FIELD STUDIES ON SEED PRODUCTION IN THREE TROPICAL PASTURE GRASSES AT SHIKA, NIGERIA

BY

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A Dissertation submitted to the Postgraduate School, Ahmadu Bello University, Zaria, in partial fulfillment of the requirements for the award of DOCTOR OF PHILOSOPHY in Animal Science

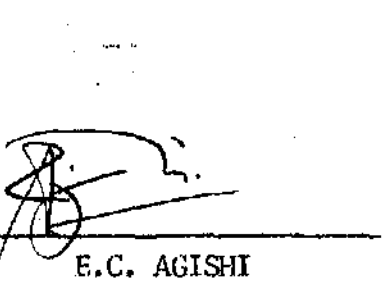
DEPARTMENT OF ANIMAL SCIENCE

FACULTY OF AGRICULTURE
AHMADU BELLO UNIVERSITY
ZARIA

September, 1984

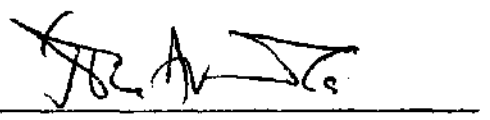
DECLARATION

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



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CERTIFICATION

This thesis entitled "FIELD STUDIES ON SEED PRODUCTION IN THREE TROPICAL PASTURE GRASSES AT SHIKA, NIGERIA" by E.C. AGISHI 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 thesis is dedicated to the glorious memory of my:

Father - AGISPI ANGULA

Mother - GAMBO AGISHI

Brother - ONA AGISHI

for their love and guidance.

ACKNOWLEDGEMENTS

I am indebted to my Supervisor, Professor J.O. Akinola, Dean, Faculty of Agriculture, Ahmadu Bello University, Zaria for his interest, encouragement, useful suggestions and objective criticisms of the thesis.

Grateful acknowledgements are also made to: all the Technical staff of Pasture Agronomy Department, N.A.P.R.I., Shika for their assistance with field work; Mr. Anthony Oochi for typing the thesis, and to Professor Saka Nuru, Provost for the Agriculture and Veterinary Medicine Complex and Director, N.A.P.R.I., A.B.U., Zaria for making the facilities for the research available to me; Mr. S.A.S. Olorunju for Statistical analysis of the data and Mr. S.A. Bello for crude protein determination and mineral analysis.

Finally, I am most grateful to my Wife, Tabitha; and to my children, Itsoga, Tishi, Onambu, Aike and Shituku, and to all those that wish me well for their patience, understanding and sacrifice throughout the long period of study.

ABSTRACT

The effects of row spacings on Biloela buffel grass and fertilizer nitrogen on Biloela buffel grass, gatton panic and green panic grown for seed production, were studied for three years at the National Animal Production Research Institute, Shika, Nigeria. The row spacing and one of the two nitrogen trials were carried out under rain-fed conditions on the upland. The remaining nitrogen trial was under limited irrigation on the 'fadama' (lowland). Row spacing involved, broadcast and 30, 60 and 90 cm while the nitrogen treatments were 0, 100, 200 and 400 kgN/ha on the fadama, and 0, 200, 400 and 600 kgN/ha on the upland. Successive method of seed harvesting by hand was used.

Row spacing had lower shoot density but higher shoot fertility than the broadcast treatment. Shoot densities increased almost linearly with decrease in row widths; narrowing row widths from 90 to 30 cm, more than doubled the shoot density. Shoot fertility, number of seeds per inflorescenc and seed size increased with wider row spacings, while inflorescence density seed yield, harvest efficiency and dry matter yield decreased. Total clean seed yields from two harvests were 895.8, 943.0, 777.2 and 488.7 kg/ha for the broadcast, 30, 60 and 90 cm spacings respectively.

Nitrogen application increased shoot density and fertility, inflorescence density number of seeds per inflorescence, seed size, caryopsis content, seed yield and dry matter yields of the three species at both sites, but the nitrogen effects were generally more pronounced for the fadama crops. The positive effect of nitrogen on shoot and inflorescence densities was probably amplified by the successive method of seed harvesting.

In this method, only the ripe heads are removed at each harvest occasion. The cutting of the heads appeared to stimulate the development of more of reproductive shoots. The fadama crops apparently benefitted more from this method of seed harvesting than the upland crops.

High seed yields were recorded at the fadama site. Harvested seed yields varied from 558 kg/ha at N_0 to 1000.00 kg/ha at N_{200} for buffel grass, with corresponding ranges of 439.2 to 927.2 kg/ha for green panic at the fadama site. In the case of gatton panic the range was 516.8 kg/ha at N_0 to 1069.8 kg/ha at N_{400}. On the upland, seed yields varied from 313.8, 234.2 and 283.6 kg/ha for buffel grass, gatton panic and green panic, respectively at N_0 to the corresponding figures of 570.6, 663.6 and 777.4 kg/ha at N_{600}.

The fadama crops had higher crop indices and efficiencies of seed yield response to applied nitrogen than the upland crops. Crops at both sites had high harvest efficiencies. Simple correlation matrix for seed yield attributes showed that inflorescence density and shoot fertility were the main determinants of potential seed yield.

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INTRODUCTION

1.1. General

For many years, Nigeria depended, to a large extent, on the Sudano-Sahelian Zone as her additional source of meat supply. This picture changed subsequent to the Sahelian drought of 1973 and 1974 when many of the livestock population within that zone perished. The country has since then relied more and more heavily on large importations of meat and meat products from overseas. While Nigeria imported, other African countries like Botswana, Kenya and Swaziland with improved pastures exported large quantities of meat.

Factors that militate against profitable livestock production in Nigeria have been identified (Agishi, 1971; Nuru, 1982). These include poor standard of animal husbandry, low plane of nutrition, inadequate water supply, diseases and insect pests and socio-economics. With the intensification of tsetsefly eradication and disease control, the supply of adequate levels of feed and water remains the major problem. Pastures form the bulk of the nutritional input in ruminant nutrition, but forage supply in the Northern Guinea Savanna and Sudan Zones is bedevilled by the seasonal fluctuations both in quantity and quality (Rains, 1963). Methods that have been employed to increase forage availability include proper brush control, judicious burning, grazing management, oversowing of the range with productive and adapted legumes and by partial or complete replacement of the unproductive natural grasslands with productive pasture species.

Though many of the improved pasture species have been evaluated in the Guinea Savanna and Sudan Zones of Nigeria and have been found to be well adapted to the environment (Agishi, 1979) the lack of seed supply has hindered large-scale establishment. So far moderate quantities of pasture

seeds have been imported from Australia into Nigeria, but experience has shown that these seeds are expensive, take long to be delivered to the importer and especially in the case of grasses, are not very reliable in their establishment. Local production of pasture seeds will reduce the drain in the country's foreign exchange, creat job opportunities, improve the monetary returns to the farmers and minimise the chances of introducing noxious weeds, diseases and parasites (Agishi, 1978).

Seed production from tropical grass species present many problems (Strickland, 1968; Boonman, 1971) not encountered with temperate species. This is due not only to a lack of adequate basic knowledge of the general biology and flowering of these species but also because of some inherent characteristics that create problems in seed production. Principal among these characteristics are the extended duration of initial head emergence within and between plants resulting in protracted flowering, low density of fertile tillers or shoots, ease of shedding of unripe and ripe seeds and low recovery of potential seed.

(i) Extended duration of head emergence and flowering

Many tropical grasses, particularly those in the genera *Chloris, Panicum and Setaria* exhibit photo-periodic insensitivity and so produce fertile tillers over a long period (Boonman, 1971). It has been observed in Rhodes grass cv. Pokot *(Chloris gayana cv. Pokot)* and Nandi Setaria (*Setaria anceps cv. Nandi*) that the great variations in initial head emergence result in lower seed yields because at no time is a high proportion of the total seed crop ready for harvest (Boonman, 1971).

Inflorescences in Narok Setaria (Setaria anceps cv. Narok) appeared twenty days after cleaning cut but continued to emerge upto the harvest time of 77 days later (Bahnisch and Humphreys, 1977). Maximum seed yield occurred before maximum inflorescence density. At the time pure germinating seed (P.G.S.) is maximum, about 30 to 40 percent of the seed would have dropped (Boonman, 1973).

(ii) Low density of fertile tillers

Most tropical pasture grasses so far studied produce few seed heads per unit area when compared with their temperate counterparts. For, example, the number of seed heads/m² was 10-41 for gamba (Haggar, 1966), 5-166 for *Setaria anceps* (Hacker and Jones, 1971), 67-293 for *Chloris gayana cv. Mbarara* (Boonman, 1972a), and less than 10 to 170 for *Setaria anceps cv. Narok* (Bahnisch and Humphreys, 1977). Data from temperate countries show seed heads/m² of 1006-1241 for *Lolium perenne* (Evans, 1954), 732-990 for Festuca pratensis (Lewis, 1962), and 2413 in *Lolium multiflorum* (Griffiths *et al., 1967).* Since the number of fertile tillers per unit area is one of the important determinants of seed yield, low fertile tiller density limits seed yields in tropical grasses.

(iii) Ease of Shedding of ripe and unripe seeds

In tropical grasses the abscission layer is below the glumes so that seed shedding involves the whole spikelet.

Shedding is not restricted to the ripe seeds alone, and this may occur as early as 4-5 weeks after head emergence (Boonman, 1971) thus a loss of seed is incurred no matter when the crop is harvested. Species differ in their intensity of seed shedding. For example, in *Chloris gayana and Setaria anceps* spikelet shedding may reach 30 to 40 per cent before maximum P.G.S. is attained (Boonman, 1973), but in *Panicum maximum* 50 to 60 per cent of the seeds on the panicle are shed between 12 and 14 days, and by 20 to 30 days, complete shedding of seeds occurs (Javier, 1970).

(iv) Low recovery of potential seed yield

Owing to the factors already discussed, the recovery of the potential seed is very low. Seed recovery of Narok Setaria in Northern Queensland using a header-harvester is estimated to be less than 10 per cent of the total potential seed yield (D.S. Loch, personal communication). Within 12 to 14 days after head emergence, total collection of standing seed of *Panicum maximum* represented only 19 per cent of the potential seed yield (Javier, 1970), the rest having been shed. Under commercial seed production conditions in Kenya, as low as 5 per cent of the potential seed yield of Nandi Setaria is recovered (Boonman, 1971).

The method of seed harvest has a profound effect on the quantity of seed recovered. Roe (1973), working at Samford, Queensland, found that yields of viable seeds harvested by cutting and drying, hand shaking, reaper and binder, and

direct heading methods were 49, 62, 42 and 19 per cent, respectively compared with total collection method. The actual per cent recovery of potential seed yield was much lower since considerable seed shedding occurred before total seed collection commenced. In gatton panic and green panic, header harvesting has been found to lose at least 50 per cent of the seed presented to it (Hopkinson and English, (1982(a).

1.2 Improvement of Seed Production from tropical pasture grasses

Limited research so far carried out on tropical pasture grasses has attempted to improve seed yields through minimising or removing completely the major causes of low seed yields already discussed above. Increase in fertile tiller production has been achieved through nitrogen fertilizer application on *Chloris gayana* (Henzell and Oxenham, 1964), gamba (Haggar, 1966), Nandi Setaria (Boonman,1972b), Rodd's Bay plicatulum (Chadhokar and Humphreys,1973a), and Narok Setaria (Bahnisch and Humphreys, 1977). Success in synchronisation of flowering in Nandi Setaria was achieved by use of fertilizer nitrogen (Boonman, 1973), and to some extent by defoliation, resulting in many shoots of similar age-groups, hence almost identical flowering dates.

The effect of growth regulators on grass seed yield such as *Cenchrus ciliaris*, has been inconsistent (Cameron and Humphreys, 1976). Seed retention is another way of improving seed yields in pasture species, and in this respect McWilliam and Schroeder (1974) have suggested the use of a solution of clear plastic spray to hold ripe seeds in place to prevent shedding. Selection of lines of *Panicum coloratum* has, however, let to about 47 per cent improvement in seed yield (Hearn and Holt, 1969).

Different harvesting techniques have been employed to minimise seed losses at harvest but none has been as successful as hand harvesting. In the developed countries, large-scale pasture seed harvesting is done almost exclusively by machines because of the high labour cost. Most of their research has therefore been geared towards improving harvest efficiency of these machines. In the developing countries, the use of manual labour for seed harvesting abounds because it is relatively cheap. In Kenya, hand harvesting of pasture grass seeds was found to be the most practical and economic and the least weather dependent (Boonman, 1971).

In Nigeria, where over 70 per cent of the population are farmers with small farm holdings, the use of large farm machinery which requires a high capital outlay, and some level of technical know-how is not common. It is envisaged that for the next decade or so the use of manual labour for cultivating, harvesting and seed cleaning will continue to assume great importance in Nigeria agriculture. Observations have shown that even with the present methods of production, the efficiency of production from these farms could be higher than that from the larger government-managed farms. The greatest impact in agricultural development and production in the country may come through improving the local farmers' skill and income and through encouraging them to use improved crop varieties rather than acquiring large farm implements for them.

In recognition of the above, this thesis approaches seed production with the local small farmers in mind. It uses nitrogen fertilizer and successive hand-harvesting techniques rather than other complicated and less familiar methods for improving seed yields in three tropical pasture grasses, namely, Biloela buffel grass, Gatton panic and Green panic.

LITERATURE REVIEW

1. History, introduction and description of the pasture grasses.

1.1. *Cenchrus ciliaris* (Buffel grass)

Buffel grass is a native of Africa, India and Indonesia (Whyte *et al., 1959).* The predecessors of most of the presently known cultivars were first introduced into Australia from Africa (Humphreys, 1967), and then exported back to Africa.

In Nigeria, the first known sowing of buffel grass was at the 'Botanist Farm' in the Institute for Agricultural Research, Samaru, Zaria. The main importations into Shika, Zaria in 1956 involved eight cultivars and these came from Kenya, Queensland in Australia, Tanzania, South Africa and Zambia. Results of evaluations at Katsina (Latitude 13°01' Longitude 07° 41'), Shika, Ilorin (Latitude 08°29' and Longitude 04°35') and Yandev (Latitude 07°23' Longitude 09°01') showed that these cultivars were adapted to the Sudan and Guinea Savanna conditions. At Katsina, buffel grass remained green long into the dry season. At Ilorin and Yandev, which are both located in the Southern Guinea Savanna Zone, it remained very vigorous and productive and exhibited a high degree of drought tolerance, but it was finally rejected because of its tendency to become stemmy quickly and for lack of bulk.

Another importation of four cultivars of buffel grass from Queensland into Shika was made in late 1964 and mid 1965. All the cultivars showed great promise in the Introduction Plats but their seeds were not bulked. In 1975, Biloela, Gayndah, Molopo and U.S.A. (American) buffel grasses were

introduced into Shika from Queensland, and these have now formed the basis of the buffel grasses currently used at Shika and many other stations in Nigeria.

Alhgren *et al.(1959)* evaluated buffel grass at Ibadan from an importation made in 1956, and found it to be one of the best adapted grasses in the Derived Savanna Zone.

Buffel grass is an erect, tussocky, deep-rooting perennial producing most of the buds for development of new stems below ground level. It is tolerant to drought (Winkworth, 1966), fire and heavy grazing (Humphreys, 1967). It grows best during the warm summar season but survives could conditions below minus 6°C (Evans, 1962). It is adapted to a wide range of soils but seems to prefer lighter soils of good fertility (Young *et al., 1959)*. While it prefers slightly acid to neutral soils, it has poor tolerance to salinity (Graham and Humphreys, 1967 and prolonged flooding (Anderson, 1972). It responds to improved soil fertility, having a good reputation as a phosphophilic grass (Schofield, 1946; Skerman, 1958 and Edye *et al., 1964)*. Its dry matter yield response is greater with N.P.K than with P or N alone (Asare, 1969, 1970).

In Nigeria, buffel grass grows well within a rainfall range of 700-1500 mm, but in Australia large-scale buffel grass establishment has been carried out in areas receiving as little as 350 mm annual rainfall.

Buffel grass produces good quantity of viable seed which im proves in germination with storage and retains its viability in dry soil for at least three years (Winkworth, 1963). It can be sown broadcast into ash, cultivated land and by direct drilling, but the best establishment occurs on cultivated land with good moisture condition (Edye *et al., 1964)*.

Buffel grass combines well with a range of tropical pasture legumes, and once established it is known to withstand severe grazing pressure though its dry matter yield is greater under less frequent defoliation (Asare, 1970).

1.2 *Panicum maximum Jacq. Var. Trichoglume Eyles* (Green panic) cv. *Petrie*

Green panic, a fine stemmed, tufted perennial, originated in Africa (Semple, 1970) and has wide tropical and subtropical distribution. It was first introduced into Shika, Nigeria, in 1956 from Kitale, Kenya and Brisbane, Australia and evaluated at Katsina, Shika, Ilorin and Yandev. Its performance at Katsina, with an annual rainfall of about 700 mm, was only marginal but at the other locations it showed considerable promise in terms of dry matter yield and persistence. It was however rejected then on the ground of high seed production during most of its growth period. The second importation from Brisbane, Queensland in late 1964 was not fully evaluated though good plant establishments were observed at Mokwa (Latitude 9°28'N Longitude 4°41'N) in the Southern Guinea Savanna. Another batch from Brisbane in 1968 established very successfully in 1969 at Mokwa. Encouraged by this success, large areas of green panic were established at the Mokwa Cattle Ranch in 1970 which gave high forage yields (de Leeuw, 1974) and remained productive for over four years. Attempts in the early 1970s to establish green panic at Shika failed (de Leeuw, personal communication) but in 1976, the author successfully established about ten hectares of green panic at Shika using seed originally obtained from Mokwa. Earlier failures in establishing green panic at Shika might have been due to lack of viability due to age, storage conditions, dormancy or time of harvesting (Akinola and Odiba, 1977).

Green panic is adapted to a wide range of climatic and edaphic conditions. In Nigeria, it grows well in areas with annual rainfall between 1000-1700 mm, but in Australia it is claimed that as little as 600 mm annual rainfall is also suitable (Anon, 1967). It grows moderarely in soils from $pH_{5.0}$ to $pH_{8.0}$ but performs best in fertile soils that are slightly acid or neutral in reaction. It has a remarkable growth response to nitrogen fertilizer application (de Leeuw, 1974).

In the tropics green panic flowers throughout the year provided conditions for growth are suitable although this results in uneven seed ripening. The seed has a long period of dormancy (Buckley, 1959) which could be reduced by 'sweating' the seed at harvest. Green panic tolerates drought moderately and shade markedly. In Zimbabwe, wide row spacing of 93 cm was found to increase dry matter and crude protein yield by 30 per cent and 33 per cent respectively compared with 31 cm apart or broadcast sowing (Barnes and Clatworthy, 1969). However, Okada and Hidaka (1973) obtained high dry matter yields from row spacings 20 or 33 cm apart or broadcast sowing than 50 cm row spacing.

Green panic combines well with a range of tropical legumes particularly glycine (*Neonotonia wightii*), Siratro (*Macroptilium atropurpureum*) (Fox and Wilson, 1959; Jones and Rees, 1972) and Centro (*Centrosema pubescens*) (de Leeuw, 1974). It is very palatable to stock at young and early mature stage, but its crude protein declines rapidly with delay in cutting (Okada and Hidaka, 1973). It withstands lenient grazing pressure but tends to be eliminated over a prolonged period of grazing (Bryan, 1968). In this respect it has proved to be even useful for conservation as hay where repeated defoliations are not required (de Leeuw, 1974).

1.3 *Panicum maximum Jacq cv.* Gatton (Gatton panic)

Gatton panic, in common with other panicums, originated in Africa. It is not as widely distributed in the tropical world as green panic, though it is very similar to it particularly in climatic and edaphic requirements. The main differences are that it is somehow more robust, longer and broader-leafed with glabrous stems and spikelets.

It was introduced into Australia from Harare in Zimbabwe, and evaluated and released as a cultivar in 1964 by the Queensland Pasture Liaison Committee. Gatton panic first came to Shika, Nigeria in 1968 and was sown at Shika and Mokwa but evaluations at both sites did not go beyond the introduction plots though it showed great potential, remaining productive for four yrears before being ploughed up. In 1975 some gatton panic seed was introduced from Queensland, and this has formed the basis of on-going work on this species at Shika. Gatton panic seed imported by the Pasture Unit, Federal Livestock Department, Kaduna in the late 1970s also gave good establishment and yield at Kachia in Kaduna State.

In Australia, gatton panic is said to be a little more vigorous, drought resistant persistent as well as more palatable than 'Petrie' green panic, and has a longer growing season (Bryant and Slater, 1974). In Shika, observations on gatton panic have shown that it grows well on both clayey and sandy-loam soils. It has a similar growth rate to green panic, and slightly more responsive to added nitrogen fertilizer giving more than 15 tonnes of dry matter per hectare per year under an application of 200 kgN/ha. It formed good mixtures with Siratro, Centro, Cook stylo (*Stylosanthes guianensis cv. Cook*) and Verano Stylo (*S. hamata cv. Verano*). Its palatability to cattle was higher than that of green panic, and because of numerous young

shoots produced late into the rainy period, it appeared to have a longer growing season.

2.1 Effects of fertilizer nitrogen application on seed yield

There is abundant information in the literature on the effects of nitrogen fertilizer applied to grass for seed production. Nitrogen is a major factor determining seed yield of grasses especially when other nutrients are non-limiting. The need for, and level of nitrogen application depend upon the soil fertility, residual effects from the previous crop, rainfall, reliability of water supply, age of stand and the species or cultivar grown. The level of nitrogen applied and the responses obtained will therefore most likely differ, depending on the environment. In the U.S.A., Buller *et al.(1955)* reviewed the results of nitrogen fertilizer application on various temperate grasses and concluded that nitrogen is the main element controlling the production of grass seed.

2.1.1 Effects of level of fertilizer nitrogen

Seed production of brome-grass (*Bromus inermis*) increased from 307 kg/ha in unfertilized control plots to 775 kg/ha when 71 kgN/ha was applied as ammonium nitrate (Wilsie and Nelson, 1949). In Canada, seed yields of bromegrass based on seven years' results increased by 65, 94 and 146 per cent when nitrogen was applied at the rate of 24, 47 and 94 kg/ha, respectively (Crowle and Knowles, 1962). In northern Nebraska, U.S.A., the highest grass seed yields of 362 kg/ha was obtained with 149 kgN/ha when averaged over a seven-year period (Carter, 1965). In Canada, the response of Russian wild-ryegrass (*Elymus junceus*) to

nitrogen application differed from place to place. While in Saskatoon, an application of 94 kgN/ha produced almost twice the seed yield obtained with 47 kgN/ha, at Lacombe and Swift Current, 47 kgN/ha was more beneficial in the second and subsequent years compared with 72 kgN/ha (Stelfox *et al., 1954).* Where the initial fertility of the soil is high, moderate nitrogen fertilizer application may not give an early benefit over the control. In the U.S.A., it took Rogler and Lorenz (1964) four years to obtain any significant response to nitrogen, applied at the rate of 0, 56, 112 and 224 kg/ha as single or split dressing on Russian wild ryegrass.

Under dryland conditions, Stitt, et al. (1965) reported significant but small seed yield increase at 112 kg/ha, applied as ammonium nitrate to an old stand of crested wheatgrass *(Agropyron desertorum (Fisch) Schult)* but higher rates were wither equal to or worse than the control. However, under soil conditions in Canada, Puglass (1964) applied nitrogen at rates ranging from 0 to 104 kg/ha to Crested wheatgrass and observed linear responses. Seed yield in tall fescue (*Festuca arundinacea L.)* was linear for nitrogen levels of 0, 67 and 209 kg/ha (Watson and Watson, 1982).

In New Zealand, the use of nitrogen fertilizer for seed production in cocksfoot *(Dactylis glomerata)* has given upto 100 per cent increase (Sears, 1950). Outstanding seed yield increases from nitrogen application to grasses in New Zealand have also been reported by Lambert (1963a, 1964, 1965). In Canada, MacVicar and Gibson (1951) applied various levels of nitrogen to cocksfoot over a two-year period and found the optimum response to be at 90 kgN/ha, and this corresponded to about 35 per cent increase over the control. At 45 kgN/ha, the increase was about 30 per cent (Fulkerson, Weir and McRostie, 1951).

At Hurley, U.K., Evans (1953) observed significant response in cocksfoot and timothy (*Phleum pratense L.*) seed yields due to applied nitrogen. In the first year there was no additional response above 90 kgN/ha, but in the next two years there was little additional response to above 135 kgN/ha. In further trials (Evans, 1954) yearly seed yield responses to 90 kgN/ha were highly significant and a mean increase over a three-year period of 382 kg/ha seed was observed. Lambert (1963b) obtained an increase of 16 per cent when nitrogen application on cocksfoot was increased from 95 to 195 kg/ha. Lambert (1965) concluded after a three-year period that the application of 195 kgN/ha is the maximum desirable level especially under threat of frost. Seed yield in perennial ryegras (*Lolium perenne L.*) cultivars Royal and Majestic (amenity) and Morenne (agricultural) decreased or did not significantly increase at nitrogen levels above 120 kg/ha (Hebblewaite and Ivins, 1977; Nordestraard (1980) and Hampton *et al.(1983).*

Though there are relatively fewer data available on the effect of nitrogen fertilizer application on seed yields of tropical and sub-tropical grasses, the very limited results so far obtained show encouraging responses to nitrogen fertilizer application. In the United States, Harlan *et al.(1956)* reported large responses in Blue panic (*Panicum antidotale*) to nitrogen fertilizer application. For 0, 67 and 202 kgN/ha in the first year he obtained 89, 132 and 204 kg/ha of seed respectively, while for the levels of 0, 268 and 404 kgN/ha applied in two split dressing, corresponding seed yields from two harbests were 122, 543 and 900 kg/ha. At Shika, Nigeria, Foster (1956) found that seed yields of Rhodes grass (*Chloris gayana*) could be increased significantly from about 271 kg/ha to 337 kg/ha where 110 kgN/ha was applied as sulphate of ammonia.

