GROWTH AND YIELD OF KENAF (*Hibiscus cannabinus* L.) AS INFLUENCED BY FERTILISERS, SPACINGS AND SOWING DATES IN IBADAN, NIGERIA

BY

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DEDICATION

This work is dedicated to the Almighty God for taking me thus far and to His Church: the waiting bride who is saying Come Lord!

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I certify that this work was carried out by Mr. Samson Oyewole OLANIPEKUN in the Department of Crop Protection and Environmental Biology, University of Ibadan under my supervision.

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ABSTRACT

Kenaf is a multi-purpose crop with numerous industrial uses. Its production is constrained by poor cultural and agronomic practices which reduce yield. Farmers rely on different types of Inorganic Fertilisers (IF), which may be harmful to the environment. Furthermore, inappropriate sowing dates and spacing results in low yield. Use of Organic Fertiliser (OF) with appropriate sowing date and plant spacing could improve yields of kenaf. However, there is dearth of information on the appropriate plant spacing, sowing date and rates of fertilisers application required for kenaf production. Therefore, effects of fertiliser types, plant spacing and sowing dates on growth and yield of kenaf were investigated in Ibadan, Nigeria.

Commercially produced OF (NPK 1.32-0.86-0.50) and IF (NPK 20-10-10) at the rate of 70, 100, 130, 160 kg N/ha were each mixed with 10 kg soil in pots. Pots were arranged in a completely randomised design with four replicates. Two kenaf (variety Ifeken 100) seeds were sown per pot and grown to maturity. Untreated pots served as control. Data were collected on Seed Yield-SY (t/ha). Best fertiliser rates; OF (160 kg N/ha), IF (100 kg N/ha) and their 50% combination (80-OF+50-IF), were evaluated on SY and Bast Fiber Yield-BFY (t/ha) of kenaf. Consequently, 80-OF+50-IF was applied to kenaf sown (2 plants/stand) at three plant spacing: 50×15, 50×20, 50×25 cm assessed for SY and BFY. Kenaf seeds were sown on three planting dates (30 days interval) from May to August at a spacing of 50×20 cm and application of 80-OF+50-IF. Data were collected on Plant Height-PH (cm), Stem Diameter-SD (cm), BFY and SY. All field trials were laid in randomised complete block design with three replicates. Data were analysed using descriptive statistics and ANOVA at $\alpha_{0.05}$.

In pot experiment, SY differed significantly among fertiliser types and rates. Among OF rates, SY ranged from 0.8±0.02 (control) to 2.0±0.02 (160 kg N/ha). Among IF rates, highest SY (1.5±0.02) was obtained under 100 kg N/ha, while control had the lowest (0.8±0.02). On the field, BFY and SY differed significantly among fertiliser types. The BFY and SY ranged from 0.7±0.4 (control) to 2.3±0.4 (80-OF+50-IF) and 1.2±0.1 (control) to 1.7±0.1 (80-OF+50-IF), respectively. Plant spacing differed significantly for BFY and SY. Highest BFY (0.9±0.03) and SY (0.5±0.01) were obtained at 50×20 cm and 50×25 cm spacing, respectively, while the lowest BFY (0.7±0.01) and SY (0.3±0.01) were obtained at 50×15 cm spacing. Planting dates differed significantly for PH, SD, BFY and SY. Plants sown in June had the highest (262.83±1.2) PH, while those sown in August had the lowest (173.79±1.2). The SD ranged from 1.19±0.02 (August) to 2.3±0.02 (May planting). The BFY was highest (0.9±0.01) in plants sown in June and lowest (0.32±0.01) in plants sown in August. The SY ranged from 1.2±0.01 (May) to 2.3±0.01 (July planting).

Combination of 80 kg N/ha organic fertiliser with 50 kg N/ha NPK 20-10-10 applied to kenaf planted at spacing of 50×20 cm in June and July improved its growth, bast fiber and seed yields in Ibadan.

Keywords: Kenaf, Organic fertiliser, Inorganic fertiliser, Kenaf Bast fibre, Kenaf seed yield

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CHAPTER ONE

INTRODUCTION

Kenaf (*Hibiscus cannabinus* L.) is a warm-season; short-day herbaceous plant grown for its fibre. Kenaf is a member of the Malvaceae, a family known for its economic and horticultural significance (Danaglatos and Archontoulis, 2004). Many scientists have reported that the plant originated from Africa, where different kind of kenaf species were identified and domesticated. The crop is related to many species in the hibiscus genus including roselle (*Hibiscus sabdariffa* L.), okra (*Abelmoschus esculentus* (L.) Moench) and cotton (*Gossypium hirsutum* L.) (LeMahieu *et al*., 2003; Danalatos and Archontoulis, 2010).

As reported by FAO (2016), the plant has been effectively grown across various countries including Nigeria and South Africa. Kenaf develops well in tropical and temperate areas and grows well with high insolation and precipitation (Liu, 2000; Adeniyan *et al*., 2014). If grown under required conditions, kenaf can grow to a height of six meters within eight months and yield as much as 30 t ha^{-1} of dry stem yield (LeMahieu *et al*., 2003). The stem of kenaf plant comprises of two particular fibres; the external bark or bast fiber which makes up 35-45% of aggregate stem weight and delivers brilliant pulp; while the inner woody main element which makes up the rest of the 55-65% has low quality pulp (Danalatos and Archontoulis, 2004).

The traditional use of the crop focuses on its fibre production, which is used for production of ropes, sacks, canvases and carpets (Liu, 2000). The percentage protein in kenaf leaf is as high as 15-30% and can be included in animal feed as well as vegetable by man (Webber and Bledsoe, 2002; Nielsen, 2004).

The outer part could be pulped and used for newsprint, bio-degradable bags, restrain ropes and textile materials (Kuchinda and Ogunwole, 2000; Webber *et al*., 2000). The core, which is the inner woody stem, is useful in livestock sector as animal beddings. It can also be used as soil amendment, oil absorbents in the petro chemical sectors, as well as board making and filtration media (Cheng, 2001). The combination of these different parts of the plant provides great opportunity to use this crop in different ways and for many products (Webber and Bledsoe, 2002). Its application in environmental bio-remediation gives it ecological and economic advantages (Webber and Bledsoe, 2002; Balogun *et al*., 2008). The high rate of biomass production coupled with it good quality fiber makes it a good source of bio-renewable material. Not only that, but the need to use bio-degradable material in transporting farm produce as against the use of synthetic bags which has a negative effect on the produce required the utilization of bio-degradable fiber like kenaf (Balogun *et al*., 2008).

In spite of every one of these advantages, Kenaf cultivation in Africa has been constrained to small area of production with attendant low yield per unit land area; hence yield as low as 0.04% of the global production has been recorded in Africa (FAO, 2016). This might be associated with the fact that tropical soils are inadequate in soil minerals which therefore calls for addition of mineral elements rich in soil nutrient to improve kenaf production. The poor fertility status is due to continuous land cultivation. The increase in human population and the pressure on land requirement is responsible for high demand on infrastructure and farm lands (Agbaje *et al*., 2005). The available lands are therefore under pressure to meet basic needs for the sustenance of man and animals especially in the developing countries of Asia and Africa (Raji, 2007). This leads to soil fertility reduction and unsustainable crop yields over time.

However, the detrimental effects of mineral fertilisers on the environment and its high cost calls for the use of organic fertilisers which are more locally available and environment friendly (Akande *et al*., 2011). Nigerian soils are low in their ability to retain soil moisture, cation exchange capacity (CEC) and nutrient, hence require organic fertilisers which had been adjudged to have environmental benefits and have the capacity to improve soil structure (Adekunle *et al*., 2014; Aluko *et al*., 2014). Therefore, there is need to determine the use of different level of organic and inorganic fertilisers and their combination on the performance of kenaf in Nigeria.

In addition, Kenaf is known to adjust and accommodate any plant population (Danalatos and Archontoulis 2010). It has been recommended that 18-37 plant per m^2 may be appropriate for optimum stem yield (Alexopoulou *et al*., 2000). More importantly, plant density according to Webber and Bledsoe (2002) is directly related to fibre yield in kenaf (Acreche *et al*., 2005). Plant density is one of the cultural practices that affect the growth and biomass accumulation of the crop. Kenaf growth can be influenced greatly by spacing since stem height and girth play significant roles in its fibre yield. Acreche *et al*. (2005) noted however that appropriate plant density for kenaf has not been ascertained and this has a great impact on the crop production. Appreciable branching takes place with few stands, while in highly populated fields, plants grow taller but thinner thereby tends to lodge before maturity. Therefore, an appropriate spacing must be ascertained. The choice of planting date is also a critical factor for this photosensitive plant in order to ensure the efficient utilization of all other inputs. Based on the above points, this study was designed to:

1. Evaluation of the fibre and seed yield potential of kenaf under varying rates of organic and inorganic fertiliser
2. Determination of the response of kenaf to varying plant densities and its effect on fibre and seed yield
3. Determination of kenaf fibre and seed yield under different sowing dates

CHAPTER TWO

LITERATURE REVIEW

2.1 History of kenaf

Kenaf (*Hibiscus cannabinus* L.) is a fibre plant which was domesticated in African and has been cultivated for many years in this region as food and industrial material (Meints and Smith, 2003; Danalatos and Archontoulis, 2004). The crop is well known in Africa and Asia (LeMahieu *et al*., 2003). The crop has many potentials as raw material for pulp and paper, and was introduced to many countries during World War II including South Africa and Cuba where it has been grown and used for many products like rope, twine, bagging and rugs (LeMahieu, 2003). The plant is currently gaining popularity across the globe as many farmers are increasingly aware of its economic potentials (Danalatos and Archontoulis, 2010). Ogunniyan (2016) reported that kenaf is grown as a subsistence crop in Nigeria, but it is gradually becoming a major crop in the country for its various applications. The CTA (1996) reported that kenaf has provided raw materials for the manufacture of bags and as composites in making high quality paper and newspaper. The bast fibre is used for producing gunny bags, clothes, rope, canvas and carpets whereas its core fibre is useful as building materials, soil modifiers, active carbon, absorbent and paper. Roots, leaves and seeds of kenaf are processed for livestock feed, human food, oil, medicine, soil amendment and dyeing materials (Liu, 2000). The crop also has potential for application in energy sector (Alexopoulou *et al*., 2004).

2.2 Production of Kenaf

Kenaf is grown on a large scale across various countries of the world according to FAO (2016). Thailand and Bangladesh are among the leading countries in kenaf production (Liu, 2000) while Africa contribute less than 1% of the world production (FAO, 2016). In 1985, global kenaf production reached 2.8 million tonnes after which its production declined to 0.4 million tonnes. Global production of kenaf is as presented in Table 2.1

Table 2.1 Global production of Jute, Kenaf and Allied Fibres in metric tonnes from 2007/08 to 2012/13

Total Jute, Kenaf & Allied Fibre	**2007/08**	**2008/09**	**2009/10**	**2010/11**	**2011/12**	**2012/13**
World	3247.8	2588.0	2863.4	3369.0	3342.2	32014.4
Developing countries	3241.1	2581.3	2856.7	3362.3	3335.5	3194.7
Far East	3175.9	2528.4	2807.2	3316.2	3258.2	3144.4
Bangladesh	1236.8	931.0	1070.1	1404.5	1332.9	1363.0
China	86.8	84.3	75.2	75.2	78.0	78.0
India	1782.0	1476.0	1620.0	1800.0	1845.0	1674.0
Cambodia Indonesia	4.7	4.1	3.8	4.0	4.0	4.0
Myanmar	19.1	3.6	4.3	9.6	3.8	1.6
Nepal	16.8	17.0	17.7	14.4	15.0	15.0
Thailand	2.2	2.9	2.0	1.7	1.7	1.3
Vietnam	25.7	7.8	12.1	5.0	3.2	6.0
Other	1.8	1.8	2.0	1.8	1.6	1.6
Latin America and Caribbean	50.4	38.0	35.6	30.9	33.4	33.4
Africa	11.2	11.2	10.3	11.8	13.4	13.4
Near East	3.6	3.6	3.6	3.5	3.5	3.5
Developed countries	6.7	6.7	6.7	6.7	6.7	6.7

Source: FAO (2016)

2.3 Taxonomical and botanical classification of kenaf

2.3.1 Taxonomical classification

Kenaf is a member of the Malvaceae, a family notable for its economical and horticultural importance. *Hibiscus* has over 400 cultivars and the genus is grouped into various sections: Fucaria, Alyogen, Abelmoschus, Ketmia, Calyphyllia and Azanza. It is closely associated to cotton (*Gossypium hirsutum* L.), okra (*Abelmoschus esculentus* (L). Moench) and hollyhock (*Althaea rosea* L.). Kenaf is grouped taxonomically in the Fucaria section of Hibiscus (Acreche *et al*., 2005; Raji, 2007) which includes several species (Su *et al*., 2004). Chromosome number is a multiple of 18 in all the species. Natural species have been found with chromosome numbers of 36, 72, 108, 144 and 180. The difference in numbers of chromosomes and gene present in the section fucaria is not common in the plant kingdom. This genetically difference is shown in high levels of morphological and physiological differences within the crop. This variation represents rich source useful material to kenaf breeders who tries to improve the crop (Hossain *et al*., 2011).

2.3.2 Botanical description of kenaf

Kenaf is an erect plant that grows in dense stands. They are largely branched or unbranched depends on the spacing and grow to a height of 4-5 m while under favourable conditions and may reach 6 m (Agbaje *et al*., 2011; Akubueze *et al*., 2014). The outer bark of the stem known as bast is used for weaving material and it makes up one quarter of the stem on a dry weight basis. Inside is a thick cylinder of short woody fibres which surrounds a narrow central core of soft pith (Hossain *et al*., 2011).

Ogunniyan (2016) reported that stem colour of several cultivars is green, however there are some red-stemmed and purple-stemmed accessions. Leaf shape varies considerably; the first set of leaves produced by the crop at early stage of growth is ovate in shape while some cultivars develop post-juvenile leaves that are very deeply lobed. The crop has an extensive root system, having a deep tap root with wide spreading lateral roots. The stalks of kenaf are usually round while some cultivar may have thorns; spike on the stems are tiny. It has two different fibre types; the outer, bast fibre that comprises about one third of the stalk dry weight and the inner, core fibres that comprises up to two third of the stalk's dry weight (Mohammed *et al*., 2001; Lin *et al*., 2004).

Kenaf plant produce simple leaves with serrated edges on the main stalk (stem) and along the branches. The position of the leaves alternate from side to side on the stalk and branches. Cultivar and plant age affect the leaf shape. The divided (split-leaf) cultivars have deeply lobed leaves with 3, 5 or 7 lobes per leaf: the cultivar at early age produce leaves that are partially lobed and are basically cordate (heart- shaped). The divided leaf characteristic was found to be dominant and entire leaf shaped was recessive (Ogunniyan, 2016).

The immature or new leaves on young kenaf plants are simple, whole and unsplit. As the plant grows older and more leaves are formed; the new leaves start to differentiate into the leaf shape characteristic of that particular variety. Lobed-leaf variety can have 3 to 10 entire young leaves before the production of the first lobed-leaf (Charles, 2002). Each leaf also contains a nectar gland on the mid-vein on the underside of the leaf. The leaf and seed capsule nectar gland are visited in large numbers by wasps (Jones *et al*., 1955).

Kenaf has very conspicuous and attractive, light yellow or creamy flower with bell-shaped and largely open. The flowers of many species are characterized with deep red or maroon coloured at the middle. The diameter of the flowers measures 8-13 cm and have five petals that are fused together (gamopetalous) in the leaf axis along the stem and branches. They usually open in the morning, start to close at noonday, finally and permanently closed by the evening. Within the corolla, the staminal column with its short stamens, surround the style. The anthers release pollen about the time the flower opens and the style emerges shortly thereafter. The five-part stigma expands; the lobes become tight but do not touch the anthers. The corolla closes spirally so that the anthers are pressed into contact with the stigma and if cross-pollination has not occurred, self-pollination may result. After pollination, a pointed, ovoid, seed capsule is formed that is about 1.9 to 2.5 cm long and 1.3 to 1.9 cm in diameter.

The capsules are overlaid with many small fine, loosely held hairy particles that are usually irritating if they touch the human skin. Each capsule contains five chambers containing a total of 20 to 26 seeds/capsule. Kenaf seeds are grayish brown, approximately 6 mm long and 4 mm wide with 35, 000 to 40, 000 seeds/kg. Once pollinated, the seeds require an additional 60-90 days of favourable weather to mature (Alexopoulou *et al*., 2000; Mohammed *et al*., 2001; Webber and Bledsoe, 2002; Meints and Smith, 2003; Liu and Labuschagne, 2009; Danalatos and Archontoulis, 2010).

2.4 Proximate analysis of kenaf

In recent time, Kenaf has gained more attention as feed ingredient in livestock industry due to its nutritional profile (Olawepo *et al*., 2014). Kenaf leaves contain an acid flower which is used for soups and the seeds can be processed to extract oil useful for both domestic and industrial purposes. Likewise the seed cake obtained after oil extraction can serve as feed for livestock (Kubmarawa *et al*., 2009). The presence of high level of unsaturated fatty acid makes it to compare favourably with soybean (Duke, 2003). Kubmarawa *et al*. (2009) have reported 13.8% crude protein and 29.6% crude fibre content in kenaf. Lipids, carbohydrate and ash contents are within values expected of dry leafy vegetables. Immature kenaf can be used as fodder crop since it is very rich in protein at the early growth stage (Philips *et al*., 1996). The nutrient content in young kenaf was found to be comparable to alfalfa hay and its production was relatively high (Najid and Ismawaty, 2001).

Crude protein level of the stalk is as high as 12.1% while protein content in the entire plant is up to 25% (Chantiratikul *et al*., 2006). Hence this plant with 15% digestible protein can be included in animal feed as hay. This has been proven with positive result in beef cattle and other ruminants (Xiccato *et al*., 1998; Philips *et al*., 2002a; Chantiratikul *et al*., 2006).

2.5 Uses of kenaf

Nearly every part of kenaf has industrial applications. The whole stalk of kenaf can be used completely. The vegetative part of kenaf can be included in human and animal diets (Kubmarawa *et al*., 2009; Adekunle *et al*., 2014; Akubueze *et al*., 2014). With concerns for a safe and healthy environment, kenaf plant can be useful in environmental as bio-technology application (Alexopoulou *et al*., 2004). The plant has the ability with it high rate of biomass production within a short growing period to mop up harmful gases from industrial wastes (Hossain *et al*., 2011; Akubueze *et al*., 2014).

2.5.1 Agro-Sack Production

Retted and processed kenaf fibre are used to manufacture twine, cordage and rope as well as agro-sacks (Ogunniyan, 2016) and hessian cloth as alternative to fibre from jute (*Corchorus* spp), sisal (*Agave sisalana*) and hemp (*Cannabis sativa*) which have been established (Hossain *et al*., 2011; Akubueze *et al*., 2014).

2.5.2 Pulp and Paper Production

Kenaf plant is a unique raw material for pulp and paper production with good turnout rate (Yu and Yu, 2007). According to LeMahieu *et al*. (2003), the crop produces up to three or five times as much fibre as pine. The cost of production of a tonne of pulp from kenaf fibre is relatively lower than other tree based pulp, because of lower lignin content, cost efficiency both in energy and chemicals needed for pulping (Hossain *et al*., 2011). Other uses of kenaf include: agro-textiles, oil and chemical absorbency, particle reinforcement, construction and housing industry (Hossain *et al*., 2011; Akubueze *et al*., 2014; Ogunniyan, 2016).

2.6 Constraints to kenaf cultivation

2.6.1 Photosensitivity

Kenaf is sensitive to day-length and its varieties differ in their response to this although it is actually the length of darkness that is the critical element that triggers the response. Knowing well the effect of day-length latitude is critical in choosing the appropriate variety for the cultivation area and the purpose for which the crop is grown (Webber *et al*., 2002). Kenaf is therefore grouped into categories according to maturity as: ultra-early, medium and late maturing cultivars according to photosensitivity.

I. Ultra-Early Maturing

The ultra-early maturing cultivars are developed for use at latitudes greater than 37 ^{o}N. These cultivars mature within 70–100 days (Webber *et al*., 2002); produce many seeds, though not a tall plant, but with very low fibre production. These varieties are not grown at lower latitude because they will flower even earlier and therefore produce shorter plant with lower seed yield (Webber *et al*., 2002; Alexopoulou *et al*., 2007).

II. **Early to Medium Maturing**

Cultivars in this category are normally referred to as photosensitive (early and medium maturing) cultivars, grouped as short-day plants. They are usually the desired varieties for their high fibre yield. These photosensitive variety starts producing flowers once the day length decreased to about 12.5 hours. For the cultivars, delaying flowering could be advantageous because the onset of flowers has a suppressing effect on its vegetative growth (Webber *et al*., 2002).

III. **Late Maturing**

Photo insensitive, late maturing (day-neutral) cultivars are good for areas that falls within the equator, 0^{o} to 10° N or S. These cultivars are semi sensitive to day-length for the initiation of flowering hence has a longer vegetative growing time (Webber *et al*., 2002) though they are classified as photo insensitive (Alexopoulou *et al*., 2007).

2.6.2 Climatic conditions

Climatic change and environmental deterioration have set up a series of changes in the intensity of abiotic stresses with time. This is globally linked with poverty, socioeconomic and political problems. It was proposed that this abiotic stress can be ameliorated through breeding resistant varieties, selection of tolerant varieties by farmers and plant physiologist to determine cellular, tissue and whole plant responses, morphological or phenological shifts that help plants ameliorate or avoid the impact of detrimental environmental factors (Lutfar *et al*., 2004).

Abiotic stress is responsible for as much as 50% yield lost for most crop plants globally. Environmental stress such as erratic and insufficient rainfall, extreme temperatures and other factors limit yield and production of many cultivated plants (Jarvis *et al*., 2005). The cultivars indicated that environmental stress are capable of limiting yield. It influences generation and maintenance of intra specific diversity of crops for increased capacity. Farmers, through the ages have been involved in the selection of best varieties that could tolerate drought. Hence there are many genetic diversity in response of plants to water deficit among traditional cultivars. However, improved cultivars that combine other desirable traits, such as high yield with drought tolerance now exist (Latiffe *et al*., 2004; Liu and Labuschagne, 2009).

Evaluation of genotypes for consistency in performance under different climatic condition is important. This is because the choice of cultivar depends on amount and distribution of rainfall because it affects both quantity and quality of yield (Parry *et al.*, 2005). However, the global change in rainfall pattern which is erratic and torrential with attendant reductions in number of rainy days greatly affect yield of crops (Morakinyo and Ajibade, 1998; Parry *et al*., 2005). Yield component on the other hand may be affected through environmental effect on vegetative parts of the plants, although other environmental factors affect the rate of plant development (Birbat *et al*., 1995). The authors stated that for obtaining good yield, selection of suitable cultivars and sowing at the proper time is necessary. Also, reduction in irradiation level per area (shading), or reducing available area per plant reduce plant growth and partly modifies morphology of the plant.

The kenaf plant is known to have wide adaptation to different environments and soils than any other fibre plant grown in large scale (Alexopoulou *et al*., 2007). Danalatos and Archontoulis (2010) reported that temperature has a direct positive influence on the kenaf yield. Hence, planting kenaf where soil moisture is adequate with high insolation and a fairly long growing season could lead to high fiber yield. While on the other hand, drop in temperature below 10 ^{o}C or prolonged frost could slow its growing rate or lead to its death (Webber *et al*., 2002). Developing a variety that could tolerate cool environment and low soil temperature would increase kenaf's area of production (Webber *et al*., 2002). There is need to have adequate knowledge of good agronomic practices such as improving soil fertility status to increase any crop growth, yield and quality (Muir, 2001, 2002; Alexopoulou *et al*., 2007; Adekunle *et al*., 2014).

2.7 Response of kenaf to mineral fertiliser

Lack of adequate soil nutrient and moisture can have limiting effect on the growth performance and fibre production of kenaf (Glass, 2003; Parry *et al*., 2005). Crop production in the tropical and subtropical region is hindered due to inadequate in soil nutrients (Adeniyan *et al*., 2014; Aluko *et al*., 2014). Although this could be corrected by the application of mineral fertilizer. Danalatos and Archontoulis (2010) noted that the application of nitrogen fertiliser has no significant effect on kenaf yield. On the other hand, Muchow (1992), Webber (1996), working in different environment reported that application of nitrogen significantly and positively influenced kenaf yield. Akande *et al*. (2011) reported that the inorganic fertiliser treated kenaf were significantly taller than the untreated one; it gave higher seed yield and plant girth. Highest plant height and seed yield were obtained with application of phosphorus fertiliser. They however noted that kenaf has high fertiliser requirements and responds well to nitrogen fertiliser. Though most farm lands are low in soil nutrients especially nitrogen, the inadequate soil nutrient is as a result of cropping on the same land without or with short period of fallowing, which are commonly practiced in many African countries. These practices are as a result of high demand on agricultural lands and the need for infrastructural developments due to increase in human population on a limited land resources (Agbaje *et al*., 2005).

