KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY KUMASI, GHANA

COLLEGE OF AGRICULTURE AND NATURAL RESOURCES

FACULTY OF AGRICULTURE

DEPARTMENT OF HORTICULTURE

EFFECT OF DIFFERENT PRIMING CONCENTRATIONS ON GERMINATION AND SEEDLING PERFORMANCE OF AGE-ACCELERATED SEEDS OF THREE OKRA (*Abelmoschus esculentus* L*)* VARIETIES.

BY

ASAMOAH FREDERICK OSEI

SEPTEMBER, 2015

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Kwame Nkrumah University of Science and Technology, Kumasi, Ghana, in partial fulfillment of the requirements for the award of Master of Philosophy (MPhil)

Seed Science and Technology

SEPTEMBER, 2015

DECLARATION

I hereby declare that except for references to other people's work, which I have duly acknowledged, this is the result of my own research work and it has neither in part nor wholly been presented elsewhere for another degree.

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DEDICATION

This work is dedicated to God almighty, H.H. Sant Rajinder Singh Ji Maharaji, my lovely mother, Mary Fremah, my late grandmother Christiana Oppong Bimpomaah and my entire family.

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ABSTRACT

Okra *Abelmoschus esculentus* L., is an economically important vegetable crop grown in the tropical and sub-tropical parts of the world. Okra farmers in Ghana face a major problem of seeds not promptly germinating after planting or the seeds not germinating at all. This has led to the famers doubling the seed rate per hectare. This experiment was set out to find out how three Ghanaian okra varieties; CRI-K-P11-11, Asontem and Manpeali responded to organic and inorganic priming agents after 72 hours of accelerated seed ageing at 45^0C and 98% relative humidity and to determine the best variety and primer concentration. Results from the study showed that, the interaction between CRI-K-P11-11 and Ascorbic acid at 150ppm concentration recorded the highest germination percentage (68.0%) and speed of germination (18.67) with the highest seed vigour index (8235) recorded for the interaction between CRI-K-P11-11 and KCl 0.4%. The varietal means differed highly significantly ($P<0.01$) with CRI-K-P11-11 recording the highest germination percentage (49.61%), speed of germination (13.78) and seed vigour index (6043). Asontem recorded relatively low scores in germination percentage (15.89%) and seed vigour index (1571) with the least speed of germination recorded by Manpeali (4.614). There were highly significant differences ($P<0.01$) in the seed primer concentrations used in the study. Ascorbic acid 150ppm recorded the highest primer mean in germination percentage (39.33%), speed of germination (10.14) and seed vigour index (4345). *Moringa oleifera* leaf extract 1:15 was the best performing organic seed primer in germination percentage (33.78%), speed of germination (8.41) and seed vigour index (3822). Accelerated ageing had deleterious effect on okra seeds. CRI-K-P11-11 was the most vigorous variety. Ascorbic acid 150ppm was the best performing seed primer.

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LIST OF ABBREVIATIONS

AA – Accelerated Seed Ageing

ANOVA-Analysis of Variance

AOSA- Association of Official Seed Analysts

CRD-Complete Randomized Design

CRI-Crop Research Institute

CSIR- Council for Scientific and Industrial Research

FAO – Food and Agriculture Organisation

GI – Germination Index (Speed of Germination)

SVI – Seed Vigour Index

ISTA - International Seed Testing Association

P1- Ascorbic acid 50ppm

P2 - Ascorbic acid 100ppm

P3 - Ascorbic acid 150ppm

P4 - KCl 0.2%

P5 - KCl 0.3%

P6 –KCl0.4

P7 - Orange juice extract 1:1

P8 - Orange juice extract 1:2

P9 - Orange juice extract 1:3

P10 - *Moringaoleifera*leaf extract 1:5

P11 - *Moringaoleifera*leaf extract 1:10

P12 - Moringa*oleifera leaf*extract 1:15

V1 - CRI-K-P11-11

V2 – Asontem

V3 – Manpeali

CHAPTER ONE

INTRODUCTION

Okra *Abelmoschus esculentus* L., is a vegetable crop of high economic importance grown in several parts of the world. It grows well in the tropical and sub-tropical regions. This crop is cultivated both as a garden and commercial crop. It is produced on a large scale in nations like India, Iran, Ghana, Nigeria, Ivory Coast, Bangladesh, Afghanistan, Malayasia, Brazil, Pakistan, Ethiopian, and the Southern parts of United States. India positions first in the world okra production with 3.5 million tons produced yearly. This represents 70% of the world's annual okra production (FAOSTAT, 2008).

Okra is known by several names in different parts of the globe. It is called gumbo in the United States of America, lady's finger in England, guino-gombo in Spanish, nkuruma by the Akans in Ghana and bhindi in India (Chauhan, 1972).

Okra is a vegetable which one finds in a fresh state in almost all markets in Ghana, during the rainy season and in a dehydrated form during the dry season. It is particularly found in Northern Ghana due to its strong commercial value for poor women farmers and its vital importance as food diet among the inhabitants of the cities and villages (Oppong-Sekyere *et al*., 2012). Okra is rich in proteins, carbohydrate and vitamin C according to Adeboye and Oputa (1996). The annual production of okra in Ghana from the year 2006 to 2008 was between 100 000 – 120 000 tons and the quantum of production is expected to rise every subsequent year (Kumar *et al*., 2010).

The quality of seeds planted mainly influences agriculture productivity. Globally, farmers and growers know the types of the seeds that they want to sow hence their expectations are clear. Firstly, the species and variety they buy should be consistent with what they believe they are buying. Secondly the seeds planted should achieve uniform and successful establishment, the crops established should be free from weeds and develop without the incidence of seed-borne infections (Powell, 2010).

Okra seeds in storage lose viability at a fast rate leading to poor germination and establishment (Desh *et al.,* 2013). Desh *et al.,* (2013) also stated that the most important single factor affecting okra production in India and the major okra producing countries is the quality of seed. Okra farmers in Ghana face the problem of seeds not germinating promptly after planting or total germination failure. This has led to the famers doubling the seed rate per hectare. This greatly increases the cost of production (Offei, 2014).

Thus it will be highly relevant to develop an insight into the basic phenomena of seed ageing and longevity. Harrington (1972) stated that each 1% reduction in seed moisture or each 5ºC reduction in temperature doubles the storage life of the seeds when the normal temperature and moisture range for seed storage is maintained. Accelerated ageing has been used widely to study the physiological and biochemical changes in seeds as they age.