Haggar (1966), working at the same station on gamba found that seed yields were more than doubled following the application of 112 kgN/ha or almost trebled by the addition of about 224 kgN/ha. He concluded that nitrogen was the most important nutrient for increasing seed yields. Phosphate played little significant part in increasing gamba seed yields (Haggar, 1966).

In India, *Paspolum scrobiculatum* gave seed yields over a three-year period of 375, 675 and 975 kg/ha when supplied 0, 9 and 17 kgN/ha/year, respectively (Gupta and Tiwari, 1966). In the tropical area of West Bengal, India, over a four-year experimental period, yields of 420 kg/ha in Kyaswa *(Pennisetum pedicellatum)* and 90 kg/ha in gamba were obtained with 39 kgN/ha (Mishra and Chatterjee, 1968). From Gayndah, Australia, Humphreys and Davidson (1967) reported that when 52 kgN/ha was applied to Burnett Makarikari grass *(Panicum coloratum var. Makarikariense)*, it resulted in seed yields of 225 kg/ha from two harvest compared with the unfertilized control yield of 10 kg/ha. Cameron and Mullaly (1969), working in a similar environment on seed production of molopo buffel grass reported a positive response to increasing levels of nitrogen from 0 to 336 kgN/ha. In a wetter area of Northern Queensland, Grof (1969) obtained seed yield of 13,25 and 31 kg/ha when 0, 56 and 112 kgN/ha were applied to paragrass *(Brachiaria mutica)*.

At Kitale, Kenya, the pure germinating seed (P.G.S.) yield of Nandi Setaria increased seven-fold when nitrogen application was raised from 0 to 100 kg/ha/crop and two-fold from 50 to 100 kg/ha/crop (Boonman, 1972a). With the cultivar Mbarara Rhodes grass, Boonman (1972b) reported a six-fold increase (6.2 to 36.7 kg/ha) in the yield of P.G.S. by increasing nitrogen level from 0 to 100 kg/ha/crop. Increasing the level of nitrogen from 50 to 100 kg/ha/crop at a row spacing of 25 cm more than doubled the P. G.S.

In Australia, Hacker and Jones (1971) showed that seed production of an ancestor of Narok setaria responded linearly up to 168 kgN/ha. At Mt. Cotton, south-eastern Queensland, seed yield of Rodds Bay plicatulum *(Paspalum plicatulum cv. Rodds Bay)* increased from 680 kg/ha without nitrogen to 1150 kg/ha with 100 kgN/ha (Chadhokar and Humphreys, 1973b). At 400 kgN/ha, though seed yield increased to 1360 kg/ha, lodging became a serious problem. Bahnisch and Humphreys (1977) working on Narok setaria in the same location obtained pure seed yields of 233, 539 and 827 kg/ha when urea was applied early at the rates of 50, 100 and 200 kgN/ha/crop, respectively, but indicated that yield was less responsive to late nitrogen application. The effect of nitrogen on seed yield in grasses is not always positive. For example, Ahring and Talieferoro (1982) found that nitrogen applied at the rates of 22-101 kg/ha on giant star grass *(Cynodon plectostachyus)* did not increase its seed yield even at the highest level.

2.1.2 Effects of time of fertilizer nitrogen application

The best returns from fertilizer nitrogen application will not be realised until the most suitable time of application to give maximum response is determined. Maximum presentation of tillers which originate from the main stems at the early vegetative stage is most essential for obtaining high inflorescence density and hence high seed yields (Haggar, 1966). The ear-brearing capacity of individual tillers of a grass declines with successively later date of origin of the tillers (Langer, 1956). The indication therefore is that nitrogen application in the early vegetative phase should give high seed yield through increased tiller density and higher tiller fertility.

Buller *et al. (1955)* in U.S.A. found that autumn nitrogen fertilizer application at 112 kgN/ha in abundant crop of cocksfoot gave the best yields while the spring application caused the crop to lodge. In Canada, Lawrence and Henrichs (1966) reported that Russian wild ryegrass yielded twice as much seed in autumn as from spring application at the same rate. In constrast Lambert (1956a) obtained higher seed yields in cocksfoot during spring than in autumn but early spring nitrogen application proved more beneficial to seed yield than late spring application (Lambert and Lewis, 1968). The decision as to whether to apply nitrogen early or late in spring depends on the earliness or lateness in flowering of the species being tested. The main benefit of spring nitrogen application is that it occurs at the stage of intense competition between tillers for soil nutrients to enable their respective growing points differentiate new leaves and inflorescences (Griffiths *et al.*, *1967*).

Under tropical and sub-tropical conditions, the importance of early nitrogen application on grass seed yields has been reported. At Shika, Nigeria, Blair Rains and Foster (1959) emphasized the beneficial effect of early nitrogen application on seed yields of rhodes grass. Seed production of molopo buffel in Queensland was favoured by early split nitrogen application (Cameron and Mullaly, 1969). Nitrogen applied to Rodds Bay plicatulum during the inflorescence differentiation phase also gave a seed yield response of similar magnitude due to better survival of tillers, high inflorescence density, increased inflorescence branching, floret differentiation and seed size (Chadhokar and Humphreys, 1970). On the other hand, nitrogen applied at the phases of final flowering and maturation had no influence on seed yield. Narok setaria produced more seed when nitrogen was applied just after cleaning cut than at first head emergence (Bahnisch and Humphreys, 1977).

2.1.3 Effects of source of fertilizer nitrogen on seed yield

Very limited data exist regarding the efficiency of different sources of nitrogen on grass seed yield. Fertilizer nitrogen can be divided into organic and inorganic. Amongst the inorganic sources of nitrogen, Purkerson, Weir and McRostie (1951) compared the effects of ammonium sulphate, calcium cyanamide, sodium nitrate and urea on orchard-grass *(Dactylis glomerata L.)* in the year of application and found that all the sources when applied at equal nitrogen levels gave almost equal seed yields. Similar results were reported by Crowle and Knowles (1962) from 25 trials in Canada comparing ammonium nitrate, ammonium sulphate and ammonium phosphate on bromegrass seed yields, and by Lawrence and Kilcher (1964) who tested ammonium nitrate and ammonium phosphate on Russian wild ryegrass. Knowles, Friesen and Cook (1951), Knowles and Cook (1952) and Lawrence (1963) in Canada, however, found ammonium nitrate preferable and economical when compared with ammonium phosphate at equal nitrogen levels.

Rampton (1945) compared organic and inorganic nitrogen sources and found with tall fescue *(Festuca arundinacea)* that mineral fertilizers were preferable to barnyard manures which contained large quantities of weed seeds and as such were not desirable for fertilizing seed crops. Stitt (1954) concluded that an inorganic nitrogen fertilizer such as ammonium phosphate was better than cotton seed meal when applied to Russian wild ryegrass. Musser (1947) on the other hand found no difference in organic and inorganic sources although the rows receiving organic nitrogen (activated sewage sludge) produced stiff straws that held panicles in upright position, in contrast to the seed stalks on inorganic nitrogen treatments which showed a tendency to lodge.

Although organic nitrogen fertilizers add organic matter to the soil to improve its physical conditions, their use in a pasture crop may be restricted to the year of establishment since after harvest enough crop residues fall unto the ground to give good soil physical condition. The decision on which organic fertilizers to use depends on its availability, relative cost per unit of nitrogen, ease of application, soil type and its effects on soil pH. For example, ammonium sulphate whose use is now restricted in Nigeria because of its acidifying effect on soils, can be beneficial in areas where soils are high in pH values by bringing down these values. In most agricultural soils in Nigeria, soil pH values are low ranging from pH 4.0 to pH 6.5. In this case, calcium ammonium nitrate *(Nitrochalk)* is preferred since it does not increase soil acidity. Large-scale farm projects such as the Ayangba, Bauchi, Funtua and Gusau Agricultural Development Projects in Nigeria now use calcium ammonium nitrate almost exclusively as their main source of nitrogen fertilizer.

2.2 Effects of fertilizer nitrogen on components of seed yield

The potential quantity of seed that can be produced per unit are is influenced by tiller density, tiller fertility, raceme number, seed number and seed size. Data from numerous studies on grass seed production show that nitrogen nutrition affects all these components of seed yield.

2.2.1 Tiller (Shoot) density

In the axil of each leaf, buds are formed, and it is from these buds that axillary shoots or tillers grow. The number of tillers appearing is low compared to the number of tillers initiated. Higher percentage of buds formed develop into tillers under adequate nitrogen supply than low nitrogen supply (McIntyre, 1964).

The leaves of the tillers also subtend axillary buds which in their turn may form tillers and this process may be repeated many times thus giving rise to a hierarchy of tillers. Primary tillers are those on the main shoots while those on the shoots produced by them are called secondary tillers and so on to denote successive orders (Langer, 1963).

The various factors affecting tillering in grasses have been identified as genotype, temperature, light intensity and photoperiod, flowering, mineral nutrition, water supply and defoliation. Tiller production is continuous in perennial grasses. The older tillers die and new ones appear and this cycle continues throughout whether a particular tiller flowered or not. There are however, periods with peaks of maximum tiller production which differ with species. For example, in gamba peak tiller production occurs within a month of the start of rains (Haggar, 1966). In grasses tillering is normally arrested around the period of rapid stem elongation but may be resumed after inflorescences have emerged. The time of onset of the non-tillering phase and its duration may both depend on nitrogen nutrition of the plants as shown in Italian ryegrass *(Lolium multiflorum am)*, perennial ryegrass

(Lolium perenne) and timothy *(Phleum pratense L.)* (Langer, 1959; Wilson, 1959). Similarly, Thorne (1962) has shown that under high continuous nitrogen supply, tillering after inflorescence emergence is possible in wheat *(Triticum aestivum)*. Tiller numbers increased with the level of applied nitrogen not only in bromegrass (Newell, 1951) but also in timothy and meadow fesuce *Festuca pratensis Huds.)* (Lambert, 1964).

In perennial ryegrass, the level of tiller production is related to time of nitrogen application. When applied at spikelet initiation, maximum production of tillers was higher and occurred earlier in the season than in treatments where nitrogen application was delayed until 70-80 per cent ear emergence (Hebblewaite and Ivins, 1978). They also found that early seed development coincided with rapid vegetative tiller death in treatments where nitrogen was applied early and with rapid increase in tillers in treatments where nitrogen was applied later.

In Nandi Setaria, tiller numbers increased sharply as nitrogen application was raised from 0 to 260 kgN/ha but this effect of nitrogen decreased with wider spacing (Boonman, 1972a). Tillering in Rodds Bay plicatulum is also increased by nitrogen application. Chadhokar and Humphreys (1973a)found that tiller densities of Rodds Bay plicatulum measured at the floral stage were 691/m² and 884/m² under low and high nitrogen applications, respectively. Tiller survival also increased with adequate nitrogen nutrition. Bahnisch and Humphreys (1977), however, reported that nitrogen application on Narok Setaria did not always increase tiller density, but when it did, the rate of tiller appearance was also increased.

2.2.2 Inflorescence density

Langer (1956) showed that the ear-bearing capacity of individual grass tillers declined with successively later dates of origin of tillers irrespective of external conditions and time of sowing. Nitrogen application increased tiller fertility particularly in the later tillers (Langer, 1959) but under low nitrogen (15 ppm), the percentage tiller fertility in timothy grass declined much more rapidly than under high (150 ppm) nitrogen (Ward, 1960). Nitrogen induced large increases in the number of fertile tillers in perennial ryegrass, cocksfoot, timothy and meadow fescue but not in red fescue (Evans and Calder, 1931). Increased ear counts/metre length of row in nitrogen-applied plots of timothy was observed by Jones (1953), and this increase in ear number was maximal at 45 kgN/ha application. Later studies at Hurley and Aberystwyth by Evans (1953, 1954, and Evans 1959, 1962) on perennial ryegrass, timothy and Cocksfoot showed significant increases in fertile tiller numbers *(Inflorescences)* at increasing levels of nitrogen. In New Zealand, Lambert (1956) reported an increase in tiller fertility in cocksfoot with increase in nitrogen levels. In a three year trial with timothy, Lambert (1963) found that nitrogen increased number of fertile tillers in only two years with increase in nitrogen levels from 98 to 196 kg/ha. But in a further trial (Lambert, 1967) increases over the control of 42 and 25 per cent in fertile tiller density were observed at 95 and 293 kgN/ha, respectively. Timing of nitrogen application has a marked effect on tiller fertility in perennial ryegrass. Hebblewaite and Ivins (1978) found that when nitrogen application on perennial ryegrass was delayed until about 30 per cent or more ears had emerged, the number of fertile tillers decreased.

Application of nitrogen has resulted in 10, 43 and 50 per cent more

tillers over control in Rodds Bay plicatulum, *Setaria sphacelata and Chloris gayana,* respectively (Henzell and Oxenham, 1964). At Shika, Nigeria, Haggar (1966) obtained 13 and 33 inflorescences per square metre of gamba under 0 and 100 kgN/ha, respectively. Grof (1969) also obtained significantly more inflorescences in para grass *(Brachiaria mutica).* Adequate nitrogen supply increased inflorescence density in Rodds Bay plicatulum (Chadhokar and Humphreys, 1973), in Nandi Setaria, Mbarara rhodes grass (Boonman, 1972a, 1972b), and in Narok Setaria (Bahnisch and Humphreys, 1977).

2.2.3 Inflorescence components

The seed yield potential (YP) of a crop is derived from the product of the inflorescence density (ID), number of flowers per inflorescence (FI) and seed size (SS), i.e. YP = ID x FI x SS. The number of shoots (tillers) which survive to flowering time determines the number of sites available for inflorescence occupation and this has been found to be positively influenced by increased nitrogen nutrition (Hebblewaite and Ivins, 1977). Inflorescence length, raceme numbers, spikelet numbers, seed density per unit length of inflorescence and seed size, the primary branches and florets in perennial ryegrass were found to respond positively to nitrogen application (Ryle, 1964, Hebblewaite and Ivins, 1977). Head lengths in timothy were regulated by nitrogen supply (Langer, 1959) and these increased with higher nitrogen application. The longer heads of timothy had greater seed bearing capacity per unit head length (Stoddart, 1959), and seed weight per head also increased with increase in nitrogen supply (Evans, 1954). Similar results have been obtained with cocksfoot (Lambert, 1966) and wheathrass (Smika and Newell, 1966). Head lengths

in cocksfoot and phalaris (*Phalaris tuberosa*) decreased as plant density was increased in the absence of nitrogen but this trend was modified in the presence of adequate nitrogen supply (Evans, 1962).

Under sub-tropical conditions in Queensland, Humphreys and Davidson (1967) reported an increase in seed weight per panicle with nitrogen in Burnett makarikari grass (*Panicum coloratum var. Makarikariense*). Chadhokar and Humphreys, (1970) working near Brisbane, Queensland, on Rodds Bay plicatulum found that nitrogen application increased the number of racemes per inflorescence from 7.1 in the control to 9.2 at the 400 kgN/ha. In a dry year, seed number per raceme was depressed by nitrogen addition but in the wet year positive effects were recorded in the 100, 200 and 400 kgN/ha treatments. Seed size increased significantly over control when nitrogen was applied at the floral initiation stage. In a dry year, seed size was substantially smaller than in a wet year. Since the weight of seed produced per inflorescence is a product of the number of racemes per inflorescence, the number of seeds per raceme and seed size, these factors also increased with nitrogen addition.

In Setaria, the effect of nitrogen supply on inflorescence length was inconsistent (Hacker and Jones, 1971; Bahnisch and Humphreys, 1977). Bahnisch and Humpreys (1977) found that significant positive effects of nitrogen rates on the inflorescence length of Narok Setaria occurred only in two out of fifteen harvests, and these represented increases of only 12 per cent. Late application of nitrogen in form of urea increased inflorescence lengths in three out of the 15 harvests from three to 13 per cent. The density of the entire florets was insensitive to nitrogen supply while the density of seeds recovered even decreased with increasing nitrogen rate.

The effect of timing of urea application on seed size was also inconsistent. Boonman (1972a), using a constant row spacing of 50 cm in Nandi Setaria, obtained head lengths of 13.7, 14.7 and 16.7 cm at nitrogen rates of 0, 100 and 200 kg/ha, respectively; the corresponding number of seeds per centimetre length of the heads were 9.7, 8.7 and 6.8. At a closer row spacing of 25 cm, head lengths at each nitrogen level decreased. Variations in seed size of Setaria were small and inconsistent in relation to nitrogen supply (Boonman, 1972a); Bahnisch and Humphreys, 1977), in contrast large variations in seed size were observed in Rodds Bay plicatulum under different levels of nitrogen application (Chadhokar and Humphreys, 1973(a). Haggar (1966) reported that high levels of nitrogen increased inflorescence in gamba but reduced seed yield per unit area. His data indicated that 0, 28, 56, 112 and 224 kgN/ha gave seed weight values per inflorescence of 0.20, 0.17, 0.16 and 0.21 g, respectively.

2.3 Effects of fertilizer nitrogen and moisture on grass seed yield

The reliability of seed production is dependent on water supply. Adequate soil water availability at all stages of plant growth is necessary for the full benefit of nitrogen supply on seed production to be realised. Seed production in Russian wild ryegrass was higher under favourable moisture supply than when rainfall was low (Stelfox *et al., 1954).* Water stress applied at or shortly after anthesis of barley plants reduced grain size while moisture stress at an earlier stage decreased grain number per ear (Aspinall et al., 1964.

Newell *et al.* *(1952)* observed that the seed production responses of wild oats (*Avena fatua*) to applied nitrogen over three years were dependent upon availability of moisture during the critical, floral initiation period. In one year, under normal rainfall, a significantly high response to 100 kgN/ha was recorded but in a drought year when water was depleted before seed maturation, seed yield was reduced to that obtained with 34 kgN/ha. Moisture stress at ear emergence in cocksfoot and timothy reduced seed yield by limiting nutrient transference to the ear (Evans, 1953). Under a condition of spring nitrogen application, seed yield of timothy was reduced when dry weather occurred at ear initiation, and this was probably due to the small root mass found in the high nitrogen treatments which limited soil moisture exploitation (Lambert, 1963a). Reduction in seed production in barley due to moisture stress has been attributed to the larger transpiration surface which arose from the stimulatory effects of high nitrogen on leaf growth (Luebs and Laag, 1967).

The appropriate row spacing and density for grass grown for seed under rainfed conditions are dependent on the seasonal and annual rainfall. Stitt (1954) obtained maximum seed yields from 60 cm rows when Russian wild ryegrass (*Elymus junceus*) was grown under irrigation in Montana, U.S.A. Under dryland conditions of 300 and 400 mm annual rainfall a row spacing of at least 180 cm was required to produce maximum seed yield. Similar findings with the same species grown at several locations in Canada have been reported (Stelfox *et al.*, *1954*). In the U.S.A. McGinnies (1971), reported that in two years of above average rainfall (290 and 370mm), row spacing of 15, 30, 45 and 60 cm had very little effect on seed yield of crested wheatgrass. With normal precipitation (150 and 200 mm) seed yeilds were highest in rows, 45 and 60 cm apart, but in dry years seed yields were low irrespective of spacing.

In a 500 mm rainfall area, Carter, (1965) obtained the highest yield of bromegrass seed from rows 50 cm apart and with 150 kgN/ha. However, when rainfall was low spacings of 90 and 180 cm and with about 56 kgN/ha gave better seed yields.

At Gayndah, Queensland, Humphreys and Davidson (1967) showed an increase of 10 and 19 per cent in seed yield of Burnett Makarikari grass grown in 240 cm rows relative to the seed yield from swards that were originally established at the same clonal density. The higher seed yield under row spacing could be due to the interrow cultivation which improved moisture status of the row plants. Chadhokar and Humphreys (1973) working with Rodds Bay plicatulum over a three-year period observed an acute moisture stress in the high nitrogen plots in a subnormal rainfall year. In these plots, moisture stress delayed floral iniation, inflorescence exsertion and seed maturity. The number of seeds per raceme, seed size, weight of seed per inflorescence and total seed yield per hectare were all adversely affected by moisture stress.

Irrigation is useful for increasing seed yield. Wet, humid and cloudy areas with leached soils have lower potential for pasture seed production than dry areas with high radiation, low wind velocity and fertile soils. Such dry environments are usually characterised by low incidence of disease and insect pest attack and can be made to produce high yields of good quality seeds if brought under irrigation. The supply of water to seed crops under irrigation can be manipulated to generate maximum components of seed yield, and also facilitate harvesting. In Queensland, irrigation was manipulated in many ways to improve seed production in Siratro *(Macroptilium atropurpureum cv. siratro)*

(Hopkinson and Loch, 1973) and it was with-held to reduce stickness in Stylo (*Stylosanthes guianensis*) prior to harvesting (Verhoeven, 1958). Smika and Newell (1965) studied the effect of nitrogen fertilizer and irrigation on wild oats (*Avena fatua*) grown at 100 cm rows for seed production and found that irrigation resulted in the highest number of racemes per unit length of row; weight of whole spikes per raceme was increased by 40 per cent and pure seed yield was higher in the irrigated stands.

In timothy, Lambert (1967) observed that the beneficial effect of irrigation on seed yield was more without nitrogen and decreased with increased nitrogen rate. Without nitrogen, the number of ears increased each year by 40 per cent with irrigation, but, at 98 and 196 kgN/ha, the increase was only slight and zero, respectively. Negative effects of irrigation, particularly at high nitrogen rates have also been reported on the seed yield of Molopo buffel by Cameron and Mullaly (1969). Early season irrigation, resulted in a depression of seed yields under varying nitrogen levels and the depression was linked with leaching of applied nitrogen. With nitrogen applied in split doses, the reduction was less, thus supporting the findings that split nitrogen application is more effective in some situations (Cameron and Mullaly, 1969). At Texas, U.S.A., no response in seed yield of *Dichanthium annulatum* to irrigation was observed (Holt, 1965). He also reported that the irrigation of over 4,000 varieties of bluestem (*Andropogon gerardi*) reduced seed yield in a good season and increased seed yield in a dry season.

2.4 Effects of fertilizer nitrogen, plant density and row spacing on grass seed yield

The effects of density and row spacing on seed production in temperature pasture grasses have been studied extensively whereas only in the past few years have attempts been made to similarly evaluate tropical grasses. Some of the comparisons used the same seeding rate per unit length of row and this confounded the effects of row spacing and plant density, thus making interpretation of data in terms of separate row spacing and density effects not difficult.

Plant density depends on the seeding rate of pure live seed, row spacing employed and the method of sowing (rows or broadcast). Both inter-and intro-plant competitions which depend on plant density operate such that the vegetative and reproductive growth phases are affected (Donald, 1954). Increased dose of fertilizer nitrogen was required to maintain seed yields, from the second year onwards in closely spaced stands of cocksfoot, timothy and meadow fesuce (Furkerson, 1959; Roberts, 1961; Calder and Cooper, 1961). Nitrogen application increased tiller fertility and reduced the harmful effects of heavy seed rate on seed yields in varieties of cocksfoot, ryegrass and timothy (Evans, 1959). Further studies by Evans (1962) indicated that a combination of low seed rate and nitrogen application produced higher seed yields in these grasses.

Fertilizer nitrogen application has been found to be less important than row spacing in influencing seed yields in old stand of Russian wild ryegrass and Cocksfoot (Calder and Cooper, 1961). In the denser spacing with low nitrogen, only one cocksfoot plant out of eighty produced inflorescences while in the wider spacing with higher

nitrogen level, 88 per cent initiated heads. When cocksfoot was sown in narrow and wide drills and given 67 and 134 kgN/ha/year (Lambert, 1966), it was observed that the higher level of nitrogen decreased seed yield by 24 per cent in the narrow drill whereas it increased seed yield by 75 per cent in the wide drill. Similarly, earlier studies on bromegrass (Klages and Stark, 1949) and on Russian wild ryegrass (Stitt, 1954) showed that a combination of wide row spacing and high nitrogen gave the highest seed yields but did not ensure high seed production every year.

In Louisiana, U.S.A., Owen (1951) working with common paspalum *(Paspalum dilatatum)* reported that seeding rate had no significant effect on seed yields but a row spacing of 105 cm gave seed yields of 175 to 229 kg/ha above the broadcast control in August and 47 to 109 kg/ha in the October harvest in the establishment year. In Sub-tropical Queensland, Humphreys and Davidson (1967) reported that Burnett makarikari grass established at equal clonal density in either 240 cm rows or as swards produced seed yields of 229 and 192 kg/ha in the 1961 harvest and 86 and 72 kg/ha in the 1962 harvest, respectively. In Colombia, row spacings of 50 to 60 cm have been recommended for seed production of *Dichanthium aristatum*, jaragua grass *(Hyparrhenia rufa)* and guinea grass *(Panicum maximum)* (Alercon, Lotero and Escobar, 1969). At Samford, Queensland, Hacker and Jones (1971) compared two ancestors of Setaria (C.P.I. 32930 and C.P.I. 33452) sown at 1 kg pure live seed (P.L.S) per hectare in either 50cm or 100cm rows. Seed yields of C.P.I. 32930 were the same for the 50 and 100 cm row spacings whereas C.P.I. 33452 gave higher seed yield at the narrower row spacing when 168 kgN/ha/crop was applied.

At Kitale, Kenya, Boonman (1972a) working on Nandi showed that both the P.L.S. yield and the number of seeds per centimetre of inflorescence were negatively correlated with row spacing at the optimum level of nitrogen input. The mean P.L.S. yields from seven crops which had been supplied with 130 kgN/ha/crop were 15.3, 14.7 and 11.5 kg/ha at 30, 60 and 90 cm row spacings, respectively. Flowering was better synchronised at close row spacing, thus facilitating better seed recovery at harvest. At the low nitrogen supply (65 kgN/ha/crop) after the first crop, P.L.S. yield increased with wider spacing. It is important to note here that these stands were established from an equal seed rate per unit length of row rather than per unit area, thus confounding close row spacing with high sowing rate.