Likewise, the recent high procurement cost of mineral fertilisers and their insufficient supply in the market calls for concern (Adeoye *et al*., 2005). The detrimental effects due to inappropriate or excess use of mineral fertiliser on soil properties need to be addressed; the need to improve soil organic matter contents of our agricultural soils and the demand for organic based crop produce in the world market (Pawar *et al*., 2003) calls for shift to the use of organic fertilisers.

2.8 Response of kenaf to organic fertiliser

Organic fertiliser is said to have the nutrient required by plants in fairly balanced proportion, and these nutrients can be supplied in such a quantity that can sustain crops for a long time (Akanbi *et al*., 2010). The use of bio-waste in the crop production is a good way of keeping the environment clean and safe thereby reducing the use of chemical fertilisers (Cuevas *et al*., 2003). However, the uptake of micronutrients and trace elements by the crop grown with bio-waste is of great concern (Mc Bride *et al*., 2004). Sundermeier *et al*. (2004) reported that organic matter consist of carbon (57% by weight) which could be very useful in ameliorating a less fertile soil to improve the soil quality and for better growth of kenaf. Beside, quantity of carbon in any particular soil dictate the measure of other soil properties to a great extent. All measured growth parameters of kenaf were significantly higher in plots treated with carbon (Hossain *et al*., 2011).

2.9 Response of kenaf to irrigation

Kenaf does significantly well on marginal soil with less water and poor soil nutrient such as arid regions Francois *et al*. (1992). Danalatos and Archontoulis (2010) reported a high positive correlation of many kenaf cultivars with desirable fibre yield to water supply. Gray *et al*. (2006) from their investigation reported that kenaf adapts well under different environmental conditions and soil types, though well drained fertile soil is preferred for good yield. However, flooding or water log area especially during seedling or early growing stage, can badly limit its growth and performance.

2.10 Spacing in kenaf production

Plant density is an important agronomic practice with direct influence on the growth of kenaf and consequently determine its fibre yield. Appropriate plant density for optimum yield in kenaf has not been reported, though this may vary with the use of available machineries while considering the end use of the fibre (Acreche *et al*., 2005). Various studies had examined kenaf response to range of plant populations Muchow (1979) (100,000 to 900,000 plant ha^{-1}) under different growing condition without any significant increase in fibre yield. However, seed yield in kenaf according to Webber and Bledsoe (2002) is affected by the plant density or spacing. Seed yield is significantly low when planted in a dense population. Spacing of 15 cm resulted into lower seed yield while spacing of 25 cm had bigger stem diameter, while kenaf spaced at 50 by 20 cm gave the highest seed yield (Agbaje *et al*., 2011). The appropriate plant density that will result to optimum yields therefore depends on cultivars used. Acreche *et al*. (2005) found that plant density of 99,000 plants/ha to 932,000 plants/ha have been researched upon for some kenaf cultivars for optimum yield. Cuba 2032 cultivar require crop population of 500, 000 to 700,000 plants ha^{-1} for optimum yields, while Tainung 1 require 300,000 to 400, 000 plants ha^{-1}. Bukhtiar *et al*. (1990) proposed 444,000 plants ha^{-1} as the optimum plant population for fibre yield. Webber *et al*. (2002) in their report proposed plant population of 185,000 to 370,000 plants ha^{-1} as appropriate for optimum yields. Danalatos and

Archontoulis (2010) reported planting kenaf at population of (200,000 plants ha^{-1}) could give higher fibre yield. He noted that density above this could lead to logging of the plant at advance stage of growth with attendant low fibre yield (Webber and Bledsoe, 2002; Danalatos and Archontoulis, 2010). With the use of planting machineries, different sowing density can be achieved (Acreche *et al*., 2005). Agbaje *et al*. (2011) proposed 50 cm apart and 20 cm within row for kenaf cultivation in Nigeria. Webber and Bledsoe (2002); Agbaje *et al*. (2011) concluded that kenaf could adjust to any planting density through the death of some weak plants.

2.11 Kenaf and sowing time

Generally, programming sowing time of crops appeared to be largely related to the start of rains in the year than to other related weather factors such as temperature, radiation and nutrient availability, which may be accounted for by soil water condition as at the time of sowing (Bukhtiar *et al*., 1990). Sowing date is closely associated to the specific pedo-climatic status of the specific environment under consideration. Planting seed when the air temperature is high could aid uniformity in the emergence of seedlings (Danalatos and Archontoulis, 2010). On the contrary, flowering in kenaf is attained at a particular time in the year due to the photosensitive nature of the crop (Gray *et al*., 2006). Also at growth and developmental period of plant, moisture status is a determinant of early emergence, seedling growth and crop performance (Togun, 1989). The choice of planting date is very important option that can be employed to take maximum advantage of the factor of weather and other environmental factors (Brown and Riesberg, 2005).

Inappropriate time of planting can delay flowering in kenaf or flower abortion and ultimately reduce its seed yield (Danalatos and Archontoulis, 2010). When plants are planted too early, seed emergence may be hampered and growth impaired. On the contrary, planting too late certainly affect growth performance and crop yield as a result of reduction in the rate of sunshine hour or unfavorable growth condition (Gray *et al*., 2006). Late maturing kenaf variety remain in its vegetative stage till mid-September before it moves to reproductive stage when flowering could be initiated. Therefore, April to May was suggested for sowing keanf seeds if the air temperature stabilizes above 15 $^{\circ}$C, otherwise the unfavourable condition may cause kenaf production to drop to 40% or less (Danalatos and Archontoulis, 2010).

2.12 Growth Analysis

Plant growth analysis is an illustrative, total and inclusive method of assessing plant process and development. It employs measurement of plant parts and their content to know some processes taking place within the entire plant system (Hunt *et al*., 2002). Growth analysis is often applied in biological research to assess how successful any species is across different environments, competitiveness within species, and differences in genetic variability with respect to yield as well as effect of agricultural treatments on crop development (Echarte *et al*., 2008; Odeleye, 2010). The importance of growth studies in agronomic experiments was studied by Hasinagul *et al*. (2013). Sinclair (1990) and Odeleye (2010) stated that growth analysis involved two assessments; (i) quantifying available plant parts (total biomass of the individual plant) and (ii) an assessment of the assimilatory system of the plant parts (total leaf area of plant). According to the authors, the purpose of calculating growth analysis functions is generally to allow the investigator to follow development and buildup of biological materials as influenced by their external or otherwise factors responsible for growth differences. These are light, temperature, water, flux and duration of photosynthetic active radiation, loss of photosynthetic tissue, nutrient supply as well as complex factors such as plant population and plant arrangement (Jollife *et al*., 1990; Leishman *et al*., 2000; Danny *et al*., 2004). Correlation between these environmental factors and growth characteristics are usually very informative. Some growth traits like dry matter yield, Crop Growth Rate, and Net Assimilation Rate have been used successfully in growth analytical studies (Nevando and Cross, 1990) as reported by (Odeleye, 2010).

2.12.1 Dry matter yield per plant

Increase in plant density per hectare could result into more biomass production per plot up to a maximum and before declining (Tollenaar, 1991). According to Echarte *et al*. (2008), the mode of biomass accumulation of a crop usually take the form of sigmoid pattern. There are three different stages that are clearly shown: (i) early growth stage or seedling stage when growth is very rapid, next to this is (ii) vegetative stage with gradual and steady rate of biomass accumulation and (iii) finally, a stage that brings reduction to apical growth, this stage is known as senescence stage with reduction in leaf production and photosynthesis declines due to leaf aging. When plants are exposed to shading an increase in height is observed (etiolation) but shaded plants gained weight more slowly than the exposed one (Odeleye, 2010). Nutrient supply affect dry matter accumulation mainly through changes in leaf area due to variation as a result of biomass accumulation arise due to differences in leaf production (Khalil *et al*., 2011).

2.12.2 Crop growth rate

Crop growth rate and absolute growth rate are mathematical tools widely employ to assess plant growth and these physiological traits are most suitable parameters to determine how well any plant is performing at any time (Nataraja *et al*., 2006). Crop Growth Rate could also be expressed in terms of energy unit as percent of an average incidence radiation or transformed into a coefficient of sunshine utilization. This coefficient indicates how economically a crop uses the solar radiation available during an interval between two harvests. It also provides a useful and practical way of comparing the production efficiency among communities, species, varieties and technique. Growth analysis variables were computed on the basis of formula used by Hasinagul *et al*. (2013). The crop growth rate (CGR) was calculated as:

$$\text{CGR} = \frac{W_2 - W_1}{\text{A}\,(t_2 - t_1)}$$

Where: W_2 and W_1 are the dry weights of plant materials per unit area of land at time t_2 and t_1. A is the land area. The unit expressed in $g.m^{-2}.day^{-1}$.

2.12.3 Net Assimilation Rate

Net Assimilation Rate (NAR) is defined as the change in plant dry weight per unit leaf area within a specific period. This determines how effective an individual leaf is and the role it plays in plant bio-chemical processes such as photosynthesis, respiratory and other roles required of the leaves by the plant (Hasinagul *et al*., 2013). It tells a lot about the plant ability to increase dry weight in terms of the area of its assimilatory surface. The

NAR does not measure real photosynthesis since it represents net result of photosynthesis gain over respiratory loss and may vary depending on the rate of respiration (Akintoye, 1997). When LAI is low, NAR is high, but as LAI increases, NAR decreases even though CGR increases during the same period. The decline in NAR results from progressive increases in mutual shading of leaves and all factors that can bring increase in LAI has negative correlation with NAR (Lucas, 1981). Joliffe *et al*. (1990) noted that NAR is a function of plant population. Also, Asif *et al*. (2010) observed that there is little chance in increasing yield through change in NAR because change in NAR with nutrient supply occurred only when low nutrient is supplied, so increasing fertiliser even above recommended rate is unlikely to increase NAR (Hunt *et al*., 2002). Net assimilation rate (NAR) was calculated as:

$$\text{NAR} = \frac{(W_2 - W_1)\,(log_e L_2 - log_e L_1)}{(t_2 - t_1)(L_2 - L_1)}$$

Where W_2 and W_1 are dry weight of plant material L_1 and L_2 are leaf areas per unit land area at time t_2 and t_1. The unit is expressed in $gm^{-2}day^{-1}$.

2.12.4 Leaf Area Index

Leaf Area Index (LAI) tells more of the assimilatory apparatus of the plant stand and use as primary value to determine other growth parameters. It was stated by Danalatos and Archontoulis (2010) as the leaf area of plant that covers a particular area of land. LAI = leaf area per plant / ground cover per plant. Leaf Area Index is the primary factor that can influence crop growth rate in crop communities. The relatively small leaf area per ground cover at the early stages of a crop grown from seed is responsible for the initial low LAI values. Improvement of crop condition through fertiliser application, selection of cultivars and breeding shortened the period of initial low values (Hossain *et al*., 2011). Hazandy *et al*. (2009) noted that when LAI is less than unity, some of the solar radiation cannot be intercepted by leaves but falls on bare soil or on weeds or on a companion crop in cases where intercropping is practiced. Danalatos and Archontoulis (2010); Hossain *et al*. (2011) showed that leaf photosynthesis per unit area declined more rapidly for old than for new hybrids when measured at plant density interaction because dry matter accumulation is due, in part, to increasing plant density. Variation in abiotic factors and leaf architecture affect LAI, CGR and NAR. Consequently, plants that have erect leaf architecture usually intercept sun light better and have higher optimum LAI or CGR (Baghestani *et al*., 2006).

2.13 Growth parameters and physiological attributes

The amount of sunlight the crop intercepted has a direct implication on the daily increment in its above ground development (Danalatos and Archontoulis (2010). Hazandy *et al*. (2009) stated that high and medium levels of fertiliser had a great impact on the quantity and volume of plant assimilatory material produced by Kenaf plant. This will increase its capacity for solar interception as well as absorption by the plant for increased biomass production for the plant biochemical process such as photosynthesis and respiration. It also plays a significant role in the crop water usage, cell development and division and other part of plant growth process (Mohammed *et al*., 2001). Stem elongation and girth development are considered to be responsible for determination of yield of a fibre crop. However, shortage of water supply during the vegetative growth of the crop has been reported to have significantly reduced these physiological parameters even when the fertilizer is adequately supplied (Hazandy *et al*., 2009). Sattar *et al*. (2010) noted that crop growth and development as well as biomass accumulation could be significantly influenced by the time of sowing. Ehsanullah *et al*. (1999) published that the judicious use of nitrogen fertiliser may improve overall growth attributes and production of crop. Crop productivity and some biochemical process in plant may be significantly influenced or altered by the amount of nitrogen fertilizer available for the plant use as at when needed (Asif *et al*., 2010). Mohammed *et al*. (2001) found that lack or inadequate supply of macro elements had significant negative implication on the growth and biomass accumulation of kenaf while adequate supply of these needed minerals aids the stem and diameter of the plant.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Experimental sites

The study consisted of a pot experiment carried out in the screen house and field trials which were conducted at the experimental farm of the Institute of Agricultural Research and Training (IAR&T), Obafemi Awolowo University, Ibadan, situated on latitude 07° 38' N, longitude 003° 84'E at an altitude of 182 m above sea level. The location lies within the tropical rainforest/ savanna transition zone of Nigeria.

3.2 Climatic description of the experimental site

The experimental fields were located within the rain forest-savanna transition agro-ecological zone of Nigeria. The ecological zone is characterized by bimodal rainfall distribution with distinct dry and wet seasons. Annual rainfall ranged from 1084 to 1315 mm for the period of the experiment (2013- 2016). The dry season occurred from early November to the end of March, while the rainy season was from April to October for each of the four years. Annual temperatures ranged from 21 to 36 °C. Relative humidity was high during the period of the field trials and ranged from 55 to 90 %. Information on rainfall and other weather parameters for the period of the experiment was collected from the Nigerian Meteorological Agency (Table 3.1).

3.3 Source and chemical analysis of the soil used for pot experiment

River base soil was collected and air dried. The soil was sieved through 2 mm mesh to separate stones as well as non-soil particles. A representative sample of the soil was analyzed for pH (H_2O), organic carbon, total nitrogen (TN), available phosphorus (P) and exchangeable bases (Ca, Mg), K and Na). Soil pH was determined in distilled water at a 1:2 soil to water ratio using electrometric method (Thomas, 1996). Total nitrogen in the sample was analyzed using macro Kjeldahl digestion procedure (Bremmer, 1965).

Table 3.1 Some recorded weather parameters at the experimental site from 2013 to 2016 the period of the experiment.

	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**June**	**July**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Total rainfall (mm)**	**Rainy days**
2013														
Total rainfall (mm)	4	23	83	150	156	182	173	147	183	179	29	6	1315	228
Max. Temp (ºC)	33	34	34	33	32	30	28	27	29	30	32	33		
Min. Temp (ºC)	21	22	23	23	22	22	21	21	22	22	22	21		
Sunshine Hour(hr/day)	5.4	6.0	5.8	6.0	6.8	5.8	5.9	5.0	5.2	5.4	6.0	6.0		
Rel. Humidity (%)	65.5	65.5	69.9	69.1	68	80.8	84.3	84	81.2	81	55	67		
2014														
Total rainfall (mm)	3.0	10	45	145	149	192	175	150	192	182	22	4.0	1269	260
Max. Temp (ºC)	32	33	33	34	31	30	29	28	30	32	33	34		
Min. Temp (ºC)	22	22	22	22	23	21	22	22	22	22	23	19		
Sunshine Hour(hr/day)	6.0	7.0	6.0	7.0	6.0	6.0	6.0	5.8	5.7	6.0	7.0	7.0		
Rel. Humidity (%)	66	77	72	55	72	90	82	90	86	77	48	55		
2015														
Total rainfall (mm)	5	15	44	144	164	192	153	146	197	168	19	2.0	1249	222
Max. Temp (ºC)	33	34	33	33	33	32	30	29	29	30	33	33		
Min. Temp (ºC)	20	23	22	21	20	20	21	22	21	21	22	20		
Sunshine Hour(hr/day)	7.4	7.0	7.0	7.0	7.6	7.0	7.0	7.8	7.0	6.8	7.0	7.0		
Rel. Humidity (%)	69	48	74	79	64	79	74	64	89	55	39	56		
2016														
Total rainfall (mm)	07	14	56	159	151	198	166	144	189	161	12	0	1084	250
Max. Temp (ºC)	34	34	34	34	33	31	29	30	31	32	34	34		
Min. Temp (ºC)	21	22	23	22	21	20	22	23	20	21	21	21		
Sunshine Hour(hr/day)	7.0	7.3	7.8	7.0	6.8	7.4	6.6	6.8	7.0	7.0	**7.2**	**7.2**		
Rel. Humidity (%)	62	65	79	72	89	88	82	80	86	64	54	48		

Source: Nigerian Meterological Agency (2013 – 2016)

Available phosphorus was extracted using Bray1 P process (Bray and Kurtz, 1945), colour developed by ascorbic acid method (Model CE 2041). Exchangeable bases including K, Ca, Mg and Na were first extracted using 1.0 N ammonium acetate (Hendershot and Lalande, 1993). Thereafter, the quantity of K and Na in the filtrates were determined using flame emission photometry (Jenway, PFP7 Model) while Ca and Mg were determined using a Perkin Elmer Atomic Absorption Spectrophotometry (AAS). Exchangeable acidity was extracted using 1 N KCl (Thomas, 1982) and determined through titration using 0.01 N NaOH by phenolphthalein indicator. Effective Cation Exchange Capacity (ECEC) was determined as sum of the exchangeable bases and total exchangeable acidity (Chapman, 1965).

3.4 Source and chemical analysis of the organic fertiliser used for the study

The organic fertiliser used for the experimenst was (Grade B pacesetter fertiliser) sourced from an organic fertiliser plant at Aleshinloye market, Ibadan**.** It was composted from municipal waste and cow dung. Samples were randomly taken from various bags of the organic fertiliser (OF), bulked and sub sampled for chemical analysis as stated in 3.3. The OF material was digested with a mixture of perchloric, nitric and concentrated sulphuric acids. Phosphorus was determined from digest by vanado-molybdate yellow colour procedure (Olsen and Dean, 1965), while the bases: K and Na were determined using flame photometer. Calcium (Ca) and Magnisium (Mg) as well as the micronutrients: Fe, Zn, Cu and Mn in the digest were read with the Atomic Absorption Spectrophotometer (Model Bulk Scientific NV 210/211).

3.5. Experiment 1: Evaluation of the fibre and seed yield potential of kenaf under varying rates of organic and inorganic fertiliser

3.5.1. Experimental design and Treatments

This experiment was conducted in pots. It consisted of a combination of two (2) fertiliser types as the main plot and five (5) application rates (0, 70, 100, 130 and 160 kg N ha^{-1}) in a completely randomized design with four replicates to give 40 pots. Forty plastic buckets of 12 kg capacity were perforated at the base to facilitate aeration but plugged with cotton wool to control drainage. Each was placed on a saucer to retain any drain material. The buckets were filled with 10 kg air dried river base soil used as potting medium. Organic fertiliser at 0.00, 26.51, 37.88, 49.24 and 60.60 g/10 kg of soil (see appendix 9 for calculation) was added and thoroughly mixed with the soil and watered for two weeks before sowing (WBS) to equilibrate and initiate mineralization. Four kenaf (Ifeken 100 variety) seeds were sown directly into each pot at 0.5 cm depth on 23 October 2013. The seedlings were thined to two plants per pot at 2 weeks after sowing (WAS). At two WAS, NPK 20:10:10 fertiliser was applied to the second group at: 0.00, 1.75, 2.50, 3.25 and 4.00 g/10 kg of soil. The quantity of fertilisers applied in each group were to release 0, 70, 100, 130 and 160 kg N ha^{-1} respectively (see appendix 9). Plants were watered regularly and weeds removed by hand picking, whenever they emerged. Laraforce (Lambda–cyhalothrin 2.5% E.C) insecticide was sprayed at the rate of 1L ha^{-1} with dilution factor of 2.5 ml/litre to control insect pests. The insecticide was sprayed at 4 and 8 WAS before the maturation of the plant.

3.5.2 Data collection and analysis

Data were collected at 4, 8 and 12 WAS on plant height, stem diameter and number of leaves from four plants per treatment. Plant height was measured from the soil surface to the tip of the stem using a meter rule graduated in centimeter. Stem diameter was measured using vernier caliper at the base of each plant, 10 cm above the soil surface. Number of leaves per plant were counted while leaf area per plant was measured using SHY- 150 leaf area meter with accuracy of ± 2% at 4, 8 and 12 WAS. At 20 WAS, harvesting was done by cutting the dried plant at 1 m above the soil surface. Capsules were separated and threshed; seed yield per pot was determined by weighing using top load weighing balance. All the data were subjected to analysis of variance ANOVA and significant means were separated using Duncan's multiple range tests at $P \leq 0.05$.

3.6.0 Experiment 1b: Response of kenaf (*Hibiscus cannabinus* L.) to varying rates and types of fertiliser (field trial)

3.6.1 Land preparation and experimental design

Field trials were conducted in 2014 and 2015 to evaluate the response of kenaf to fertiliser types and rates. The experimental field was ploughed and harrowed, then marked out with wooden pegs. The whole field measured 34 m × 19 m was divided into main plot of 19 m × 4 m. There was a space of 2 m between two main plots. Sub plot measured 3 m x 4 m each with 1 m gap between two sub plots. The main plots were for the fertiliser types while subplots were for the fertiliser rates and were laid side by side in each replicate. The experiment was arranged in a randomized complete block design (RCBD) with three replicates (Figure 3.1).

3.6.2 Soil analysis

Soil samples were randomly taken within 0-15 cm depth, bulked and sub samples were taken for soil analysis before the experiment start in each year. The samples were air-dried and passed through a 2.0 mm mesh sieve and another part with 0.5 mm mesh sieve (for organic carbon). The samples were analyzed for pH (H_2O), organic carbon, total nitrogen, available phosphorus (P), exchangeable bases; Ca, Mg K, and Na as stated in section 3.3.

3.6.3 Fertiliser application on the field

Organic fertiliser (OF) were applied as: 0, 6.36, 9.09, 11.82 and 14.55 kg per plot (see appendix 9 for calculation) and thoroughly mixed with the soil two weeks before sowing. At two weeks after sowing, the following quantity of NPK 20-10-10: 0, 0.42, 0.60, 0.78 and 0.96 kg per plot were applied to the plots designated for inorganic fertiliser (IF). Both organic and inorganic fertilisers applied were expected to release 0, 70, 100, 130 and 160 kg N/ha.

