NITROGEN INFLUENCE AND FRUIT HARVESTING METHOD ON THE PERFORMANCE AND SEED QUALITY OF OKRA (*Abelmoschus esculentus* L. Moench) IN MINNA, NIGERIA

BY

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ABSTRACT

The study was carried out both on the field at the Teaching and Research Farm and in the laboratory of the Department of Crop Production, Federal University of Technology, Minna, in the Southern Guinea Savanna Ecological Zone of Nigeria during the 2019 and 2020 cropping seasons. The treatments consisted of two okra varieties (NHAe47-4 and LD 88-1), five rates of nitrogen fertilizer (0, 30, 60, 90 and 120 kg N ha^{-}1).The experimental design was a 2 x 5 factorial giving 10 treatments combinations fitted into a Randomized Complete Block Design (RCBD) replicated three times.Each plot measures 2×5.25 m (10.5m^{2}) comprising of eight ridges with 3 replications. Parameters measured includesdays to first flower bud sight and opening, days to 50% flowering, plant height, number of leaves, stem girth and leaf area at days to flower bud sight and opening and days to 50% flowering, number of productive branches, flower abortion incidence, number of fresh fruits, fresh fruit diameter and fresh fruit length, fresh fruit weight/plot, dry fruit diameter, dry fruit length, number, weight of seeds per fruit and 100-seed weight. Seed qualityexperiment (I) consisted of three factors,two okra varieties (NHAe47-4 and LD 88-1), five nitrogen rates (0, 30, 60, 90, and 120 kg ha^{-1}) and six fruit positions on the mother-plant (1, 2, 3, 4, 5 and 6th) which was a 2 x 5 x 6 factorial fitted into a Completely Randomized Design (CRD) with four replicates.Seed quality experiment (II) consisted of three factors of two okra varieties (NHAe47-4 and LD 88-1),five nitrogen rates (0, 30, 60, 90, and 120 kg N ha^{-1}) and seven fruit harvesting stages (14, 21, 28, 35, 42, 49 and 56 days after anthesis) which was 2 x 5 x 7 factorial fitted into a Completely Randomized Design (CRD) and replicated four times.The seed quality tests were evaluated using fruit diameter, fruit length, number of seeds, seed weight, seed moisture content, germination test, germination rate index, electro-conductivity test after harvest. The data collected were subjected to analysis of variance (ANOVA) using SAS Statistical package 9.2 (2016) at 5% level of probability; means were separated using Least Significant Difference (LSD) Test.The results revealed thatapplication of 90-120 N kg/hais optimum for okra due to enhanced growth and yields in the study area. However, flowering was delayed when N was applied. Plants to which no fertilizer was applied performed poorly in respect of all parameters studied. Seeds of LD88-1 also stored better than seeds of NHAe47-4. Seeds harvested at 42 (DAA) maintainedsuperior longevity, irrespective of the cultivar used.With the result of this study, we could advise okra farmers in the zone toplant NHAe47-4 with the application of 90-120 N kg/ha for its bigger fruits. Fruits harvested at 42 days after anthesis produced seeds which germinated and stored better than other harvesting stages. The fruits formed at the lower position 1-3 on the mother-plants at 42 DAA should be harvested for high quality seed and storage. The results also showed that significantly enhanced growth, fruit and seed yield was recorded at 90-120 N kg/ha in this agro-ecological zone.

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ABBREVIATIONS

ANOVA: Analysis of Variance

ASG: American Society of Agronomy

CRD: Completely Randomized Design

DAA: Days After Anthesis

FAO: Food and Agriculture Organization

IBPGR: International Board for Plant Genetic Resources

ISTA:International Seed Testing Association,

MC: Moisture Content

NIHORT:National Horticultural Research Institute

NSPI: Nigeria Seed Portal Initiative.

RCBD: Randomized Complete Block Design

SAS: Statistical Analysis System

LSD: Least Significance Difference

WAS: Weeks After Sowing

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

Okra [*Abelmoschus esculentus* (L.) Moench], also known as Ladies' Finger, originated from Ethiopia (Pandey *et al*., 2017) and was then propagated in North Africa, in the Mediterranean, in Arabia and India by the 12th Century BC (Nimona, 2019). It is one of the most widely known and utilized species of the family Malvaceae (Dantas *et al*., 2021) and an economically important vegetable crop grown in tropical and sub-tropical parts of the world, suitable for cultivation as garden crop as well as on large commercial farms (Ibitoye and Kolawole, 2022). The nutritional compositions of okra include calcium, protein, oil and carbohydrates, iron, magnesium and phosphorus and play a vital role in human diet (Omoniyi *et al*., 2020). Okra, which is currently grown mainly as a vegetable crop, has a potential for cultivation as an essential oilseed crop because its seeds contain high amount of oil (20-40%) (Ibitoye and Kolawole, 2022).

Okra grows best on well-drained sandy loam soil; it prefers slightly acidic soils with a pH between 6.0 and 6.8 (Nisar *et al.*, 2021). The minimum and maximum soil temperatures for growth are 20°C and 30 °C, respectively, and relative humidity of 21% – 30% (Makinde, 2022).

Nitrogen is the second-most absorbed nutrient by vegetables, which plays a fundamental role in their yield (Souza *et al*., 2017), being an essential macronutrient required for growth and development of a plant. It performs important structural function and is a part of several organic compounds that are essential for the plants, such as amino acids, proteins, and proline (Ferraz *et al*., 2017). In all plants, N considerably influences the utilization of P and K and other plant nutrients (Xu *et al.*, 2020). Nitrogen influences the process of flower opening, fruit setting and fruit development. The addition of nitrogen in adequate amounts enhances vegetative and reproductive growth and its deficiency leads to stunted growth, small yellow leaves and low production (Ibrahim *et al*., 2013; Zubairu *et al*., 2017). Therefore, proper management of this nutrient contributes to the vegetative growth and increase in the productivity of the cultures. There are several recommendations of this nutrient, varying from 60 kg ha^{-1} to 180 kg ha^{-1}, depending on the soil fertility of the growing region (Dhakal *et al*., 2021).

There are variations among okra species in the attainment of maximum seed quality during development and its association with seed and fruit characteristics. Apart from seed development stage, the quality of seed depends on various factors such as cultural practices, climatic conditions and fruit position on the mother-plant (Ibrahim *et al*., 2011; Bareke, 2018). Good seed nutrition of the mother-plant during growth is important as it has been reported (Ibrahim and Oladiran, 2011; Yakubu and Abubakar-Sadiq, 2017) to result in rapid seedling emergence in okra varieties. The seed crop requires the right stage of maturity followed by proper drying to ensure high germinability after harvest and storage. This is because seed longevity is known to be influenced by the initial seed quality, which is affected by the production procedure (Ibrahim *et al*., 2013; Kumar *et al.,* 2021). Seeds attain maximum quality in terms of germinability at the end of the seed filling period and thereafter viability and vigour decline (Kumar *et al.,* 2021).

1.2 Statement of the Research Problem

The inadequate availability of good seeds remains a constraint to wide cultivation of vegetables in Africa (Ibrahim and Oladiran, 2011).

The viability of most farmers' seeds is usually poor because of the use of inadequate production techniques (Yakubu and Abubakar-Sadiq, 2017). Some of the factors that affect seed quality include the quality of nutrition of the mother- plant, the physiological state at which a seed is harvested and the positions of fruit on the mother-plant.

Nitrogen (N) is an essential nutrient for plant growth and limiting factor in most agro-ecosystems in the tropics, thereby affecting the nutrition of the mother-plant. It is a constituent of amino acids, which is required to synthesize proteins and other related compounds (Anas *et al*., 2020). However, excess of N application can lead to delay maturity in plants (Anas *et al*., 2020). Application of adequate N to plants during growth can promote the nutrient contents of resulting seeds; this can increase the germination and storability of such seeds (Ibrahim *et al*., 2013; Shah *et al*., 2016).

Fruits often left on the mother-plant to dry before harvest, thus exposing the fruits to severe weathering due to repeated cycles of soaking and drying during the rains. Some of the matured seeds in the fruit may attempt to germinate but may be stopped by dry spells (Ibrahim *et al.*, 2013). This pre-germinative process sets in deterioration in the germinative capacity of the seeds. During seed harvest, all the fruits are collected and seeds are extracted for storage for the next planting. This practice accounts for the severe variation in the quality of farmers seeds which have resulted in poor quality seeds and subsequent low yield on farmer's field (Ibrahim *et al.,* 2017).

1.3 Justification of the Research Study

Some of the causes of seed quality variations include genetic effect, nutrition of the mother-plant, time of flowering, position of fruits on the mother-plant and position of seed within a fruit seed age (Mitchell *et al*., 2017).

Agronomic practices that affect seed quality include nutrition of mother plant, especially nitrogen nutrition of the savanna ecology and time of fruit harvest (Letting *et al*., 2018). Nutrient uptake and fruit yield of okra can be boosted substantially through the application of adequate quantities of NPK fertilizers (Musa *et al*., 2020). Fertilizers are generally applied to improve the crop yield, nutritional quality and aesthetic value of crops (Ibrahim *et al*., 2013; Nuri *et al.,* 2021). Fertilizer is a material that is added to the soil to supply one or more elements required for plant growth and development (Ginindza *et al*., 2015).

Post-harvest practices also influence the longevity of seeds in storage. These include the genotype, initial seed quality, seed moisture content, the temperature, relative humidity of the storage environment and storage periods (Dadlani *et al*., 2023)

The availability of sufficient seed reserves has been documented to influence early and rapid seed germination and subsequent seedling emergence and establishment in crop species (Ibrahim *et al.*, 2013).

Seed viability is a measure of the germination capability of seed. When a seed germinates it's simply a viable seed. Therefore, germination reveals the viability status of a seed, while vigour describes the performance capability of a seed in terms of emergence of seedling, seedling establishment, growth, among others which translates to the eventual yield of the crop (Van der Walt and Witkowski, 2017). Seed quality is affected by several factors and seed germination, vigour and health assessment plays an important role in determination of seed quality (Ndinya *et al*., 2020).

Seed vigour is an important factor that affects seedling establishment and crop growth and ultimately production rate. Vigour of the seeds declines progressively during storage and the last to be affected is the viability (germination) which is usually evident by death of the living entity of the seed (embryo) (Ramtekey *et al.*, 2022). Each biotic or non-biotic factor that affects seed vigour and germination during seed's development, subsequently will affect production especially when seeds are produced under stress condition (Chi *et al*., 2021).

Seed maturation, however, is closely associated with fruit maturation and complete fruit drying (Bortey *et al.*, 2022). Literature on optimum stage of fruit harvest and appropriate drying method for the production of high quality seeds of okra is limited. The suitable stage of harvest could also vary with species and cultivars. The stage of harvest of okra fruit has a significant influence on the quality of its seed (Ibrahim *et al*., 2018; Finch-Savage and Bassel, 2016). Silva *et al*. (2017) stated that okra seed pod should be harvested when they are dry at 35 days after anthesis (DAA). Delayed harvest may lead to low germination and vigour due to adverse weather conditions in okra (Farzana and Gohar, 2022). In some other species, however the best quality may not be obtained until sometimes afterwards (Hillary and Beloved, 2016). In tomato, Nitish *et al*. (2021) reported that mass maturity (end of the seed-filling period) occurred 41 and 39 DAA in the first and second trusses, respectively. Similarly, Bortey and Dzomeku (2016) observed that maximum germination of okra occurred at 30 days after anthesis.

The common practice in okra is the harvesting of fruits from all positions at the end of the rains. The mother-plant has a significant influence over seed traits, including seed size, dormancy, germination and storage. In many species, factors such as age of the mother-plant and position of the seed in the fruit, inflorescence, or canopy can affect seed properties (Lu *et al*., 2017). Positive effect of nitrogen fertilizer on mother-plant can be attributes to its role in delaying ageing cycle and providing enough time to obtain photosynthetic matters which translate to more weigh and higher quality (Bita and Maryam, 2011). The poor germination of early-harvested seeds could have been due to the large proportion of immature seeds in these sets of seeds (Ibrahim and Oladiran, 2011). Bigger seeds were found in the earlier positions than in later ones (position 7) could be due to the fact that less nutrients were made available to the developing fruits and seeds of later (upper) positions (Ibrahim and Oladiran, 2011).

1.4 Aim and Objectives

The aim of this study was to investigate nitrogen influence and fruit harvesting method on the performance and seed quality of okra in Minna, Nigeria.

The objectives were to determine the effect of:

(i) nitrogen application rates on growth, fruit and seed yields of two okra cultivars

(ii) nitrogen application rates and position of fruit on the mother-plant on seed quality of two okra cultivars

(iii) nitrogen application rates and days after anthesis on seed quality of two okra cultivars

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Origin and Distribution of Okra

Okra is one of the oldest cultivated vegetable crops. There is no unanimity over the geographical origin of okra. Some opined that okra originated in West Africa, East Africa, particularly Ethiopia, and South Asia (Nimona, 2019). It was cultivated by the ancient Egyptians since 12th century BC. In later years, the cultivation of okra spread throughout the Middle East and North Africa, and today, the crop is grown in many parts of the world, especially in tropical and sub-tropical regions (Thomas, 2022).

Okra was presumed to have been taken from Ethiopia to Arabia across the Red sea or narrow strait with southern end (Rao *et al.*, 2017). Although it has been commonly cultivated in Egypt for hundreds of years, no sign of it has ever been found in any of the ancient monuments or relics of old Egypt. The Spanish Moors and the Egyptians of the 12th and 13thcenturies used an Arab word for okra, it probably was taken into Egypt by the Moslems from the East who conquered Egypt in the 7th century (Ogunbor, 2020). From Arabia, okra spread over North Africa, completely around the Mediterranean, and eastward. The absence of any ancient Indian names for it suggests that it reached India after the beginning of the Christian era. It is grown commercially in India, Turkey, Iran, Western Africa, Yugoslavia, Bangladesh, Afghanistan, Pakistan, Burma, Japan, Malaysia, Brazil, Ghana, Ethiopia, Cyprus and the Southern United States (Davis, 2022).

2.2 Botanical Description of Okra

The okra plant belongs to the genus *Abelmoschus* in the plant family Malvaceae (Iyagba *et al*., 2013). The common okra *Abelmoschus esculentus* is one of the most widely known and utilized species. The okra plant was previously included in the genus *Hibiscus* but later designated to *Abelmoschus* (Ogunbor, 2020). It is distinguished from *Hibiscus* by the characteristics of the calyx, spathulate, with five short teeth, connate to the corolla and caducous after flowering (Ogunbor, 2020; Swamy, 2023).

The genus *Abelmoschus* has about 50 species which have been described by taxonomists in the genus *Abelmoschus,* an up-to-date classification was adopted at the International Okra Workshop held at National Bureau of Plant Genetic Resources (NBPGR) in 1990 (IBPGR 1991), *A. moschatus,A. manihot* (L.), *A. esculentus* (L.) Moench, *A. tuberculatus,A. ficulneus* (L.), *A. crinitus ,A. angulosus* and *A. caillei. Abelmoschus esculentus* (usually $2n = 130$) is probably an amphidiploids derived from *Abelmoschus tuberculatus* Pal & H.B.Singh ($2n = 58$), a wild species from India, and a species with $2n = 72$ chromosomes (possibly *Abelmoschus ficulneus* (L.). Another edible okra species *Abelmoschus caillei* occurs in the humid parts of West and Central Africa. There are strong indications that also *Abelmoschus caillei* is amphidiploids with *Abelmoschus esculentus* being one of the parental species (Nanjundappa *et al.,* 2022).

The genus *Abelmoschus*, of okra has four domesticated species known today (Babalola *et al*., 2020). These include *A.esculentus* (common okra) which is the most widely cultivated species in many parts of the world including South and East Asia, Africa, and the southern USA. The next species is the *A. caillei* (West African okra). This species has a longer production cycle, and it is mainly cultivated in the humid zone of West and Central Africa (Babalola *et al*., 2020). In some countries such as Solomon Islands and Papua New Guinea, *A. caillei* is cultivated for its leaves as it does not flower and develop pods. *A.moschatus* is another domesticated species mainly cultivated for its seed. What is interesting is that, not all of these species can do well under the same cropping systems and growth conditions especially at the germination stage. There are no apparent differences in use between the common and West African okra, which is why they are often lumped together. Morphologically, *Abelmoschus caillei* differs in several respects from *A. esculentus*, but the epicalyx offers the best discriminating characteristic: the width of the epicalyx segments is 0.5–3 mm in *A.esculentus* and 4-13 mm in *Abelmoschus caillei*. The two okra species can be quite reliably (but not with absolute certainty) recognized on the basis of fruit form. Fruits of *A. esculentus* are cylindrical to pyramidal, whereas fruits of *A. caillei* are ovoid (Chanchal *et al.*, 2018). Literature references on common okra have to be interpreted with care because they may include information related to *A. caillei*. There are many cultivars of common okra. Some of the better known are 'Clemson Spineless', 'Indiana', 'Emerald' (United States) and 'Pusa Sawani' (India), which have been in use for about 30 years (Kumar *et al*., 2013).

A few bred cultivars in Nigeria include the following: NHAe47-4 is from NIHORT which is characterized by early flowering with thick fresh pods. It is a late maturing plant of about 120 days, short to medium in height and with deeply lobed leaves and profuse branching (Iyagba *et al*., 2013). LD 88-1 is also late maturing variety. Number of branches per plant is high, long pod, thick fruits and spineless fruits. Maha F1 is a hybrid okra variety from the East West Seed, produces large leaves, resistant to the mosaic virus and has a maturity time of 55-60days. Kirikou f1 is one of the hybrid varieties from Technisem. The variety is notable for its high yield, pest and disease resistance. Produces short pods and matures 55-60days (Nigerian Seed Portal Initiative, 2023).

Okra is known by many local names in different parts of the world. It is called lady's finger in England, gumbo in the United States of America, guino-gombo in Spanish, guibeiro in Portuguese and bhindiin India (Tesfa and Yosef, 2016). In Nigeria, it is called 'kubewa' by the Hausas, 'ila' by the Yorubas and 'okulo' by the Igbos. In its origin of Ethiopia, it is also called Kenkase (Berta), Andeha (Gumuz), Bamia (Oromica/Amharic). The name Okra probably derives from one of Niger-Congo group of languages (the name for okra in the Twi language is nkuruma) (Omar *et al*., 2023).

2.3 Soil and Climatic Requirements of Okra

Okra grows best on well-drained sandy loam soil; it prefers slightly acidic soils with a pH between 6.0 and 6.8 (Ibrahim and Oladiran, 2011; Kumar *et al.*, 2019). Poorly drained soils may result in water logging which is the major cause of drowning (low oxygen) of the plants. On clay soils, seedlings have difficulty emerging and transplanting is therefore recommended. Okra is very sensitive to soils with a hard pan and soil compaction can severely restrict plant growth. Okra is a hot weather crop; it can be successfully grown in rainy season even in heavy rainfall area, requires a moderate rainfall of about 800 – 1000mm (Kumar *et al*., 2019). The minimum and maximum soil temperatures for growth are 18 and 32 °C respectively (Ibrahim *et al*., 2013; Budania and Dahiya, 2018). Ashwani *et al*. (2012) observed relative humidity of 75 – 90%. Planting dates may vary with favorable soil temperatures. At 24 °C the first flower bud may appear in the third leaf axil while at 28°C it may appear in sixth leaf axil (Budania and Dahiya, 2018). This higher position is not necessarily accompanied with a delay in time because at higher temperatures the plants grow faster and the higher position is reached earlier. For faster plant growth, higher temperature helps though it delays the fruiting. But at higher temperatures beyond 40°C– 42°C, flowers may desiccate and drop, causing yield losses. For seed germination, optimum soil moisture and a temperature between 25°C and 35°C are needed with fastest germination observed at 35°C (Ndunguru and Rajabu 2004). Beyond this range, the germination will be delayed and weak seeds may not even germinate (Iyagba *et al*., 2013). The average monthly temperature 22.1 °C to 32.2 °C and relative humidity 77.0 % to 79.0 % range were considered optimal for the growth and development of okra in the Southern Guinea Savannah ecological zone of Nigeria (Ijoyah *et al*., 2010).

2.4 Production Statistics

Okra or ladies' finger is an important vegetable of the tropical countries and most popular in India, Nigeria, Mali, Sudan, Pakistan, Cameroon, Iraq and Ghana (FAO, 2021). Although, it is virtually not grown in Europe and North America, yet, lot of people in these countries have started liking this vegetable because of its good amount of vitamin A and folic acid, besides carbohydrates, phosphorus, magnesium and potassium. The total world production of okra in 2021 is put at 10.822, 248.74 tons growing at an average annual rate of 3.85% (FAO, 2021). Largest area and production is in India (6,466,000t) followed by Nigeria (1,917,406.63t), Mali (669,688t), Sudan (322,403.39t) and Pakistan (263,448t) (FAO, 2021). The West Africa region accounts for more than 75%of okra produced in Africa, but the average productivity in the region is very low (2.5 t/ha) compared to East Africa (6.2 t/ha) and North Africa (8.8 t/ha) (FAO, 2021). In West Africa, Nigeria is the largest producer (1,917,406.63t) followed by Mali, Coted'Ivoire, Ghana and others (FAO, 2021).

2.5 Nutritional Importance of Okra

The potential of okra as both leafy and fruit vegetable has not been fully tapped. The need to increase and strengthen the production of vegetables as well as seed support systems at farms, villages, communities, institutional, national and regional levels have been reported by Yakubu and Abubakar-Sadiq (2017) due to the numerous nutritional and economic benefits of the crop. Its medicinal value has also been reported in curing ulcers and relief from hemorrhoids. Unspecified parts of the plant were reported in 1898 to possess diuretic properties this is referenced in numerous sources associated with herbal and traditional medicine (Swamy, 2023). Okra roots are used for medicinal purposes. The roots are very rich in mucilage, having a strongly demulcent action. This mucilage can be used as a plasma replacement. An infusion of the roots is used in the treatment of syphilis (Kumar *et al*., 2013). The juice of the roots is used externally in Nepal to treat cuts, wounds and boils. The leaves furnish an emollient poultice. A decoction of the immature capsules is demulcent, diuretic and emollient. It is used in the treatment of catarrhal infections, dysuria and gonorrhoea (Kumar *et al*., 2013). Unspecified parts of the plant were reported in 1898 to possess diuretic properties this is referenced in numerous sources associated with herbal and traditional medicine. Some studies are being developed targeting okra extract as remedy to manage diabetes (Swamy, 2023). Okra *(Abelmoschus esculentus* (L.) Moench) is a medicinal plant of immense importance with large pharmacological applications. Besides having the above-mentioned nutritional and medical, industrial properties, it has been used as an ingredient of many herbal formulations, which are used for the cure of various ailments, in particular the regulation of blood pressure, fat, diabetes, chronic dysentery genito-urinary disorders, simple goiter and ulcer (Ogunbor, 2020). The leaves and immature fruit long have been popular in the East for use in poultices to relieve pain (Ogunbor, 2020).

The composition of okra pods per 100 g edible portion is water 88.6 g, energy 144.00 kJ (36 kcal), protein 2.10 g, carbohydrate 8.20 g, fat 0.20 g, fibre 1.70 g, Ca 84.00 mg, P 90.00 mg, Fe 1.20 mg, βcarotene 185.00 μg, riboflavin 0.08mg, thiamin 0.04 mg, niacin 0.60 mg, ascorbic acid 47.00 mg. Protein, carbohydrate and vitamin C contains of okra (Singh *et al*., 2014). Okra is a popular health food due to its high fiber, vitamin C, and folate content and also known for being high in antioxidants. Okra is also a good source of calcium and potassium (Ravindrakumar and Shanthakumar, 2019). The composition of okra pods per 100 g edible portion is water 88.6 g, energy 144.00 kJ (36 kcal), protein 2.10 g, carbohydrate 8.20 g, fat 0.20 g, fibre 1.70 g, Ca 84.00 mg, P 90.00 mg, Fe 1.20 mg, β-carotene 185.00 μg, riboflavin 0.08mg, thiamin 0.04mg, niacin 0.60 mg, ascorbic acid 47.00 mg. Protein, carbohydrate and vitamin C contains of okra and plays a vital role in human diet (Ogunbor, 2020). It is a major source of vitamins A, B, C, minerals, Iron and Iodine and important vegetable source of viscous fiber but it is reportedly low in sodium saturated fat and cholesterol. Presence of Fe, Zn, Mn and Ni also has been reported (Yousaf *et al*., 2017). Okra provides an important source of vitamins, calcium, potassium and other mineral matter which are often lacking in the diet in developing countries. Seven days old fresh okra pods have the highest concentration of nutrients (Ogunbor, 2020). Known as a high-antioxidant food, it can fight free radical damage and support improvements in cardiovascular and coronary heart disease, type 2 diabetes, digestive diseases, and even some cancers. Additionally, it’s abundant in several other vitamins and minerals, including thiamine, riboflavin/vitamin B2 and zinc (Axe, 2021).

