

**EFFECTS OF NPK FERTILIZER APPLICATION RATES AND
INTRA-ROW SPACING ON GROWTH AND YIELD OF RADISH
(*Raphanus sativus* L.)**

BY

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of the Requirement for the Award of Masters Degree in Agronomy**

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DECLARATION

I hereby declare that this work is the product of my own research efforts; undertaken under the supervision of Dr. B. M. Giginyu and Prof. A. A. Manga and has not been presented and will not be presented elsewhere for the award of degree or certificate. All sources have been duly acknowledged.

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CERTIFICATION

This is to certify that the research work for this dissertation titled EFFECTS OF NPK FERTILIZER APPLICATION RATES AND INTRA-ROW SPACING ON GROWTH AND YIELD OF RADISH (*Raphanus sativus* L.) was carried out by Aminu Umar Hassan (SPS/11/MAG/00020) under our supervision and meets the regulations governing the award of Masters Degree in Agronomy at Bayero University Kano and it is approved for its contribution to scientific knowledge and literary presentation.

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This work has been dedicated to my late father Malam Umar Hassan and my mother Malama Khadijat Muhammad and entire members of my family including my wife and children.

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ABSTRACT

Field experiments were conducted during 2013 rainy season at the Kano State Institute of Horticulture Bagauda, Kano and Federal College of Horticulture Research and Training Farm Dadinkowa, Gombe State. Both the locations are in sudan savanna of Nigeria. The experiment investigated the effects of NPK fertilizer application rates and intra-row spacing on growth and yield of radish (*Raphanus sativus* L.). The treatments were six level of NPK fertilizer (0, 40, 80, 120, 160 and 200kg/ha) and spacing of three levels (10, 15 and 20cm). The treatments were laid down in a randomized complete block design (RCBD), treatments were factorially combined and assigned to plots and replicated three times. Vegetative growth, yield and yield components were measured and data were analyzed using ANOVA. NPK fertilizer application at various rates significantly influenced vegetative growth characters (plant height, stem diameter, number of leaves per plant as well as leaf area). Intra-row spacing significantly affected some of the vegetative growth characters particularly plant height, stem girth, leaf area, root diameter and root length. Significant interactions were recorded on number of leaves, plant height, stem girth, root length and leaf area. In conclusion, the result of the study indicated that application of increasing level of NPK fertilizer from 0 to 200kg/ha significantly increase all growth characters as well as yield components, parameters were all increased with the increasing level of NPK fertilizer up to 120kg/ha. Increasing intra-row spacing from 10 to 20cm had produced significant increase in all growth and yield characters, including root yield in both locations. Significant interactions were also recorded on some of the growth and yield characters such as leaf area, number of leaves, root diameter and root length. Finally 120kg with 20cm intra-row spacing appeared optimum for good yield of radish.

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND INFORMATION

Radish (*Raphanus sativus L*) belongs to the family Brassicaceae. The area of maximum diversity of radish lies between the eastern Mediterranean and Caspian Sea, which is the original gene center for this species (Sounda, 1998). Radish was cultivated usually in ancient times in the Mediterranean, from where it spread to China in about 500 BC and to Japan in about 700 AD. It is also a crop that has been cultivated in the oases of the Sahara and in Mali. Radish is a popular root vegetable in both tropical and temperate region. Radish has a very short life cycle (35 to 60 days), which provides a rapid return of capital (Juen *et al.*, 2010). World production of radish was estimated at 7 million tons per year; accounting for about 2% of the total world production of vegetables (Hogland *et al.*, 2003) Radish is a cool season annual crop (depending on when it is planted). Radish has been cultivated for thousands of years in both China and the Mediterranean area (Sharma and Gulshanlal 1990). Radish was a common food in Egypt before the building of the pyramids and is one of the most ancient cultivated plants. Generally, commercial radish is approximately 2 cm in diameter and is either red

or white. It reaches market size in 21 to 28 days (or longer in cool weather), there is also a radish group called daikon, which is the Chinese Oriental radish. It may grow up to 75 cm long with a diameter of up to 25 cm (Juen *et al.*, 2010). It may weigh several kilograms and radish varies in color from white to black (Singh *et al.*, 1990).

Radish is useful in the treatment of liver, gall bladder troubles, sleeplessness, chronic diarrhea, neuralgic headaches, urinary complaints, piles and gastrodynia (Sadhu, 1993).

Radish is a quick growing cool season root vegetable; therefore, it remains in prime condition for only a few days. Roots of globe varieties tend to elongate and develop poor shape in hot weather when the tops also grow taller and larger than in cool weather (Singh, 2001). Long days induce flowering or seed stalks (bolting) and with warm weather the seed stalk may develop so rapidly that no edible root is formed. Radish becomes more pungent in hot weather. Roots remain in marketable condition for only a short time before becoming pithy. Growth must be continuous and rapid for good quality. Radish reaches market size in 21 to 28 days so crop can be on the market from June to the end of October. Chinese radish takes 50 to 90 days to mature. These become available to market in August and with storage can be marketed into November and December. Yields per hectare depend on the variety and the number of crops per year. Regular radish yields 10,000 to 15,000 kg per hectare. Chinese radish may yield 30,000 to 44,000 kg per hectare (Singh, 2001).

1.2 CLIMATIC REQUIREMENTS

Radish is a cool season crop that can withstand slightly high temperature. It thrives well within a temperature range of 16-24 °C (60-75 °F). It is best suited for the rainy season (Mortensen, 1994). Sandy and sandy loam soils are ideal for radish (Muthuswamy, 1984). Light soil encourages early roots development. The crop does well in a pH of 5.6-6.8 (Sinnadurai, 1992).

Radish is very tolerant to climatic condition. The vegetative stage of growth appears to be little affected by a wide range of temperature and day length variation, although cool conditions favor optimum growth (Parraga, 1995). White flesh cultivars will flower under short day length at low elevations but the red-fleshed cultivars normally require long days or elevations in the region of 1000 m for flower and seed production. The white-fleshed are more pungent than the red-fleshed cultivars (Saleem, *et al* 2010).

1.3 SOIL REQUIREMENTS OF RADISH

Sandy and sandy loam soils are ideal for radish. Light soil encourages early roots development (Muthuswamy, 1984). The crop does well in a pH of 5.6-6.8 (Sinnadurai, 1992). Light, well drained soils favor early root production but an adequate supply of organic materials is also necessary for good yields (Burns, 1997). Optimum pH is about 6.0-7.0. The crops can be grown under soils with low fertility or at very high temperature may have a very pungent smell flavor. These conditions include water shortage (Tindall, 1992).

1.4 PROBLEM STATEMENT

Despite the usefulness and nutritional value of Radish for human consumption, its production is still very low in Nigeria. The lack of awareness on the consumption and productivity of the crop due to low inherent fertility of the soil and inadequate plant

nutrients application especially the NPK fertilizer or wrong timing of their applications, use of low yielding varieties, improper spacing, pest and disease prevalence, soil and climatic condition, technical knowhow of crop production by farmers and above all market for the sales of the crop. Despite the importance of radish to human and Nigerian economy, very little work on the crop was done, while in some areas such as India and other Asian countries some studies have shown that intra row spacing and fertilizer application are important determinants of growth and yield of Radish production.

1.5 JUSTIFICATION FOR THE STUDY

Radish is one of the most important vegetable crops worldwide, which has a wide range of adaptability (Muthuswamy and Muthukrishnan, 1984). Radish can be eaten raw as salad, spices or cook as a dish. But inadequate soil fertility more especially Nitrogen, Potassium and Phosphorus can hinder the production of radish leading to low yields and total failure. The application of the appropriate or optimum rate of fertilizer can increase the soil fertility, thereby, increasing production of radish. Imbalanced use of fertilizers leads to loss of soil fertility, causes soil degradation and has adversely impacted agricultural productivity. Ecological balance and sustainable production is possible only through adoption of sustainable farming system by the use of organic and bio-fertilizers. This study was conducted to determine optimum rates of NPK fertilizer for efficient radish production and to increase awareness of radish production as an alternative economic crop to the farmers in the study area that could help them to reduce the poverty among them

1.6 OBJECTIVES OF THE STUDY

- i. To determine the effect of NPK fertilizer rates on the growth and yield of radish
- ii. To recommend the best intra row spacing for the growth and yield of radish
- iii. To determine the performance of radish crop in sudan savanna zone of Nigeria.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.1 EFFECT OF NPK FERTILIZER ON THE GROWTH AND YIELD RADISH

NPK fertilizer, generally, has its most profound influence on the vegetative development of crops. When supplied in adequate quantity NPK fertilizer ensures a healthy plant growth, which is manifested by the increased vigor, size and the deeper green colour of the foliage. The effect of N fertilizer on the general vigor of crops is as a result of its positive effects on cell division, cell elongation and cell expansion, synthesis of amino acids, enzymes and chlorophyll (Muhammad and Muhammad, 2002). Unfortunately, most tropical soils are deficient or low in recorded Nitrogen. Consequently most workers have recorded positive responses by most crops (including radish) to NPK fertilizer applications.