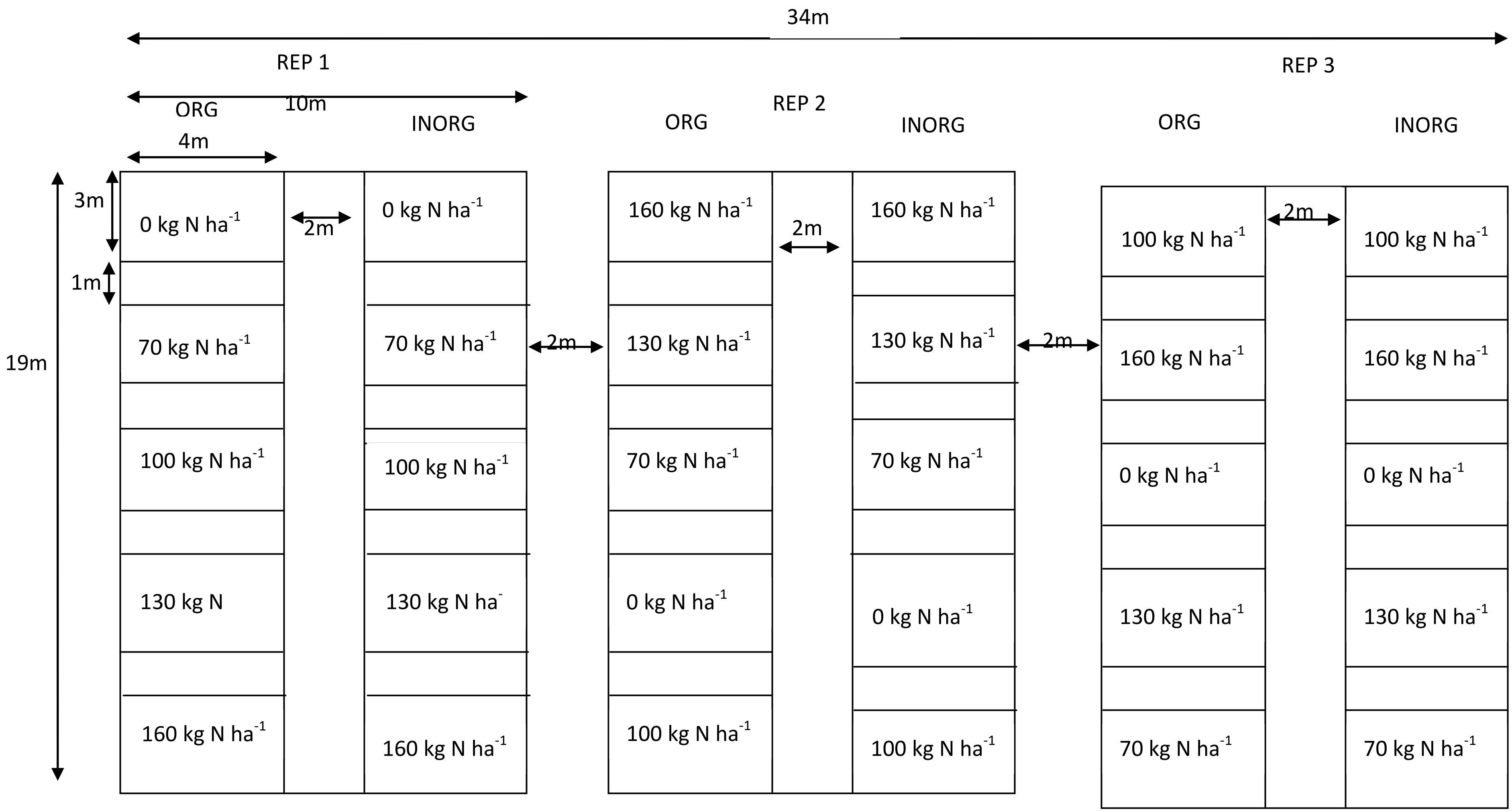

Figure 3.1: Field layout for experiment on the response of kenaf (*Hibiscus cannabinus* L.) to varying rates and types of fertiliser

3.6.4 Planting and field management

Four seeds of Ifeken 100 variety of Kenaf were planted at 0 - 0.5 cm depth with spacing of 50 cm × 20 cm on the 24 May, 2014. The plants were thinned to two plants per stand at 2 WAS, resulting in a plant density of 240,000 plant ha^{-1}. Hoe weeding was done at 3 and 6 WAS, while insect pests were controlled at 4 and 8 WAS using Laraforce (Lambda halothrin 2.5% E.C) insecticide at the rate of 1L ha^{-1} with dilution factor of 2.5 ml/litre as in the pot experiment.

3.6.5 Data collection

Ten plants were randomly selected from the middle of each plot and these were tagged for data collection on crop performance. Data were collected on growth parameters as described for experiment 1a at 4, 6, 8, 10 and 12 WAS. For dry matter determination, two plants per replicate were uprooted at 4, 6, 8 and 10 WAS and washed with water to remove soil from their roots. Each sample was separated into components (leaves stem and roots) and oven dried at 70 ^{o}C till constant weight. Dry matter yield of the plant components were determined by weighing using Mettler PM 4000 weighing balance to get root dry weight, stem dry weight and leaves dry weight. Total plant dry weight was determined by adding the values of dry weight of leaves with dry weight of stem. Percentage shoot weight was also calculated by dividing the total above ground dry weight by the total whole plant and then multiplied by 100. Absolute growth rate (AGR) and relative growth rate (RGR) were calculated according to Muchow (1979) as applied by Hazandy *et al*. (2009).

$$\text{AGR (g.day}^{-1}\text{)} = \frac{W_2 - W_1}{(t_2 - t_1)}$$

Where: AGR : Absolute growth rate

W_1 : Biomass at first reading

W_2 : Biomass at second reading

T_1 : Time of first biomass reading

T_2 : Time of second biomass reading

$$\text{RGR (g.day}^{-1}\text{)} = \frac{log_e W_2 - log_e W_1}{(t_2 - t_1)}$$

Where: RGR	: Relative growth rate
log_e	: Natural log
W_1	: Biomass at first reading
W_2	: Biomass at second reading
T_1	: Time of first biomass reading
T_2	: Time of second biomass reading

3.6.6. Fibre yield determination

At 10 WAS, plants within 1 m^2 were cut at height of 10 cm from plant base within the inner row of each plot in each replicate to avoid border effects. The leaves were removed and whole stems were subjected to water retting. The plants were soaked in water for 14 days. After the 14^{th} day, the plants were removed from water and the bast was separated from the core. The bast and core were thereafter washed with clean water and sun dried. Dried bast and core yield were determined by weighing using Mettler PM 4000 weighing balance.

3.6.7 Determination of seed yield and yield components

At 20 WAS (when more than 80% of the capsules were already dried but before the seed started to shatter), the plants were cut at about 1 m above ground level. Five plants were selected from each plot to determine: number of capsule per plant and number of seed per capsule through visual counting. Weight of 100-seed and the total seed weight per plot were also determined using top load weighing balance.

3.6.8 Determination of nutrient content in kenaf tissue

3.6.8.1 Plant sample preparation and analysis

Five plants were randomly selected per plot at 10 WAS and cut at 10 cm above soil surface. The plants were rinsed in clean water to remove soil and any other dirt particles on it before being separated into shoot and root. The shoot was oven dried at 70 $^{\circ}C$ till constant weight was attained. These dried materials were milled into powder using a Glen Creston mill equipped with stainless steel grinding chamber with knives and sieve (0.5 mm operations) and stainless cup. The materials obtained were then analyzed for N, P, K, Ca and Mg concentration according to procedures described in the IITA manual for soil and plant nutrient analysis (IITA, 1984). To determine total nitrogen in the samples, the milled samples were subjected to Kjedahl digestion using concentrated sulphuric acid with selenium and sodium sulphate as catalyst. Total nitrogen in form of NH_4-N released from the digest by steam distillation with excess NaOH was trapped in boric acid. The nitrogen was then determined by titration with 0.1 N HCl.

The P, K, Ca and Mg were determined by ashing 0.2 g plant samples in a crucible and placed in muffle furnace for 2 hours at 600 °C. The ash was cooled and dissolved in 1N HCl and solution passed through filter paper into 50 ml volumetric flask and made up to the mark with distilled water. Phosphorus concentration was determined by the vanado molybdate yellow colorimetric method using spectrophotometer. The K, Ca and Mg in the digest were read with the atomic absorption spectrophotometer (Model Buck Scientific 210 VGP). Nutrient uptake was then calculated as

Nutrient uptake = Y× NC

Where Y = dry matter (g)

NC = Nutrient concentration (%)

3.6.8.2 Determination of crude protein

The estimation of crude protein involves the determination of total nitrogen by the Kjedhal procedure. The amount of crude protein was obtained by multiplying the nitrogen content with a factor (6.25). This factor is based on the assumption that all crude proteins contain 16 % nitrogen and that all nitrogen in the tissue is present as protein (AOAC, 2000).

3.6.8.3 Moisture content determination

The moisture content was determined according to AOAC (2000). Empty crucible was oven dried and allowed to cool in the desiccator and weighed (W_0). Two grams of milled plant material was added to crucible and reweighed (W_1). The samples were then dry in the hot air drying oven at 105 – 110°C for 24 hours. It was allowed to cool in the desiccators before weighing (W_2). It was returned to the oven for another 24 hours to get a constant weight.

Calculation: Moisture = $\frac{W_1 - W_2}{(W_1 - W_0)} \times 100$

Where:

W_1 = weight of the empty crucible

W_1 = weight of the crucible with plant sample before oven drying

W_2 = weight of the crucible with plant sample after oven dried

3.6.8.4 Ash content determination

Following AOAC (2000), empty crucible was weighed without sample (W_0) and with the sample (W_1). It was then ashed in the muffle furnace at 500 $^{\circ}$C. The crucibles were then allowed to cool with the samples in the desiccator and reweighed the crucible and ash (W_2). Percentage ash content was then calculated as:

$$\% \text{ Ash} = \frac{W_2 - W_0}{W_1 - W_0} \times 100$$

Where:

W_0 = weight of empty crucible

W_1 = weight of crucible with sample

W_2 = weight of crucible with ash of the sample

3.6.8.5 Fibre content determination

Two grams of milled plant material was carefully measured into the fibre flask and 100 ml of 0.255 N H_2SO_4 was added. The mixture was gently heated under reflux for 1 hour with the heating mantle. The hot mixture was filtered through a fibre sieve cloth. The filtrate was discarded while the remaining content was returned into the fibre flask to which 100 ml of 0.313 N NaOH was added and heated under reflux for another 60 minutes. The mixture was filtered through a fibre sieve cloth and 10 ml of acetone was added to dissolve any organic constituent present. The content was washed with about 50 ml hot water on the sieve cloth before it was finally transferred into the crucible. The crucible and its content were oven-dried at 105 °C overnight to eliminate moisture. The oven-dried crucible containing the residue was left to cool in desiccators and later weighed to obtain the weight W_1. The crucible with weight W_1 was transferred to the muffle furnace for ashing at 550 ^{o}C for 4 hours. The crucible containing white or grey ash (free of carbonaceous material) was cooled in the desiccator and weighed to obtain W_2. The difference ($W_1 - W_2$) gives the weight of fibre. The percentage fibre was obtained by the formula: % fibre = $\frac{W_1 - W_2}{wt\ of\ sample} \times 100$

Where:

W_1= weight of the empty crucible

W_2 = weight of the crucible with the sample

Wt = weight of the plant sample

(AOAC, 2000).

3.6.8.6 Nitrogen free extracts (NFE):

Following AOAC (2000), this was determined by subtracting the summation of (% moisture + % crude protein + % ether extract + % crude fibre + % ash) from 100

i.e. [100 – (% M + % CP + % EE + % CF + % ash)]

3.6.8.7 Crude fat or ether extract:

One gram of each dried material was weighed into fat free extraction thimble and plugged lightly with cotton wool. The thimble was placed in the extractor and fitted up with reflux condenser and a 250 ml soxhlet flask which has been previously dried in the oven, cooled in the desiccator and weighed. The soxhlet flask was then filled to ¾ of its volume with petroleum ether (with boiling point of 40 – 60 ^oC) and the soxhlet flask. Extractor plus condenser set was placed on the heater for 6 hours with continuous running water from the tap for condensation of ether vapour. The set was closely monitored for ether leaks and the heat source was adjusted as required for the ether to boil gently. The ether was left to siphon over several times say over at least 10 – 12 times. Then was the ether content of the extractor carefully drained into the ether stock bottle. The thimble containing sample was removed and dried on a clock glass on the bench top. The extractor, flask and condenser were replaced and the distillation continued until the flask was dry. The flask, which now contains the fat or oil was detached, its exterior cleaned and dried to a constant weight in the oven. The percentage fat/oil was obtained by the formula:

$$\frac{W_1 - W_0}{wt\ of\ sample} \times 100 \qquad \text{AOAC (2000)}$$

Where:

W_0 = Initial weight of the soxhlet flask

W_1 = Final weight of oven dried flask + oil extract

W_t = Weight of the sample

3.6.9 Statistical analysis

Data on plant height, stem diameter, number of leaves, leaf area, dry matter yield, fibre yield and seed yield were subjected to ANOVA using SAS statistical package (SAS, 2007) and the mean comparisons were performed by Duncan's multiple range test (DMRT) at $P \leq 0.05$.

3.7 Economic Analysis (Partial Budgeting)

Economic analysis was conducted to assess the profitability of using each rate of Nitrogen for either organic or inorganic fertiliser compared to the control. The partial budgeting method was used. It involves the organization of experimental data and information about costs and benefits of the alternative treatments. However, only those costs which were affected by the alternative treatments being considered were included in the budget. The budget preparation included calculating:

(i) the average yield (t/ha) from each N treatment in each fertiliser type

(ii) the gross field benefits (₦/ha) based on the field price of each crop yield, gross field benefits (₦/ha) = Yield of each crop component × fixed price.

The gross field benefit of different components of kenaf in each fertiliser types were added to give the gross field benefit for the N rate in each fertiliser type.

(iii) the total cost that vary (₦/ha) were also calculated for each treatment by costing all the inputs and labour used under each treatment.

(iv) the net benefits (₦/ha) under each treatment were calculated as:

Net benefits (₦/ha) = Gross field benefits – Total cost that vary.

3.8 Experiment 1c: Effects of fertiliser combination on the growth performance of kenaf evaluated on the field

3.8.1 Experimental procedure and design

Field measuring 15 m × 11 m was ploughed, harrowed and demarcated into plots of 3 m × 3 m consisting of 12 plots with gap of 1 m between two plots. Soil samples were randomly collected from 0-15 cm depth, bulked and sub-samples taken for pre-planting soil analysis according to the procedure stated in 3.3. The rate of organic fertiliser which performed higher in experiment 1b (160 kg N/ha) since both 100 and 130 kg N/ha of inorganic fertiliser used in the experiment 1b were not significantly different, hence 100 kg N/ha was chosen. The two rates were combined to form: 160 kg N/ha (sole organic), 100 kg N/ha (sole inorganic), 80 kg N/ha organic + 50 kg N/ha of inorganic (50: 50 of organic and inorganic) and control (no fertiliser application). These rates were used in this experiment to assess the effects of combined fertilisers on the growth performance, fibre and seed yield of kenaf. The OF was thoroughly mixed with the soil 2 weeks before sowing while the inorganic fertiliser was added 2 weeks after sowing. The trial was arranged in a randomized complete block design (RCBD) with three replicates (Figure 3.2). The field was sowed using spacing 50 cm × 20 cm in June 2014 and 2015. Weed and insect pest management was as described in section 3.5.1. Data on vegetative growth, fibre yield, seed yield and seed yield components were recorded at harvest. Data collection and analysis were done as in section 3.5.2

3.9.0 Experiment 2: Effect of varying population density on the growth and fibre yield of kenaf

3.9.1 Experimental procedure and design

The experiment was designed to assess the performance of kenaf (*Hibiscus cannabinus* L.) in response to varying plant population. Three different spacing: 50 cm × 15 cm, 50 cm × 20 cm and 50 cm × 25 cm to attain plant population 380,000, 280, 000 and 240,000 plants ha^{-1} respectively) were assessed using the Combined fertiliser from experiment 1b. The experimental design was a randomized complete block design with three replicates. Field measuring 11 m × 11 m was ploughed, harrowed and marked out into plot of 3 m × 4 m with 1 m space between plots. The field layout is as shown in Figure 3.3. Soil samples were randomly obtained from 0-15 cm depth, bulked and sub-sample were taken for pre-planting soil analysis according to the procedure stated in section 3.3. Sowing was done in June 2014 and 2015. Weed and insect pest management was as described in 3.6.4.

3.9.2 Data collection and analysis

Five plants were randomly selected and tagged from the inner rows of each plot for data collection. Data on plant height and stem diameter were recorded at 4, 6, 8, 10 and 12 WAS following the procedure stated in section 3.5.2. Two plants per plot were uprooted at 4, 6, 8 and 10 WAS for total dry plant material. The plants were washed with water to remove soil and any other material from the plant root after which they were oven dried at 70 ^{o}C to constant weight and recorded. At 10 WAS, plants within 1m^2 from the inner row of each plot were cut at 10 cm above the soil surface. The core and bast fibre yield were determined following the process described in 3.6.6. Seed were harvested at 20 WAS. Data were analyzed using ANOVA.

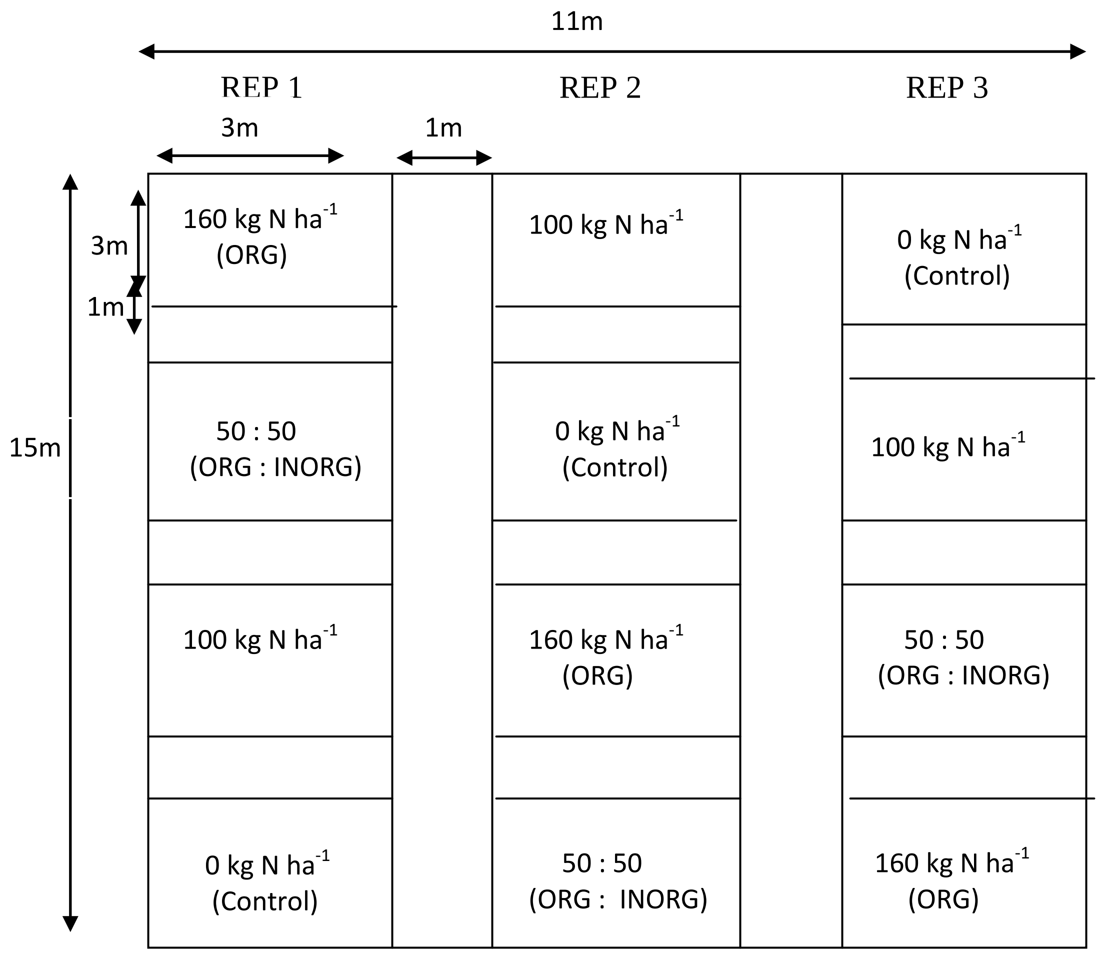

Figure 3.2 Field Layout for Experiment 1c

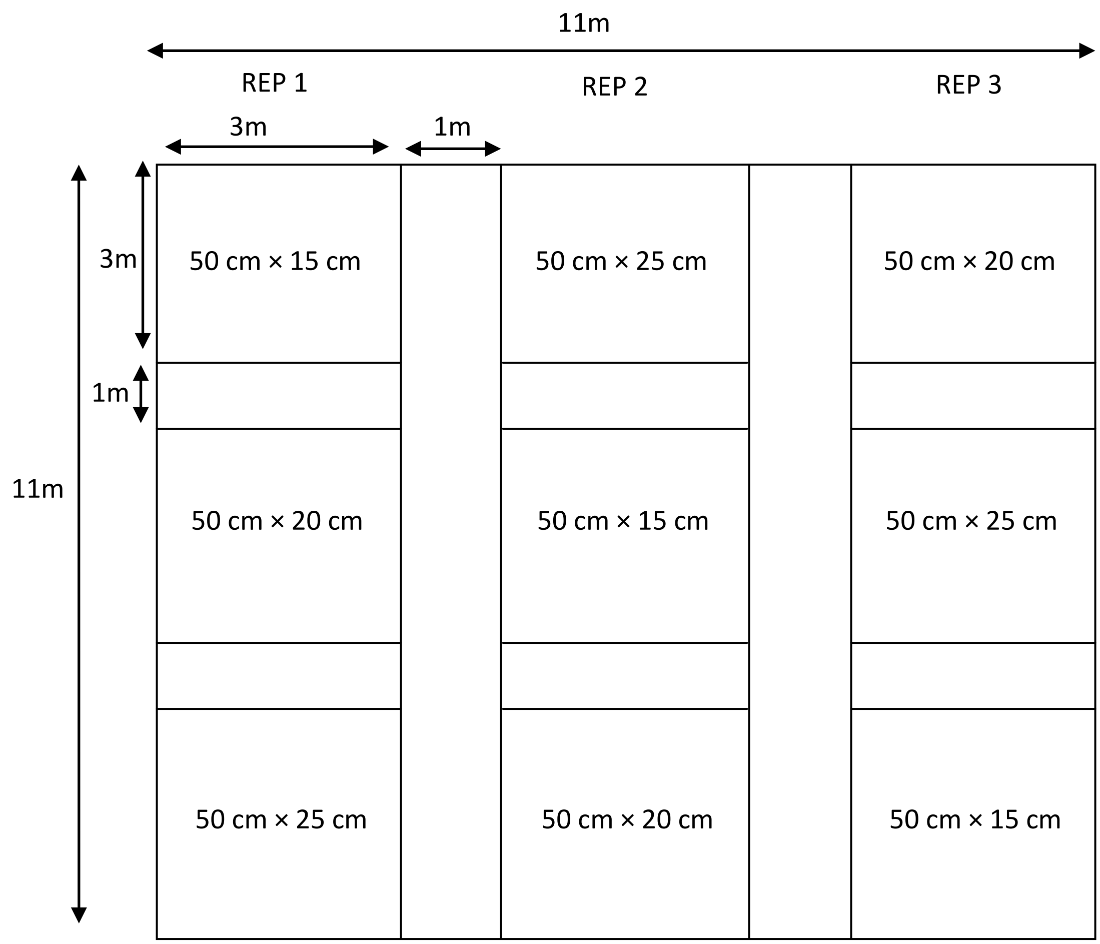

Figure 3.3: Field Layout for Experiment 2

3.10.0 Experiment 3: Effects of sowing date on fibre and seed yield of kenaf (*Hibiscus cannabinus* L.)

3.10.1 Experimental procedure and design

The field experiment was established in May, June, July and August of 2015 and 2016. It was an experiment set up to determine the effects of sowing date on the fibre and seed yield of kenaf. The spacing 50 cm × 20 cm (280,000 plant/ha) used was based on the results obtained from Experiment 2. The experimental field was ploughed, harrowed and marked out into 3 m × 3 m plot size with 1 m space between two plots. The design used was randomized complete block design with three replicates. A sample of the field layout is shown in Figure 3.4. Soil samples were randomly collected from 0-15 cm depth, bulked and sub-sampled for pre-sowing soil analysis according to the procedure stated in section 3.3. Using combined fertiliser that was adjudged best in Experiment 1b, weeds and insect pest were managed according to the procedure described in section 3.6.4.

3.10.2 Data collection and analysis

Five plants were randomly selected and tagged from each plot for data collection at 4, 6, 8, 10 and 12 WAS as in section 3.5.2. The data were subjected to ANOVA and the means were compared using Least Significant Difference at $P \leq 0.05$.