As a vegetable, okra may be prepared like asparagus, sautéed, or Okra is valued for its edible green pods which plays a vital role in human diet (Ibrahim *et al*., 2013; Salman *et al*., 2022). It is rarely used "straight," except when fried with a meal, just a little of it usually being cooked with other vegetables or added to soups and stews. Okra alone is generally considered too "gooey," or mucilaginous, to suit American tastes. It is a multipurpose crop due to its various uses of the fresh leaves, buds, flowers, pods, stems and seeds (Alessandra *et al*., 2019). Okra immature fruits (green seed pods), which are consumed as vegetables, can be used in salads, soups and stews, fresh or dried, fried or boiled. It offers mucilaginous consistency after cooking. In recent years, however, it has become an important commercial crop in certain localities in the South, where thousands of tons of the pods are grown for the large soup companies.

A little dried okra in prepared dishes produces much the same results as does the fresh product. In some lands, the seeds rather than the whole young pods are of most interest. When ripe, the seeds yield edible oil that is the equal of many other cooking oils. Okra seeds are source of oil and protein. It seeds have been used on a small scale for oil production. It can be also used as non-caffeinated substitute for coffee. Okra seeds may be roasted and ground to form a caffeine-free substitute for coffee (Buela, 2019). It also has industrial applications and is used in confectionary (Soma *et al*., 2019). It mucilage has medicinal applications when used as a plasma replacement or blood volume expander. The mucilage of binds cholesterol and bile acid carrying toxins dumped into it by the liver. The immature pods are also used in making pickle. The entire plant is edible and is used to have several foods (Soma *et al*., 2019). It is currently grown mainly as a vegetable crop but has potential for cultivation as an essential oilseed crop because okra seeds contain high amount of oil (20-40%) (Khan *et al*., 2021). It has been called “a perfect villager’s vegetable” because of its robust nature, dietary fiber, and distinct seed protein balance of both lysine and tryptophan amino acids (unlike the proteins of cereals and pulses) (Kumar and Shanthakumar, 2019).

2.6 Effect of Nitrogen on Quality of Okra Seeds

Nitrogen is the important part of plant parts such as chlorophyll, amino acid, proteins and pigments. It is most essential for vigorous growth, branching, leaf development and enlargement or root expansion, high photosynthetic activity and formation of protoplasm (Muhammad *et al.*, 2017). Application of judicious nitrogen is the reliable way of increasing the seed quality of okra (Pamar *et al.,* 2016). According to Ibrahim *et al*. 2013; Kamal and Dinesh (2020), increase in nitrogen levels resulted in the production of quality fruits. Adequate supply of nitrogen is essential for vegetative growth, and desirable quality (Muhammad *et al.*, 2017). Nurul *et al.* (2022) had earlier reported that seeds attain maximum quality with adequate available nitrogen, in terms of germinability at the end of the seed filling period and thereafter, viability and vigour declines. In some other crops, however, the best seed quality may not be obtained until some times after seed filling period (Finch-Savage and Bassel, 2016).

Sajid *et al.* (2012) reported that maximum number of pods per plant and maximum seed yield in okra were recorded in plots having received both 150 kg N ha^{-1} and 90 kg P ha^{-1}.

Olaniyi *et al.* (2008) found out that plant height, number of leaves, dry matter yield of the leaves and stem of the grain amaranth increased significantly as N rates was increased from 0 kg ha^{-1} up to 60 kg ha^{-1} of N. The seed yield and quality of the amaranth varieties were increased from 0 up to 45 kg N ha^{-1} and declined thereafter. Adequate nitrogen increases the quality, fruit size, keeping quality, colour and taste (Ramjan and Ansari, 2018). Increase in nitrogen levels and spacing resulted in the production of quality fruits (Brar and Singh, 2016). Excessive application of nitrogen on the other hand is not only uneconomical but also induces physiological disorder and pollutes the environment (Olaniyi *et al*., 2008). Okra loses their viability very quickly so that it becomes essential to produce fresh good quality seeds every year to get higher yield of crop. Among the various agronomic practices influencing seed production of okra, adequate nutrition is reported to exert a great influence on yield and seed quality of okra. Reasons for low yield and quality of crops are imbalanced fertilizer use; improper nitrogen sources and high rate of leaching of the nitrogen (Li *et al*., 2019).

The optimum stage of harvest has a significant influence on the quality of a seed. The seed maturation however, is closely associated with fruit maturation and complete fruit drying (Bortey *et al.*, 2022). There are various ways for improving yield and seed production of okra but the best way is to provide appropriate amount of fertilizers and to select high yielding cultivars. Ijoyah *et al*., (2010) reported the optimal intra-row spacing for 'NHAe47-4' okra variety in the Guinea Savannah ecological zone in Nigeria was found to be 30 cm. This is associated with a greater number of branches per plant, leaf area, pod length, pod diameter, number of pods per plant, pod weight and yield respectively.

2.7 Effect of Nitrogen on the Growth of Okra

Nitrogen (N) is the second-most absorbed nutrient by okra, which plays a fundamental role in their yield (Souza *et al.,* 2017), which is an essential macronutrient during the growth and development of the plant. The proper management of this nutrient contributes to the vegetative growth and increase in the productivity of the cultures; therefore, a part of several organic compounds that are essential for the plant, such as amino acids, proteins, and proline (Medeiros *et al.,* 2017).

Depletion or shortage of N indicates that either the crop will not be able to maintain its leaf area expansion rate or cannot maintain its leaf and plant N concentration. Either of this will have effects on crop growth and production of economic products (John and Gordon, 2017). A study conducted by Akanbi *et al.* (2010) showed that plant height, number of leaves and number of fruits per plant of okra increased significantly with application of nitrogen up to the highest 100 kg N $^{-1}$ rate. Similarly, application of 100 kg N^{-1} to okra plants gave the highest values of plant growth, yield and quality in two studied seasons (Ahmed and Mohamed, 2015). Sufficient nitrogen supply improves cell division, foliage production, and photosynthetic activity of the plant, thus producing higher numbers of flowers and fruits (Xu *et al.,* 2020). Application of 90 kg N^{-1} significantly increased maximum plant height, number of branches per plant, number of fruits, fruit length, girth of fruit and total yield of okra (Shahbaz *et al.,* 2014). Shelar *et al*. (2012) carried out field experiment in okra crop and reported that 50% N through urea plus 50% N through neem cake significantly increased plant height, number of leaves, leaf area, number of branches, number of nodes, weight, breadth, length of fruit, number of fruits per plant and yield per hectare.

Gayatri and Reddy (2013) conducted an experiment on okra plants fertilized with recommended dose of NPK (100: 50: 50 kg ha $^{-1}$) gave maximum plant height (104.42 cm), plant girth (3.18 cm), number of nodes per plant (15.07), and dry weight of the plant (53.77 g), with least number of days to 50 % flowering (32.8 days), days to first picking (38.47 days), maximum number of pods per plant (16.47), maximum pod length (17.07 cm), maximum pod weight (15 g), maximum pod yield per plant (238.33 g), maximum pod yield per plot (10.29 kg) and maximum pod yield (135.83 ha^{-1}).

However, overuse of N in vegetable cultivation leads to excessive accumulation of nitrates beyond its safe limits in various parts of vegetables which caused health risks to humans (Brkic *et al.,* 2017). According to Zubairu *et al*. (2017), application of 90 – 120 kg N/ha resulted in progressive increase in plant height which is optimum for okra growth in the Guinea Savannah ecological zone in Nigeria. Fasakin *et al*. (2019) recorded significant differences in plant height, number of leaves/plants, number of fruits/plants, and the average length of the fruits with the application of N fertilizer in the Guinea Savannah ecological zone in Nigeria.

2.8 Effect of Nitrogen on Fruit Yield of Okra

Maintaining optimum plant population and nitrogen fertilization dose are the most important elements in improving productivity of okra. Optimum plant density is the key element for higher fruit yield of okra, as plant growth and yield are affected by nitrogen fertilization (Funda *et al*., 2021). The yield of okra could reach as high as 30 t ha^{-1}, but in most of the developing countries, it is very low (1.77 t ha^{-1}) as compared to the yield of other agriculturally developed countries of the world (Gemechu, 2018). Reports are available for okra that indicates the potential of obtaining up to 30-40 t ha^{-1} tender fruit yield with optimum nitrogen fertilizer application (Kanal *et al*., 2020). The research conducted by (Atif and Nahed, 2016) revealed that increase in nitrogen fertilizer from the control (0 N) to 160 kg N ha^{-1} significantly increased total fruit yield from 3.72 to 6.73 t ha^{-1}.

In the okra culture, N provides greater response in the fruit production (Zubairu *et al.,* 2017) as well as to obtain satisfactory yields. There are several recommendations of this nutrient, varying from 60 to 180 kg ha^{-1}, depending on the soil fertility of the growing region (Oliveira *et al.,* 2014).

Okra crop response to required dose of nitrogen for the highest fruit yield appeared in various books and journals ranges from 120 to 200 kg ha^{-1} (Brar and Singh, 2016). The research conducted by Amanga *et al,* (2017) showed the application of nitrogen fertilizer increased plant growth, delayed flowering and fruit setting of okra. It was also reported that the maximum fresh pod weight yield (46.14 t ha^{-1}) was obtained from the application of nitrogen fertilizer rate of 46 kg N ha^{-1} and from plants spaced at 45 cm x 30 cm, whereas, minimum fresh pod weight yield (34.52 t ha^{-1}) was attributed due to spacing of 45 cm x30 cm from plots without nitrogen application. Reports are available for okra that indicate the potential of obtaining up to 30-40 t ha^{-1} tender fruit yield with optimum plant spacing and nitrogen fertilizer application (Amanga *et al.,* 2017).

A field experiment was conducted by Haque *et al*. (2011) to observe the combined effects of nitrogen (N) and boron (B) on growth, yield and nutrient content in plants of tomato. With increasing the levels of N, all the yield contributing characters and yield of tomato increased up to the 120 kg N ha^{-1}. Application of N at 120 kg ha^{-1} gave the highest flowers cluster/plant, fruits cluster/plant, fruits/plant, fruit weight/plant, fruit weight/plot and fruit yield (48.33 t ha^{-1}). In interaction, N at 120 kg ha^{-1} along with B at 0.6 kg ha^{-1} produced the highest flower clusters /plant, flower/cluster, fruits/plant, fruit weight/plant, fruit weight/plot, and fruit yield (58.59 t ha^{-1}).

2.9 Effect of Position of Fruit on Seed Quality

The main reasons of seed mass variations are paternal genetic effect, timing of flowering and fecundation, brood size and position effect of seeds within a plant, or in inflorescence, and the position of a seed within fruit (Ibrahim and Oladiran, 2011; Jeremi, 2017).During an experiment on a pepper plant, depending on the formation order of the fruits on the pepper plant, Sbirciog (2015) found out that there were significant differences between the values of the main physiological indices of the seeds' quality, both for the germinative faculty of the seeds and for their germinative energy. Considering the influence of the fruit position on the plant over the seed germination, he concluded that there are big variations between the germinative capacity of the seeds from the first fruit that developed on the plant and the germination capacity of the seeds from the fruits which have been formed in the 6 or 7 position on the plant (Ibrahim and Oladiran, 2011).

Seed development and seed position are two intrinsic factors which influence the seed quality (Ibrahim *et al*., 2013). Number of fruits on the mother-plant and position of the ovules within the fruit determine the quality of melon seed. Seeds continue to develop and mature in the fleshy fruits until they got extracted from fruits (Ibrahim and Oladiran, 2011; Bortey *et al*., 2022). The quality of seeds in fleshy fruited species was further enhanced after acquisition of desiccation tolerance and maximum dry weight (Newton, 2013).

Fruit development and seed maturation may occur independently, thus seed harvested at a time can be of different developmental stages (Lidiane *et al*., 2022). Fruit retention on mother plant has a significant effect on seed setting and seed quality. Retention of a greater number of fruits on mother-plant resulted in high seed setting with poor seed quality and vice versa. Studies have shown that germination differs largely among seeds collected from different zones of sunflower capitulum (Ahmad *et al.,* 2011). Seeds from the peduncular fruit segments were delayed in reaching maximum quality compared with seeds from other positions in cucumber (Ibrahim and Oladiran, 2011; Hu *et al.,* 2019).

A field experiment was conducted by Kumar *et al*. (2019) to study the effect of fruit retention and seed position in fruit on the seed yield and seed quality in pumpkin cultivar, *Pusa* Hybrid 1. Among two methods of fruit retentions, one fruit per vine showed superiority over two fruits per vine in germination (94.27 %), total seedling length (32.76 cm), seedling dry weight (51.01 mg), vigour index- I (3032.24), vigour index- II (4721.10) and low moisture content. Within the fruit, middle segment showed highest number of filled seed (166.40), total number of seed (175.70), germination (90.64 %), seedling length (20.94 cm), seedling dry weight (47.53 mg), and low moisture content (8.63%). Kołodziejek (2017) observed that seed mass and germination percentage of *Angelica archangelica* were higher in seeds on the umbel than in those on secondary, tertiary, and quaternary umbels. Thomas (1996) found reduced germination of *Petroselinium crispum, Daucus carota* and *Apium graveolens* seeds produced on secondary, tertiary, and quaternary umbels compared with those on primary umbels. Panayotov (2010) found that umbel order affected germination of *D. carota* seeds, but on the other hand, in *Heracleum mantegazzianum* and in *Angelica acutiloba* germination percentage of the seeds obtained from different umbel orders and umbel positions did not differ significantly. Zubairu *et al.* (2017) found that the higher N level of 120 kg/ha and lower fruit position of 3 significantly gave higher number of fruit yield while the yield decreased with decrease in N level and increase in fruit position on the mother-plant. Similarly, heavier fruits were recorded in lower fruit positions and higher N levels. The fruits formed at the lower position 3 and 5 produced more seeds with higher seed weight than those formed at the higher positions.

2.10 Effect of Fruit Age at Harvest on Seed Quality

The optimum stage of harvest has a significant influence on the quality of a seed. The seed maturation however, is closely associated with fruit maturation but may occur independently (Nurul *et al.*, 2022). The suitable stage of harvest could also vary from cultivar to cultivar. For most crop species, the more matured the fruit is at harvest, the higher the quality of its seeds (Ibrahim and Oladiran, 2011; Bortey *et al.*, 2022). Diana *et al*. (2018) also reported that different seeds within a fruit do not mature at the same rate. This therefore suggests that the different seeds contained in a fruit are of different ages and therefore of varying qualities.

Apart from the inherent variation that exists among seeds of the same fruit and among fruits of the same plant, it has also been found that farmers also add to this variation due to the post-harvest measures fruits are subjected to. Depending on the level of the pressure on land, some farmers harvest melon fruits as soon as leaves senesce (wither) while others may not gather the fruits until all the vines have dried. Also, while some farmers harvest fruits and commence processing by breaking open the fruits on harvest day others may pile up the fruits for days before the commencement of the process of seed extraction. It has been reported that fruits harvested even before physiological maturity and allowed some days of post-harvest ripening may produce good quality seeds since seed development continues in fleshy fruits owing to continuous supply of nutrients and food reserves from fruit to seed (Barroso *et al.,* 2017).

Therefore, it is recommended from this study that for optimum seed quality, fruits of *Cucumeropsis mannii* should be harvested when all leaves on the plant are dry. For higher seed quality still, harvested fruits should be stored to after-ripen for about 10 - 20 days before processing (Kortse and Oladiran, 2013). The significant improvement in fruit weight and seed yield recorded when fruits were stored for twenty days before processing in this study suggests that seed filling continued in stored fruits. This explanation agrees with that of Passam *et al.* (2010) who also recorded seed filling in-situ and hence higher seed weight of after-ripened fruits of eggplant. The significantly bigger fruits obtained in 2005 in comparison to the subsequent years may have been responsible for the significantly greater seed yields per fruit that were later obtained.

A study conducted by (Seal *et al.,* 2013) noted that there was a positive linear correlation between fruit weight and seed dry weight on kiwifruit. They stated that flowers that opened earlier had a larger ovary and set larger seeds leading to large fruits explaining that this may be because of either their innate superiority or their position on the vine. The decline in seed viability after a storage period of one or two years is indicative of seed deterioration which is linked with disruption of cell organelles due to free radical production in the cells of embryos (Ratajczak *et al*., 2019). Fruits of garden egg left on the mother-plant to mature delay the development of new fruits. Farmers generally believe that once seeds are not fully ripened, they would not germinate. They therefore allow fruits from which seed extraction is intended to over-ripen on the stand before harvest. Rao *et al.* (2017) advised that seeds should be harvested at proper time to ensure their quality in terms of germinability and vigour. Some farmers allow ripened garden egg fruits to remain and dry on the mother-plant before harvest. Even after harvest, such fruits remain intact with seeds preserved in them and are extracted only when they are to be planted. Others on the other hand harvest the ripe fruits and either slice or cut open to facilitate proper drying in the sun. These dried fruit parts are also stored with seeds preserved for extraction at the time of sowing. It is therefore important that seed farmers obtain information about when to harvest, and the post-harvest handling operations required (Kortse *et al.,* 2017). In a study conducted to determine the effects of season, time of fruit harvesting and after-ripening durations on the quality of ‘egusi’ melon seeds, Kortse and Oladiran (2013) found out that after-ripening duration significantly influence 100 seed-weight and germination percentage while the other parameters studied (i.e. fruit weight, number of seeds per fruit and dry seed weight per fruit) were not significantly affected.

However, for okra seed production, fruits are left on the mother- plant until they are dry before harvested. The seed crop requires the right stage of maturity followed by proper drying to ensure high germinability after harvest and storage. This is because seed longevity is known to be influenced by the initial seed quality, which is affected by the production procedure (Bortey and Dzomeku, 2016). Ibrahim *et al*. (2017a) recommended that for optimum seed quality, fruits of *Solanum macrocarpon* L. should be harvested when all leaves on the plant are dry. For higher seed quality still, harvested fruits should be stored to after-ripen for about 10 - 20 days before processing.

2.11 Effect of Temperature and Moisture Content on Seed Quality

There are several factors influencing the longevity of seed in any storage environment. These include genotype of the seed, initial seed quality, seed moisture content, temperature and relative humidity of the storage environment and storage periods (Ibrahim *et al*., 2013a; Nadarajan *et al.,* 2023).

Simic *et al*. (2007) reported that within the same plant species, different varieties may exhibit different storing abilities either from genetic variations or other external factors. Seed moisture content is the most important factor that influences seed longevity in any storage environment (Kim, 2018). Hence, seed must be dried to safe moisture level before storage. However, unfavourable storage conditions, particularly high temperature and relative humidity contribute to accelerating seed deterioration (Wang *et al.,* 2018) High relative humidity and temperature cause high moisture content in seeds and result in low germination at the end of storage (Sawant *et al*., 2012).

Biological and biochemical activities occur only when moisture is present. Hence, for safe storage of seed, both the moisture content of the seed and that of the surrounding air should be reduced and monitored (Angelovic *et al.,* 2018). Moisture content plays a significant role in the storage of seed, when seed has more moisture, it heats up and can have mold spoilage (Mukkun *et al.,* 2018). As a general expression, the higher the moisture content, the more susceptible the maize seed is to mold and insect deterioration (Suleiman *et al.,* 2018). Seed moisture content (MC) plays a critical role in determining the longevity of seed in several vegetables (Wang *et al*., 2001). Generally, seeds are harvested at high moisture content and need to be dried before storage with a careful attention to the rate and extent of post-harvest drying (Babiker *et al*., 2010). Moisture content is an important factor in seed viability due to the role of water in the activity of the processes which determine the vigour and longevity, and which allow the development of insects and storage fungi. High temperatures accelerate physiological damage in seed. Consequently, seed longevity can be increased by not only reducing seed moisture content but the storage temperature as well. Seed death is indicated by the failure to germinate and seed longevity in the period until seed death occurs (Wanda *et al.*, 2019).

The principal purpose of seed storage is to preserve economic crops from one season to another. Storage temperature and moisture content are the most important factors affecting seed longevity, with seed moisture content usually being more influential than temperature. Many investigators reported that the speed of decline in seed quality is largely dependent on storage temperature, relative humidity, seed moisture content, length of storage, type of seed and seed quality.

Alhamdan *et al*. (2011) investigated the effect of storage temperature and moisture content on the vigour of onion seeds. The seed quality declined as storage temperature and seed moisture content increased. Khaldun and Haque (2009) studied the effect of temporal variation on the cucumber (*Cucumis sativus)* seed quality. They reported that the maximum germination parentage was observed when moisture contents was 10.66 and 10.95 but slightly decreased when the moisture content attained at 11.03 and 11.08, respectively. The declination of germinability with high moisture content is related to the hygroscopic (moisture absorption) nature of seeds, especially under worm temperatures, which in turn is associated with the relative humidity of the surrounding air (Alhamdan, 2011). After ten months of storage period, maximum decrease in all the seed quality parameters with higher moisture content was noticed in tomato seeds (Alhamdan, 2011). As the general rule the lower the seed moisture content and temperature are the longer the seed survival (Tangney *et al*., 2019).

Cold storage of lettuce seed is preferable, but when uncontrolled ambient storage is necessarily practiced in different regions, seeds should be stored at low seed moisture contents of approximately 7% and storage no longer than 4-6 months at a maximum in order to keep viability for commercially acceptable level (Tangney *et al*., 2019).

2.12 Effect of Seed Dormancy on Germination

Okra crop exhibits seed hardness that complicates its management. This seed hardness interferes with seed germination and other management factors (Vishal *et al.*, 2018). It was reported that the percentage of hard seediness increased significantly in all cultivars with the increase in the maturity of seed. This may be due to the deposition or development of hard cuticle or impermeable cell layer of the seed coat during the later stages of seed development (Vishal *et al.*, 2018). It has been reported that seeds that were harvested in pods in middle and lower part of the plant than upper part of plant produced more seed germination and less seed hardness. Ekwealor *et al*. (2019) has reported that seeds from pods located in the middle of the plant had higher germination.

The occurrence of hard seediness and the low percentage of seed germination are major challenges in growing okra. The percentage of seed germination of okra is frequently low, due to tegument impermeability and is the major barrier to the emergence of okra seeds for commercial producers .The percentage of hard seediness varies among the cultivars with some cultivars not having hard seediness or having a low percentage of hard seeds that doesn’t impose any impedance on their germination, whereas for other cultivars the high percentage of hard seeds does not allow them to germinate, or allows only for low germination percentage (Vishal *et al.*, 2018). Tough seed coats may regulate germination by establishing a permeability barrier that can interfere with the water uptake required for imbibition and subsequent radicle emergence; for gaseous exchange, particularly oxygen uptake required for respiration; and/or for the outward diffusion of endogenous germination inhibitors. Typical characteristics of hard seeds are seed coats having permeability to water but not to gases or vice versa (Babale *et al.*, 2018).

Seed dormancy results in non-uniform and delayed germination which makes scheduling of farm operations difficult. *Solanum* species are mainly propagated by seed and studies have shown that their seeds have a certain period of time with reduced ability to germinate (Chiara *et al*., 2020). According to the Nikolaeva-Baskin classification system, there are five classes of seed dormancy, that is, physiological dormancy (PD), morphological dormancy (MD), morpho-physiological dormancy (MPD), physical dormancy (PY), and combinational dormancy (PY + PD) (Thompson, 2010; Baskin and Baskin, 2014). PD is caused by low growth potential of the embryo, and it occurs in three increasing degrees or depths (intensities) of dormancy as follows: non-deep PD < intermediate PD < deep PD. Non-deep PD can be broken by high (≥15°C) or low (0–10°C and wet, i.e., cold stratification) temperatures, depending on the species, and it is the most common kind of seed dormancy on Earth. In temperate regions of the world, intermediate and deep PD can be broken by long periods of cold stratification. However, exposure of seeds with intermediate PD to high temperatures for 2–3 months before the beginning of cold stratification significantly decreases the length of the cold treatment required to break dormancy.

Pallavi *et al*. (2010) utilized temperature treatments to break dormancy of sunflower seeds. Temperature treatments of 60 ^{o}C for 15 minutes significantly increased germination over control by desiccating waxes, weakening the impermeable layer, and allowing water to be absorbed. The poor germinability of lettuce seeds was linked to its freshness since the capacity was significantly promoted over time in storage in all the lots tested (Zahra *et al*., 2011). The study conducted by Ibrahim *et al.* (2011) on the germination behavior of okra seeds showed that germination percentages were low prior to storage but that general increases were noticeable with time in storage before decline set in. Similar result was recently reported in *C. olitorius* by Ibrahim *et al.* (2013b).

2.13 Effect of Seed Age on Quality Components of Seed

All living things age, including seeds, which contain embryonic plants, lying dormant, waiting to break their protective coats and push through the soil. As a seed ages, the tiny living plant consumes the nutrients stored inside the seed around it. When all the nutrients are consumed, the embryo must grow or wither. Some seeds lose viability rather quickly, but others contain plants that have well-developed survival mechanisms (Ibrahim *et al*., 2017b). Those embryonic plants sink baby roots and lift their first leaves, called cotyledons, through the soil when they receive cues from their environment. These cues may be any combination of soil temperature, moisture and light and differ for each plant. By keeping seeds cool at 40 ^{o}C or lower and dry 8% relative humidity or lower their drive to germinate can be repressed. As seeds age, the embryos still wither, decreasing the number of viable seeds, or rate of germination. Seeds packaged for the current year should have an 80% or higher germination rate, but as the seed ages, the germination rate decreases (Reynolds, 2018).