Muhammad and Muhammad. (2002) reported that carrot root yield significantly increased by different doses of Nitrogen and Potassium. The percent yield increase over control treatments due to different doses of Nitrogen and Potassium were 15.95%, 121.8% and 136.7% when 100, 150 and 200 kg N/ha were applied respectively.

Muneshwar *et al.* (2001) also reported that application of potassium at 196 kg/ha gave the best yield and quality carrot. Yield increase due to different treatments over control treatment as a result of interaction of Nitrogen and Potassium showed that 200

kg N and 250 kg K/ha increased the yield by 324% and the lowest (39%) was in 100 kg N and 0 kg K.

Noland (1998) noticed that the application of fertilizers at a dose of 60 N 60 P 60 K (kg ha^{-1}) improved the yield by 42.1% (7.6t ha^{-1}) and dose of 120 N 120 P 180 K (kg/ha) increased the yield by 71.15% (12.3 t/ha). Yield is a quantitative character, which results from the interactions of many components such as plant height, root diameter, length of fresh weight etc. Root yield was considered as the resultant variable, it was observed that root yield had a significant positive correlation with all the growth and yield components except leaf number.

Different doses of NPK fertilizer showed significant effect on radish root yield. The highest was recorded when crop was fertilized with 200Kg/ha and minimum in the control treatments (Huchmuth *et al.*, 1999).

The application of nitrogen had significant on cracking of radish root. Roots were highly cracked with increased levels of nitrogen (Jadhao *et al.*, 1999). Potassium also shows significant effect on cracking of roots. The roots were highly cracked when the crop was fertilized with 250kg NPK/ha and the lowest cracking was in the control treatment. The interaction between different doses of N, P and K had no significant effect on root cracking, but root cracking increases gradually with the increasing levels of N, P and K (Hassan *et al.*, 1992).

There are many factors responsible for decline in radish yield and its quality. Apart from other factors, nutrients played vital role in the production of radish crop and its application is one of the quickest and easiest ways in increasing yield per unit area (Saleem *et al.*, 2010). Among nutrients, N P and K are the major nutrients required by

the plants for their growth, development and yield (Singh *et al.*, 2003). Jadhao *et al.*, (1999) noted significant response of radish growth and yield to NPK fertilizer application at 80 and 120 kg/ha. Muthuswamy and Muthukrishnan (1984) observed a marked increase in fresh top weight and root diameter with 200 kg NPK/ha. Cabonco (1993) reported that radish plant supplied with 80 kg NPK/ha produced longer, bigger and heavier roots over all other treatments. Sounda *et al.* (1998) reported that NPK fertilizer significantly influenced the root length and girth, root fresh weight, length of leaves, number of leaves, weight of leaves per plant and number of marketable roots. The highest yield of marketable roots (503.73 g/ha) was obtained with the highest NPK fertilizer level (Saleem *et al.*, 2010). Hadge (1992) stated that NPK fertilizer up to 120 kg/ha increased the root yield. Pandey and Joshua (1996) reported that NPK at 80 kg/ha with ridge sowing gave maximum average yield (11.73 t/ha).

Ghanti *et al.* (1997) tried different NPK fertilizer levels, various irrigation treatments. They found that NPK significantly influenced radish yield, leaf and root length, root girth and number of marketable roots per hectare. The highest radish yield (369.40 g/ha) was obtained with 100 kg NPK fertilizer (Kakar *et al.*, 2001). (Hassan *et al.*, 1992) reported that increasing NPK fertilizer level up to 100 kg /ha resulted in longer leaves (64.83), greater number of leaves per plant (17.90), maximum single bulb weight (42.60 g) and bulb yield per plant (7.08 kg) and total bulb yield (6746.03 kg/ha) of garlic. Further, increase in NPK levels had no appreciable effect on the performance of garlic. Ali *et al.* (2003) reported that root yield increased progressively and significantly with increased application of NPK in Carrot. Pervez, *et al.* (2004) reported maximum plant height (83cm), root length (38.4cm), root diameter (4.5cm) and root

yield (16.6 kg) of radish with 200 kg NPK/ha at different plant spacing. Ali *et al.* (2003) obtained maximum number of leaves, plant height, root length, root diameter, fresh and dry weight of shoot, fresh and dry weight of root and root yield when 130 kg NPK/ha was applied in carrot.

2.2 EFFECTS OF INTRA-ROW SPACING ON GROWTH AND YIELD RADISH

One of the factors responsible for reduced growth and lower yield of vegetables in cultural practices are time of sowing and spacing (FAO, 2010). The scientific vegetable production reveals the significance and importance of sowing date and plant population to be used for raising vegetable crops in order to get higher production of good quality crops (Huchmuth *et al.*, 1999). FAO, (2010) reported an experiment in radish with inter-row spacing of 10 and 20 cm and intra-row spacing of 5 and 10 cm. Maximum plant height and yield was observed with spacing of 20 cm between row and 10cm between plants. The wider spacing of 45 X 30 cm showed the significant superiority over other spacing for all the growth characters (Barnes, 1979). This might be due to erect growing habit of radish crop and leaves are grown horizontally in later stages and hence in wider spacing due to the availability of more space, nutrient and light, the crop produce maximum leaf area, and more number of leaves per plant (Islam and Hassan, 1992). The larger intra-row spacing of 30cm increased the root yield and decreases the shoot resulting in a higher root-shoot ration (Sarkar *et al.*, 1989).

Radish planted at 20cm intra-row spacing produced significantly higher number of leaves per plant than radish planted at 5 and 10cm. As intra-row spacing increased from 5 to 20 cm, the number of leaves per plant increased from 9.5 to 11.94 at maturity stage (Khasay *et al.*, 2013). It is apparent that when intra-row spacing increases the

number of plants per unit area decreases; more mineral nutrients, light, moisture and space become available leading to vigorous growth, possible that increase in planting density resulted in reduction in number of leaves because of shortage of more minerals nutrient, light, moisture and space. Malik, *et al.* (1999), Akoun (2005), Ali *et al.* (2003), Huchmuth *et al.* (1999) reported that increase in planting density resulted in reduction in number of leaves. Ibrahim (1994) also reported that garlic planted at 15 and 20 cm intra-row spacing produced significantly higher number of leaves per plant than the 10cm intra-row spacing. Ibrahim (1994) and Kakar *et al.* (2002) also observed widely spaced garlic plant tend to grow more vegetative and bear more leaves per plant. Maximum plant height (42.10 cm) in radish plant having 20cm spacing and minimum radish plant height (20.08 cm) was observed. Ali *et al.* (2003) also found superior plant height at 25 cm intra-row spacing than at 15 cm intra-row spacing. The various intra-row spacing showed significant difference in terms of leaf diameter, leaf length and fresh weight of leaf (g) per plant, leaf dry weight, total root yield and marketable root yield. Among the intra-row spacing of radish the closest (5 cm) caused the lowest leaf diameter, leaf length, root diameter, fresh weight and dry weight of leaves and roots and significant different to both treatment (10 and 20 cm) Perez *et al.* (2004).

The increase in plant height, leaf number per plant, leaf length and dry matter production per plant of radish with increasing intra-row spacing's from 10 or 15 to 20 cm could probably be due to the fact that radish plants grown at wider intra-row spacing are less exposed to intra-specific competition for nutrient, moisture, light and space, therefore tend to grow vigorously. High plant population associated with narrow intra-

row spacing tends to exert pressure on scarce growth sources such as moisture, space, light and nutrient thereby leading to poor growth (Jadhao *et al.*, 1999).

2.3 SEED COLLECTION IN RADISH PRODUCTION

Seeds are produced either by “root-to-seed” or “seed-to-root method, the mature roots, called steckhings, are removed and planted by cutting the tops. Seed size and weight determines seed quality. With increased seed size, the field emergence increases (Pandita and Randhawa., 1992). Large seeds also give higher yield than smaller seeds (Sharma and Gulshanlal, 1990). Proper cultural practices, such as adequate spacing, irrigation, and plant protection measures, are to be followed for production of quality seed (Yousaf and Shafi, 1971). Radish is a cross-pollinated crop; therefore, bees and other insects bring about pollination. Thus, a minimum isolation distance of 1,600 m is maintained between cultivars. The off-type roots are rouged base on shape and colour (Pandita & Randhawa, 1992). The crop is harvested when pods turn brown and seeds near maturing. Dried pod are collected and threshed; seeds are removed, dried, cleaned and packed for storage (Sharma and Gulshanlal, 1990).