In another field study on stoloniferous Mbarara rhodes grass, Boonman (1972) found that P.L.S. yield was insensitive to sowing rates of 0.2 to 0.18 kg P.L.S/ha in row spacings of 25 to 100 cm. Yield of clean seed of establishment crop was significantly higher at lower densities of 0.2, 0.6 and 1.0 kg P.L.S/ha than at the higher densities of 1.04 and 1.8 kg P.L.S/ha. Except in the broadcast treatments which gave higher clean seed yield than any other treatments, the clean seed yield tended to increase with wider row spacing. In over six subsequent crops, establishment row spacing and seed rate had no significant effect on mean P.L.S. or clean seed yield. In Jhansi, India, buffel grass grown at inter-and intra-row spacings of 15, 30, 60 or 75 cm gave maximum seed yields at 30 x 30 cm spacing in 1974 while the 75 x 75 cm spacing gave maximum seed yields of 243.6, 60.0 and 24.2 kg/ha in 1975, 1976 and 1977, respectively (Rai *et al.*, *1979*).

In Likoni guinea grass, a row spacing of 100 cm between plants gave maximum seed yields, being 11 and 26 per cent higher than those given by 30 and 60 cm spacings, respectively (Sarroca and Concepcion, 1981).

CHAPTER 3

MATERIALS AND METHODS

3.1. The Shika environment

The experiments were carried out at the National Animal Production Research Institute (N.A.P.R.I.), Shika, (Latitude 11°12'N, Longitude 07°33'E and 667 m above sea level), 22 km north-west of Zaria in the Northern Guinea Savanna Zone of Nigeria. The soils are derived from gneiss and schists of the basement complex, and belong to the furruginous tropical soil group (Klinkerberg and Higgins, 1968).

3.1.1. Climate

The Shika climate is characterised by well-defined dry and wet seasons. The dry season lasts from October to April and consists of a November to January period of low relative humidity with strong, cold and dry north-east harmattan winds. The wet season begins in late April/early May and ends in late September/early October. The total annual rainfall ranges from 617 mm to 1365 mm with a 50-year mean of 1041 mm (Agishi and Olorunju, (unpublished). Most of the rains fall between July and September. Daily rainfall records during the experimental period are presented in Appendix 1, while the monthly records for 1929 to 1978 are provided in Appendix 2. No reliable temperature records are available in Shika.

However, records from Samaru about 10 km north-east of Shika showed that the highest mean maximum screen temperature of 36.8°C occurred in April, while the lowest mean minimum temperature of 11.4°C was recorded in December. Mean daily sunshine was about 7.7 hours. Weather observations during the experimental period are summarised in Table 1.

3.1.2 Soil

In the broad valleys commonly referred to in Hausa as'Fadama', the soils are deep, grey-brown sandy loams which become heavier at depths and are imperfectly drained, silty and consequently subject to surface sealing. The water table is high on the lower slopes causing poor drainage and temporary flooding after the rains. The upland soils are either gravelly and stony or sandy loam. Bot the lowland and upland soils are generally weakly acid and deficient in nitrogen and phosphorus (Tables 2 and 3).

3.1.3 Vegetation

On the undisturbed gravelly and stony soils or on sites underlain with ironstone, the vegetation consists mainly of *Afrormosia laxiflora, Detarium microcarpum, Isoberlinia tomentosa, Monotes kerstingii, Crossopteryx febrifuga, Adenodolichos paniculatus and Sphenostylis schweinfurthii;* while the grass cover was dominated by *Andropogon pseudapricus, A. schirensis, Loudetia simplex and Trachypogon spicatus.*

On the deeper, undisturbed sandy-loam soils, the main shrub species were *Isoberlinia doka, Terminalia avicennioides, Dichrostachys cinerea*

and *Piliostigma thonningii* in association with dominant grasses such as *Andropogon ascinodis, A. gayanus pobeguinii, Panicum phragmatoides, Urelytrum muricatum, Brachiaria jubata, Setaria anceps, Hyparrhenia soluta* and *Hyparthelia dissoluta.*

The dominant fadama plants include *Syzygium guineense, Terminalia macrocarpa, Khaya senegalensis, Vernonia ambigua, V. pauciflora and Aeschynomene abyssinica* with a herbaceous cover comprising *Cyperus spp, Acroceras amplectens, Echinochloa spp., Hyparrhenia cyanescens, H. rufa, Eragrostis atrovirens, Paspalum orbiculare and Panicum spp.*

The fallowland vegetation consisted of *Parkia clappertoniana, Butyrospermum paradoxum, Acanthospermum hispidum, Aspilia africana, Ageratum conyzoides, Amranthus spinosus, Bidens pilosa, Cassia rotundifolia, Sida urens, Vernonia spp, and Tephrosia spp,* and the associated grass cover of *Andropogon gayanus, Brachiraria stigmatisata, B. xantholeuca, Chloris pilosa, Dactyloteniun aegyptium, Eleusine indica, Eragrostis ciliaris, Pennisetum pedicellatum, Setaria anceps, Digitaria spp., Sporobolus pyramidalis, Thelopogon elegans and Rottboellia exaltata.*

3.2 Experiment 1: Effects of fertilizer nitrogen on seed production of Bilocia buffel grass, gatton panic and green panic under limited irrigation

3.2.1 Experimental site

The wide-bottomed valley used for the experiment had been under fallow for over forty years prior to cultivation in preparation for maize cropping in early 1975.

The cultivated area consisted of four bays, each measuring 120 m x 20 m and separated from each other by 3m-wide bunds. The bays were set on contour and planed to facilitate flood irrigation. Before the commencement of the experiment, random soil samples taken at 0-15, 15-30 and 30-45 cm depths were analysed for nitrogen. The soil was then bulked and analysed for P, Ca, Mg and K contents (Table 2).

3.2.2. Land preparation

The bays were disc-ploughed and twice harrowed in January, 1976. Two days before re-harrowing on 15/2/76, the bays were flooded with irrigation water to make it easier for demarcation of plots with wooden pegs and seed sowing on 16/2/76.

3.2.3 Experimental design

The experiment comprised four levels of fertilizer nitrogen applied to three grasses in a factorial design. The four levels of fertilizer nitrogen 0, 100, 200 and 400 kgN/ha, designated N_0, N_{100}, N_{200} and N_{400}, were applied as nitrochalk (Calcium ammonium nitrate, 26%N) subsequent to a basal dressing of single superphosphate (18% P_2O_5) at the rate of 125 kg/ha. The treatments were arranged in completely randomised blocks with four replications, giving 48 plots, each 4.8m x 3.0m. The plots were separated from each other by 1.0m paths. Each of the four bays formed a replication.

3.2.4 Seed sowing and crop management

The Biloela buffel and gatton panic seeds used in the experiment originated from Brisbane, Australia while the green panic seeds were obtained from Mokwa in the Southern Guinea Savanna Zone of Nigeria. On 16/2/76, the seeds were drilled at 5 kg/ha pure seed in rows, 60 cm apart, giving 9 rows per plot. The seeds were lightly covered with soil by raking. All plots were watered at two-day intervals at the rate of 20 litres per plot from the data of sowing and hand-weeded four weeks after sowing.

3.2.5 Evaluation of shoot and inflorescence densities

The plots were first sampled on 5/5/76, 79 days after sowing, for evaluation of shoot and inflorescence densities using 30 x 30 cm quadrats. Thereafter, samplings were repeated at approximately two-week intervals. At the later harvests which commenced on 18/5/76 when the seeds had started ripening, sampling included ripe and unripe inflorescences. Seed maturity was recognised when the seed became hard, started changing colour from green to brown and when seed-shedding from the top-end of the inflorescences was noticed. The ripe inflorescences were cut, placed in separate paper bags and oven-dried at 40°C for 24 hours using Gallenkamp oven, Model OV-330. The ripe inflorescences per quadrat were counted and their lengths measured. Ten randomly chosen inflorescences from each plot were used to determine the number of seeds per inflorescence. Ten seedlots of 100 seeds each per plot were examined for seed size, and caryopsis contents.

The abscission calluses on the individual inflorescences were counted with the aid of a hand lens, providing estimates of the potential number of seeds produced and the harvest efficiency for each harvest occasion.

Potential seed yield was calculated from the equation:

PSY = ID x NS x SS

where PSY = potential seed yield per unit area (g/m^2)

ID = inflorescence density (No/m^2)

NS = Number of seeds per inflorescence

SS = Seed size (mg/seed)

Potential crude seed yield includes all empty florets and florets with caryopsis. The product of potential seed yield percentage and caryopsis content gives 'potential pure seed yield'. Similarly, 'harvested pure seed yield was obtained from the product of harvested seed yield and percentage caryopsis content'.

3.2.6 Determination of herbage dry matter (DM) yield

Immediately after the final seed harvesting, 105 days after sowing, cuts for herbage yield determinations were made at 10 cm above the ground level in each of the 30 x 90 cm quadrats assigned randomly to each plot. The whole fresh material from each quadrat was weighed separately and sub-sampled for oven-drying. The fresh sub-samples were weighed in the laboratory, oven-dried at 60°C for 48 hours, cooled and re-weighed for the estimation of dry matter yield per unit area.

Crop index was calculated from the ratio of total seed yield to total herbage dry matter yield. Crop index was calculated separately for potential seed yield and harvested clean seed yield.

3.2.7 Laboratory determination of percentage crude protein (%CP)

The grass samples were ground with a hammermill and the crude protein content (%CP) determined on dry matter basis by the standard Kjeldahl Method (A.O.A.C., 1970). The following is a summary of the procedure and the reagents employed:-

Procedure	Reagents
Digestion	Concentrated sulphuric acid with copper sulphate and potassium sulphate mixture, 1:20 W/W as catalyst.
Distillate	40% $W/_V$ Sodium hydroxide.
Collection distillate	20% Boric acid containing 2-3 drops of 0.1% methyl red and bromo-cresol green solution as indicator.
Titration	0.02N Hydrochloric acid.
Estimation of crude protein	From the per cent nitrogen (%N) obtained (%CP) was calculated using the relationship: %CP = %N x 6.25

The procedure was followed in estimating crude protein per cent in experiments 2 and 3.

3.2.8 Statistical analysis of data

The data was examined using the statistical analysis of variance (ANOVA) method, and the means compared by the technique of standard errors of difference between means according to Steel and Torrie, (1960). Simple correlation matrix was used to examine the relationships between the various

attributes of seed production in experiments 1 and 3 as described by Patterson (1939).

3.2.9 Determination of nutrient status of experimental sites

Before the commencement of the experiments, random soil samples taken at 0-15, 15-30 and 30-45 cm depths were analysed chemically in order to estimate the fertility level of the soils. The standard Kjeldahl method was used to estimate the total nitrogen content of the soil. Available phosphate was extracted by shaking 2g of soil with 40 ml of 0.002N sulphuric acid, followed by filtering (Troug 1930). The extracted phosphate was determined by Molybdate blue colour method (Gray and Kurt 1945). Exchangeable cations were extracted by shaking 2g of soil with 3% acetic acid, at a 1:40 soil: solution ratio for 2 hours and filtering (Reith, 1967). Calcium, magnesium and potassium in the filtrates were determined with an atomic absorption spectrophotometer (Perkin Elner, Model 306).

3.3 Experiment 2: Effect of row spacing on seed production of Biloela buffel grass on the upland.

3.3.1 Experimental site

The experimental site on the upland in Shika was under an intermittently and variably stocked rhodes grass/stylo pasture from 1966 to 1977 during which it received mean annual blanket applications of ammonium sulphate (21%N) at about 250 kg/ha and single superphosphate at 62.5 kg/ha.

3.3.2 Land preparation

Before the commencement of the experiment random soil samples were taken at 0-15, 15-30 and 30-45 cm depths for soil chemical analysis (Table 3). The field was ploughed and harrowed on 17/5/77 and 23/6/77 respectively. On 15/7/77, it was harrowed once before and twice after a blanket broadcast application of single superphosphate (18%P_2O_5) at the rate of 125 kg/ha. The repeated harrowings were aimed at obtaining a fine seedbed for sowing and a thorough soil/fertilizer mixture.

3.3.3 Experimental design

Four spacings viz:- broadcast (control) and 30, 60 or 90 cm between rows designated Br, R_{30}, R_{60} and R_{90}, respectively, were arranged in completely randomised blocks with four replications, Plot size was 9.6m x 9.6m, giving row lengths of 18, 9 and 6 for the 30, 60 and 90 cm row spacings respectively. The plots were separated by 1m paths and the blocks by 2m paths.

3.3.4 Seed sowing and crop management

The seed used in the experiment was harvested at the NAPRI Farm, Shika on 12/10/75 and stored under room temperature conditions. A month before the experiment, the "Seeds" *(Fascicles)* were hand-cleaned of impurities, and further cleaned in a Laboratory Seed Blower. Fascicles contained mostly one, but sometimes two or three caryopsis. The quantities of seed sown per row length therefore were 1.44, 2.88 and 4.33g

for the 30, 60 and 90cm row spacings, respectively. For each row, a shallow furrow of about 1 cm deep was made with a small hoe into which seeds were evenly hand-drilled. ,or the 'Br' plots, the seeds were hand-broadcast as evenly as possible. In each plot a rake was used to cover the seeds lightly with soil, and this was followed by a basal application of calcium ammonium nitrate (26%N), at the rate of 100 kgN/ha or 1.994 kg of nitrochalk per plot. The plots were hand-weeded on 17/8/77.

3.3.5 Estimation of shoot density and seed yield components

3.3.5.1 Shoots and inflorescence densities

Shoot and inflorescence counts were made 63, 77, 91 and 105 days after sowing in randomly distributed permanent quadrats. ;he quadrats were of metal frame, each measuring 30 cm x 30 cm, with one open end. On each sampling occasion, all the shoots and inflorescences within one quadrat per plot were recorded. On day 91, all the ripe inflorescences within each plot were hand harvested with sickless and bagged separately. On day 105, all the inflorescences within each plot were harvested when they were found to be all ripe. In both harvests all the inflorescences collected were oven-dried at 40°C for 24 hours. The inflorescences per quadrat were counted and the length per inflorescence measured.

3.3.5.2 Determination of seed yield components, herbage DM yield and CP content.

The same methods of estimating seed yield components, herbage dry matter yield and herbage crude protein content as described in experiment 1 above were employed.

3.4 Experiment 3: Effects of levels of fertilizer nitrogen application on seed production of Biloela buffel grass, gatton panic and green panic on the upland.

3.4.1 Experimental site

The trial occupied the remaining part of the land prepared for experiment 2.

3.4.2 Experimental design

A 3 x 4 completely randomised factorial design with four replications was used. Three grasses, namely, Biloela buffel, gatton panic and green panic were studied in relation to four levels of fertilizer nitrogen 0, 200, 400 and 600 kgN/ha as nitrochalk (26%N), designated N_0, N_{200}, N_{400} and N_{600}, respectively. The plots measured 10m x 5.4m and were separted by 1m paths, while the blocks were 2m apart.

3.4.3 Seed sowing and crop management

The seeds used in the experiment were harvested at NAPRI, Shika on 6/10/77 and had since been kept in jute bags in a store at room temperature. The seeds were first hand-cleaned, and later a small Laboratory Seed Blower was used to separate the empty florets from the caryopsis-containing florets. The seeds were hand-drilled on 18/7/78 into about 2cm - deep furrows, 60 cm apart at the rate of 5 kg/ha pure seed for each of the three species.

The seeds were lightly covered with soil using a rake. A basal dressing of single superphosphate at the rate of 125 kg/ha was applied at sowing, and this was followed immediately by the application of the four levels of fertilizer nitrogen.

The plots were weeded on 18/8/78. Bird damage to the seeds of gatton panic and green panic crops was minimised only after some caricatures or scare-crows were erected at different points between the plots.

3.4.4. Estimation of shoot density and seed yield components

The sampling and measurement procedures for estimating shoot density and the various seed yield components were the same as those previously described for experiments 1 and 2 above. Sampling for seeds was restricted to between 9 and 10 a.m. when seed-shedding in the panics was minimal. Shoot density counts were carried out only after sampling for inflorescences had been completed, so as to minimise disturbance to the ripe heads which could aggravate seed shedding.

CHAPTER 4

RESULTS

4.1 Experiment 1: Effect of fertilizer nitrogen on seed production of Biloela buffel grass, gatton panic and green panic under limited irrigation in 1976

4.1.1 Meteorological observations

Rainfall during the experimental period commenced in April and by the end of June 1976, 445.8 mm of rain had fallen (Table 1). Mean relative humidity between February and March was 21.1 per cent but this increased gradually from 42.5 per cent in April to 75.3 per cent in June. Monthly maximum and minimum temperatures averaged 32.9°C respectively for the February to June period. The experimental period was characterised by relatively long sunshine hours, ranging from 8.9 hours in February to 7.3 hours in June, with the period average of 8.18 hours.

4.1.2 Soil properties

Data on the chemical constituents of the experimental site are presented in Table 2. Total nitrogen content decreased with increasing soil depth, being 0.075, 0.053 and 0.036 per cent for 0-15, 15-30 and 30-45 cm depths respectively. The bulked soil contained 330 ppm of available (acid soluble) phosphorus. Exchangeable cations of calcium, magnesium and potassium were 4.171, 1.239 and 0.644 milliequivalents

Table 1: Meteorological observations at Samaru*(Rainfall at Shika+).

Parameter	Year		Months											
			J.	F	M	A	M	J	J	A	S	O	N	D
Rainfall (mm)		1976	0.0	0.0	0.0	90.4	124.5	230.9	320.3	265.7	92.2	160.2	0.0	0.0
		1977	0.0	0.0	0.0	0.0	64.0	102.6	85.6	232.2	287.0	0.0	0.0	0.0
		1978	0.0	0.0	2.3	90.9	164.1	188.2	159.5	385.3	182.9	32.3	0.0	0.0
	Means	1929-1978	0.2	1.1	3.7	37.1	113.7	160.0	216.3	300.1	200.4	8.2	1.2	0.0
Number of rainy days		1976	0	0	0	5	9	11	14	16	12	13	0	0
		1977	0	0	0	0	9	12	11	22	10	0	0	0
		1978	0	0	1	5	10	10	15	18	12	5	0	0
	Means	1929-1978	0.0	0.7	3.6	9.6	12.6	15.2	18.4	14.9	14.9	3.9	0.1	0.0
Mean Relative Humidity (%)		1976	16.7	24.6	17.5	42.5	68.0	75.3	81.1	81.5	75.0	74.7	40.6	20.6
		1977	20.0	12.0	14.0	20.5	49.0	61.5	70.0	77.0	70.5	55.0	22.0	22.5
		1978	19.0	15.5	24.0	52.5	62.0	71.5	77.0	74.5	72.5	59.5	28.5	20.5
Mean Screen Temperatures(%)		1976	Max. 29.3	33.0	34.8	35.1	32.2	29.5	27.7	27.6	30.3	29.4	29.9	29.8
			Min. 13.3	17.5	16.7	21.2	21.1	19.5	19.4	19.1	19.2	19.3	12.9	11.4
		1977	Max. 29.4	30.6	32.3	36.8	34.3	30.7	29.7	27.6	30.0	30.7	30.7	27.9
			Min. 12.7	14.0	18.9	20.8	21.3	20.3	20.2	19.9	19.5	17.0	12.0	12.1
		1978	Max. 29.3	33.6	35.5	33.7	32.0	29.6	26.8	28.6	29.5	31.7	30.1	29.7
			Min. 12.9	16.0	19.4	22.0	20.3	19.8	19.7	19.5	18.9	19.1	14.1	12.8
Sunshine (Hours/day)		1976	9.4	8.9	8.6	8.0	8.1	7.3	6.5	6.0	7.6	7.0	9.5	8.8
		1977	8.0	7.9	4.7	7.7	8.4	7.7	6.0	4.6	7.7	8.8	10.1	8.4
		1978	9.2	9.8	8.7	6.9	8.1	7.4	4.6	6.2	7.4	8.2	8.6	9.0

+ Shika: (Lat.11°12'N, Long. 07°33'E, Alt. 667m)
* Samaru: (Lat.11°11'N, Long. 07°38'E, Alt. 686m).

Table 2: Chemical composition of the soil at the irrigation site, Shika.

Soil depths (cm)	Total N (%)	P (ppm)	Exchangeable cations (me/100g soil)			pH (H_2O)*
			Ca	Mg	K	
0-15	0.075					
15-30	0.053	330	4.171	1.239	0.644	6.3
30-45	0.036					

*See interpretations in Appendix 3.

per 100g soil, respectively. The soil had a pH value of 6.3 which indicated slight acidity. Based on the interpretations of the soil analysis (Appendix 3), the above chemical contents of the soil could be described as adequate for good grass growth.

4.1.3 Shoot density and fertility

Shoot density increased significantly both within and between species with increasing levels of nitrogen. In Biloela buffel grass and gatton panic, maximum shoot density occurred at the N_{200} level, being 1236 and 1101/m² respectively, compared with the corresponding values of 856 and 544 for the control, N_0 (Table 4(a). In green panic, shoot density increased from 738 at N_0 to 1249 at N_{400} with the greatest response occurring between the N_{100} and N_{200} levels (Table 4(a). Buffel grass and green panic, had similar average shoot densities, which were significantly higher ($P<0.001$) than that of gatton panic. Shoot densities increased with time in all the three grasses (Table 4(b), the ranges between the first and final sampling dates being 778 to 1355, 477 to 1242 and 561 to 1523 shoots/m² for buffel grass, gatton panic and green panic respectively. The rate of increase in shoot density in buffel was slowest between the second and third samplings, but in the panics the slowest rate was between the third and fourth sampling dates. In the first two sampling dates, rates of increase in shoot density were similar for the three species, the differences were significant only at the last two harvests, by which time the respective figures for buffel grass, gatton panic and green panic were 203, 268 and 408.

Percentage shoot fertility, calculated as the current number of fertile shoots per total number of existing shoots at harvest, times

Table 4 : Effect of nitrogen levels and date of harvest on shoot density (no/m²)

(a): Effect of nitrogen levels on shoot density/m²

Species	Nitrogen levels				Means	S.E.
	N_0	N_{100}	N_{200}	N_{400}		
Buffel grass	856	1003	1236	1167	1066	
Gatton panic	544	714	1101	1080	860	±15.5
Green panic	738	860	1154	1249	1000	
Means	713	859	1163	1165		±771

(b): Effect of date of harvest on shoot density.

Species	Dates of sampling in 1976*					Means	S.E.
	5MAY	18MAY	1 JUN	15JUN	29JUN		
Buffel grass	778	991	1051	1152	1355	1066	
Gatton panic	477	691	914	974	1242	860	±15.5
Green panic	561	784	1018	1115	1523	1000	
Means	605	822	995	1081	1373		±86.2

The Standard errors (S.E) for

Nitrogen (N) x Species (S) = ±31.0

Species(S) x Date (D) = ±33.7

*The sampling dates correspor to 78, 92, 106, 120 and 134 days after sowing.

100, is shown in Table 5. Gatton panic gave significantly higher ($P<0.001$) percentage shoot fertility at all levels of nitrogen than buffel grass and green panic (Table 5(a). Similarly green panic was superior to buffel grass at all nitrogen levels. In all grass species, minimum percentage shoot fertility occurred at the control, (N_0) treatment. In gatton panic and green panic, there was a tendency for percentage shoot fertility to rise with increase in levels of nitrogen, but in buffel grass, the response to nitrogen was inconsistent. On the whole, percentage shoot fertility was independent of nitrogen treatment within each grass species.

In buffel grass, percentage shoot fertility decreased progressively with later dates of sampling, the range being 51.4 per cent at 5 May, 1976 to 7.2 per cent at 15 June, 1976, seven-fold ball. Gatton panic and green panic showed peak percentage shoot fertility of 68.0 and 58.4 per cent on 1 June, and 18 May, respectively. The lowest percentage shoot fertility in gatton panic occurred on 5 May, while that of green panic was on 15 June.

4.1.4 Seed yield components and seed yields

4.1.4.1 Inflorescence density

Inflorescence densities was significantly affected by nitrogen levels and the species used (Table 6(a). Nitrogen levels of N_{100} and above gave higher densities than the control, N_0, the treatment ranges being 225 to 466 and 190 to 330 for gatton panic and green panic, respectively.

Table 5: Effect of nitrogen levels and dates of sampling on percentage shoot fertility.

(a): Effect of nitrogen levels on percentage shoot fertility.

	Nitrogen levels					
Species	N_o	N_{100}	N_{200}	N_{400}	Means	S.E.
Buffel grass	30.3	36.7	33.8	34.9	33.9	
Gatton panic	49.8	52.4	50.6	53.7	51.6	±1.49
Green panic	36.0	38.5	40.9	41.4	39.2	
Means	38.7	42.5	41.8	43.3		±1.58

(b): Effect of dates of harvest on percentage shoot fertility.

	Dates of Sampling in 1976*					
Species	5MAY	18MAY	1JUNE	15JUNE	Means	S.E.
Buffel grass	51.4	50.7	26.4	7.2	33.9	
Gatton panic	37.3	54.3	68.0	46.9	51.6	±1.49
Green panic	46.9	58.4	31.3	20.3	39.2	
Means	45.2	54.5	41.9	24.8		±1.58

S.E. for

N x S = ±1.94

S x D = ±1.94

*The third order interactions were consistently non-significant in all the parameters measured in this experiment, and so is being excluded.

Table 6 Effect of nitrogen levels and date of harvest on inflorescence density (no/m²)

(a): Effect of nitrogen levels on inflorescence density.

	Nitrogen levels					
Species	N_o	N_{100}	N_{200}	N_{400}	Means	S.E.
Buffel grass	185	260	297	292	259	
Catton panic	225	314	422	466	357	±6.0
Green panic	190	234	320	330	269	
Means	200	269	346	363		

(b): Effect of dates of harvest on inflorescence density

	Dates of harvest in 1976						
Species	5MAY	18MAY	1 JUN	15JUN	29JUN	Means	S.E.
Buffel grass	399	503	287	84	20	259	
Gatton panic	177	411	613	446	136	357	±6.0
Green panic	261	450	318	228	86	269	
Means	279	455	406	253	81		±30.3

S.E.