Many biochemical changes are linked to the process of seed deterioration and the changes during accelerated aging were mostly the same as those in natural ageing with only difference being the rate at which they occur. Decreased vigour and viability follow increased ageing. Impairment in the quantity and quality total soluble protein content and protein profiles also showed alteration in their number and intensity of bands in aged seeds. Quantitative and qualitative changes in protein were detected during ageing (Radha *et al.*, 2014).

In rapid and slow ageing (natural ageing), the pattern of deterioration preceding the death is the same whether seed survives for few hours or decades. Accelerated ageing is an important procedure for understanding the events that lead to the loss of seed viability (Zhang *et al*., 2021). Many hypotheses have been proposed regarding causes of seed ageing such as loss of vigour and viability in terms of germination due to many physiological changes like cell membrane perturbation in deteriorated seeds (Brar *et al.*, 2019). Physiological markers (germination, seedling vigour) are universally adopted as classical tools to understand the mechanism of seed deterioration in terms of vigour potential.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Location

The study was carried out at the Teaching and Research Farm of the Federal University of Technology, Minna (latitude 9^0 51 N and longitude 6^0 44E), for two cropping seasons (2019 and 2020). Minna is located in the Southern Guinea Savanna ecological zone of Nigeria. The agro ecology has a tropical climate with two distinct seasons, the rainy season with average annual rainfall of 1200 mm, distributed between April and early October with the peak around August. The dry season occursbetween October and April, with temperature ranging from 35^oC to 37.5^oC. The relative humidity ranges between 40 % and 60 % around January and increases to between 60 and 80 % towards October. Soils of Minna originated from the Basement Complex rocks and generally are classified as Alfisols (Lawal *et al*., 2012).

3.2 Source of Seeds

Seeds of okra cultivars (NHAe47-4 and LD 88-1) were sourced from the National Horticultural Research Institute (NIHORT) Ibadan, Nigeria. Both varieties are popular varieties grown by farmers in the Southern Guinea Savanna; they show good adaptation to the local environment.

3.2.1 Varietal characteristics

NHAe47-4 is characterized by early flowering with thick fresh pods. It is a late maturing plant of about 120 days, short to medium in height and with deeply lobed leaves and profuse branching (Iyagba *et al*., 2013). LD 88 is also a late maturing variety. Number of branches per plant is high, long pod, thick fruits and spineless fruits (Nigerian Seed Portal Initiative, 2023).

3.3 Soil Sampling and Analysis

Soil samples were collected from surface (0-30cm) with an auger from 10 points along four diagonal transects, each bulked together to give four composite samples. The soil samples were air dried and sieved with 2mm mesh sieve. The soil samples werethen subjected to routine physical and chemical analyses according to the procedure described by Agbenin (1995).

3.4.1 **Experiment 1:** Effect of nitrogen application rate on growth, fruit and seed yields of two okra cultivars

3.4.1.1 *Treatments and experimental design*

The experiment was a 2 x 5 factorial treatment combination of two okra cultivars (NHAe47-4 and LD 88-1) and five N levels (0, 30, 60, 90, and 120 kg N ha^{-1}) arranged in a Randomized Complete Block Design (RCBD) with three replications. Each net plot size was 2m × 5.25m with a gross plot of 10.5m^2 comprising eight ridges of 2m long. The spacing between treatment plots was 0.5m and 1m between replicates. The total size of the experimental field was 24.5 x 17.75 = 434.875m^2.

3.4.1.2 *Agronomic practices*

The land was manually cleared and ploughed with a tractor mounted plough. Ridges were constructed manually at 75 cm apart each measuring 2 m long with 1m apart between each plot. Inter row spacing were 75 cm while intra row spacing was 50 cm. Two seeds were manually sown per hole and then thinned to one seedling per stand two weeks after seedling emergence.

Fertilizers were applied at the rate of 50 kg ha^{-1} each of P_2O_5 and K_2O to all the plots as basal application 2 weeks after sowing (WAS), using single super phosphate and muriate of potash as sources respectively. Nitrogen application were split applied using urea (46 % N) as source at 2 WAS, and at 4 WAS (before flowering). Fertilizer was applied by side placement, 5 cm away from the plant and about 5 cm deep and then covered. Manual weeding commenced at 2 WAS and as found necessary afterwards till the end of the experiment. Incidence of insect pests was controlled with the application of Zap® (Lambda Cyhalothrin 25g/L) at 0.005kg a.i/ha at 2weeks intervals.

3.4.1.3 *Crop performance indices*

In this study, crop performance was measured by the activities on the field of plant growth, fruit and seed yield characters of the two okra varieties for the two cropping seasons (2019 and 2020).

3.4.1.4 *Data collection*

The following growth and yield parameters were taken from the net plot (2m × 5.25m) and means were recorded:-

Days to first flower bud sight- this was determined by counting the number of days from sowing to the first flower bud sight on any plant in a plot.

Days to first flower opening –This was determined by counting the number of days from sowing to the first flower opening on any plant in a plot.

Days to 50% flowering- This was recorded by counting the number of days from sowing to when half of the plant population on a plot had flowered.

Plant height –Plant height at different stages of plant growth was measured from the base of the plant to the tip of the terminal leaf, using a meter rule at first flower bud sight, first flower bud opening, 50% flowering and when plant was fully matured (at its peak of growth).

PLATE I: A picture showing the open

PLATE II: A clear picture of a flower bud about to full bloomed flower

PLATE III: A picture of the field showing 50% flowering

Number of leaves- Number of leaves at different stages of growth was determined by counting the number of leaves at first flower bud sight, first flower opening, 50% flowering and at plant maturity, excluding the coteledonary leaves (first leaves on the shoot).

Stem girth – Stem girth was determined by measuring the stem at 5cm from the base of the plant with the use of Vernier caliper at first flower bud sight, first flower opening, 50% flowering and at maturity.

Leaf area – Leaf area was determined by measuring the length of the mid-rib of the leaf and the breadth using a meter rule.

Number of productive branches- This was determined by counting the number of branches that produced fruit(s) on the plant at maturity per plot.

Flower abortion incidence- This was achieved by counting the number of flowers that fell per plant after formation (opening) at plant maturity.

Number of fresh fruits – Number of fresh fruits per plot was determined by counting fruits harvested per plot, fruits were picked at five-day interval.

Weight of fresh fruits – Weight of fresh fruits per plot was determined by weighing fruits at each harvest per plot using The Mettler weighing balance and the sum of all the weights were recorded.

Fresh fruit diameter- Fresh Fruit diameter was determined by measuring the fruit with the use of a Vernier caliper at the point where the fruit was widest (middle).

Fresh fruit length – Fruit length was determined by using the meter rule to measure the fruit from the base to the tip of the fruit.

Dry fruit diameter- Dry fruits diameter was determined by using the Vernier caliper to measure the dry harvested fruit at the point where the fruit was wider (middle). Fifteen fruits were randomly sampled and divided into 3 replicates for the measurements.

Dry Fruit Length – Dry fruit length was determined by using the meter rule to measure dry fruits from the base to the tip of the fruits.

Number of seeds per fruit - This was determined by counting the number of seeds per fruits in four replicates and the means were recorded per plant per plot.

Weight of seed – The weight of seeds per fruit was aimed at determining the seed yield. This was determined by weighing the seeds on Mettler balance; the sum of all the weights were calculated and recorded per plot.

100–Seed weight determination- Four replicates of 100 seeds from each seed lot were counted and weighed on a Mettler balance and the means were calculated and expressed in grams.

Seed quality test

3.4.2 Experiment II: Effect of nitrogen application rate and fruit harvesting stages on seed quality of two okra cultivars.

3.4.2.1 *Treatments and experimental design*

The experiment was 2 x 5 x 7 factorial treatment combinations of two okra cultivars (NHAe47-4 and LD 88-1), five nitrogen rates (0, 30, 60, 90, and 120 kg N ha^{-1}) and seven fruit harvesting stages (14, 21, 28, 35, 42, 49 and 56 days after anthesis) arranged in a Completely Randomized Design (CRD) and replicated four times.

3.4.2.2 *Fruit tagging and harvesting*

The experiment was carried out in the laboratory of the crop production department of the Federal University of Technology Minna. Flowers were date tagged on the field immediately they opened on the plants daily which is an index of anthesis. Successfully tagged flowers were harvested at different maturity stages (14, 21, 28, 35, 42, 49 and 56) days after anthesis from the first positions on the mother-plant.

3.4.2.3 *Seed handling*

Following each harvest on the field, fruit diameter and length were measured using the venier caliper and means of the respective parameters were recorded.

Number of seeds per fruit was recorded by counting the number of seeds per fruit and means were recorded.

The weights of seeds per fruit were taken using a The Mettler balance; the sum of all the weights was calculated and recorded per plant. Fruits were broken to extract the seed. The seeds were left to dry further at room temperature for two weeks before storage.

PLATE IV: Samples of harvested fruits at 14-28 Days after anthesis (Dark green)

PLATE V: Samples of harvested fruits at 35 Days after anthesis (light green fruit, ridges had begun to split)

PLATE VI: Samples of harvested fruits at 42 DAA (Straw color and ridges completely split)

PLATE VII:A n image of an Okra fruit at 42 DAA on the mother-plant

PLATEVIII: Okra fruit at 49 and 56 DAA (Greyish color and exposed to weathering)

3.4.2.4 *Seed moisture content determination*

The initial moisture content (MC) of the seed was determined using the oven drying method at 130 °C for one hour (ISTA, 2006) and were expressed on wet weight basis as follows:

$$\frac{\text{Weight of wet seeds} - \text{weight of oven dried seeds}}{\text{Weight of wet seed}} \times 100 \qquad (1)$$

3.4.2.5 *Seed quality indices*

In this study, germination and Electro-conductivity tests were used as seed quality indices.

3.4.2.6 *Electro-conductivity test*

Fifty seeds each of two cultivars were counted for each of the treatment into beakers to which 30 ml of distilled water was added. The seeds were left in water for 24 hours after which the mixture was stirred and the supernatant decanted into clean beaker (ISTA, 2006). The electro-conductivity of the supernatant was measured using Jenway DDS-307 conductivity meter. The results were expressed as mean $\mu Scm^{-1}g^{-1}$ seeds.

3.4.2.7 *Seed storage*

Samples of seeds of each of the treatment combinations were put in small open plastic plates measuring 300 ml and then placed in an incubator at 35 °C and relative humidity of 90 %. This was aimed at accelerating the ageing of the seeds to determine the relative longevity of the seeds of the different lots (Delouche and Baskin, 1973). The seeds were stored in this environment for 4 weeks and seed samples were drawn for germination test prior to storage and at two week intervals after wards for 4 weeks.

3.4.2.8 *Seed germination test*

Samples were drawn from the containers in storage for germination test at 0, 2 and 4 weeks after storage. This was done by counting four replicates of 50 seeds each of the treatment combinations which were placed on filter paper moistened with distill water in plastic Petri-dishes. Germination counts were taken every-other-day and results were expressed in percentages.

PLATE IX: Setting up seeds in the petri dishes

PLATE X: Sprouted seeds from the germination test

3.4.3 **Experiment III;** Effect of nitrogen application rate and fruit position on mother-plant on seed quality of two okra cultivars.

3.4.3.1 ***Treatments and experimental design***

The experiment was 2 x 5 x 6 factorial treatmentcombinations of two okra cultivars (NHAe47-4 and LD 88) five nitrogen rates (0, 30, 60, 90, and 120 kg N ha^{-1}) and six fruit positions on the mother-plant (1, 2, 3, 4, 5 and 6th) arranged in a Completely Randomized Design (CRD) and replicated four times.

3.4.3.2 *Fruit harvesting*

The experiment was carried out in the laboratory of the crop production department of the Federal University of Technology Minna. Plants were date tagged at flowering daily on the field. The tagged fruits were harvested at different positions on the mother-plant (1, 2, 3, 4, 5, 6 and 7) at 42 DAA (Days after anthesis). Following each harvest, the fruits were broken to extract the seeds. The seeds were left to dry further at ambient temperature for about two weeks before storage.

PLATE XI: A picture of okra showing positions of fruits on the mother-plant

PLATE XII: Positions of fruits at 42 DAA on the mother-plant

3.4.3.3 *Seed moisture content determination*

The initial moisture content (MC) of the seed was determined using the oven drying method at 130 °C for one hour (ISTA, 2006). This was expressed on wet weight basis as follows:

$$\frac{\text{Weight of wet seeds – weight of oven dried seeds}}{\text{Weight of wet seed}} \times 100 \qquad (2)$$

3.4.3.4 *Electro-conductivity test*

Fifty seeds each of two cultivars were counted for each of the treatment into beakers to which 30 ml of distilled water was added. The seeds were left in water for 24 hours after which the mixture was stirred and the supernatant decanted into clean beaker (ISTA, 2006). The electro-conductivity of the supernatant was measured using Jenway DDS-307 conductivity meter. The results were expressed as mean $\mu Scm^{-1}g^{-1}$ seeds. Electro-conductivity test is an index of seed quality.

3.4.3.5 *Seed storage*

Samples of seeds of each of the treatment combinations were put in small open plastic plates measuring 300 ml, and then placed in an incubator at 35 °C and a relative humidity of 90 %. This was aimed at accelerating the ageing of the seeds to determine the relative longevity of the seeds of the different lots (Delouche and Baskin, 1973). The seeds were stored in this environment for 4 weeks and seed samples were drawn for germination test prior to storage and at two weeks afterwards for 4 weeks.

3.4.3.6 *Seed germination test*

Samples were drawn from the containers in storage for germination test at 0, 2, and 4 weeks after storage. This was done by counting four replicates of 50 seeds each of the treatment combinations which were placed on filter paper moistened with distill water in plastic Petri-dishes. Germination counts were taken every-other-day and results were expressed in percentages.

3.5 Data analysis

The data collected were subjected to analysis of variance (ANOVA) using Statistical analysis system (SAS, 2013) version 9.2. Means were separated using Least Significant Difference (LSD) test at 5 % level of probability. Data in percentages were transformed to arcsin before statistical analysis if there were wide variations between mean values.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSIONS

4.1 Results

4.1.1 Soil properties of the experimental sites

The results of the chemical and physical properties of the soil at the experimental sites before the two cropping years 2019 and 2020 are presented in the Table 4.1. The particle size distribution showed that the soil of the site is sandy loam in texture with a moderate pH indicating the soil to be slightly acidic (H_2O) 6.7, 6.8 and (CaCl) 5.5, 6.1, respectively. Soil organic carbon (SOC) of 4.50(gkg^{-1}), 4.51(gkg^{-1}) and Soil Total N of 1.21 (gkg^{-1}), 1.23(gkg^{-1}) was found to be low. The available phosphorus for the two cropping years 2019 and 2020 were 8.25, 8.50(mg kg^{-1}) and ECEC 8.2, 7.69($cmol^{+}$ kg^{-1}), respectively of the soil samples were also found to be low. The exchangeable bases ($Cmol^{+}$ kg^{-1}) Ca2+ 3.75, 3.85, K+ 0.17, 1.55 and Na+ 0.07, 0.03, respectively were considered to be moderate. The exchangeable Mg^{2+} 3.0, 2.90 was considered sufficient to support plant growth (Marschner, 2012).

4.1.2.1 Days to first flower bud sight, opening and 50 % flowering

The effects of nitrogen application rates on days to first flower bud sight, opening and 50 % flowering of two okra cultivars in 2019 and 2020 are presented in Table 4.2. Days to first flower bud site and opening were significantly different among the cultivars in 2019, but there was no significant difference on days to 50 % flowering in 2019. At first flower bud sight in 2019, LD 88-1flowered significantly (59 days) than NHAe47 – 4 which took longer days to first flower bud sight (60 days).

Table 4.1: **Physical and chemical properties of the soil samples of the experimental field**

Soil Properties	2019	2020
Particle Size distribution (g kg^{-1})		
Sand	813	814
Silt	109	110
Clay	78	76
Textural class	SL	SL
pH (1:2)		
H_2O	6.7	6.8
Kcl or $Cacl_2$	5.5	6.1
Total N (g kg^{-1})	1.21	1.23
Organic C (g kg^{-1})	4.50	4.51
Available P (mg kg^{-1})	8.25	8.50
Exchangeable bases ($Cmol^+$ kg^{-1})		
Ca^{2+}	3.75	3.85
Mg^{2+}	3.00	2.90
K^+	0.17	1.55
Na^+	0.07	0.03
Exchangeable acidity (Cmol kg^{-1})		
Al^{3+} H^+	0.8	0.70
ECEC	8.2	7.69

SL: Sandy Loam

Table 4.2: Effect of nitrogen application rates on days to first flower bud site, opening and 50 % flowering of two okra cultivar in 2019 and 2020

	First flower bud sight		First flower bud opening		50 % flowering	
	2019	2020	2019	2020	2019	2020
Cultivar (C)						
NHAe47-4	60.0a	63.87a	72.0b	73.93a	84.0a	86.67a
LD 88-1	59.0b	63.73a	74.0a	73.67a	84.0a	83.80a
LSD (0.05)	1.72	2.08	2.41	2.27	3.58	3.87
N(kgha^{-1})						
0	61.0a	65.17a	71.0b	75.50a	88.0a	88.00a
30	62.0a	63.33a	73.0ab	73.33a	86.0a	88.00a
60	58.0bc	63.00a	72.0ab	72.50a	78.0b	81.50b
90	60.0ab	63.50a	73.0ab	73.67a	81.0b	83.17ab
120	57.0c	64.00a	75.0a	74.00a	87.0a	85.50ab
LSD (0.05)	2.72	3.28	3.80	3.40	5.66	6.12
Interaction						
C x N	NS	NS	NS	NS	NS	NS

Means with the same letter(s) under the same column are not significantly different from each other at $P \leq 0.05$ according to LSD.

At first flower bud opening in 2019, NHAe47 – 4 recorded the earliest days to first flower bud opening (72 days) than LD88-1 which had the longer days to first flower bud opening (74 days). Nitrogen rates had a significant effect on days to first flower bud site, opening and 50 % flowering. At first flower bud site in 2019, the application of 120 kg N ha^{-1} had the earliest days to first flower bud sight (57 days) than the other nitrogen rates compared with 0 and 30 kg N ha^{-1} which recorded statistically similar longest days to first flower bud sight (61 and 62 days). At first flower bud opening in 2019, zero application had the earliest days to first flower bud opening (71days) than the plots with nitrogen application compared with the application of 120 kg N ha^{-1} which took longer days to first flower bud opening (75 days). At 50 % flowering in 2019, the applications of 60 and 90 kg N ha^{-1} produced statistically similar earliest days to 50 % flowering (78 days and 81days) than N rates of 0, 30 and 120 kg N ha^{-1} which had similar longest days to 50 % flowering (88, 86 and 87 days). In 2020, the application of 60 kg N ha^{-1} had the earliest days to 50 % flowering than the other rates compared with 0 and 30 kg N ha^{-1} which had similar longest days to 50 % flowering (88 days).

4.1.2.2 *Number of leaves*

The effect of nitrogen application rates on number of leaves of two okra cultivars at different stages of growth in 2019 and 2020 are shown in Table 4.3. Number of leaves was significantly different among the okra cultivars at first flower bud sight in 2020, first flower bud opening and at maturity in 2019. The cultivar LD 88-1 produced significantly higher number of leaves (20.0), at 50% flowering than NHAe47 – 4 which produced the lower number of leaves (19). Nitrogen rates had a significant effect on number of leaves throughout the growth stages except at 4 WAS in 2020, first flower bud sight and at maturity in 2019 which were not significant. At 4 WAS in 2019, the application of 60 kg N ha^{-1} resulted in significantly higher number of leaves (7.67) statistically similar with the application of 30 and 90 kg N ha^{-1} (6.83 and 7.50) respectively, compared with zero application which recorded the lowest number of leaves (5.50) similar with the application of 120 kg N ha^{-1} (6.00). At first flower bud sight in 2020, the application of 120 kg N ha^{-1} produced significantly higher number of leaves which is statistically similar with the applications of 60 and 90 kg N ha^{-1} (10.0) compared with the applications of 0 and 30 kg N ha^{-1} which recorded statistically similar lowest number of leaves (9.50 and 9.83) respectively.

At first flower bud opening, the application of 120 kg N ha^{-1} consistently recorded the highest number of leaves (10.50 and 14.2) in both years, respectively than the other rates compared with zero application in 2019 (12.0), zero application, 30 and 60 kg N ha^{-1} which recorded similar lowest number of leaves (13.17, 14.67 and 14.67) in 2020, respectively in this study. At 50 % flowering, all the plots with nitrogen application recorded significantly similar highest number of leaves than zero application which had the lowest in 2019. In 2020, the applications of 90 and 120 kg N ha^{-1} recorded significantly highest number of leaves (17.67) though statistically similar with the other rates of nitrogen applications compared with zero application which recorded the lowest number of leaves (14.0).

At maturity in 2020, the application of 60 kg N ha^{-1} recorded higher number of leaves (4.83) than the other rates compared with zero application which had the lowest number of leaves (3.33) in this study.

Table 4.3: Effect of nitrogen application rate on number of leaves of okra cultivars at different growth periods in 2019 and 2020

	Number of leaves									
	At 4 WAS		First Flower bud sight		First Flower bud opening		50 % flowering		At maturity	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Cultivar (C)										
NHAe47-4	6.0a	4.73a	12.0a	9.60b	12.0b	15.00a	19.0a	16.00a	3.0b	4.00a
LD 88-1	7.0a	4.87a	12.0a	10.33a	14.0a	14.73a	20.0a	17.27a	4.0a	4.13a
LSD (0.05)	1.03	0.46	0.60	0.36	0.62	1.46	1.27	2.01	0.49	0.35
N (kgha^{-1})										
0	5.50c	4.67a	12.0a	9.50b	12.0c	13.17b	17.0b	14.00b	3.0a	3.33c
30	6.83abc	4.50a	12.0a	9.83b	13.0bc	14.67b	19.0a	16.67ab	4.0a	4.33ab
60	7.67a	4.83a	12.0a	10.00ab	13.0bc	14.67b	19.0a	17.17ab	3.0a	4.83a
90	7.50ab	5.17a	12.0a	10.00ab	13.3ab	14.83ab	21.0a	17.67a	4.0a	3.83bc
120	6.00bc	4.83a	12.0a	10.50a	14.2a	17.00a	21.0a	17.67a	4.0a	4.00b
LSD (0.05)	1.63	0.73	0.95	0.58	0.98	2.31	2.01	3.17	1.78	0.56
Interaction										
C x N	NS	NS	NS	NS	NS	**	NS	NS	*	NS

Means with the same letter(s) under the same column are not significantly different from each other at P≤ 0.05 according to LSD.

The interaction between cultivar and nitrogen rates on number of leaves at different maturity periods in 2019 and 2020 is shown in (Table 4.4). At first flower bud opening in 2020, the combination of NHAe47 – 4 with application of 120 kg ha^{-1} produced significantly highest number of leaves (19.00) than the other combinations compared with the combination of NHAe47 – 4 with application of 0 and 30 kg ha^{-1} which recorded the lowest number of leaves (11.67 and 12.00), respectively. At maturity in 2019, the combination of LD 88-1 with 120 kg ha^{-1} produced the highest number of leaves (5.0) compared with the combination of NHAe47 – 4 with application of 0 and 30 kg ha^{-1} which produced the lowest number of leaves (2.0 and 2.0), respectively.

Table 4.4: Interaction of cultivars and nitrogen application rates on number of leaves at first flower bud opening in 2020 and at maturity in 2019

	N (kgha^{-1})				
	0	**30**	**60**	**90**	**120**
			First flower bud opening in 2020		
Cultivar					
NHAe47- 4	11.67g	12.00g	15.33c	17.00b	19.00a
LD 88-1	14.67d	17.33b	14.00e	12.67f	15.00cd
LSD (0.05)			1.10		
			At maturity in 2019		
Cultivar					
NHAe47- 4	2.0d	3.0c	2.0d	4.0b	3.0c
LD 88-1	4.0b	4.0b	4.0b	4.0b	5.0a
LSD (0.05)			0.80		

Means with the same letter(s) in the same column are not significantly different from each other at $P \leq 0.05$ according to LSD.

4.1.2.3 *Plant height*

The effect of nitrogen application rates on plant height of two okra varieties at different stages of growth in 2019 and 2020 cropping season were shown in Table 4.5. Cultivar affected all the growth stages in both cropping seasons except at maturity in 2020. At 4 WAS, LD 88-1 produced taller plants (10.55 cm) than NHAe47 – 4 which produced the shortest plants (8.96 cm). In 2020, NHAe47 – 4 produced the tallest plants (8.96 cm) than LD 88-1 which had the shortest (7.61 cm). At first flower bud sight, the cultivar LD 88-1 consistently produced the tallest plants (49.13 and 45.29 cm) while NHAe47 – 4 consistently produced the shortest plants (38.18 cm and 42.27 cm) in both years, respectively. At first flower bud opening and 50 % flowering in 2019, NHAe47 – 4 produced taller plants (60.12 cm) and (84.98 cm), respectively than LD 88-1 which had the lowest (55.63 cm) and (75.14 cm). In 2020, LD 88-1 produced the taller plants (74.22 cm) than NHAe47 – 4 which produced the shortest plants (57.69 cm) (78.75 cm). At maturity in 2019, LD 88-1produced taller plants (104.85 cm) than NHAe47 – 4 which produced the shortest plants (89.91 cm).