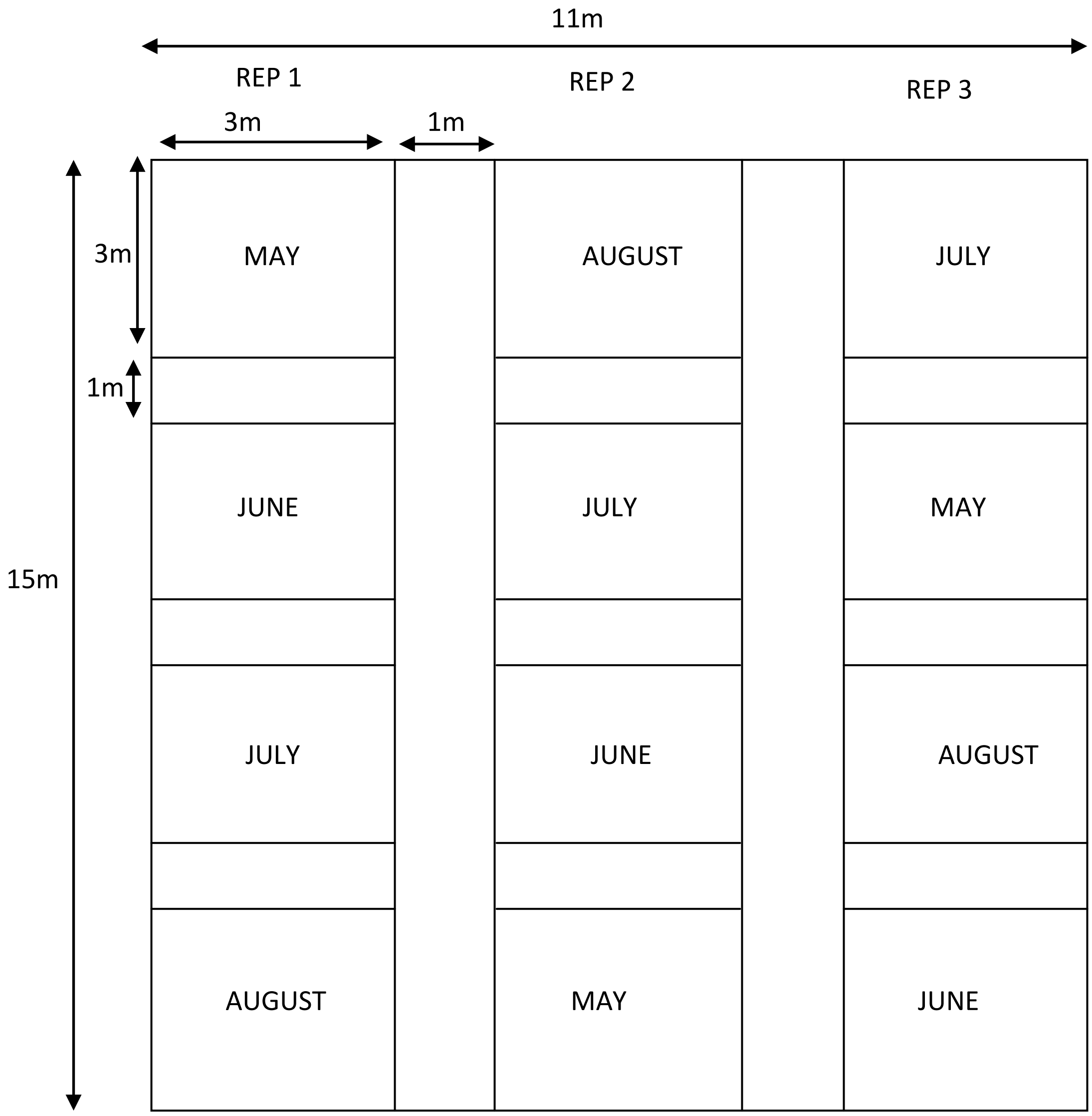

Figure 3.4: Field Layout for Experiment 3

CHAPTER FOUR

RESULTS

4.1 Physico-chemical properties of the soil used for the experiments

The physio-chemical properties of the soils used for both pot and field experiments before cropping are shown in Table 4.1. Soil pH (H_2O), ranged from 6.08 to 6.53 in the 2013, 2014, 2015 and 2016 field trials. The pH (7.37) of the soil in the pot was slightly alkaline while those soils from the experimental field were slightly acidic to neutral (6.08 to 6.53). The organic carbon content in the soils ranged from 2.1 g/kg to 14.9 g/kg from 2013 to 2016 respectively. Total nitrogen in pot is 0.77 g/kg while it ranged from 0.2 g/kg in 2013 to 1.3 g/kg in 2016. These values were considered medium to moderately high according to soil fertility maps of Nigeria. The available P for potted soil was 6 mg/kg while it was from 3.25 mg /kg to 5.63 mg/kg in the field. The soils were generally low in P considering 7 mg/kg to 20 mg/kg as moderate. The exchangeable Ca ranged between 1.2 mg/kg to 2.87 mg/kg. The exchangeable K ranged between 0.1 cmol/kg to 0.62 cmol/kg. The effective cation exchange capacity ranged between 2.3 cmol/kg (pot) to 6.09 cmol/kg (field) in the soils used for this study. These values were however, low in these soils with the lowest recorded in the soil for pot experiment. The textures of the soils used were loamy sand except that of the pot which is sandy.

4.2 Nutrient content of the organic fertiliser used

Grade B organic fertiliser used shows appreciable level of various nutrient elements. The total nitrogen, available phosphorus and carbon content of the Grade B were 1.32 g/kg, 0.86 g/kg and 31.94 g/kg respectively. The exchangeable cations (Ca^{2+}, Mg^{2+} and K^{+}) were 2.34, 0.24 and 0.5 cmol/kg respectively with appreciable levels of micronutrients such as Na^{+}, Mn^{+}, Fe^{2+}, Cu^{+} and Zn^{+} present (Table 4.2).

Table 4.1: Physical and chemical properties of the soils of both pot and field used for this study

Parameters	**Results**				
	Pot	**Field**			
	2013	**2013**	**2014**	**2015**	**2016**
pH (H_2O)	7.37	6.09	6.24	6.53	6.08
Organic Carbon (g kg^{-1})	7.70	2.10	9.10	7.20	14.90
Total Nitrogen (g kg^{-1})	0.77	0.20	0.90	0.70	1.30
Avail. P (mg kg^{-1})	6.0	6.0	3.0	5.0	4.0
Exchangeable cations (cmol kg^{-1})					
Ca^{++}	1.2	2.87	2.21	2.19	2.50
Mg^{++}	0.8	2.52	0.90	0.24	1.10
K^{+}	0.1	0.17	0.22	0.33	0.62
Na^{+}	0.2	0.43	0.41	0.44	0.34
Exchangeable acidity (cmol kg^{-1})	ND	0.10	0.12	0.08	0.11
ECEC	2.3	6.09	3.86	4.43	4.66
Particle Size (g kg^{-1})					
Sand	892	828	864	848	766
Silt	68	48	68	96	69.2
Clay	40	124	68	56	164.8
Textural Class (USDA)	Sand	Loamy sand	Loamy sand	Loamy sand	Sandy loam

ND: not detected

Table 4.2: The chemical analysis of the Aleshinloye grade B organic fertiliser used for the experiment

Parameter	Value
N (g kg^{-1})	1.32
P (g kg^{-1})	0.86
C (g kg^{-1})	31.94
Exchangeable cations (cmol kg^{-1})	
Ca^{++}	2.34
Mg^{++}	0.24
K^{+}	0.5
Micronutrient (mg kg^{-1})	
Na^{+}	29.61
Mn^{+}	106.67
Fe^{++}	891.39
Cu^{+}	16.98
Zn^{+}	1.99

4.3 Experiment 1: Evaluation of the fibre and seed yield potential of kenaf under varying rates of organic and inorganic fertiliser

4.4 Effects of varying rates of organic and inorganic fertilisers on the vegetative growth and seed yield of kenaf grown in pot

The effects of different fertiliser types, rates and their interaction on the kenaf plant height at 4, 8 and 12 WAS is presented in Table 4.3. Generally, the plant height increased over time in all the treatments. At 4, 8 and 12 WAS, there was significant difference in plant height among fertiliser types. The highest plant height (54.22 cm) was obtained with the application of inorganic fertiliser at 4 WAS while the application of organic fertiliser resulted in significantly taller kenaf plants at 8 WAS (98.63 cm) and 12 WAS (182.44 cm).

At 4 WAS, kenaf Plant height (65.3 cm) in 160 kg N/ha was taller than those from other rates. When fertiliser was not applied, plant height (39.03 cm) was not significantly different from plant height (43.68 cm) in 70 kg N/ha. Plant height (95.25 cm and 94.41 cm) from kenaf with 130 and 160 kg N/ha were not significantly different but they were however taller than the plant height (89.41 cm) obtained in 100 kg N/ha at 8 WAS. At 12 WAS, plant height (186.9 cm) from the application of 130 kg N/ha was not significantly different from plant height (183.3 cm) obtained in100 kg N/ha but they were however taller than plant height (179.6 cm) in 160 kg N/ha. The least plant height (145.2 cm) was from kenaf grown without fertiliser application. The interaction of fertiliser type and rate at 4 WAS showed that organic fertiliser applied at 160 kg N/ha had the highest PH (74.3 cm) followed by the inorganic fertiliser of 100 and 130 kg N/ha with plant height 60.1 cm and 59.6 cm respectively, though they were not significantly different. The plant height 55.1 cm and 56.2 cm obtained from organic fertiliser (130 kg N/ha) and inorganic fertiliser (160 kg N/ha) were not significantly different from each other. However, plant height 46.9 cm from inorganic fertiliser (70 kg N/ha) was taller than plant height 40.5 cm obtained from organic fertiser (70 kg N/ha). The plant height (105.0 cm and 103.8 cm) obtained from the application of organic fertiliser (160 kg N/ha and 130 kg N/ha) were not significantly different from each other but they were however taller than plant height (83.8 cm and 86.8 cm) from inorganic fertiliser of the same rates (160 kg N/ha and 130 kg N/ha) at 8 WAS. Plant height (95.7 cm) from organic fertilser (100 kg N/ha) was taller than plant height (83.1, 86.8 and 83.8 cm) from inorganic (100, 130 and 160 kg N/ha) respectively at 8 WAS. The least plant height (74.9 and 74.6 cm) obtained when no fertiliser was applied in both organic and inorganic fertiliser at 8 WAS.

At 12 WAS, the plant height (194.0 cm) was obtained from organic fertiliser (160 kg N/ha). This was significantly taller than plant height (187.4 cm) from inorganic fertiliser (130 kg N/ha). However, plant height (187.4 cm) was not significantly different from plant height (186.3, 183.6 and 183.0 cm) obtained from 130 kg N/ha (organic fertiliser), 100 kg N/ha (inorganic fertiliser) and 100 kg N/ha (organic fertiliser) respectively. Plant height (165.1 cm) from inorganic fertiliser (160 kg N/ha) was significantly lower compared to plant height from other rates, however, it was taller than the plant height (145.3 cm) obtained from plot without fertiliser application.

Stem diameter (1.3 cm, 1.4 cm and 1.7 cm) obtained from plots that had organic fertiliser were higher than (0.6 cm, 0.8 cm an d1.2 cm) those obtained from plots that had inorganic fertiliser irrespective of the rate applied at 4, 8 and 12 WAS respectively as shown in Table 4.4. The bigger plants with stem diameter (0.9 cm, 1.1 cm and 1.8 cm) were obtained at 4, 8 and 12 WAS from the application of 160 kg N/ha. These values were significantly higher than those obtained from the application of other rates. Stem diameter (0.5 cm and 0.9 cm) obtained at 4 and 8 WAS from plot with rates 70 kg N/ha were not significantly different from stem diameter (0.5 cm and 0.9 cm) obtained from the application of rate 100 kg N/ha. The least stem diameter (0.4 cm, 0.9 and 1.7 cm) were obtained in plot without fertiliser at 4, 8 and 12 WAS. Organic fertiliser (160 kg N/ha) had the bigger stem diameter (0.8 cm, 1.4 cm an d2.3 cm) at 4, 8 and 12 WAS and the values are significantly higher than values obtained from inorganic fertiliser of the same rate (160 kg N/ha) with stem diameter (0.5 cm, 0.7 cm and 1.4 cm) respectively. Stem diameter (1.7 cm and 1.8 cm) obtained from organic fertilizer (100 and 130 kg N/ha) were not significantly different from each other but they were significantly higher than stem diameter (1.5 cm and 1.6 cm) obtained from plot with inorganic fertiliser (100 an d130 kg N/ha). Stem diameter (1.4 cm) in organic fertiliser (70 kg N/ha) was significantly higher than stem diameter (1.3 cm) obtained from the same rate (70 kg N/ha) of inorganic fertiliser. The least stem diameter (1.2 cm) was from plot without fertiliser of either types.

Table 4.3: Effects of organic and inorganic fertiliser types on the plant height (cm) of pot grown kenaf in 2013

Treatments	Weeks After Sowing		
	4	8	12
Fertiliser types			
OF	52.09 [b]	98.63 [a]	182.44 [a]
IF	54.22 [a]	76.51 [b]	161.79 [b]
Rate (kg N/ha)			
0	39.03 [d]	74.76 [c]	145.22 [c]
70	43.68 [d]	79.03 [c]	169.13 [b]
100	55.45 [c]	89.41[b]	183.32 [a]
130	57.38 [b]	95.25 [a]	186.85 [a]
160	65.27 [a]	94.41 [a]	179.57 [b]
Interaction			
OF× 0 kg N	39.74 [g]	74.88 [d]	145.13 [e]
OF × 70 kg N/ha	40.49 [f]	83.81 [cd]	182.75 [bc]
OF × 100 kg N/ha	50.81 [d]	95.69 [b]	183.00 [bc]
OF × 130 kg N/ha	55.13 [c]	103.75 [a]	186.31 [b]
OF × 160 kg N/ha	74.33 [a]	105.00 [a]	194.00 [a]
IF × 0 kg N	38.32 [g]	74.63 [d]	145.31 [e]
IF × 70 kg N/ha	46.86 [e]	74.25 [d]	155.50 [d]
IF × 100 kg N/ha	60.09 [b]	83.13 [cd]	183.63 [bc]
IF × 130 kg N/ha	59.63 [b]	86.75 [c]	187.38 [b]
IF × 160 kg N/ha	56.20 [c]	83.81 [c]	165.13 [c]

OF = organic fertiliser; IF = inorganic fertiliser; Means with same letter among treatments are not significantly different at $p \leq 0.5$.

Table 4.4: Effect of organic and inorganic fertiliser type on the stem diameter (cm) of pot grown kenaf in 2013

Treatments	Weeks After Sowing		
	4	**8**	**12**
Fertiliser types			
OF	1.27 [a]	1.35 [a]	1.70 [a]
IF	0.56 [a]	0.78 [b]	1.23 [b]
Rate (kg N/ha)			
0	0.40 [d]	0.97 [d]	1.17 [e]
70	0.49 [c]	0.89 [c]	1.37 [d]
100	0.49 [c]	0.89 [c]	1.65 [c]
130	0.81 [b]	0.96 [b]	1.68 [b]
160	0.92 [a]	1.07 [a]	1.82 [a]
Interaction			
OF× 0 kg N	0.39 [e]	0.64 [f]	1.17 [f]
OF × 70 kg N/ha	0.44 [d]	0.99 [b]	1.41 [d]
OF × 100 kg N/ha	0.45 [d]	1.00 [b]	1.72 [b]
OF × 130 kg N/ha	0.46 [d]	1.02 [b]	1.75 [b]
OF × 160 kg N/ha	0.76 [a]	1.41 [a]	2.27 [a]
IF × 0 kg N	0.40 [e]	0.66 [f]	1.16 [f]
IF × 70 kg N/ha	0.53 [c]	0.78 [d]	1.33 [e]
IF × 100 kg N/ha	0.53 [c]	0.79 [d]	1.58 [c]
IF × 130 kg N/ha	0.69 [b]	0.89 [c]	1.60 [c]
IF × 160 kg N/ha	0.54 [c]	0.72 [e]	1.36 [e]

OF = organic fertiliser; IF = inorganic fertiliser; Means with same letter among treatments are not significantly different at $p \leq 0.5$.

Number of leaves were significantly higher (11.2, 36.6 and 59.1) from plot treated with organic fertiliser compared to number of leaves (9.7, 24.9 and 45.7) from pot with inorganic fertiliser at 4, 8 and 12 WAS as showed in Table 4.5. Fertiliser rates had no significant effect on the number of leaves at 4 WAS while number of leaves obtained from all the rates were though not significantly different from one another they were however higher than Number of leave obtained from pot without fertiliser. At 12 WAS, the highest number of leaves (66.1) was obtained from pot treated with 130 kg N/ha and it was significantly higher than number of leaves obtained from other rates while pot without frtiliser had the least number of leaves (45.6). The interaction of fertiliser types and rates showed significant difference on number of leaves of kenaf. At 4 WAS, significantly highest number of leaves (16.6) was obtained from pot treated with organic fertiliser (160 kg N/ha). Number of leaves (9.6 and 9.9) obtained from pot with organic fertiliser 70 and 100 kg N/ha respectively were not significantly different from Number of leaves (9.6) from 160 kg N/ha inorganic fertiliser. Number of leaves (11.1) from pot treated with 130 kg N/ha organic fertiliser was though more than number of leaves (10.8) from 130 kg N/ha inorganic fertiliser, they were however not significantly different. Number of leaves (46.3 and 70.4) were significantly highest from pot treated with organic fertiliser (160 kg N/ha) at 8 and 12 WAS respectively. Number of leaves (66.5 and 65.6) obtained from inorganic fertiliser (130 kg N/ha) and organic fertiliser (130 kg N/ha) were not significantly different. The least Number of leaves (7.6, 25.0 and 41.6) were obtained from pots without any fertiliser application.

Fertiliser type and rate had significant effect on seed yield as indicated in Figure 4.1. Seed yield from pot without feriliser application and 70 kg N/ha were not significantly different. Similarly, pot with inorganic fertilier at 100, 130 and 160 kg N/ha had seed yield that were not significantly different from one another. Seed yield obtained from pot treated with organic fertilier applied at 100 and 130 kg N/ha had kenaf seed yield that were not significantly different. The highest seed yield was obtained from pot treated with organic fertiliser at rate of 160 kg N/ha and it was significantly higher than sed yield obtained from all other rates of the two fertiliser types.

Table 4.5: Effects of organic and inorganic fertiliser type on the number of leaves of pot grown kenaf in 2013

Treatments	Weeks After Sowing		
	4	**8**	**12**
Fertiliser types			
OF	11.23 [a]	36.59 [a]	59.06 [a]
IF	9.68 [b]	29.94 [b]	45.69 [b]
Rate (kg N/ha)			
0	7.60	25.38 [b]	45.63 [e]
70	9.19	34.01 [a]	53.41 [d]
100	11.22	35.63 [a]	58.91 [c]
130	10.91	32.88 [a]	66.07 [a]
160	13.10	37.09 [a]	62.87 [b]
Interaction			
OF× 0 kg N	7.50 [f]	25.75 [e]	49.63 [e]
OF × 70 kg N/ha	9.63 [d]	34.63 [bc]	53.44 [d]
OF × 100 kg N/ha	9.88 [d]	36.94 [b]	56.19 [d]
OF × 130 kg N/ha	11.06 [c]	37.38 [b]	65.63 [b]
OF × 160 kg N/ha	16.56 [a]	46.25 [a]	70.44 [a]
IF × 0 kg N/	7.69 [f]	25.00 [e]	41.63 [e]
IF × 70 kg N/ha	8.75 [e]	33.38 [c]	53.38 [d]
IF × 100 kg N/ha	12.56 [b]	34.31 [c]	61.63 [c]
IF × 130 kg N/ha	10.75 [c]	28.38 [d]	66.50 [b]
IF × 160 kg N/ha	9.63 [d]	27.93 [d]	55.31 [d]

OF = organic fertiliser; IF = inorganic fertiliser; Means with same letter among treatments are not significantly different at $p \leq 0.5$

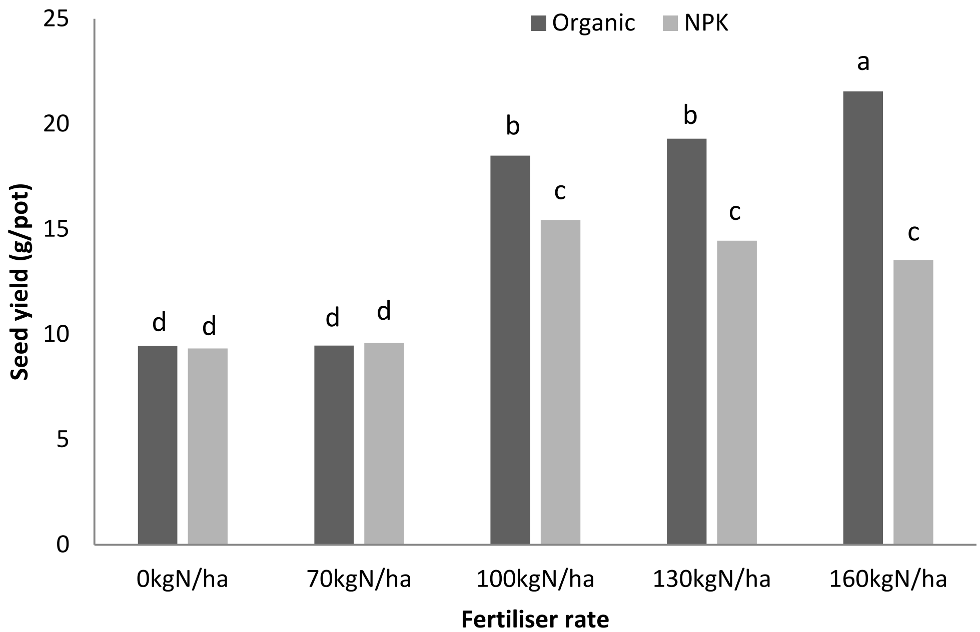

Figure 4.1: Effect of fertiliser rates on kenaf seed yield grown in pot in 2013

4.4.1 Effects of organic and inorganic fertiliser on the vegetative growth of field grown kenaf in 2014.

Plot treated with inorganic fertiliser had the highest Plant height (68.69 cm) of kenaf at 4 WAS. Significantly taller kenaf plant height (88.9 cm, 134.4 cm, 163.9 cm and 181.2 cm) were obtained from plots treated with organic fertiliser at 6, 8, 10 and 12 WAS as showed in (Table 4.6). Plant height (78.7 cm and 79.3 cm) obtained from the application of 160 and 130 kg N/ha were not significantly different from each other at 4 WAS. At 6 WAS, plant height was highest (105.7 cm) but not significantly higher than (105.6 cm) obtained from plot treated with 130 and 160 kg N/ha respectively. Plant height (179.3 cm) from plot with 160 kg N/ha was significantly taller at 8 WAS while plant height from plot treated with 160 an d130 kg N/ha were not significantly different from each other at 10 and 12 WAS they were however, taller than plant from other rates with the shortest plant from plot without frtiliser application. The application of organic fertiliser (160 kg N/ha) gave the highest plant height (81.95 cm) though not significantly higher than (81.78 cm) obtained in 130 kg N/ha. The two rates (160 and 130 kg N/ha) had the tallest plant among other rates at 4 WAS. Plant height from plots with application of inorganic fertiliser at rates 100, 130 and 160 kg N/ha were not significantly different from one another at 4 WAS. The plant height (121 cm, 196 cm, 218 cm and 237 cm) were obtained from plot treated with organic fertiliser (160 kg N/ha) at 6, 8,10 and 12 WAS respectively. The least plant height were obtained from plots without fertiliser application from 4 to 12 WAS.

Highest stem diameter (0.8 cm) was from plot treated with inorganic fertiliser and it was significantly higher than stem diameter (0.8 cm) obtained with application of organic fertiliser at 4 WAS as shown in Table 4.7. The two fertiliser types had same stem diameter (1.3 cm) at 6 WAS while plots treated with organic fertiliser had the bigger plant (1.6 cm, 2.0 cm and 2.2 cm) at 8, 10 and 12 WAS respectively. These values were significantly higher than (1.5 cm, 2.0 cm) obtained from plots treated with inorganic fertiliser during the same period. Stem diameter (0.9 cm, 1.5 cm, 2.2 cm and 2.5 cm) were bigger in 160 kg N/ha at 4, 6, 10 and 12 WAS respectively. Stem diameter (1.8 cm) was however not significantly different in 160 and 130 kg N/ha at 8 WAS. However, the stem diameter obtained from organic fertiliser (1.05 cm) was significantly higher at 4 WAS. Stem diameter (0.9 cm) was obtained from plots treated with inorganic fertiliser (100,130 and 160 kg N/ha) were not significantly different from one another at 4 WAS stem diameter (0.7 and 0.8 cm) obtained in organic fertiliser (100 and 130 kg N/ha) were though not significantly different from each other they were however higher than (0.6 cm) obtained from plots without fertiliser application. Stem diameter (1.6 cm, 2.0 cm, 2.5 cm and 2.9 cm) were significantly higher in plot with organic fertiliser (160 kg N/ha) at 6,8 10 and 12 WAS. Stem diameter were least in plots without fertiliser application.