Accelerated seed ageing after days of exposure to high relative humidity and high temperature is a good predictor of seed storability (Sung and Jeng, 1994). This ageing test can give a better indication of probable field emergence than germination and growth tests for vegetable crop seeds

(Pandey *et al.,* 1990). The main difference between accelerated ageing and actual deterioration in poor storage conditions is the speed at which the changes occur in case of accelerated ageing. This can be used to investigate the factors responsible for seed deterioration in storage and the efficacy of various pre-sowing treatments that can improve the performance of a given seed lot (Milosevic *et al.,* 2010).

Seed priming before planting shows remarkable results in seed emergency and vigour. Priming is carried out by regulated hydration, in osmotic solutions or water. This prevents germination but allows the improvement of some metabolic processes. When seeds dehydrate the advantages obtained in the priming process is retained. These benefits include uniform germination, increased seed vigour which translates into rapid seedling development (Bray, 1995). The process of priming treatment in the laboratory imitates the seasonal changes in the soil. The physiological process of priming constitutes an acclimation mechanism of the plants to their environment.

This experiment was thus set out to show how three Ghanaian okra varieties; CRI-K-P11-11, Asontem and Manpeali aged and how well they responded to organic and inorganic priming agents after 72 hours of accelerated seed ageing at 45^0C and 92% - 98% relative humidity.

The specific objectives of this experiment were to determine;

- which of the three varieties of okra best responded to the various priming agents after accelerated seed ageing;

- the storability of the seeds of the three varieties of okra;

- the effect of different concentrations of organic primers on the germination and seedling characteristics of the accelerated aged okra seeds;

- the best performing synthetic primer at different concentrations on the artificially aged okra seed; and

- the effect of accelerated seed ageing on okra germination and seedling characteristics after 72 hours of accelerated seed ageing without seed priming.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 OKRA

Okra *Abelmoschus esculentus* L., is a vegetable crop of high economic importance grown in several parts of the world. It grows well in the tropical and sub-tropical regions. Okra is believed to have originated from East Africa and is distributed widely in the tropics, subtropics and parts of the temperate region which records warmer temperatures (ECHO, 2003). This crop is cultivated both as a garden and commercial crop. It is produced on a large scale in nations like India, Iran, Ghana, Nigeria, Ivory Coast, Bangladesh, Afghanistan, Malaysia, Brazil, Pakistan, Ethiopia, and the Southern parts of United States. India positions first in the world okra production with 3.5 million tons produced yearly. This represents 70% of the world's annual okra production (FAOSTAT, 2008).

Okra is known by several names in different parts of the globe. It is called gumbo in the United States of America, lady's finger in England, guino-gombo in Spanish, nkuruma by the Akans in Ghana, bhindi in India, fetri by the Ewes in Ghana. Okra is a vegetable which one finds in a fresh state in almost all markets in Ghana, during the rainy season and in a dehydrated form during the dry season. It is particularly found in Northern Ghana due to its strong commercial value for poor women farmers and its vital importance as food diet among the inhabitants of the cities and villages (Oppong-Sekyere *et al*., 2012). Until recently little attention was paid to the improvement of okra in international research programmes (Duzyaman, 1997)

2.1.1. Taxonomy

Okra used to be in the genus *Hibiscus,* section *Abelmoschus* and family Malvaceae in the past. A proposal was subsequently made to raise the section *Abelmoschus* to the rank of a distinct genus.

The utilization of *Abelmoschus* was in this way acknowledged in contemporary writing and scientific classification (Hochreutiner, 1924). The features of the spathulate, with five short teeth, calyx, caduceus after flowering and connate to the corolla distinguishes it from the genus *Hibiscus* (Kundu and Biswas, 1973)

Taxonomists have described about fifty species of okra. The most completely archived investigations of the genus *Abelmoschus* is the taxonomical modification carried out by van Borssum Waalkes (1966), this was preceded by Bates (1968). The International Workshop on Okra held at National Bureau of Plant Genetic Resources (NBPGR) India, in 1990 considered the classification of van Borssum Waalkes as the premise and embraced the classification of okra as shown in table 2.1

Table 2.1: Taxonomy of Okra

Kingdom	Plantae
Division	Magnoliophyta
Class	Magnoliopsida
Order	Malvales
Family	Malvaceae
Genus	*Abelmoschus*
Species	*esculentus*

Source: IBPGR 1991

2.1.2. Growth and Development

Okra is spread by seeds and has a maturation of 90 to 100 days. It is typically an annual plant with a robust stem which is erect with variation in branching. Okra varies from 0.5m to 4.0m in height. Its leaves alternate and are usually palmately five lobed, with solitary axillary flowers.

Okra plants grow indeterminately with continuous flowering but highly reliant upon biotic and abiotic stress. The plant begins to bear its first flower usually after one to two months after sowing.

After flowers develop, the fruit grows quickly with the great increases in fruit length, fruit height and diameter. This takes place after 4th to 6th days of pollination. The fruit is often plucked for consumption at this stage. Harvesting okra is done when the fruits are immature and a high mucilage composition, but before becoming extremely fibrous. Fiber production generally starts from the 6th day after fruits form with a rapid rise from the 9th day onwards (Nath, 1976). Okra plant continues flowering and fruiting indeterminately depending on variety, season and soil characteristics. Regular harvesting boosts continued fruiting, which makes daily harvesting in climates with vigorous growth necessary.

2.1.3. Pollination and Fertilization

Climatic factors like humidity and temperature and plant characteristics like genotype influences the initiation of flower buds, flowering, anthesis and stigma receptivity (Venkatramini, 1952). Sulikeri and Rao (1972) studied six varieties of okra and stated that flower buds begin to initiate at 22 to 26 days after planting and the first flower opens after 41 to 48 days after sowing. Once, plants begin to flower, flowering continues for 40 to 60 days. Anthesis in okra is observed between 6 am and 10 a.m. Self pollination may occur in okra at anthesis since anthers dehisce before flower opening. Transverse dehiscence of the anthers occurs with full dehiscence occurring in 5 to 10 minutes (Purewal and Randhawa, 1947). The fertility of the pollen is greatest an hour before and after the opening of the flower (Srivastava, 1964). Pollen in storage for 24 hours at a temperature of 27^{o}C and 88% relative humidity loose viability. The stigma is receptive about 24 hours before

50 to 70% flowering and the day after 1 to 15% flowering. Flower opening occurs once in the morning and closes the same day after pollination. The corolla withers the next morning.