Nitrogen application rates had a significant effect on plant height in this study except at first flower bud opening, 50 % flowering and at maturity in 2020. At 4 WAS in 2019, the application of 90 and 120 kg N ha^{-1} recorded significantly similar tallest plants (10.48 cm and 10.52 cm) than the application of 0, 30 and 60 kg N ha^{-1} which recorded statistically similar shortest plants (8.90 cm, 9.18 cm and 9.25 cm). In 2020, zero application recorded taller plants (9.28 cm) which was statistically similar with the applications of 30, 60 and 90 kg N ha^{-1} compared with the application of 120 kg N ha^{-1} which had the shortest plants (7.70 cm). At first flower bud sight in both years, the application of 120 kg N ha^{-1} consistently recorded significantly tallest plants (51.28 cm and 53.20 cm) than all the other nitrogen

Table 4.5: Effect of nitrogen application rate on plant height (cm)of okra cultivars at different growth periods in 2019 and 2020 cropping season

	Plant height (cm)									
	At 4 WAS		First Flower bud sight		First Flower bud opening		50 % flowering		At maturity	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Cultivar (C)										
NHAe47-4	8.78b	8.96a	38.18b	42.27b	60.12a	57.69b	84.98a	78.75b	89.91b	92.58a
LD 88-1	10.55a	7.61b	49.13a	45.29a	55.63b	74.22a	75.14b	94.25a	104.85a	173.21a
LSD (0.05)	0.77	0.96	2.20	0.58	3.13	8.78	4.74	11.35	7.99	141.67
N (Kg ha^{-1})										
0	8.90b	9.28a	36.15d	38.42e	51.42b	63.47a	73.83b	82.53a	65.77d	89.90a
30	9.18b	8.27ab	40.33c	39.82d	59.33a	68.48a	78.72b	93.70a	89.60c	102.10a
60	9.25b	8.22ab	46.43b	40.87c	58.82a	67.10a	80.83ab	83.08a	113.60ab	101.00a
90	10.48a	7.97ab	45.65b	46.60b	58.05a	66.18a	79.18b	80.25a	102.45b	94.20a
120	10.52a	7.70b	51.28a	53.20a	61.75a	64.55a	87.73a	92.93a	115.50a	277.30a
LSD (0.05)	1.22	1.52	3.49	0.91	4.95	13.89	74.49	17.95	12.64	223.99
Interaction										
C x N	*	NS	NS	**	NS	NS	NS	NS	NS	NS

Means with the same letter(s) under the same column are not significantly different from each other at P≤ 0.05 according to LSD.

application rates compared with zero application which consistently recorded the shortest plants (36.15 cm and 38.42 cm) in 2019 and 2020, respectively.

At first flower bud opening in 2019, all the plots with nitrogen application produced similar tallest plants than zero application which recorded the shortest plants. At 50 % flowering in 2019, the application of 120 kg N ha^{-1} produced tallest plants (87.73 cm) than all the other rates which recorded statistically similar shortest plants. At maturity in 2019, the application of 120 kg N ha^{-1} produced significantly taller plants (115.50 cm) than the other rates compared with zero application which recorded the shortest plants (65.77 cm).

The interaction between cultivar and nitrogen application rates on plant height at different maturity periods in 2019 and 2020 is shown in (Table 4.6). At 4 WAS in 2019, the combination of LD 88-1 with 90 kg ha^{-1} produced taller plants (11.40 cm) than the other combinations compared with the combination of NHAe47 – 4 with application of 0 and 30 kg ha^{-1} which produced the shortest plants (7.03 cm and 7.73 cm). at first flower bud sight in 2020, the combination of LD 88-1 with 120 kg ha^{-1} produced the tallest plants (54.80 cm) than the other combinations compared with the combination of NHAe47 – 4 with zero application which produced the shortest plants (36.93 cm).

Table 4.6: Interaction of cultivars and nitrogen rates on plant height (cm) at 4 weeks after sowing in 2019 and at first flower bud site in 2020

	N(kg ha^{-1})				
	0	**30**	**60**	**90**	**120**
			At 4 WAS in 2019		
Cultivar					
NHAe47- 4	7.03e	7.73e	9.07d	9.57bcd	10.50abc
LD 88-1	10.77ab	10.63abc	9.43cd	11.40a	10.53abc
LSD (0.05)			1.25		
			First flower bud sight in 2020		
Cultivar					
NHAe47- 4	36.93h	39.43g	40.53ef	42.83d	51.60b
LD 88-1	39.90fg	40.20fg	41.20e	50.37c	54.80a
LSD (0.05)			0.94		

Means with the same letter(s) in the same column are not significantly different from each other at P≤ 0.05 according to LSD.

4.1.2.4 *Stem girth*

The effect of nitrogen application rates on stem girth of two okra cultivar at different stages of growth in 2019 and 2020 are shown in Table 4.7. Stem girth was significantly different between cultivars at 4 WAS in 2019 and at first flower bud sight in 2020.

At 4 WAS in 2019, the cultivar LD 88-1 produced wider stems (2.36 cm) than NHAe47 – 4 which produced the smallest stems (2.05 cm). At first flower bud sight in 2020, LD 88-1 produced wider stems (6.85 cm) than NHAe47 – 4 which recorded the smallest stems (6.29 cm).

Stem girth differed significantly among the nitrogen application rates among the rates except at 4 WAS, 50 % flowering in 2020 and at maturity in 2019. At 4 WAS in 2019, all the plots with the application of nitrogen produced statistically wider stems than zero application which recorded the smallest stems. At first flower bud sight in 2019, the application of 120 kg N ha^{-1} produced significantly widest stems (8.18 cm) than the other rates compared with the application of 0 and 30 kg N ha^{-1}which produced statistically similar smallest stems (6.38 cm and 6.72 cm), respectively. In 2020, the application of 120 kg N ha^{-1} produced significantly wider stems (7.72 cm) than the other rates compared with zero application which produced the smallest stems (5.88 cm).

At first flower bud opening in 2019, the application of 60 kg N ha^{-1} produced widest stems (6.93 cm) than the other rates compared with zero application which had the smallest stems (6.28 cm). In 2020, the application of 30 kg N ha^{-1} produced widest stems (6.63 cm) than the other rates compared with the application of 120 kg N ha^{-1} which produced the smallest stems (6.02 cm). At 50 % flowering in 2019, the applications of 30, 60 and 90 kg N ha^{-1}

Table 4.7: Effect of nitrogen application rate on stem girth of okra cultivars at different growth periods in 2019 and 2020

	Stem girth (cm)									
	At 4 WAS		First Flower bud sight		First Flower bud opening		50 % flowering		At maturity	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Cultivar (C)										
NHAe47-4	2.05b	2.07a	7.10a	6.29b	6.67a	6.28a	6.89a	6.63a	7.93a	8.06a
LD 88-1	2.36a	1.99a	7.28a	6.85a	6.63a	6.50a	6.92a	6.54a	8.25a	8.10a
LSD (0.05)	0.16	0.18	0.26	0.09	0.32	0.35	0.30	0.39	0.71	0.49
N (kgha^{-1})										
0	1.88b	2.00a	6.38c	5.88e	6.28b	6.33ab	6.47b	6.63a	7.90a	7.63b
30	2.18a	1.98a	6.72c	6.15d	6.78ab	6.63a	7.02a	6.75a	7.85a	8.50a
60	2.28a	2.10a	7.38b	6.38c	6.93a	6.50ab	7.12a	6.40a	8.23a	7.78ab
90	2.42a	2.13a	7.28b	6.73b	6.73ab	6.47ab	7.07a	6.57a	8.47a	8.23ab
120	2.27a	1.93a	8.18a	7.72a	6.50ab	6.02b	6.82ab	6.57a	8.02a	8.25ab
LSD (0.05)	0.26	0.28	0.41	0.14	0.50	0.55	0.48	0.62	1.12	0.79
Interaction										
C x N	NS	NS	NS	**	NS	NS	NS	NS	NS	NS

Means with the same letter(s) under the same column are not significantly different from each other at P≤ 0.05 according to LSD.

produced significantly similar widest stems (7.02 cm, 7.12 cm and 7.07 cm respectively) than zero application which had the smallest stems (6.47 cm). At maturity in 2020, the application of 30 kg N ha^{-1} produced wider stems (8.50 cm) though statistically similar with all the other plots with the nitrogen applications compared with zero application which produced the smallest stems (7.63 cm).

The interaction between cultivar and nitrogen application rates on stem girth at different maturity periods in 2019 and 2020 is shown in Table 4.8. At first flower bud sight in 2020, the combination of NHAe47 – 4 with 120 kg ha^{-1} produced the widest stems (7.70 cm) than all the other combinations compared with the combination of NHAe47 – 4 with zero application which had the smallest stems (5.4 0 cm).

4.1.2.5 *Leaf area*

The effect of nitrogen application rates on leaf area of two okra cultivars at different stages of growth in 2019 and 2020 are shown in Table 4.9. Leaf area differed significantly among the cultivars at 4 WAS in both years. At 4 WAS in 2019, the variety LD 88-1 produced the widest leaves (140.92 cm) than NHAe47 – 4 which recorded the smallest leaves (124.92 cm^2). In 2020, NHAe47 – 4 produced the widest leaves (145.09 cm^2) than LD 88-1 which produced the smallest leaves (115.41 cm^2).

Nitrogen application rates had a significant effect on leaf area at 4 WAS, first flower bud opening and at 50 % flowering in 2020 only. At 4 WAS in 2019, all the plots with the application of nitrogen produced significantly similar widest leaves than zero application which produced the smallest leaves. At first flower bud opening in 2019, the application of 90 and 120 kg N ha^{-1} produced statistically similar widest leaves (582.82 cm^2 and 591.70 **Table**

4.8: Interaction of cultivar and nitrogen rates on stem girth (cm) at first flower bud sight in 2020

	N (kgha^{-1})				
	0	**30**	**60**	**90**	**120**
	first flower bud sight in 2020				
Cultivar					
NHAe47- 4	5.40h	5.70g	6.03f	6.63d	7.70a
LD 88-1	6.36e	6.60d	6.73cd	6.83c	7.33b
LSD (0.05)			0.14		

Means with the same letter(s) in the same column are not significantly different from each other at P≤ 0.05 according to LSD.

Table 4.9: Effect of nitrogen application rate on leaf area of okra cultivar at different growth periods in 2019 and 2020

	Leaf area (cm^2)							
	At 4 WAS		First Flower bud sight		First Flower bud opening		50 % flowering	
	2019	2020	2019	2020	2019	2020	2019	2020
Cultivar (C)								
NHAe47-4	124.20b	145.09a	515.42a	501.85a	548.87a	477.67a	506.38a	419.89a
LD 88-1	140.92a	115.41b	537.19a	516.55a	578.04a	510.18a	525.49a	443.15a
LSD (0.05)	9.13	25.61	34.19	34.01	35.72	57.07	30.24	81.39
N ($kgha^{-1}$)								
0	113.55b	146.07a	497.40a	516.07a	524.10b	455.15a	485.12b	391.35a
30	134.72a	120.92a	526.73a	501.67a	566.38ab	530.72a	534.90a	402.97a
60	135.22a	140.15a	522.00a	509.02a	552.28ab	461.95a	509.55ab	440.37a
90	144.42a	127.08a	546.82a	508.10a	582.82a	508.78a	505.53ab	494.57a
120	134.90a	117.03a	538.58a	511.17a	591.70a	513.03a	544.58a	428.35a
LSD (0.05)	14.44	40.49	54.06	53.78	56.48	90.23	47.81	128.68
Interaction								
C x N	NS	NS	NS	NS	NS	NS	NS	NS

Means with the same letter(s) under the same column are not significantly different from each other at P≤ 0.05 according to LSD cm^2 respectively) than the other rates compared with zero application which produced the smallest leaves (524.10 cm^2). At 50 % flowering in 2019, the application of 30 and 120 kg N ha^{-1} produced statistically similar widest leaves (534.90 cm^2 544.58 cm^2), respectively than the other rates compared with zero application which produced the smallest leaves (485.12 cm^2).

4.1.2.6 ***Number of productive branches/plot***

The effect of nitrogen application rates on number of productive branches of two okra cultivars in 2019 and 2020 are shown in Table 4.10. Number of productive branches was not significantly different between the cultivars in both years in this study.

Number of productive branches differed significantly among the nitrogen application rates in 2019 and 2020 cropping season. In 2019, the application of 60, 90 and 120 kg N ha^{-1} produced significantly similar highest number of branches (5) than zero application which produced the lowest number of productive branches (2). In 2020, the application of 120 kg N ha^{-1} produced the highest number of productive branches (4.5) statistically similar with the application of 90 kg N ha^{-1} compared with the applications of 0 and 30 kg N ha^{-1} which produced similar lowest number of productive branches (2.83).

4.1.2.7 ***Abortion incidence/plot***

The effect of nitrogen application rates on abortion incidence of two okra cultivars in 2019 and 2020 are also presented in Table 4.10. Abortion incidence was not significantly different among the okra cultivars in both years in this study.

Table 4.10: Effect of nitrogen application rates on number of productive branches and abortion incidence/plot of two okra cultivars in 2019 and 2020

	Number of productive branches		Abortion incidence	
	2019	2020	2019	2020
Cultivar (C)				
NHAe47-4	4.0a	3.67a	2.40a	2.20a
LD 88-1	4.0a	3.53a	2.27a	2.53a
LSD (0.05)	0.87	0.45	0.86	0.44
N (kg ha^{-1})				
0	2.0c	2.83c	2.00a	3.50a
30	4.0b	2.83c	2.33a	2.67b
60	5.0a	3.67b	2.83a	1.83c
90	5.0a	4.17ab	2.00a	1.67c
120	5.0a	4.50a	2.50a	2.17bc
LSD (0.05)	1.38	0.70	1.36	0.70
Interaction				
C x N	NS	NS	NS	NS

Means with the same letter(s) under the same column are not significantly different from each other at P≤ 0.05 according to LSD.

Nitrogen rates had a significant effect on abortion incidence in 2020 only, such that the application of 60 and 90 kg N ha^{-1} produced similar lowest abortion incidence (1.83 and 1.67), respectively compared with zero application which produced the highest abortion incidence (3.50).

4.1.2.8 *Fruit diameter/plot*

The effect of nitrogen application rates on fresh fruit diameter of two okra cultivars in 2019 and 2020 are shown in Table 4.11. Fresh fruit diameter was significantly different between the cultivars in 2019 only. The cultivar LD 88-1 produced bigger fruits (12.75 cm) than NHAe47 – 4 which produced the smallest fruits (11.71 cm).

Nitrogen rates had a significant effect on fresh fruit diameter in both years. In 2019, the application of 120 kg N ha^{-1} produced significantly wider fresh fruits (12.97 cm) statistically similar with all the other plots with nitrogen application compared with zero application which had the smallest fresh fruits (11.47 cm). In 2020, the application of 60, 90 and 120 kg N ha^{-1} produced statistically similar widest fresh fruits (12.58 cm, 13.43 cm and 13.45 cm), respectively than 0 and 30 kg N ha^{-1} which had similar smallest fresh fruits (10.33 cm and 10.70 cm), respectively.

The effect of nitrogen application rates on dry fruit diameter of two okra varieties in 2019 and 2020 is also presented in Table 4.11. Dry fruit diameter differed significantly between the cultivars in 2020 only. The variety LD 88-1 produced wider dry fruits (9.08 cm) than NHAe47 – 4 which produced the smallest fruits.

Nitrogen application rates affected dry fruit diameter significantly in both years. The application of 90 and 120 kg N ha^{-1} significantly produced similar widest dry fruits (9.77 cm

Table 4.11: Effect of nitrogen application rates on fresh and dry fruit diameter/plot of two okra cultivars in 2019 and 2020

	Fresh fruit diameter (cm)		Dry fruit diameter (cm)	
	2019	2020	2019	2020
Cultivar (C)				
NHAe47-4	11.71b	12.47a	8.72a	8.69b
LD 88-1	12.75a	11.73a	8.74a	9.08a
LSD (0.05)	0.76	1.15	0.59	0.31
N(kg ha^{-1})				
0	11.47b	10.33b	7.78b	6.28e
30	12.17ab	10.70b	7.85b	9.20c
60	12.47ab	12.58a	8.32b	8.57d
90	12.10ab	13.43a	9.77a	9.83b
120	12.97a	13.45a	9.93a	10.53a
LSD (0.05)	1.20	1.83	0.93	0.49
Interaction				
C x N	*	NS	NS	NS

Means with the same letter(s) under the same column are not significantly different from each other at P≤ 0.05 according to LSD.

and 9.93 cm) than 0, 30 and 60 kg N ha^{-1} which produced statistically similar smallest dry fruits (7.78 cm, 7.85 cm and 8.32 cm), respectively in 2019. The application of 120 kg N ha^{-1} produced bigger dry fruits (10.53 cm) than all the other rates compared with zero application which had the smallest dry fruits (6.28 cm).

The interaction between cultivars and nitrogen rates on fruit diameter in 2019 is shown in (Table 4.12). The combination of LD 88-1 with application of 30 and 60 kg ha^{-1} produced significantly biggest fruits (13.53 cm and 13.83 cm), respectively than the other combinations compared with the combination of NHAe47 – 4 with application of 30 kg ha^{-1} which had the smallest fruits (10.80 cm).

4.1.2.9 *Fruit length/plot*

The effect of nitrogen application rates on fresh fruit length of two okra cultivars in 2019 and 2020 are shown in Table 4.13. Fresh fruit length was significantly different between the okra cultivars in 2019 (1.21cm) and 2020 (9.52cm). The cultivar LD 88-1 consistently produced longer fresh fruits (11.21 cm and 9.52 cm) in both years than NHAe47 – 4 which consistently produced the shortest fresh fruits (9.71 cm and 8.25 cm) in 2019 and 2020, respectively.

Nitrogen application rates had a significant effect on fresh fruit length in both years. In 2019, the application of 60 (11.15cm) and 120 kg N ha^{-1}(11.4cm) produced significantly similar longest fresh fruits statistically similar with the applications of 30 and 90 kg N ha^{-1} compared with zero application which produced the smallest fresh fruits (9.30 cm). In 2020, the application of 90 and 120 kg N ha^{-1} produced similar longest fresh fruits (10.15 cm and

Table 4.12: Interaction of cultivars and nitrogen application rates on fruit diameter (cm) in 2019

	N ($kgha^{-1}$)				
	0	**30**	**60**	**90**	**120**
			fruit diameter in 2019		
Cultivar					
NHAe47- 4	11.83cde	10.80e	11.10de	12.07bcd	12.77abc
LD 88-1	11.10de	13.53a	13.83a	12.13bcd	13.17ab
LSD (0.05)			1.23		

Means with the same letter(s) in the same column are not significantly different from each other at P≤ 0.05 according to LSD.

Table 4.13: Effect of nitrogen application rates on fresh and dry fruit length/plot of two okra cultivars in 2019 and 2020

	Fresh fruit length (cm)		Dry fruit length (cm)	
	2019	2020	2019	2020
Cultivar (C)				
NHAe47-4	9.71b	8.25b	9.86b	8.25b
LD 88-1	11.21a	9.52a	10.79a	9.51a
LSD (0.05)	1.05	0.68	0.23	0.47
N (kgha^{-1})				
0	9.30b	7.23c	9.35d	7.35c
30	10.07a	7.53c	9.82c	7.70c
60	11.15a	8.80b	10.43b	8.97b
90	10.32ab	10.15a	10.90a	10.00a
120	11.48a	10.72a	11.13a	10.38a
LSD (0.05)	1.66	1.08	0.37	0.75
Interaction				
C x N	*	*	**	NS

Means with the same letter(s) under the same column are not significantly different from each other at $P \leq 0.05$ according to LSD.

10.72 cm) compared with 0 and 30 kg N ha^{-1} which recorded statistically similar shortest fresh fruits (7.23 cm and 7.53 cm), respectively.

The effect of nitrogen application rates on dry fruit length of two okra cultivars in 2019 and 2020 are also shown in Table 4.13. Dry fruit length was significantly different between the okra cultivars in 2019 and 2020.

The cultivar LD 88-1 consistently produced longer dry fruits (10.79 cm and 9.51 cm) in both years than NHAe47 – 4 which consistently produced the shortest dry fruits (9.86 cm and 8.25 cm) in the two years.

Nitrogen application rates had a significant effect on fresh fruit length in both years. The application of 90 and 120 kg N ha^{-1} consistently produced statistically similar longest dry fruits (10.90 cm and 11.13 cm) in 2019 and (10.00 cm and 10.38 cm) in 2020, respectively compared with zero application in 2019 (9.35 cm), application of 0 and 30 kg N ha^{-1} in 2020 (7.35 cm and 7.70 cm) respectively, which produced the shortest dry fruits.

The interaction between cultivar and nitrogen rates on fresh and dry fruit length in 2019 and 2020 is shown in (Table 4.14). The combination of NHAe47 – 4 with application of 120 kg ha^{-1} and LD 88-1 with zero application produced significantly similar longest fruits (11.90 cm) and (11.80 cm), respectively than the other combinations compared with the combination of NHAe47 – 4 with zero application which produced the shortest fruits (6.80 cm) in 2019. In 2020, the combination of NHAe47 – 4 with 120 kg ha^{-1} and LD 88-1 with 90 kg ha^{-1} produced significantly similar longest fruits (10.83 cm and 10.80 cm), respectively than the other combinations compared with the combination of NHAe47 – 4 with application of 0 and 30 kg ha^{-1} which recorded similar shortest fruits (5.93 cm and 6.30

Table 4.14: Interaction of cultivar and nitrogen application rates on fresh and dry fruit length/plot in 2019 and 2020

	N (kg ha^{-1})				
	0	**30**	**60**	**90**	**120**
			Fresh fruit length(cm) in 2019		
Cultivar					
NHAe47- 4	6.80d	9.27c	10.80abc	9.80bc	11.90a
LD 88-1	11.80a	10.87abc	11.50ab	10.83abc	11.07ab
LSD (0.05)			1.70		
			Fresh fruit length in 2020		
Cultivar					
NHAe47- 4	5.93d	6.30d	8.70c	9.50bc	10.83a
LD 88-1	8.53c	8.77c	8.90c	10.80a	10.60ab
LSD (0.05)			1.11		
			Dry fruit length in 2019		
NHAe47- 4	9.10e	9.30de	9.60d	10.17c	11.13b
LD 88-1	9.60f	10.33c	11.27ab	11.63a	11.13b
LSD (0.05)			0.38		

Means with the same letter(s) in the same column are not significantly different from each other at P≤ 0.05 according to LSD.

cm), respectively. Longest dry fruit length was produced by the combination of LD 88-1 with application of 90 kg ha^{-1} (11.63 cm) than the other combinations compared with the combination of NHAe47 – 4 with zero application which produced the shortest dry fruits (9.10 cm).

4.1.2.10 *Number of fresh fruits and number of seed/plot*

The effect of nitrogen application rates on number of fresh fruits of two okra cultivar in 2019 and 2020 are shown in Table 4.15. Number of fresh fruits was significantly different between the cultivar in 2020 only such that LD 88-1 produced the higher number of fresh fruits (16.80) than NHAe47 – 4 which produced the lowest number of fresh fruits (12.87).

Nitrogen application rates affected number of fresh fruits significantly in 2019 and 2020 cropping season. In 2019, the application of 60, 90 and 120 kg N ha^{-1} produced statistically similar highest number of fresh fruits (19.50, 21.67 and 20.1), respectively than 0 and 30 kg N ha^{-1} which recorded similar lowest number of fresh fruits (14.00 and 13.33), respectively. In 2020, the application of 120 kg N ha^{-1} produced significantly highest number of fresh fruits (21.67) than the other rates compared with 0 (8.17) and 30 kg N ha^{-1}(9.17) which had similar lowest number of fresh fruits. The effect of nitrogen application rates on number of seed of two okra cultivars in 2019 and 2020 is also shown in Table 4.15. Number of seed was not significantly different between the cultivars in 2019 and 2020. Nitrogen application rates had a significant effect on number of seed in both years. In 2019, the application of 90 (69.0) and 120 kg N ha^{-1}(75.0) produced significantly similar highest number of seed than 0 and 30 kg N ha^{-1} which recorded statistically similar lowest number of seed (44.0 and 50.0), respectively. In 2020, the application of 120 kg N ha^{-1} produced the highest number of seed

Table 4.15: Effect of nitrogen application rates on number of fresh fruits and number of seed/plot of two okra cultivars in 2019 and 2020

	Number of fresh fruit/plot		Number of seed/plot	
	2019	2020	2019	2020
Cultivar (C)				
NHAe47-4	17.00a	12.87b	59.0a	74.66a
LD 88-1	18.47a	16.80a	62.0a	70.73a
LSD (0.05)	3.36	1.56	4.41	6.85
Nitrogen rate				
0	14.00b	8.17c	44.0c	36.83d
30	13.33b	9.17c	50.0c	49.83c
60	19.50a	16.83b	62.0b	84.50b
90	21.67a	18.33b	69.0a	92.17ab
120	20.17a	21.67a	75.0a	100.17a
LSD (0.05)	3.73	2.40	6.97	10.83
Interaction				
C x N	*	**	NS	NS

Means with the same letter(s) under the same column are not significantly different from each other at P≤ 0.05 according LSD.