2.4 SEED STORAGE IN RADISH PRODUCTION

Radish is raised commercially through seeds, seed show orthodox storage behaviors’ and are capable of maintaining high viability, vigor and genetic stability on long-term conservation (Huchmuth *et al.*, 1999). Radish seed retain viability longer than other cruciferous seeds. The economic life of spring and winter radish is 9-12 years (Huchmuth *et al.*, 1999). Seed germination decreases to 50% after 7 years of storage under ambient conditions (Doijode, 1999). Prolonged seed storage increases the percentage of substandard produce and the risk of inversion by many diseases. Well

drained seeds stored for 9-12 years at 10^{-1} at 10^{-12} mille bar (mb) preserve high seed quality without loss of viability (Aminuddin, 1995). Hedge (1992) stored low moisture seed (4.2%) in plastic at -20°C for ten years. There was little change in moisture content, and initial germination (86%) remained unchanged. Likewise seed with 6% moisture packed in polythene bag and laminated aluminum foil pouches and stored at 5 and -20°C maintained viability for 15 years. These stored seeds when sown in the field did not show any morphological abnormalities for root and shoot characteristics (Aminuddin, 1995). 10-15 kg/ha of radish seeds can be used for sowing.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 EXPERIMENTAL SITES

Field experiment was conducted during the rainy season of 2013 at the Kano State Institute of Horticulture (KIHORT) Bagauda, Kano and Federal College of Horticulture Research and Training Farm, Dadinkowa. The study area (Bagauda) lies between latitudes $8^{\circ} 41' N$ and $9^{\circ} 30'$ and between longitudes $9^{\circ} 30' E$ and $12^{\circ} 30' E$ with a mean annual rainfall range of 787 mm to 960mm, a mean annual minimum temperature range of $20^{\circ} C$ to $24^{\circ} C$ and a mean maximum temperature range of $21^{\circ} C$ to $39^{\circ} C$ (KNARDA, 2003), In the sudan savannah ecological zone. The study area (Dadinkowa) lies between the latitudes $11^{\circ}.23'$ and $10^{\circ} 18' N$ and longitudes $11^{\circ} 31' E$ with a mean annual rainfall 1029.2 mm, a mean annual minimum temperature of $25^{\circ} C$ and a mean maximum temperature of $32^{\circ} C$ (UBRBDA 2013), in the Northern guinea savannah ecological zone.

3.1.1 Meteorological data

Data on weather condition such as rainfall, temperature and relative humidity covering the period of the study was collected from National Horticultural Research Institute Bagauda sub-station, Kano State, and Federal College of Horticultural Technology Dadinkowa, Gombe State. (Appendix 1)

3.2 TREATMENTS AND EXPERIMENTAL DESIGN

The experiment comprised of 18 treatments with six levels of NPK fertilizer 15-15-15 (0, 40, 80, 120, 160 and 200 kg NPK/ha), and three intra-row spacing (10, 15, and 20 cm). The experiment was laid out in a randomized complete block design. Treatments were factorially combine and assigned to plots and replicated three times.

3.3 LAND PREPARATION

The experimental plots were properly ploughed and harrowed twice to obtain fine tilth. Ridges were done and the size of each plot was 3 x 2 m (6 m²). One meter was left between plots and replications.

3.4 CULTURAL PRACTICES

3.4.1 Seed source

Certified seed of Ural variety from National Horticultural Research Institute Bagauda sub-station, Kano state was sourced from healthy and vigorous plants.

3.4.2 Sowing

Two seeds per hole was sowed on ridges of 75 cm apart at the appropriate intra row spacing as per the varied treatments (10, 15 and 20 cm) while supplying was done at 2 weeks after sowing (WAS).

3.4.3 Fertilizer application

NPK fertilizer 15-15-15 was applied as per the varied treatments (40, 80, 120, 160 and 200 kg/ha) at 2 WAS.

3.4.4 Weed Control

While the young seedlings were developing they were weeded manually three times to minimize weed competition in the plot at 3, 6 and 9 WAS.

3.4.5 Pest and Disease Control

No incidence of pest and diseases was recorded throughout the period of experimentation in all the locations.

3.4.6 Soil Sample

Soil samples from both the locations (Kano and Gombe state) were collected randomly at 0-30 cm depths using tubular auger. The samples were mixed thoroughly in a container after which a representative sample was scooped out from the bulk and analyzed to determine the initial soil fertility levels. The pH was measured in 0.01M CaCl₂ using a cyber scan 20 pH meter. The soil organic carbon was determined through wet oxidation method (Walkely and Black., 1965). The total nitrogen was determined by micro kjeldahl digestion distillation method (Bremmer, 1965). While available phosphorous was determined by Bray 1 method (Bray and Kurtz, 1945). The exchangeable cat ions (Ca, Mg, K and Na) were determined.

3.5 DATA COLLECTION

The crop was monitored from planting to harvest and parameters on growth, yield and yield components were assessed at two weeks interval. Five plants were selected randomly from each plot and tagged.

3.6 OBSERVATIONS

3.6.1 Plant Height (cm)

Plant height was measured at 4, 6, 8 and 10 WAS from ground level to the tip of the apex of the highest leaf in five tagged plants. Average plant height was measured with a meter rule and then expressed in cm. Mean values for each plot was recorded.

3.6.2 Leaf Length (cm)

Leaf length was measured from base to the tip of the leaves at 2, 4, 6, 8, and 10 WAS, with a meter rule and the leaf length was expressed in cm.

3.6.3 Number of Leaves per Plant

The numbers of leaves in five (5) randomly tagged plants in each plot were counted and the average value was worked out and recorded.

3.6.4 Fresh Weight of Leaves (g/plant)

The fresh weight of leaves was taken from each five plants in each replication and the average fresh weight of leaves determined and expressed in grams.

3.6.5 Dry Weight of Leaves (g/plant)

The leaves of the five tagged plants were collected and dried in oven at 80 °c for 72 hours and their average dry weight was then expressed in grams per plant.

3.6.6 Leaf area/ Plant (cm²)

The leaf area per plant was determined by measuring length and breadth; the product was then multiplied by 0.74 as described by Sharma and Sing, (1947) and mean values were recorded.

3.6.7 Root Length (cm)

The length of root was measured with meter rule in five randomly selected plants at 4, 6, 8 and 10 WAS from the base of the root to top of the root and average root length was expressed in cm.

3.6.8 Root Diameter (cm)

The circumference of five roots randomly selected at 2, 4, 6, 8 and 10 WAS was measured with varneir caliper (150 mm) from the basal portion of the root with the help of thread and scale and the average root diameter was expressed in cm.

3.6.9 Fresh Weight of Root (g/plant)

The fresh weight of five roots selected randomly after harvest were recorded and the average fresh weight of root was expressed in grams/plant. Using Radwag wagi electronize model: WTB 200

3.6.10 Dry Weight of Root (g)

The roots from five randomly selected plants in each replication were dried in oven at 800 C for 72 hours until a constant weight was achieved and their dry weights recorded. The average dry weight of root was expressed in grams/plant.

3.6.11 Yield (t/ha¹)

Total roots yield was computed from the yield of plot and expressed in tones per hectare.

3.6.12 Number of Days Attains Edible Size

The number of days from planting to maturity level was counted and recorded.

3.6.13 Data Analysis

Data collected was subjected to analysis of variance (ANOVA), using Genstat 16th edition. Where means were found to be significantly different, they were separated at 5% level of probability using Turkey's. HSD Test.

CHAPTER FOUR

RESULTS

4.1 SOIL ANALYSIS

The results of the soil analysis of the experimental sites (Kano and Gombe) in the rainy season indicated that the soils were sandy loam in texture at all the locations. The soil at Bagauda and Dadinkowa had pH (5.9 and 6.5) which is neutral; the soil had the medium organic carbon of (0.692 and 0.638%). Total nitrogen content of Bagauda and Dadinkowa were (0.062 and 0.49 gkg⁻¹) and is considered low. The available phosphorus content of the study area was low (8.44 and 6.32 mgkg⁻¹). The exchangeable cations [ca, mg] were medium at both the locations. Whereas Potassium was medium at Bagauda and low in Dadinkowa Sodium (Na) content of both locations was also low. The CEC of the soil analysis from both locations medium and range between 9.02 coml⁺kg⁻¹ for Bagauda and 9.47 coml⁺kg⁻¹ for Dadinkowa soil.

4.1.2 Plant height (cm)

The effects of NPK fertilizer application rates and intra-row spacing on plant height of Radish at both locations are presented in Table 2. Application of NPK fertilizer significantly influences plant height throughout the sampling periods. At Bagauda the application of 120 and 160 kg NPK/ha were statistically similar but significantly higher than all other levels at 2 WAS. However at 10 WAS the increase was only up to 80 kg/ha. At Dadinkowa the increase due to NPK application was up to 80 kg/ha at 4, 6 and 10 WAS.