Okra has both male and female reproductive parts in the same flower this allows self-pollination. 100% of the flowers will develop seeds when okra flowers are bagged to prevent pollinators. Studies have demonstrated that there is no huge contrast in fruits set under open-pollination, selfpollination by bagging only and self pollination by hand pollination of bagged flowers, which shows that okra is likely a self pollinating crop (Purewal and Randhawa, 1947). Inbreeding depression has not been reported in okra. Insects are unnecessary for okra pollination and fertilization. The flowers are very attractive to bees which lead to cross-pollination. There is up to 4-19% cross pollination in okra (Shalaby, 1972) with values as high as 42.2% recorded (Mitidieri and Vencovsky, 1974). The extent of cross pollination is dependent on the cultivar, the population of insects, the season and competitive flora etc.

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2.1.4. Methods of Reproductive Isolation

Maintaining the purity of okra requires a significant level of isolation between varieties even though it is an example of a self-pollinating crop. There is the contention in a few circles that confinement of self-pollinators is not necessary. McCormack (2004) expressed the opposite that the capacity to self pollinate as often as possible has little to do with the measure of cross pollination that normally occurs. Studies available have shown that an amount of natural crosspollination can occur. For foundation seeds production an isolation distance of 400 meters is required as per Indian minimum seed certification standards (Tunwar and Singh, 1988). Confined

field trial of genetically engineered okra varieties/hybrids require 400 meters as the isolation distance.

2.1.5. Production Statistics and Cropping Systems

Notwithstanding the importance of the crop, Ghana cannot boast of any improved varieties; varieties that are perennial in growth habit and at the same time combine higher yields and early maturity with longer harvest duration and more so resistant to diseases and pests. Improved varieties in terms of fruit size, shape and colour are also very much desired in the Ghanaian okra export market, as a quality standard in vegetable export (Oppong-Sekyere *et al.,* 2012). West and Central Africa is home to around 100 million of the world's poorest individuals with the world's most delicate ecosystem for agribusiness however 80% of the populace rely on agriculture for their livelihood. Over 75% of okra produced in Africa takes place in West and Central Africa, with a low average productivity of (2.5 t/ha) compared to East Africa (6.2 t/ha) and North Africa (8.8 t/ha) (FAOSTAT, 2006). The largest production is in Nigeria with an annual production of about 1.1 million tons with Cote d'Ivoire and Ghana following (FAOSTAT, 2008).

In Ghana, and the rest of West and Central Africa region, production of okra is often done by women and is mostly rain fed on marginalized lands they can access, with the soils low in organic matter. Population growth and fast urbanization in West and Central Africa has led to market-oriented production of okra increase in peri-urban zones. In these areas okra is now cropped on irrigated fields or in waterlogged areas that gets drier in the dry seasons. It is often produced as a mixed crop with other vegetable. Intercropping of okra with papaya has been reported (Aiyelaagbe and Jolaoso, 1992).

2.1.6. Varieties and Cultivar Selection

Cultivars of okra vary in plant height, yield potential and days to maturity. Pods may be smooth or ridged and shape may be fat or slender depending on the cultivar. Pod colour varies. It may be red, green or nearly white. Larger pod sizes that remain tender are produced in some cultivars. There is less irritation when harvesting the spineless cultivars since they have fewer spines on the leaves and stems. Private and commercial breeders keep improving existing varieties by developing hybrids since there is the seldom release of new varieties of okra unlike other vegetables. Hybrid okra mostly produce higher yields, but with their seeds being more expensive than established varieties (Offei, 2014).

2.1.7. Climate and Soil Requirements

Okra grows well on a wide range of soils as long as the soil is well drained but does very well on fertile, silt loam soils with good drainage. Successes in production can be obtained in hot humid areas too. Poorly drained soils may result in low oxygen supply to the plants. Slightly acidic soils with a pH between 5.8 and 6.5 are preferred for okra production. Frost and extremely low temperatures are not favourable. A temperature range of 24°C to 28°C is preferred for normal growth and development. The first flower bud usually appears in the 3rd leaf axil at a temperature

of 24°C and at 28°C it may appear in the 6th leaf axil. The higher position is as result of the plant growing faster at higher temperatures hence the higher position is reached earlier. Higher temperatures however delay fruiting. Temperatures beyond 42°C may causes flowers to dry out and drop, leading to yield losses (Offei, 2014).

Faster germination is observed at 35°C and for optimum seed germination temperature must range from 25°C to 35°C with adequate soil moisture. There is delayed germination beyond this range and weak seeds may not even germinate. Transplanting is recommended on clay soils since seedlings may find it difficulty emerging in such soils. Soil compaction can restrict plant growth hence soils with hard pans should be avoided in Okra production. To plant an acre of okra 4.5 to 5.5kg of seeds are required. It is possible to transplanted okra to the field, this has the potentially to provide an earlier harvest. High yields have been obtained in cases where okra has been transplanted using black plastic mulch and drip irrigation (Offei, 2014).

2.1.8. Fertilization

In Ghana small holder farmers hardly apply organic fertilizer but a number use household waste and some organic manure on their okra farms. Soil fertility should be tested before planting for commercial okra production and recommendations followed accordingly. 136kg per acre of a NPK fertilizer is generally recommended to be incorporated in the soil before planting. When fruits begin to form, sidedressing with 9kg to 11.5kg of nitrogen per acre is recommended. Avoid over fertilization with nitrogen since high rates of nitrogen causes excessive vegetative growth which

can lead to a reduction in yield. Lime is recommended in soils with high pH and should be applied three to four months before seeding (Kumar, 2004).

2.1.9. Cultivation and Weed Control

All season weed control in okra production is more often than not required since it is harvested over a longer period of time. Controlling broadleaf weed species may require mechanical cultivation as and when necessary. Cultivation should be carried out as shallow as possible to avoid root damage to the crop. Growers are cautioned to avoid fields with profound infestations of broadleaf weeds.