N x S = ±12.1
S x D = ±13.5

In buffel grass maximum inflorescence density of 297 occurred at the N_{200} level, giving an increase of 112 inflorescences over the control. There was an inflorescence build-up with time which in buffel and green panic peaked on 18 May, 92 days after sowing, and 14 days later in gatton panic (Table 6(b). Inflorescence production was observed to have been least even in gatton panic, followed by green panic resulting in many heads being presented for harvest at each of the harvest dates. In buffel grass, with a more restricted flowering period, only 84 inflorescences per m^2 were available for harvest during the last but one harvest (Table 6(b).

4.1.4.2 Number of ripe inflorescences

The number of ripe heads presented for harvest appeared to reflect the original inflorescence density. All the nitrogen levels from N_{100} upwards gave significant increases in number of ripe inflorescences over the control (Table 7(a). In buffel grass and green panic maximum number of ripe heads occurred at the N_{200} level, but in gatton panic the maximum was at the N_{400} level. Highly significant differences ($P<0.001$) were observed between species the overall mean numbers of ripe inflorescences harvested being 138, 231 and 172 per m^2 for buffel grass, gatton panic and green panic respectively (Table 7(b).

4.1.4.3 Number of seeds per inflorescence

Seeds per inflorescence increased in all the three species as the rates of nitrogen application increased (Table 8(a). Increases in seed

Table 7 Effect of fertilizer nitrogen levels and date of harvest on number of ripe inflorescences (no/m²)

Table 7(a): Effect of fertilizer nitrogen on number of ripe inflorescences.

	Nitrogen levels					
Species	N_o	N_{100}	N_{200}	N_{400}	Means	S.E
Buffel grass	103	135	160	152	138	
Gatton panic	138	216	264	305	231	±4.9
Green panic	113	160	212	204	172	
Means	118	170	212	221		±18.1

(b): Effect of dates of harvest on number ripe inflorescences

	Dates of harvest					
Species	18 MAY	1 JUN	15 JUN	29 JUN	Means	S.E.
Buffel grass	247	218	65	20	138	
Gatton panic	255	222	310	136	231	±4.9
Green panic	347	122	141	80	172	
Means	283	188	172	79		±18.1

S.E.

N.x S = ±9.9

S x D = ±9.9

Table 8 . Effect of nitrogen levels and date of harvest on number of seeds per inflorescence.

(a): Effect of nitrogen levels on number of seeds per inflorescence

	Nitrogen levels					
Species	N_o	N_{100}	N_{200}	N_{400}	Means	S.E.
Buffel grass	118	123	126	130	124	
Gatton panic	748	507	522	542	512	±3.6
Green panic	425	445	477	498	461	
Means	340	358	375	390		±11.3

(b): Effect of dates of harvest on number of seeds per inflorescence

	Dates of harvest					
Species	18MAY	1JUN	15JUN	29JUN	Means	S.E.
Buffel grass	128	126	124	119	124	
Gatton panic	510	544	502	392	512	±3.6
Green panic	558	508	435	345	461	
Means	432	393	354	285		±11.3

S.E

N x S = ±7.2

S x D = ±7.2

numbers in buffel grass were only moderate, but in gatton panic and green panic, N_{100} and above gave significantly higher ($P<0.05$) number of seeds than the nonfertilized control. At all levels of nitrogen application gatton panic produced significantly more ($P<0.001$) seeds than green panic and consistently quadrupled buffel grass. There was generally a progessive decrease in number of seeds of buffel grass and green panic with later dates of harvest; this decrease was highly significant ($P<0.001$) in green panic but not in buffel grass (Table 8(b). In gatton panic the maximum number of seeds per inflorescence of 644 coincided with the 1 June harvest, but by the final harvest, the number had declined to only 392. The average number of seeds per inflorescence for buffel grass, gatton panic and green panic were 124, 512 and 461 respectively, over all harvests.

4.1.4.4 Seed size

Significant increases in seed size occurred in response to added nitrogen both within and between species. Seed sizes varied from 1.598 mg/seed at N_o to 1.776 mg/seed at N_{400} for buffel grass, with corresponding figures of 0.339 to 0.467 and 0.361 to 0.480 mg/seed for gatton panic and green panic respectively (Table 9(a). Regardless of nitrogen level, green panic seeds were significantly ($P<0.01$) heavier than those of gatton panic, while buffel grass seed was, on the average, 4.1 and 3.9 times heavier than gatton panic and green panic seeds respectively. The earlier-formed seeds in all species were heavier than the later-formed seeds, the ranges being from 1.723 mg/seed at 18 May to 1.582 mg/seed at 29 June for buffel grass, with corresponding values of 0.464 to 0.409 and 0.496 to 0.435 mg/seed for gatton panic and green panic, respectively Table 9(b).

Table 9 Effect of nitrogen levels and date of harvest on seed size (mg/seed).

(a): Effect of nitrogen levels on seed size.

Species	Nitrogen levels				Means	S.E.
	N_o	N_{100}	N_{200}	N_{400}		
Buffel grass	1.598	1.632	1.695	1.766	1.673	
Gatton panic	.339	.393	.438	.467	.409	±0.006
Green panic	.361	.425	.471	.480	.435	
Means	.768	.816	.868	.904		±0.013

(b): Effect of date of harvest on seed size1

Species	Dates of harvest				Means	S.E.
	18MAY	1JUN	15JUN	29JUN		
Buffel grass	1.723	1.706	1.681	1.582	1.673	
Gatton panic	.464	.444	.400	.328	.409	±0.006
Green panic	.496	.483	.418	.343	.435	
Means	.894	.878	.833	.751		±0.013

S.E.

N x S = ±0.013

S x D = ±0.013

4.1.4.5 Caryopsis content

Caryopsis contents in all species increased significantly with increase in nitrogen levels up to N_{200} (Table 10(a). The mean caryopsis content of 69 per cent for buffel grass significantly ($P<0.001$) exceeded those for gatton panic (43 per cent) and green panic (42 per cent) respectively. There was a general increase in the caryopsis contents of all species with later dates of harvest, the values ranging from 63 per cent at 18 May to 74 per cent at 29 June for buffel. The equivalent figures for gatton panic and green panic were 41 to 44 and 39 to 44 per cent, respectively.

4.1.4.6 Potential seed yield

Nitrogen application and species differences had marked effects on the potential seed yields (Table 11(a). In buffel grass, seed yields range from 787.2 kg/ha at N_o to 1458.4 kg/ha at N_{400}. In gatton panic N_{100} and above significantly superceded the control, but in green panic at least N_{200} was needed to cause appreciable differences. The total potential seed yields from the four harvests, averaged over the four nitrogen levels were 1160.7, 2174.0 and 1690.4 kg/ha for buffel grass, gatton panic and green panic, respectively (Table 11(b). These figures are far below the maximum seed yields for buffel grass, gatton panic and green panic of 1458.4, 3406.8 and 2330.0 kg/ha, respectively, obtained at the N_{400} level (Table 11(a).

In buffel grass and green panic, about 84 and 62.2 per cent of the total quantity of seeds produced, respectively, were obtained during the first two harvests. In gatton panic, two harvest peaks occurred, one on 15 May, and the other on 15 June, though of the final harvest, a

Table 10 Effect of nitrogen levels and date of harvest on caryopsis contents (%).

(a): Effect of nitrogen levels on caryopsis content.

	Nitrogen levels					
Species	N_o	N_{100}	N_{200}	N_{400}	Means	S.E.
Buffel grass	65	70	72	71	69	
Gatton panic	39	43	45	45	43	±0.63
Green panic	38	41	44	43	42	
Means	48	51	53	53		±0.77

(b): Effect of date of harvest on caryopsis content.

	Dates of harvest in 1976					
Species	18 MAY	1 JUN	15 JUN	29 JUN	Means	S.E.
Buffel grass	63	68	73	74	69	
Gatton panic	41	43	43	44	43	±0.63
Green panic	39	41	43	44	42	
Means	48	51	53	54		±0.77

S.E

N x S = ±1.27

S x D = ±1.27

Table 11 Effects of nitrogen levels and date of harvest on potential seed yield (kg/ha).

(a): Effects of nitrogen levels on potential seed yield (kg/ha).

	Nitrogen levels					
Species	N_o	N_{100}	N_{200}	N_{400}	Means	S.E.
Buffel grass	787.2	974.8	1422.4	1458.4	1160.7	
Gatton panic	912.8	1842.8	2533.6	3406.8	2174.0	±67.2
Green panic	796.4	1364.0	2271.2	2330.0	1690.4	
Means						±366.8

(b): Effect of date of harvest on potential seed yield (kg/ha).

	Dates of harvest in 1976					
Species	18 MAY	1 JUN	15 JUN	29 JUN	Means	S.E.
Buffel grass	2051.6	1888.8	550.8	151.6	1160.7	
Gatton panic	3151.6	2221.6	2616.4	706.4	2174.0	±67.2
Green panic	3629.2	1624.8	1082.4	425.2	1690.4	
Means	2944.1	1911.7	1416.5	427.7		±366.8

S.E.

N x S = ±134.8

S x D = ±134.8

fairly high proportion of seed was collected. In all three species, highest quantities of seeds were obtained in the first harvest, on 15 May, and these represented 43.3, 36.2 and 47.7 per cent of the total quantity of seed produced by buffel grass, gatton panic and green panic, respectively.

The product of potential seed yield and caryopsis content gives potential pure seed yield, and these are presented in Table 12(a). Nitrogen caused considerable increases in the potential pure seed yields of all species but there was apparently no justification in applying over N_{200} to buffel grass and green panic. The mean pure seed yields over the four harvests, of 812.0, 944.8 and 709.7 kg/ha for buffel grass, gatton panic and green panic were significantly different from one another. In buffel grass and green panic, most of the total seed produced were harvested in the first two harvests, 15 May and 1 June (Table 12(b). In the gatton panic, about one third of the total seed produced was harvested at the third harvest on 15 June.

4.1.4.7 Harvested seed yield

Harvested clean seed yields from four harvests are shown in Table 13. Although all species responded favourably to nitrogen application, maximum seed yields in buffel and green panic of 1000 and 927.6 kg/ha respectively were attained at the N_{200} level (Table 13(a). The highest seed yield of 1059.6 kg/ha was obtained in gatton panic at the N_{400} level. Overall nitrogen treatments, buffel grass and gatton panic had similar seed yields which were significantly higher ($P<0.001$) than that of green panic.

Table 12 Effects of nitrogen levels and date of harvest on potential pure seed produced (kg/ha).

a): Effects of nitrogen levels on potential pure seed produced (kg/ha).

	Nitrogen levels					
Species	N_o	N_{100}	N_{200}	N_{400}	Means	S.E.
Buffel grass	483.2	758.0	981.2	1025.6	812.0	
Gatton panic	350.4	792.0	1124.8	1512.0	944.8	±32.8
Green panic	282.8	529.2	989.6	1037.2	709.7	
Means	372.1	693.1	1031.9	1191.6		±184.4

(b): Effects of dates of harvest on potential pure seed produced (kg/ha).

	Dates of harvest in 1976					
Species	18MAY	1 JUN	15 JUN	29 JUN	Means	S.E.
Buffel grass	1432.8	1296.8	404.8	113.6	812.0	
Gatton panic	1352.0	971.2	1137.2	318.8	944.8	±32.8
Green panic	1656.0	518.0	473.6	191.2	709.7	
Means	1480.3	928.7	671.9	207.9		±184.4

S.E.

N x S = ±65.6

S x D = ±65.6

Table 13: Effects of nitrogen levels and date of harvest on harvested seed yield (kg/ha).

(a) Effects of nitrogen levels on harvested seed yield (kg/ha)

	Nitrogen levels					
Species	N_o	N_{100}	N_{200}	N_{400}	Means	S.E.
Buffel grass	558.0	906.0	1000.0	942.4	851.6	
Gatton panic	516.8	823.6	1043.2	1059.6	860.8	±25.2
Green panic	439.2	817.6	927.2	829.2	753.4	
Means	504.7	849.1	990.1	943.7		±119.6

(b) Effects of date of harvest on harvested seed yield (kg/ha)

	Date of harvest in 1976					
Species	18MAY	1JUN	15JUN	29JUN	Means	S.E.
Buffel grass	1558.4	1349.2	391.2	107.6	851.5	
Gatton panic	1225.6	900.6	1022.0	294.8	860.8	±25.2
Green panic	1786.8	548.4	480.4	197.6	753.3	
Means	1523.6	932.8	631.2	200.0		±119.6

S.E.

N x S = ±50.8

S x D = ±50.8

The quantity of clean seed obtained decreased progressively with later dates of harvest. In buffel grass and green panic, about 85.4 and 77.5 per cent respectively, the total quantity of seed produced were recorded from the first two harvests, but in gatton panic, with longer period of flowering, high seed yield was still recorded in the third harvest (Table 13(b). The total clean seed yields of 851.6 and 860.8 kg/ha for buffel grass and gatton panic respectively were similar, but were significantly higher ($P<0.001$) than the 753.3 kg/ha for green panic 1

The yields of pure seed, presented in Table 14 were obtained from the product of harvested clean seed yield and percentage caryopsis contents. The harvested pure seed yields were influenced by the levels of nitrogen and dates of harvest in the same way as the harvested clean seed yields. Buffel grass, with an average of 578.0 kg/ha of harvested pure seed, was superior to gatton panic and green panic which produced 372.1 and 308.0 kg/ha respectively.

4.1.4.8 Efficiency of seed yield response to applied nitrogen

The efficiency of response of potential and harvested seed yields to applied nitrogen Table 15(a) decreased with increase in nitrogen levels, although the potential seed yield in green panic and buffel grass exhibited a different pattern (Table 15(a). Efficiency of potential seed yield response varied from 1.88 kg/kgN at the N_{100} to 1.67 kg/kgN at the N_{400} level in buffel grass and 9.3 from kg/kgN at N_{100} to 6.24 kg/kgN at N_{400} level in gatton panic. In the green panic, the highest return of 7.37 kg seed per kg of applied nitrogen occurred at the N_{200} level.

On the average, the efficiency of potential seed yield responses to applied nitrogen in gatton panic and green panic more than doubled that of buffel grass.

Table 14 Effects of nitrogen levels and dates of harvest on harvested pure seed yield (kg/ha).

(a): Effects of nitrogen levels on harvested pure seed yield (kg/ha).

	Nitrogen levels					
Species	N_o	N_{100}	N_{200}	N_{400}	Means	S.E.
Buffel grass	346.0	612.0	692.0	662.0	578.0	
Gatton panic	200.0	350.4	461.6	476.4	372.1	±15.2
Green panic	156.0	313.6	403.6	358.8	308.0	
Means	234.0	425.3	519.1	499.1		±67.6

(b): Effects of date of harvest on harvested pure seed yield (kg/ha)

	Dates of harvest in 1976					
Species	18MAY	1 JUN	15 JUN	29 JUN	Means	S.E.
Buffel grass	1023.6	922.4	287.2	78.8	578.0	
Gatton panic	524.0	391.2	442.0	131.2	372.1	±15.2
Green panic	704.8	229.2	209.6	88.4	308.0	
Means	750.8	514.3	312.9	99.5		±67.6

S.E.

N x S = ±30.4

S x D = ±30.4

Table 15 Effects of nitrogen levels on efficiency of seed yield response to applied nitrogen (kg/kgN)

(a): Potential seed yield per unit of applied nitrogen.

	Nitrogen levels				
Species	N_{100}	N_{200}	N_{400}	Means	S.E.
Buffel grass	1.88	3.18	1.67	2.24	
Gatton panic	9.30	8.10	6.24	7.88	±2.10
Green panic	5.68	7.37	3.83	5.62	
Means	5.62	6.22			±0.97

S.E

N x S = 3.78

(b): Harvested seed yield per unit of applied nitrogen.

	Nitrogen levels				
Species	N_{100}	N_{200}	N_{400}	Means	S.E.
Buffel grass	3.48	4.42	0.96	2.95	
Gatton panic	3.07	2.63	1.36	2.35	±2.10
Green panic	3.78	2.44	0.98	2.40	
Means	3.44	3.16	1.10		±0.97

S.E.

N x S = ±1.90

For the harvested seed yield, the efficiency of response of gatton panic to applied nitrogen was lower than that of green panic at N_o, but increased with nitrogen levels (Table 15(b). Buffel grass had higher efficiency values than gatton panic and green panic at N_{100} and N_{200} but lower at N_{400}. The average efficiency figures for buffel grass, gatton panic and green panic were 2.95, 2.35 and 2.40 kg/kgN , respectively. Efficiencies of response of harvested seed yield to applied nitrogen in gatton panic and green panic were three and two times respectively lower than those of potential seed yield. In contrast, buffel grass had a higher efficiency in the harvested rather than potential seed yields (Tables 15(a) and 15(b).

Calculated values of efficiency of pure seed response to applied nitrogen are shown in Table 16. The patterns of response to applied nitrogen are similar to those of potential crude seed and harvested clean seed yields. In all species the efficiencies of harvested pure seed yield response to applied nitrogen were lower than those of potential pure seed yields.

4.1.4.9 Harvest efficiency

Harvest efficiencies, calculated as percentage of total harvested clean seed yield to total potential seed yield are shown in Table 17. Maximum seed efficiencies of 92.9 and 59.9 per cent were recorded for buffel grass and green panic, respectively at the N_{100} level; for gatton panic, harvest efficiency declined from the highest figure of 56.6 per cent without nitrogen to progressively lower values with increasing nitrogen application.

Table 16: Efficiency of pure seed yield response to applied nitrogen (kg/kg)(

Species		Nitrogen levels N100	N200	N400	Means
Buffel grass	(a)*	2.75	2.49	1.36	2.20
	(b)**	2.66	1.73	0.79	1.73
Gatton panic	(a)	4.42	3.87	2.90	3.73
	(b)	1.50	1.31	0.69	1.17
Green panic	(a)	2.46	3.53	1.89	2.63
	(b)	1.58	1.23	0.51	1.11

* Returns of potential pure seed yield to applied nitrogen

** Returns of harvested pure seed yield to applied nitrogen

Table 17: Effect of nitrogen levels on harvest efficiency (%)

Species	Nitrogen levels N_o	N_{100}	N_{200}	N_{400}	Means	S.E.
Buffel grass	70.9	92.9	70.3	64.6	74.7	
Gatton panic	56.6	44.7	41.2	31.1	43.4	±1.71
Green panic	55.1	59.1	59.9	35.6	47.9	
Means	60.9	65.8	50.8	43.8		±1.85

S.E.

N x S = ±3.08

In all the species, the least harvest efficiencies of 64.6, 31.1 and 35.6 per cent for buffel grass, gatton panic and green panic, respectively, occurred at N_{400}. Harvest efficiencies, averaged over the four nitrogen levels were 74.7, 43.4 and 47.9 per cent, respectively for buffel grass, gatton panic and green panic.

4.1.5 Herbage dry matter yield and efficiency of response to applied nitrogen

Extremely high herbage dry matter yields were recorded for all species without nitrogen treatment. Dry matter yields increased up to N_{400} for all species, but only in buffel grass were significant differences observed beyond the N_{100} level (Table 18). For the range, N_o to N_{100}, dry matter yields of buffel grass, gatton panic and green panic varied from 11501 to 16494, 10813 to 16844, and 10654 to 13976 kg/ha respectively. Average dry matter yields of buffel grass and gatton panic were similar, and significantly higher ($P<0.05$) than that of green panic.

Efficiencies of herbage dry matter response to applied nitrogen decreased with increasing levels of nitrogen application (Table 19). Gatton panic had the highest efficiency while those of buffel grass and green panic, were similar. In the range, N_{100} to N_{400}, efficiencies of dry matter yield response to applied nitrogen in buffel grass, gatton panic and green panic were 20.6 to 12.5, 43.7 to 15.1 and 27.8 to 8.3 kg/kgN, respectively1

Table 18: Effect of nitrogen levels on herbage dry matter yields (kg DM/ha).

Species	Nitrogen levels N_o	N_{100}	N_{200}	N_{400}	Means	S.E.
Buffel grass	11501	13563	15075	16494	14158	
Gatton panic	10813	15184	15967	16844	14702	±463.6
Green panic	10654	13432	13881	13976	12986	
General means	10989	14060	14974			±418.3

S.E.

N x S = ±642.1

4.1.6 Crop index

Crop index figures, calculated as the percentage of seed yield to herbage dry matter yield on individual treatment basis, are presented in Table 20. Crop indices were calculated separately for potential seed yield (Table 20(a) and for harvested clean seed yield (Table 20(b). Crop indices based on the above two parameters increased markedly with additional nitrogen, except in buffel grass where maximum crop index occurred at the N_{200} level (Table 20(a) and 20(b). Crop indices based on potential seed yields for buffel, gatton panic and green panic averaged 8.08, 14.17 and 12.67 per cent respectively, with corresponding figures for harvested clean seed yield of 5.97, 5.76 and 5.70 per cent. Gatton panic and green panic were more than two times better in the potential seed yield than harvested clean seed yields.

4.1.7 Herbage crude protein and phosphorus contents

Addition of fertilizer nitrogen resulted in significant increases ($P<0.05$) in herbage crude protein contents within and between the species (Table 21). The crude protein levels ranged from 5.11 to 9.51, 5.73 to 11.76 and 5.48 to 9.75 per cent in buffel grass, gatton panic and green panic respectively. Irrespective of nitrogen level, gatton panic was the richest in crude protein.

Phosphorus contents maximised without nitrogen application in all the species, decreasing to the lowest values at the N_{400} level in all but gatton panic where the lowest value of 0.835 per cent occurred at N_{200} (Table 22).

Table 19: Efficiency of herbage dry matter yield response to applied nitrogen (kgDM/kgN).

Species	Nitrogen levels			Means	S.E.
	N_{100}	N_{200}	N_{400}		
Buffel grass	20.6	17.9	12.5	17.0	
Gatton panic	43.7	25.8	15.1	28.2	±0.71
Green panic	27.8	16.1	8.3	17.4	
Means	30.7	19.9	12.0		±0.64

S.E.

N x S = ±1.02

Table 20 . Effect of nitrogen levels on crop index (%).

(a): Total potential seed yield/herbage dry matter yield (%).

Species	Nitrogen levels N_o	N_{100}	N_{200}	N_{400}	Means	S.E.
Buffel grass	6.85	7.19	9.44	8.84	8.08	
Gatton panic	8.44	12.14	15.87	20.23	14.17	±0.527
Green panic	7.47	10.15	16.37	16.67	12.67	
Means	7.59	9.83	13.89	15.25		±0.412

S.E.

N x S = ±0.805

(b); Total harvested clean seed yield/herbage dry matter (%)

Species	Nitrogen levels N_o	N_{100}	N_{200}	N_{400}	Means	S.E.
Buffel grass	4.85	6.68	6,63	5.71	5.91	
Gatton panic	4.78	5.42	6.53	6.29	5.76	±0.409
Green panic	4.12	6.09	6.68	5.93	5.70	
Means	4.58	6.06	6.61	5.97		±0.368

S.E.

N x S = ±0.641

Table 21: Effects of nitrogen levels on herbage crude protein contents (%)

Species	Nitrogen levels N_o	N_{100}	N_{200}	N_{400}	Means	S.E.
Buffel grass	5.11	5.55	8.28	9.51	7.11	
Gatton panic	5.73	7.31	9.57	11.76	8.59	±0.416
Green panic	5.48	6.03	8.38	9.75	7.41	
Means	5.44	6.30	8.70	10.34		±0.331

S.E.

N x S = ±0.734.

Table 22: Effect of nitrogen levels on herbage phosphorus content (ppm)

Species	Nitrogen levels				Means	S.E.
	N_o	N_{100}	N_{200}	N_{400}		
Buffel grass	1698	866	829	814	1052	
Gatton panic	1369	1035	839	845	1022	±20.0
Green panic	1363	900	854	813	983	
Means	1477	934	841	824		±90.0

S.E.

N x S = ± 130.

Relative to no nitrogen application, N_{100} resulted in decreases of 49.0, 24.4 and 34.0 per cent phosphorus in the herbages of buffel grass, gatton panic and green panic respectively. Buffel grass and gatton panic herbages contained almost the same amount of phosphorus, which very highly significantly ($P<0.001$) exceeded that of green panic.

4.2 Experiment 2: Effect of row spacing on seed production of Biloela buffel grass.

4.2.1 Soil properties

Soil nitrogen levels at the experimental site increased with increasing soil depth. Total nitrogen contents varied from 0.087 at 0-15 cm to 0.112 per cent at 30-45 cm depth (Table 3). Phosphorus content of the bulked soil was 351 ppm. Exchangeable cations of calcium, magnesium and potassium were 2.38, 0.436 and 0.190 milliequivalents per 100 gm of soil respectively. The soil had a pH value of 6.3, indicating slight acidity. When compared with the interpretations of soil mineral analyses, as summarised in Appendix 3, the levels of soil nitrogen, phosphorus and calcium were adequate for good grass growth, while magnesium and potassium were deficient.

4.2.2 Meteorological observations

Rainfall records for the experimental year 1976, showed that the rains came as late as May, terminated in September and totalled 771.4 mm/annum in 64 rainy days. This is far below the 50-year average of 1041 mm/annum in 79 rainy days. Mean relative humidities during July, August, September and October (the experimental period), were 70.0, 77.0, 70.5 and 55.0 per cent respectively. Mean maximum and mean minimum temperatures between July and October were 29.5 and 19.2°C respectively, while daily sunshine hours were 6.0, 4.6, 7.7 and 8.8 hours for July, August, September and October respectively.

Table 3: Chemical composition of the soil on the upland experimental site, Shika.

Soil depths (cm)	Total N (%)	P (ppm)	Exchangeable cations (me/100g soil)			pH (H_2O)*
			Ca	Mg	K	
0-15	0.087					
15-30	0.093	351	2.38	0.436	0.190	6.5
30-45	0.112					

* See interpretations in Appendix 3.