(100.17) statistically similar with the application of 90 kg N ha^{-1} compared with zero application which produced the lowest number of seed (36.83).

The interaction between cultivar and nitrogen application rates on number of fresh fruits in 2019 and 2020 is shown in (Table 4.16). In 2019, the combination of LD 88-1 with application of 90 kg ha^{-1} produced significantly highest number of fresh fruits (26.00) than the other combinations compared with the combinations of NHAe47 – 4 with application of 0 (12.67) and 30 kg ha^{-1}(13.33). In LD 88-1 application of 30 kg ha^{-1} (13.33) produced the lowest number of fresh fruits. The combination of LD 88-1 with 90 and 120 kg ha^{-1} produced significantly similar highest number of fresh fruits (25.67 and 25.67) than the other combinations compared with the combination of NHAe47 – 4 with zero application (7.33) which had the lowest number of fresh fruits in 2020.

4.1.2.11 *Fresh fruit weight/plot*

The effect of nitrogen application rates on fresh fruit weight of two okra cultivar in 2019 and 2020 is shown in Table 4.17. Fresh fruit weight differed significantly between the cultivars in 2020 only. LD 88-1 produced the heaviest fresh fruits (585.29 g) than NHAe47 – 4 which had the lighter fresh fruits (450.61 g).

Nitrogen application rates had a significant effect on fresh fruit weight in both years. In 2019, the application of 60, 90 and 120 kg N ha^{-1} produced significantly heaviest fresh fruits (630.18 g, 726.77 g and 677.57 g), respectively than 0 and 30 kg N ha^{-1} which recorded similar lightest fresh fruits (273.53 g and 381.80 g), respectively.

Table 4.16: Interaction of cultivar and nitrogen application rates on number of fresh fruits/plot in 2019 and 2020

	N (kg ha^{-1})				
	0	**30**	**60**	**90**	**120**
			Number of fresh fruits in 2019		
Cultivar					
NHAe47- 4	12.67e	13.33e	19.67bc	17.33cd	22.00b
LD 88-1	15.33de	13.33e	19.33bc	26.00a	18.33bcd
LSD (0.05)			3.81		
			Number of fresh fruits in 2020		
Cultivar					
NHAe47- 4	7.33e	11.00cd	17.33c	11.00cd	17.67b
LD 88-1	9.00de	7.33e	16.33b	25.67a	25.67a
LSD (0.05)			2.52		

Means with the same letter(s) in the same column are not significantly different from each other at P≤ 0.05 according to LSD.

4.1.2.12 *Seed weight*

The effect of nitrogen application rates on seed weight of two okra cultivars in 2019 and 2020 is shown in Table 4.17. Seed weight was not significantly different between the cultivars in 2019 and 2020.

Nitrogen application rates affected seed weight significantly across the years. In 2019, application of 120 kg N ha^{-1} produced heavier seeds (6.25 g) than the other rates compared with 0 and 30 kg N ha^{-1} which had similar lightest seeds (3.03 g and 3.80 g). In 2020, the application of 90 and 120 kg N ha^{-1} produced significantly similar heaviest seeds (5.61 g and 6.12 g), respectively than the other rates compared with zero application which produced the lightest seeds (1.53 g).

4.1.2.13 100 *seed weight/plot*

The effect of nitrogen application rates on 100 seed weight of two okra cultivars in 2019 and 2020 are shown in Table 4.17. The 100 seed weight was significantly different among the varieties in 2019. The variety LD 88-1 produced the heaviest 100 seeds (5.23 g) than NHAe47 – 4 which produced the lighter 100 seeds (3.90 g).

Nitrogen application rates had a significant effect on 100 seed weight in both years. In 2019, the application of 120 kg N ha^{-1} produced significantly heaviest 100 seeds (7.20 g) than the other rates compared with zero application which produced the lightest 100 seeds (3.07 g) which was statistically similar with the application of 30 and 60 kg N ha^{-1}. In 2020, the application of 90 and 120 kg N ha^{-1} produced statistically similar heavier 100 seeds (6.59 g and 7.26 g), respectively than application of 60 kg N ha^{-1} compared with the 0 and 30 kg N ha^{-1} which recorded similar lightest 100 seeds (2.35 g and 2.99 g).

Table 4.17: Effect of nitrogen application rates on fresh fruit weight, seed weight and 100 seed weight/plot of two okra cultivars in 2019 and 2020

	Fresh fruit weight(g)		Seed weight(g)		100 seed weight(g)	
	2019	2020	2019	2020	2019	2020
Cultivar (C)						
NHAe47-4	540.11a	450.61b	4.43a	3.89a	3.90b	4.54a
LD 88-1	602.86a	585.29a	4.57a	3.92a	5.23a	4.86a
LSD (0.05)	92.56	76.39	0.28	0.40	0.88	0.70
N (kg ha^{-1})						
0	413.22b	273.53c	3.03d	1.53d	3.07c	2.35c
30	409.68b	381.80c	3.80d	2.23c	3.93bc	2.99c
60	630.18a	507.47b	4.29c	4.05b	3.87bc	4.32b
90	726.77a	697.03a	5.64b	5.61a	4.75b	6.59a
120	677.57a	729.93a	6.25a	6.12a	7.20a	7.26a
LSD (0.05)	146.35	120.78	0.44	0.64	1.39	1.11
Interaction						
C x N	**	**	**	NS	NS	NS

Means with the same letter(s) under the same column are not significantly different from each other at $P \leq 0.05$ according to LSD.

The interaction of cultivar and nitrogen application rates on fresh fruit weight in 2019 and 2020 is shown in (Table 4.18). In 2019, the combination of LD 88-1 with application of 90 kg ha^{-1} produced significantly heaviest fruits (936.27 g) than the other combinations compared with the combination of NHAe47 – 4 with zero application which recorded the lightest fresh fruits (357.90 g). In 2020, the combination of LD 88-1 with 90 and 120 kg ha^{-1} produced statistically similar heaviest fruits (904.53 g and 907.73 g), respectively than the other combinations compared with the combination of NHAe47 – 4 with zero application and LD 88 with zero application which had similar lightest fresh fruits (269.93 g and 277.13 g), respectively.

Table 4.18: Interaction of cultivar and nitrogen application rates on fresh fruit weight in 2019 and 2020

	N (kg ha^{-1})				
	0	**30**	**60**	**90**	**120**
			Fresh fruit weight(g) in 2019		
Cultivar					
NHAe47- 4	357.90g	390.83fg	653.17bc	517.27c-f	781.37b
LD 88-1	468.53d-g	428.53efg	607.20cd	936.27a	573.77cde
LSD (0.05)			149.80		
			Fresh fruit weight in 2020		
Cultivar					
NHAe47- 4	269.93d	429.33bc	512.13b	489.53b	552.13b
LD 88-1	277.13d	334.27cd	502.80b	904.53a	907.73a
LSD (0.05)			123.60		

Means with the same letter(s) in the same column are not significantly different from each other at P≤ 0.05 according to LSD.

The interaction of cultivar and nitrogen application rates on seed weight in 2019 is shown in (Table 4.19). The combination of LD 88-1 with application of 120 kg ha^{-1} produced significantly heavier seeds (6.47 g) than all the other combinations compared with the combination NHAe47 – 4 with zero application and LD 88-1 with zero application which produced similar lightest seeds (3.11 g and 2.96 g).

4.1.3 Harvesting stages (Days after anthesis)

4.1.3.1 *Fruit diameter/plot*

The effect of nitrogen application rates on fruit diameter of two okra cultivars at different days after anthesis in 2019 and 2020 are presented in Table 4.20. Fruit diameter differed significantly between the cultivars at 14 days in 2019 and 21, 28 and 35 days in both years and 42 days in 2020 only. The cultivar LD 88-1 consistently produced bigger fruits than NHAe47 – 4 which consistently produced the smallest fruits throughout the study.

Nitrogen application rates affected fruit diameter significantly at each sampling periods across the years. At 14 days in 2019, the application of 120 kg N ha^{-1} produced significantly widest fruits (13.95 cm) than the other rates compared with the applications of 0 and 30 kg N ha^{-1} which produced statistically similar smallest fruits (11.92 cm and 12.10 cm), respectively. In 2020, the application of 90 and 120 kg N ha^{-1} produced significantly similar biggest fruits (13.03 cm and 13.78 cm) than 0, 30 and 60 which had statistically similar smallest fruits (11.43 cm, 11.85 cm and 12.13 cm), respectively.

Table 4.19: Interaction of cultivar and nitrogen application rates on weight of seed in 2019

	N (kg ha^{-1})				
	0	30	60	90	120
	Seed weight (g) in 2019				
Cultivar					
NHAe47- 4	3.11f	3.60e	4.17d	6.24ab	6.02b
LD 88	2.96f	3.99de	4.42d	5.03c	6.47
LSD (0.05)			0.45		

Means with the same letter(s) in the same column are not significantly different from each other at P≤ 0.05 according to LSD.

At 21 days in both years, the application of 120 kg N ha^{-1} produced significantly wider fruits (14.04 cm and 13.59 cm), respectively than the other rates compared with the application of 0 and 30 kg N ha^{-1}which produced statistically similar smallest fruits (11.85 cm and 12.22 cm in 2019) and (11.83 and 12.10 cm, respectively in 2020).At 28 days in 2019, the application of 90 and 120 kg N ha^{-1} produced statistically similar biggest fruits (13.78 cm and 14.08 cm) than the other rates compared with zero application which had the smallest fruits (12.00 cm). In 2020, the application of 120 kg N ha^{-1} produced significantly biggest fruits (14.07 cm) than the other rates compared with the application of 0 and 30 kg N ha^{-1} which produced the smallest fruits (11.85 cm and 12.22 cm), respectively. at 35 days in 2019, the application of 90 and 120 kg N ha^{-1} produced statistically similar bigger fruits (13.87 cm and 14.01 cm), respectively than zero application which had the smallest fruits (11.05 cm). In 2020, the application of 120 kg N ha^{-1}, produced widest fruits (14.08 cm) than the other rates compared with zero application which produced the smallest fruits (12.00 cm). At 42 days, the application of 120 kg N ha^{-1} produced the biggest fruits (13.98 cm) in 2019 and the application of 90 and 120 kg N ha^{-1} produced similar widest fruits (13.85 cm and 14. 10 cm), respectively in 2020 than the other rates. Zero application produced the smallest fruits (10.03 cm and 11.05 cm) at 42 days in 2019 and 2020, respectively. At 49 and 56 days, the application of 120 kg N ha^{-1} consistently produced significantly bigger fruits (14.08 cm and 13.98 cm) in 2019 and 2020, respectively than the other rates compared with zero application which consistently produced the smallest fruits (10.42 cm and 10.03 cm) in 2019 and 2020 respectively.

Table 4.20: Effect of nitrogen application rate on fruit diameter of okra cultivars at different days after anthesis

	Fruit diameter (cm)													
	14 days		21 days		28 days		35 days		42 days		49 days		56 days	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Cultivar (C)														
NHAe47-4	12.6b	12.4a	12.7b	12.6b	12.9b	12.7b	12.4b	12.9b	12.4a	12.4b	12.1a	12.4a	12.1a	12.1a
LD 88-1	13.2a	12.5a	13.3a	13.2a	13.4a	13.3a	13.4a	13.5a	12.6a	13.4a	12.2a	12.6a	12.1a	12.1a
LSD (0.05)	0.23	0.52	0.27	0.19	0.30	0.27	0.27	0.27	0.23	0.27	0.25	0.23	0.24	0.24
N (kg ha^{-1})														
0	11.9d	11.4b	11.9c	11.8d	12.0d	11.9c	11.1d	12.0d	10.0e	11.1d	10.4e	10.0e	10.4e	10.4e
30	12.1d	11.9b	12.2c	12.1d	12.5c	12.2c	12.3c	12.5c	12.0d	12.3c	11.4d	12.0d	11.4d	11.3d
60	13.0c	12.1b	13.3b	13.0c	13.2b	13.3b	13.2b	13.4b	12.6c	13.2b	12.1c	12.6c	12.1c	12.0c
90	13.6b	13.0a	13.6b	13.6b	13.8a	13.6b	13.9a	13.78ab	13.6b	13.9a	12.7b	13.6b	12.7b	12.6b
120	13.9a	13.8a	14.1a	13.9a	14.1a	14.1a	14.0a	14.1a	14.0a	14.1a	14.1a	13.9a	14.0a	14.1a
LSD (0.05)	0.36	0.82	0.43	0.29	0.48	0.43	0.42	0.42	0.36	0.42	0.40	0.36	0.38	0.37
Interaction														
C x N	**	NS	**	**	*	**	*	**	NS	*	NS	NS	NS	NS

Means with the same letter(s) under the same column are not significantly different from each other at P≤ 0.05 according to LSD.

The interaction of cultivar and nitrogen application rate on fruit diameter at different days after anthesis in 2019 and 2020 is shown in (Table 4.21). At 14 days in 2019, 21 and 28 days in both years, irrespective of the variety used, fruit diameter increased with an increase in nitrogen application rates. At 35 days in 2019, the combination of LD 88-1 with 90 kg ha^{-1} produced widest fruits (14.40 cm) than the other combinations compared with the combination of NHAe47 – 4 with zero application which had the smallest fruits (10.30 cm). In 2020, LD 88-1 with 90 and 120 kg ha^{-1} (14.20 cm and 14.03 cm) produced bigger fruits respectively, than the other combinations compared with the combination of NHAe47 – 4 with zero application which recorded the smallest fruits (12.00 cm). At 42 days, the combination of LD 88-1 with 90 kg ha^{-1} produced significantly widest fruits (14.37 cm) than the other combinations compared with the combination of NHAe47 – 4 with zero application which had the smallest fruits (10.30 cm).

Table 4.21: Interaction of cultivar and nitrogen application rates on fruit diameter (cm) at different days after anthesis

	N (kg ha^{-1})				
	0	**30**	**60**	**90**	**120**
			14 days in 2019		
Cultivar					
NHAe47- 4	11.80d	12.07cd	12.17c	13.20b	13.90a
LD 88-1	12.03cd	12.13cd	13.87a	13.90a	14.00a
LSD (0.05)			0.37		
			21 days in 2019		
Cultivar					
NHAe47- 4	11.43e	12.33cd	12.63c	13.13b	14.10a
LD 88-1	12.27cd	12.10d	13.93a	14.07a	14.03a
LSD (0.05)			0.44		
			21 days in 2020		
NHAe47- 4	12.0d	12.1cd	12.2c	13.0b	14.0a
LD 88-1	12.0cd	12.1c	14.0a	14.0a	14.0a
LSD (0.05)			0.30		
			28 days in 2019		
NHAe47- 4	11.50d	12.53c	12.73c	13.37b	14.13a
LD 88-1	12.50c	12.51c	13.75ab	14.20a	14.03a
LSD (0.05)			0.49		
			28 days in 2020		
NHAe47- 4	11.43e	12.33cd	13.00c	13.13b	14.10a
LD 88-1	12.27cd	12.10d	14.00a	14.1a	14.00a
LSD (0.05)			0.44		
			35 days in 2019		
NHAe47- 4	10.30f	11.93e	12.60d	13.33c	14.03ab
LD 88-1	11.80e	12.60d	13.83b	14.40a	14.17ab
LSD (0.05)			0.43		
			35 days in 2020		
NHAe47- 4	12.00d	12.53c	12.73c	13.40b	14.13a
LD 88-1	12.50c	12.51c	13.80ab	14.20a	14.03a
LSD (0.05)			0.50		
			42 days in 2020		
NHAe47- 4	10.30f	11.93e	12.60d	13.33c	14.03ab
LD 88-1	11.80e	12.60d	13.83b	14.37a	14.17ab
LSD (0.05)			0.43		

Means with the same letter(s) in the same column are not significantly different from each other at P≤ 0.05 according to LSD.

4.1.3.2 *Fruit length/plot*

The effect of nitrogen application rates on fruit length of two okra cultivars at different days after anthesis in 2019 and 2020 are shown in Table 4.22. Fruit length was significantly different between the cultivars throughout the sampling periods except at 14 days in both years, 21 days in 2020 and 42 days in 2019. At 21 days in 2019, the cultivar LD 88-1 produced longer fruits (10.65 cm) than NHAe47 – 4 which produced the shortest fruits (9.97 cm). At 28 and 35 days, LD 88-1 consistently produced longer fruits (11.04 cm and 10.65 cm at 28 days) and (11.27 cm and 11.04 cm at 35 days) than NHAe47 – 4 which consistently produced the shortest fruits (9.66 cm and 9.97 cm at 28 days) and (9.82 cm and 9.64 cm at 35 day) in both 2019 and 2020 years, respectively. At 42 days in 2019, LD 88-1 produced longer fruits (11.07 cm) than NHAe47 – 4 which had the shortest fruits (9.97 cm). At 49 and 56 days, LD 88-1 variety produced longer fruits (11.01 cm and 11.43 cm at 49 days) and (11.01 cm at 56 days) than NHAe47 – 4 which consistently produced the shortest fruits (10.04 cm and 9.28 cm at 49 days) and (10.04 cm at 56 days) in 2019 and 2020, respectively

Fruit length differed significantly among the nitrogen application rates throughout the sampling times and across the years. At 14 days in 2019, the application of 90 and 120 kg N ha^{-1} produced significantly similar longest fruits (11.52 cm and 12.32 cm), respectively than the application of 0, 30 and 60 kg N ha^{-1} which produced statistically similar shortest fruits (8.50 cm, 8.53 cm and 9.52 cm), respectively. In 2020, the application of 90 and 120 kg N ha^{-1} produced similar longest fruits (11.48 cm and 12.05 cm), respectively compared with zero application which had the shortest fruits (7.98 cm).

Table 4.22: Effect of nitrogen application rate on fruit length of okra cultivar at different days after anthesis in 2019 and 2020

	Fruit length (cm)													
	14 days		21 days		28 days		35 days		42 days		49 days		56 days	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Cultivar (C)														
NHAe47-4	9.8a	9.9a	9.9b	9.8a	9.7b	9.97b	9.8b	9.6b	12.4a	9.9b	10.0b	9.8b	10.0b	10.0b
LD 88-1	10.4a	10.2a	10.7a	10.5a	11.0a	10.7a	11.3a	11.0a	12.6a	11.1a	11.0a	11.4a	11.0a	11.0a
LSD (0.05)	0.66	0.41	0.66	0.69	0.46	0.66	0.71	0.47	0.23	0.46	0.24	0.40	0.24	0.23
N (kg ha^{-1})														
0	8.5b	7.9d	8.7b	8.5b	9.2c	8.6b	9.8c	9.1c	10.0e	9.2c	9.1e	9.6d	9.1e	9.12e
30	8.5b	8.7c	8.9b	8.8b	9.1c	8.9b	9.2c	9.2c	12.0d	9.2c	9.5d	9.5d	9.5d	9.52d
60	9.5b	10.1b	9.7b	9.5b	9.8c	9.6b	9.9c	9.8c	12.6c	9.8c	10.1c	10.4c	10.0c	10.1c
90	11.5a	11.5a	11.8a	11.6a	11.3b	11.8a	11.4b	11.2b	13.6b	11.5b	11.2b	11.2b	11.1c	11.2c
120	12.3a	12.1a	12.5a	12.3a	12.4a	12.5a	12.6a	12.3a	14.0a	12.6a	12.8a	12.4a	12.8a	12.7a
LSD (0.05)	1.05	0.65	1.05	1.08	0.73	1.05	1.12	0.74	0.36	0.72	0.38	0.64	0.38	0.38
Interaction														
C x N	NS	NS	NS	NS	**	NS	NS	**	NS	**	**	NS	**	**

Means with the same letter(s) under the same column are not significantly different from each other at $P \leq 0.05$ according to LSD.

At 21, 28 and 35 days, the application of 120 kg N ha^{-1} consistently produced longer fruits similar with the application of 90 at 28 days in 2020 than the application of 0, 30 and 60k kg N ha^{-1} which produced statistically similar shortest fruits in both years. At 42 days in both years, the application of 120 kg N ha^{-1} produced longest fruits (13.98 cm in 2019) and (12.55 cm in 2020) than the other rates compared with zero application which produced the shortest fruits (10.03 cm) in 2019 and the application of 0, 30 and 60 kg N ha^{-1}produced 9.32 cm, 9.15 cm and 9.85 cm, respectively in 2020. At 49 days in both years, the application of 120 kg N ha^{-1} consistently produced longer fruits (12.78 cm and 12.38 cm) than zero application which consistently produced long fruits (9.12 cm) in 2019, application of 0 and 30 kg N ha^{-1} (9.60 cm and 9.50 cm) in 2020. At 56 days in both years, the application of 120 kg N ha^{-1} consistently produced longest fruits (12.78 cm) than the other rates compared with zero application which consistently produced long fruits (9.11 cm) in this study.

The interaction of cultivar and nitrogen application rates on fruit length at different days after anthesis in 2019 and 2020 is shown in (Table 4.23). At 28 days in 2019, the combination of NHAe47 – 4 and LD88-1 had similar with 120 kg ha^{-1} had similar longest fruits (12.57 cm) than the other combinations compared with the combination of NHAe47 – 4 with 0 and 30 kg ha^{-1} which recorded the long fruits (98.17 cm and 7.90 cm). At 35 days in 2020, the combination of NHAe47 – 4 with 120 kg ha^{-1} produced significantly longer fruits (12.60 cm) than the other combinations compared with the combination of NHAe47 – 4 with 0, 30 and 60 kg ha^{-1} which had statistically similar shortest fruits (8.20 cm, 7.90 cm and 8.60 cm).

Table 4.23: Interaction of cultivar and nitrogen application rates on fruit length (cm) at different days after anthesis

	N (kg ha^{-1})				
	0	**30**	**60**	**90**	**120**

28 days in 2019					
Cultivar					
NHAe47- 4	8.17fg	7.90g	8.67f	11.00cd	12.57a
LD 88-1	10.23e	10.37de	10.93cde	11.50bc	12.17ab
LSD (0.05)			0.75		
35 days in 2020					
Cultivar					
NHAe47- 4	8.20e	7.90e	8.60e	10.97cd	12.60a
LD 88-1	10.23d	10.40d	10.93cd	11.50bc	12.17ab
LSD (0.05)			0.76		
42 days in 2020					
NHAe47- 4	8.87e	8.10f	8.67ef	11.07c	12.67a
LD 88-1	9.77d	10.20d	11.03c	11.93b	12.43ab
LSD (0.05)			0.74		
49 days in 2019					
NHAe47- 4	9.17fg	9.30fg	9.47ef	10.23d	12.03b
LD 88-1	9.07g	9.73e	10.63c	12.10b	13.53a
LSD (0.05)			0.39		
56 days in 2019					
NHAe47- 4	9.20fg	9.30fg	9.50ef	10.23d	12.03b
LD 88-1	9.10g	9.70e	10.63c	12.10b	13.53a
LSD (0.05)			0.39		
56 days in 2020					
NHAe47- 4	9.17fg	9.30fg	9.47ef	10.20d	12.00b
LD 88-1	9.07g	9.70e	10.61c	12.00b	13.51a
LSD (0.05)			0.38		

Means with the same letter(s) in the same column are not significantly different from each other at P≤ 0.05 according to LSD.

At 42 days in 2020, the application of NHAe47 – 4 with 120 kg ha^{-1} produced significantly longer fruits (12.67 cm) than the other combinations compared with the combination of

NHAe47 – 4 with zero application which recorded the shortest fruits (8.87 cm). At 49 days in 2019, the combination of LD 88-1 with 120 kg ha^{-1} produced longer fruits (13.53 cm) than the other combinations compared with the combination of NHAe47 – 4 with 0 and 30 kg ha^{-1} (9.17 cm and 9.30 cm), LD 88-1 with zero application (9.07 cm) which had the shortest fruits. At 56 days, the combination of LD 88-1 with 120 kg ha^{-1}produced longest fruits (13.53 cm and 13.51 cm) than the other combinations compared with the combination of NHAe47 – 4 and LD88-1 with zero application which had short fruits in 2019 and 2020, respectively.

4.1.3.3 *Number of seed/plot*

The effect of nitrogen application rates on number of seed/plot of two okra cultivars at different days after anthesis in 2019 and 2020 are shown in Table 4.24. Variety differed significantly in terms of their number of seed throughout the sampling periods of the study and across the years except at 14 days in 2020 only. The cultivar LD 88-1 consistently produced the highest number of seeds between (58 – 68.5) than NHAe47 – 4 which consistently produced the lowest number of seeds between (46 – 52.6) in this study.

Nitrogen application rates had a significant effect on number of seed/plot of okra at each sampling periods across the years.