2.1.10. Biotic Stresses

A number of biotic and abiotic stresses cause high yield losses under large scale commercial production although okra is considered a robust crop. The leaf curl disease caused by the begomovirus transmitted by the white fly (*Bemisiatabaci*) is the most relevant biotic stress of okra. According to N'Guessan *et al.,* (1992) this disease is more common in the savannah than in the tropical rain forest. Root-knot nematodes (*Meloidogyne* spp.) follow this viral disease. This major production problem is not only in the West and Central Africa region but also in Middle East and Asia (Fauquet and Thouvenel, 1987). The utilization of resistance sources and efforts to screen germplasm for viral resistance are pending. The tomato fruit worm (TFW) (*Helicoverpa armigera*) is the most vicious okra pest. Using pigeon-pea borders this worm may be controlled (Youm *et al.,* 2005). This methodology is been used on okra fields in Niger (Ratnadass *et al.,* 2010).

2.1.11. Disease Control and Pest Management

The serious diseases of okra are mainly fusarium wilts, verticillium and Southern stem blight. Reductions in yields are also caused by root knot nematodes. To control the diseases in okra, crop rotation can be used. In the rainy season, rotting of flowers and fruits may occur when there are dense canopies. To create a room for better air circulation, lower leaves should be removed. This will reduce the problems of blossom and pod rot.

A standout amongst the most constraining components for yield capability of okra is insect pest infestation. Okra is inclined to damages by viruses, insects, nematodes and fungi. There are however variability in their degree of infestations. Some of the important insect pests are aphids, fruit and shoot borer, ants, white flies, etc. Okra is subject to the attack by diseases affecting the leaves, flowers and fruits. The severity of insect damage varies at each stage of plant development and from year to year. Aphids are usually the first to attack okra in the early parts of the season. The plants and pods may be attacked later by cabbage loopers, European corn borers stink bugs, corn earworms and the leaf-footed plant bug.

2.1.12. Abiotic Stress

Okra is mainly farmed as a rain fed crop in Ghana. Good crop establishment is obtained when optimum soil moisture is provided in the first month after sowing. Okra is sensitive to the mild winters of the Sudano-Sahel regions of West and Central Africa since is a tropical crop. Less rainfall in the north and salinity in the coast are abiotic factors that adversely affect okra production in Ghana.

2.1.13. Harvest and Storage

Okra pods are harvested five to six days after flowering while still tender. Pods are cut from plants typically at 5 to 9cm long. This is then followed by grading according to size. Pods may need to be picked every day or every other day during periods of rapid growth. Labour should be on hand for timely harvesting since pods that are allowed to stay on the plant will become too large and loose commercial value. Few days separate a profitable harvest and having pods that are too large to be sold during hot weathers. Regular picking increases yield although harvesting can span several weeks. Unharvested mature pods will cause a reduction in flowering and fruit set. When the tips of pods bend without breaking it indicates they are too matured for use as a fresh vegetable.

Under the proper conditions okra may be stored for up to 10 days. Okra fruits quickly lose moisture after harvest. This causes a reduction in the quality of pods. Cooler parts of the day is recommended for harvesting, thus in the mornings or evenings. The pods should be kept as cool as possible after harvest. Leaving harvests in the sun for long should be avoided. Good pod quality is maintained when the harvested pods are stored in shaded areas. The containers for storage of harvests should be well ventilated. When fruits are kept in non ventilated containers, heat can buildup due to respiration and the fruits will lose colour quickly due to bleaching. Care should be taken to avoid bruising after harvest. Bruised pods turn brown or black in a matter of hours. When harvesting and handling pods, cotton gloves are recommended. Pickers and handlers should wear long sleeved shirts and gloves to protect the skin. Yields average 3.6 to 4.5 tons per acre basis (Kumar, 2004).

2.2. POTENTIAL OF OKRA

2.2.1. Potential for Enhancing Livelihoods

Okra has the prospect to enhance the livelihoods of growers and several stakeholders in urban and rural areas. Small and large scale producers and all those in the okra value chain can prosper when the potential of okra is harness. The EU and Asia has large market for vegetables from Ghana and okra is no exception. This when exploited will lead to the country getting the foreign exchange it badly needs. The life of small holder farmers will also be improved with an increase in the volume of okra exported (Oppong-Sekyere *et al.*, 2012).

2.2.2. Nutritional and Health Potential

Okra is an important source of calcium, potassium, vitamins and minerals which are mostly absent in the diet of the poor in underdeveloped countries (IBPGR, 1990). The pods contain 17% of seeds which contain potassium, sodium, magnesium and calcium. The Presence of zinc, iron, nickle and manganese has been reported (Moyin-Jesu, 2007). The calorie level in okra is 20g per 100 g. Fresh pods are practically high in fiber, no fats and have several nutrients, 10% to 20% of folate, 30% of the recommended levels of vitamin C (16mg- 29 mg) and about 5% of vitamin A (14 to 20 RAE) (NAP, 2006). Okra seed is made up of oligomeric catechins and flavonol derivatives, with the mesocarp largely poised with hydroxycinnamic and quercetin derivatives. Important biological components like quartering derivatives, catechin oligomers, hydroxycinnamic derivatives and rich sources phenolic compounds have been found in the seeds and pods (Arapitsas, 2008). Coupled with high carbohydrate content, proteins, glycol-protein, and added dietary elements augment the value of okra in human diet (Arapitsas, 2008). Viscous fiber which is an important dietary component to lower cholesterol has its most important vegetable

source in fresh okra pods (Kendall and Jenkins, 2004). Agbo *et al.*, (2008) stated that okra pods at seven days old have the highest concentration of nutrients.

Okra is said to be helpful in genito-urinary disorders, chronic dysentery and spermatorrhoea prevention (Nadkarni, 1927). Okra has been reported to have the medicinal value in curing ulcers and reprieve hemorrhoids (Adams, 1975)

Table 2.2: Composition per 100 g of edible portion of okra

Constituent	Composition	Constituent	Composition
Moisture	89.6 g	Minerals	0.7 g
Protein	1.9 g	Carbohydrates	6.4 g
Fat	0.2 g	Calcium	66 mg
Fibre	1.2 g	Iron	0.35 mg
Calories	35	Potassium	103 mg
Phosphorus	56 mg	Thiamine	0.07 mg
Sodium	6.9 mg	Nictonic acid	0.6 mg

Sulphur	30 mg	Vitamin C	13 mg
Riboflavin	0.1 mg	Magnesium	53 mg
Oxalic acid	8 mg	Copper	0.19 mg

Source: (Gopalan *et al.*, 2007).