Intra-row spacing also affected the plant height significantly. Throughout the sampling periods and at both locations there was a linear increase in plant height with each increase in intra-row spacing.

The interaction effects of NPK fertilizer application rates and intra-rows pacing were not significant all through the sampling period with the exception of Bagauda at 8 weeks after sowing (WAS). The interaction effects of NPK fertilizer application rates on plant height of radish plant at Bagauda are presented in table 3. The result shows that the interaction between 160kg NPK/ha and 20cm intra-row spacing produced the highest plant height. The interaction between the control and 10cm intra-row spacing produced the lowest plant height.

Table 1: Physico-chemical properties of soils at the experimental sites Bagauda and Dadinkowa during 2013 rainy season

Soil property	Bagauda	Dadinkowa
	0-30cm	0-30
Particle size distribution 9(%)		
Sand	72.96	79
Silt	16	11

Clay	11.04	10
Textural class	Sandy loam	Sandy Loam

Chemical Properties

pH	5.9	6.5
Organic Carbon (gkg^{-1})	0.692	0.638
Total Nitrogen (gkg^{-1})	0.062	0.49
Available P (mg kg^{-1})	8.44	6.32

Exchangeable Bases (cmol kg^{-1})

Ca	3.12	2.63
Mg	1.01	1.66
K	0.61	0.29
Na	0.32	0.16
CEC	9.02	9.47

Table 2: Effects of NPK fertilizer application rates and intra-row spacing on Plant height of radish at 2, 4, 6, 8 and 10 WAS Bagauda and Dadinkowa during 2013 rainy season

Treatment	Bagauda (WAS)					Dadinkowa (WAS)				
	2	4	6	8	10	2	4	6	8	10
NPK (Kgha ⁻¹)										
0	4.33b	7.47d	11.74c	14.52d	17.26d	4.12c	7.32d	11.36c	13.81c	17.23c
40	4.90b	12.43c	21.87ab	27.67c	30.40c	4.61b	10.92c	15.90b	22.44b	25.86b
80	5.02ab	16.67a	22.07ab	28.19bc	39.67a	5.06b	16.69a	21.43a	26.73a	37.62a
120	5.78a	13.64bc	19.47b	27.22c	37.00ab	5.67a	10.00bc	19.58ab	27.46a	34.98a
160	4.92ab	16.42ab	23.97a	31.36a	34.39b	4.97b	14.97a	22.97a	30.28a	34.23a
200	4.70b	15.04abc	21.03ab	29.82ab	35.28b	4.61bc	14.96ab	21.86a	28.90a	35.40a
SED	0.281	0.920	1.234	0.650	1.022	0.193	0.851	1.361	1.399	1.470
Spacing (cm)										
10	4.57b	11.99b	17.26b	23.36c	31.00b	4.53b	11.19b	15.89b	21.94b	28.56b
15	4.89ab	13.30b	20.47a	27.14b	31.67b	4.85a	12.65b	19.53a	25.36a	30.86ab
20	5.36a	15.54a	22.34a	28.84a	34.32a	5.40a	15.09a	21.12a	27.51a	33.25a
SED	0.204	0.169	0.332	0.460	0.723	0.136	0.602	0.962	0.989	1.039
Interaction										
FxS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS

Means followed by same letter within a set of interaction are not statistically different at 5% level of significance using Tukey's (HDS).

TABLE 3: Interaction of fertilizer application rates and intra-row spacing on plant height of radish plant interaction at Bagauda at 8 WAS

Treatment	Intra-row-spacing (cm)		
	10	15	20
NPK (Kgha ⁻¹)			
0	13.03f	15.10f	15.43f
40	26.00cd	26.50bcd	30.50ab
80	22.77de	29.73abc	32.07a
120	20.50e	29.77abc	31.40a
160	29.93abc	31.70a	32.13a
200	27.73abc	30.03abc	31.50a
SED 1.126			

Means followed by the same letter in a set of interaction are not statistically difference at 5%level of probably using Tukey's (HDS).

4.1.3 Number of leaves per plant

The effects of NPK fertilizer application rates and intra-row spacing on number of leaves per plant of radish at Bagauda and Dadinkowa are presented in (Table 4). NPK fertilizer application shows no significant effect at 2 WAS at Bagauda but highly significant ($P<0.05$) at 4, 6, 8 and 10 WAS. Application of 120kg NPK/ha produced significant higher number of leaves per plant than the rest of the treatments at 4, 6 and 8 WAS, but statistically similar to 160 and 200kg NPK/ha at 8 WAS. However, at Dadinkowa it was observed that NPK application rates had no significant effect on the number of leaves per plant at 2 WAS but significant at 4, 6, 8 and 10 WAS. Similarly 120kg NPK/ha produced significantly higher number of leaves per plant than the other treatments at 8 WAS but statistically at par with 80, 160 and 200kg NPK/ha.

Intra-row spacing on number of leaves per plant had affected the plant significantly throughout the sampling period at Bagauda, with 20cm being significantly higher than 15 and 10cm spacings. At Dadinkowa the treatment was similar with 20cm intra-row spacing giving the highest number of leaves.

The interaction of NPK fertilizer application rates and intra-row spacing on number of leaves per plant of radish at Bagauda at 2 WAS is presented in Table 5. The result indicated that the interaction between NPK fertilizer application rates and intra-row spacing was significant. Application of 40kg NPK/ha and 20cm intra-row spacing gave the highest number of leaves while the least was obtained with NPK at 40-80kg/ha and 10cm intra-row spacing.

Interaction between NPK fertilizer application rates and intra-row spacing on number of leaves per plant at 4 WAS at Bagauda is presented in Table 6. The result revealed that the interaction between 120kg NPK/ha and 20cm intra-row spacing

produced the highest number of leaves while the interaction between control and 10cm intra-row spacing produced the least.

Interaction effect of NPK fertilizer application rates and intra-row spacing on the number of leaves per plant of radish at 6 WAS at Bagauda is presented in Table 7. The result indicated that the interaction between 120kg NPK/ha and 20cm intra-row spacing produced highest number of leaves, the interaction between control and 40kg NPK/ha together with 10cm intra-row spacing produced the lowest number of leaves than the other interactions.

The interaction effect of NPK fertilizer application rates and intra-row spacing on number of leaves per plant of radish at 8 WAS at Bagauda are presented in Table 8. Application of 160kg NPK/ha and 20cm intra-row spacing gave significantly higher number of leaves than all the other interactions.

Table 4: Effects of NPK fertilizer application rates and intra-row spacing on number leaves of radish plant at Bagauda and Dadinkowa during 2013 rainy season

Treatment	Bagauda (WAS)					Dadinkowa (WAS)				
	2	4	6	8	10	2	4	6	8	10
NPK (Kgha ⁻¹)										
0	3.67b	6.26e	10.67e	12.11b	6.67c	3.52c	6.01e	10.11c	11.46b	6.61d
40	3.92b	9.44d	12.22d	12.91b	9.44bc	3.78bc	8.91d	11.66c	11.99b	9.37c
80	3.11b	13.11b	17.78bc	24.67a	17.00a	3.67bc	13.22ab	17.58ab	24.52a	16.89a
120	4.91a	15.00a	22.00a	28.00a	19.78a	4.78ab	13.79a	19.62a	24.91a	17.59a
160	5.00a	12.66c	19.11b	26.56a	12.67b	5.00a	12.26b	18.44ab	24.22a	12.60b
200	5.19a	11.66c	17.67c	24.67a	11.11b	4.67abc	10.66c	16.63b	22.69a	10.89bc
SED	0.278	0.240	0.469	1.231	1.070	0.385	0.480	0.811	1.963	0.817
Spacing (cm)										
10	3.10c	10.13c	14.61c	18.94b	10.83b	3.06b	9.37c	13.68c	17.58b	10.12c
15	4.72b	11.16b	16.56b	20.28b	13.22a	4.53a	10.69b	15.45b	19.08b	12.61b
20	5.22a	12.77a	18.56a	24.83a	14.28a	5.12a	12.37a	17.89a	23.23a	14.24a
SED	0.196	0.169	0.332	1.001	0.757	0.272	0.340	0.378	1.388	0.577
Interaction										
FxS	*	*	*	*	NS	NS	NS	NS	NS	NS

Means followed by same letter within a set of interaction are not statistically different at 5% level of significance using Tukey's (HDS).

Table 5: Interactions of NPK fertilizer application rates and intra-row spacing on number of leaves of radish plant at Bagauda at 2 WAS

Treatment	Intra-row-spacing		
	10	15	20
NPK (Kgha ⁻¹)			
0	2.67de	4.33bcd	4.00cd
40	2.00e	4.00cd	6.33a
80	2.00e	4.00cd	4.00cd
120	5.00abc	5.00abc	5.00abc
160	4.00cd	5.00abc	6.00ab
200	3.00de	6.00ab	6.00ab
SED 0.4821			

Means followed by the same letter in a set of interaction are not statistically difference at 5%level of probably using Tukey's (HDS).