Table 4.8 showed that number of leaves increased across the period of the experiment for both organic and inorganic fertilisers. Number of leaves (32.5 and 48.7) obtained from plot treated with inorganic fertiliser were significantly higher than number of leaves (28.6 and 46.2) obtained from plots treated with organic fertiliser at 4 and 6 WAS respectively. The number of leaves were significantly higher in plots with organic fertiliser compared to those obtained from plots with inorganic fertilizer at 8, 10 and 12 WAS respectively. Significantly higher number of leaves (38.7, 58.2, 82.9, 98.7 and 123.9) were obtained from rate 160 kg N/ha and it was least in plots without fertiliser application irrespective of the fertiliser types. At 4 WAS, number of leaves obtained from plots treated with organic fertiliser (160 kg N/ha) and inorganic fertiliser (100, 130 and 160 kg N/ha) were not significantly different from one another, they were however higher than number of leaves obtained from other fertiliser rates combinations. Number of leaves (32.2 and 34.5) obtained from plots treated with organic fertiliser (100 and 130 kg N/ha) were not significantly different from each other but they were significantly higher than number of leaves (30.5) obtained from plot treated with inorganic fertiliser (70 kg N/ha). Number of leaves was least in plots without fertiliser application at 4 WAS. At 6 WAS, number of leaves (58.4) was highest in plot with inorganic fertiliser (130 kg N/ha) but not significantly different from number of leaves (57.9 and 57.4) obtained in plot treated with organic fertiliser (160 kg N/ha) and inorganic fertiliser (100 kg N/ha) respectively. Number of leaves (90.7) was highest in plot with organic fertiliser (160 kg N/ha), while the number of leaves 77.7 and 72.6 from plots treated with organic fertiliser (130 and 100 kg N/ha), 75.1 and 73.9 from inorganic fertiliser (130 and 100 kg N/ha) were not significantly different from one another, they were however higher than number of leaves

(70.8) obtained from plot with inorganic fertiliser (160 kg N/ha) at 8 WAS. The highest number of leaves (108.9 and 135.8) were obtained from plots treated with organic fertiliser (160 kg N/ha) at 10 and 12 WAS respectively.

Leaf area were not significantly different at 4 WAS while leaf area (4943 cm^2) was significantly higher in organic fertilsier at 6 WAS. It was not significantly different at 8 and 12 WAS while (32052.9 cm^2) obtained from plots treated with inorganic fertiliser was higher at 10WAS as showed in Table 4.9. Rate 160 kg N/ha had the highest leaf area (3688 cm^2, 4657 cm^2 and 695553 cm^2) at 4, 6 and 10 WAS respectively while it was not significantly different at 8 WAS. Highest leaf area (3990 cm^2, 5357 cm^2, 7301 cm^2 and 10361 cm^2) were obtained from plots treated with organic fertiliser (160 kg N/ha). The leaf area in organic fertiliser (70,100, 130 and 160 kg N/ha) were not significantly different from one another but they were however higher than leaf area obtained from plots treated with inorganic fertiliser of the same rates. The least leaf area were obtained from plots without fertiliser application.

4.4.2 Effect of varying rates of fertiliser on dry matter production of kenaf

The plot treated with inorganic fertiliser had highest dry matter at 4 and 6 WAS while plot treated with organic fertiliser had the kenaf with higher dry matter production at 8, 10 and 12 WAS as showed in (Table 4.10). The dry matter (20.4, 35.8, 58.3, 86.1 and 109.5 g/plant) produced in plots treated with 160 g N/ha were significantly higher than dry matter from other rates. The least dry matter production were from plots without any fertiliser application. Organic fertiliser applied at rate (160 kg N/ha) produced the highest dry matter (25.3, 17.1 and 28.1g/plant) at 4, 6 and 8 WAS while the dry matter produced (100.8 and 90.3 g/plant) at 10 and (125 and 114.8 g/plant) at 12 WAS were not significantly different in 130 and 160 kg N/ha. Kenaf dry matter (89.1 g/plant) produced from plots treated with organic fertiliser (100 kg N/ha) was not significantly different from (85.4 g/plant) profuced from plot treated with organic fertiliser (70 kg N/ha). They were however higher than those from plots without fertiliser. Dry matter obtained from inorganic fertiliser (70, 100 and 130 kg N/ha) were not significantly different from one another at 12 WAS. The lowest kenaf dry matter were obtained from plots without fertiliser application.

Table 4.6: Effect of organic and inorganic fertiliser type on plant height (cm) of kenaf evaluated at Ibadan in 2014

Treatments	**Weeks After Sowing**				
	4	**6**	**8**	**10**	**12**
Fertiliser Type					
OF	64.45 [**b**]	88.86 [a]	134.39 [a]	163.92 [a]	181.19 [a]
IF	68.69 [a]	86.02 [b]	122.55 [b]	151.71 [b]	168.56 [b]
Rate (kg N/ha)					
0	42.67 [d]	66.05 [d]	102.04 [e]	116.51 [d]	143.82 [d]
70	64.95 [c]	86.68 [c]	125.71 [d]	157.88 [c]	168.16 [c]
100	71.93 [b]	93.12 [b]	146.34 [c]	165.76 [b]	183.70 [b]
130	79.31 [a]	105.68 [a]	164.83 [b]	185.94 [a]	204.22 [a]
160	78.67 [a]	105.63 [a]	179.28 [a]	188.00 [a]	204.51 [a]
Interaction					
OF × 0 kg N	42.39 [f]	66.25 [i]	101.93 [f]	116.55 [g]	144.39 [h]
OF × 70 k N/ha	60.20 [e]	84.10 [h]	126.18 [e]	158.60 [f]	170.63 [f]
OF × 100 k N/ha	65.98 [d]	92.58 [d]	157.88 [c]	166.78 [c]	175.40 [e]
OF × 130 k N/ha	81.78 [a]	119.65 [b]	193.25 [b]	209.48 [b]	227.72 [b]
OF × 160 k N/ha	81.92 [a]	121.00 [a]	196.35 [a]	218.20 [a]	237.84 [a]
IF × 0 k N	42.95 [f]	65.85 [i]	102.14 [f]	116.47 [g]	143.25 [h]
IF × 70 k N/ha	69.70 [c]	89.25 [g]	125.23 [e]	157.15 [f]	165.69 [g]
IF × 100 k N/ha	77.88 [b]	93.65 [c]	134.80 [d]	164.73 [d]	191.99 [c]
IF × 130 k N/ha	76.83 [b]	91.70 [e]	136.40 [d]	162.40 [e]	180.71 [d]
IF × 160 k N/ha	76.13 [b]	90.25 [f]	126.20 [e]	157.80 [f]	171.18 [f]

OF = organic fertiliser; IF = inorganic fertiliser; Means with same letter among treatments are not significantly different at $p \leq 0.5$

Table 4.7: Effect of organic and inorganic fertiliser type on stem diameter (cm) of kenaf evaluated at Ibadan in 2014

Treatments	Weeks After Sowing				
	4	6	8	10	12
Fertiliser Type					
OF	0.76 b	1.29 a	1.63 a	1.96 a	2.19 a
IF	0.81 a	1.28 a	1.49 b	1.49 b	2.00 b
Rate (kg N/ha)					
0	0.57 d	1.01 e	1.17 d	1.38 d	1.48 e
70	0.76 c	1.22 d	1.40 c	1.78 c	1.96 d
100	0.82 b	1.35 c	1.66 b	1.99 b	2.18 c
130	0.84 b	1.39 b	1.76 a	1.98 b	2.34 b
160	0.96 a	1.49 a	1.76 a	2.20 a	2.53 a
Interaction					
OF × 0 kg N	0.57 f	1.01 e	1.12 h	1.38 f	1.46 h
OF × 70 k N/ha	0.69 e	1.16 d	1.46 e	1.82 d	2.00 f
OF × 100 k N/ha	0.74 d	1.31 c	1.65 c	1.99 b	2.21 d
OF × 130 k N/ha	0.76 d	1.39 b	1.87 b	2.01 b	2.41 b
OF × 160 k N/ha	1.05 a	1.61 a	1.98 a	2.51 a	2.87 a
IF × 0 k N	0.56 f	1.01 e	1.22 g	1.38 f	1.49 h
IF × 70 k N/ha	0.82 c	1.27 c	1.39 f	1.73 e	1.92 g
IF × 100 k N/ha	0.89 b	1.38 b	1.66 c	1.99 b	2.14 e
IF × 130 k N/ha	0.91b	1.39 b	1.65 c	1.95 b	2.26 c
IF × 160 k N/ha	0.87 b	1.36 b	1.54 d	1.88 c	2.19 d

OF = organic fertiliser; IF = inorganic fertiliser; Means with same letter among treatments are not significantly different at $p \leq 0.5$

Table 4.8: Effect of organic and inorganic fertiliser type on number of leaves of kenaf evaluated at Ibadan in 2014

Treatments	**Weeks After Sowing**				
	4	**6**	**8**	**10**	**12**
Fertiliser Type					
OF	28.64 b	46.23 b	67.32 a	81.69 a	106.33 a
IF	32.47 a	48.68 a	62.18 b	73.86 b	96.44 b
Rate (kg N/ha)					
0	12.88 e	29.77 e	36.84 e	43.80 e	53.05 e
70	27.69 d	42.57 d	58.06 d	73.27 d	97.29 d
100	35.55 c	51.43 c	70.69 c	83.87 c	114.65 c
130	37.98 b	55.32 b	75.28 b	89.28 b	117.94 b
160	38.68 a	58.18 a	82.88 a	98.68 a	123.98 a
Interaction					
OF × 0 kg N	12.95 e	30.12 f	37.20 e	43.35 f	51.08 d
OF × 70 k N/ha	24.87 d	40.42 e	58.43 d	76.68 d	100.90 c
OF × 100 k N/ha	32.20 b	49.40 c	72.61 b	87.39 c	118.35 b
OF × 130 k N/ha	34.49 b	53.24 b	77.68 b	98.22 b	125.47 b
OF × 160 k N/ha	38.70 a	57.95 a	90.71 a	108.85 a	135.84 a
IF × 0 k N	12.82 e	29.42 g	36.48 e	44.27 f	55.02 d
IF × 70 k N/ha	30.52 c	44.72 d	57.69 d	69.85 e	93.68 c
IF × 100 k N/ha	38.90 a	57.41 a	73.89 b	86.34 c	110.95 bc
IF × 130 k N/ha	41.47 a	58.40 a	75.05 b	88.51 c	112.14 bc
IF × 160 k N/ha	38.65 a	53.45 b	70.79 c	80.36 c	110.42 bc

OF = organic fertiliser; IF = inorganic fertiliser; Means with same letter among treatments are not significantly different at $p \leq 0.5$

Table 4.9: Effect of organic and inorganic fertiliser type on leaf area (cm^2) of kenaf evaluated at Ibadan in 2014

	Weeks After Sowing				
	4	**6**	**8**	**10**	**12**
Fertiliser Type					
OF	2931.7 [a]	3454.3 [a]	4943.3 [a]	7101.9 [b]	11227.6 [a]
IF	2913.7 [a]	3307.2 [b]	4609.9 [a]	32052.9 [a]	9938.9 [a]
Rate (kg N/ha)					
0	2206.7 [d]	2502.3 [e]	3974.0 [b]	6012.6 [c]	9572.0 [a]
70	2833.9 [c]	2909.8 [d]	4212.2 [b]	6916.2 [bc]	9992.0 [a]
100	2837.9 [c]	3144.5 [c]	4701.3 [ab]	7039.1 [bc]	10131.0 [a]
130	3047.2 [b]	3689.9 [b]	4967.6 [a]	8365.8 [b]	11153.0 [a]
160	3688.0 [a]	4657.3 [a]	6028.1 [a]	69553.5 [a]	12068.0 [a]
Interaction					
OF × 0 kg N	2315.6[c]	2388.1 [d]	3669.2 [cd]	5445.7 [d]	7576.9 [b]
OF × 70 k N/ha	2638.1 [bc]	2658.5 [d]	4167.2 [c]	5910.6 [c]	10263.1 [a]
OF × 100 k N/ha	2715.6 [bc]	3060.4 [cd]	4262.9 [c]	6280.7 [c]	10779.5 [a]
OF × 130 k N/ha	2999.5 [b]	3906.8 [b]	5316.0 [b]	7511.3 [b]	12786.2 [a]
OF × 160 k N/ha	3990.0 [a]	5257.7 [a]	7301.4 [a]	10361.2 [a]	14732.5 [a]
IF × 0 k N	2097.7 [c]	2346.0 [d]	2781.0 [d]	3744.0 [c]	3881.0 [c]
IF × 70 k N/ha	3029.6 [b]	3431.4 [c]	4162.0 [c]	5370.0 [d]	5605.0 [d]
IF × 100 k N/ha	2960.3 [b]	3228.6 [c]	4619.0 [bc]	5567.0 [cd]	6404.0 [c]
IF × 130 k N/ha	3175.6 [b]	4057.0 [b]	5733.0 [b]	6516.0 [c]	6620.0 [c]
IF × 160 k N/ha	3386.1 [b]	3472.9 [c]	4853.0 [bc]	5387.0 [d]	5568.0 [d]

OF = organic fertiliser; IF = inorganic fertiliser: Means with same letter among treatments are not significantly different at $p \leq 0.5$

Table 4.10: Effect of organic and inorganic fertiliser type on dry plant (g/plant) of kenaf evaluated at Ibadan in 2014

Treatments	**Weeks After Sowing**				
	4	**6**	**8**	**10**	**12**
Fertiliser Type					
OF	12.74 ^{b}	26.78 ^{b}	50.01 ^{a}	79.75 ^{a}	98.57 ^{a}
IF	14.72 ^{a}	27.67 ^{a}	44.45 ^{b}	68.98 ^{b}	84.18 ^{b}
Rate (kg N/ha)					
0	5.53 ^{e}	15.87 ^{e}	29.92 ^{e}	52.16 ^{e}	66.22 ^{e}
70	9.50 ^{d}	25.25 ^{d}	46.21 ^{d}	73.09 ^{d}	85.37 ^{d}
100	13.54 ^{c}	27.71 ^{c}	48.07 ^{c}	77.28 ^{c}	89.13 ^{c}
130	19.69 ^{b}	31.43 ^{b}	53.60 ^{b}	83.29 ^{b}	106.64 ^{b}
160	20.38 ^{a}	35.84 ^{a}	58.33 ^{a}	86.05 ^{a}	109.52 ^{a}
Interaction					
OF × 0 kg N	5.40 ^{f}	14.61 ^{d}	27.78 ^{c}	52.52 ^{c}	64.99 ^{c}
OF × 70 k N/ha	9.79 ^{e}	22.99 ^{c}	46.06 ^{bc}	73.93 ^{b}	91.78 ^{b}
OF × 100 k N/ha	14.29 ^{d}	25.69 ^{bc}	50.78 ^{b}	81.31 ^{ab}	96.48 ^{b}
OF × 130 k N/ha	18.87 ^{c}	30.09 ^{b}	56.01 ^{b}	90.25 ^{a}	114.57 ^{a}
OF × 160 k N/ha	25.25 ^{a}	40.49 ^{a}	69.40 ^{a}	100.75 ^{a}	125.03 ^{a}
IF × 0 k N	5.66 ^{f}	17.13 ^{b}	28.07 ^{c}	51.49 ^{c}	63.45 ^{c}
IF × 70 k N/ha	9.21 ^{e}	27.51 ^{bc}	34.38 ^{c}	61.35 ^{c}	78.95 ^{bc}
IF × 100 k N/ha	12.79 ^{de}	29.73 ^{b}	46.37 ^{bc}	72.26 ^{b}	81.78 ^{bc}
IF × 130 k N/ha	20.53 ^{b}	32.76 ^{b}	51.19 ^{b}	76.32 ^{b}	98.72 ^{b}
IF × 160 k N/ha	15.50 ^{d}	31.19 ^{b}	47.26 ^{bc}	73.25 ^{b}	94.01 ^{b}

OF = organic fertiliser; IF = inorganic fertiliser; Means with same letter among treatments are not significantly different at $p \leq 0.5$

4.4.3 Effect of fertiliser on the absolute growth rate (AGR) and relative growth rate (RGR) of kenaf grown in the field

The effect of fertiliser type, rates and their interactions on absolute growth rate and relative growth rate of kenaf were significant $p<0.05$ as presented in Table 4.11. The result showed that organic fertiliser had AGR that were significantly higher than those obtained from inorganic fertiliser. The highest AGR (16.3 g/plant) was obtained in plots with fertiliser rate 130 kg N/ha at 4-6 WAS. While the AGR (15.3 g/plant) from plot treated with 160 kg N/ha which was not significantly different from AGR (15 g/plant) obtained from 100 kg N/ha it was however higher than AGR (12.8 g/ plant) in 70 kg N/ha at 4-6 WAS. At 6-8 WAS, the significantly higher AGR (19.9 g/plant) was obtained from plots with 160 kg N/ha. Rate 130 kg N/ha had the highest AGR (18.9 g/plant) at 6-8 WAS while at 8-10 WAS, the AGR (19.7 and 19.2 g/plant) were not significantly different in 130 and 160 kg N/ha respectively. The lowest AGR were obtained from plots without fertiliser. Application of organic fertiliser (160 kg N/ha) had the highest AGR (16.7, 23.5, 20.7 and 23.8 g/plant) at 4-6, 6-8, 8-10 and 10- 12 WAS) respectively. These were however not significantly higher than AGR (16.6, 18.7 and 20.7 g/plant) obtained from plots with organic fertiliser (130 kg N/ha) and AGR (15.6, 19.0 and 18.7 g/plant) obtained from plots treated with inorganic fertiliser (130 kg N/ha) at 4-6, 8-10 and 10-12 WAS respectively. While inorganic fertiliser (100 and 160 kg N/ha) had no significant different effect on the AGR obtained at 8-10 and 10-12 WAS respectively, the least AGR (5.6, 6.9, 8.9 and 6.9 g/plant) were obtained from plots without fertiliser at 4-6,6-8, 8-10 an d10-12 WAS respectively.

Relative growth rate (RGR) from plots treated with organic fertiliser ranged from 2.4 g/plant at 4-6 WAS to 2.5 g/plant at 10-12 WAS and were significantly higher than RGR obtained from plots with inorganic fertiliser as presented in Table 4.12. The highest RGR (2.6 g/plant) obtained from plots with application of 160 kg N/ha was not significantly different from RGR (2.5 g/plan) from 130 kg N/ha at 4-6 WAS. Rates 130 and 160 kg N/ha were not different in their effect on the RGR at 6-8. 8-10 and 10-12 WAS. Fertiliser and rate interaction were significant on RGR with higher RGR from plots treated with either types of fertiliser compared to plots without fertiliser.

Table 4.11: Effect of organic and inorganic fertiliser type on AGR (g/plant) of kenaf evaluated at Ibadan in 2014

Treatments	**Weeks After Sowing**			
	4-6	**6-8**	**8-10**	**10-12**
Fertiliser Type				
OF	13.18 [a]	15.29 [a]	14.85 [a]	9.66 [a]
IF	12.47 [b]	13.62 [b]	13.89 [b]	8.01 [b]
Rate (kg N/ha)				
0	5.70 [d]	7.21 [e]	9.01 [e]	7.86 [c]
70	12.84 [c]	12.53 [d]	12.67 [d]	12.37 [c]
100	15.01 [b]	15.81 [c]	15.19 [c]	15.12 [b]
130	16.31 [a]	16.83 [b]	18.87 [a]	19.68 [a]
160	15.29 [b]	19.90 [a]	17.66 [b]	19.17 [a]
Interaction				
OF × 0 kg N	5.76 [e]	7.50 [f]	9.12 [d]	8.76 [d]
OF × 70 k N/ha	13.81 [c]	12.87 [e]	13.28 [c]	13.44 [bc]
OF × 100 k N/ha	15.01 [b]	17.51 [b]	13.50 [c]	14.68 [b]
OF × 130 k N/ha	16.63 [a]	15.06 [d]	18.72 [a]	20.67 [a]
OF × 160 k N/ha	16.71 [a]	23.49 [a]	20.66 [a]	23.77 [a]
IF × 0 k N	5.64 [e]	6.92 [f]	8.89 [d]	6.95 [d]
IF × 70 k N/ha	11.87 [d]	12.19 [e]	12.05 [c]	11.29 [c]
IF × 100 k N/ha	15.00 [b]	14.10 [d]	16.86 [b]	15.55 [b]
IF × 130 k N/ha	15.99 [a]	18.59 [b]	19.01 [a]	18.68 [a]
IF × 160 k N/ha	13.86 [c]	16.31 [c]	14.66 [b]	14.56 [b]

OF = organic fertiliser; IF = inorganic fertiliser; Means with same letter among treatments are not significantly different at $p \leq 0.5$

Table 4.12: Effect of organic and inorganic fertiliser type on RGR (g/plant) of kenaf evaluated at Ibadan in 2014

Treatments	**Weeks After Sowing**			
	4-6	**6-8**	**8-10**	**10-12**
Fertiliser Type				
OF	2.37 [a]	2.38 [a]	2.49 [a]	2.48 [a]
IF	2.34 [b]	2.34 [b]	2.45 [b]	2.43 [b]
Rate (kg N/ha)				
0	1.98 [d]	1.99 [d]	2.73 [d]	2.22 [d]
70	2.35 [c]	2.85 [c]	3.92 [c]	2.92 [c]
100	2.45 [b]	3.92 [b]	5.99 [b]	4.65 [b]
130	2.49 [a]	4.49 [a]	6.58 [a]	4.94 [a]
160	2.57 [a]	4.55 [a]	5.56 [b]	4.97 [a]
Interaction				
OF × 0 kg N	1.99 [b]	2.01 [c]	3.13 [e]	2.20 [d]
OF × 70 k N/ha	2.39 [b]	3.32 [b]	4.43 [d]	3.42 [c]
OF × 100 k N/ha	2.45 [a]	3.46 [b]	6.51 [b]	4.82 [b]
OF × 130 k N/ha	2.49 [a]	4.48 [a]	8.59 [a]	6.37 [a]
OF × 160 k N/ha	2.65 [a]	4.64 [a]	8.60 [a]	6.43 [a]
IF × 0 k N	1.97 [b]	1.98 [c]	2.32 [e]	2.23 [d]
IF × 70 k N/ha	2.30 [b]	2.37 [c]	3.40 [e]	2.42 [d]
IF × 100 k N/ha	2.44 [a]	4.38 [a]	5.47 [c]	4.48 [b]
IF × 130 k N/ha	2.50 [a]	4.52 [a]	4.57 [d]	3.51 [c]
IF × 160 k N/ha	2.48 [a]	4.45 [a]	4.52 [d]	3.50 [c]

OF = organic fertiliser; IF = inorganic fertiliser; Means with same letter among treatments are not significantly different at $p \leq 0.5$

4.4.4 Effects of fertiliser on kenaf fibre and seed yield evaluated at Ibadan in 2014

The difference in the response of the two fertilizer type were not significant at $p \leq 0.05$ for core fibre and bast fibre yield as well as for seed yield (Table 4.13). Core fibre (1.97 t/ha) was obtained from plots treated with 160 kg N/ha. This though not significantly higher than core fibre from other rates it was however, higher than core fibre (1.6 t/ha) from plots without fertiliser treatment. Core fibre yield (2.0, 1.9, 1.8 and t/ha) obtained from plots treated with organic fertiliser (160, 130 and 100 kg N/ha) were not significantly higher than core fibre yield (1.9 t/ha) obtained from plot with inorganic fertiliser (130 kg N/ha). The core fibre yield (1.7 t/ha) obtained from plot with organic fertiliser (70 kg N/ha) was not significantly higher than core fibre yield (1.7 t/ha) obtained from plots treated with inorganic fertilser (70,100 and 160 kg N/ha). They were however significantly higher than core fibre yield (0.5 t/ha) obtained from plot without fertiliser application.

Bast fibre (1.24 t/ha) was significantly higher in rate 160 kg N/ha while other rates were not different from plot without fertiliser in their effect on bast fibre yield. The highest bast fibre yield (1.4 t/ha) was obtained from plot with organic fertiliser (130 kg N/ha). It was however not significantly different from bast fibre yield (1.2 and 0.9 t/ha) obtained from plots with organic fertiliser (160 and 100 kg N/ha) and bast fibre yield (0.9- 1.2 t/ha) from plot with inorganic fertilser (70 -160 kg N/ha). The lowest bast fibre yield (0.3 t/ha) was from plot without fertiliser.