4.2.3 Shoot density and fertility

The broadcast treatment gave a significantly higher ($P<0.01$) shoot density than all the row spacing treatments, at all the four dates of sampling (Table 23). Shoot densities increased almost linearly with decrease in row widths, narrowing row widths from 90 to 30 cm more than doubled the shoot density. Maximum shoot densities in the broadcast and 30 cm row spacing treatments occurred on the first date of sampling (64 days after sowing) compared with the wider rows of 60 and 90 cm where this was observed on day 106. In the broadcast and all row spacing treatments, shoot densities decreased significantly ($P<0.05$) at the second harvest (78 days after sowing), and thereafter rose again, with the increase in shoot number by day 106 being most rapid in the broadcast and 60 cm rows.

Shoot fertility was estimated 92 days after sowing when the first seed harvest was carried out. Shoot fertility increased from 30.6 per cent in the broadcast treatment to 47.3 per cent in the 60 cm row spacing, then fell to 43.1 per cent in the 90 cm row spacing, but these differences were not significant (Table 24).

4.2.4 Seed yield and seed yield components

4.2.4.1 Inflorescence density

Inflorescence density increased with narrower row spacing (Table 25). By reducing the inter-row spacing from 90 to 30 cm, the inflorescence densities more than doubled during the first three sampling dates.

Table 23: Effect of row spacing on shoot density (no/m²) of Biloela buffel grass.

Sampling (1977)		Spacings(cm)					
Date	Days after sowing	Br*	30	60	90	Means	S.E.
20 September	64	1280	981	531	341	783	
3 October	78	791	681	407	250	533	±27.1
17 October	92	934	803	551	362	662	
31 October	106	1167	862	689	391	777	
Means		1043	832	544	360		±20.9

S.E.

D x S = ±45.2

*Br = Broadcast.

Table 24: Effect of row spacing on shoot fertility and inflorescence length of Biloela buffel grass

Parameters	Spacings (cm) Br	30	60	90	Means	S.E.
Shoot fertility (%)	30.6	39.3	47.3	43.1	40.1	±3.350
Inflorescence length (cm)	9.2	9.6	9.9	10.3	9.73	±0.566

Table 25: Effect of row spacing on inflorescence density (no/m²) of Biloela buffel grass.

Sampling (1977)		Spacings (cm)					
Date	Date after sowing	Br	30	60	90	Means	S.E.
20 September	64	142	119	67	40	92.0	
3 October	78	192	231	231	95	165.0	±7.2
17 October	92	386	392	309	186	318.3	
31 October	106	73	81	70	46	67.5	
Means		198.3	205.8	147.0	91.8		±8.5

S.E.

D x S = ±13.2

Broadcast treatment produced significantly higher ($P<0.01$) inflorescence densities than the 60 and 90 cm row spacing treatments, and was superior to the 30 cm rows at the first sampling date. In all the treatments, inflorescence densities increased to a peak on day 92 (at the first harvest of ripe heads); the increases being 244, 273, 242 and 146 for the broadcast, 30, 60 and 90 cm rows respectively over the 28-day period.

4.2.4.2 Number of ripe inflorescences and inflorescence length

The number of ripe inflorescences obtained at the two harvest were 399, 413, 329 and 201 for the broadcast, 30, 60 and 90 cm row treatments respectively (Table 26). The number of ripe heads obtained at the first harvest represented 79.9 per cent of the total number of ripe heads that were harvested. Effects of row spacing and broadcasting on number of ripe heads were of the same order as those of inflorescence density, described above.

Inflorescence lengths increased steadily as rows became wider, but the differences were not significant (Table 24). Broadcast treatment produced the shortest average inflorescence length of 9.2 cm, and the 90 cm rows had the longest heads of 10.3 cm.

4.2.4.3 Number of seeds per inflorescence

The broadcast and 30 cm row spacing produced the same number of seeds per inflorescence, which were significantly lower ($P<0.05$) than those of the 60 and 90 cm rows (Table 27). In all treatments, the earlier-formed inflorescences had significantly more seeds than the later-formed inflorescences.

Table 26: Effect of row spacing on number of ripe inflorescence (heads)

Number of harvest	Spacings (cm) Br	30	60	90	Means	S.E.
1	326	332	259	155	268	
2	73	81	70	46	67.5	±6.5
Total number heads harvested	399	413	329	201		±6.9
Means	99.5	206.5	164.5	100.5		

S.E.

D x S = ±8.6

Table 27: Effect of row spacing on number of seeds (no/m²) per inflorescence.

Times of harvest	Spacings (cm) Br	30	60	90	Means	S.E.
1	125	125	128	130	127	
2	116	117	121	124	119	±1.279
Means	120.5	121	124.5	127		±2.094

S.E.

Times of harvest(T) x Spacing(S) = ±2.865

In both the early and late-formed inflorescences, the number of seeds produced increased with wider row spacings, with a significant between the 30 and 90 cm row spacing treatments.

4.2.4.4 Seed size

Seed sizes (seed weight) under the row spacing treatments were slightly higher than that of the broadcast; and between the row spacings, seed size increased with increase in row widths, but the difference was not statistically significant (Table 28). In both the broadcast and row spacing treatments, the earlier-formed seeds were heavier than the later-formed seeds.

4.2.4.5 Caryopsis content

Row spacing treatments did not have any significant effect on the caryopsis contents of the florets, but gave slightly higher values than the broadcast treatment (Table 29). The later harvested florets had significantly lower ($P<0.05$) caryopsis contents than the earlier-harvested florets. In both harvests maximum caryopsis content was attained at the 60 cm row spacing.

4.2.4.6 Potential seed yield

Potential seed yield included shed seeds, which were estimated from examination of the number of abscission calluses using hand lens, and all seeds still attached to the inflorescence.

Table 28: Effect of row spacing on seed size (mg/seed)

	Spacings (cm)					
Times of harvest	Br	30	60	90	Means	S.E.
1	1.832	1.865	1.892	1.902	1.873	
2	1.767	1.780	1.792	1.835	1.794	±0.0115
Means	1.800	1.822	1.842	1.869		±0.0450

S.E.

T x S = ±0.0563

Table 29: Effect of row spacing on caryopsis content (%)

Times of harvest	Spacings (cm)				Means	S.E.
	30	50	60	90		
1	52.75	53.50	54.00	53.75	53.50	±0.612
2	50.50	51.50	51.75	51.25	51.25	
Means	51.62	52.50	52.88	52.50		

S.E.

T x S = ±3.075

The methods of establishment had very strong effects on the potential amount of seed produced. Though both number of seeds and seed sizes increased with wider row spacings, the increases did not alter enough to influence the pattern observed in the number of ripe inflorescences harvested in the two harvests, which were in favour of narrower row spacings and braodcast. Thus the first harvest gave about 81.6 per cent of the total potential seed yield, and the 30 cm row spacing had the highest potential seed yield of 943.0 kg/ha which was almost double that of the 90 cm row spacing (Table 30). The broadcast treatment produced a significantly higher quantity of seed than the 60 and 90 cm rows, and compared favourably with yield from the 30 cm row.

Pure seed yield was highest in the 30 cm row spacing and decreased significantly with increase in row width. The second harvest contributed only 20.4 per cent of the total pure seed yield. Broadcast treatment gave lower pure seed yield than the 30 cm row spacing, but was significan superior to yield from wider row widths.

4.2.4.7 Harvested seed yield and harvest efficiency

The quantity of seed recovered in the two harvests are presented in Table 31. Significantly more seeds were collected in the first harvest than the second. At both harvests the broadcast and the 30 cm rows gave similar clean seed yields which significantly ($P<0.001$) exceeded those from the 60 cm rows, and more than doubled the 90 cm row output.

The harvest efficiencies, based on totals of two harvests were 50.6, 49.5, 44.8 and 45.1 per cent for the broadcast, 30, 60 and 90 cm row spacings respectively, showing that less seed was recovered from wider row spacings (Table 32).

Table 30: Effect of row spacing on potential seed yield (kg/ha)

Times of harvest	Spacings (cm) Br	30	60	90	Means	S.E.
1	747.0	775.z	627.1	383.8	533.4	±13.09
2	148.8	167.3	150.1	104.9	142.8	
Total	895.8	943.0	777.2	488.7		
Means	447.9	471.5	388.6	244.3		±22.99

S.E.

T x S = ±31.05

Table 31: Effect of row spacing on harvested seed yield (kg/ha)

	Spacings (cm)					
Times of harvest	Br	30	60	90	Means	S.E.
1	389.3	384.8	284.4	177.1	308.9	±5.10
2	64.3	82.3	63.8	43.1	63.4	
Total	453.6	467.1	348.2	220.2		
Means	226.8	233.6	174.1	110.1		±10.09

S.E.

T x S = ±13.37

Table 32: Effect of row spacing on harvest efficiency (%)

	Spacings (cm)					
Times of harvest	Br	30	60	90	Means	S.E.
1	52.1	49.6	45.4	46.1	48.3	±0.93
2	43.2	49.1	42.5	41.1	44.0	
Means	47.7	49.4	44.0	43.6		±1.27

S.E.

T x S = ±1.88

However, when harvest efficiency is calculated for individual harvests the values, as expected are lower; thus, only 47.7, 49.4, 44.0 and 43.6 per cent recoveries were observed for the broadcast, 30, 60 and 90 cm row spacings respectively giving an overall mean of 46.2 per cent compared with 47.5 per cent for the previous method. Calculations based on individual harvests show that clean seed recovery was better in the first harvest. Seed recovery in the second harvest was significantly higher in the 30 cm row spacing than the broadcast and wider row spacings.

Since harvested pure seed yield is determined by the caryopsis content of the harvested clean seed samples, its value followed the same trend as that of the clean harvested seed yields.

4.2.5 Herbage dry matter yield

The highest herbage dry matter yield of 9.357 kg/ha, obtained from the broadcast treatment was significantly higher ($P<0.001$) than those from the 60 and 90 cm row spacings (Table 33). Narrowing the rows from 90 to 30 cm was more than doubled the herbage dry matter yield. Broadcast treatment gave over one and half times more dry matter yield than the 60 cm row spacing.

4.2.6 Crop index

Crop index values, calculated as the percentage of seed yield per treatment to dry matter yield under the same treatment, were higher from row spacings than broadcast but the difference was not significant (Table 32).

Table 33: Effect of row spacing on herbage dry matter yield (kg/ha) and Crop Index (%)

	Spacings (cm)					
	Br	30	60	90	Means	S.E.
Dry matter yield (kg/ha)	9357	8576	6050	3934	6979	±498
Crop Index* (Potential)	9.57	11.00	12.85	12.42	11.46	±0.87
Crop Index* (Harvested)	4.85	5.45	5.76	5.60	5.42	±0.42

Crop indices based on potential seed yields were about twice those based on harvested clean seed yields. In both potential and harvested clean seed yield-based crop indices, maximum values of 12.85 and 5.76 per cent respectively were obtained at the 60 cm row spacing.

4.3 Experiment 3: Effect of fertilizer nitrogen on seed production of Biloela buffel grass, gatton panic and green panic on the upland in 1978.

4.3.1 Meteorological observations and soil properties

The weather data for the experimental year, 1978, showed that the rains came as early as March, and by April about 91 mm of rain had been received. There was a good monthly distribution of rainfall before and during the experimental period, with the peak of 385.3 mm occurring in August. A total of 1205.5 mm rain fell that year, compared with the 50-year rainfall mean of 1041 mm for the same station (See also Appendix 2). Mean relative humidities during July, August, September and October were 77.0, 74.5, 72.5 and 59.5 per cent respectively. Mean maximum and mean minimum temperatures from July to October were 29.2 and 19.3°C respectively, while daily sunshine averaged 4.6, 6.2, 7.4 and 8.2 hours for July, August, September and October respectively. The characteristics of the soil at the site used for the trial have been reported in Experiment 2.

4.3.2 Shoot density and fertility

Shoot densities of the three species were estimated at the two harvests on 10 and 24 October or 84 and 98 days after sowing. Shoot densities estimated at the second harvest included the main fertile shoots from which inflorescences had been cut at the first harvest. The three species showed marked positive responses to increasing levels of fertilizer nitrogen (Table 34(a). Highly significant differences ($P<0.01$) in shoot densities occurred between fertility levels up to N_{400} in gatton panic and green panic and N_{600} in buffel grass.

Table 34 : Effect of nitrogen levels and date of harvest on shoot density (no/m²)

(a): Effect of nitrogen levels on shoot density (no/m²)

	Nitrogen levels					
Species	N_o	N_{200}	N_{400}	N_{600}	Means	S.E.
Buffel grass	858	939	1019	1182	1000	
Gatton panic	502	581	662	703	612	±18.19
Green panic	457	657	738	777	657	
Means	606	726	807	887		°21.00

(b): Effect of nitrogen levels and date of harvest on shoot density (no/m²) irrespective of species.

Harvesting (1978)		Nitrogen levels					
Date	Days after sowing	N_o	N_{200}	N_{400}	N_{600}	Means	S.E.
10 October	83	558	686	719	812	694	±13.08
24 October	97	653	765	894	963	819	
Means		606	726	807	887		±21.00

(c): Effect of date of harvest on shoot density (no/m²)

Harvesting (1978)		Species				
Date	Days after sowing	Buffel grass	Catton panic	Green panic	Means	S.E.
10 October	83	942	525	615	694	±13.08
24 October	97	1057	700	699	819	
Means		1000	612	657		±18.19

Buffel grass produced the highest number of shoots at every level of nitrogen application, the ranges being 858 without nitrogen to 1182 at N_{400} for buffel grass, 502 to 703 for gatton panic and 457 to 777 shoots/m² for green panic. Rate of shoot production between the first and second harvests was highest at the N_{400} level and lowest in the N_{200} with an overall average increase of 125 shoots/m² (Table 34(b). Significant increases in shoot density occurred between the first and second harvests, the increases being 115, 175 and 84 shoots/m² for buffel grass, gatton panic and green panic respectively (Table 34(c).

Shoot fertility was estimated only at the first date of harvest. The second harvest was taken rather late after the end of the rains. In buffel grass shoot fertility rose from 23.2 per cent at the N_0 to a maximum of 27.9 per cent at the N_{400} level then fell to 25.5 per cent at the N_{600}. The increases over the control were significant at the N_{400} and N_{600} levels (Table 35). Although significant increases in shoot fertility over the control in gatton panic occurred at all levels of nitrogen, the maximum fertility of 42.2 per cent was at the N_{200} level. Above the N_{200} level there were significant decreases in per cent shoot fertility. In green panic, nitrogen levels of N_{200} and above had similar per cent shoot fertility, which were significantly higher ($P<0.05$) than the control. Shoot fertility ranged from 37.8 per cent at N_0 to 59.8 per cent at N_{600}. The highest mean shoot fertility per cent of 54.0 was obtained from green panic, followed by gatton panic with 39.6 per cent, and buffel grass with 25.5 per cent.

Table 35: Effect of nitrogen levels on shoot fertility (%)*

Species	Nitrogen levels N_o	N_{200}	N_{400}	N_{600}	Means	S.E.
Buffel grass	23.2	25.2	27.9	25.5	25.5	
Gatton panic	36.5	42.2	40.1	39.5	39.6	±0.78
Green panic	37.8	59.7	58.8	59.8	54.0	
Means	32.5	42.4	42.3	41.6		±0.91

*$\frac{\text{Total number of inflorescences produced}}{\text{Number of shoots at final harvest.}}$

S.E.

N x S = ±1.53.

4.3.3 Seed yield components and seed yield

4.3.3.1 Inflorescence density

The number of inflorescences increased significantly with increase in nitrogen levels in all three grass species (Table 36(a). In green panic inflorescence density increased more than two-fold between the N_0 and N_{600} levels. Moderate increases in inflorescence densities were observed in buffel grass and gatton panic, the ranges between N_o and N_{600} being 135 to 202 and 165 to 255 inflorescences/m² respectively. Differences in inflorescence densities were more marked between species at all levels of nitrogen, and tended to increase with higher nitrogen doses. Average inflorescence densities were 173, 210 and 293/m² for buffel grass, gatton panic and green panic respectively.

Interactions between date of harvest and nitrogen levels were highly significant (Table 36(b). On the average the first harvest had more than three times the number of inflorescences of the second harvest. Counts in buffel grass and green panic showed that the first harvest had more than four and five times respectively more inflorescences than the second harvest. Compared with buffel grass and green panic, there were relatively more inflorescences in the gatton panic in the second harvest, as the first harvest was only about 63 per cent higher (Table 36(c). The interactions between nitrogen, species and date of harvest were not significant.

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Inflorescence lengths were determined during the first harvest only. In buffel grass and green panic infloresence lengths increased up to the highest nitrogen level. The ranges between N_0 and N_{600} were 9.05 to 10.05,

Table 3C : Effect of nitrogen levels and harvest date on inflorescence density (n/m²)

(a): Effect of nitrogen levels on inflorescence density (no/m²)

Species	Nitrogen levels				Means	S.E.
	N_o	N_{200}	N_{400}	N_{600}		
Buffel grass	135	170	184	202	173	
Gatton panic	165	201	220	255	210	±8.65
Green panic	174	308	331	358	293	
Means	158	227	245	272		±9.99

(b): Effect of nitrogen levels and date of harvest on inflorescence density (no/m²) irrespective of species.

Harvesting (1978		Nitrogen levels					
Date	Days after sowing	N_o	N_{200}	N_{400}	N_{600}	Means	S.E.
10 October	83	236	344	376	419	344	
24 October	97	81	110	114	124	107	±6.00
Means		158	227	245	272		±9.99

(c): Effect of date of harvest on inflorescence density (no/m²).

Harvesting (1978)		Species				
Date	Days after sowing	Buffel grass	Gatton panic	Green panic	Means	S.E.
10 Oct.	83	277	266	488	344	
24 Oct.	97	68	155	98	107	±6.00
Means		173	210	293		±8.65

S.E.
NxS = ±17.30 S x D = ±12.23
NxD = ±14.13 N x S xD ±19.98 N.S
V.S. = Not significant at P<0.05.

and 22.48 to 23.25 cm per inflorescence respectively (Table 37) but the increases were significant only at the N_{600} level. In gatton panic, maximum inflorescence length of 24.27 cm was observed at the N_{400}, but the increase over the control did not reach significant level. Gatton panic had significantly longer inflorescences at all levels of nitrogen than green panic. Both gatton panic and green panic inflorescences were more than two times longer than those of buffel grass, the average lengths being 9.59, 23.92 and 22.91 cm for buffel grass, gatton panic and green panic respectively.

4.3.3.2 Number of ripe inflorescences

The data on ripe inflorescences as presented in Table 38(a) are means of two harvests. In all the three species, the number of ripe inflorescences increased with increase in nitrogen levels. In buffel grass the increase over the control was significant ($P<0.05$) at the N_{400} and N_{600} levels, while in gatton panic and green panic, all the nitrogen levels used gave highly significant increases over the control. Gatton panic and green panic produced the same number of ripe inflorescences at the N_o level, but at nitrogen levels above this, green panic was clearly superior to gatton panic. The number of ripe inflorescences ranged from 280 at N_o to 420 at N_{600} for gatton panic with the corresponding figures of 224 to 338 and 280 to 600 for buffel grass and green panic respectively. The numbers of ripe inflorescence/m^2, averaged over the four nitrogen levels were 292, 366 and 482 for buffel grass, gatton panic and green panic respectively.

Table 37: Effects of nitrogen levels on inflorescence length (cm).

Species	Nitrogen levels				Means	S.E.
	N_o	N_{200}	N_{400}	N_{600}		
Buffel grass	9.05	9.57	9.70	10.05	9.59	
Gatton panic	23.55	24.05	24.27	23.92	23.92	±0.44
Green panic	22.43	22.82	23.13	23.25	22.91	
Means	18.34	18.82	19.03	19.03		±0.34

S.E.

N x S = ±0.78

Table 3: Effects of nitrogen levels and dates of harvest on number of harvested ripe inflorescences (no/m²)

(a) Effect nitrogen levels on number of harvested ripe inflorescences (no/m²)

Species	Nitrogen levels N_o	N_{200}	N_{400}	N_{600}	Means	S.E.
Buffel grass	224	276	330	228	292	
Gatton panic	280	368	392	420	366	±10.40
Green panic	280	510	540	600	482	
Means	262	384	420	452		±33.88

(b): Effect of nitrogen levels and date of harvest on number of harvested ripe inflorescences (no/m²). irrespective of species.

Harvesting (1978) Date	Days after sowing	Nitrogen levels N_o	N_{200}	N_{400}	N_{600}	Means	S.E.
10 Oct.	83	364	556	612	654	546	
24 Oct.	97	162	212	228	248	212	±33.88
Means		262	384	420	452		±33.88

(c): Effect of date of harvest on number of harvested ripe inflorescence (no/m²)

Harvesting (1978) Date	Days after sowing	Nitrogen levels Buffel grass	Gatton panic	Green panic	Means	S.E.
10 October	83	452	420	768	546	
24 October	97	132	310	196	212	±33.88
Means		292	366	482		±10.40

S.E.
N x S = ±36.24
S x D = ±37.84
N x S x D ±67.20 NS
N.S = Not significant at P<0.05.

The interactions between nitrogen and date of harvest were very highly significant ($P<0.001$). The first date of harvest having more than twice the number of ripe inflorescences at all levels of nitrogen treatments than the second harvest date (Table 38(b). The difference in ripe inflorescences at various dates of harvest increased progressively as the levels of nitrogen increased. On the first harvest date buffel grass and gatton panic had similar number of ripe inflorescences which were significantly lower than that of green panic (Table 38(c). The second harvest contributed 22.6, 42.3 and 20.3 per cent inflorescences to the total numbers of 292, 366 and 482 inflorescences/m^2 in buffel grass, gatton panic and green panic respectively. The interactions between nitrogen, species and date of harvest were not significant.

4.3.3.3 Number of inflorescences with shed spikelets

The number of inflorescences with shed spikelets was estimated for each of the three species on the first date of harvest, and this is presented on percentage basis in Table 39. Buffel grass had the lowest number of inflorescences with shed spikelets while gatton panic had the highest. In buffel grass, the number of inflorescences with shed spikelets was higher at the N_0 level, and decreased progressively from 20.2 per cent at N_o to 13.0 per cent at N_{600}, but the differences were not significant. The pattern in gatton panic was a complete reverse of that in buffel grass where the percentage inflorescences with shed spikelets increased from 40.0 at N_0 to 51.2 per cent at N_{600}. The percentages of shed spikelets at N_{400} and N_{600} were significantly higher ($P<0.01$) than that at N_o.

Table 39: Effects of nitrogen levels on number of shed inflorescences(%)

Species	Nitrogen levels N_0	N_{200}	N_{400}	N_{600}	Means	S.E.
Buffel grass	20.2	18.3	15.8	13.0	16.8	
Gatton panic	40.0	41.3	50.0	51.2	45.6	±3.50
Green panic	43.8	45.0	43.8	31.2	40.9	
Means	34.7	34.8	36.5	31.8		±3.60

S.E.

N x S = ±6.8

In green panic, nitrogen had little effect on the percentage inflorescences with shed spikelets which increased only slightly, from 43.8 per cent at N_0 to a maximum of 45.0 per cent at N_{200}, then fell to 43.8, and 31.2 per cent at N_{400} and N_{600} levels respectively. Gatton panic and green panic had similar percentage infloresces with shed spikelets at all levels of nitrogen, except at the N_{600} where it was significantly higher in green panic. The mean percentages of inflorescence with shed spikelets of 16.8, 45.6 and 40.9 for buffel grass, gatton panic and green panic respectively, showed that the panics were significantly more prone to shedding than buffel grass.

4.3.3.4 Number of seeds per inflorescence

The addition of nitrogen increased the number of seeds borne on each inflorescence although the difference in seed numbers between the range of nitrogen used and the control was not significant in buffel grass (Table 40(a). The greatest response in number of seeds per inflorescence to nitrogen levels occurred in gatton panic. On the average, gatton panic and green panic had about 4.5 and 4.1 times more seeds per inflorescence respectively than buffel grass.

Date of harvest had a marked effect on number of seeds per inflorescence under the various nitrogen regimes. A significantly higher ($P<0.001$) number of seeds per inflorescence resulted from the first harvest (Table 40(b). In gatton panic and green panic, the number of seeds per inflorescence obtained from the second harvest was significantly lower than those from the first harvest (Table 40(c).

Table 40: Effects of nitrogen levels and date of harvest on number of seeds per inflorescence.

(a): Effects of nitrogen levels on number of seeds per inflorescence.

Species	Nitrogen levels N_o	N_{200}	N_{400}	N_{600}	Means	S.E.
Buffel grass	119	124	131	136	127	
Gatton panic	500	566	613	614	573	±7.65
Green panic	494	510	534	543	520	
Means	371	400	426	431		±8.83

(b): Effects of nitrogen levels and date of harvest on number of seeds per inflorescence. irrespective of species.

Harvesting (1978) Date	Days after sowing	Nitrogen levels N_o	N_{200}	N_{400}	N_{600}	Means	S.E.
10 October	83	425	460	475	471	458	
24 October	97	317	340	377	390	356	±6.82
Means		371	340	377	390	356	±6.82

(c): Effect of date of harvest on number of seeds per inflorescence

Harvesting (1978) Date	Days after sowing	Species Buffel grass	Gatton panic	Green panic	Means	S.E.
10 October	83	132	653	589	458	
24 October	97	123	393	452	356	±6.82
Means		127	573	520		±7.65

S.E.
N x S = ±15.29
S x D = ±10.81
N x D = ±12.49
N x S x D= ±17.66 N.S.
N.S = Not significant at P<0.05.

The number of seeds per inflorescence in buffel grass, gatton panic and green panic, averaged over the four nitrogen levels, were 127, 573 and 520 respectively.

4.3.3.5 Seed size

Nitrogen caused significant increases in seed size among the three grass species with the greatest influence being observed in buffel grass and the least in green panic followed by gatton panic (Table 41(a) and (b). Increase in seed size due to nitrogen was highest at the N_{200} level and thereafter decreased progressively up to the N_{600} level. On the average, the weight of individual buffel grass seed was at least three times that of gatton panic and green panic. The ratios of buffel grass seed weight to gatton panic and green panic seed weights were highest at the N_0 level, being 4.3 and 3.5 respectively, and lowest at N_{600} with the corresponding values of 3.4 and 3.3.