2.2.3. Seed as Potential Edible Oil and Flour Source

Okra seed oil is rich in unsaturated fats (60 to 70%) (Rao, 1985). Okra seeds have been reported to be a rich source of tryptophan (94 mg/g N), has sufficient sources of sulphur containing amino acid (189 mg/g N). This combination makes okra seeds remarkably useful in reducing human undernourishment (NAP, 2006). Okra seed protein has a net protein utilization (NPU) value as good as that many cereals (except wheat), with seed oil yield as good as that of most oil seed crops except for oil palm and soybean and a good protein efficiency ratio (PER) (Rao, 1985). Okra seed oil has the potential of hypocholesterolemic effect (Rao *et al.*, 1991). Okra has a high potential for large scale cultivation for edible oil as well as for cake (Rao, 1985). Adelakun *et al.*, (2008) stated that okra seed flour could be used to fortify cereal flour. In nations like Egypt, to improve dough quality, okra seed flour has been utilized to supplement corn flour for quite a while (Taha el-Katib, 1947).

Table 2.3: List of selected Okra cultivars in West and Central Africa.

Country	**Name of cultivar**
Ghana	Indiana, Asontem, Torkor, Manipeali, Saloni (F1),
Senegal	Lima (F1), POP-11 (Emerald) Lolli,, Volta, Indiana, PoP-12 (landrace)
Mali	Yelen, Sabalibougou, Clemson Spineless, Keleya

Cote d'Ivoire	Perkins Long Pod, Hire, Tomi (*A. caillei*), Koto
Cameroon	Volta, Emerald, Gombo Cafeier , Gombo Paysan, Clemson Spineless
Togo	Local (*A. caillei*), Konni (purified landrace)
Nigeria	V-35, White Velvet, Spineless, Clemsion, LD 88, Lady's Finger, Ex-Borno
Niger	Konni, Volta, Terra (purified landrace)

Afr. J. Agric. Res.

2.3. SEED DORMANCY

Seed dormancy is a condition that prevents germination even under most favorable environmental conditions. Delayed germination keeps some seedlings safe from likely burst of unfavourable weather conditions or herbivores that feed on them. This trait is an evolutionary survival tactic which guarantees that seed will only germinate when the environmental conditions are suitable for seedling growth and plant establishment. This mechanism also spreads the period of germination over a period of time (Baskin and Baskin, 2000). Dormancy is not often noticed in crops that have been selected out by the act of cultivation over several thousands of years.

For seeds to come out of dormancy, their dormancy factors must be broken. Seeds might posses physical dormancy, that is a hard or thick seed coat. This can be broken by scarifying (scratching the surface) or soaking of seeds. Some seeds may have internal metabolic or chemical conditions that prevent germination (chemical dormancy). The presence of some plant hormones, particularly, abscisic acid can affect seed dormancy by inhibiting germination while the presence of gibberellin ends seed dormancy. Chemical dormancy in seeds is broken by leaching, cold/moist stratification or fire scarification. Cold temperatures between 10–15°C allow oxygen to get into the seed but

warm temperatures prevent oxygen uptake in seeds. At cool temperatures the seed digests some of its food reserve hence giving it energy. Putting such seeds in the refrigerator allows them to gain sufficient energy and oxygen to germinate (CASL, 2009).

Okra demonstrates a sort of seed dormancy, called delayed permeability. This is because of structure of the seed coat and especially by the chalazal plug. A relationship has been observed linking delayed permeability and the seed moisture content with variations between moisture contents and cultivars (Rao, 1985).

2.4. SEED PRIMING

Priming is carried out by regulated hydration, in osmotic solutions or water. This prevents germination but allows the improvement of some metabolic processes. When seeds dehydrate the advantages obtained in the priming process is retained. These benefits include uniform germination, increased seed vigour which translates into rapid seedling development (Bray, 1995). In seed priming the natural stages of seed germination occur but the radicle does not surface. The first part of the seedlings that sprouts from the seed is the radicle. High seed moisture content is required for radicle emergence. When seeds are primed there is a limit to its water content, and the metabolic steps necessary for germination can occur without the irrevocable act of radicle emergence.

2.4.1. Reasons for Priming

According to Sugishita (2014) seeds are primed for these reasons;

- To overcome or alleviate phytochrome-induced dormancy in plants
- To decrease the time necessary for germination and emergence
- To improve the stand uniformity, aiding in production management and increasing the chance of uniformity at harvest
- To extend the temperature range at which a seed can germinate
- To increase the rate of germination at any particular temperature. Priming can reduce field germination times up to 50% upon subsequent rehydration

2.4.2. Benefits of Priming Seeds

- Emergence can occur before soil crusting becomes fully detrimental
- Crops can compete more effectively with weeds
- Priming allows growers to better control their water usage and scheduling.
- Priming can eliminate or greatly reduce the amount of seed-borne fungi and bacteria.

According to Farooq *et al.*, (2008) not only do primed seeds establish better but they grew vigorously, flowered earlier, had improved emergence, stand establishment, tillering, grain and straw yields, high harvest index and yielded higher.

2.4.3. Seed Priming Methods

Solid matrix priming and liquid or osmotic priming are examples of some of the several priming methods that have been reportedly used commercially. Seeds can be imbibed in organic or inorganic solutions (chemopriming) (Nowak, 1998), potassium chloride (KCl)

(Misra and Dwibedi, 1980) and polyethylene glycol (PEG) (Dell Aquila and Taranto, 1986). These osmoticum have shown good potential to enhance emergence, growth, germination and yield of crops. Water has also been effectively used as a seed priming medium for many cereals (Harris *et al.*, 2001). Misra and Dwibedi (1980) stated that there was 15% increase in the yield of wheat when seeds were soaked in 2.5% potassium chloride (KCl) for 12 hours before sowing. Seeds soaked with 0.5 to 1% solution of KCl recorded significant increases in plant height, yield and yield attributes of wheat (Paul and Choudhury, 1991). Priming of corn seed using potassium salt (KNO_3) or polyethylene glycol resulted in accelerated germination according to Basra *et al.(*1989). Ascorbic acid, a naturally occurring organic compound with oxidation properties has been widely used for seed priming in vegetables, legumes and cereals. It has shown remarkable results in improving germination in wheat, sesame and soya bean (Levy, 2009).

