	NA
July						
1-10	28.9	21.8	79.6	59.6	36.8	NA
11-20	30.2	22.7	79.4	66.9	52.3	NA
21-31	30.3	20.8	82.2	73.4	67.81	NA
August						
1-10	28.7	20.0	84.0	74.4	88.4	NA
11-20	29.1	19.5	82.8	73.1	73.6	NA
21-31	28.6	20.8	78.5	80.6	96.7	NA
September						
1-10	29.5	21.9	81.9	78.1	239.3	NA
11-20	29.4	18.9	81.6	68.7	80.5	NA
21-30	30.9	20.5	80.5	62.7	39.3	NA
October						
1-10	31.1	20.1	77.8	68.7	32.5	NA
11-20	32.6	18.7	71.2	44.5	0	NA
21-31	32.6	18.3	74.2	54.2	0	NA

NA : Not available
Source: Meteorological data at the Institute for Agricultural Research, Samaru, Zaria

Appendix 7: Weed occurence at the sites of the trial during the wet seasons of 1993 to 1995 at Samaru

Weeds type	Level of infestation		
	1993	1994	1995
Grass Weeds			
Chloris pilosa Schumach			*
Cynodon dactylon (L.) Pers	**	*	
Dactyloctenum aegyptium (L.) Beauv	*		*
Digitaria horizontalis Willd.	*	*	*
Echinochloa colona L.			***
Eleusine indica (L.) Gaertn		*	
Eragrostis ciliaris L.			*
Pennisetum polystachion (L.) Schlt	*	*	
Rottboelia cochinchinensis (L.) Roxb	*	*	**
Setaria spp		*	*
Broad-leaved weeds			
Ageratum conyzoides L.	**	*	*
Acanthospermum hispidum D.C	**	**	***
Amaranthus spinosus L.	**	*	
Euphorbia hetrophylla L.			*
Chenopodium album (Sp) L.		*	*
Convolvulus arvensis L.		*	*
Crotalaria retusa L.	*	*	*
Commelina benghalensis L.			*
Euphorbia hirta	*	*	
Ipomea aquatica	**	*	
Solanum nigrum L.	*	*	*
Pueraria spp		*	
Vernonia galamensis (cass.) Less	**	**	***
Sedge weeds			
Cyperus esculentus (L.)	*	*	*
Cyperus rotundus (L.)	*	**	*

*** high infestation (> 60% frequency of occurence)
** moderate infestation (30-60% frequency of occurence)
* low infestation (< 30% frequency of occurence)

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