Earlier-formed seeds were heavier than later-formed seeds, particularly at the N_0 to N_{200} range (Table 41(b), but differences in seed size between harvest dates within species was significant only in respect of buffel grass. In buffel grass, gatton panic and green panic seed sizes ranged from 1.706, 0.483 and 0.525 mg/seed respectively at the first harvest to 1.722, 0.461 and 0.511 mg/seed in the second harvest, giving corresponding mean values of 1.754, 0.472 and 0.518 mg/seed (Table 41(c). As in all the other parameters studied, the interactions between nitrogen, species and ate of harvest were not statistically significant.

Table 41: Effects of nitrogen levels and date of harvest on seed size (mg/seed).

(a): Effects of nitrogen levels on seed size (mg/seed)

Species	Nitrogen levels N_o	N_{200}	N_{400}	N_{600}	Means	S.E.
Buffel grass	1.628	1.774	1.796	1.818	1.754	
Gatton panic	0.378	0.471	0.510	0.528	0.472	±0.006
Green panic	0.457	0.523	0.543	0.549	0.518	
Means	0.821	0.923	0.950	0.965		±0.010

(b): Effects of nitrogen levels and date of harvest on seed size (mg/seed) irrespective of species.

Harvesting (1978) Date	Days after sowing	Nitrogen levels N_o	N_{200}	N_{400}	N_{600}	Means	S.E.
10 October	83	0.849	0.948	0.957	0.971	0.931	
24 October	97	0.793	0.897	0.943	0.958	0.898	±0.006
Means		0.821	0.923	0.950	0.965	.	±0.010

(c): Effects of date of harvest on seed size (mg/seed)

Harvesting (1978) Date	Days after sowing	Species Buffel grass	Gatton panic	Green panic	Means	S.E.
10 October	83	1.786	0.483	0.525	0.931	
24 October	97	1.722	0.461	0.511	0.898	±0.006
Means		1.754	0.472	0.518		±0.008

S.E.

N x S	=	±0.016
S x D	=	±0.011
N x D	=	±0.013
N x S x D	=	±0.018 N.S
N.S	=	Not significant at P<0.05.

4.3.3.6 Caryopsis content

The application of N_{200} and above resulted in significant increases in caryopsis contents over the non-fertilized treatment (Table 42(a). Maximum response to nitrogen application occurred at the N_{200} level, with buffel grass, gatton panic and green panic giving 11.5, 6.38 and 2.37 per cent more caryopsis respectively than the control. The magnitude of increase in caryopsis content decreased with increase in nitrogen levels in all the three grass species, except in green panic which showed a slight increase at the N_{600} level. At the N_{200} and N_{400} levelsp gatton panic caryopsis was significantly heavier ($P<0.01$) than green panic even though green panic caryopsis was heavier at N_o. The addition of nitrogen gave a greater increase in the caryopsis content of buffel grass than those of gatton panic and green panic. Earlier-harvested inflorescences at N_{200} and above had significantly more caryopses ($P<0.05$) than later-harvested inflorescences that were similarly fertilized (Table 42(b). Significant differences in caryopsis contents between harvests occurred in gatton panic and green panic, but not in buffel grass (Table 42(c). The interactions occurred between nitrogen, species and date of harvest were not statistically significant.

4.3.3.7 Potential seed yield

Highly significant potential clean seed yield increases over the control, N_o were observed in all the three grass species; up to the highest level of nitrogen tested (N_{600}). The ranges were 439.4 kg/ha at N_o to 845.6 kg/ha at N_{600} in buffel, with corresponding ranges of

Table 42: Effects of nitrogen levels and date of harvest on caryopsis content (%).

(a): Effects of nitrogen levels on caryopsis content (%)

Species	Nitrogen levels N_o	N_{200}	N_{400}	N_{600}	Means	S.E.
Buffel grass	48.50	60.00	60.50	61.00	57.50	
Gatton panic	30.25	36.63	37.88	38.13	35.72	±1.00
Green panic	30.88	33.25	34.75	37.00	33.97	
Means	36.54	43.29	44.38	45.38		±1.15

(b): Effects of nitrogen levels and date of harvest on caryopsis content (%) irrespective of species.

Harvesting (1978) Date	Days after sowing	Nitrogen levels N_o	N_{200}	N_{400}	N_{600}	Means	S.E.
10 October	83	38.25	46.33	47.00	48.00	44.90	±0.44
24 October	97	34.83	40.25	41.75	42.75	39.90	
Means		36.54	43.29	44.38	45.38		±1.15

(c): Effects of date of harvest on caryopsis content (%)

Harvesting (1978) Date	Days after sowing	Species Buffel grass	Gatton panic	Green panic	Means	S.E.
10 October	83	58.88	38.81	37.00	44.90	
24 October	97	56.13	32.63	30.94	39.90	±0.44
Means		57.50	35.72	33.97		±1.00

S.E.

N x S	=	±1.99
S x D	=	±1.41
N x D	0	±1.62
N x S x D	=	±2.30 N.S

NS = Not significant at P<0.05

534.8 to 1387.4 and 694.4 to 1888.2 kg/ha for gatton panic and green panic respectively, (Table 43(a). Seed yield increases above the N_{400} level were highly significant for green panic but not buffel grass and gatton panic. Green panic and gatton panic produced more than two times and one a half times more seed respectively than buffel grass at all levels of nitrogen tested. Between the panics, green panic was superior at all the levels of nitrogen tested with the highest and lowest differences occurring at the N_{600} and N_0 levels, respectively.

The interaction between date of harvest and nitrogen levels was significant ($P<0.001$) the first harvest seed yield being over 330 per cent of the second harvest seed yield (Table 43(b). Highly significant interactions were also observed between date of harvest and grass species (Table 43(c). The quantities of seed produced at the first harvest by buffel grass, gatton panic and green panic were about 3.8, 1.9 and 5.2 times higher than those of the second harvest respectively. The interactions between nitrogen, species and date of harvest were as usual, not significant.

Pure seed yield greatly responded to nitrogen application (Table 44(a). At the N_o level pure seed yields were 218.6, 161.8 and 224.2 kg/ha for buffel grass, gatton panic and green panic respectively, with the corresponding pure seed yields of 524.4, 542.6 and 739.6 kg/hr at the N_{600} level. Buffel grass and gatton panic differed only slightly at N_{200} and above, but green panic produced highly significantly ($P<0.01$) of pure seed than these species at all levels of nitrogen. The rate of increase in pure seed yield was highest at the N_{200} treatment and decreased progressively with higher levels of nitrogen. Nitrogen and date of harvest interacted strongly, as the first harvest date produced 3.6,41, 3.8 and

Table 43: Effects of nitrogen levels and dates of harvest on potential seed yield (kg/ha).

(a): Effects of nitrogen levels on potential seed yield (kg/ha)

Species	Nitrogen levels				Means	S.E.
	N_o	N_{200}	N_{400}	N_{600}		
Buffel grass	439.4	644.4	791.4	845.6	680.0	
Gatton panic	534.8	1025.4	1255.4	1387.8	1050.8	±57.56
Green panic	694.4	1517.4	1677.2	1888.2	1444.3	
Means	556.2	1062.4	1241.3	1373.7		±66.46

(b): Effects of nitrogen levels and date of harvest on potential seed yield (kg/ha). irrespective of species.

Harvesting in 1978		Nitrogen levels					
Date	Days after sowing	N_o	N_{200}	N_{400}	N_{600}	Means	S.E.
10 October	83	850.0	1665.2	1902.8	2080.2	1624.6	
24 October	97	262.4	459.6	579.8	667.2	492.3	±42.30
Means		556.2	1062.4	1241.3	1373.7		±66.46

(c): Effects of date of harvest on potential seed yield(kg/ha)

Harvesting in 1978		Species				
Date	Days after sowing	Buffel grass	Gatton panic	Green panic	Means	S.E.
10 October	83	1076.0	1375.2	2422.4	1624.6	±42.34
24 October	97	284.2	726.4	466.2	492.3	
Means		680.1	1050.8	1444.3		±57.56

S.E.

N x S	=	±115.12
S x D	=	±81.40
N x D	=	±94.00

3.6 times more pure seed than the second harvest date at the N_0, N_{200}, N_{400} and N_{600} levels respectively (Table 44(b). A significant interaction occurred between date of harvest and species, with first harvest seed yields in buffel grass, gatton panic and green panic respectively being 3.8, 2.3 and 6.2 times higher than those of the second harvest (Table 44(c). No significant interactions were observed between nitrogen, species and date of harvest.

4.3.3.8 Harvested seed yields

Positive harvested seed yield responses to nitrogen were recorded for all the three grass species (Table 45(a). The magnitude of increase in seed yield was highest at the N_{200} level and thereafter decreased progressively with further nitrogen increments. Gatton panic had a significantly lower ($P<0.01$) harvested seed yield than buffel grass at the N_0 level. At the N_{600} level however, the superiority was reversed in favour of gatton panic which produced 663.6 kg/ha compared with 570.6 kg/ha for buffel grass. Harvested seed yield in green panic varied from 383.6 kg/ha at N_0 to 777.4 kg/ha at N_{600}. At nitrogen levels of N_{200} and above, green panic gave significantly higher seed yields than buffel grass and gatton panicF

Harvested seed yield was positively and markedly influenced by levels of nitrogen application at each harvest date (Table 45(b). Though buffel grass produced significantly higher ($P<0.01$) yield of harvested seed at the first harvest date than gatton panic, tota. seed yield from the two harvests were similar, due to the superior second harvest seed yield by gatton panic (Table 45(c).

Table 44: Effects of nitrogen levels and dates of harvest on potential pure seed yield (kg/ha).

(a): Effects of nitrogen levels on potential pure seed yield (kg/ha)

Species	Nitrogen levels				Means	S.E.
	N_o	N_{200}	N_{400}	N_{600}		
Buffel grass	218.6	393.0	478.2	524.4	403.6	
Gatton panic	161.8	386.0	488.4	542.6	394.8	±45.00
Green panic	228.2	533.6	611.0	739.6	528.1	
Means	202.8	437.5	525.9	602.2		±52.00

(b): Effects of nitrogen levels and date of harvest on potential pure seed yield (kg/ha) irrespective of species.

Harvesting in 1978		Nitrogen levels					
Date	Days after sowing	N_o	N_{200}	N_{400}	N_{600}	Means	S.E.
10 October	83	317.0	703.8	831.2	943.4	698.0	
24 October	97	88.6	171.2	220.6	260.8	185.3	±43.00
Means		202.8	437.5	525.9	602.		

(c): Effects of date of harvest on potential pure seed yield (kg/ha)

Harvest in 1978		Species				
Date	Days after sowing	Buffel grass	Gatton panic	Green panic	Means	S.E.
10 October	83	640.0	548.2	908.6	698.9	
24 October	97	1067.2	241.4	147.6	185.4	±43.00
Means		403.6	394.8	528.1		±45.00

S.E.

N x S	=	±90.00
S x D	=	±63.60
N x D	=	±73.60
N x S x D	=	±127.00

Table 45: Effects of nitrogen levels and dates of harvest on harvested clean seed yield (kg/ha)

(a): Effects of nitrogen levels on harvested seed yield (kg/ha)

Species	Nitrogen levels				Means	S.E.
	N_o	N_{200}	N_{400}	N_{600}		
Buffel grass	313.8	442.6	532.4	570.6	464.9	.
Gatton panic	234.2	425.8	590.0	663.6	478.4	±23.90
Green panic	283.6	559.2	702.2	777.4	580.6	
Means	277.2	475.9	608.2	670.4		±27.60

(b): Effects of nitrogen levels and dates of harvest on harvested seed yield (kg/ha) irrespective of species.

Harvest in 1978		Nitrogen levels					
Date	Days after sowing	N_o	N_{200}	N_{400}	N_{600}	Means	S.E.
10 October	83	433.2	726.6	918.8	1001.2	770.2	
24 October	97	121.2	225.2	297.4	339.6	245.8	±26.64
Means		277.2	475.9	608.2	670.4		±27.60

(c): Effects of dates of harvest on harvested seed yield(kg/ha)

Harvest in 1978		Species				
Date	Days after sowing	Buffel grass	Gatton panic	Green panic	Means	S.E.
10 October	83	715.8	162.6	965.1	770.2	±26.64
24 October	97	214.0	327.2	196.2	245.8	
Means		464.9	478.4	580.6		±23.90

S.E.

N x S	=	±47.80
S x D	=	±33.80
N x D	=	±38.02
N x S x D	=	±55.20

In green panic, buffel grass and gatton panic, the first harvest seed yields were respectively five, three and two times greater than those of the second harvest. There were no significant interactions betweeen nitrogen, species and date of harvest.

Harvested pure seed yields increased progressively as the levels of nitrogen were increased (Table 46(a). Pure seed yields increased from 159.8, 72.8 and 94.0 kg/ha for buffel grass, gatton panic and green panic respectively to the corresponding seed yields of 351.6, 259.0 and 304.0 kg/ha at the N_{600} level. Buffel grass consistently and significantly gave more ($P<0.001$) pure seed yields than gatton panic and green panic at all levels of nitrogen. At all nitrogen levels green panic produced more pure seed yields than gatton panic but the difference was not significant.

Significant interactions occurred between date of harvest and nitrogen levels. Harvested pure seed yield from the first harvest was more than three and half times higher than that of the second harvest (Table 46(b). The superiority of the first harvest yields over the second harvest yields was also demonstrated by each of the grass species (Table 46(c), but no significant interactions occurred between nitrogen, species and date of harvest.

4.3.3.9 Efficiency of seed yield response to applied nitrogen

The efficiencies of the potential and harvested seed yield response to applied nitrogen are summarised in Table 47(a) and 47(b). A curvilinear response to increasing nitrogen levels was observed for both the potential and harvested seed yields.

Table 46: Effects of nitrogen levels and dates of harvest on harvested pure seed yields (kg/ha)

(a): Effects of nitrogen levels on harvested pure seed yields (kg/ha)

	Nitrogen levels					
Species	N_o	N_{200}	N_{400}	N_{600}	Means	S.E.
Buffel grass	149.8	267.8	328.8	351.6	274.5	
Gatton panic	72.8	156.6	229.8	259.0	179.6	±12.32
Green panic	94.0	196.6	256.4	304.0	212.7	
Means	105.0	207.0	271.7	304.9		±14.24

(b): Effects of nitrogen levels and dates of harvest on harvested pure seed yield (kg/ha) irrespective of species.

Harvest in 1978		Nitrogen levels					
Date	Days after sowing	N_o	N_{200}	N_{400}	N_{600}	Means	S.E.
10 October	83	168.6	327.0	422.8	471.4	347.5	
24 October	87	42.4	87.0	120.4	138.2	97.0	±10.92
Means		105.5	207.0	271.6	304.8		±14.24

(c): Effects of dates of harvest on harvested pure seed yields (kg/ha)

Harvest in 1978		Species				
Date	Days after sowing	Buffel grass	Gatton panic	Green panic	Means	S.E.
10 October	83	429.4	249.8	363.2	347.5	
24 October	87	119.6	109.2	62.2	97.0	±10.92
Means		274.5	179.5	212.7		±12.32

S.E.

$\overline{N \times S}$	=	24.66
S x D	=	17.44
N x D	=	20.12
N x S x D	=	28.46

Buffel grass, gatton panic and green panic at N_{200} respectively had potential seed yields response to applied nitrogen of 0.88, 1.80 and 2.46 kg/kgN compared with the corresponding value of 0.68, 1.42 and 1.99 kg/kgN at N_{600}. Efficiency of potential seed yield response in buffel grass, averaged over the four nitrogen levels was less than one-half and a third of those of gatton panic and green panic respectively. Efficiency of response was more than two times higher in the potential seed yield than in the harvested seed yield for gatton panic and green panic, but in buffel grass, the ratio was about one and half times.

4.3.3.10 Harvest efficiency

Buffel grass had a significantly higher ($P<0.001$) harvest efficiency than gatton panic and green panic at all nitrogen levels (Table 48). In buffel grass the highest harvest efficiency, 77.9 per cent, occurred at the N_{400} level and this was significantly higher than that of the control. Harvest efficiency was lowest at the N_{600} level for buffel grass and green panic and at N_{200} for gatton panic. Nitrogen application had an inconsistent effect on harvest efficiency of gatton panic. Gatton panic and green panic had about the same harvest efficiencies over the range of nitrogen levels tested.

4.3.4 Herbage dry matter yield

Gatton panic produced significantly higher ($P<0.001$) herbage dry matter yield than buffel grass without nitrogen but the yields were similar at higher nitrogen levels (Table 49). Gatton panic dry matter yields substantially exceeded those of green panic at all levels of

Table 47: Effects of nitrogen levels on efficiency of seed yield response (kg/kgN)

(a): Potential seed yield per unit of applied nitrogen (kg/kgN)

Species	Nitrogen levels N_{200}	N_{400}	N_{600}	Means	S.E.
Buffel grass	1.03	0.88	0.68	0.86	
Gatton panic	2.45	1.80	1.42	1.89	±0.190
Green panic	4.12	2.46	1.99	2.86	
Means	2.53	1.71	1.36		±0.163

S.E.
N x S = ±0.572

(b): Harvested seed yield per unit of applied nitrogen (kg/kgN)

Species	Nitrogen levels N_{200}	N_{400}	N_{600}	Means	S.E.
Buffel grass	0.64	0.55	0.43	0.54	
Gatton panic	0.93	0.89	0.72	0.85	±0.190
Green panic	1.38	1.05	0.82	1.08	
Means	0.98	0.83	0.66		±0.163

S.E.

N x S = ±0.314

Table 48: Effect of nitrogen levels on harvest efficiency (%)

Species	Nitrogen levels				Means	S.E.
	N_o	N_{200}	N_{400}	N_{600}		
Buffel grass	68.8	71.7	77.9	68.0	71.6	
Gatton panic	43.8	41.2	47.0	47.1	44.8	±1.61
Green panic	42.2	44.2	44.1	40.6	42.8	
Means	51.6	52.4	56.3	51.9		±1.66

S.E.

N x S = ±2.96

Nitrogen. In all the three grass species, dry matter yields increased progressively with increases in nitrogen levels, giving the ranges between the N_o and N_{600} levels of 3841 to 8920, 4715 to 3558 to 7491 kg DM/ha for buffel grass, gatton panic and green panic respectively. Highly significant interactions occurred between nitrogen levels and species.

The efficiency of herbage dry matter yield response to applied nitrogen for the three grass species is presented in Table 50. Dry matter yield decreased progressively with increasing levels of nitrogen in the three grasses. The efficiency of response declined from 15.7 kg additional dry matter/kgN applied at N_{200} to 8.5 kgDM/kgN at N_{600} for buffel grass, 9.4 to 7.2 for gatton panic and 10.3 to 6.6 kgDM/kgN for green panic. Interactions between species and nitrogen levels were significant.

4.3.5 Crop index (%)

Green panic had significantly higher ($P<0.01$) crop index values than buffel grass and gatton panic across all nitrogen treatments (Table 51(a). Without added nitrogen, buffel grass and gatton panic had similar crop indices but with N_{200} and above gatton panic was superior to buffel grass. The highest crop index value for buffel grass of 11.88 per cent occurred at N_o, but for gatton panic and green panic the highest crop index percentages of 15.56 and 27.06 respectively were observed at N_{200}. On the whole nitrogen had no consistent effect on crop index, but very marked differences were evident among the species. Green panic had more than double the crop index of buffel grass, and was also significantly higher ($P<0.001$) than gatton panic.

Table 49: Effect of nitrogen levels on herbage dry matter yield (kg/ha)

Species	Nitrogen levels					
	N_o	N_{200}	N_{400}	N_{600}	Means	S.E.
Buffel grass	3841	6976	8233	8920	6992	
Gatton panic	4715	6588	8150	9008	6865	±182.0
Green panic	3558	5608	6827	7491	5871	
Means	4038	6391	7403	8473		±177.4

S.E.

N x S = 1346.1

Table 50: Effects of nitrogen levels on efficiency of herbage dry matter yield (kg/kgN)

Species	Nitrogen levels N_{200}	N_{400}	N_{600}	Means	S.E.
Buffel grass	15.7	11.00	8.5	11.7	
Gatton panic	9.4	8.6	7.2	8.4	±0.53
Green panic	10.3	8.2	6.6	8.4	
Means	11.8	9.3	7.4		±0.49

S.E.

N x S = ±0.91

4.3.5.2 Crop index based on harvested clean seed yield

Crop index derived from potential seed yield was superior to that based on harvested seed yield at all levels of nitrogen (Tables 51(a) and 51(b). Buffel grass had a significantly higher crop index than gatton panic without nitrogen, but at N_{200} and above, they were similar (Table 50(b). Without nitrogen, green panic had a similar crop index as buffel grass, but with the addition of nitrogen, the values for green panic were significantly higher. Gatton panic had significantly lower crop indices at all levels of nitrogen than green panic. In buffel grass crop index decreased from 8.17 per cent at N_o to 6.39 per cent at N_{600}, whereas in gatton panic and green panic the roverse was true in that in crop index values increased from 4.97 and 7.97 per cent at N_o to 7.34 and 10.38 per cent at N_{600} respectively. Interactions between nitrogen and species on crop index based on potential and harvested seed yield were significant.

4.3.6 Herbage crude protein content (%)

Herbage crude protein increased significantly with increase in nitrogen levels (Table 52). Gatton panic contained more crude protein than those of buffel grass or green panic regardless of level of nitrogen application. Crude protein contents ranged from 5.20 per cent at N_o to 10.47 per cent at N_{600} for buffel grass and in gatton panic and green panic the corresponding values were 6.66 to 12.90 and 5.73 to 12.13 per cent, respectively. The magnitude of crude protein increase was highest at N_{200} and decreased at higher levels of nitrogen application.

Table 51: Effect of nitrogen levels on Crop index (%)

(a): Total potential seed yield/dry matter yield.

Species	Nitrogen levels				Means	S.E.
	N_o	N_{200}	N_{400}	N_{600}		
Buffel grass	11.88	9.24	9.61	9.48	10.05	
Gatton panic	11.35	15.56	15.40	15.40	14.43	±0.339
Green panic	19.53	27.06	24.57	25.20	24.09	
Means	14.25	17.29	16.53	16.69		±0.314

S.E.

N x S = 1.12, 1.14.

(b): Total harvested clean seed yield/dry matter yield.

Species	Nitrogen levels				Means	S.E.
	N_o	N_{200}	N_{400}	N_{600}		
Buffel grass	8.17	6.35	6.47	6.39	6.85	
Gatton panic	4.97	6.38	7.24	7.34	6.48	±0.339
Green panic	7.97	9.97	10.29	10.38	9.65	
Means	7.04	7.57	8.00	8.04		±0.314

S.E.
N x S = ±0.637

Table 52: Effect of nitrogen levels on crude protein content (%)

Species	Nitrogen levels N_o	N_{200}	N_{400}	N_{600}	Means	S.E.
Buffel grass	5.20	8.30	9.44	10.47	8.35	
Gatton panic	6.66	10.54	11.94	12.90	10.51	±0.283
Green panic	5.73	9.45	10.81	12.13	9.53	
Means	5.86	9.43	10.73	11.83		±0.291

S.E.

N x S = ±0.546

4.3.7 Simple correlation matrix for seed yield attributes

Simple correlation matrix for 10 seed yield attributes in respect of buffel grass, gatton panic and green panic are presented in Table 53. Attributes that are positively and significantly correlated with seed yield are inflorescence density, number of ripe inflorescences and shoot fertility. Those that are poorly and negatively correlated with potential seed yield are seed size and caryopsis content. Seed yield attributes of low correlation with potential seed yield are inflorescence length and number of seeds per inflorescence. There is no correlation between shoot density and potential seed yield. The most important determinant of potential seed yield, therefore, is inflorescence density.

Table 53: Correlation matrix for seed yield attributes of buffel grass, gatton panic and green panic. d.f. = 49.

1.	Shoot density	1.0000								
2.	Inflorescence density	0.1308	1.0000							
3.	Number of ripe inflorescences	0.1452	0.9803	1.0000						
4.	Shoot fertility	-0.5030	0.7684	0.7395	1.0000					
5.	Inflorescence length	-0.7887	0.3217	0.3006	0.7520	1.0000				
6.	Number of seeds/inflorescence	-0.7745	0.3110	0.2811	0.7356	0.9749	1.0000			
7.	Number of inflorescences with shed spikelets.	-0.7278	0.1237	0.0952	0.5546	0.7900	0.8197	1.0000		
8.	Seed size	0.8311	-0.2949	-0.2630	-0.7617	-0.9800	-0.9695	-0.7909	1.0000	
9.	Caryopsis content	0.7904	-0.2295	-0.2101	-0.6806	-0.8329	-0.8031	-0.7236	-0.8799	1.0000
10.	Potential seed yield	0.0063	0.9537	0.9594	0.7889	0.4693	0.4732	0.2688	-0.4148	-0.3088	1.0000
		1	2	3	4	5	6	7	8	9	10

*Positive or negative values greater than 0.4978 and 0.6425 respectively are significant at 5% and 1% levels.

CHAPTER 5

5.1 DISCUSSION

Experiment 1

The term 'shoot' has been preferred to 'tiller', here, because it includes both the main shoot and the tillers. The main shoot is not strictly a tiller, since tiller refers to a shoot that arises from the main shoot or from another tiller.

Soil chemical analysis of the irrigation site did not indicate nitrogen deficiency prior to seedbed preparation, but it is most unlikely that the soil nitrogen content was enough to produce the high herbage dry matter yields that were recorded in the unfertilised (control) plots. A substantial nitrogen flush could have occurred due to wetting and drying. Birch (1958, 1960(a), 1960(b) had shown that drying soil samples prior to remoistening them markedly increased the mineralisation of natural nitrogen during subsequent incubation. He found that for a particular soil, the amount of nitrogen mineralised was a direct logarithm of the length of time the soil was dry before wetting and incubation, and of the temperature of the soil during the dry period. For the humic soils of East Africa, Birch calculated the nitrogen produced to be equivalent to 2471 kg/ha of ammonium sulphate fertilizer, for the first flush. Semb and Robinson (1969) found the magnitude of the observed flush to vary from 183.3 down to 13.0 N kg/ha. The high temperatures that prevailed during the experimental period particularly, before the true rains came in May, coupled with the long dry season would be ideal conditions for considerable nitrogen flushes.

hes.