Seed yield (1.7 t/ha) and seed yield parameters were significantly higher in 130 kg N/ha with plot without any fertiliser application having the lowest seed yield (1.1 t/ha). Sesd yield (1.96 t.ha) obtained from plot treated with organic fertiliser (160 kg N/ha) was significantly higher than seed yield from other rates of fertiliser types. Seed yield (1.77 t/ha) obtained from plot with inorganic fertiliser (100 kg N/ha) was not significantly different form seed yield (1.65 t/ha) obtained from plot with organic fertiliser (130 kg N/ha). Seed yield (1.1 t/ha) in plot without fertiliser were not significantly different from seed yield (1.1 t/ha) in plot with organic fertiliser (to kg N/ha). Plots treated with inorganic fertilizer (70 kg N/ha) has seed yield (1.30 t/ha).

Table 4.13: Effect of organic and inorganic fertiliser type on fibre and seed yield (t/ha) of kenaf evaluated at Ibadan in 2014

Treatments	Yield (t/ha)		Number of		Seed yield (t/ha)
	Core	Bast	Capsule/plant	Seed/capsule	
Fertiliser Type					
OF	1.85 a	1.05 a	35.08 a	20.19 a	1.41 a
IF	1.68 a	1.01 a	36.43 a	20.57 a	1.39 a
Rate (kg N/ha)					
0	1.63 b	0.94 b	31.16 c	19.15 b	1.09 b
70	1.72 ab	0.96 b	34.23 ab	20.01 ab	1.18 b
100	1.74 ab	0.99 b	36.52 ab	20.16 ab	1.63 a
130	1.75 ab	1.01 b	36.89 ab	20.72 ab	1.71 a
160	1.97 a	1.24 a	39.99 a	21.85 a	1.39 b
Interaction					
OF × 0 kg N	0.54 c	0.34 c	20.00 e	13.05 c	1.08 e
OF × 70 k N/ha	1.70 b	0.81 b	33.60 d	19.61 b	1.12 e
OF × 100 k N/ha	1.83 a	0.98 ab	35.05 c	20.04 ab	1.23 d
OF × 130 k N/ha	1.99 a	1.37 a	38.55 b	21.67 a	1.65 b
OF × 160 k N/ha	2.05 a	1.22 a	44.38 a	23.36 a	1.96 a
IF × 0 k N	0.54 c	0.35 c	21.50 e	13.04 c	1.07 e
IF × 70 k N/ha	1.65 b	0.96 ab	34.86 c	20.28 a	1.30 d
IF × 100 k N/ha	1.68 b	0.99 ab	41.60 a	21.34 a	1.77 b
IF × 130 k N/ha	1.96 a	1.21 a	38.73 b	20.78 ab	1.55 c
IF × 160 k N/ha	1.68 b	1.03 a	36.48 bc	20.39 ab	1.28 d

OF = organic fertiliser; IF = inorganic fertiliser; Means with same letter among treatments are not significantly different at $p \leq 0.5$

4.4.5 Effect of N rates on biochemical properties of kenaf plant tissue evaluated using organic and inorganic fertiliser at Ibadan in 2014

Significant difference due to biochemical properties existed between the two types of fertilisers, rates and their interactions (Table 4.14). All the parameters assessed increased with increase in N fertiliser, while the least was in control. Percentage crude protein (15.48 %), Fat (3.57 %) and moisture content (11.79 %) were all significantly higher in plots treated with inorganic fertiliser compared to those in organic fertiliser. Percentage crude fibre (18.74 %), total ash (10.82 %), dry matter (88.42 %) and Nitrogen free extract (39.91 %) were significantly higher in plots treated with organic fertiliser. The application of 160 kg N/ha had significantly higher crud protein (15.76 %) while crude protein (15.4 %) in plots with 70 kg N/ha and 100 kg N/ha are not significantly different from each other.

Percentage fat (3.62 %) obtained in 130 kg N/ha is not significantly different from percentage fat (3.63 %) in plot treated with 160 kg N/ha. The least percentage fat (3.45 %) was from plot without fertiliser application. Crude fibre ranges from 18.7 to 19.2 %) in plot treated with 100, 130 and 160 kg N/ha are not significantly different from one another. However, they were significantly higher than crude fibre (18.47 %) in plot treated with 70 kg N/ha and least (18.12 %) in plot without fertiliser application. Percentage total ash (11.01 %), moisture content (11.92 %), dry matter (88.55 %) and Nitrogen free extract (40.72 %) were all significantly higher in plots treated with 160 kg N/ha and least in plots without fertiliser. The effect of the interaction of fertiliser types and rates vary for different parameter. Crude protein ranges from 15.55 to 15.90 % were significantly higher in plots treated with 100, 130 and 160 kg N/ha of organic or inorganic fertiliser while plot without fertiliser had the least. The highest fat (3.68 %) was obtained from plot with inorganic fertiiser (160 kg N/ha) however, it was not significantly higher than those (3.67 %) obtained from plot treated with inorganic fertiliser (130 kg N/ha), 3.67 % from plot with organic fertiliser (160 kg N/ha), 3.58 %, from organic fertiliser (130 kg N/ha) and 3.57 % from plot treated with organic fertiliser (100 kg N/ha) respectively. Although, percentage fat content was the least in plot without fertiliser of either types however, they were not significantly lower than 3.51 % obtained from plots treated with inorganic fertiliser (70 kg N/ha) and 3.49 % from plot treated with organic fertiliser (70 kg N/ha). Crude fibre (19.26 %) was higher in plot treated with inorganic fertiliser (130 kg N/ha) however, it was not significantly higher than 19.10 % and 19.08 % obtained from plots with organic fertiliser (160 and 130 kg N/ha). Similarly percentage crude fibre (18.44 %, 18.47 % and 18.38 %) obtained from plot treated with inorganic fertiliser (160 kg N/ha, 100 kg N/ha and 70 kg N/ha) were not significantly different from 18.55 % obtained in plot treated with organic fertiliser (70 kg N/ha) while plot with fertiliser application had the least crude fibre (18.12 %). The total ash (11.46 %) was higher in plot with inorganic fertiliser (130 kg N/ha) but not significantly higher than the total ash (11.16 %) obtained from plot with organic fertiliser (160 kg N/ha). However, this was not significantly higher than (10.93 %) obtained from plot with organic fertiliser (130 kg N/ha) and (10.80 %) obtained in plot treated with inorganic fertiliser (100 kg N/ha). Total Ash (10.80 %) obtained in plot with inorganic fertiliser (160 kg N/ha) was not significantly higher than 10.76 % and 10.70 % obtained in plots with organic fertiliser (70 kg N/ha and 100 kg N/ha) respectively.

4.4.6 Effects of fertiliser on nutrient uptake (mg/plant) of kenaf grown at Ibadan in 2014

Fertiliser type, rate and their interaction were significant on the nutrient uptake of kenaf as shown in Table 4.15. Effects of organic fertiliser on N, K, Na, Ca and Mg were significantly higher than inorganic fertiliser while P was significantly higher in inorganic fertiliser. All the elemental nutrients were higher in 160 kg N/ha and the nutrient uptake increased with increase in N rate except Na (253.00 and 253.37 mg/plant) that were not significantly different in plot treated with 130 and 160 kg N/ha. The concentration of N, P, K and Na were higher in plots treated with organic fertiliser (160 kg N/ha) and were significantly higher. The Ca (940.86 mg/plant) obtained in plot treated with organic fertiliser (160 kg N/ha) and (935.49 mg/plant) from plot treated with organic fertiliser (130 kg N/ha) and (935.10 mg/plant) from plot with inorganic fertiliser (160 kg N/ha) were not significantly different from one another but they were significantly higher than what was obtained in other rates. Inorganic fertiliser (100 kg N/ha and 130 kg N/ha) were not significantly different in their effects on Ca concentration (900.78 and 906.27 mg/plant) in kenaf plant respectively. Magnesium was significantly higher (115.16 mg/plant) in organic fertiliser (160 kg N/ha).

Table 4.14: Effect of organic and inorganic fertiliser type on the biochemical content (%) of kenaf evaluated at Ibadan in 2014

Treatments	C.P	Fat	CF	TA	MC	DM	NFE
				%			
Fertiliser Type							
OF	15.41 [b]	3.55 [b]	18.74 [a]	10.82 [a]	11.58 [b]	88.42 [a]	39.91 [a]
IF	15.48 [a]	3.57 [a]	18.55 [b]	10.78 [b]	11.79 [a]	88.21 [b]	39.83 [b]
Rate (kg N/ha)							
0	15.19 [d]	3.45 [d]	18.12 [d]	10.54 [e]	11.45 [e]	88.08 [e]	39.51 [e]
70	15.35 [c]	3.51 [c]	18.47 [b]	10.78 [d]	11.51 [d]	99.22 [d]	39.52 [d]
100	15.35 [c]	3.59 [b]	18.67 [a]	10.82 [c]	11.76 [c]	88.24 [c]	39.67 [c]
130	15.57 [b]	3.62 [a]	19.17 [a]	10.86 [b]	11.78 [b]	88.49 [b]	39.91 [b]
160	15.76 [a]	3.63 [a]	18.77 [a]	11.01 [a]	11.92 [a]	88.55 [a]	40.72 [a]
Interaction							
OF × 0 kg N	14.85 [c]	3.42 [b]	18.12 [d]	10.27 [e]	11.37 [b]	87.05 [b]	39.26 [a]
OF × 70 k N/ha	15.24 [b]	3.49 [b]	18.55 [c]	10.76 [c]	11.49 [a]	88.42 [a]	39.58 [a]
OF × 100 k N/ha	15.55 [a]	3.57 [ab]	18.87 [b]	10.70 [c]	11.58 [a]	88.42 [a]	39.77 [a]
OF × 130 k N/ha	15.55 [a]	3.58 [ab]	19.08 [ab]	10.93 [b]	11.95 [a]	88.63 [a]	40.08 [a]
OF × 160 k N/ha	15.77 [a]	3.67 [a]	19.10 [ab]	11.16 [ab]	11.40 [a]	88.61 [a]	40.57 [a]
IF × 0 k N	14.83 [c]	3.42 [b]	18.12 [d]	10.28 [e]	11.50 [a]	87.15 [b]	39.25 [a]
IF × 70 k N/ha	15.15 [b]	3.51 [b]	18.38 [c]	10.41 [d]	11.37 [b]	88.02 [a]	39.49 [a]
IF × 100 k N/ha	15.75 [a]	3.52 [b]	18.47 [c]	10.94 [b]	11.65 [a]	88.35 [a]	39.75 [a]
IF × 130 k N/ha	15.77 [a]	3.67 [a]	19.26 [a]	11.46 [a]	12.25 [a]	88.55 [a]	40.87 [a]
IF × 160 k N/ha	15.90 [a]	3.68 [a]	18.44 [c]	10.80 [c]	11.99 [a]	88.43 [a]	39.77 [a]

CP = crude protein; CF = crude fibre; TA = Total Ash; MC = moisture content; DM = dry matter; NFE = Nitrogen free extract; OF = organic fertiliser; IF = inorganic fertiliser; Means with same letter among treatments are not significantly different at $p \leq 0.5$.

Table 4.15: Effect of organic and inorganic fertiliser type on the nutrient concentration (mg/plant) of kenaf evaluated at Ibadan in 2014

Treatments	Nitrogen	Phosphorus	Potassium	Sodium	Calcium	Magnesium
	(mg/plant)					
Fertiliser Type						
OF	308.61 [a]	21.50 [b]	245.56 [a]	224.05 [a]	831.09 [a]	89.77 [a]
IF	282.78 [b]	24.39 [a]	227.43 [b]	207.49 [b]	785.77 [b]	77.89 [b]
Rate (kg N/ha)						
0	174.20 [e]	12.23 [e]	141.75 [e]	128.81 [d]	480.43 [e]	49.98 [e]
70	261.49 [d]	20.64 [d]	206.19 [d]	185.52 [c]	717.76 [d]	75.24 [d]
100	324.84 [c]	22.25 [c]	276.66 [c]	253.00 [b]	908.12 [c]	94.05 [c]
130	345.99 [b]	27.78 [b]	278.09 [b]	253.37 [b]	920.85 [b]	99.85 [b]
160	371.93 [a]	31.84 [a]	279.77 [a]	258.16 [a]	1014.98 [a]	100.03 [a]
Interaction						
OF × 0 kg N	162.63 [e]	9.27 [g]	131.23 [f]	119.25 [f]	500.03 [d]	51.17 [f]
OF × 70 k N/ha	265.85 [d]	15.59 [f]	190.91 [e]	171.45 [e]	709.66 [c]	77.19 [d]
OF × 100 k N/ha	358.46 [b]	18.21 [e]	299.31 [b]	273.36 [b]	915.43 [b]	98.67 [bc]
OF × 130 k N/ha	325.43 [c]	26.99 [c]	305.79 [a]	273.47 [b]	935.49 [a]	106.64 [b]
OF × 160 k N/ha	408.64 [a]	34.43 [a]	300.56 [a]	282.71 [a]	940.86 [a]	115.16 [a]
IF × 0 k N	163.76 [e]	8.88 [g]	132.27 [f]	118.37 [f]	460.83 [d]	48.79 [f]
IF × 70 k N/ha	257.14 [d]	22.23 [d]	221.48 [d]	199.59 [d]	725.87 [c]	67.29 [e]
IF × 100 k N/ha	324.24 [c]	32.56 [a]	255.02 [c]	232.65 [c]	900.78 [b]	93.04 [c]
IF × 130 k N/ha	333.52 [b]	29.24 [b]	253.76 [c]	233.26 [c]	906.27 [b]	89.46 [c]
IF × 160 k N/ha	335.21 [b]	28.07 [b]	254.62 [c]	233.61 [c]	935.10 [a]	84.90 [cd]

OF = organic fertiliser; IF = inorganic fertiliser; Means with same letter among treatments are not significantly different at $p \leq 0.5$

4.5.0 Experiment 1c: Effects of combined organic and inorganic fertiliser on the growth performance of kenaf grown at Ibadan in 2013 and 2014

There were significant differences in plant height, stem diameter, number of leaf and leaf area due to fertiliser types as showed in Table 4.16. The parameters assessed were significantly higher from plot with combined fertiliser. The effects of organic and inorganic are not significantly different for all the parameters while they were least in plot without fertiliser. The application of organic and inorganic fertiliser combined resulted into a significantly highest plant height (220.17 cm). Stem diameter (2.11 cm) was highest in plot with combined organic and inorganic fertiliser combined. Stem diameter (2.0 cm) was obtained in plot with organic and it was significantly higher than stem diameter (1.9 cm) obtained in plot treated with inorganic fertiliser. The least stem diameter (1.04 cm) was from plot without fertiliser application. Number of leaves (74.06) was highest in plot treated with organic and inorganic fertiliser combined but not significantly higher than (69.12) obtained from plot with only organic fertiliser while the lowest number of leaves (51.84) was in plot without fertiliser. Leaf area (195.5 cm^2) was highest in plot with combined organic and inorganic fertiliser and was significantly higher than (147.9 cm^2 and 150.4 cm^2) obtained from plots with only inorganic and organic fertiliser respectively while the effects of sole organic and inorganic fertiliser on leaf area were not significantly different. Plant height and stem diameter were higher in 2013 while number of leaves were not significantly different in both year, leaf area was higher in 2014 than 2013.

Core fibre yield (2.5 t/ha) and bast fibre yield (2.3 t/ha) were significantly higher in plots treated with combined organic and inorganic fertiliser, while the core fibre (1.4 t/ha) and bast fibre yield (1.3 t/ha) were obtained from plots treated with organic and inorganic solely as showed in Table 4.17. Number of capsule per plant ranges from 41.4 to 43.2) in plot with any type of the fertiliser used but were significant higher than (36.8) obtained from plots without fertiliser. Number of seed per capsule (27.44), weight of 100 seed (3.74 g) and seed yield (1.69 t/ha). Sole organic and inorganic fertilisers were not different in their effects on number of seed per capsule, weight of 100 seed and the total seed yield. Core and bast yield were higher in 2013 than 2014 while number of capsule per plant and number of seed per capsule were higher in 2014 than 2013.

Table 4.16: Effect of fertiliser combination on the vegetative performance of kenaf evaluated at Ibadan in 2013 and 2014

Treatments	Plant height (cm)	Stem diameter (cm)	Number of leaves	Leaf Area (cm^2)
Fertiliser Type				
Organic	208.17 [b]	2.00 [b]	69.12 [a]	150.39 [b]
Inorganic	209.99 [b]	1.88 [c]	60.02 [b]	147.86 [b]
Org. and Inorg.	220.17 [a]	2.11 [a]	74.06 [a]	195.46 [a]
Without Fert.	174.41 [c]	1.04 [d]	51.84 [c]	111.24 [c]
Year				
2013	217.63 [a]	2.08 [a]	67.98 [a]	118.43 [b]
2014	194.29 [b]	1.95 [b]	64.03 [a]	211.44 [a]

Sole organic = expected to release 160 kg N/ha, Sole inorganic = 100 kg N/ha Combined = 50:50 organic: inorganic, Control = No fertiliser; Means with same letter among treatments are not significantly different at $p \leq 0.5$

Table 4.17: Effect of fertiliser combination on the fibre and components of seed yield of kenaf evaluated at Ibadan in 2013 and 2014

Treatments	Fibre yield (t/ha)		No of capsule/plant	No of seed / Capsule	Weight of 100 seed (g)	Seed yield (t/ha)
	Core	Bast				
Fertiliser Type						
Organic	1.43 [b]	1.26 [b]	41.39 [a]	24.00 [b]	2.40 [b]	1.34 [b]
Inorganic	1.43 [b]	1.26 [b]	42.11 [a]	24.17 [b]	2.72 [b]	1.35 [b]
Combined	2.45 [a]	2.27 [a]	43.22 [a]	27.44 [a]	3.74 [a]	1.69 [a]
Without fert.	0.91 [c]	0.73 [c]	36.83 [b]	20.72 [c]	2.00 [c]	1.15 [c]
Year						
2013	2.54 [a]	2.29 [a]	25.56 [b]	22.96 [b]	2.93 [a]	1.18 [b]
2014	2.33 [b]	2.23 [b]	63.82 [a]	28.91 [a]	3.75 [a]	1.64 [a]

Sole organic = expected to release 160 kg N/ha, Sole inorganic = 100 kg N/ha Combined = 50:50 organic: inorganic, Control = No fertiliser; Means with same letter among treatments are not significantly different at $p \leq 0.5$

4.6.0 Effect of spacing on the plant height, stem diameter and dry matter accumulation of kenaf evaluated at Ibadan in 2014 and 2015

Plant height, stem diameter and dry matter accumulation increased throughout the period of the experiment for both 2014 and 2015 (Table 4.18). Planting at a spacing of 50 cm × 15 cm gave significantly highest plant height values at 4, 6, 8, 10 and 12 WAS in 2014. The other two spacings (50 cm × 20 cm and 50 cm × 25 cm) were not significantly different in their effects on plant height for the period of the experiment except at 10 WAS where plant height (169.81 cm) was significantly higher than the plant height (154.67 cm) obtained from spacing of 50 cm × 25 cm. Likewise in 2015, spacing of 50 cm × 15 cm had the tallest plant at 4, 6, 8, 10 and 12 WAS. The plant height obtained from spacing 50 cm × 20 cm and 50 cm × 25 cm were not significantly different at 4, and 12 WAS. However, plant height obtained at spacing 50 × 20 cm were significantly higher in 50 cm × 25 cm at 6, 8 and 10 WAS.

Stem diameter were higher in spacing of 50 cm × 25 cm at 4, 6, 8, 10 and 12 WAS while spacing 50 cm × 15 cm and 50 cm × 20 cm are not significantly different in stem diameter at 4, 6, 8 and 10 WAS but at 12 WAS with stem diameter (2.88 and 3.33 cm) respectively in 2014. Spacing had significant effects on stem diameter of kenaf at 4 and 10 WAS in 2015. Planting at the spacing of 50 cm × 25 cm gave the highest stem diameter (1.14 cm, 2.25 cm and 3.54 cm) at 6, 8 and 12 WAS respectively in 2015. However, there was no significant effects of spacing on dry matter accumulation of kenaf at 4 and 6 WAS. At 8 and 10 WAS however, planting at 50 × 25 cm significantly increased the dry matter accumulation in kenaf compared to other spacing.

Table 4.18**:** Effect of spacing on the plant height, stem diameter and dry matter accumulation of kenaf evaluated at Ibadan in 2014 and 2015

Spacing (cm)	Plant height (cm)					Stem diameter (cm)					Dry matter Accumulation g/ plant			
	Weeks After Sowing													
	4	6	8	10	12	4	6	8	10	12	4	6	8	10
2014														
50 × 15	50.55[a]	96.60[a]	165.47a	187.93[a]	207.77[a]	0.58[b]	1.36[b]	1.44[b]	2.13[b]	2.18[b]	5.60[a]	19.67[a]	115.86[b]	140.37[b]
50 × 20	39.83[b]	83.97[b]	155.03[b]	169.81[b]	199.97[b]	0.68[b]	1.59[b]	1.84[b]	2.03[b]	2.88[a]	5.36[a]	18.20[a]	115.32[b]	140.83[b]
50 × 25	39.36[b]	82.00[b]	149.73[b]	154.67[c]	197.50[b]	0.91[a]	2.66[a]	2.69[a]	2.73[a]	3.33[a]	4.90[a]	22.95[a]	139.51[a]	150.59[a]
2015														
50 × 15	50.63[a]	124.43[a]	133.13[a]	210.34[a]	247.13[a]	0.49[a]	1.05[b]	1.27[b]	1.70[a]	2.01[b]	45.30[c]	76.41[c]	105.28[c]	120.12[c]
50 × 20	41.40[b]	117.87[b]	129.00[a]	200.01[b]	219.00[b]	0.51[a]	1.03[b]	1.23[b]	1.83[a]	2.32[b]	59.20[b]	90.68[b]	120.83[b]	135.03[b]
50 × 25	40.97[b]	109.63[c]	104.97[b]	189.34[c]	204.97[b]	0.55[a]	1.14[a]	2.25[a]	2.75[a]	3.54[a]	76.29[a]	109.40[a]	147.93[a]	151.13[a]

Means with same letter among treatments are not significantly different at $p \leq 0.5$

4.6.1 Effects of spacing on the core and bast fibre and seed yield of kenaf evaluated at Ibadan in 2014 and 2015

The results of Core and bast fibre and seed yield in both 2014 and 2015 are presented in Figure 4.2. The spacing of 50 cm × 20 cm gave the highest core and bast fibre yield, while 50 cm × 25 cm and 50 cm × 15 cm had values that were not significantly different for core fibre yield and bast fibre yield in 2014. Seed yield was significantly highest at spacing of 50 cm × 25 cm while 50 × 20 cm and 50 × 15 cm were not significantly different in their effects on seed yield in 2014. The three spacings are not significantly different with respect to core yield in 2015 while 50 cm × 20 cm gave highest bast yield than other two spacing in 2015. The spacing 50 cm × 25 and 50 × 20 cm were not significantly different with regards to their seed yield with the least seed yield obtained from spacing of 50 cm × 15 cm in 2015.

4.7.0 Effect of sowing date on the plant height and stem diameter

Sowing date significantly affected growth and development of kenaf as shown in Table 4.19. Plant height were higher in May and |June at 4, 6 and 8 WAS. At 10 and 12 WAS, kenaf sowed in June had the tallest (200.2 cm and 262.8 cm) respectively. Kenaf sowed in May had stem height (244.1 cm) but was not significantly taller than (240.6 cm) obtained from kenaf sowed in July while the lowest plant (173.8 cm) was from those sowed in August. Stem diameter (0.71 cm and 1.49 cm) were obtained at 4 and 6 WAS from kenaf sowed in May. While stem diameter (2.3 cm, 2.1 cm and 2.0 cm) obtained from kenaf sowed in May, June and July respectively were not significantly different but they were all significantly higher than (1.2 cm) obtained from kenaf sowed in August. Number of leaves steadily increased from 4 to 12 WAS. At 12 WAS, the highest number of leaves (98.8) was obtained from kenaf sowed in May but not significantly different from number of leaves (80.4 and 76.1) obtained from those sowed in June and July respectively and lowest (44.0) in August. All the parameters assessed were significantly higher in 2015 than those obtained in2016.