Fruit juices have significant sources of ascorbic acid. Storage conditions determine the quality of ascorbic acid of fruit juices since they are easily oxidized and lost during staying at rates that depend on the storage environment. It is obvious that the quality of any fruit juice as a good source of vitamin C is dependent on its content and the rate of loss upon staying (Kabasakalis *et al*., 2000).

Moringa oleifera leaves are rich sources of phenolic compounds, zeatin, calcium, ascorbate and potassium; hence it is being explored as organic crop growth enhancer (Basara, 2011). Garlic is another promising natural seed primer considering its highly significant antimicrobial properties and antifungal activity (Grozav and Foarce, 2005). Leaf extracts from eucalyptus and gliricidia have all been used as seed priming agents successfully.

2.5. GERMINATION

Laboratory germination of seeds is the emergence and development of the seedling to a stage where the facets of its vital structures can be identified regardless of whether it has the capacity to develop into a suitable plant under optimal conditions in soil (ISTA. 1985). These key structures include a well developed and intact root system, hypocotyls, plumule and one or two cotyledons depending on the species. Seedlings can't be assessed in a germination test until these fundamental structures are plainly expressed and the reported percentage germination expresses based on the proportion of seeds which have produced normal seedlings inside of the period indicated for the species (Gupta *et al.,* 1990).

Viable seeds are living and must hold living and healthy embryonic tissues in order for it to germinate. All fully developed seeds hold an embryo and, in most plant species, a store of food reserves, wrapped in a seed coat. When conditions like soil moisture and temperature are favourable for growth, seeds generally germinate (Miles and Brown, 2007).

2.5.1. Environment Required for Seeds to Germinate

Temperature, moisture, light and air conditions must be favourable for seeds to germinate. All seeds have the most favorable temperature ranges within which seeds will germinate. The minimum temperature is the most minimal temperature, at which seeds can germinate effectively, with the maximum temperature being the temperature above which seeds cannot germinate. Temperature values above or below this temperature range can harm seeds or make cause dormancy. There is fast and uniform germination at ideal temperatures. There is rapid and uniform germination at optimal temperatures.

The correct moisture is needed in all seeds to kick off the internal mechanism leading up to germination. In the field it is about 50–75% of field aptitude. For optimal germination in a finetextured seedbed and good seed-to-soil contact is indispensable. Aeration gives way for good gaseous exchange between the germinating embryo and the soil. The carbon dioxide produced by the seeds needs to be expelled. If the soil is not well aerated due to compaction or overwatering, the CO_2 will not disperse and seeds can suffocate.

Light requirements of seeds vary. Dark conditions favour germination in most seeds and might even be inhibited by light. However, some species require light to germinate
(Miles and Brown, 2007). Sunlight is vital for all seedlings. Seedlings will become fragile, tall and thin and will not produce to their potential if they do not have sufficient sunlight.

2.5.2. Germination Testing

The intent of a germination test is to make available optimal conditions for germination in order for the maximum potential of the seed to be discovered. The idyllic conditions for germination of diverse species may differ in terms of temperature, substrate and time. The media for germination may be on top of paper, sand, between papers or an organic medium. Temperatures for germination may alternate where one temperature is applied for a particular length of time, followed by another temperature for the rest of a 24 hour period or can be held constant (ISTA, 2009a).

In assessing the planting value of a seed, germination testing is considered as the most essential quality. The capacity of seeds to produce normal seedling and plants later on is measured as far as germination test. Substandard results which normally cannot be reproduced with reliability after testing of seeds occur under field conditions. Laboratory tests have thus been set out in a way that the external factors are regulated to produce uniform, complete and rapid germination (Gupta *et al*., 1990).

Testing conditions in the laboratory can be reproduced since they have been standardized within limits as nearly as possible as those determined by random sample variations.

The ultimate goal of germination testing is to obtain information on the planting value of a seed and obtain results which could be used in comparing the values of different seed lots (Gupta *et al.*, 1990).

2.5.3. General Principles of Germination

The pure seed fraction of a purity test is used for germination testing. Depending on the size of seeds and size of containers for the substrate, a minimum of 16 replications of 25 seeds each or eight replicates of 50 seeds each or four hundred seeds are required in four replicates of 100 seeds each (ISTA, 2006).

The seeds are tested under favourable moisture conditions in replicates. The replicates are evaluated and counts made and seeds in various categories of seedlings required for reporting as presented.

2.5.4. General Requirements for Germination

Seeds need certain environments for normal germination to occur. These requirements include moisture, temperature, substrata and light. The substratum serves as the moisture reservoir and provides a medium for which the seeds can germinate and the seedlings can grow. The frequently used substrates include; sand, paper and soil.

2.5.6. Duration of the Test

The period of dormancy breaking prior to or at the time of the test is not taken as a part of the germination test period. The time of first count is estimated, but must be sufficient for full seedling development that permits accurate seedling evaluation. When conducting germination tests in sand media, the first count may be omitted (Gupta *et al*., 1990).

2.6. NORMAL AND ABNORMAL SEEDLINGS

Normal seedlings show the ability for continuous growth into mature plants when grown in good quality soil, favourable water supply, temperature and light. The capacity for continued growth and development is dependent on the accuracy and correct functioning of the developing structures during germination. Under favourable conditions an abnormal seedling cannot have the ability to develop into a normal plant when grown in the soil because one or more of the vital structures is irreparably substandard.

Table 2.4: Differentiation of Normal and Abnormal Seedlings

NORMAL SEEDLING
Seedling as a whole
All essential structures are normal, as detailed in the following:
Root system

the primary root	is intact or shows acceptable defects : • discoloured, necrotic spots • healed cracks and splits • superficial cracks and splits
Shoot system	
the hypocotyl	Is intact Or shows acceptable defects : • discoloured, necrotic spots • healed cracks and splits • superficial cracks and splits • loose twists
the terminal bud and surrounding tissue	(usually not visible) Is intact
the cotyledons	are intact or show acceptable defects: • up to 50% of tissues not functioning normally. • only one (intact) cotyledon • three cotyledons