Table 6: Interaction of NPK fertilizer application rates and intra-row spacing on number of leaves of radish plant at Bagauda at 4 WAS

Treatment	Intra-row-spacing		
	10	15	20
NPK (Kgha ⁻¹)			
0	5.80i	6.00i	7.00hi
40	8.00h	9.66g	10.67efg
80	10.33fg	13.33cd	15.66ab
120	14.00c	14.00c	17.00a
160	11.66ef	12.00de	14.33bc
200	11.00efg	12.00de	12.00de
SED 0.4157			

Means followed by the same letter in a set of interaction are not statistically difference at 5%level of probably using Tukey's (HDS).

Table 7: Interaction of NPK fertilizer application rates and intra-row spacing on number of leaves of radish plant at Bagauda at 6 WAS

Treatment	Intra-row-spacing		
	10	15	20
NPK (Kgha ⁻¹)			
0	9.67f	10.33.f	12.00ef
40	10.21f	12.43ef	14.67de
80	14.33de	19.00bc	20.01ab
120	21.39ab	22.76a	22.83a
160	16.67cd	19.21bc	21.52ab
200	16.20cd	16.40cd	21.14ab
SED 0.812			

Means followed by the same letter in a set of interaction are not statistically difference at 5%level of probably using Tukey's (HDS).

Table 8: Interaction of NPK fertilizer application rates and intra-row spacing on number of leaves of radish plant at Bagauda at 8 WAS

Treatment	Intra-row-spacing		
	10	15	20
NPK (Kgha ⁻¹)			
0	10.33e	11.00de	15.00cde
40	10.33e	13.00de	13.00de
80	22.33bcd	23.67bc	28.00b
120	27.80b	28.00b	29.00b
160	19.67bcd	21.00bcd	39.00a
200	24.00bc	25.00b	25.00b
SED 0.4157			

Means followed by the same letter in a set of interaction are not statistically difference at 5%level of probably using Tukey's (HDS).

4.1.4 Leaf area per plant

The leaf area response of radish plant to NPK fertilizer application rates and intra-row spacing is presented on (Table 9). At all the sampling periods and in both locations significant increase in leaf area were observed with each increase in NPK fertilizer application rates up to 80kg NPK/ha except at 4 WAS, where 120kg NPK/ha gave the highest leaf area, whereas in Dadinkowa 120kg NPK/ha gave the highest leaf area at 4 and 6 WAS. Significant increase in leaf area was observed with increase in intra-row spacing at all the sampling periods in both locations. In most of the cases 20cm intra-row spacing gave the highest leaf area.

The interaction of NPK fertilizer application rates and intra-row spacing on leaf area per plant of radish at 2 WAS in Bagauda is presented in Table 10. 200kg NPK/ha and 10cm intra-row spacing resulted in the highest leaf area, whereas the control and 20cm intra-row spacing produced the least leaf area.

Interaction of NPK fertilizer application rates and intra-row spacing on leaf area per plant of radish at 4 WAS in Bagauda is presented in Table 11. The result shows that 80kg NPK/ha and 20cm intra-row spacing produced highest leaf area, while the control and 10cm intra-row spacing produced the least leaf area.

Interaction of NPK fertilizer application rates and intra-row spacing on leaf area per plant of radish at 8 WAS in Bagauda is presented in Table 12. The result revealed that 200kg NPK/ha and 10cm intra-row spacing produced the highest leaf area, while 0kg NPK/ha and 10cm intra-row spacing produced the least leaf area.

The interaction of NPK fertilizer application rates and intra-row spacing on leaf area per plant of radish at 10 WAS in Bagauda is presented in Table 13. The result

indicates that 160kg NPK/ha and 20cm produced the highest leaf area, and 120kg NPK/ha and 20cm intra-row spacing had the least leaf area.

The Dadinkowa location interaction between NPK fertilizer application rates and intra-row spacing at 10 WAS is presented in Table14. The result of the interaction revealed almost the same treatment as the one in 10 WAS with respect to highest and lowest leaf area per plant.

Table 9: Effects of NPK fertilizer application rates and intra-row spacing on leaf area of radish plant at Bagauda and Dadinkowa during 2013 rainy season

Treatment	Bagauda (WAS)					Dadinkowa (WAS)				
	2	4	6	8	10	2	4	6	8	10
NPK (Kgha ⁻¹)										
0	5.38c	9.84d	30.6d	50.5bc	41.5bc	5.61c	9.61c	28.84c	49.98b	40.53c
40	11.79b	37.31c	54.9c	62.6ab	57.4ab	9.37bc	34.25b	63.99b	83.09a	61.51ab
80	12.67ab	51.96a	74.3ab	70.0a	60.7a	12.56ab	55.01a	85.95a	70.03ab	61.11ab
120	14.69a	43.58bc	62.4bc	73.8a	37.8c	14.35a	49.60a	74.77ab	73.12ab	41.49bc
160	12.24b	43.25bc	67.6bc	64.8a	67.6a	11.63ab	46.76ab	76.79ab	63.44ab	66.44a
200	14.68a	49.66ab	92.2a	50.1c	63.7a	10.86ab	54.08a	93.54a	50.45b	64.41a
SED	0.780	2.432	6.35	4.90	5.65	1.469	4.236	6.853	8.593	6.658
Spacing (cm)										
10	11.47b	32.65c	52.9b	54.7b	51.4b	9.48b	31.70c	52.62c	55.04b	54.34ab
15	11.30b	38.35b	67.7a	62.6a	49.8b	10.16ab	41.06b	71.07b	64.33ab	50.24b
20	12.97a	46.80a	70.4a	68.6a	63.3a	12.55a	51.90a	88.75a	75.69a	63.16a
SED	0.551	1.719	4.49	2.89	4.00	1.039	2.995	4.846	6.076	4.708
Interaction										
FxS	*	*	NS	*	*	NS	NS	NS	NS	*

Means followed by same letter within a set of interaction are not statistically different at 5% level of significance using Tukey's (HDS).

Table 10: Interaction of NPK fertilizer application rates and intra-row spacing on leaf area of radish plant at Bagauda at 2 WAS

Treatment	Intra-row-spacing		
	10	15	20
NPK (Kgha ⁻¹)			
0	2.24c	7.73ef	6.17fg
40	8.70ef	11.43cde	15.26a-d
80	8.26ef	13.88bcd	15.88abc
120	14.96a-d	17.38ab	11.74cde
160	15.5a-d	11.46cde	11.12def
200	19.48a	5.92fg	18.65ad
SED 1.350			

Means followed by the same letter in a set of interaction are not statistically difference at 5%level of probably using Tukey's (HDS). WAT: WAP

Table 11: Interaction of NPK fertilizer application rates and intra-row spacing on leaf area of radish plant at Bagauda at 4 WAS

Treatment	Intra-row-spacing		
	10	15	20
NPK (Kgha ⁻¹)			
0	4.6e	59.1a-e	51.7cde
40	60.8a-e	53.7cde	73.3abc
80	40.0e	82.3ab	85.8a
120	67.3a-e	70.0a-d	84.2a
160	61.2a-e	67.0a-e	66.2a-e
200	56.4b-e	43.2de	50.5cde
SED 7.08			

Means followed by the same letter in a set of interaction are not statistically difference at 5%level of probably using Tukey's (HDS).

Table 12: Interaction of NPK fertilizer application rates and intra-row spacing on leaf area of radish plant at Bagauda at 8 WAS

Treatment	Intra-row-spacing		
	10	15	20
NPK (Kgha ⁻¹)			
0	2.24g	7.73ef	6.17fg
40	8.70ef	11.43cde	15.26a-d
80	8.26ef	13.88bcd	15.88abc
120	14.96a-d	17.38ab	11.74cde
160	15.5a-d	11.46cde	11.12def
200	19.48a	5.92fg	18.65ad
SED 1.350			

Means followed by the same letter in a set of interaction are not statistically difference at 5%level of probably using Tukey's (HDS).

Table 13: Interaction of NPK fertilizer application rates and intra-row spacing on leaf area of radish plant at Bagauda at 10 WAP

Treatment	Intra-row-spacing		
	10	15	20
NPK (Kgha ⁻¹)			
0	32.7de	37.7de	54.3cde
40	35.9de	43.4de	92.7ab
80	60.8b-e	51.1de	70.1a-d
120	37.5de	46.9de	29.2e
160	99.1a	60.2b-e	43.5de
200	42.2de	59.3b-e	89.6abc
SED 9.79			

Means followed by the same letter in a set of interaction are not statistically difference at 5%level of probably using Tukey's (HDS).