In the Northern Guinea Savanna and Sudan Savanna zones of Nigeria, where shortage of forage is very acute during the long dry months, the production of fresh herbage from a grass seed production enterprise could be immensely useful for livestock farming.

Shoot density and shoot fertility

Nitrogen application had a marked effect on shoot density, in agreement with the findings for both temperate and tropical grasses (Newell, 1951; Langer, 1959; Wilson, 1959; Lambert, 1964; Boonman, 1972; 1973; Chadhokar and Humphreys, 1973 and Bahnish and Humphreys, 1977). Cutting the ripe inflorescences on each sampling occasion removed the apical dominance, thereby prompting a rapid shoot production. Cutting also improved the light environment of the lower shoots. Shoot density increased with time to the highest value on the final date of harvest. The general pattern is for shoot density to increase with time to a peak and then drop due to inter-shoot competition for light, moisture and soil nutrients (Griffiths *et al., 1967)*. The successive method of hand-harvesting of only ripe inflorescences could thus be said to have the added advantages of replenishing and promoting new shoot production that would become reproductive hence increasing the potential seed yield.

Percentage shoot fertility was independent of nitrogen treatments. This agrees with Chadhokar and Humphreys (1970, 1973), Bahnisch and Humphreys (1977), but not Boonman (1972a), In the successive seed harvesting method, shoot fertility was calculated at each harvest, and this was believed to have given a better estimation of than calculations based on the final harvest (Chadhokar and Humphreys1973a, on the time of minimum inflorescence density (Bahnish and Humphreys, 1977.

The under-estimation of shoot fertility with these methods is thought to stem from the fact that inflorescences produced and harvested in the earlier cuts or after the cut at maximum inflorescence density did not enter into the calculation.

Effects of nitrogen application on percentage shoot fertility was inconsistent, in conformity with observations by Chadhokar and Humphreys (1970, 1973a), and Bahnisch and Humphreys (1977). The higher percentage shoot fertility noted in gatton panic could be due to reduced competition among its relatively fewer shoots compared with buffel grass and green panic. With reduced competition, these shoots would grow faster accumulate metabolities and subsequently contribute more towards seed yield (Langer, 1957). The progressive decrease in percentage shoot fertility with time suggests that there was a corresponding gradual depletion of soil mutrients by the crops. Furthermore, later-formed tillers had a competitive disadvantage against the main shoots and earlier formed tillers because of their distance from the nutrient source (Ryle, 1959, Haggar, 1966). The high shoot fertility observed in gatton panic at successive sampling dates was an indication that seed ripening was more diffuse and protracted than in buffel grass and green panic, Boonman (1971) had concluded that prolonged heading was one of the causes of low seed yield in tropical grasses. However, it is suggested that staggered inflorescence production and ripening could be an insurance against adverse climatic conditions.

Seed yield components

Inflorescence density, a primary factor controlling seed yield, was positively affected by nitrogen treatments. This could be explained in terms of the stimulation of tillering, with the subsequent increase in shoot fertility. Similar findings have been reported by numerous authors on temperate and tropical grasses (Evans, 1959; Lambert, 1956; Haggar, 1966; Boonman, 1972(a); Chadhokar and Humphreys, 1973; Bahnisch and Humphreys, 1977). It would appear that the successive hand-harvesting of ripe inflorescences also contributed to the increase in inflorescence density. This harvesting method appeared more beneficial to gatton panic in terms of sustained high shoot fertility at each harvest date unlike buffel grass and green panic which had better synchronised heading pattern. For successive manual seed harvesting, the duration of spikelet retention on the inflorescence is probably more important than the degree of synchronisation. In machine-harvesting where some immature infloresences are invariably destroyed, resulting in substantial loss of seed (Hopkinson and English, 1973a), close synchronisation of heads is preferable.

The estimation of optimum harvest date in most tropical grasses is a major problem because apart from the proneness of their seeds to rapid shedding, even when green, they have a very narrow margin between the under-and over-ripe phases. In the present study, a 14-day harvest interval was chosen for practical reasons only since closer harvest intervals would be too labour-intensive for the farmer and might not give him enough time to attend to his other crops.

In any case, the 14-day harvest interval might not result in appreciable loss of caryopsis-filled florets, since much of the shed seed before an inflorescence ripens are empty (Mwakha, 1970; Boonman, 1973; Padilla and Febles, 1980). Hopkinson and English (1982) had observed that spikelets which failed to set seed in gatton panic were shed about one week earlier than those that matured. Boonman (1973) noted in a range of tropical grasses that seed harvesting could be carried out safely over a range of dates covering one to two weeks or more, and that for Coloured Guinea grass (*Panicum coloratum*), yield of pure germinating seed was only affected when 30 to 50 per cent or more of the spikelets had shed.

The four successive harvests gave a total of 923 ripe inflorescences/m^2 for gatton panic, which more than quadrupled the 224 inflorescences/m^2 reported by Hopkinson and English (1982) for the same species grown in the subtropical region of Australia.

Nitrogen application increased the number of seeds per inflorescence. Similar observations have been reported for cocksfoot, meadow-fescue and ryegrass (Ryle, 1964), Rodds Bay *paspatum* (Chadhokar and Humphreys, 1973) and ryegrass (Hebblethwaite and Ivins, 1977). In contrasts, Bahnisch and Humphreys (1977) found number of seeds (floret density) per inflorescence to be independent of nitrogen level. In buffel grass and green panic, number of seeds per inflorescence decreased progressively with later dates of harvest but in gatton panic a peak occurred at the second harvest. This decline might be related to competition for soil nutrients, since the successively later-formed inflorescences would be disadvantaged because of their relative distances from the source of the soil nutrients.

Chadhokar and Humphreys (1973) obtained a decline from 65.9 seeds per raceme on main shoots to 59.0 seeds per raceme on shoots developed on days 41 to 50 from sowing. In contrast, Langer (1959) and Ryle (1963) reported that raising the levels of nitrogen applied to single plants of timothy grass increased the number of florets per inflorescence in late-formed shoots more than in early-formed shoots. In this study, number of seeds per inflorescence fluctuated widely between nitrogen treatments and dates of harvest, particularly in gatton panic and green panic. Up to 900 seeds per inflorescence had been counted in gatton panic and green panic (Agishi, unpublished). A range of 819 to 385 seeds per inflorescence has been reported for gatton panic in sub-tropical Australia (Hopkinson and English 1982b).

Significant between and within-plant increases in seed size were observed in response to added nitrogen. The N_{400} increased seed size over the unfertilized control by 10.5, 37.8 and 33.0 per cent in buffel grass, gatton panic and green panic respectively. Seed size has been found to respond positively to nitrogen in perennial ryegrass (Ryle, 1964; Hebblethwaite and Ivins, 1977) and in Rodds Bay Plicatulum (Chadhokar and Humphreys, 1982b). Inconsistent or negative effects of nitrogen on seed size have been observed in buffel grass (Hacker and Jones, 1971), perennial ryegrass (Spiertz and Ellen, 1972), Nandi Setaria (Boonman, 1972a, 1972b) and Narok setaria (Bahnisch and Humphreys, 1977). The progressive decrease in seed sizes with later dates of sampling is in agreement with the finding of Chadhokar and Humphreys, (1973(b) for plicatulum. In all the species, maximum response in percentage caryopsis contents occurred at N_{200}, and this was only statistically significant over the control at the 5 per cent level.

Mean caryopsis contents were 69.0, 43.0 and 41.3 per cent for buffel grass, gatton panic and green panic respectively. Lower caryopsis contents have been observed in *Setaria* species. For example, caryopsis contents of 13 to 36 per cent for eight strains of *Setaria anceps* (Gildenhuys, 1950), 5 to 7 per cent for *S. anceps* or *S. sphacelata* (Hacker and Jones, 1971) and 5 to 14 per cent for Narok setaria (Bahnisch and Humphreys, 1977) have been recorded. Hopkinson and English (1982b) obtained 39.8 per cent for gatton panic. Buffel grass has one to three caryopses per fascicle (Humphreys, 1967). In this study, a filled fascicle was equated to a caryopsis, since fascicles are generally recognised as seed units for buffel grass rather than individual grain.

Seed yields

Potential seed yield was strongly influenced by increases in levels of applied nitrogen and the method of seed harvesting. The effect of nitrogen was more marked in gatton panic and green panic than in buffel grass. The significantly larger seeds of buffel grass did not sufficiently compensate for the very low number of seeds per inflorescence to increase seed yields to the levels of the panics. However, the seed yields obtained in this study were extremely high for tropical grasses, and could be attributed both to the successive method of hand-harvesting and the applied nitrogen. Nitrogen appeared to have sustained and maintained to maturity the numerous reproductive shoots induced by the removal of ripe inflorescences in the successive harvests. Though, Brzostowski and Owen (1966) adopted the successive method of seed harvesting employing both hand and machine, their annual buffel grass seed yields of 156.8 to 201.6 kg/ha were low compared with the harvest seed yields of 558.0 to 100.0 kg/ha reported in this study.

It should be noted however, that Brzostowski and Owen harvested the seeds five months after the rains, when moisture stress might have restricted seed filling and maturation, particularly in the later harvests. Boonman (1971) had attributed the higher seed yields in temperate than tropical grasses to higher fertile shoot production. From their detailed study of spikelet population dynamics in seed crops of gatton panic, Hopkinson and English (1983b) concluded that "manipulation of rates of emergence and maximum densities of heads was the only present available route through which potential seed yield could be increased". Successive seed harvesting appears to be the route through which high potential seed yield could be achieved. In this study, the total number of inflorescences harvested per square metre was 923 which is comparable to inflorescence densities of 1006 to 1241 for *Lolium perenne* (Evans, 1954) and 732 to 990 for *Festuca pratensis* (Lewis, 1962).

The significantly lower seed-shedding in buffel grass than gatton panic and green panic, resulted in its high harvested seed yield. Agishi (unpublished) has found greater seed shedding in gatton panic and green panic than buffel grass. Buffel grass took 21 days after initial heading to mature, by which time, no single spikelet was shed. In contrast, at 21 days after initial head emergence, gatton panic and green panic had shed 62.9 and 48.9 per cent of their spikelets respectively. And by 25 days after the initial head emergence, seed loss had increased to 85.1 and 71.8 per cent in gatton panic and green panic respectively. The harvested seed yields of 1000.0 and 942.4 kg/ha for buffel grass at N_{200} and N_{400} respectively, appeared quite high, compared to 259.2 and 267.4 kg/ha obtained at corresponding nitrogen levels.from Biloela buffel grass in Cuba (Gomez *et al.*, 1978) and 330 kg/ha at 672 kgN/ha from Molopo buffel grass in Australia (Cameron and Mullaly, 1969).

The harvested pure seed yield of 372 kg/ha for gatton panic was also superior to the 194 kg/ha reported by Hopkinson and English (1982b) for gatton panic. The markedly higher seed yields obtained in this study attests to the benefit of the successive method of seed harvesting.

Harvest efficiencies averaged 74.7, 43.4 and 47.9 per cent for buffel grass, gatton panic and green panic, respectively. The lower efficiencies for gatton panic and green panic could be ascribed to the combined effect of high levels of seed-shedding and low caryopsis contents. It should be noted that most of the empty florets were removed at seed cleaning. Gatton panic had the highest efficiency of response to nitrogen for potential seed yield and the lowest for harvested seed yield. This probably resulted from the inherently higher rate of seed loss in gatton panic than in buffel grass and green panic (Agishi, unpublished). It was observed that even at the highest nitrogen level, seed yield responses were positive and substantial for all species. This contrasts with the negative values reported by Chadhokar and Humphreys (1973a) on Rodds Bay plicatulum at N_{200} and N_{400}. At the unsubsidized market price of nitrochalk, (26%N) of ₦10.00 for a 50 kg bag or 77 kobo/kgN in Zaria, even the N_{400} level of application is highly economic for seed production from these grasses.

Herbage dry matter yield and crop index

The utilization of herbage left after seed harvests from irrigated seed crops by livestock could be of great importance, particularly in those areas of the Northern States of Nigeria which experience 5 to 8 months of dry season.

Herbage dry matter yields, estimated immediately after the final seed harvest, were remarkedly high. The high dry matter yields produced in plots without added nitrogen suggests that the soil was inherently fertile. The weather conditions during the experimental period appeared favourable to good plant growth. In addition, the method of seed harvesting adopted which encouraged profuse tillering was encouraged, could have beneficial to dry matter accumulation. Although, Haggar (1966), at Shika, reported dry matter yields of only 2,430 kg/ha from non-fertilized *Andropogon gayanus* and 7,437 kg/ha with 200 kgN/ha, higher herbage dry matter yields of these species have been reported from soils without added nitrogen. In Tanzania, Naveh and Anderson (1967) obtained over 10 tonnes dry matter/ha without fertilizer nitrogen application to Biloela buffel grass and green panic. Herbage dry matter yield of over 17 t/ha was also reported for Biloela buffel grass without nitrogen in Ghana (Asare, 1970). It is therefore apparent that the yield of a grass crop depends upon the particular species, the nutrient content of the soil, the weather conditions and management practices.

Mean values of efficiency of herbage dry matter yield response to applied nitrogen of 20.6, 43.7 and 27.8 kg DM/kgN at N_{100} for buffel grass, gatton panic and green panic respectively were lower than the 46.7 and 65.0 kg DM/kgN at N_{100} reported by Haggar (1966) and Boonman (1973a) on *Andropogon gayanus* and Nandi Setaria respectively. In this study, gatton panic was more efficient in utilizing applied nitrogen than buffel grass and green panic.

Compared with crop plants, pasture grasses have very low crop indices. Crop index of rice can be as high as 117 per cent (Van Ittersum, 1973).

By contrast, the mean crop indices of 8.08, 14.17 and 12.67 per cent for potential seed yield were obtained for buffel grass, gatton panic and green panic respectively, with the corresponding values of 5.97, 5.76 and 5.70 for harvested seed yield. In Kenya, Boonman (1973a, 1973b) obtained crop index values of 1.1 and 3.0 per cent for *Setaria sphacelata* cv *Nandi* and *Chloris gayana* cv. *Kabarara*, respectively. Haggar's (1966) data on *Andropogon gayanus* gave calculated crop indices of 1.22, 0.[illegible], and 0.9[illegible] per cent for N_o, N_{100} and N_{200} respectively, which are even lower than the value of obtained in the present study.

Herbage crude protein and phosphorus contents

Crude protein contents of herbage from the N_{400} treatment were as high as those from stylo hay and groundnut haulms (Brinckman, 1975), and meet the minimum protein requirement of adult beef cattle. Even without the addition of nitrogen, the hays contained more than 5 per cent crude protein on dry matter basis, compared with 2 to 3 per cent found in natural grasses of the Northern Guinea Savanna at the dry hay stage (Miller *et al.*, 1964).

Phosphorus contents tended to decrease with increasing levels of nitrogen. The progressive decrease in herbage phosphorus contents with increasing levels of nitrogen may indicate that either nitrogen was inhibiting phosphorus uptake or that the phosphorus was being diluted, since higher nitrogen level was associated with faster grass growth. Buffel grass contained significantly more phosphorus at N_o than gatton panic and green panic, suggesting that it is a better accumulator of soil phosphorus than the panics.

Schofield (1940) tested a range species and found that buffel grass had the highest phosphorus content, while Skerman (1958) found it very responsive to superphosphate. In Tanzania, phosphorus pentoxide was found to have a beneficial effect on the establishment of buffel grass (Krzostowski, 1962).

Experiment 2

Soil chemical analysis prior to seedbed preparation revealed adequate levels of nitrogen (N), calcium (Ca) and available phosphorus (P), but a deficiency of magnesium (Mg) and Potassium (K) for good plant growth. The sufficiency of N, Ca and P was expected since, for over ten years before the experiment commenced, the paddock received 500 kg/ha nitrochalk annually and 125 kg/ha single superphosphate biennially. No Mg or K fertilizers were ever applied, and the removal of these minerals by the grazing stock without replenishment could have resulted in their deficiency.

Rainfall in 1977 was far below the 50-year average for Shika. The rains ceased 16 and 44 days before the first and second seed harvests respectively. During these periods the plants depended on residual soil moisture only. The relatively high temperatures during late September and October, coupled with the onset of strong, dry harmattan wind in October might have rapidly depleted the soil moisture and arrested tillering, tiller fertility, seed setting and seed maturation. In Kenya, grass seed yield was reported to be highly sensitive to climatic variations in contrast to herbage yield (Boonman, 1972a).

Shoot density and fertility

Broadcast seeding produced significantly higher shoot densities than row spacings, on each harvest date. Shoot densities decreased with wider row spacings, in conformity with Boonman's (1972a) finding with *Setaria sphacelata*, sown at the similar row spacings, but in contrast with Boonman's (1972(b) observation on the stoloniferous *Chloris gayana cv.* Mbarara. Shoot densities were higher at the narrower than the wider row widths. This might be due to the effect of plant density. More seed was sown per unit length of row in the wider row spacings than the narrower rows, therefore a greater intra-row competition between shoots for light, moisture and soil nutrients would exist in the wider rows, culminating in reduction of the number of tillers formed.

Shoot fertility or percentage heading shoots increased significantly over the broadcast 60 and 90 cm row spacings, with the maximum occurring at 60 cm row treatment. Boonman (1972a) reported similar results but showed that doubling the rate of nitrogen application gave higher shoot fertility in the narrower row than in the wider row width. In cocksfoot, shoot fertility was higher at lower shoot densities (Lambert, (1963b) as was observed at the wider row spacings.

Seed yield components

Inflorescence and shoot densities were closely associated. The narrower row spacings encouraged inflorescence production, as was reported by Boonman (1972a) for *Setaria sphacelata*, but unlike his findings on the stoloniferous *Chloris gayana cv.* Mbarara which was little

affected by row spacing. the effect of row spacings on inflorescence density is usually modified by nitrogen application. Increased inflorescence density has been found to be positively related to good nitrogen nutrition. Boonman (1972a) reported that for a given row spacing, inflorescence densities in Nandi Setaria increased with increase in nitrogen level.

At harvest ripeness (time most inflorescences were ripe for harvesting) which occurred 92 days after sowing, the proportion of ripe to unripe inflorescences tended to decrease as row spacing increased, suggesting that the formation of new inflorescences stopped earlier in the narrower row spacing. Unripe inflorescences constituted 20 per cent of the total number of inflorescences obtained at harvest ripeness. Most of these unripe inflorescences could have been cut at the first harvest if the crop were machine-harvested. By employing the successive method of harvesting, where only the ripe inflorescences were cut at any given harvest time, these unripe inflorescences were able to mature and contribute to the total seed yield.

Inflorescence were longer at wider row widths paralleling the findings of Boonman (1972a) on Nandi Setaria. Prolonged flowering and non-uniform seed ripening within the same inflorescence are usually associated with long inflorescences. Boonman (1971) concluded that low seed yield resulted from prolonged flowering in a seed crop. However, in the harvesting method whereby only the ripe inflorescences are removed, this conclusion might not apply.

Seed numbers increased with wider row spacings, but the increases did not appear large enough to compensate for the significantly lower inflorescence densities at these spacings. Later-formed inflorescences produced fewer seeds than the earlier-formed inflorescences. This might

have been due to moisture stress since the rains terminated 30 September, 1977,and by 17 and 31 October when the seeds were harvested, the moisture stress could be very acute. The total rainfall for September was only 54.8 mm, which was far below the evapotranspiration for the same period (Kowal and Knabe 1972). Chadhokar and Humphreys (1973a) had observed more seeds per racerne on main shoots than in the later-formed shoots.

The lowest seed weight (smallest seed size) was observed in the broadcast treatment. Smika and Newell (1968) had similarly, observed that side-oats grama produced heavier caryopsis weight when sown in rows than by broadcast. Row spacing had no significant effect on seed size, as had been reported by Boonman (1972a). Further studies by Boonman (1973), however, showed that Nandi Setaria and Coloured Guinea grass increased in seed size with delayed harvest date, unlike in rhodes grass where the earlier-formed inflorescences produced heavier seeds than those formed later. Since in this trial, most of the later-formed inflorescences developed after the cessation of the rains, they might have suffered from moisture stress resulting in poor grain-filling prior to seed maturation. This was also reflected in the reduced caryopsis contents of the later-formed florets. Lighter caryopsis weight of later-formed inflorescences has been observed in Rodds Bay plicatulum (Chadhokar and Humphreys, 1973a). In contrast, Bahnisch and Humphreys (1977) obtained lighter seeds from tillers which appeared before or after 62-68 days after cleaning cut.

Seed yields

Potential seed yield was dependent on row spacing. By reducing interrow spacing from 90 to 30 cm, the potential seed was more than doubled.

The primary factor controlling potential seed yield was inflorescence density, since other seed yield components varied little with row spacing. Narrowing row spacings from 90 to 30 cm had been reported to significantly increase the yield of pure germinating seed of Nandi Setaria (Boonman, 1972a). The higher seed yield produced by broadcast than row spacings is not in agreement with Boonman (1972a). Visual observations revealed very little shedding at the time of first harvest, when up to 79.9 per cent of the inflorescences were ripe. The potential seed yield obtained from these inflorescences represented about 81.6 per cent of the total seed yield of the crop. This contrasts strongly with Coloured Guinea and Mbarara rhodes grass where peak clean seed yield concided with about 30 per cent shed spikelets (Boonman, 1973a).

Harvested clean seed yield was also highest in the broadcast, and decreased significantly with wider row spacings. Boonman (1972a) recorded similar responses for pure perminating seed yield of Nandi setaria, but not clean seed yield. The first harvest clean seed yield represented about 83 per cent, suggesting that buffel grass has a better synchronisation of inflorescences than most tropical grasses (Boonman, 1971). Harvest efficiencies were observed to decrease with wider row spacings in both harvests. Seed losses from shedding or harvesting method were minimal. Therefore the observed low recovery of potential seed yield was probably due to seed cleaning, which removed most of the empty florets. Despite the low levels of seed recovery, even the lowest seed yield of 220.2 kg/ha, obtained from 90 cm row spacing would be worth ₦1101.00 at the current N.A.P.R.I. price of ₦5.00/kg of grass seed. This value is much higher than the gross returns from many agricultural crops in Nigeria, that are in fact more expensive to produce.

Herbage dry matter yield and crop index

Broadcast treatment produced the highest dry matter yield, and the wider row spacings the lowest, probably because of the higher shoot densities in the broadcast and narrower spacing treatments. Maximum crop index percentages for both the potential (%) and the harvested (%) seed yields occurred at the 60 cm row spacing, which agrees with Boonman (1972a). Boonman's (1972a) crop index values rarely exceeded one per cent. The relatively high crop indices obtained in buffel grass showed that seed production was more sensitive to row spacing than dry matter yield. Limited seed shedding, and seed losses during harvesting and processing combined to bring down the crop index percentages of harvested seed.

Experiment 3

Soil properties and meterological observations

The soil characteristics for the experimental site has been fully discussed in Experiment 2. There was above average rainfall for Shika Station, with very good distribution during the experimental year, 1978. During the experiment (July to October), the mean maximum and mean minimum temperatures were 29.2 and 19.3°C respectively, while mean daily sunshine was 6.6 hours. These conditions appeared ideal for grass growth.

Shoot density and fertility

Despite the higher level of applied fertilizer nitrogen of N_{600}, the upland crops produced markedly lower shoot densities than the fadama (lowland) crops of Experiment 1. The superior shoot density in the fadama crops was probably due in part to the longer duration of the successive method of harvesting which was carried out at the time of moisture adequacy which could also have favoured good tillering. Shorter growing period and harvesting duration, including moisture stress on the other hand, adversely affected tillering in the upland crop. These might also account for the lower percentage shoot fertility observed in the rain-fed upland crops. Buffel grass appeared particularly less fertile in the upland crop than the fadama crop.

Seed yield components

Added nitrogen addition increased inflorescence density significantly in all species but the effect was greatest in green panic. Buffel grass and green panic had relatively more ripe inflorescences at the first harvest than gatton panic, indicating that they have a better synchronisation of heading. The second harvest involved the later-formed inflorescences, which were apparently affected by moisture stress. These inflorescences were also observed to be shorter than those formed earlier.

Gatton panic and green panic had inflorescence length about twice that of buffel grass, a difference attributable to species rather than nitrogen treatments. The finding that inflorescence length was not significantly affected by nitrogen treatments up to N_{400}, agreed with those reported by

Hacker and Jones (1971) in *Setaria spacelata* and Bahnisch and Humphreys (1977) in Narok setaria, but deviated from that observed by Boonman (1972(a), 1972(b) for Nandi Setaria. Longer inflorescence is usually associated with higher seed contrary to the observation in the present study. Chadhokar and Humphreys (1973a)associated longer inflorescence with greater number of seeds per inflorescence and hence higher potential seed yield. The disadvantage of increased inflorescence length lies in prolonged flowering within the same head, resulting in low seed yield (Boonman, 1971). In the successive method of seed harvesting, however, it has been observed that prolonged flowering *per se* was not the cause of low seed yield, but rather the duration of seed retention on the individual inflorescence.

Boonman (1971) ascribed low seed yield in tropical grasses to shedding. However, Agishi (unpublished) found that seed shedding was not serious a problem in buffel grass as in gatton panic and green panic. Seed shedding is, nevertheless, an important practical ripeness indicator in grass seed production. Although, percentage inflorescences with shed spikelets is not the same as a more commonly measured parameter of percentage spikelets shed, it is also a good indicator of ripeness. Most of the early-shed seeds are empty (Boonman, 1973, Hopkinson and English, (1982b).Clean seed yield is affacted more by shedding than pure germinating seed yield. Coloured Guinea *(Panicum coloratum)* could tolerate up to 30 to 50 per cent spikelet shedding before being adversely affected (Boonman, 1973b).