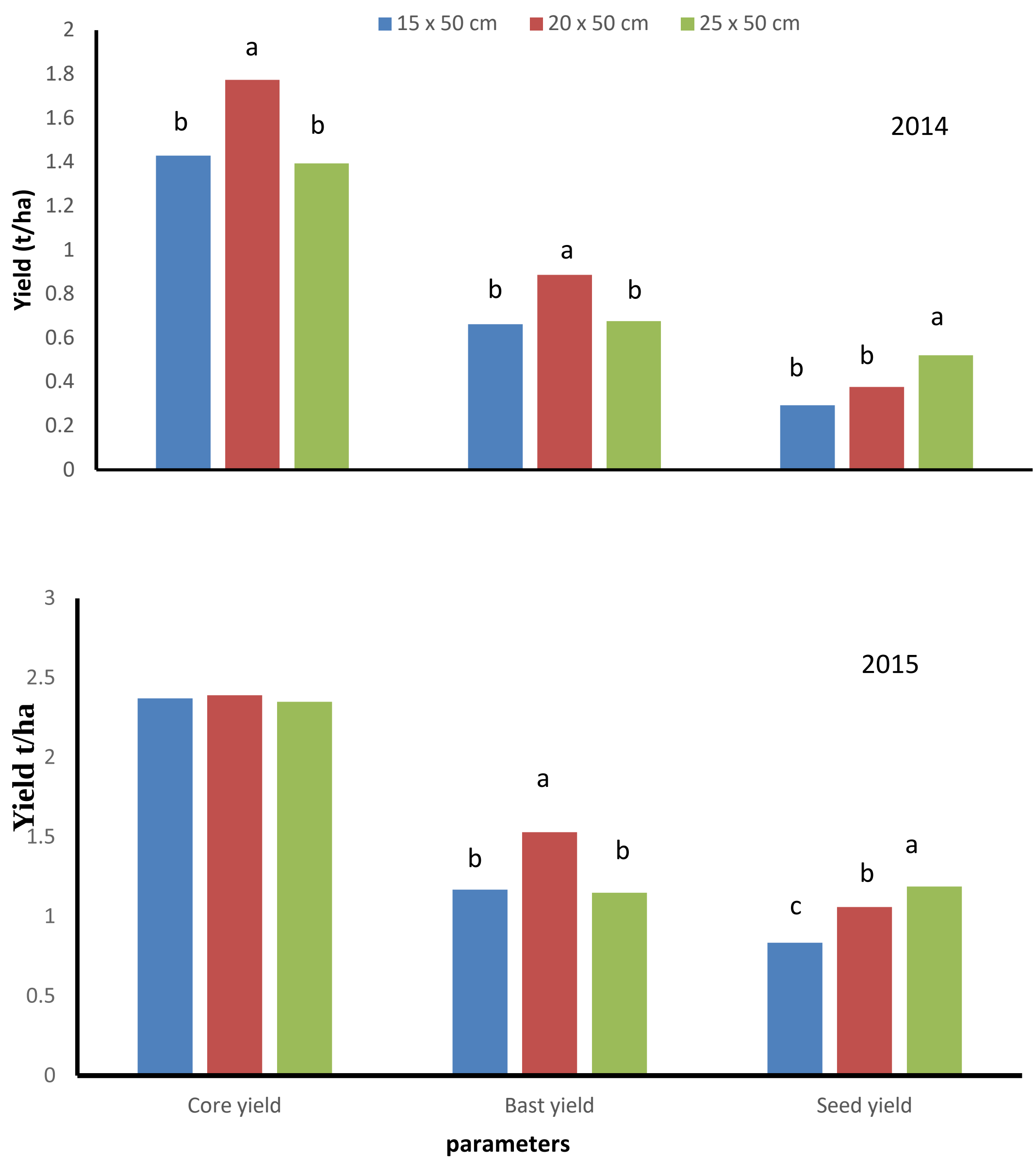

Figure 4.2: Effect of spacing on kenaf fibre and seed yield in 2014 and 2015

Mean with same letter within a group are not significant different at $p \leq 0.5$

Table 4 19**:** Effect of sowing date on the vegetative growth of kenaf cultivated at Ibadan in 2015 and 2016

Sowing date	Plant height (cm)					Stem diameter (cm)					Number of leaves				
	Weeks After Sowing														
	4	6	8	10	12	4	6	8	10	12	4	6	8	10	12
May	52.52^{a}	94.21^{a}	146.07^{a}	173.08^{b}	244.05^{b}	0.71^{a}	1.49^{a}	1.78^{a}	1.95^{a}	2.32^{a}	22.57^{a}	45.03^{a}	64.21^{a}	75.96^{a}	98.80^{ab}
June	52.14^{a}	98.42^{a}	151.86^{a}	200.22^{a}	262.83^{a}	0.64^{b}	1.23^{b}	1.58^{a}	1.84^{a}	2.14^{a}	13.51^{b}	20.59^{b}	35.19^{bc}	67.29^{a}	80.40^{b}
July	36.16^{b}	76.65^{b}	130.72^{b}	160.17^{b}	240.57^{b}	0.42^{c}	0.84^{c}	1.35^{a}	1.74^{a}	1.99^{a}	10.80^{bc}	20.90^{b}	45.06^{b}	55.20^{b}	76.12^{b}
August	28.17^{c}	50.07^{c}	84.79^{c}	133.70^{c}	173.79^{c}	0.41^{c}	0.46^{d}	0.71^{b}	0.96^{b}	1.19^{b}	8.04^{c}	8.12^{c}	22.32^{c}	35.10^{c}	44.01^{c}
Year															
2015	42.38	83.78	137.42^{a}	165.12	241.43^{a}	0.57	1.04^{a}	1.46^{a}	2.53^{a}	2.12^{a}	14.63	25.33	38.75	57.53	87.12^{a}
2016	42.11	75.89	119.30^{b}	168.47	219.19^{b}	0.52	0.91^{b}	1.24^{b}	1.57^{b}	1.71^{b}	12.83	21.99	44.64	54.25	62.55^{b}

Means with same letter among treatment are not significantly different at $p \leq 0.5$

4.7.1 Effects of sowing date on the fibre and seed yield of kenaf

Sowing date significantly influenced bast fibre, core fibre and seed yield (Figure 4.3 and 4.4). The bast fibre yield obtained from kenaf sowed in May, June and July are not significantly different at ($P< 0.05$) but higher than the bast in August. Core yield (1.37 and 1.88 t/ha) in May and June respectively differed significantly. The highest core yield (2.52 t/ha) was obtained in July but are not significantly different from the core yield in June (1.88 t/ha) while core yield (0.69 t/ha) in August was the least. Seed yield obtained in July (2.28 t/ha) was the highest and the lowest was in May and August 1.04 and 1.19 t/ha respectively.

4.8.0 Changes in Soil Properties

Chemical properties of the soil after 2015 cropping seasons (Table 4.20) indicated that soil acidity decrease from pH 6.2 to pH 6.8 in plots that were treated with organic fertiliser. In plot that were treated with inorganic fertiliser, soil acidity increased with increase in N rate with pH ranged from 6.4 to 5.7. Total acidity decreased with increase in effective cation exchange capacity (ECEC) in plots with organic fertiliser application but for inorganic fertilised plot, both total acidity and ECEC increased generally with increase in N rate. Soil total nitrogen increased (30 -35 %) in organic fertilised plots. Similarly, soil organic carbon increased by 34-40 % with increase in N rate in organic fertilised plots than inorganic fertilised plots. Available P increased significantly in plots treated with either of the fertiliser types.

The exchangeable K content of the soil slightly increased in organic fertilised plots while the increase was significant in the inorganic fertilised plots with increase in N rate applied. Exchangeable Ca significantly increased in plots treated with either of the fertiliser type with increase in N rate applied while Mg decreased from 1.35 to 0.91 cmol kg^{-1} and from 1.33 to 0.98 cmol kg^{-1} in plots with organic and inorganic fertiliser respectively

4.9.0 Economic analysis of Kenaf cultivation using varying N rates

Partial budget for Kenaf fibre and seed using different fertilizer types in 2014 cropping seasons are presented in Tables 4.21 a and b. Highest net benefits (₦ 2,974,100 and ₦

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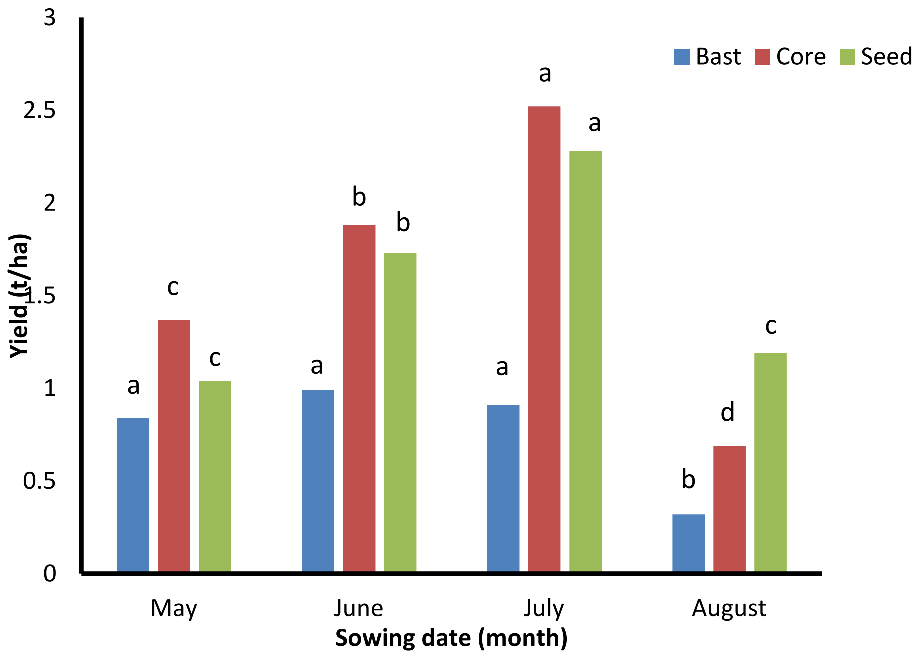

Figure 4.3: Effect of sowing date on fibre and seed yield of kenaf at Ibadan for different months. Mean with same letter within a parameter are not significant different at $p \leq 0.5$

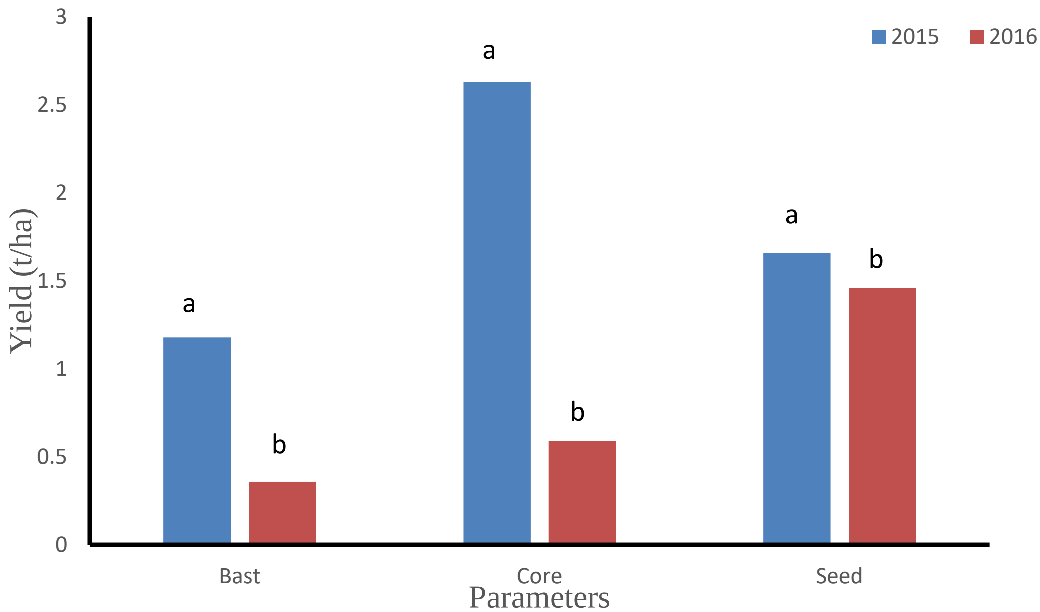

Figure 4.4: Effect of sowing date on the fibre and seed yield of kenaf at Ibadan in 2015 and 2016. Mean with same letter within a group are not significant different at $p \leq 0.5$

Table 4.20: Soil chemical properties of organic and inorganic fertilised field at the end of 2015 cropping season

N rate (kg/ha)	pH	Org. C	Total N.	Avil. P	Ca	Mg	K	Total acidity	ECEC
		g/kg		mg/kg		Cmol/kg			
Organic fertiliser									
0	6.20	6.87	0.50	3.45	2.01	1.35	0.19	0.27	11.4
70	6.60	13.58	1.40	4.03	5.33	1.47	0.68	0.21	12.26
100	6.70	16.61	1.60	4.44	6.50	0.95	0.82	0.25	12.91
130	6.60	18.20	1.80	4.62	6.83	0.96	0.95	0.22	15.47
160	6.80	18.22	2.00	5.04	8.50	0.91	1.12	0.18	16.01
LSD	N.S	0.23	0.45	0.10	0.23	0.07	N.S	0.02	0.50
Inorganic fertiliser									
0	6.40	6.77	0.70	3.45	2.00	1.33	0.16	0.05	10.36
70	6.20	10.02	1.00	4.05	6.05	1.19	0.69	0.11	11.12
100	6.00	10.52	1.05	5.65	6.12	1.05	0.71	0.12	12.21
130	5.90	11.13	1.12	5.66	6.42	1.01	0.88	0.15	12.82
160	5.70	11.07	1.10	5.60	6.55	0.98	0.92	0.19	13.26
LSD	N.S	2.23	0.44	0.1	0.22	0.11	0.08	N.S	N.S

Means ≥ LSD among treatments are not significantly different at p ≤ 0.5, N.S = not significant

Table 4.21a: Partial budget for Kenaf fibre yield as influenced by organic and inorganic fertilisers in 2014

	Organic fertiliser					Inorganic fertiliser				
N kg/ha	0	70	100	130	160	0	70	100	130	160
Average fibre yield										
Core kg/ha	540	1700	1830	1990	2050	550	1650	1680	1960	1680
Bast kg/ha	340	810	980	1370	1220	350	960	990	1210	1030
Gross field benefit (N/ha)										
Core (N 500 / kg)	270,000	850,000	915,000	995,000	1,025,000	275,000	825,000	840,000	980,000	840,000
Bast (N 2000 / kg)	680,000	1,620,000	1,960,000	2,740,000	2,440,000	700,000	1,920,000	1,980,000	2,420,000	2,060,000
Total gross benefit	950,000	2,470,000	2,875,000	3,735,000	3,465,000	975,000	2,745,000	2,820,000	3,400,000	2,900,000
Cost of Input/Labour (N/ha)										
Land preparation	40,000	40,000	40,000	40,000	40,000	40,000	40,000	40,000	40,000	40,000
Seed (N 1,800 / kg)	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000
Planting (N 1,500 / md)	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500
Weeding (N 1,500 / md)	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000
Organic fertiliser (N 2,500/bag)	0	250,000	400,000	500,000	600,000	0	0	0	0	0
Inorganic fertiliser (N 7,500 / bag)	0	0	0	0	0	0	52,500	75,000	97,500	120,000
Fertiliser application (N 1,500/md)	0	7,500	7,500	7,500	7,500	0	7,500	7,500	7,500	7,500
Insecticide /application	12,900	12,900	12,900	12,900	12,900	12,900	12,900	12,900	12,900	12,900
Harvesting (N 1,500 / md)	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000
Processing fibre	80,000	80,000	80,000	80,000	80,000	80,000	80,000	80,000	80,000	80,000
Transportation	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000
Total cost that vary	253,400	510,900	660,900	760,900	860,900	253,400	313,400	335,900	358,400	380,900
Net benefit	696,600	1,959,100	2,214,100	2,974,100	2,604,100	721,600	2,431,600	2,484,100	3,041,600	2,519,100
Marginal Net benefit		1,262,500	255,000	760,000	-370,000		1,710,000	52,500	557,500	-522,500

1. Gross field benefits: Field price/kg * average yield (kg/ha). Where field price is market value of 1 kg of the crop.
2. Costs that vary: Include only those cost that are affected by alternative treatments being considered.
3. Net benefit: This is caculated by subtracting the total costs that vary from the total benefits. (4). Md: Manday

Table 4.21b: Partial budget of Kenaf seed as influenced by organic and inorganic fertiliser in 2014

	Organic fertiliser					Inorganic fertiliser				
N kg/ha	0	70	100	130	160	0	70	100	130	160
Average Seed yield kg/ha	510	720	1230	1650	1900	490	1260	1350	1770	1550
Gross field benefit (N/ha)										
Seed (N 1,800/ kg)	918,000	1,296,000	2,214,000	2,970,000	3,420,000	882,000	2,268,000	2,430,000	3,186,000	2,790,000
Cost of Input/Labour (N/ha)										
Land preparation	40,000	40,000	40,000	40,000	40,000	40,000	40,000	40,000	40,000	40,000
Seed (N 1,800 / kg)	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000
Planting (N 1,500 / md)	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500
Weeding (N 1,500 / md)	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000
Organic fertiliser (N 2,500/bag)	0	250,000	400,000	500,000	600,000	0	0	0	0	0
Inorganic fertiliser (N7,500 / bag)	0	0	0	0	0	0	52,500	75,000	97,500	120,000
Fertiliser application (N 1,500/ md)	0	7,500	7,500	7,500	7,500	0	7,500	7,500	7,500	7,500
Insecticide/application	12,900	12,900	12,900	12,900	12,900	12,900	12,900	12,900	12,900	12,900
cost of harvesting (N 1,500/md)	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000
cost of processing seed	80,000	80,000	80,000	80,000	80,000	80,000	80,000	80,000	80,000	80,000
cost of transportation	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000
Total cost that vary	253,400	510,900	660,900	760,900	860,900	253,400	313,400	335,900	358,400	380,900
Net benefit	664,600	785,100	1,553,100	2,209,100	2,559,100	628,600	1,954,600	2,094,100	2,827,600	2,409,100
Marginal Net benefit		120,500	768,000	656,000	350,000		1,326,000	139,500	733,500	-418,500

1 Gross field benefits: market value of 1kg of the crop
2 Costs that vary: Include only those that are affected by alternative treatments being considered.
3 Net benefit: This is calculated by subtracting the total cost that vary from the total gross benefit
4. Md: Manday

3,041,600) derived from fibre (core and bast) were realized under 130 kg N/ha organic and inorganic fertilized field respectively in 2014 cropping season. In the case of Kenaf seed, the highest net benefit (₦2,559,100) was realized in plots with organic fertiliser application at 160 kg N/ha but with marginal net benefit (₦768,000) in 100 kg N/ha. However, highest net benefit (₦2,827,600) and marginal net benefit (₦733,500) were realized from inorganic fertilized field at 130 kg N/ha. Table 4.23a and b show the net benefit and marginal net benefit from the residual effects of the fertiliser applied on the Kenaf fibre and seed in 2015.

The highest net benefit (₦2,636,600) was attained at 160 kg N/ha while the highest marginal net benefit (₦650,000) was at 130 kg N/ha under organic fertiliser treated field. Both net and marginal net benefits (₦481,600 and ₦25,000) respectively were obtained at 130 kg N/ha under inorganic fertilized field in 2015 for fibre yield. For seed, both net benefit and marginal net benefit (₦1,589,600 and ₦198,000) respectively were at 160 kg N/ha under organic fertilized field. While under inorganic fertilized field, net benefit was at 70 kg N/ha with negative marginal benefit.

Table 4.22a: Partial budget of Kenaf fibre yield as influenced by residual organic and inorganic fertiliser in 2015

	Organic fertiliser					Inorganic fertiliser				
N kg/ha	0	70	100	130	160	0	70	100	130	160
Average fibre yield										
Core kg/ha	490	850	910	1210	1650	450	450	450	460	470
Bast kg/ha	250	620	700	950	1020	230	220	230	240	230
Gross field benefit (N/ha)										
Core (N 500 / kg)	245,000	425,000	455,000	605,000	825,000	225,000	225,000	225,000	230,000	235,000
Bast (N 2000 / kg)	500,000	1,240,000	1,400,000	1,900,000	2,040,000	460,000	440,000	460,000	480,000	460,000
Total gross benefit	745,000	1,665,000	1,855,000	2,505,000	2,865,000	685,000	665,000	685,000	710,000	695,000
Cost of Input/Labour (N/ha)										
Land preparation	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000
cost of seed (N 1,800 / kg)	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000
Planting (N 1,500 /md)	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500
Weeding (N 1,500 / md)	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000
Insecticide /application	12,900	12,900	12,900	12,900	12,900	12,900	12,900	12,900	12,900	12,900
Harvesting (N 1,500 / md)	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000
cost of processing fibre	80,000	80,000	80,000	80,000	80,000	80,000	80,000	80,000	80,000	80,000
cost of transportation	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000
Total cost of input	228,400	228,400	228,400	228,400	228,400	228,400	228,400	228,400	228,400	228,400
Net benefit	516,600	1,436,600	1,626,600	2,276,600	2,636,600	456,600	436,600	456,600	481,600	466,600
Marginal Net benefit		920,000	190,000	650,000	360,000		-20,000	20,000	25,000	-15,000

1. Gross field benefits: market value of 1kg of the crop
2. Net benefit: This is calculated by subtracting the total cost of input from the total gross benefit
3. Md: Manday

Table 4.22b: Partial budget of Kenaf seed yield as influenced by residual organic and inorganic fertiliser in 2015

	Organic fertiliser					Inorganic fertiliser				
N kg/ha	0	70	100	130	160	0	70	100	130	160
Average Seed yield kg/ha	340	510	820	900	1010	330	340	330	320	320
Gross field benefit (N/ha)										
Seed (N 1,800/ kg)	612,000	918,000	1,476,000	1,620,000	1,818,000	594,000	612,000	594,000	576,000	576,000
Cost of Input/Labour (N/ ha)										
Land preparation	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000
Seed (N 1,800 / kg)	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000
Planting (N 1,500 / md)	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500
Weeding (N 1,500 /md)	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000
Insecticide/application	12,900	12,900	12,900	12,900	12,900	12,900	12,900	12,900	12,900	12,900
Harvesting (N 1,500 / md)	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000
Processing seed	80,000	80,000	80,000	80,000	80,000	80,000	80,000	80,000	80,000	80,000
Transportation	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000
Total cost of input	228,400	228,400	228,400	228,400	228,400	228,400	228,400	228,400	228,400	228,400
Net benefit	383,600	689,600	1,247,600	1,391,600	1,589,600	365,600	383,600	365,600	347,600	347,600
Marginal Net benefit		306,000	558,000	144,000	198,000		18,000	-18,000	-18,000	0

1. Gross field benefits: Field price/kg * average yield (kg/ha). Where field price is market value of 1 kg of the crop.
2. Net benefit: This is calculated by subtracting the total costs of input from the total benefits.
3. Md: Manday

CHAPTER FIVE

DISCUSSION

Kenaf responses are accounted for by differences in environmental factors and inputs such as fertiliser (Hazandy *et al*., 2009). The improved performance of kenaf in this study when viewed across different fertiliser types and rates showed that the crop can perform optimally when grown under favourable conditions. The kenaf grown with organic fertiliser were found to be taller than those grown with inorganic fertiliser of the same rate. This could be attributed to the fact that more nutrients were available in pot with higher rates which may have been leached or washed off in the case of inorganic fertiliser, hence the crop performance in this study. The result agreed with Zhang, (2003) who reported that application of organic fertiliser reduced N fertiliser required in crop production due to reduction in N leaching, hence increase N use efficiency by the plant. From the result, rate above 130 kg N/ha of inorganic had a decreasing effect on the plant height and stem diameter of the crop compare to organic fertiliser of the same rate. Number of leaves and leaf area were also higher under organic fertiliser grown kenaf than those grown under inorganic of the same rate of application.

Dry matter production of kenaf grown with organic fertiliser increased with increase in the rate. Biomass accumulation of kenaf grown with inorganic fertiliser at 100, 130 or 160 kg N/ha differed not significantly. Growth rates equally increased with increase in the rate of organic fertiliser while there was decrease in the growth rate of kenaf grown with inorganic fertiliser above 130 kg N/ha. This was similar to the report of Danalatos and Archontoulis (2004, 2010) who reported that kenaf does not require high dose fertiliser. Core fibre yield increased with increase in rate of organic fertiliser applied and were significantly higher than those obtained from those grown with inorganic fertiliser.