Table 14: Interaction of NPK fertilizer application rates and intra-row spacing on leaf area of radish plant at Dadinkowa at 10 WAS

Treatment	Intra-row-spacing		
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	10	15	20
NPK (Kgha ⁻¹)			
0	32.69d	37.80d	51.11bcd
40	54.93a-d	45.19cd	80.40abc
80	60.71a-d	51.02bcd	71.59a-d
120	37.79d	47.96bcd	38.72d
160	97.21a	59.00a-d	43.10cd
200	42.71cd	60.48a-d	90.04ab
SED 11.532			

Means followed by the same letter in a set of interaction are not statistically difference at 5%level of probably using Tukey's (HDS).

4.1.5 Root diameter per plant (cm).

The effects of NPK fertilizer application rates and intra-row spacing on radish root diameter are presented in Table 15. At Bagauda and Dadinkowa (10 WAS) increase in NPK fertilizer application rates from the control to 120kg NPK/ha significantly

increased root diameter, a further increase to 200kg NPK/ha significantly reduced this parameter.

Each increase in intra-row spacing from 10-20cm led to a significant increase in root diameter at both locations.

Interaction between NPK fertilizer application rates and intra-row spacing on root diameter of radish plant was significant at 4 WAS at Bagauda is presented in Table 16. It was observed that the interaction between 120kg NPK/ha fertilizer and intra-row spacing of 20cm produced the highest root diameter, whereas, control and 10cm intra-row spacing produced the least root diameter.

Interaction of NPK fertilizer application rates and intra-row spacing of radish plant at 6 WAS at Bagauda is presented in Table 17. The result indicates that the interaction between 80kg NPK/ha and 20cm intra-row spacing produced highest root diameter while control and 10cm intra-row spacing produced the least root diameter.

Interaction effects of NPK fertilizer application rates and intra-row spacing of root diameter of radish plant at 6 WAS at Dadinkowa is presented in Table 18. The result revealed that the interaction between 80kg NPK/ha and 20cm intra-row spacing produced highest root diameter, while control and 10cm intra-row spacing produced the least root diameter.

Table 15: Effect of NPK fertilizer application rates and intra-row spacing on root diameter of radish plant at Bagauda and Dadinkowa during 2013 rainy season

Treatment	Bagauda (WAS)				Dadinkowa (WAS)			
	2	4	6	8	2	4	6	8
NPK (Kgha ⁻¹)								
0	3.29c	7.37c	11.09b	14.33e	3.16c	6.30c	10.58d	14.33e
40	3.23c	7.80c	12.69b	17.68d	4.09c	7.61c	13.16c	17.68d
80	8.06b	20.54a	24.89a	29.38bc	8.30b	21.54a	25.00ab	26.38bc
120	12.61a	18.12b	25.04a	34.24a	12.97a	18.19b	26.04a	34.26a
160	12.76a	19.08ab	23.63a	27.60c	12.99a	19.01b	23.86b	27.64c
200	11.83a	18.02b	26.58a	32.24ab	12.31a	19.09b	25.01ab	32.22ab
SED	0.364	0.524	1.153	0.998	0.425	0.524	0.695	0.961
Spacing (cm)								
10	7.30c	12.92c	18.33b	23.02c	7.55c	12.12c	18.58c	23.61c
15	8.33b	14.17b	20.92a	26.09b	8.68b	14.91b	20.74b	26.07b
20	10.26a	17.84a	22.71a	28.65a	10.67a	17.99a	22.80a	28.65a
SED	0.257	0.371	0.815	0.706	0.300	0.371	0.491	0.756
Interaction								
FxS	NS	*	*	NS	NS	NS	*	NS

Means followed by same letter within a set of interaction are not statistically different at 5% level of significance using Tukey's (HDS).

Table 16: Interaction of NPK fertilizer application rates and intra-row spacing on root diameter of radish plant at Bagauda at 4 WAS

Treatment	Intra-row-spacing		
	10	15	20
NPK (Kgha ⁻¹)			
0	2.30g	2.87g	4.70efg
40	2.70g	3.20g	3.80fg
80	5.77ef	6.57e	11.83a-d
120	10.83cd	12.80abc	14.20a
160	11.97a-d	12.83abc	13.47ab
200	10.23d	11.70bcd	13.57ab
SED 0.630			

Means followed by the same letter in a set of interaction are not statistically difference at 5%level of probably using Tukey's (HDS).

Table 17: Interaction of NPK fertilizer application rates and intra-row spacing on root diameter of radish plant at Bagauda at 6 WAS

Treatment	Intra-row-spacing		
	10	15	20
NPK (Kgha ⁻¹)			
0	5.63g	6.77fg	9.70ef
40	6.80fg	7.47fg	9.13f
80	17.90d	19.23bcd	24.50a
120	13.00e	18.97bcd	22.40ab
160	17.27d	18.53cd	21.43abc
200	16.90d	17.27d	19.90bcd
SED 0.908			

Means followed by the same letter in a set of interaction are not statistically difference at 5%level of probably using Tukey's (HDS).

Table 18: Interaction of NPK fertilizer application rates and intra-row spacing on root diameter of radish plant at Dadinkowa at 6 WAS

Treatment	Intra-row-spacing		
	10	15	20
NPK (Kgha ⁻¹)			
0	5.63g	6.77fg	9.70ef
40	6.80fg	7.47fg	9.13f
80	17.90d	19.23bcd	24.50a
120	13.00e	18.97bcd	22.40ab
160	17.27d	18.53cd	21.43abc
200	16.90d	17.27d	19.90bcd
SED 0.908			

Means followed by the same letter in a set of interaction are not statistically difference at 5%level of probably using Tukey's (HDS).

4.1.6 Root length per plant (cm)

The effects of NPK fertilizer application rates and intra-row spacing on root length of radish plant are presented in Table 19. Response of root length of radish plant to NPK fertilizer shows significant effects on root length at all the sampling period at both locations. The rates of 200kg NPK/ha and 20cm intra-row spacing produced the higher

root length of radish plant at both locations at 2 WAS. At Bagauda the increase in root length was up to 80kg NPK/ha in most of the cases and the treatment was true for Dadinkowa.

The effect of intra-row spacing was also significant and 20cm intra-row spacing was significantly higher than the other spacing followed by 15 and 10cm in that order. The treatment was true for both locations except at 4 WAS at Dadinkowa. The interaction was not significant.

4.1.7 Number days to attain edible size.

The effects of NPK fertilizer and intra-row spacing on number of days to attain edible size of radish plant are shown in Table 20. Result obtained showed that 200kg NPK/ha fertilizer rates at Bagauda attain edible size earlier than the rest of the treatments. In Dadinkowa 160kg NPK/ha fertilizer application rates attain edible size earlier. In both locations the result revealed that number of days to edible size was decreasing as the fertilizer rates were increasing. Intra-row spacing indicates no significant difference at Dadinkowa. However, at Bagauda 10cm intra-row spacing had lower number of days to attain edible size than 20cm intra-row spacing but was statistically similar to 15cm spacing.

4.1.8 Root Yield of Radish (t/ha)

The effect of NPK fertilizer application rates and intra-row spacing on root yield of radish plant is presented in Table 21. The results obtained shows that NPK fertilizer application rates had significant effects on root yield of radish. Application of 200kg NPK/ha had significantly higher yield in both locations but was at par with 120 and 80kg NPK/ha.

Intra-row spacing significantly affected root yield of radish. Thus planting of radish at 20cm intra-row spacing was observed to produce significantly higher root yield of radish when compared with planting at 10cm intra-row spacing but was statistically similar to 15cm intra-row spacing in both locations.

Table 19: Effects of NPK fertilizer application rates and intra-row spacing on Root Length of Radish plant at Bagauda and Dadinkowa during 2013 rainy season

Treatment	Bagauda (WAS)					Dadinkowa (WAS)				
	2	4	6	8	10	2	4	6	8	10
NPK (Kgha ⁻¹)										
0	2.02b	3.11c	5.23d	7.10d	9.51e	2.11bc	3.19b	5.11d	7.10d	9.51c
40	2.35ab	4.06c	8.21c	10.30c	16.28d	2.40abc	4.14b	7.92c	10.12c	15.48b
80	2.32ab	8.94a	11.16ab	10.28b	23.27a	2.58ab	8.88a	11.16ab	14.76ab	26.02a
120	1.80b	6.20b	9.58bc	13.08bc	20.02b	1.95c	7.24a	9.46bc	13.08b	25.23a
160	2.19b	7.70ab	12.21a	13.88b	17.31cd	2.27bc	7.92a	12.01a	13.51b	22.63a
200	2.64a	6.74b	9.92abc	16.81a	19.17bc	2.94a	6.74a	9.40abc	16.91a	22.82a
SED	0.2111	0.513	0.735	0.763	0.659	0.1876	0.712	0.711	0.728	1.333
Spacing (cm)										
10	1.71c	4.79c	7.11c	10.52c	15.20c	1.878c	5.13b	7.11c	10.67c	18.04c
15	2.23b	5.94b	9.43b	12.26b	17.12b	2.378b	6.17b	9.43b	12.26b	20.17b
20	2.82a	7.64a	11.46a	14.98a	20.46a	2.878a	7.77a	11.46a	14.98a	22.64a
SED	0.149	0.363	0.520	1.501	0.466	0.132	0.504	0.520	05.15	0.942
Interaction										
FxS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by same letter within a set of interaction are not statistically different at 5% level of significance using Tukey's (HDS)