Table 4.24: Effect of nitrogen application rate on number of seed of okra cultivar at different days after anthesis

	Number of seed													
	14 days		21 days		28 days		35 days		42 days		49 days		56 days	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Cultivar (C)														
NHAe47-4	46.5b	48.4a	47.6b	46.7b	47.9b	47.6b	51.2b	47.9b	52.6b	51.2b	52.5b	52.6b	52.5b	52.5b
LD 88-1	58.3a	45.7a	60.9a	58.0a	60.3a	60.9a	67.5a	60.7a	68.5a	67.5a	66.8a	68.4a	66.8a	66.8a
LSD (0.05)	3.03	2.72	3.18	2.99	3.15	3.18	2.07	3.09	1.03	2.07	2.96	1.03	2.96	2.96
N (kg ha^{-1})														
0	36.8d	31.8d	36.8d	36.8c	36.5d	36.8d	41.3e	36.5d	44.2e	41.3e	43.3e	44.1e	44.4e	44.4e
30	49.3c	39.0c	51.8c	48.3b	49.2c	51.8c	51.2d	49.2c	51.3d	51.1d	49.5d	51.3d	49.5d	49.5d
60	52.8c	50.8b	55.0c	52.8b	57.8b	55.0c	61.0c	57.8b	60.5c	60.0c	59.5c	60.5c	59.5c	59.5c
90	58.7b	55.2a	60.8b	59.0a	60.0b	60.8b	66.5b	61.0b	69.0b	66.5b	68.5b	69.0b	68.5b	68.5b
120	64.5a	58.5a	66.8a	63.7a	66.8a	66.8a	76.7a	66.8a	77.7a	76.6a	76.5a	77.6a	76.5a	76.5a
LSD (0.05)	4.78	4.30	5.02	4.74	4.98	5.02	3.27	4.88	1.63	3.26	4.68	1.62	4.68	4.68
Interaction														
C x N	NS	NS	NS	NS	NS	NS	**	NS	**	**	NS	**	NS	NS

Means with the same letter(s) under the same column are not significantly different from each other at P≤ 0.05 according to LSD.

The application of 120 kg N ha^{-1} consistently produced significantly highest number of seeds between (58 – 77) statistically similar with the application of 90 kg N ha^{-1} at 14 and 21 days in 2020 which was between (55.17 – 59.00) than the other rates compared with zero application which consistently produced the lowest number of seed/plot between (31 – 44) at the sampling periods in both years.

The interaction between cultivar and nitrogen application rates on number of seed/plot at different days after anthesis in 2019 and 2020 is shown in (Table 4.25). At 35 days after anthesis in 2019, the combination of LD 88-1 with 90 and 120 kg ha^{-1} produced significantly highest number of seeds/plot 77.67 and 80.67, respectively than the other combinations compared with the combination of NHAe47 – 4 with zero application which produced the lowest number of seeds (35.00). At 42 days after anthesis, irrespective of the variety used, number of seed/plot increased as the nitrogen application increases in 2019 and 2020. At 49 days after anthesis in 2020, the combination of LD 88-1 with 120 kg ha^{-1} produced the highest number of seeds/plot (83.00) than the other combinations compared with the combination of NHAe47 – 4 with zero application which had the lowest number of seeds/plot (39.00).

Table 4.25: Interaction of cultivar and nitrogen application rates on number of seed at different days after anthesis

	N (kg ha^{-1})				
	0	**30**	**60**	**90**	**120**
			35 days in 2019		
Cultivar					
NHAe47- 4	35.00g	42.00f	51.00e	55.33d	72.67b
LD 88-1	47.67e	60.33c	71.00b	77.67a	80.67a
LSD (0.05)			3.34		
			42 days in 2019		
Cultivar					
NHAe47- 4	38.67i	43.67h	51.33g	57.00f	72.33c
LD 88-1	49.67g	59.00e	69.67d	81.00b	83.00a
LSD (0.05)			1.67		
			42 days in 2020		
NHAe47- 4	35.00g	42.00f	51.00e	55.00d	72.67b
LD 88-1	48.00e	60.30c	71.00b	78.00a	81.00a
LSD (0.05)			3.33		
			49 days in 2020		
NHAe47- 4	39.00i	44.0h	51.00g	57.00f	72.00c
LD 88-1	50.00g	59.00e	70.00d	81.00b	83.00a
LSD (0.05)			1.70		

Means with the same letter(s) in the same column are not significantly different from each other at P≤ 0.05 according to LSD.

4.1.3.4 *Seed weight*

The effect of nitrogen application rate on seed weight of two okra varieties at different days after anthesis in 2019 and 2020 is shown in Table 4.26. Weight of seed was significantly different among the varieties except at 14 and 21 days in both years, 28 days in 2020 and 42 days in 2019. The cultivar LD 88-1 consistently produced the heaviest seeds between 7 g and 12 g than NHAe47 – 4 which consistently produced the lightest seeds between (5 g and 11 g) in both years.

Seed weight differed significantly among the nitrogen application rate throughout the sampling times in both years. At 14, 21 and 28 days, the application of 120 kg N ha^{-1} consistently produced the heaviest seeds of between 12 g and 13 g than the other rates compared with zero application which consistently produced the lighter seeds of between (8 g and 10 g in both years. At 35 days after anthesis in 2019, the application of 60, 90 and 120 kg N ha^{-1} produced significantly similar heaviest seeds (8.74 g, 8.64 g and 8.79 g) than 0 and 30 kg N ha^{-1} which produced statistically similar heavy seeds (6.98 g and 7.70 g). In 2020, the application of 120 kg N ha^{-1} produced heaviest seeds (12.57 g) than the other rates compared with zero application which had heavy seeds (10.24 g). At 42 days in 2019, the application of 120 kg N ha^{-1} produced heaviest seeds (10.20 g) than zero application which produced the heavy seeds (6.42 g). In 2020, the applications of 60, 90 and 120 kg N ha^{-1} produced significantly similar heaviest seeds than 0 and 30 kg N ha^{-1} which produced similar heavy seeds. At 49 and 56 days after anthesis in both years, the application of 120 kg N ha^{-1} consistently produced heaviest seeds/plot of between 8 g and 10 g than the other rates compared with zero application which consistently produced the heavy seeds of between 4 g and 6 g in both years.

Table 4.26: Effect of nitrogen application rate on seed weight of okra cultivar at different days after anthesis

	Seed weight (g)													
	14 days		21 days		28 days		35 days		42 days		49 days		56 days	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Cultivar (C)														
NHAe47-4	11.6a	11.7a	11.5a	11.6a	11.1b	18.4a	7.6b	11.0b	8.4a	7.6b	5.5b	8.3a	5.5b	5.5b
LD 88-1	11.0a	11.7a	11.8a	11.6a	12.1a	11.8a	8.7a	12.0a	8.6a	8.7a	7.9a	8.5a	7.7a	7.9a
LSD (0.05)	1.24	0.42	0.21	0.28	0.19	16.57	0.52	0.19	0.49	0.52	0.47	0.49	0.72	0.47
N (kg ha^{-1})														
0	3.4c	9.7c	9.68d	9.9d	10.2d	9.7a	6.9b	10.2d	6.4d	6.9b	4.8d	6.4d	4.8c	4.8d
30	10.9b	11.7b	11.0c	10.9c	11.0c	11.0a	7.7b	11.0c	7.2c	7.7b	6.2c	7.2c	6.1b	6.2c
60	11.9ab	11.9b	12.0b	11.9b	11.9b	20.2a	8.7a	11.8b	9.1b	8.7a	6.6c	9.0b	6.6b	6.6b
90	12.2ab	12.3ab	12.3b	12.2b	12.1b	12.3a	8.6a	12.1b	9.3b	8.7a	7.2b	9.3b	6.5b	7.2b
120	13.1a	12.8a	13.2a	13.1a	12.6a	13.2a	8.8a	12.5a	10.2a	8.8a	8.9a	10.1a	8.8a	8.9a
LSD (0.05)	1.97	0.66	0.34	0.44	0.30	25.47	0.83	0.30	0.77	0.82	0.75	0.76	1.14	0.75
Interaction														
C x N	*	NS	**	**	**	NS	**	**	NS	**	**	NS	*	**

Means with the same letter(s) under the same column are not significantly different from each other at P≤ 0.05 according to LSD.

The interaction between cultivar and nitrogen application rates on seed weight at different days after anthesis in 2019 and 2020 is shown in Table 4.27. At 14 days after anthesis in 2019, the cultivar NHAe47 – 4 and LD 88-1 with zero application produced heavier seeds (13.24 g and 13.03 g) than the other combinations compared with the combination of LD 88-1 with zero application which produced heavy seeds (5.96 g).

At 21 days in 2019, the combination of NHAe47 – 4 and LD88-1 with 120 kg ha^{-1} produced heaviest seeds (13.32 g and 13.02 g) than the other combinations compared with zero application which had the lightest seeds (10.15 g and 9.22 g). In 2020 at 21 days after anthesis with the application of 120kg N ha^{-1} NHAe47-4 recorded similar results 13.24 and 13.01g and lighter seeds with zero application.

At 28 days in 2019, the combination of LD 88-1 with 90 and 120 kg ha^{-1} produced significantly heavier seeds (12.81 g and 13 10 g) than the other combinations compared with the combination of NHAe47 – 4 with 30 kg ha^{-1} (10.30 g) and LD 88-1 with zero application (10.33 g) which produced the lightest seeds. At 35 days after anthesis in 2019, the combination of LD 88-1 with 90 and 120 kg ha^{-1} produced heaviest seeds than the other combinations compared with the combination of NHAe47 – 4 with 30 and LD 88-1 with zero application which had the lightest seeds. In 2020, the combination of LD 88-1 with 120 kg ha^{-1} produced heaviest seeds (9.37 g) than the other combinations compared with the combination of NHAe47 – 4 with 30 kg ha^{-1} which produced the lightest seeds (6.31 g). At 42 days after anthesis in 2020, the combination of LD 88-1 with 60 kg ha^{-1} and 120 kg ha^{-1} produced heavier seeds (9.50 g and 9.40 g) than the other combinations compared with the combination of NHAe47 – 4 with 30 kg ha^{-1} which had the lightest seeds (6.03 g).

Table 4.27: Interaction of cultivar and nitrogen application rates on seed weight (cm) at different days after anthesis

	N (kg ha^{-1})				
	0	**30**	**60**	**90**	**120**
			14 days in 2019		
Cultivar					
NHAe47- 4	10.79b	10.89b	11.28ab	11.83ab	13.24a
LD 88-1	5.96c	10.98b	12.57ab	12.61ab	13.01a
LSD (0.05)			2.01		
			21 days in 2019		
Cultivar	10.15g	10.95f	11.37e	11.90d	13.32a
NHAe47- 4	9.22h	11.10ef	12.65c	12.74bc	13.02ab
LD 88-1			0.35		
LSD (0.05)					
			21 days in 2020		
NHAe47- 4	10.78e	10.89de	11.28d	11.83c	13.24a
LD 88-1	8.97f	10.98de	12.57b	12.61b	13.01ab
LSD (0.05)			0.45		
			28 days in 2019		
NHAe47- 4	10.20e	10.30e	11.40d	11.43d	12.10c
LD 88-1	10.33e	11.80c	12.41b	12.81a	13.10a
LSD (0.05)			0.32		
			35 days in 2019		
NHAe47- 4	10.15e	10.27e	11.35d	11.43d	12.08c
LD 88-1	10.33e	11.79c	12.41b	12.81a	13.05a
LSD (0.05)			3.11		
			35 days in 2020		
NHAe47- 4	7.24ef	6.31g	8.00de	8.40bcd	8.22cd
LD 88-1	6.72fg	9.10ab	9.48a	8.88abc	9.37a
LSD (0.05)			0.85		
			42 days in 2020		
NHAe47- 4	7.20ef	6.30g	8.00de	8.40bcd	8.20cd
LD 88-1	6.71fg	9.00ab	9.50a	8.90abc	9.40a
LSD (0.05)			0.84		
			49 days in 2019		
NHAe47- 4	4.82f	5.63e	4.68f	5.02ef	7.49d
LD 88-1	4.85g	6.75d	8.51c	9.36b	10.22a
LSD (0.05)			0.76		
			56 days in 2019		
NHAe47- 4	4.80e	5.60de	4.70e	5.00e	7.50bc
LD 88-1	4.85e	6.75cd	8.51b	8.03b	10.22
LSD (0.05)			1.17		
			56 days in 2020		
NHAe47- 4	4.83f	5.62e	4.67f	5.02ef	7.51d
LD 88-1	4.83f	6.80d	8.50c	9.40b	10.24a
LSD (0.05)			0.77		

Means with the same letter(s) in the same column are not significantly different from each other at P≤ 0.05 according to LSD.

At 49 days after anthesis in 2019, the combination of LD 88-1 with 120 kg ha^{-1} produced significantly heaviest seeds (10.22 g) than the other combinations compared with the combination of LD 88-1 with zero application which produced the lightest seeds (4.85 g). At 56 days after anthesis in both years, the combination of LD 88-1 with 120 kg ha^{-1} produced significantly heavier seeds (10.22 g and 10.24 g) than the other combinations compared with the combination of NHAe47 – 4 with zero application (4.08 g and 4.83 g) and LD 88-1 with zero application (4.84 g and 4.83 g) which had the lightest seeds in 2019 and 2020 respectively.

4.1.3.5 *Seed moisture content*

The effect of nitrogen application rates on seed moisture content of two okra cultivar at different days after anthesis in 2019 and 2020 is presented in Table 4.28. Seed moisture content was significantly different between the cultivar at 49 and 56 days after anthesis in both years. The cultivar LD 88-1 produced the lowest seed moisture content (10.5 %) than NHAe47 – 4 which was statistically similar (12.4 %) at 56 days after anthesis.

Nitrogen application rate had a significant effect at each sampling periods across the years. At 14 days in 2019, the application of 120 kg N ha^{-1} produced the lowest seed moisture content (15.19 %) than the other nitrogen rates compared with zero application which had the highest seed moisture content (20.86 %). At 21 days in 2019, the application of 120 kg N ha^{-1} recorded the lowest seed moisture content (13.35 %) than all the other nitrogen rates which had statistically similar highest seed moisture content. In 2020, seed moisture content (15.19 %) was lowest when 120 kg N ha^{-1} was applied compared with zero application which recorded the highest seed moisture content (28.86 %).

Table 4.28: Effect of nitrogen application rate on seed moisture content of okra cultivars at different days after anthesis

	Seed moisture content (%)													
	14 days		21 days		28 days		35 days		42 days		49 days		56 days	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Cultivar (C)														
NHAe47-4	18.1a	18.2a	16.4a	18.1a	14.9a	16.4a	15.4a	14.9a	13.7a	15.4a	12.4a	13.6a	12.4a	12.4a
LD 88-1	18.0a	17.2a	15.9a	18.0a	15.5a	15.9a	14.6a	15.5a	14.6a	14.7a	10.6b	14.6a	10.5b	10.6b
LSD (0.05)	1.49	29.82	1.38	1.49	0.88	1.37	0.89	0.85	1.64	0.92	1.35	1.64	1.32	1.32
N (kg ha^{-1})														
0	20.9a	17.7a	17.2a	20.9a	18.1a	17.2a	17.9a	18.1a	16.0a	17.9a	14.2a	16.0a	14.2a	14.2a
30	17.6b	17.8a	16.9a	17.6b	16.9a	16.9a	17.1a	16.8a	16.9a	17.1a	13.0ab	16.9a	13.0ab	13.0ab
60	18.5b	17.7a	16.0a	18.5ab	14.3b	15.9a	14.6b	14.3b	13.0b	14.6b	11.7bc	13.0b	11.6bc	11.7bc
90	18.1b	21.1a	17.2a	18.1b	13.0b	17.2a	13.0c	13.1b	12.0b	13.2bc	8.8d	12.1b	8.7d	8.8d
120	15.2c	34.2a	13.4b	15.2c	13.9b	13.3b	12.3c	13.8b	12.6b	12.3c	9.87cd	12.6b	9.8cd	9.9cd
LSD (0.05)	2.35	35.00	2.18	2.35	1.39	2.17	1.4	1.35	2.59	1.46	2.14	2.59	2.08	2.07
Interaction														
C x N	NS	NS	*	NS	NS	*	NS	NS	NS	NS	*	NS	*	**

Means with the same letter(s) under the same column are not significantly different from each other at P≤ 0.05 according to LSD.

At 28 days in 2019, the application of 60, 90 and 120 kg N ha^{-1} produced significantly similar lowest seed moisture content than 0 and 30 kg N ha^{-1} which produced statistically similar highest seed moisture content. In 2020, application of 120 kg N ha^{-1} produced the lowest seed moisture content (13.35 %) than all the other rates which had statistically similar highest seed moisture content. At 35 days, the application of 90 and 120 kg N ha^{-1} in 2019 and 60, 90 and 120 kg N ha^{-1} in 2020 produced similar lowest seed moisture content than 0 and 30 kg N ha^{-1} which produced statistically similar highest seed moisture content in both years. At 42 days, the application of 60, 90 and 120 kg N ha^{-1} in 2019 and 120 kg N ha^{-1} in 2020 produced the lowest seed moisture content compared with 0 and 30 kg N ha^{-1} which produced statistically similar highest seed moisture content. At 49 days in 2019, the application of 90 kg N ha^{-1} produced the lowest seed moisture content (8.87 %) which was statistically similar with that of 120 kg N ha^{-1} (9.87 %) compared with zero application which had the highest seed moisture content (14.21 %). In 2020, the application of 60, 90 and 120 kg N ha^{-1} produced significantly similar lowest seed moisture content than 0 and 30 kg N ha^{-1} which recorded statistically similar highest seed moisture content. At 52 days in both years, the application of 90 kg N ha^{-1} produced the lowest seed moisture content (8.78 %) statistically similar with the application of 120 kg N ha^{-1} (9.87 %) compared with zero application which produced the highest seed moisture content in this study

The interaction of cultivar and nitrogen application rates on seed moisture content at different days after anthesis in 2019 and 2020 is shown in (Table 4.29).

Table 4.29: Interaction of cultivar and nitrogen application rates on seed moisture content (%) at different days after anthesis

	N (kg ha^{-1})				
	0	**30**	**60**	**90**	**120**
21 days (%) in 2019					
Cultivar					
NHAe47- 4	15.27cd	18.02ab	17.34abc	16.65bcd	14.78d
LD 88-1	19.17a	15.85bcd	14.60d	17.81ab	11.92e
LSD (0.05)			2.23		
28 days in 2020					
Cultivar					
NHAe47- 4	15.30cd	18.00ab	17.30abc	16.70bcd	14.80d
LD 88-1	19.20a	15.90bcd	14.60d	17.80ab	11.90e
LSD (0.05)			2.20		
49 days in 2019					
NHAe47- 4	17.12a	13.49b	12.79bc	9.78efg	8.97fg
LD 88-1	11.30b-e	12.59bcd	10.55def	7.97g	10.76c-f
LSD (0.05)			2.19		
56 days in 2019					
NHAe47- 4	17.11a	13.50b	12.80bc	9.77efg	8.97fg
LD 88-1	11.30cde	12.55bcd	10.54def	9.77g	10.76c-f
LSD (0.05)			2.10		
56 days in 2020					
NHAe47- 4	17.00a	13.45b	12.74bc	9.80efg	8.95fg
LD 88-1	11.28cde	12.60bcd	10.60def	7.80g	10.75c-f
LSD (0.05)			1.00		

Means with the same letter(s) in the same column are not significantly different from each other at $P \leq 0.05$ according to LSD.

At 21 days after anthesis in 2019 and 28 days in 2020, the combination of LD 88-1 with 120 kg ha^{-1} produced significantly lowest seed moisture content (11.92 % and 11.90 %), respectively than the other combinations compared with the combination of LD 88-1 with zero application which produced the highest seed moisture content of between 19.17 % and 10.20 %. At 49 days after anthesis in 2019, irrespective of the cultivar, seed moisture content reduced as the nitrogen application rate increases. At 56 days after anthesis, the combination of LD 88-1 with 90 kg ha^{-1} produced the lowest seed moisture content (9.75 % and 7.80 %) in 2019 and 2020, respectively than the other combinations, compared with the combination of NHAe47 – 4 with zero application which had the highest seed moisture content (17.11 % and 17.00 %) in 2019 and 2020, respectively.

4.1.4 Positions on the mother-plant

4.1.4.1 *Fruit diameter/plot*

The effect of nitrogen application rates on fruit diameter of two okra cultivar at different harvesting positions in 2019 and 2020 is shown in Table 4.30. Fruit diameter differed significantly between the cultivar across the positions and years except at position 1 in 2020, position 4 in 2019, position 5 in 2020. The cultivar LD 88-1 consistently produced the biggest fruits between 11 cm and 12 cm than NHAe47 – 4 which consistently recorded the smallest fruits of between10 cm and 11 cm.

Nitrogen application rates affected fruit diameter significantly throughout the sampling periods in both years, while the cultivars behaved similarly during these period and position on the mother plant.

Table 4.30: Effect of nitrogen application rate on fruit diameter of okra cultivars at different plant positions on the mother plant

	Fruit diameter (cm)											
	Position 1		Position 2		Position 3		Position 4		Position 5		Position 6	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Cultivar (C)												
NHAe47-4	11.51a	12.35a	10.83b	10.83b	10.23b	10.83b	8.79a	10.52b	11.51a	8.78a	10.83b	8.59a
LD 88-1	10.04b	12.56a	11.87a	12.07a	12.07a	11.87a	9.11a	11.27a	10.04b	9.11a	11.87a	8.63a
LSD (0.05)	0.74	0.23	0.50	0.21	0.21	0.49	0.55	0.40	0.74	0.55	0.50	0.77
N (kg ha^{-1})												
0	9.83c	10.03e	10.37c	10.32e	10.32e	10.37c	7.87d	9.78c	9.38c	7.87d	10.37c	8.30ab
30	9.25c	12.00d	10.73c	10.85d	10.85d	10.73c	8.35cd	10.28bc	9.25c	8.35c	10.73c	8.68ab
60	9.70c	12.63c	11.10bc	11.47c	11.47c	11.10bc	8.95bc	10.73b	9.70c	8.95bc	11.10bc	7.83b
90	12.10b	13.62b	11.87b	11.97b	11.97b	11.87b	9.53ab	11.65a	12.10b	9.53ab	11.87b	8.75ab
120	13.45a	14.00a	12.70a	12.63a	12.63a	12.70a	10.02a	12.03a	13.45a	10.02a	12.70a	9.48a
LSD (0.05)	1.18	0.36	0.79	0.34	0.34	0.79	0.87	0.64	1.18	0.87	0.79	1.21
Interaction												
C x N	NS	NS	NS	NS	NS	NS	**	NS	NS	**	NS	NS

Means with the same letter(s) under the same column are not significantly different from each other at P≤ 0.05 according to LSD.

At position 1 (close to the base) in both years, the application of 120 kg N ha^{-1} produced the widest fruits (13.45 cm and 14.00 cm) the smallest fruits were recorded from the application of 0, 30 and 60 kg N ha^{-1} (9.38 cm, 9.25 cm and 9.70 cm) in 2019 and zero application (10.03 cm) in 2020. At position 2 across the years, the application of 120 kg N ha^{-1} consistently produced the biggest fruits (12.07 cm to 12.63 cm) than the other rates compared with 0 and 30 kg N ha^{-1} (10.37 cm and 10.73 cm) in 2019 and zero application (10.23 cm) in 2020 which produced the smallest fruits. At position 3 in both years, significantly widest fruits were produced with the application of 120 kg N ha^{-1} (12.60 cm to 12.70 cm) than all the other rates. Zero application (10.32 cm) in 2019 and 0 and 30 kg N ha^{-1} (10.37 cm and 10.73 cm), respectively in 2020 produced the smallest fruits.

Similarly, at position 4 the application of 120 kg N ha^{-1} (10.02 cm) in 2019 and application of 90 and 120 kg N ha^{-1} (11.65 cm and 12.03 cm) in 2020 produced significantly biggest fruits. Smallest fruits were recorded with zero application (7.87 cm and 9.78 cm) in 2019 and 2020 respectively. At position 5, the application of 120 kg N ha^{-1} consistently produced the widest fruits (13.45 cm and 10.20 cm) in both years than all the other rates compared with 0, 30 and60 kg N ha^{-1} in 2019 and zero application in 2020 which recorded the smallest fruits. At position 6 in both years, application of 120 kg N ha^{-1} produced widest fruits (12.70 cm to 9.48 cm) than 0 and 30 kg N ha^{-1} in 2019 (10.37 cm to 10.73 cm), though not significantly different from the value obtained in 2020 with 90 kg N ha^{-1} while application of 60 kg N ha^{-1} in 2020 (7.83 cm) which produced the smallest fruits.

The interaction of cultivar and nitrogen application rates on fruit diameter at different harvesting positions in 2019 and 2020 is presented in (Table 4.31).