Seed size increased significantly in all species with increase in added nitrogen levels. This agrees with observations by Chadhokar and Humphreys (1973(b) in Rodds Bay plicatulum but in contrasts to Boonman (1972(a), 1972(b) in Nandi Setaria and Bahnisch and Humphreys (1977) in Narok Setaria. At all levels of nitrogen, the upland crops produced heavier seeds but lower caryopsis content than the fadama crops. Moisture stress might have caused the reduced grain-filling in the upland crops, since these were harvested late in the dry season. In Tanzania, Brzostowski and Owen (1966) reported a caryopsis content of 72 per cent from buffel grass that was hand-harvested during the dry season after about five months' growth. It should be noted that the caryopsis content of any seed sample is a reflection of the level of post harvest cleaning.

Seed yields

Applied nitrogen increased seed yield in all the three species, particularly, buffel grass. The N_{200} and N_{400} levels gave harvested clean seed yields of 442.6 and 532.4 kg/ha respectively, for Biloela buffel grass, which is quite high when compared to seed yields of 259.2 and 267.4 kg/ha obtained in Cuba from the same species at the corresponding levels of nitrogen (Gomez, *et al., 1978).* Probably higher seed yields could have been obtained in this study if the later-formed inflorescences had adequate moisture supply at the seed maturation phase. Seed harvesting was, as a consequence, restricted to only two harvests, both of which occurreed after the rains, thus the beneficial effect of increased seed yield associated with successive seed harvesting as observed in Experiment 1 could not be realised.

Early crop establishment, say, in Mid June for Shika, would have assured of longer crop growing period and allowed for more harvests to be made. In this study crop establishment was delayed to allow most weed seeds to germinate and be ploughed under. This would not have been the case if herbicides were available for early weed control.

Late planting coupled with poor rainfall distribution lowers seed yield as observed in Experiment 2, above. In the present study, limited or supplementary irrigation could have prolonged the growing period and increased seed yields. Canode and Keuren (1963), reported significant increased in seed in yields of cultivars of agrostis, cocksfoot, red fescue and increased timothy grass with irrigation than-irrigation. Similar findings on agrostis, red fescue and tall fescue by Rampton (1945) and on timothy by Lambert (1966) have been reported. Though, Cameron and Mullaly (1969), reported negative effects of irrigation on seed yields of Molopo buffel grass, it should be noted that *Cenchrus ciliaris* generally, is intolerant of waterlogging (Anderson, 1970).

Harvest efficiencies in Biloela buffel grass and green panic increased with increase in nitrogen levels, up to a maximum of N_{400}. Nitrogen had an inconsistent effect on the harvest efficiencies in gatton panic. The lower harvest efficiencies for gatton panic and green panic than buffel grass could be ascribed to the combined effect of high levels of seed-shedding and low caryopsis contents. The generally low harvest efficiencies obtained in this study by hand harvesting could still be regarded as high when compared with those obtained by machine - harvesting of these species. Hopkinson and English (1982a) had reported that under commercial seed harvesting in Queensland, Australia, using machines, only about 10 per cent of the potential seed yields of gatton panic and green panic were recovered.

In the present investigations, seed harvest efficiencies in buffel grass, gatton panic and green panic were similar for the fadama and upland sites, indicating that both the caryopsis contents and the levels of seed-shedding in these crops were of the same order.

The efficiency of seed yield response to applied nitrogen was higher for the potential than the harvested seed yields. This was expected because of seed losses which occurred before, during and after seed harvest. For both the potential and harvested seed yields, the efficiency of response to applied nitrogen were highest in green panic and lowest in buffel grass, suggesting that more of the applied nitrogen was been used by green panic for seed production than dry matter accumulation, and and *vice versa* with Biloela buffel grass. It is most probable that in all the three grasses, higher efficiencies of seed yield response to applied nitrogen would have been obtained if the duration of crop growth were longer, to allow for better utilisation of the nitrogen.

Herbage dry matter yield and efficiency of response to applied nitrogen

Added nitrogen increased herbage, dry matter yields in all species but the effect was highest in buffel grass. Though buffel grass had more vegetative shoots than gatton panic and green panic, it is unlikely that this was the main cause of its superior herbage dry matter accumulation, since this trend was not reflected between the panics (Table 40 and 49). Buffel has been reported to grow stemmy much earlier during its vegetative growth than most sown pasture grasses (Humphreys, 1967), and this might explain its superior herbage dry matter yield compared with gatton panic and

green panic. High herbage dry matter yield have been reported for Biloela buffel grass with nitrogen in Ghana (Asare, 1970)L

Maximum values of efficiency of herbage dry matter yield response to applied nitrogen of 15.7, 9.4 and 10.3 kg D.M./kgN at N_{200} for Biloela buffel grass, gatton panic and green panic respectively. These were mucy lower than the values of 46.7 and 65.0 kg D.M/kg N at N_{100}, reported by Haggar (1966) and Boonman (1973a) on *Andropogon gayanus* and Nandi Setaria respectively.

Crop index

Nitrogen application had an inconsistent effect on crop index in all the three grass species studied. Green panic had significantly higher crop indices at all levels of nitrogen than buffel grass and gatton panic. Mean crop indices for buffel grass, gatton panic and green panic were 10.65, 14.43 and 24.09 per cent respectively, for the potential seed yield, with corresponding values of 6.85, 6.48, and 9.85 for harvested seed yield. These figures are quite high when compared to the crop indices of 1.1 and 3.0 per cent for *Setaria sphacelata cv. Nandi and Chloris gayana cv. Ibarara,* respectively, (Boonman 1973a). Calculated crop indices from Haggar's (1966) data on *Andropogon gayanus* of 1.22, 0.80, and 0.98 per cent for N_0, N_{100} and N_{200} respectively, were even lower than the values obtained in the present study.

Herbage crude protein content

Crude protein contents of 5.20, 6.66 and 5.73 per cent in the unfertilised buffel grass, gatton panic and green panic hays were reasonably high when compared with the 2 and 5 per cent crude protein obtained from unfertilized natural grasses, cut at hay stage at Shika (Miller *et al.*, *1964, Haggar, 1975).* Crude protein contents of the N_{200} were 8.3, 10.54 and 9.45 per cent for buffel grass, gatton panic and green panic, respectively. These values are as high as those obtained from stylo hay and groundnut haulms (Brinckman, 1975), and meet the minimum protein requirement of adult beef cattle.

Correlations between seed yield components and seed yields

Simple correlation matrix for grass plant attributes affecting seed yield were calculated for the upland crops only, but these are assumed to apply to the fadama crops as well. Potential seed yield was highly and positively correlated with inflorescence density, number of ripe inflorescences as well as shoot fertility and marginally but positively with inflorescence length and number of seeds per inflorescence. Favoretto and Toledo (1975) obtained a positive correlation between seed yield and density of fully emerged inflorescences. Shoot density and number of inflorescences with shed spikelets were poorly correlated with potential seed yield. Negative and poor correlations existed between seed yield and seed size or caryopsis content.

It is therefore concluded from these correlations that if improvements in grass seed yield are envisaged, attempts should be made to increase inflorescence density, shoot fertility and the total number of ripe inflorescences harvested. Increases in these parameters could be effected through use of appropriate levels of fertilizer nitrogen, adoption of the successive method of harvesting which engendered profuse development of reproductive tillers. Carr and Eng Kok Ng (1966) reported that the removal of the terminal bud in *Pennisetum clandestinum* caused auxillary buds to become reproductive. Increased intensity of grazing increased seed yield of *Dactylotechium aegyptium* in India (Sant, 1964). Increase in inflorescence length and number of seeds per inflorescence would also be beneficial to seed yield. Stoddart (1959), obtained increased seed yields of timothy by increasing inflorescence length through repeated defoliation.

5.2 SUMMARY AND CONCLUSIONS

Investigations were carried out over three years at the National Animal Production Research Institute, Shika to observe the effects of row spacings on Biloela buffel grass and fertilizer nitrogen on Biloela buffel grass, gatton panic and green panic grown for seed production. The row spacing and one of the two nitrogen trials were carried out on the upland, under rain-fed conditions, while the other nitrogen trial was under limited irrigation on the lowland (fadama). Rates of fertilizer nitrogen applications were 0, 100, 200 and 400 kgN/ha for the fadama crop and 0, 200, 400 and 600 kgN/ha for the upland crops. Row spacing treatments involved broadcast and 30, 60 and 90 cm. Summary and conclusions on nitrogen apply to the two sites, unless otherwise stated.

1. Nitrogen application significantly increased shoot density and fertility in all species. Buffel grass and gatton panic recorded the lowest and the highest shoot fertility respectively. Shoot fertility tended to decrease with successively later-produced shoots.

2. Inflorescence density increased in all species as nitrogen levels increased leading to an inflorescence build-up with time. Gatton panic exhibited more protracted inflorescence development than buffel grass and green panic. The promotive effect of nitrogen on inflorescence density was probably aplied by the successive method of seed harvesting.

In this method, only the ripe heads are cut at any given harvest occasion. The cutting of the inflorescences results in increased development of reproductive shoots. As more and more ripe inflorescences are cut, so are more reproductive shoots developed. In this way higher seed yields can be achieved provided the duration of harvesting of ripe inflorescences is sufficiently long to permit the successively-formed inflorescences to mature.

3. In the upland crops where inflorescence length was measured, nitrogen addition increased inflorescence length in all species, but the effect on buffel grass was more marked. Inflorescence length was poorly correlated with potential seed yield.

4. The application of nitrogen increased number of seeds per inflorescence, seed size and caryopsis contents in all species. The crops grown on the upland produced more seeds per inflorescence and heavier seed than those on the fadama, but had lower caryopsis contents. These seed yield contents did not influence potential seed yield in any significant way.

5. Potential and harvested clean seed yields of the fadama crop were higher than those of the upland at all the nitrogen levels tested. The highest seed yield was produced on the fadama by gatton panic and on the upland by green panic. Seed yields of the fadama crop decreased with later dates of harvests. Total seed yields from the four harvests were very high in all the

species, being higher than virtually all seed yields so far reported in the literature for temperate and tropical pasture grasses. The general claim that temperate grasses are superior to tropical grasses in seed yield potential is doubtful.

6. Higher values of efficiency of seed yield response to applied nitrogen were obtained in the fadama crops than the upland crops. These values were generally high for tropical pasture grasses. Harvest efficiencies for gatton panic and green panic were similar, but generally lower than that of buffel grass.

7. Very high dry matter yields were obtained from the fadama crop. Yield at N_{600} under upland conditions was in fact lower than that at N_o in the fadama. Irrigated pasture seed production may therefore appear attractive not only in terms of higher seed and herbage dry matter yields but also lower rate of fertilizer use.

8. Crop indices were higher for the fadama crop than the upland crop. Crops at both sites produced much higher crop indices than those normally reported for tropical grasses.

9. Crude protein content of the residual herbage after the final harvests were higher in the upland crop and this was expected since the fadama crop at the final harvest was 134 days old compared with only 97 days of the upland crops.

10. Simple correlation matrix for seed yield attributes showed that inflorescence density and shoot fertility were the main determinants of potential seed yield. The successive method of seed harvesting which resulted in increased development of reproductive shoots could therefore be one of the major ways of increasing seed yield.

11. Seeding by broadcast gave higher shoot density, but lower shoot fertility than row spacings. Inflorescence density, seed yield, dry matter yield and harvest efficiency all decreased with wider row spacings, while fertility, number of seeds per inflorescence and seed size increased.

12. Seed yield was greater in the broadcast and 30 cm row spacing than at wider row spacings.

5.3 AREAS FOR POSSIBLE FUTURE INVESTIGATIONS

The use of successive method of seed harvesting whereby only the ripe inflorescences are harvested at each harvest occasion was adopted in this study, so as to minimise the high seed losses resulting from protracted heading, which is characteristic of tropical grasses. The method is effective for a small-scale grass seed production enterprise. For large-scale grass seed production, the use of machinery may be more suitable; in which case there will be need to study for each grass species the optimum harvest dates for maximum seed recovery.

Experiment 1 has clearly demonstrated the beneficial effect of irrigation water on grass seed production. Most of the large irrigation projects in Nigeria are located in the Sudan Savanna Zone, where incidentally, the environmental conditions are suitable for large-scale seed production. Since these irrigation sites are likely to become centres for large-scale seed production projects, it will be most appropriate to carry out future investigations on irrigated seed production at these locations. The timing of fertilizer nitrogen applications is critical for grass seed production in both the irrigated and rainfed conditions. This aspect of the work was not covered in this study. With the ever-increasing cost of fertilizers in this country, it will be advisable to investigate the optimum time to apply fertilizers in order to minimise wastage and cost of seed production.

Rows, 60 cm apart were used in Experiments 1 and 3 of the present study out of convenience and not necessarily because they implied the best arrangement of plants in terms of full utilisation of space and light. In anticipation of mechanised agriculture in the near future efforts might be directed towards investigating closer row spacings and seed broadcast which, as observed in Experiment 2 of this study, may give higher seed and herbage dry matter yields.

The present investigations were restricted to establishment grass crops only. Since most tropical pasture grasses are perennials, there is need to study the seed yields of post-establishment crops to find out when these are maximal. The effects of defoliation, either by cutting or grazing by livestock of establishment and post-establishment grass crops on seed production need to be studied, since mixed farmers would like to know when and how long a paddock with seed crops can be grazed before being closed for seed production.

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5.5. APPENDICES

Appendix 1: Rainfall Data for NAPRI, Shika.

1976

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
1							9.1	6.4	21.3			
2						25.4						
3					2.0		30.5		4.6			
4							51.1	1.8				
5					1.3			48.5		2.5		
6						6.7			3.4			
7					9.9					13.7		
8						24.1	36.8	26.2				
9										10.2		
10				1.5		22.9		11.9				
11					22.1	2.5		.8	6.4			
12							5.3			20.8		
13				52.1			16.8		1.8	16.3		
14					6.1	32.8	6.1		2.5			
15								44.5		7.4		
16							26.4	5.3		34.0		
17								13.2				
18					1.8	1.0	20.6	29.2	1.5			
19										4.3		
20						24.1		6.4	14.2	19.1		
21					1.3			2.0	3.8	3.8		
22									19.8			
23					26.4	24.9	8.9		2.3	6.4		
24							12.7					
25							46.0			4.8		
26				4.6		4.3						
27										16.8		
28				21.1	53.6			6.1	5.6			
29				11.2			15.2	2.0				
30						62.7		60.5				
31							34.9	1.0				
Total (mm)				90.4	124.5	230.9	320.3	265.7	92.2	160.2		
Accumulated Total (mm)					214.9	445.6	765.9	1031.6	1123.8	1284.0		
Number of Rainy Days					5	9	11	14	16	12	13	
Accummulated Total(days)						14	25	39	45	57	70	

1977

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
1					12.7		3.6					
2							3.9	1.8	10.9			
3						13.5						
4									74.9			
5						1.3		7.3				
6						26.9		4.1	61.7			
7							3.3	1.3				
8							1.5	1.8	5.6			
9								6.4	33.3			
10					4.3				21.3			
11.						4.1		44.5				
12						2.8		13.2	8.4			
13						17.8		9.4	15.5			
14								12.7				
15								2.0				
16								2.0				
17						3.0	5.8	19.3				
18						2.8	38.9					
19							5.8	11.2				
20					15.0		1.8					
21									37.3			
22								10.2				
23					9.1	4.6	6.4	3.8				
24					.8	1.5		17.8				
25							9.1	22.4				
26								9.9				
27												
28					3.0	13.5	5.8	22.9				
29					1.3			4.3				
30					12.2	10.9			18.0			
31					5.6			8.1				
Total (mm)					64.0	102.6	85.6	232.2	287.0			
Accumulated Total (mm)						166.6	252.2	484.4	771.4			
Number of Rainy Days					9	12	11	22	10			
Accumulated Total (days)						21	32	54	64			

1978

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
1						28.4				7.4		
2						4.1	12.2	37.6				
3				11.9				24.9				
4								28.2	24.9			
5												
6						27.2						
7									8.6	5.8		
8			2.3						31.8			
9					33.0				42.2			
10								9.9				
11							7.1	35.6				
12					1.8		7.1		12.4			
13						34.0	2.3		5.8			
14			30.7	12.7			4.3	13.0	4.1			
15						1.8	12.7					
16						34.5	12.2	5.8	14.2			
17					3.6	1.5	15.2	17.8	11.7	3.8		
18								26.2				
19			9.1			27.9		1.0	12.4			
20								11.7				
21					17.5		12.2	26.4	13.5			
22									1.3			
23						27.7	24.9	62.7				
24							9.1					
25			27.4				21.8	5.3		2.5		
26					16.3			42.2				
27					16.8	1.9				12.7		
28					23.9		5.8					
29							4.8	24.6				
30					29.5			5.8				
31			11.7	9.1			7.6	6.6				
Total (mm)		2.3	90.9	164.1	188.2	159.5	385.3	182.9	32.3			
Accumulated Total (mm)			95.2	257.3	455.5	605.0	990.3	1173.2	1205.5			
Number of Rainy Days		1	5	10	10	15	18	12	5			

APPENDIX 2: MONTHLY RAINFALL RECORDS AT SHIKA (mm)

	Rainfall (mm)											Number of Rainy Days									
YEAR	JAN	FEB	MAR	APR.	MAY	JUN	JULY	AUG	SEPT	OCT	NOV	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT
1929	0	0	0	3.5	92.7	153.7	222.8	414.3	275.0	58.4	0	0	0	0	4	8	15	13	19	19	4
1930	0	0	0	55.3	142.7	74.6	209.9	520.1	210.3	25.4	0	0	0	0	4	11	9	18	17	14	2
1931	0	0	0	52.3	206.7	179.5	245.1	215.6	235.9	5.5	0	0	0	0	7	9	12	12	15	17	2
1932	0	0	0	37.0	114.0	260.1	151.1	181.1	186.6	70.3	0	0	0	0	4	9	13	12	13	12	7
1933	0	0	0	43.6	93.2	298.9	208.2	283.9	160.2	0	0	0	0	0	5	10	14	17	14	14	0
1934	0	0	0	48.2	189.2	175.2	158.5	452.1	112.0	30.4	0	0	0	0	4	12	12	18	19	12	3
1935	0	0	13.2	41.1	48.2	228.6	200.9	410.2	193.8	3.4	0	0	0	1	3	6	15	16	24	14	1
1936	0	0	2.7	102.6	139.9	191.2	332.9	275.8	300.0	19.5	0	0	0	2	6	11	13	15	12	17	2
1937	0	0	0	15.2	79.0	66.0	192.3	289.6	185.9	39.4	0	0	0	0	5	11	11	16	22	21	2
1938	0	0	1.6	53.3	91.7	269.2	111.0	302.0	195.1	20.6	0	0	0	2	5	8	17	17	24	17	3
1939	0	6.3	3.6	58.7	185.4	193.3	158.8	276.6	257.1	41.7	0.8	0	1	2	5	12	15	13	20	19	6
1940	0	0	0	26.7	111.3	167.9	197.4	250.4	203.2	62.7	20.3	0	0	0	1	8	8	17	21	13	8
1941	0	0	11.7	64.5	126.0	187.7	196.3	280.4	180.9	0	0	0	0	2	7	13	11	10	14	13	0
1942	0	15.2	0	9.4	222.0	101.6	147.6	211.8	127.0	45.7	0	0	1	0	2	8	10	10	15	8	5
1943	0	0	17.5	0	82.0	148.3	191.5	574.0	214.4	0	0	0	0	2	0	6	12	15	22	16	0
1944	0	0	0	12.2	40.9	116.3	114.8	373.4	89.4	17.0	0	0	0	0	2	3	14	11	20	11	2
1945	0	0	0	13.2	79.0	97.0	312.9	308.4	317.3	49.5	0	0	0	0	1	9	11	15	21	17	7
1946	0	0	7.6	0	105.9	197.4	252.2	367.8	267.7	98.8	0	0	0	1	0	11	9	14	16	16	8
1947	0	0	0	0	163.6	155.7	317.8	276.9	216.2	34.5	0	0	0	0	0	8	12	18	23	15	3
1948	0	0	0.5	55.1	59.9	108.2	180.1	253.2	164.9	0	0	0	0	1	6	8	13	17	21	19	0
1949	0	0	8.1	13.2	147.1	159.5	125.5	446.3	131.6	2.5	0	0	0	1	3	12	10	12	21	15	2
1950	0	0	0	5.1	65.5	77.0	192.5	252.0	188.2	4.3	0	0	0	0	3	13	16	16	23	17	2
1951	0	0	1.3	0	139.5	119.9	212.9	313.7	241.6	106.2	0	0	0	1	0	13	10	16	20	16	16
1952	0	0	1.0	1.8	104.4	137.2	343.9	273.1	276.6	58.6	0	0	0	1	1	14	14	21	24	19	6

	Rainfall (mm)											Number of Rainy Days										
YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NO
1953	0	13.7	0	2.5	269.2	148.3	290.1	259.8	199.4	37.3	0	0	1	0	1	14	11	14	13	15	2	0
1954	0	19.8	48.5	81.4	231.9	131.3	148.3	320.0	270.3	32.0	17.8	0	1	1	6	11	14	9	20	14	5	1
1955	0	0	0	59.4	65.0	237.5	394.2	337.3	219.7	46.2	0	0	0	0	3	6	16	16	17	15	5	0
1956	0	0.5	8.1	32.6	35.1	93.1	125.2	238.2	301.9	62.7	0	0	1	4	3	5	10	16	19	16	5	0
1957	0	0	0	58.9	169.4	168.2	266.5	335.8	213.9	67.1	0	0	0	0	5	15	14	14	19	18	6	0
1958	1.5	0	0	11.2	74.4	160.8	92.2	152.7	223.8	8.1	0	1	0	0	6	9	14	11	16	13	3	0
1959	0	/	8.6	35.6	79.8	138.4	212.1	324.4	205.0	3.8	0	0	0	1	1	9	12	16	25	16	1	0
1960	0	0	0	61.2	58.4	180.1	303.5	236.8	355.6	13.0	0	0	0	0	7	9	16	18	16	20	3	0
1961	10.7	0	0	40.2	117.4	173.7	257.8	145.8	159.8	0	0	1	0	0	4	4	13	13	13	11	0	0
1962	0	0	0	19.3	37.3	153.2	283.7	380.0	297.9	88.4	16.8	0	0	0	6	7	13	17	18	17	4	1
1963	0	0	1.0	32.5	63.0	112.0	161.5	254.5	125.0	144.5	2.8	0	0	1	5	11	14	13	15	16	10	1
1964	0	0	2.8	47.8	73.2	158.8	255.5	198.1	202.4	0	0	0	0	1	3	10	12	20	23	18	0	0
1965	0	0	0.5	27.4	19.3	352.3	248.9	200.9	127.3	13.0	0	0	0	1	4	3	20	17	21	14	2	0
1966	0	0	0	38.9	187.2	154.2	232.9	332.5	252.7	52.6	0	0	0	0	4	13	14	14	21	19	5	0
1967	0	0	6.9	68.9	85.6	167.6	236.0	211.8	251.2	1.5	0	0	0	2	6	7	14	14	13	16	1	0
1968	0	0	0	101.3	181.6	138.9	281.7	304.8	117.6	4.3	0	0	0	0	6	13	11	33	19	11	1	0
1969	0	0	0	45.5	146.8	216.2	322.6	234.4	168.7	68.1	0	0	0	0	5	11	15	14	21	14	8	0
1970	0	0	3.8	4.1	105.7	69.6	233.7	360.2	153.2	4.6	0	0	0	2	1	10	10	20	18	9	1	0
1971	0	0	1.8	0	98.3	83.8	128.7	349.5	281.7	38.8	0	0	0	1	0	6	5	11	10	10	2	0
1972	0	0	1.0	41.7	194.6	152.7	149.1	301.8	98.6	50.5	0	0	0	1	4	11	9	11	17	10	5	0
1973	0	.0	0	24.6	53.3	158.0	218.9	323.9	189.7	0	0	0	0	0	2	5	10	13	19	14	0	0
1974	0	0	30.5	29.2	43.4	165.6	252.2	323.3	214.4	49.0	0	0	0	1	4	8	9	18	20	18	4	0
1975	0	0	0	85.9	113.3	98.0	246.1	140.0	172.0	1.5	0	0	0	0	8	10	9	15	13	18	1	0
1976	0	0	0	90.4	124.5	230.9	320.3	265.7	92.2	160.2	0	0	0	0	5	9	11	14	16	12	13	0
1977	0	0	0	0	64.0	102.6	85.6	232.2	287.0	0	0	0	0	0	0	9	12	11	22	10	0	0
1978	0	0	2.3	98.9	184.1	188.2	159.5	385.3	182.9	32.3	0	0	0	1	5	10	10	15	18	12	5	0
Total	12.2	56.1	182.6	1355.4	5685.6	7597.0	10813.0	15002.4	10019.5	410.8	58.5	2	5	33	182	468	628	762	922	747	185	5
Mean	0.2	1.1	3.6	37.1	113.7	159.9	216.3	300.1	200.4	8.2	1.2	0.0	0.1	0.7	3.6	9.4	12.6	15.2	18.4	14.9	3.7	0.

50-Year mean Rainfall = 1041.8 mm

50-Year mean number of rainy days = 79.

Appendix 3: Inter-pretation of mineral analytical data on soils*

Nutrients **	Definitions				
	Very low	Low	Medium	High	Very high
Total nitrogen (%)	0-0 02	0.02-0.04	0.04-0.08	0.08-0.12	0.12-0.20
Available phosphorus (ppm)	30-60	60.120	120-180	180-200	>200
Calcium (ppm)	0-100	100-200	200-400	400-600	>600
Magnesium (ppm)	-	0-60	60-120	120-280	>280
Potassium (ppm)	25-50	50-100	100-200	>200	

** As Measurements are expressed either as parts per million (ppm) or millieqivalents per 100g of soil (me/100g), the following conversions are used:

1meCa/100g is equivalent to 200 ppm Ca
1meMg/100g " " " 123 ppm Mg
1meK/100g " " " 391 ppm K

* After F.A.O., 1971 "Establishment of a Soil Chemistry Section" Technical Report 4, on Savanna Forestry Research Station, to Government of Nigeria.