Table 20: Effects of NPK fertilizer application rates and intra-row spacing on total number of days attain edible size of radish plant at Bagauda and Dadinkowa during 2013 rainy season

Treatment	Bagauda	Dadinkowa
NPK (Kgha ⁻¹)		
0	68.11a	66.87a
40	60.43b	60.21ab
80	42.12c	55.19b
120	40.09c	53.60b
160	38.93c	41.82c
200	39.29c	38.63c
SED	1.580	21.98
Spacing (cm)		
10	50.27a	53.67a
15	47.76ab	52.98
20	46.46b	51.51
SED	1.117	1.554
Interaction		
FxS	NS	NS

Means followed by same letter within a set of interaction are not statistically different at 5% level of significance using Tukey's

Table 21: Effects of NPK fertilizer application rates and intra-row spacing on yield of radish plant at Bagauda and Dadinkowa during 2013 rainy season

Treatments	Bagauda	Dadinkowa
NPK (Kgha ⁻¹)		
0	4.15b	4.21b
40	6.08ab	6.29b
80	8.44a	8.48a
120	7.84a	8.05a
160	7.08ab	7.15b
200	8.83a	8.54a
SED	1.044	1.097
Spacing (cm)		
10	5.41b	5.45b
15	7.55a	7.63a
20	8.26a	8.27a
SED	0.738	0.776
Interaction		
FxS	NS	NS

Means followed by same letter within a set of interaction are not statistically different at 5% level of significance using Tukey's (HDS)

4.1.9 Fresh weight of root per plant (g)

Effect of NPK fertilizer and intra-row spacing on fresh weight of root per plant of radish is shown in Table 22. It was revealed that 120kg NPK/ha produced

higher fresh weight of root at Bagauda and Dadinkowa, and it was significantly higher than all the other treatments.

Intra-row spacing significantly affected fresh weight of root of radish plant. Thus planting of radish at 20cm intra-row spacing was observed to produce significantly higher fresh weight of root of radish than 15cm intra-row spacing which was also significantly higher than 10cm spacing.

4.1.10 Fresh weight of leaves per plant (g)

Effects of NPK fertilizer application rates and intra-row spacing on fresh weight of leaves per plant of radish are shown in Table 23. Responses of fresh weight of leaves to NPK fertilizer application rates show significant effects on fresh weight of leaves. At both locations 120 and 80kg NPK/ha produced significantly higher fresh weight of leaves than all the other treatments but they were statistically similar.

Fresh weight of leaves shows significant increase at both locations with the increase in intra-row spacing from 10cm to 20cm intra-row spacing.

Table 22: Effect of NPK fertilizer application rates and intra-row spacing on fresh weight of root of radish plant at Bagauda and Dadinkowa during 2013 Rainy Season

Treatment	Bagauda	Dadinkowa
NPK (Kgha ⁻¹)		

0	38.11e	36.00d
40	65.33d	65.89c
80	191.67b	191.33b
120	201.56a	204.33a
160	176.22c	189.89b
200	178.44c	190.67b
SED	2.814	2.694
Spacing (cm)		
10	137.39c	137.17c
15	1461.94b	146.72b
20	152.33a	155.17aa
SED	1.990	1.905
Interaction		
FxS	NS	NS

Means followed by same letter within a set of interaction are not statistically different at 5% level of significance using Tukey's (HDS).

4.1.11 Dry Weight of root per plant

Effects of NPK fertilizer application rates and intra-row spacing on dry weight of root of radish per plant are presented in Table 24. The result revealed that 120kg NPK/ha produced higher dry weight of root of radish plant at both locations. Control produced the least dry weight of root of radish plant.

Dry weight of root shows significant increase at both locations with an increase in intra-row spacing up to 15cm and 20cm at Dadinkowa and Bagauda respectively.

4.1.12 Dry Weight of leaves per plant

Effects of NPK fertilizer application rates and intra-row spacing on dry weight of leaves of radish per plant are presented in Table 25. Response of dry weight of leaves per plant of radish to NPK fertilizer application rates revealed that at Bagauda 80kg NPK/ha fertilizer application rates produced higher dry leaves of radish per plant, similarly 80 and 120kg NPK/ha produced statistically similar result. At Dadinkowa 80kg NPK/ha produced higher dry weight of leaves of radish. Control produced the least dry weight of leaves per plant.

Dry weight of leaves shows significant increase at both locations with an increase in intra-row spacing up to 20 and 15cm intra-row spacing at Bagauda and Dadinkowa respectively.

Table 23: Effects of NPK fertilizer application rates and intra-row spacing on fresh weight of leaves per plant of radish plant at Bagauda and Dadinkowa during 2013 rainy Season

Treatment	Bagauda	Dadinkowa
NPK (kg ha ⁻¹)		
0	13.17c	14.00c
40	14.59c	17.10c
80	50.58a	53.59a
120	47.41a	48.92a
160	29.81b	39.60b
200	34.25b	36.84b
SED	1.785	2.105
Spacing (cm)		

10	26.71c	30.92b
15	35.75b	34.52b
20	36.71a	39.58a
SED	1.262	1.489
Interaction		
FXS	NS	NS

Means followed by same letter within a set of interaction are not statistically different at 5% level of significance using Tukey's (HDS).

Table 24: Effect of NPK fertilizer application rates and intra-row spacing on dry weight of root of radish productivity Bagauda and Dadinkowa during 2013 raining season

Treatments		
	Bagauda	Dadinkowa
NPK(kgha ¹)		
0	6.79f	6.67e
40	12.24e	13.02d
80	37.43b	37.84ab
120	39.32a	39.66a
160	35.02c	35.69bc
200	31.37d	33.59c
SED	0.450	1.141
Spacing (cm)		
10	25.25c	25.69b
15	26.72b	27.89a

20	29.12a	29.66a
SED	0.318	0.807
Interaction		
FxS	NS	NS

Means followed by same letter within a set of interaction are not statistically different at 5% level of significance using Tukey's.

Table 25: Effects of NPK fertilizer application rates and intra-row spacing on dry weight of leaves per plant of radish at Bagauda and Dadinkowa during 2013 raining season

	Bagauda	Dadinkowa
Treatments		
NPK (kg ha ⁻¹)		
0	3.21c	2.97c
40	4.32c	3.78c
80	12.89a	9.94a
120	11.34ab	9.47a
160	9.12b	6.54b
200	8.34b	7.77b
SED	1.033	0.552
Spacing (cm)		
10	6.68b	5.48c

15	7.97a	6.78b
20	9.96a	7.98a
SED	0.731	0.390
Interaction		
FxS	NS	NS

Means followed by same letter within a set of interaction are not statistically different at 5% level of significance using Tukey's.

4.1.13 Correlation Analysis between Crop Growth and Yield Components

The result of the correlation analysis to show the type and magnitude of the association between radish root yield and yield components at Bagauda and Dadinkowa in 2013 was presented in Table 26 and 27. Highly significant and positive correlations exist between radish crop growth characters and root yield. Number of leaves per plant, plant height, stem diameter, leaf area, number of days to attain edible size, fresh root weight, dry weight of root, fresh weight of leaves and dry weight of leaves in both locations were observed to have a significant positive correlation.

2	DWR	0.834**	1.000									
3	FWL	0.868**	0.905**	1.000								
4	FWR	0.778**	0.979**	0.890**	1.000							
5	LA	0.482**	0.511**	0.541**	0.559**	1.000						
6	NL	0.754**	0.820**	0.829**	0.845**	0.650**	1.000					
7	PH	0.773**	0.845**	0.764**	0.849**	0.721**	0.787**	1.000				
8	RG	0.776**	0.926**	0.875**	0.956**	0.649**	0.889**	0.862**	1.000			
9	RL	0.752**	0.843**	0.840**	0.869**	0.767**	0.884**	0.892**	0.906**	1.000		
10	TAES	-0.767**	-0.948**	-0.851**	-0.957**	-0.513**	-0.793**	-0.848**	-0.919**	-0.863**	1.000	
11	YIELD	0.516**	0.498**	0.468**	0.485**	0.324*	0.456**	0.610**	0.481**	0.571**	-0.489**	1.000

* = Significant at 5% level of significant

1= Dry weight of leaves

2= Dry weight of root

3= Fresh weight of leaves

** = Significant at 1% level of significant

4= Fresh weight of root

5= Leaf area

6= Number of leaves

7= Plant height

8= Root diameter 11= Root yield

9= Root length

10= Total number of day to edible size

DISCUSSION

4.2.1 Effect of NPK fertilizer on growth and yield of radish.

Time taken by the roots to attain edible size, the number of days to reach edible size of radish plant due to NPK fertilizer application ranges from 38.63 to 68.11 days. Application of NPK fertilizer at 200 kg/ha significantly influenced attaining edible size earlier at 38.63 days in Bagauda and similarly 76 in Dadinkowa, 200 kg/ha is the least days. These results are in conformity with the findings of Banga (1953), Yousaf and Shafi (1971) and Shoe Maker (1949) that the minimum time is 5.56 weeks and the slight difference can be attributed to differences in ecological as well as climatic conditions.