Table 4.31: Interaction of cultivar and nitrogen application rates on fruit diameter at different plant positions on the mother plant in2019 and 2020

	N (kg ha^{-1})				
	0	**30**	**60**	**90**	**120**
			Fruit diameter (cm) at position 4 2019		
Cultivar					
NHAe47- 4	8.40b	8.50b	8.13bc	8.67b	10.20a
LD 88-1	7.33c	8.20bc	9.77a	10.40a	9.83a
LSD (0.05)			0.89		
			Fruit diameter(cm) at position 3 2020		
Cultivar					
NHAe47- 4	8.40b	8.50b	8.13bc	8.67b	10.20a
LD 88-1	7.33c	8.20bc	9.80a	10.40a	9.80a
LSD (0.05)			0.89		

Means with the same letter(s) in the same column are not significantly different from each other at P≤ 0.05 according to LSD.

At position 1 in 2019, the combinations of NHAe47 – 4 with application of 120 kg ha^{-1} (10.2 cm), LD 88-1 with 60, 90 and 120 kg N ha^{-1}produced the widest fruits of between 9.77 cm–10.40cmfruits than the other combinations compared with the combination of LD 88-1 with zero application which had the smallest fruits (7.33 cm). Also, with 120kg N ha^{-1} application in position 1 in 2019 with NHAe47-4 had widest fruit diameter. At position 3 in 2020, similar trend was observed.

4.1.4.2 *Fruit length/plot*

The effect of nitrogen application rates on fruit length of two okra cultivar at different harvesting positions in 2019 and 2020 is shown in Table 4.32. Fruit length was significantly different between the okra cultivar except at position 1, position 4 in 2019 and position 5 in both years. The cultivar LD 88-1 produced longer fruits 11.36cm at position 1 than NHAe47 – 4 which produced the shorter fruits 9.77 cm in 2020.

Nitrogen application rates had a significant effect on fruit length throughout the sampling periods and across the years. At position 1, the application of 90 and 120 kg N ha^{-1} in 2019 and application of 120 in 2020 produced the longest fruits than the other rates while 0, 30 and 60 kg N ha^{-1} in 2019, 0 and 30 kg N ha^{-1} in 2020 produced statistically similar shortest fruits. At position 2, the application of 120 kg N ha^{-1} produced significantly longer fruits (11.60 cm to 11.58 cm) in both years, than the other rates compared with 0 and 30 kg N ha^{-1} (9.00 cm and 9.27 cm) in 2019 and zero application (9.35 cm) in 2020 which had the shortest fruits.

Table 4.32: Effect of nitrogen application rate on fruit length of okra cultivar at different plant positions on the mother plant

	Fruit length (cm)											
	Position 1		Position 2		Position 3		Position 4		Position 5		Position 6	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Cultivar (C)												
NHAe47-4	8.45a	9.77b	9.93b	9.86b	9.86b	9.93b	7.98a	9.20b	8.45a	7.98a	9.93b	8.09a
LD 88-1	8.83a	11.36a	10.43a	10.97a	10.97a	10.43a	8.78a	10.19a	8.83a	8.78a	10.43a	8.53a
LSD (0.05)	0.51	0.28	0.29	0.23	0.23	0.29	0.93	0.77	0.51	0.93	0.29	0.52
N (kg ha^{-1})												
0	7.87b	9.57d	9.00d	9.35e	9.35e	9.00d	7.57b	8.27c	7.87b	7.57b	9.00d	7.50b
30	8.25b	9.53d	9.27d	9.82d	9.82d	9.27d	7.85ab	9.35bc	8.25b	7.85ab	9.27d	8.15b
60	8.25b	10.33c	10.27c	10.43c	10.43c	10.27c	8.53ab	9.72ab	8.25b	8.53ab	10.27c	7.73b
90	9.43a	11.02b	10.77b	10.90b	10.90b	10.77b	9.15a	10.47ab	9.43a	9.15a	10.77b	9.13a
120	9.38a	12.37a	11.60a	11.58a	11.58a	11.63a	8.80ab	10.67a	9.38a	8.80ab	11.60a	9.03a
LSD (0.05)	0.80	0.44	0.47	0.37	0.37	0.47	1.47	1.22	0.80	1.47	0.47	0.83
Interaction												
C x N	NS	NS	**	*	*	**	*	*	NS	*	**	*

Means with the same letter(s) under the same column are not significantly different from each other at P≤ 0.05 according to LSD.

At position 3, the application of 120 kg N ha^{-1} consistently produced longer fruits (11.58 cm and 11.60 cm) across the years compared with zero application (9.35 cm) in 2019, 0 and 30 kg N ha^{-1} (9.00 cm and 9.27 cm) in 2020 which recorded the shortest fruits. At position 4 in 2019, the application of 90 kg N ha^{-1} produced the longest fruits (9.15 cm) which was statistically similar with other nitrogen application rates compared with zero application which recorded the shortest fruits (7.57 cm).

In 2020, the application of 120 kg N ha^{-1} produced longer fruits (10.67 cm) which was statistically similar with the application of 60 and 90 kg N ha^{-1} compared with zero application which recorded the shortest fruits (8.27 cm). At position 5, the application of 90 and 120 kg N ha^{-1} produced significantly similar longest fruits (9.43 cm and 9.38 cm) than 0, 30 and 60 kg N ha^{-1} which produced statistically similar shortest fruits (7.87 cm, 8.25 cm and 8.25 cm) in 2019. In 2020, the application of 90 kg N ha^{-1} produced significantly longest fruits (9.15 cm) statistically similar with other nitrogen application rates compared with zero application which had the shortest fruits (7.57 cm). At position 6 in 2019, the application of 120 kg N ha^{-1} recorded longer fruits (11.60 cm) than the other rates compared with 0 and 30 kg N ha^{-1} which produced statistically similar shortest fruits (9.00 cm and 9.27 cm). In 2020, the application of 90 and 120 kg N ha^{-1} produced similar longest fruits (9.13 cm and 9.03 cm) than 0, 30 and 60 kg N ha^{-1} which had statistically similar shortest fruits (7.50, 8.15 and 7.73 cm).

The interaction between cultivar and nitrogen application rates on fruit length at different harvesting positions in 2019 and 2020 is presented in (Table 4.33). At position 2 in 2019, irrespective of cultivar used, fruit length increased with an increase in the nitrogen application rates.

Table 4.33: Interaction of cultivar and nitrogen application rates on fruit length (cm) at different plant positions on the mother plant in2019 and 2020

	N (kg ha^{-1})				
	0	**30**	**60**	**90**	**120**
	Fruit length at position 2 2019				
Cultivar					
NHAe47- 4	9.27d	9.20de	9.67d	10.30c	11.20b
LD 88-1	8.73e	9.33d	10.87b	11.23b	12.00a
LSD (0.05)			0.48		
	Fruit length at position 2 2020				
Cultivar	9.10f	9.30ef	9.60e	10.17d	11.13c
NHAe47- 4	9.60e	10.33d	11.27bc	11.63b	12.03a
LD 88-1			0.38		
LSD (0.05)					
	Fruit length at position 3 2019				
NHAe47- 4	9.10f	9.30ef	9.60e	10.17d	11.13c
LD 88-1	9.60e	10.33d	11.27bc	11.63b	12.03a
LSD (0.05)			0.38		
	Fruit length at position 3 2020				
NHAe47- 4	9.30d	9.20de	9.67d	10.30c	11.20b
LD 88-1	8.73e	9.30d	10.90b	11.23b	12.00a
LSD (0.05)			0.47		
	Fruit length at position 4 2019				
NHAe47- 4	8.50bcd	8.10cde	7.50de	8.23cd	7.63de
LD 88-1	6.67e	7.63de	9.57abc	10.07a	9.97ab
LSD (0.05)			1.51		
	Fruit length at position 4 2020				
NHAe47- 4	9.10cd	8.30de	8.90cd	8.97cd	9.73bc
LD 88-1	7.43e	10.40ab	10.53ab	10.97ab	11.60a
LSD (0.05)			1.24		
	Fruit length at position 5 2020				
NHAe47- 4	8.50bcd	8.10de	7.50de	8.23cd	7.63de
LD 88-1	6.70e	7.63de	9.60abc	10.10a	9.97ab
LSD (0.05)			1.51		
	Fruit length at position 6 2019				
NHAe47- 4	9.30d	9.20de	9.70d	10.30c	11.20b
LD 88-1	8.73e	9.33d	10.90b	11.23b	12.00a
LSD (0.05)			0.48		
	Fruit length at position 6 2020				
NHAe47- 4	8.00cd	8.00cd	7.23de	9.13ab	8.13c
LD 88-1	7.03e	8.30bc	8.23c	9.13ab	9.93a
LSD (0.05)			0.85		

Means with the same letter(s) in the same column are not significantly different from each other at P≤ 0.05 according to LSD.

Generally, the combination of LD 88-1 with 120 kg ha^{-1} produced the longest fruits (12.00 cm) than the combination of LD 88-1 with zero application which produced the shorter fruits. In 2020, similar trend occurred as in 2019, but the combination of LD 88-1 with 120 kg ha^{-1} produced the longest fruits (12.03 cm) than the other combinations compared with the combination of NHAe47 – 4 with zero application which recorded the shortest fruits (9.10 cm).

At position 3, fruit length increased with an increment in nitrogen application in 2019 and 2020. At position 3, 4, 5 and 6 irrespective of the investigating years, interaction of LD 88-1 with 90 and 120kg N ha^{-1} produced the longest fruit except position 6, in 2019 and 2020 where the values were at par with NHAe47-4.

4.1.4.3 ***Number of seed/plot***

The effect of nitrogen application rates on number of seed of two okra cultivar at different harvesting positions in 2019 and 2020 is shown in Table 4.34. Number of seed was significantly different between the okra cultivars at plant position 1 in 2020 only, such that LD 88-1 produced the highest number of seed (72.47) than NHAe47 – 4 (68.0).

Nitrogen application rates rates had a significant effect on number of seed throughout the sampling positions in 2019 and 2020. At position 1, the application of 120 kg N ha^{-1} produced the highest number of seed in both years (88.33 and 87.50) than the other rates compared with zero application in 2019 (39.88), 0 and 30 kg N ha^{-1} in 2020 (51.83 and 58.00) which produced the lowest number of seeds.

Table 4.34: Effect of nitrogen application rate on number of seed of okra cultivar at different plant positions on the mother plant

	Number of seed											
	Position 1		Position 2		Position 3		Position 4		Position 5		Position 6	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Cultivar (C)												
NHAe47-4	63.13a	68.00b	56.53a	58.73a	58.73a	56.53a	40.67a	50.07a	63.13a	40.67a	45.87a	38.20a
LD 88-1	63.20a	72.47a	58.73a	61.67a	61.67a	58.73a	38.53a	51.53a	64.20a	38.53a	42.93a	39.33a
LSD (0.05)	3.41	3.99	4.78	4.41	4.41	4.78	5.03	5.44	3.41	5.03	6.17	5.52
N (kg ha^{-1})												
0	39.83e	51.83d	38.83c	44.17c	44.17c	38.83c	30.00c	33.00c	39.83e	30.00c	38.83a	30.33b
30	48.67d	58.00d	53.83b	50.17c	50.17c	53.83b	34.33bc	41.00c	48.67d	34.33bc	44.00a	36.17ab
60	60.33c	72.67c	62.50a	62.17b	62.17b	62.50a	41.50b	50.83b	60.33c	41.50b	45.67a	41.83a
90	81.17b	81.17b	67.67a	69.17a	69.17a	67.67a	41.83b	67.67a	81.17b	41.83b	47.67a	41.67a
120	88.33a	87.50a	65.33a	75.33a	75.33a	65.33a	50.33a	61.50a	88.33a	50.33a	45.83a	43.83a
LSD (0.05)	5.39	6.30	7.55	6.97	6.97	7.55	7.96	8.66	5.40	7.96	9.75	8.73
Interaction												
C x N	**	NS	NS	NS	NS	NS	NS	NS	**	NS	NS	NS

Means with the same letter(s) under the same column are not significantly different from each other at P≤ 0.05 according to LSD.

At position 2 in 2019, the application of 60, 90 and 120 kg N ha^{-1} produced significantly similar highest number of seeds (62.50, 67.67 and 65.33) than zero application which had the lowest number of seed (38.83).In 2020, the application of 90 and 120 kg N ha^{-1} produced statistically similar highest number of seed (69.17 and 75.33) than the application of 60 kg N ha^{-1} (62.17) compared with 0 and 30 kg N ha^{-1} which recorded similar lowest number of seed (44.17 and 50.17). At position 3 in 2019, the application of 90 and 120 kg N ha^{-1} produced similar highest number of seed (69.17 and 75.33) compared with 0 and 30 kg N ha^{-1} which had similar lowest number of seed (44.2 and 50.2).

In 2020, the application of 60, 90 and 120 kg N ha^{-1} produced significantly similar highest number of seeds (63.0, 68.0 and 65.0) than 0 and 30 kg N ha^{-1} which had similar lowest number of seeds (34.0 and 54.0). At position 4 in 2019, the application of 120 kg N ha^{-1} produced highest number of seeds (50.33) than the other rates compared with zero application which recorded the lowest number of seeds (30.0). In 2020, the application of 90 and 120 kg N ha^{-1} produced statistically similar highest number of seeds (67.67 and 61.50) than application of 0 and 30 kg N ha^{-1} which had similar lowest number of seeds (33.0 and 41.0). At position 5, the application of 120 kg N ha^{-1} produced significantly highest number of seeds (88.33 and 50.33) in 2019 and 2020, respectively than all the other rates compared with zero application which recorded the lowest number of seed (39.83 and 30.0) in both years. At position 6 in 2020, the application of 60, 90 and 120 kg N ha^{-1} produced similar highest number of seed which was at a par with the application of 30 kg N ha^{-1} compared with zero application which had the lowest number of seeds.

In table 4.34, irrespective of years, number of seeds in plant positions 1, 2, 3, 4, 5 and 6 with 120 kg N ha^{-1} application as well as 90 kg N ha^{-1} at positions 2, 3 and 4 produced highest number of seeds where the least number of seeds at 0 kg N ha^{-1} application irrespective of investigating year and plant positions on the mother plant.

The interaction of cultivar and nitrogen application rates on number of seed at different plant positions in 2019 and 2020 is shown in (Table 4.35). At position 1 in 2019, the combination of NHAe47 – 4 with 90 and 120 kg ha^{-1}with 88.0 and 86.0 number of seeds, respectively and LD 88-1 with 120 kg ha^{-1} (90.0) produced statistically similar highest number of seeds than the other combinations compared with the combination of NHAe47 – 4 with zero application and LD 88-1 with zero application which recorded similar lowest number of seeds (40.0) each. At position 5 in 2019, the combination of NHAe47 – 4 with 90 and 120 kg ha^{-1}with 87.67 and 86.33, respectively and LD 88-1 with 120 kg ha^{-1} (90.33) produced significantly similar highest number of seeds than the other combinations compared with the combination of NHAe47 – 4 with application of 0 and 30 kg ha^{-1} which produced the lowest number of seeds of 39.67 and 44.33, respectively.

4.1.4.4 *Seed weight*

The effect of nitrogen application rates on seed weight of two okra varieties at different plant positions in 2019 and 2020 is shown in Table 4.36. Seed weight differed significantly across the positions and years except at position 1 in 2019, position 4 and 5 in both years and position 6 in 2020 which showed no significant difference between the cultivars. The cultivar LD 88-1 consistently produced the heaviest seeds between (3 g and 5 g) than NHAe47 – 4 which consistently produced the lightest seeds between (3 g and 4 g) across the years.

Table 4.35: Interaction of cultivar and nitrogen application rates on number of seed at different plant positions on the mother plant in2019 and 2020

	N (kg ha^{-1})				
	0	**30**	**60**	**90**	**120**
			Number of seed at position 1 2019		
Cultivar	40.0e	44.0e	58.0cd	88.0a	86.0a
NHAe47- 4	40.0e	53.0d	63.0c	75.0b	90.0a
LD 88-1			5.52		
LSD (0.05)					
			Number of seed at position 5 2019		
Cultivar	39.67e	44.33e	57.67cd	87.67a	86.33a
NHAe47- 4	40.00e	53.00d	63.00c	74.67b	90.33a
LD 88-1			5.50		
LSD (0.05)					

Means with the same letter(s) in the same column are not significantly different from each other at P≤ 0.05 according to LSD.

Table 4.36: Effect of nitrogen application rate on of seed weight of okra cultivars at different plant positions on the mother plant

	Seed weight (g)											
	Position 1		Position 2		Position 3		Position 4		Position 5		Position 6	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Cultivar (C)												
NHAe47-4	4.63a	4.80b	4.05b	4.22b	4.22b	4.05b	3.05a	3.60a	3.09a	3.05a	4.05b	2.91a
LD 88-1	4.57a	5.21a	4.30a	4.53a	4.53a	4.30a	3.17a	3.88a	3.14a	3.18a	4.30a	2.91a
LSD (0.05)	0.28	0.22	0.24	0.28	0.28	0.24	0.30	0.30	0.46	0.29	0.24	0.31
N (kg ha^{-1})												
0	3.03e	4.09d	3.22c	3.66c	3.66c	3.22c	2.52c	2.62c	3.03ab	2.52c	3.22c	2.40c
30	3.79d	4.31d	3.97b	3.88c	3.88c	3.97b	2.83bc	3.43b	3.55a	2.83bc	3.97b	2.76c
60	4.29c	5.01c	4.45a	4.42b	4.42b	4.45a	3.35a	3.70b	2.95ab	3.36a	4.45a	2.93ab
90	5.64b	5.54b	4.65a	4.81ab	4.81ab	4.65a	3.23ab	4.63a	3.43a	3.23ab	4.65a	3.11ab
120	6.25a	6.07a	4.59a	5.11a	5.11a	4.59a	3.63a	4.33a	2.60b	3.63a	4.59a	3.35a
LSD (0.05)	0.44	0.35	0.38	0.44	0.44	0.38	0.47	0.48	0.73	0.47	0.38	0.49
Interaction												
C x N	**	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means with the same letter(s) under the same column are not significantly different from each other at P≤ 0.05 according to LSD.

Nitrogen application rates affected seed weight significantly throughout the sampling periods in 2019 and 2020. At position 1, the application of 120 kg N ha^{-1} produced significantly heavier seeds in both years (6.25 g and 6.07 g) than the other rates compared with zero application in 2019 (3.03 g), application of 0 and 30 kg N ha^{-1} in 2020 (4.09 g and 4.3 g) which produced the lightest seeds. At position 2 in 2019, the application of 60, 90 and 120 kg N ha^{-1} produced statistically similar heaviest seeds (4.45 g, 4.65 g and 4.59 g), respectively than zero application which had the lightest (3.22 g). In 2020, the application of 120 kg N ha^{-1} produced significantly heaviest seeds (5.11 g) similar with the application of 90 kg N ha^{-1} (4.18 g) compared with 0 and 30 kg N ha^{-1} which had similar lightest seeds of 3.66 g and 3.88 g, respectively. At position 3 in 2019, the application of 120 kg N ha^{-1} recorded heaviest seeds (5.11g) similar with 90 kg N ha^{-1} compared with 0 and 30 kg N ha^{-1} which produced similar lightest seeds (3.7 g and 3.9 g). In 2020, the application of 60, 90 and 120 kg N ha^{-1} produced statistically similar heaviest seeds than zero application which had the lightest seeds. At position 4, the application of 60, 90 and 120 kg N ha^{-1} in 2019, application of 90 and 120 kg N ha^{-1} in 2020 produced the heaviest seeds than the other rates compared with zero application which had the lightest seeds in both years.

At position 5 in 2019, the application of 30 and 90 kg N ha^{-1} produced similar heaviest seeds of 3.55 g and 3.43 g, respectively compared with 0 and 120 kg N ha^{-1} which recorded similar lightest seeds of 3.03 g and 2.60 g, respectively. In 2020, the application of 60 and 120 kg N ha^{-1} produced significantly similar heaviest seeds of 3.36 g and 3.63 g, respectively statistically similar with 90 kg N ha^{-1}when compared with zero application which had the lightest seeds (2.52 g). At position 6, the application of 60, 90 and 120 kg N ha^{-1} in 2019 and application of 120 kg N ha^{-1} in 2020 produced significantly heaviest seeds when compared with zero application in 2019, 0 and 30 kg N ha^{-1} in 2020 which recorded the lightest seeds.

The interaction of cultivar and nitrogen application rate on seed weight at different plant positions in 2019 is shown in Table 4.37. At position 1, the combination of LD 88-1 with application of 120 kg ha^{-1} significantly produced heaviest seeds (6.47 g) than all the other combinations compared with the combination of NHAe47 – 4 with zero application (3.11 g) and LD 88-1 with zero application (2.96 g) which had similar lightest seeds.

4.1.4.5 *Seed moisture content*

The effect of nitrogen application rates on seed moisture content of two okra cultivars at different plant positions in 2019 and 2020 is shown in Table 4.38. Seed moisture content was not significantly different between the cultivars at each plant positions and across the years in this study.

Nitrogen application rates had a significant effect on seed moisture content at each harvesting plant positions in 2019 and 2020 except at position 2 in 2019. At position 1, the application of 90 kg N ha^{-1} in 2019 (9.12 %), application of 90 and 120 kg N ha^{-1} in 2020 (8.17 % and 8.09 %) produced the lowest seed moisture content than 0 and 30 kg N ha^{-1} which had similar highest seed moisture content (12.41 % and 12.58%) in 2019 (13.29 % and 12.22 %) in 2020.

Table 4.37: Interaction of cultivar and nitrogen application rates on seed weight (g) at different plant positions on the mother plant in 2019

	N (kg ha^{-1})				
	0	**30**	**60**	**90**	**120**
	Seed weight at position 1 in 2019				
Cultivar					
NHAe47- 4	3.11f	3.60e	4.17d	6.24ab	6.02b
LD 88-1	2.96f	3.99de	4.41d	5.03c	6.47a
LSD (0.05)			0.45		

Means with the same letter(s) in the same column are not significantly different from each other at P≤ 0.05 according to LSD.

Table 4.38: Effect of nitrogen application rate on seed moisture content of okra cultivar at different plant positions on the mother plant

	Seed moisture content (%)											
	Position 1		Position 2		Position 3		Position 4		Position 5		Position 6	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Cultivar (C)												
NHAe47-4	10.73a	10.76a	12.32a	12.67a	12.67a	12.32a	15.12a	15.15a	8.99a	15.12a	9.78a	16.60a
LD 88-1	11.07a	10.18a	83.69a	12.49a	12.49a	11.69a	15.32a	14.31a	9.55a	15.28a	9.70a	15.81a
LSD (0.05)	1.14	0.80	151.27	1.00	1.00	1.48	0.83	1.14	0.70	0.78	0.47	1.21
N (kg ha^{-1})												
0	12.41a	13.29a	17.60a	14.11a	14.11a	17.59a	18.48a	17.67a	9.83a	18.48a	9.56ab	18.22a
30	12.58a	12.22a	12.80a	14.45a	14.45a	12.78b	16.72b	16.99a	9.60ab	16.72b	9.20b	17.46a
60	10.99ab	10.57b	10.30a	12.42b	12.42b	10.28cd	14.75c	14.46b	9.54ab	14.65c	10.06a	16.71ab
90	9.12c	8.17c	8.40a	10.91b	10.91b	8.41d	12.76d	12.83bc	8.80ab	12.76d	9.75ab	15.39b
120	9.41bc	8.09c	191.0a	11.03b	11.03b	10.95bc	13.41d	11.70c	8.60b	13.41d	10.13a	13.24c
LSD (0.05)	1.81	1.26	239.18	1.58	1.58	2.34	1.31	1.81	1.10	1.23	0.74	1.92
Interaction												
C x N	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**	NS

Means with the same letter(s) under the same column are not significantly different from each other at P≤ 0.05 according to LSD.

At position 2 in 2020, the application of 90 and 120 kg N ha^{-1} had similar lowest seed moisture content of 10.91 % and 11.03 %, respectively than 0, 30 and 60 kg N ha^{-1} which had similar highest seed moisture content of 14.11%, 14.45 % and 12.42 %, respectively. At position 3 in 2019, application of 60, 90 and 120 kg N ha^{-1} produced statistically similar lowest seed moisture content (12.42 %, 10.91 % and 11.03 %) than 0 and 30 kg N ha^{-1} which had similar highest seed moisture content of 14.11 % and 14.45 %, respectively. In 2020, the application of 90 kg N ha^{-1} produced the lowest seed moisture content (8.41) similar with application of 60 kg N ha^{-1} (10.28 %) compared with zero application which had the highest seed moisture content (17.59 %).

Similarly, at position 4, the application of 90 kg N ha^{-1} (12.76 %) and 120 kg N ha^{-1} (13.41 %) in 2019 and application of 120 kg N ha^{-1} (11.70 %) in 2020 produced the lowest seed moisture content than zero application (18.48 %) in2019, application of 0and 30 kg N ha^{-1} in 2020 which produced the highest seed moisture content of 117.67 and16.99 %, respectively. At position 5, the application of 120 kg N ha^{-1} (8.60 %) in 2019, application of 90 and 120 kg N ha^{-1} with moisture content of 12.76 % and 13.41 %, respectively in 2020 produced the lowest seed moisture content than zero application which had the highest seed moisture content (9.83 % and 18.48 %) in 2019 and 2020 respectively.