ABNORMAL SEEDLING
Seedling as a whole

The seedling is abnormal if it	• is deformed • is fractured • the cotyledons emerge before the primary root from the seed coat • consists of fused twin seedlings • is yellow or white • is spindly • is glassy • is decayed as a result of primary infection
one or more of the essential structures are abnormal as detailed in the following:	
the primary root	Is defective if it is stunted or stubby • is retarded • is missing • is broken • is split from the tip • is trapped in the seed coat • shows negative geotropism • is constricted • is spindly • is glassy • is decayed as a result of primary infection
Note A seedling is classed as abnormal, if the primary root is defective, even if secondary roots have developed.	
A seedling with its primary root trapped in the seed coat is considered normal, if by the end of the test the root tip has found its way out of the seed coat,	

Shoot system	
The hypocotyl	Is defective if it • is too short and thick • is deeply cracked or broken • is split right through • is missing • is bent over or forming a loop • is tightly twisted or forming a spiral • is constricted • is spindly • is glassy • is decayed as a result of primary infection
the terminal bud or surrounding tissues	(usually not visible) Is defective
the cotyledons	are defective if they • are defective to such an extent, that less than50% of the original tissue (or estimated tissue) is functioning normally • are swollen or curled • are deformed • are broken or otherwise damaged • are separate or missing • are discoloured or necrotic • are glassy • are decayed as a result of primary infection

Source: ISTA 2006

2.7. VIGOUR TESTS

An idea of the performance of a seed lot in storage or on the field is supplemented by an important quality parameter called seed vigour after assessing germination and viability. Seed vigour has several definitions. The ISTA congress in 1977 adopted the sum total of those properties of the seed which determine the level of activity and performance of the seed or seed lot during germination and seedling emergence as the definition of seed vigour (Perry, 1984).

The primary evaluation of the capability of seed to germinate and emerge in the field is the germination test. The result of a standard germination test gives a good connection between germination and field emergence in favorable conditions but a germination test can fail to indicate the ability of a seed lot to establish a crop in the field when conditions are poor. Instances have been shown in a wide range of species where seed lots having equally high laboratory germinations show recorded wide differences in field emergence with grain legumes included (Powell *et al.*, 1984); small seeded vegetable species, (Matthews, 1980); cucurbit species (Perry, 1973); maize (Nijenstein, 1986).

This failure of the germination test to predict differences in field emergence, especially in poor field conditions, proposes that there is a further physiological angle to seed quality, which has come to be alluded to as seed vigour (ISTA, 1995). Seed lots having high germination, but poor field emergence are considered as low vigour seeds, whereas those with good field emergence are termed high vigour seeds.

Vigour is also noticed in the rate of germination and seedling growth, in both favourable and unfavourable conditions. There is slow germination in low vigour seeds over a long period of time

to produce a range of seedling, whereas high vigour seeds germinate rapidly and produce large and uniform seedlings. High vigour seeds have good storage potential while low vigour seeds lose the ability to germinate more rapidly during the storage period (ISTA, 2009a).

Contrasts in germinability of seeds can be clarified by the process of seed ageing. The seed survival curve (Fig. 1) demonstrates the progressions that happen in germination of a seed lot over a timeframe. There is a long stretch when germination falls gradually when seeds are ageing. There is an increment in the occurrence of death in the seed population and the germination rate falls quickly. A seed lot at the beginning of the decline is physiologically young and has high vigour; a lot at the end of the decline is physiologically old and has low vigour (ISTA, 2009a).

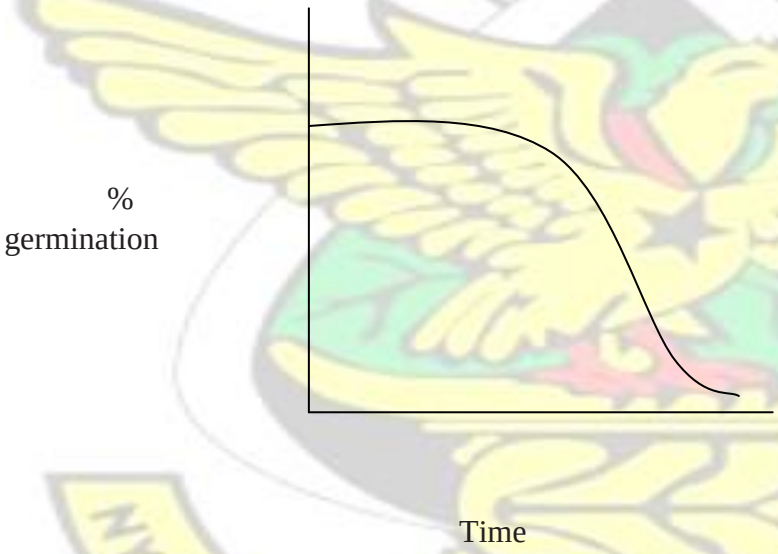

Figure. 2.1: Seed survival curve

Seed vigour remains a concept rather than a specific property of a seed. Environmental factors and the nutrition of mother plant, genetic constitution, maturity at harvest, deterioration and ageing, seed size and weight, mechanical integrity and pathogens are known to influence seed vigour (Perry, 1984). Therefore, care must be taken in selecting a seed vigour test to do the job.

Two criteria have been used by the ISTA seed vigour committee to evaluate, the performance of seed vigour test methods for different crops:

(i) Reproducibility of vigour method

(ii) The relationship between vigour test results and seedling emergence in the field.

There is no universally established vigour test for all kinds of seeds. Several tests are therefore used to determine and gain additional information on seed quality. These include;

2.8. GROWTH TESTS

Principles: Using growth tests to evaluate seed vigour is based on the principle that vigorous seeds grow at a faster rate than poor vigour seeds even under favourable environmental conditions. There is rapid germination in vigorous seeds, high metabolism and rapid field establishment. Methods used in determining the rapidity of growth of seedlings will give an indication of seed vigour level.

(a) ***First count:*** The test is carried out in tandem with the standard germination test. The number of normal seedlings germinating on the first count day is counted. The number of normal seedlings suggests the level of seed vigour in that particular sample. The higher the number of normal seedlings greater is the seed vigour (ISTA, 2009).

(b) ***Seedling growth rate and dry weight:*** The seedlings are grown either in the green house, laboratory or field. In the laboratory, between rolled towel papers method should be used. Ten seeds are planted in the centre of the moist towel papers in such a manner that the micropyles are oriented towards bottom to avoid root twisting. The setup is kept in the germinator maintained at a temperature recommended for that particular crop. After the specified duration, the towel papers

are removed and five seedlings are selected and their lengths are measured. The mean seedling length is then calculated. Seed lots producing the taller seedlings are considered more vigorous. For dry weight determination, the seedlings are removed and oven dried at 100°C temperature for 24 hours (AOSA, 1995).