The core fibre yields under inorganic differed significantly not for any of the rates. Similar with the bast yield, the highest bast yield was obtained from the organic fertiliser grown kenaf. Although, there was slight decrease in the bast yield at the highest rate of organic fertiliser, however, the result was higher than the highest bast yield obtained under inorganic. This may be as a result of excessive soluble salts (or salinity) supplied by the higher rate of organic fertiliser. Stephenson *et al*. (1990) stated that excessive use of chicken manure could increase electrical conductivity thereby causing salinity in soils and consequently impair plant growth. The consistent low yield of kenaf under inorganic fertiliser as reflected in this study may be attributed to the nature of the soil used. Okafor (1998), Hamzah *et al* (2009), Saga *et al* (2010), Zaidey *et al* (2010) have reported that application of mineral fertiliser to the tropical soil, which is poor in water holding capacity, low in cation exchange capacity (CEC) and nutrient availability could result to leaching of applied nutrient and mineralization due to high temperature and erratic rainfall, hence the low performance of kenaf with the application of inorganic fertiliser (Chen, 1985).

Number of capsule per plant increased with increase in the rate of organic fertiliser applied while there was a decrease in the number of capsule per plant at rate above 130 kg N/ha for inorganic. Number of seeds per capsule were not affected by the rate of inorganic fertiliser but increased with increase in the level of organic fertiliser applied. The increase in the number of capsule and seed yield of kenaf is in line with the reports of Fatokun and Chedda (1983) which linked the positive effect to adequate amount of nutrient available for plant use. Kabura (2002) stated that availability of soil nutrient improved photosynthesis and translocation from source to sink resulting in increased capsule and seed yield of okra. The seed yield of kenaf grown with organic fertiliser was also found to be higher than those grown with inorganic fertiliser of same rate equivalent to 100, 130 and 160 kg N/ha. This result is in agreement with Hossain *et al* (2011) whose findings showed that the application of 20 t/ha of organic carbon has a significant effect on the growth parameters of kenaf.

The percentage crude protein, crude fibre and ash content of the plant increased with increase in the rate of fertiliser applied for both organic and inorganic. The advantages of organic fertiliser reflected in the fact that these parameters were higher in plants grown with organic fertiliser than in those grown with inorganic of same rate of application. The crude protein of 14.83 % to 15.90 % confirmed the claim of Webber *et al.* (2002) who reported that crude protein in kenaf leaves ranged from 14 % to 34 %. It was noted that the percentage crude fibre and total ash were higher in plant tissue grown with organic fertiliser than those under inorganic. Moisture content increased with increase in the rate up to 130 kg N/ha before it declined again for both fertiliser types. Dry matter and nitrogen free extract decreased with increase in the rate of inorganic fertiliser at a rate higher than 130 kg N ha^{-1} but increased with increase in the rate of organic fertiliser.

Nutrient concentrations in the plant tissue were aided by organic fertiliser than inorganic. The nitrogen concentration in organically grown kenaf plant was higher with increase in rate of fertiliser applied. Phosphorus was higher in inorganically grown kenaf plant than organically grown one up till 130 kg N/ha after which its concentration decreased while it increased in organic grown plant even at 160 kg N/ha. Potassium, sodium, calcium and magnesium concentrations were higher in organic grown kenaf than inorganically grown one. Their concentrations increased with increase in rate of fertiliser application for organic fertiliser. This is in agreement with the findings of Ahmed *et al.*, (2008) who indicated that nutrient uptake efficiency of crops could be enhanced by applying organic fertiliser.

The application of organic fertiliser combined with inorganic fertiliser had significant positive effect on the growth and yield performance of kenaf. The combined fertiliser resulted into taller plant, wider basal stem diameter and larger fibre and seed yield than organic or inorganic fertiliser applied solely. This result is supported by the findings of Islam *et al.* (2011) who stated that differences in combination of application of organic and inorganic fertilisers significantly increased the growth and yield of plants. Srivastava *et al.* (2012) reported that the combination of organic fertiliser with inorganic fertiliser significantly increased the number of leaves, stem diameter, fresh weight and leaf length of onion. The use of 80 kg N/ha (organic) + 50 kg N/ha (inorganic) had a complementary and synergistic effects on the kenaf performance. Zhou *et al*. (2002)

reported that plants grown on soil treated with organic combined with inorganic fertiliser grow well by adjusting nutrients release into the soil.

Findings in this study agreed with Mohd Hadi *et al*. (2013) who reported the use of poultry manure with mineral fertiliser combined as being effective in the cultivation of kenaf. It also confirmed the yield increase observed in other crops when organic fertiliser are used as soil amendment (Adeyemo and Agele, 2010; Lin *et al*., 2010). The trial on residual cropping of Kenaf on previously treated plots was conducted to assess the residual fertility of the fertiliser treatments. The results showed that yield of Kenaf fibre and seed on the plots previously treated with organic fertiliser were higher than those obtained from the plots previously treated with inorganic fertiliser which proved that addition of organic fertiliser improved soil fertility as reported by Mohd Hadi *et al*. (2013). Organic fertiliser has the ability to retain nutrients, reduce nutrient leaching, improve soil quality and carbon sequestration, hence, evenly supply of nutrients to plants (Lahmann and Joseph, 2009; Graber *et al*., 2010).

To make good recommendation for farmers CIMMYT (1988) had opined that research must be able to evaluate alternative technologies from the farmers perspectives based on the premises that farmers: (1) are concerned with the benefit and cost of the particular technologies; (2) usually adopt innovations in a stepwise fashion; and (3) will consider the risks involved in adopting new practices. The economic analysis or partial budgeting of this study indicated that in changing from the use of inorganic fertiliser to the use of organic fertiliser, farmers make an extra investment in terms of cost of N fertiliser but in turn they will obtain extra benefits due to higher yield. Considering the benefit of organic fertiliser on the soil and environment, the farmer makes extra benefit in terms of yield in the subsequent year hence same land could be used continuously for a long time. The increase in the net benefit at higher N rate suggests that the farmers could benefit by applying optimal N rate for either fibre or seed yield. Generally, cultivating Kenaf for fibre or seed, 130 kg N/ha is more profitable than other rates, be it organic or inorganic, while organic fertiliser is rather preferred considering the slow release of nutrient in organic fertilisers makes the nutrient available over a longer period for biomass production. This reduces nutrient escape into the environment through run-off, leaching and volatilization, thus preventing environmental pollution.

The response of kenaf to spacing of 50 × 25 cm significantly increased biomass accumulation and not the seed yield. Higher bast and core fibre yield obtained at spacing of 50 × 20 cm could be attributed to the compensatory effect of kenaf as reported (Webber and Bledsoe, 2002) that closer spacing resulted in taller plant height and wider spacing resulted in bigger stem diameter hence account for each other in their bast and core fibre yield. The seed yield was significantly higher at spacing of 50 × 25 cm contrary to Agbaje *et al*. (2011) who reported that seed yield was highest at 50 × 20 cm spacing. This implies that if a farmer is interested in seed production, wide spacing will be more appropriate.

Generally, over different sowing dates, the performance of kenaf during some of the sowing dates in this study showed that time of planting has a direct effect on growth performance of kenaf bearing in mind that this is photosensitive plant coupled with the rain fall pattern. This may have caused reduction in growth performance and yield in July and August. This is because too little or too much water at critical stages of growth of kenaf can reduce either fibre or seed yield since adequate moisture availability promotes vegetative growth and seed yield in kenaf (Danalatos and Archontoulis, 2010). The result indicated that kenaf planted earlier than May or after August did not perform well perhaps due to lack of adequate moisture and this could hamper kenaf growth and yield. The plant height and stem diameter which are indicators for fibre yield declined as the year advances from May. The highest plant height (262.83 cm) and diameter (2.32 cm) were recorded in plant established in June and May respectively. Results from this study revealed that kenaf could be planted in May, June or July for fibre yield while July is most appropriate for seed production. The result showed that August is not appropriate for planting of kenaf either for fibre or seed production and it confirmed the report of Alexopoulou *et al.* (2004) who reported that early planting favoured growth and fibre yield of kenaf than late planting except with irrigation.

CHAPTER SIX

SUMMARY AND CONCLUSIONS

Kenaf, a native to East-Central Africa is utilized in the cordage and sacking manufacture (Mohd Hadi *et al*., 2013). The renewed effort to boost agricultural production through the use of agro produce bag in the packaging of the farm produce has led to the increasing interest in fibre crops. Although tropical in origin (Meints and Smith, 2003) kenaf yield is very low in Africa.

Hence as part of efforts to increase the seed and fibre yield of kenaf, pot and field experiments were therefore conducted to: (1) evaluate the fibre and seed yield potential of kenaf under varying rates of organic and inorganic fertiliser; (2) determine the response of kenaf to varying plant density and it effect on fibre and seed yields of kenaf; and (3) determine kenaf fibre and seed yields under different sowing date at the Institute of Agricultural Research and Training (I.A.R.&.T.), Ibadan between 2012 and 2016 to verify the effect of type and rates of fertiliser application, spacing and time of planting on the growth performance, fibre and seed yield of kenaf in southwest Nigeria. The findings are summarized as follows:

1. Higher rate above 130 kg N/ha of inorganic application is considered a waste since it did not translate to higher yield of kenaf.
2. Nutrient uptake was high with the application of 160 kg N/ha of organic fertiliser.
3. The use of organic and inorganic fertiliser combined at 80 kg N/ha (organic) + 50 kg N/ha (inorganic) was more productive than sole organic or inorganic fertiliser.
4. Application of sole inorganic fertiliser should be discouraged due to its detrimental effects on the environment but could be complemented with organic fertiliser.

5. The economic analysis of the cost of N in the Kenaf cultivation indicated that farmers make extra investment by applying organic fertiliser but in return, they obtain extra benefit due to higher yield in first and following year.
6. The marginal net benefit ranged from ₦ 255,000 to ₦ 760,000 in the first year and ₦ 190,000 to ₦ 650,000 in the second year from organic fertilized field for fibre.
7. The marginal net benefit for seed under organic fertiliser ranged from ₦ 120,500 to ₦ 768, 000 in the first year and ₦ 306,000 to ₦ 558, 000 in the second year.
8. May to June is appropriate for planting of kenaf for fibre production while planting in July is for seed production in Ibadan Nigeria.
9. Spacing of 50 × 15 cm and 50 × 20 cm are appropriate when planting for fibre while 50 × 25cm is appropriate for seed production.

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Appendix 1

Mean square value of the evaluate fertiliser on kenaf growth parameters at Ibadan in 2013

Source	df	Organic fertiliser			Inorganic fertiliser		
		Weeks after sowing			Weeks after sowing		
		4	8	12	4	8	12
Plant height	4	3170.31 ***	450.96 ***	1660.88 ***	626.48 ***	239.01 ***	2079.18 ***
Stem diameter	4	0.47	0.70 ***	2.07 ***	0.08 ***	0.08 ***	0.39 ***
No of leaf	4	161.09 ***	704.24 ***	1205.72 ***	68.61 ***	217.00 ***	231.63 **
Leaf area	4	2185.18	1278.49	5833.08 ***	2316.89 ***	1104.71	2041.37 **
Total seed weight	4	NA	NA	468.46 $^{***\ ah}$	NA	NA	243.86 $^{***\ ah}$

*,**,*** significant at 0.05.0.01 and 0.001 %

NA = Not Available, ^{ah} = at harvest

Appendix 2

Mean square value for kenaf evaluated under organic fertiliser at Ibadan in 2014

Source	df	Weeks after sowing				
		4	6	8	10	12
Plant height	4	2596.92***	3403.20***	6330.12***	11092.34***	11155.88***
Stem diameter	4	0.37 ***	0.63 ***	1.11***	1.79***	2.21***
No of leaf	4	1225.72***	1470.26***	5005.04***	7127.95***	13388.53***
Leaf area	4	4911240.08***	16145892.38***	25164086.00***	46880801.40***	87515870.60***
Total biomass	4	717.98***	1087.38***	2766.69***	3987.55***	6401.35***
AGR	4	219.41***	416.49***	126.79***	43.82***	NA
RGR	4	0.56***	0.66***	0.15***	0.26***	NA
Core	4	NA	NA	NA	0.39	NA
Bast	4	NA	NA	NA	0.24	NA
No of capsule	4	NA	NA	NA	77.58	
No of seed	4	NA	NA	NA	NA	27.17
Weight (g) of 100 seed	4	NA	NA	NA	NA	0.13*
Seed yield	4	NA	NA	NA	NA	1.75**

*, **, *** significant at 0.05.0.01 and 0.001 %: NA = Not Available

Appendix 3

Mean square for growth parameters of kenaf evaluated under inorganic fertiliser at Ibadan in 2014

Source	df	Weeks after sowing				
		4	6	8	10	12
Plant height	4	2608.41***	1650.59***	1773.92***	4777.32***	2951.24***
Stem diameter	4	0.25 ***	0.30***	0.41***	0.72***	1.16***
No of leaf	4	1651.82***	1740.42***	3013.91***	3913.34***	7126.89***
Leaf area	4	2812238.93***	4605761.02***	6515725.1	383740639.22***	28983051.4
Total biomass	4	392.89***	460.79***	634.00***	1161.93***	1863.61***
AGR	4	203.31***	237.51***	120.81***	80.11***	NA
RGR	4	0.57***	0.52***	0.12***	0.17***	NA
Core	4	NA	NA	NA	NA	0.43
Bast	4	NA	NA	NA	NA	0.19
No of capsule	4	NA	NA	NA	NA	209.05
No of seed	4	NA	NA	NA	NA	23.08
Weight (g) of 100 seed	4	NA	NA	NA	NA	0.05
Seed yield	4	NA	NA	NA	NA	0.89

*, **, *** significant at 0.05.0.01 and 0.001 %; NA = Not Available

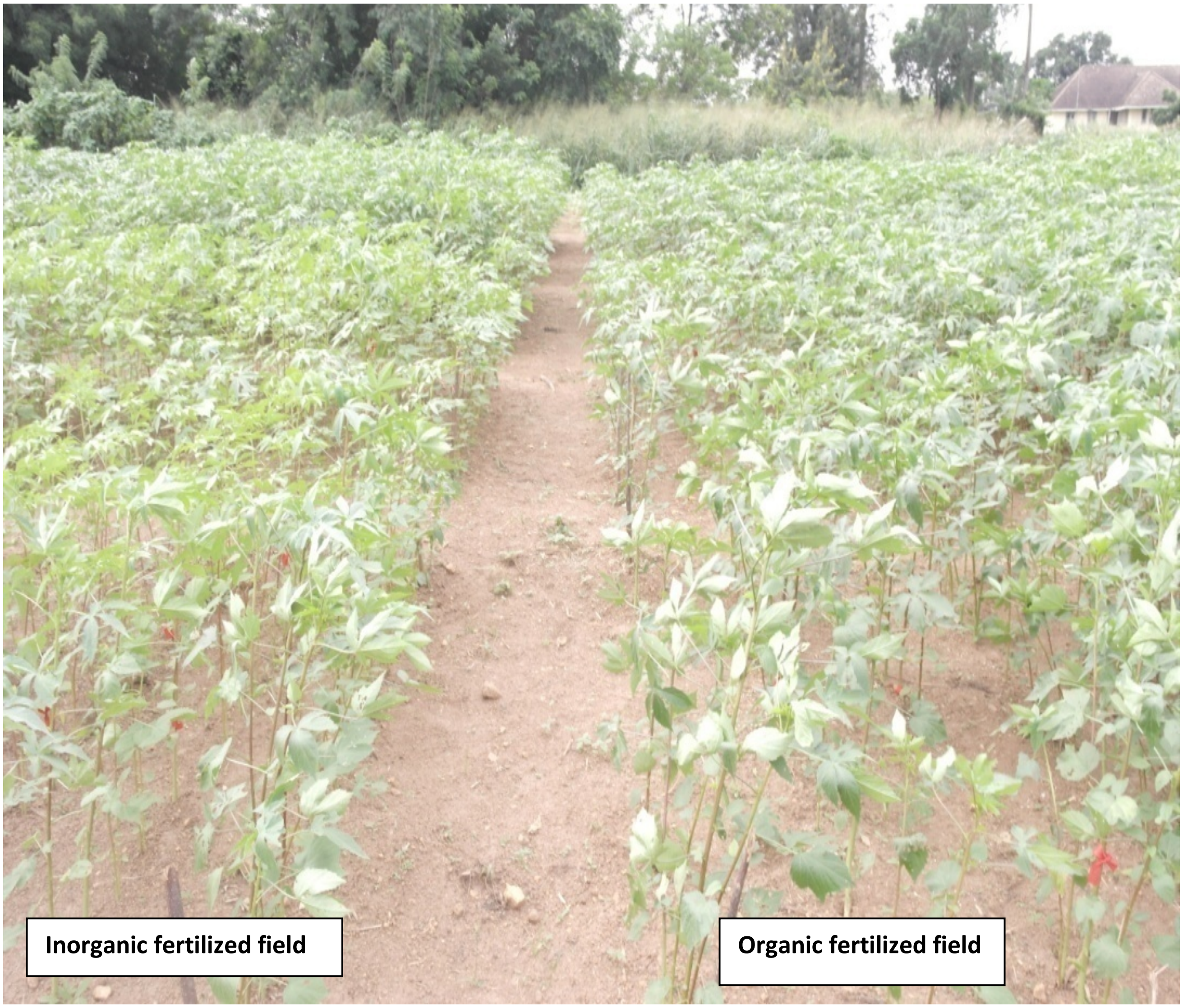
Appendix 4

Mean square for nutrient content of kenaf evaluated under organic and inorganic fertiliser at Ibadan in 2014

Source	df	Organic	INORGANIC
Protein	4	1.28***	2.61***
Fat	4	0.10***	0.11***
Fibre	4	2.08***	2.01***
Total Ash	4	0.62***	0.83***
Moisture	4	0.64***	1.19***
Dry matter	4	0.64***	1.19***
NFE	4	2.18***	4.63***
N	4	899.17***	655.95***
Ca	4	635.79***	477.66***
Mg	4	7970.03***	3839.90***
K	4	7679.76***	2364.93***
P	4	984.86***	1035.91***
Na	4	6619.56***	2046.08***

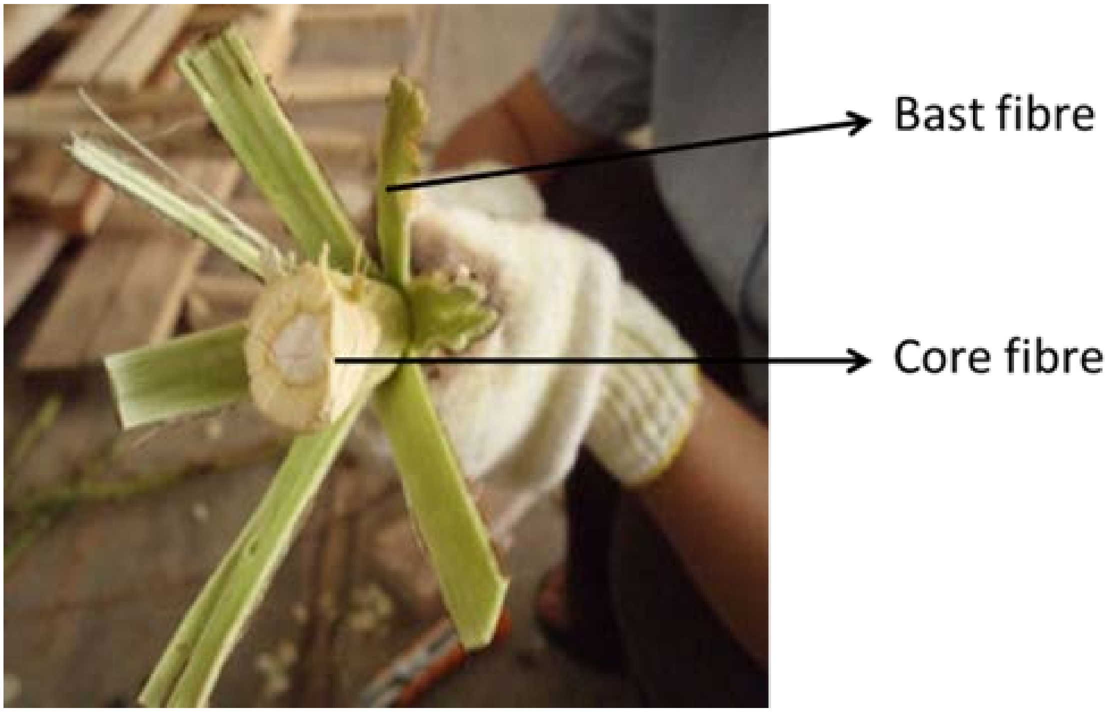
*, **, *** significant at 0.05.0.01 and 0.001 %

APPENDIX 5



Photographs showing organic (right) and inorganic (left) fertilised field

Appendix 6



Photograph Showing bast and core parts of kenaf

Appendix 7

Photograph showing Kenaf capsule

Appendix 8

Photograph showing kenaf seeds

APPENDIX 9

Calculation of the rates of fertiliser applied

Note: 1 ha = 10, 000 m^2 =2 × 10 ^{6} kg soil; Weight of soil used for the pot experiment = 10 kg

Plot size = 4 m × 3 m = 12 m^2, Rates used: 0, 70, 100, 130 and 160 kg N ha $^{-1}$

Treatment 1: 160 kg N ha $^{-1}$ using organic fertiliser

1000 kg OF contains 13.2 kg N

X kg OF would supply 160 kg N

X = (1000 × 160) / 13.2 = 12, 121.21 kg OF / ha

If 2 × 10 ^{6} kg soil requires 12, 121.21 kg OF

10 kg would require (12,121.21 × 10) / 2 × 10 ^{6} =0.0606 kg = **60.6 g pot-1**

If 10, 000 m^2 requires 12, 121.21 kg OF

12 m^2 would require (12, 121.21 × 12) / 10,000 = **14. 55 kg per plot**

Treatment 2: 130 kg N ha $^{-1}$ using organic fertiliser

X = (1000 × 130) / 13.2 = 9,848.48 kg OF / ha

10 kg soil would require (9,848.48 × 10) / 2 × 10 ^{6} = 0.049 kg =**49.24 g pot-1**

12 m^2 would require (9,848.48 × 12) / 10,000 = **11.82 kg per plot**

Treatment 3: 100 kg N ha $^{-1}$ using organic fertiliser

X = (1000 × 100) / 13.2 = 7,575.75 kg OF /ha

10 kg soil would require (7,575.75 × 10) / 2 × 10 ^{6} =0.0378kg = **37.88 g pot-1**

12 m^2 would require (7,575.75 × 12) / 10,000 = **9.09 kg per plot**

Treatment 4: 70 kg N ha $^{-1}$ using organic fertiliser

X = (1000 × 70) / 13.2 = 5,303.03 kg OF / ha

10 kg soil would require (5,303.03 × 10) / 2 × 10 ^{6} = 0.0265 kg = **26.51 g pot-1**

12 m^2 would require (5,303.03 × 12) 10,000 = **6.36 kg per plot**

Treatment 5: control (no fertiliser application)

Calculation for inorganic fertiliser

Treatment 1: 160 kg N ha $^{-1}$ using NPK 20-10-10 fertiliser

100 kg NPK contains 20 kg N

X kg NPK would supply 160 kg N

X = (100 × 160) / 20 = 800 kg NPK / ha

If 10,000 m^2 or 2 × 10 ^{6} kg soil requires 800 kg NPK

10 kg would require (800 × 10) / 2 × 10 ^{6} =0.004 kg = **4g pot-1**

12 m^2 would require (800 × 12) / 10,000 = 0.96 kg = **960g per plot**

Treatment 2: 130 kg N ha $^{-1}$ using NPK 20-10-10 fertiliser

X kg NPK would supply 130 kg N

X = (100 × 130) / 20 = 650 kg NPK / ha

10 kg would require (650 × 10) / 2 × 10 ^{6} = 0.00325 kg = **3.25g pot-1**

12 m^2 would require (650 × 12) / 10,000 = 0.78 kg = **780g per plot**

Treatment 3: 100 kg N ha $^{-1}$ using NPK 20-10-10 fertiliser

X kg NPK would supply 130 kg N

X = (100 × 100) / 20 = 500 kg NPK / ha

10 kg would require (500 × 10) / 2 × 10 ^{6} = 0.0025 kg = **2.5g pot-1**

12 m^2 would require (500 × 12) / 10,000 = 0.6 kg = **600g per plot**

Treatment 4: 70 kg N ha^{-1} using NPK 20- 10-10 fertiliser

X kg NPK would supply 70 kg N

X = (100 × 70) / 20 = 350 kg NPK / ha

10 kg would require (350 × 10) / 2 × 10^6 = 0.00175 kg = **1.75g pot-1**

12 m^2 would require (350 × 12) / 10,000 = 0.42 kg = **420g per plot**

Treatment 5: control (no fertiliser application)