At position 6 in 2019, the application of 30 kg N ha^{-1} produced the lowest seed moisture content (9.20 %) than the other rates compared with 120 kg N ha^{-1} which had the highest seed moisture content of between 9.5 and 10.13 %. In 2020, the application of 120 kg N ha^{-1} produced the lowest seed moisture content (13.24 %) than the other rates compared with 0 and 30 kg N ha^{-1} which produced statistically similar highest seed moisture content of 18.22 % and 17.46 %, respectively.

The interaction of cultivar and nitrogen application rate on seed moisture content at different harvesting plant positions in 2019 is shown in (Table 4.39). At position 1, the combination of NHAe47 - 4 with zero application produced the lowest seed moisture content than the other combinations compared with the combination of NHAe47 – 4 with the application of 120 kg ha^{-1} which had the lowest seed moisture content.

4.1.4.6 *Germination percentage at different days after anthesis and storage periods*

Table 4.40 is showing the effect of harvesting at different days after anthesis and storage periods on germination percentage of two okra cultivars in 2019 and 2020. Cultivar significantly affected seed viability at different storage periods. Seeds obtained from fruit of LD88-1 at 0 week had higher viability percentage (66.16 %, 74.25%) in 2019 and 2020. At 0 weeks, seed from fruit of NHAe47-4 had a low viability percentage (49.21%) in 2019, compared to two (2) week after storage (54.9% in 2019) but higher than that of four (4) weeks storage period (33.00% in 2019). Days after anthesis had a significant effect on seed viability at different weeks of storage and years. Prior to storage there was an increase in viability with an increase in DAA, where (42) DAA had the highest viability percentage (79.25 % and 82.93%) for both years, respectively. The decrease began at 49 DAA (60.45% in 2019) and 56 DAA (55.00% in 2019). Whereas for 2020, the decrease began in 35 DAA (77.03%) and 49 DAA (61. 25%).This is showing that beyond 42 DAA, seed begins to lose its viability, this indicates that there was an increase in viability of seed from 14 DAA to 42 DAA but declines beyond 42 DAA.

Table 4.39: Interaction of cultivar and nitrogen application rates on seed moisture content (%) at different harvesting plant positions on the mother plant in 2019

	N (kg ha^{-1})				
	0	**30**	**60**	**90**	**120**
	Seed moisture content at position 1 in 2019				
Cultivar					
NHAe47- 4	8.73f	8.93ef	10.40ab	10.18abc	10.65a
LD 88-1	10.40ab	9.47c-f	9.71bcd	9.32def	9.60cde
LSD (0.05)			0.76		

Means with the same letter(s) in the same column are not significantly different from each other at P≤ 0.05 according to LSD.

Table 4.40: Effect of days after anthesis on germination percentage of two okra cultivars at 0, 2, and 4 weeks of storage

	Week 0		Week2		Week 4	
	2019	2020	2019	2020	2019	2020
Cultivar (C)						
NHAe47-4	49.21b	51.61b	54.9a	58..89a	33.00b	34.54
LD 88-1	66.16a	74.25a	58.09a	59.92a	36.56a	44.86a
LSD (0.05)	1.09	2.13	2.18	0.40	0.87	0.70
DAA						
14	30.92e	33.53e	38.90c	29.53e	25.75d	21.35e
21	48.25d	49.80d	48.65bc	32.23d	27.25d	20.99d
28	57.00c	57.47c	56.25b	45.05c	34.00c	43.26b
35	72.95b	77.03b	57.15b	46.61b	35.65cb	60.59a
42	79.25a	82.93a	75.45a	64.34a	52.80a	41.32b
49	60.45c	61.25b	61.35b	60.25ab	39.90b	34.23c
56	55.00c	54.63c	57.90b	52.61b	28.00d	33.76c
LSD (0.05)	2.04	2.24	4.08	3.64	1.63	1.11
Interaction						
C x A	*	NS	NS	NS	NS	NS

Means with the same letter(s) under the same column are not significantly different from each other at P≤ 0.05 according to LSD.

At 2 weeks after storage, there was an increase in viability percentage from 14 DAA (38.90 %, 29.53%)to 42 DAA (75.45 %, 64.34%), respectively and began to decrease after 49 DAA (61.35 %, 60.25%) and 56(57.90 %, 52.61%) in 2019 and 2020, respectively. Similar to 4 weeks after storage, there was also an increase in germination percentage from fourteen 14 DAA (25.75%) to 42 DAA (52.80%) and began to decrease at 49 and 56 DAA with 39.90 % to 28.00% in 2019.

In 2020 at 4 weeks after storage, there was an increase in seed viability from 14 DAA (21.53%) to 35 DAA (60.59%) and began to lose viability from 42 DAA (41.32%) to 49 DAA (34.23%) to 56 DAA (33.76%).

Table 4.41 shows Interaction effect of cultivar and days after anthesis on germination percentage at 0 week after storage shows that LD88-1 at 42 DAA had the highest viability percentage (88.50%) compared to all other interactions. Whereas, NHAe47-4 at 14 DAA recorded the least viability percentage (20.30%).

The interaction table is also showing that at every DAA, LD88-1 had the highest viability percentage compared to NHAe47-4, it is also showing that the germination percentage increased from 14 DAA to 42 DAA and began to decrease at 49 days and above. This is showing that seed viability increased from 14 DAA to 42 DAA and viability began to decrease from 49 days and above.

4.1.4.7 *Fruit position on the mother plant and seed germination*

Table 4.42 showed cultivar significantly affected fruit position on the mother plant at 0 weeks before storage.

Table 4.41: Interaction effect of cultivars and days after anthesis on viability percentage at 0 week after storage in 2019

	Germination (%)	
DAA	Cultivar	Storage period (0 week)
14	NHAe47-4	20.30h
21	NHAe47-4	37.00g
28	NHAe47-4	44.00f
35	NHAe47-4	67.50c
42	NHAe47-4	70.00c
49	NHAe47-4	53.70c
56	NHAe47-4	51.20c
14	LD88-1	41.50fg
21	LD88-1	58.70d
28	LD88-1	77.00c
35	LD88-1	78.40b
42	LD88-1	88.50a
49	LD88-1	67.20c
56	LD88-1	58.80d
SE±		2.89

Means with the same letter(s) in the same column are not significantly different from each other at P≤ 0.05 according to LSD.

Table 4.42: The effect of fruit position on mother-plant on the viability percentage of seeds of two okra cultivars at different storage periods and cropping years

	Week 0		Week2		Week 4	
	2019	2020	2019	2020	2019	2020
Cultivars (C)						
NHAe47-4	49.57a	51.61b	46.25a	32.89b	33.60a	34.54b
LD 88-1	43.50b	54.25a	39.02b	35.92a	32.12a	35.86a
LSD (0.05)	1.71	2.13	0.71	0.40	1.21	0.70
Positions (P)						
1	61.50a	59.25b	54.30a	50.25ab	5015a	40.23b
2	58.85a	54.93b	57.25a	59.34a	44.90b	41.32a
3	50.40b	76.03a	47.65b	41.21b	35.50c	30.59c
4	45.10c	77.47a	43.60c	39.05c	34.50c	29.23c
5	35.45d	39.80c	30.30d	22.23d	15.50d	20.99d
6	27.90e	25.53d	22.70e	20.53e	16.55d	14.35e
LSD (0.05)	2.22	2.24	1.22	3.64	1.02	1.11
Interaction						
C x P	NS	NS	*	NS	NS	NS

Means with the same letter(s) under the same column are not significantly different from each other at P≤ 0.05 according to LSD.

Seeds of NHAe47-4 germinated significantly higher 49.57% than LD88-1 43.50 % in 2019 while in 2020 LD88-1 recorded (54.25%) than seeds of NHAe47-4 (51.61%). NHAe47-4 recorded higher viability (46.25%) than LD88-1(39.02%) in 2019. Whereas, in 2020 the reverse was recorded where LD88-1 germinated significantly higher with (35.92%) than NHAe47-4 (32. 89%).The same trend was recorded with the trait.

However, fruit position on the mother plant affected viability percentages significantly across storage periods. Prior to storage, seeds extracted from fruits of lower base (positions 1 and 2) germinated significantly higher (61.50% and 58.85%) than those of upper positions (positions 3-6) with values ranging between 50.40% and 27.90% in 2019. In 2020, seeds from positions 4 and 3 germinated significantly higher 77.47% and 76.03%, respectively.

Furthermore, with seeds stored after 2 weeks, viability declined generally, irrespective of positions. The superiority in seeds viability values of seeds of position 2 (57.25%, 59.34%) and position 1 (54.30%, 50.25%), respectively in 2019 and 2020 over seeds of other positions was maintained. In 2019, at 4 weeks after storage, position 1 recorded seeds with higher viability (50.15%) while in 2020, seeds from position 2 were significantly higher in viability (41.32%) than seeds from other positions on the mother plant.

Table 4.43 showed that cultivar difference was significantly recorded at 2 weeks after storage with NHAe47-4 seeds extracted from fruits of position 5 germinated better (59.90%) than position 4(54.00%) and 6(53.30%). Seeds extracted from position 5 and 6 for LD88-1 cultivar were statistically similar with 55.00% and 55.80%, respectively. The interaction table showed statistical similarity of germinated seeds in position 5 and 6 for both cultivars NHAe47-4 and LD88-1.

Table 4.43: The Interaction effect of cultivar and position on the mother plant on viability percentage at week 2 after storage in 2019

	Viability (%)	
Positions (P)	Cultivar	Storage period (Week 2)
1	NHAe47-4	29.07f
2	NHAe47-4	33.80e
3	NHAe47-4	47.20c
4	NHAe47-4	54.00b
5	NHAe47-4	59.50a
6	NHAe47-4	53.30b
1	LD88-1	15.70g
2	LD88-1	26.80f
3	LD88-1	40.00d
4	LD88-1	41.30d
5	LD88-1	55.00b
6	LD88-1	55.30b
SE±		1.73

Means with the same letter(s) in the same column are not significantly different from each other at P≤ 0.05 according to LSD.

4.2 Discussions

Fertilizer application is an important aspect of field crop management which is needed to enhance plant growth, fruit and seed yield. Maintaining optimum plant population and nitrogen fertilization dose are most important elements in improving productivity of okra (Musa *et al*., 2020). Optimum plant density is the key element for higher fruit yield of okra, as plant growth and yield are affected by nitrogen fertilization (Navdeep and Daljeet, 2016; Ibrahim *et al*., 2020). Ali (2015) stated that the use of extra N on vigorous plants as the practice may result in plants producing heavy foliage which will delay flowering. Nwokwu *et al*. (2020) reported that higher rates (150kg ha^{-1}) of N resulted in significant delay in flowering and reduced fruiting of egg plants compared to plants of control and 50 kg ha^{-1} of N. The delay in flower bud sighting, subsequent opening and attainment of 50% flowering recorded in the two varieties that were fertilized with 150kg ha^{-1} of N in this study is an indication that N at those rates were relatively high. This agrees with the results of Musa *et al*. (2010) who reported similar rates in eggplant. Application of 100kg ha^{-1}of N delayed flowering however reduced the incidence of flower abortion, which eventually resulted in higher yield (Ibrahim *et al*., 2015).

Michael *et al*. (2018) reported that an increase in N application resulted in maximum vine length, delayed flowering and fewer fruits in cucumber. The similarity in the performance of the two varieties in the traits mention above suggests that the two varieties exhibited genetic similarity and capacity to absorb and utilize N. The research conducted by Atif and Nahed (2016) revealed that increase in nitrogen fertilizer from the control (0 N) to 160 kg N ha^{-1} significantly increased total fruit yield.

The variations observed between the two okra varieties in terms of the evaluated parameters may be due to genetic compositions.

The significantly taller plants, higher number of leaves and higher number of fruits per plant produced with the application of 90 and 120 kg N per hectare at all the stages of plant growth in this study may be linked to N from inorganic sources being ready for uptake by plants. Nitrogen from such sources is readily depleted through rapid crop removal, leaching and/or denitrification. This can retard the growth of plants at later growth stages (John and Gordon, 2017). Higher rates of N coupled with split application as was the case in this study ensures the supply of nitrogen nutrient at all the stages of plant growth. This might have guaranteed the consistence in plant growth stages over time which might have conferred the superiority in height at all the growth stages in this study. These results are supported by the reports of Li *et al*. (2017) in tomato.

The increase in plant height, as a result of the application of inorganic fertilizer at different levels, might have enhanced cell division and formation of more tissues resulting in luxuriant vegetative growth (Zubairu *et al*. 2017) giving rise to the observed tall plants recorded in the present study. In zero N dose plots which recorded minimum plant height might be due to the meager nutritional standing which resulted in stunted growth resulting in short plants. Muhammed *et al*. (2013) recorded similar result in their experiment conducted to evaluate the influence of nitrogen and phosphorous fertilizer on the phenology of okra. Similar trend was also obtained by Oladiran *et al*. (2016) who recorded maximum plant height with application of 120 kg N. Ncama and Sithole (2022) reported that leaf number is substantially increased by increasing N levels.

According to Nwokwu *et al*. (2020), the height, number of fruits per plant and number of branches per plant of eggplant was found to be increased by increase in the levels of nitrogen fertilizer up to 150kg N ha^{-1}. Whereas, the lowest height, fruit numbers and number of branches were found with the control without N. Growing okra plants with 80 and 100 kg N ha^{-1} generally resulted in lower flower abortion incidences compared to other nitrogen treatments in this study. This suggests that adequate crop nutrition is important for good crop establishment and vigour expression which enhances successful flowering and subsequent fruit set. Significantly greater number of flower drops has been reported in okra plots treated with zero and low nitrogen doses compared with higher rates (Brar and Singh, 2016). Poor or insufficient soil nutrients such as nitrogen during flowering is known to impede the production of hormone called auxin which is responsible for flower stimulation and fruit set (Iqbal *et al*., 2017). Molla *et al*. (2019) recorded fewer flower and fruit drops in pepper plots amended with higher nitrogen rates against a severe case of lower rates and absolute control fields. The significantly better performance in most of the parameters scored for plants to which 100 and 120 kg N ha^{-1}were applied compared to all other nitrogen rate in this study indicates that nitrogen at those rates is sufficient for optimum growth than the other rates of application (Kamal *et al*., 2020). This view has also been expressed by Ibrahim *et al*., 2019b; Anas *et al*. (2020) who adjudged adequate nitrogen to be most valuable instrument for plant performance than poor or deficiency of the nutrient. The seed yield and quality of the seed amaranth varieties were increased from 0 up to 45 kg N ha^{-1} and declined thereafter. Adequate nitrogen increases the quality, fruit size, keeping quality, colour and taste (Anas *et al.*, 2020). Increase in nitrogen levels and spacing resulted in the production of quality fruits (Brar and Singh, 2016).

Zinelabidine *et al*. (2021) reported that differences in genetic makeup may be responsible for variations in fruit and seed yield under given set of environmental condition. The unfertilized plants (control) in all the traits recorded poor performance due to poor plant nutrition. The performance of okra is determined largely by application of fertilizers (Olaniyi *et al.,* 2010). Olaniyi *et al.* (2010) stressed that adequate supply of nitrogen is essential for vigorous vegetative growth and optimum yield in okra.

Leaf area of the plant increases with the increase in nitrogen application up to the highest level at different growth stages (Ibrahim *et al*., 2013; Sriman *et al*., 2018). Kumar *et al*. (2022) observed similar patterns of response, indicating that nitrogen promotes general crop vigour through its influence on cell division, cell elongation and expansion, synthesis of essential amino acid and chlorophyll formation.

Rao *et al.* (2017) advised that seeds should be harvested at proper time to ensure their quality in terms of germinability and vigour. However, Bortey *et al.* (2022) reported that fruits harvested even before physiological maturity and allowed some days of post-harvest ripening may produce good quality seeds since seed development continues in fleshy fruits owing to continuous supply of nutrients and food reserves from fruit to seed.

The seed maturation however, is closely associated with fruit maturation and complete fruit drying (Bortey *et al.,* 2022). The suitable stage of harvest could also vary from cultivar to cultivar (Diana *et al*., 2018). For most crop species, the more matured the fruit is at harvest, the higher the quality of its seeds (Ibrahim and Oladiran 2011; Tetteh *et al.,* 2018). Wulff (1986) also reported that different seeds within a fruit do not mature at the same rate. This therefore suggests that the different seeds contained in a fruit are of different ages and therefore of varying qualities.

A study conducted by (Seal *et al.,* 2013) noted that there is a positive linear correlation between fruit weight and seed dry weight on kiwifruit. They stated that flowers that open earlier have a larger ovary and set larger seeds leading to large fruits explaining that this may be because of either their innate superiority or their position on the vine.

The longest fruits size was from position 1 (position closest to the plant base) while the shortest were from position 6 (upper position). This result agrees with the trend reported by Lu *et al*. (2022) for pepper in which fruit weight gradually declined from positions closest to the plant base to those at upper layers. Also, the result was similar with that of Zubairu *et al.* (2017). The significant increase in fruit diameter, fruits length, number of seeds, seeds weight and moisture content in response to increasing addition of N in this study indicates that okra fruits at upper positions are poor physiological sinks. Oladiran *et al*. (2016) reported that okra fruits located on higher position were smaller and lighter due to their low capacity to compete for photo-assimilates. Kortse and Oketa (2016) also observed that okra fruit size was affected by position on mother-plant due to competition for assimilates. Seeds from the peduncular fruit segments were delayed in reaching maximum quality compared with seeds from other positions in cucumber (Hu *et al.*, 2019). Position 1(base) fruits weighed the heaviest compared to those of the other upper positions (4, 5 and 6) on the mother-plant, this result agrees with the trend reported by Alan and Eser (2007) for pepper in which fruit weight gradually declined from position closest to the plant base to those at the upper layer.

The decline in seed viability after a storage period of 49 days is indicative of seed deterioration which is linked with disruption of cell organelles due to free radical production in the cells of embryos (Bewley and Black, 2012).

However, for okra seed production, fruits are left on the mother plant until they are dry before harvested. The seed crop requires the right stage of maturity followed by proper drying to ensure high germinability after harvest and storage. This is because seed longevity is known to be influenced by the initial seed quality, which is affected by the production procedure (Ibrahim *et al*., 2011; Bortey and Dzomeku, 2016).

The results of this study showed that germination and longevity were best maintained in seeds from plants to which 90 and 120 kg N ha^{-1} were applied to their mother plants during growth on the field. Ibrahim *et al*. (2016) suggested that this might be due to adequate nutrition of mother plants during growth, which is believed to have been supplied by nitrogen fertilizer with P and K fertilizer. Ibrahim *et al*. (2019a) reported application of 120 kg N ha-1 significantly increased yield of lettuce in compared to control treatment. Sumathi *et al*. (2013) also expressed that the nutrients applied at optimum dose, induced the formation of protease enzymes in adequate quantities that activated the anabolic metabolism in seeds that resulted in improved seed quality. Plants normally have certain limitation in potential uptake and utilization of nutrients for their growth and metabolism, beyond which excess or minimum application of nutrients has no role, but which in turn decreased the growth and yield parameters (Yousaf *et al*., 2017).

The initial decrease in germination and seedling emergence recorded within two weeks of storage irrespective of fertilizer treatment in this study suggests that dormancy which is known with fresh seeds of most vegetable is yet to be broken before storage. It is a common phenomenon in some vegetables, to have seed lots exhibiting delayed germination which are characterized by improved germination with increased storage time compared to germination at seed harvest (Ibrahim *et al*., 2012; Maleki *et al*., 2022). Some period of storage had been reported by Lee *et al.* (2002) to break dormancy in some crop species. Ibrahim *et al.*, 2014; Finch-Savage and Bassel (2016), reported that as seeds aged they undergo gradual changes which lower their potential vigour and performance capability. According to Storme and Mason (2014), seedlings that emerge from old seeds show various cytological abnormalities such as chromosome breakage and the disturbance of mitotic spindle. Seedling growth reduction has also been shown to be recorded with age in storage by Belay *et al.*, 2017).

Result of this study further reveals that germination where significantly better in seeds of NHAe47-4 while LD88-1 performed better prior to storage. This may be attributed to bigger size of seeds in LD88-1. Edjie and Ossom (2009) noted seed size as an indispensable quality trait which was responsible for higher seed germination and vigour in some vegetables. (Finch-Savageand and Bassel 2016; Ibrahim *et al.*, 2010) recorded okra seedlings with less vigour to have developed from small seeds. This implies that larger seeds have more food reserve in their cotyledons which were metabolized to achieve higher germination and early vigorous plant growth. The low percentage germination and poor longevity of seeds from plants without fertilizer supplement may also be due to low seed weight (Emilia and Jan, 2022). Dormancy was recorded with freshly harvested seeds of the two okra varieties. However, this was broken with time in storage. Deterioration of seeds set in after attainment of the maximum points in different treatments.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

It is concluded from this study that application of 90-120 kg N ha^{-1} to okra (*Abelmoschus esculentus* L. Moench) mother-plantswas optimum for growth, fruit andseed yield compared to other fertilizer treatments. Flowering was delayed when these rates (90-120Kg N ha^{-1}) of fertilizer was applied to plants. Plants which received no fertilizer application performed poorly in respect to all parameters scored. Results further revealed that, greater plant height (173 cm), number of leaves per plant (20), stem girth (8.3 cm), leaf area (578.04 cm^2) and 100-seed weight (5.23 g) were recorded in LD88-1 compared to the values of: plant height (92.58 cm), number of leaves per plant (19), stem girth (8.06 cm), leaf area (548.87 cm^2) and 100-seed weight (4.54 g) recorded with NHAe47-4 cultivar. LD88-1 fruits contained more seeds than NHAe47-4 cultivar while seeds of NHAe47-4 were bigger than those of LD88-1. Seeds of LD88-1maintained superiority in viability both before and during storage than the seeds of NHAe47-4. Harvesting fruits at 42 DAA irrespective of varieties produced seeds which germinated and stored significantly better throughout storage than other harvesting stages. Fruits formed at the lower positions (1-3) produced more and bigger seeds than those formed at the upper positions (4-6). Okra seeds of the two cultivars exhibited dormancy in this study; these dormancies were broken with time in storage.

5.2 Recommendations

Based on the results from this study, it is recommended that application of 90-120 kg N ha^{-1} should be applied to mother-plant of okra for optimum plant growth, development, fruit and seed yield and quality. For quality seed production, it is recommended that soil should be amended with 90-120 kg N ha^{-1}during plant growth. On the basis of agronomic traits LD 88-1 was proven and recommended for fruit and seed production. Furthermore, earlier formed fruits on the mother-plant (Positions 1-3) should be harvested at 42 DAA for high quality seed production; which should be used as planting material.

5.3 Contribution to knowledge

This study revealed that though, harvesting seeds at 35 DAAs for the two cultivars resulted in high viability percentage values.

1. In the current study, harvesting seeds at 42 DAA maintained superiority for longer period in storage than the 35 DAA, suggesting that the physiological maturity for harvesting fruits of these varieties for seed extraction is attained at this stage as against the earlier conclusion of 35 DAA by several workers.

2. Application of 90-120Kg N ha^{-1}to mother-plants of the two okra cultivars enhanced growth, fruit and seed yield.

3. Application of 90-120Kg N ha^{-1}to mother-plants of the two okra cultivars produced seeds which germinated and stored significantly better than other fertilizer treatments.

4. NHAe47-4 okra cultivars can be adopted in the Guinea Savanna ecological zone for its bigger fruits.

5. Seeds produced from the lower positions (1-3) on mother-plants of okra are more viable and storable.

6. Dormancy was established in seeds of all the two cultivars which was overcome with time in storage

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Appendix I: Temperature and Rainfall distribution during 2019 and 2020 cropping seasons

	2019 Cropping Season		2020 Cropping Season	
	Temperature (^{o}C)	Rainfall (mm)	Temperature (^{o}C)	Rainfall (mm)

Month	Max	Min		Max	Min	
January	35.7	21.0	0	34.5	20.6	0
February	36.5	23.1	1.5	36.2	23.3	0
March	38.9	26.1	0	38.4	24.9	21.5
April	37.9	26.4	24.6	37.0	24.9	77.3
May	33.7	24.3	132.4	34.3	23.3	158.5
June	30.2	23.2	223.1	30.9	22.6	275.07
July	29.6	22.6	297.2	29.4	22.9	361.4
August	29.0	22.4	355.6	28.9	22.3	326.1
September	30.6	22.0	346.5	29.3	21.8	383.7
October	30.3	22.0	313.3	32.2	22.0	160
November	34.6	21.5	0	35.7	21.2	0
December	35.3	19.7	0	36.2	21.1	0
Mean	**33.5**	**22.9**	**141.2**	**33.6**	**22.6**	**146.9**

Appendix II: Relative humidity during 2019 and 2020 cropping seasons

RELATIVE HUMIDITY (%)

MONTH	**2019**	**2020**
JAN	33	29
FEB	37	25
MAR	55	50
APR	55	60

MAY	69	71
JUN	77	82
JUL	83	85
AUG	85	84
SEP	83	86
OCT	79	77
NOV	53	43
DEC	36	39