The increase in plant height, leaf number per plant, leaf length and dry matter production per plant of radish with increasing rate of NPK fertilizer up to 120 kg/ha could be attributed to the positive influence of nitrogen on cell division, cell elongation, cell expansion synthesis of amino acids enzymes and chlorophyll which might increase the growth, the vigour of the crops. Higher number of leaves per plant indicates more photosynthetic surface area; consequently, more assimilate production and translocations could have direct positive effect on the rate and amount of dry matter produced per plant. These results agree with the findings of Singh and Singh (1996) Barnes, (1979) and Heryati and Thalibb (2003). Sharma, (2000) reported that height of plant can be considered as one of the indices of plant growth and it depends upon vigour and growth habit of the plant. Soil nutrients are also very important for the height of plant, higher dose of

NPK increased plant height, leaf number, leaf length which is in line with Koch *et al.* (1988), Barnes (1979) who reported that increasing application of NPK enhances vegetative growth of crops.

The leaf weight indicated the ration of leaf dry matter to the total dry matter produced and it was more during early stages and decreased towards maturity due to reduced contribution of leaf dry matter toward total dry matter produced and it was more during early stages and decrease toward maturity due to reduced contribution of leaf dry matter. In the present study, application of NPK fertilizer recorded significantly higher leaves weight compared with control. These results were similar to the findings of Jirali (2001).

The root length increased at different level of NPK fertilizer application. The higher root was obtained from 200 kg/ha and the lowest root length obtained from control. The results are in agreement with the findings of Huchmuth *et al.* (1999); Balooch *et al.* (1998); Sarker (1989) and Ali *et al.* (2003) who noted that the application of NPK fertilizer significantly increased the root length in radish. Root diameter exhibited significant variation with NPK fertilizer level. The biggest root diameter (34.26 cm) resulted from 120 kg/ha which was significantly greater than those of the remaining doses of NPK fertilizer, these results were in agreement with Parraga *et al.* (1995) who reported that application of Organic matter with NPK increased the diameter of root per plant, in general the treatments produced taller plant height and higher number of leaves per plant and higher roots diameter.

The application of NPK fertilizer had significant effects on cracking of roots which increased with increased level of NPK fertilizer. The cracking was high when the crop was fertilized with 200kg/ha and low or none in the control. The results of the present experiment are in agreement with the observation of Jadhao, (1999) and Gill *et al.* (1995) who noted an increased cracking of roots with increasing rate of NPK fertilizer in radish.

The highest Yield (8.83 t/ha) was attained from 200 kg/ha. The increased in yield of radish root might be attributed to higher individual root weight, higher number of leaves per plant and higher dry matter content of root. Sharma, (2000) reported that NPK fertilizer at 180 Kg/ha gave the best yield and quality in radish Sarker *et al.* (1991) mentioned that maximum yield of 35.9 t/ha was obtained when NPK was applied at the ration 120:120:60 kg/ha to carrot. Similarly, Ali *et al.* (2003) also found that the highest yield (27.82) t/ha was obtained from nitrogen applied to carrot at 150 kg/ha which was significantly different from other nitrogen levels. Uddin *et al.* (2004) also found that combination of fertilizer 120-45-120-30 kg/ha of NPKS 5 t/ha could produce the highest root yield of 27.22 t/ha.

4.2.2 Effect of intra-row spacing on growth and yield of radish.

The increase in plant height, leaf number per plant, leaf length and dry matter production per plant of radish with increasing intra-row spacing from 10 or 15 to 20 cm, could be probably due to the fact that, radish plants grown at wide intra-row spacing are less expose to intra-specific competition for nutrients, moisture, height and spaces, therefore tended to grow vigorously. High plant

populations associated with narrow intra-row spacing tended to exert pressure on scarce growth resources such as light and nutrients there by leading to poor growth. This agreed with the findings of Jadhao *et al.* (1999) and Muhammad and Muhammad (2001).

Intra-row spacing also had a significant and positive effect on radish root length, weight of root per plant and root yield respectively. Planting of radish at 20 cm intra-row spacing was observed to produce higher root length, root diameter, root fresh weight, leaves fresh weight and radish root yield compared to planting of radish at 10 or 15 cm intra-row spacing. This could be at wider intra-row spacing, plants were not competing for light, nutrients, moisture and space for growth and development. The lower values obtained at close spacing could be due to intense competition for light, nutrients and space. The implications was that at wider spacing more photosynthesis would be produced by the source and turn translocate to the sink, thus resulted in higher yield of radish. The results of the present study are in agreement with previous findings of Jadhao *et al.*, (1999) and that of Muhammad and Muhammad (2002).

4.2.3 Interaction of NPK fertilizer and intra-row spacing.

Application of 120 kg/ha along with 20cm intra-row spacing had resulted in producing taller plants that were comparable to another combination of NPK fertilizer and spacing this could be due to the fact that NPK fertilizer nutrition is usually enhanced by wider spacing, specifically due to the effect of wider spacing on root development, formation and transfer which improves the efficiency of nutrients uptake and thus synthesis of assimilate. The result also indicated that

120 kg/ha and 20cm spacing to be optimum for maximum growth in radish. Similar result were reported by Sharma and Singh (1981); Huchmuth *et al.* (1999); Otani, (1974) and Hassan *et al.* (1992).

Statically, more number of leaves/plant was produced with 120 kg/ha along with 20cm spacing indicating this combination as optimum for increased leaf number. Sharma and Singh (1981) recorded a significant increase in leaf number of radish with the application of NPK fertilizer along with optimum spacing.

CHAPTER FIVE

5.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary

Two locations trials were conducted during 2013 rainy season at Federal College of Horticultural Technology Dadinkowa and Kano State Institute of Horticulture KIHORT Bagauda to study the effects of NPK fertilizer application rates and spacing on growth and yield of radish (*Raphanus Sativus L*). The treatments consisted of six rates of NPK fertilizer (0 kg, 40 kg, 80 kg, 120 kg, 160 kg and 200 kg) and three intra-row spacing's (10 cm, 15 cm and 20 cm) the treatments were factorially laid in a randomized complete block design. The treatments were replicated three times in both locations.

The results from the analyzed data revealed that application of NPK fertilizer at 80 kg to 120 kg NPK/ha produced statistically taller plants, more leaves per plants, longer leaves, high leaf area, higher fresh weight of leaves, higher fresh weight of roots, higher root length, higher root diameter, at all the sampling periods in both locations.

The result also revealed that increasing levels of NPK fertilizer from 0 kg to 200 kg significantly increased all growth characters as well as yield components, total number of days to attain edible size were all increased with the increasing levels of NPK fertilizer.

Increasing intra-row spacing from 10 to 20 cm had produced significant increase in all growth and yield, including root yields at all the stages of sampling in all the locations of study area. The significant interactions were also recorded

on some of the growth and yield characters such as number of leaves per plants, leaf area and root diameter and root length.

5.2 Conclusion

In conclusion, the results of the study indicated that applications of NPK fertilizer 120 kg and with 20 cm intra-row spacing appeared to be optimum for good yield of radish.

5.3 Recommendation

From the result obtained in the study, it may be recommended that the use of NPK fertilizer at 120kg/ha with intra-row spacing of 20cm will lead to better growth, yield and quality of radish.

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Appendix I

Metrological Data Record of The Experimental Sites Bagauda and Dadinkowa During 2013 Rainy Season

Month	BAGAUDA			DADINKOWA		
	Rainfall (mm)	Relative Humidity (%)	Temperature (°c)	Rainfall(mm)	Relative Humidity (%)	Temperature (°C)
May	26.4	42.2	33.8	125.6	44.1	38.45
June	158.3	50.6	29.7	141.8	60.4	34.78
July	355.9	59.8	27.2	209.6	61.1	33.36
August	270.7	63.2	24.8	350.3	64.9	32.45
September	97.6	51.6	29.2	348	52.8	32.98
October	11.6	39.7	30.1	13	38.69	36.23

SOURCE: Metrological unit of Nihort, Kano station and Upper Benue River Basic development Authority, Dadinkowa Gombe State