(c) ***Speed of germination:*** One hundred seeds in four replications are planted in the recommended media for germination. The substratum is kept in a germinator maintained at recommended temperature for the crop under study. Daily counts of the numbers of seedlings emerging from the day of planting the seeds in the medium till the time germination is complete is carried out. A germination index (G.I.) is computed using the following formula:

$$\mathbf{G.I} = \mathbf{n/d}$$

n = number of seedlings emerging on day 'd'

d = day after planting

The seed lot recording a greater germination index is considered to be more vigorous (Gupta, 1995).

(d) ***Seed vigour index (S.V.I):*** This is computed by determining the germination percentage and seedling length of the same seed lot. Fifty seeds in four replications are germinated in a media as approved for the crop specie. While evaluating the number of normal seedlings at final count, 5 seedlings are randomly selected and measured. The seed vigour index is calculated by multiplying seedling length in mm and germination percentage. The seed lot showing the higher seed vigour index is assumed to be more vigorous (Abdul-Baki and Anderson, 1973).

2.9. SEED AGEING

Ageing of seeds starts right from physiological maturity. It is one of the most intriguing and challenging scientific problems of universal concern (Moment, 1978). Thus it will be highly relevant to develop an insight into the basic phenomena of seed ageing and longevity. Seeds in storage deteriorate. This ageing is noticed in the reduction in percentage germination, with seeds germinating producing week seedlings. During ageing, seeds lose their viability for germination, vigour and ultimate feasibility. There are increases in losses when seeds are stored at high temperatures and/or high relative humidity conditions (Maity *et al.*, 2000).

Membrane disruption is one of the major reasons attributed to the deterioration of seeds which results in seed cells able to retain their normal physical conditions and functions. The main causes of membrane disruption are an increased in free fatty acid level and free radical productivity by lipid oxidation (Goel *et al.,* 2003). The rate at which seeds lose vigour during storage is affected by environmental factors such as moisture, temperature and the ratio of oxygen to carbon dioxide concentrations. Harrington (1972) stated that each 1% reduction in seed moisture or each 5ºC reduction in temperature doubles the storage life of the seeds when the normal temperature and moisture range for seed storage is maintained.

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2.10. ACCELERATED SEED AGEING TEST

Seed producers face the problems of production, storage, processing and trade yearly. An important issue that must be tackled each year is the question of which seed lots should be placed on the market and which seed lot can be safely stored for the next season. This decision is important in cases of the low market prices or in cases where the seeds formed the seed stock for the next year. This decision cannot be made considering only information on the germination percentage, as parties with similar and usually high germination are stored. Longevity in storage depends on conditions under which the seed lots are stored and plant species. The loss of seed germination under favourable storage conditions may take several years and depends on the seed biology. Many vegetable seeds retain germination greater than 50% even after more than 10 years of storage (Milosevic *et al*., 2010).

Accelerated seed ageing is a type of stress test with two main applications in seed;

(1) to predict the potential storage life of seeds; (2) to assess the vigour of a seed lot. Delouche and Baskin (1973) developed the accelerated seed ageing test procedure to measure seed storability and evaluate vigour. Accelerated seed ageing is based on the conjecture that if seeds deteriorate at a certain predictable rate under a given set of storage conditions (temperature and humidity), then deterioration will occur much faster under conditions of storage with increases in temperature and/or humidity. The basic theory is that the same process of deterioration which takes place during natural ageing period occurs for the duration of the short period when the seeds are exposed to the poor conditions (Delouche and Baskin, 1973). Thus natural deterioration is virtual and condensed into a short test period. Under such conditions high vigour seed lots will have a slight decline in their germination whilst low-vigour seed lots will have remarkable declined in germination and

seed vigour after exposure to accelerated ageing (Elam and Blanche, 1989). To study the physiological and biochemical changes in seeds storage during ageing, artificial seed ageing has been widely recommended. In artificial or accelerated seed ageing, the seeds are self aged by subjecting them to high relative humidity (>90%) and temperatures of (≥40ºC). The seeds aged are compared for physiological, morphological, biochemical and genetic changes with the seed lot considered as the controls (Milosevic *et al*., 2010).

Accelerated seed ageing has been shown as a functional method for assessing parameters correlated to seed deterioration. It is evident that at least some factors have a larger influence on accelerated seed ageing than what occurs during natural ageing. Micro-flora (fungi) and repair mechanism of cell organelles are two factors apparently more prevailing under accelerated ageing conditions than under natural ageing (Priestley 1986). Accelerated ageing test is one of the most often used tests for seed vigour testing because it is well correlated with field emergence (Lovato *et al.,* 2001). The ISTA standardized this method for soybean seed testing in 2007.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1. LOCATION

The research was conducted at the Department of Horticulture of Kwame Nkrumah University of Science and Technology, Kumasi-Ghana in a period of ten months. Kumasi is in the semi deciduous forest zone, where the annual rainfall ranges between 1500mm and 2000mm.

3.2. SOURCE OF PLANTING MATERIAL

The varieties CRI-K-P11-11 and Asontem used for this experiment were obtained from the Crop Research Institute, Kwadaso- Kumasi and Manpeali was obtained from the Savannah Agriculture Research Institute -Tamale.

3.3. SEED PLANTING, FERTILIZATION AND WEED CONTROL

A well drained loamy soil of high fertility free from foreign materials was used for the seed production. The Nitrogen, Phosphorus and Potassium content of the soil was analyzed to determine the fertility of the soil. The soil was also analyzed to check for the presence of plant pathogenic nematodes. Soil samples for the analysis were taken at a depth of 20cm at four different spots. The soil analysis was performed at the Department of Soil Science laboratory, Kwame Nkrumah University of Science and Technology. Three methods were used to determine the nutrients concentrations of the soil samples. The method developed by Walkley and Black (1934) was used to determine the organic carbon concentration, Kjeldahl method developed by Bremmer (1965) in determining the nitrogen concentration and the Bray method developed by Bray and Kurtz (1945) to determine the phosphorus concentration.

The three varieties used for the research were each planted on a 30m x 20m plot at a spacing of 70cm x 30cm. The seeds were sown at a depth of 4cm. Rate of fertilization and quantities applied were determined by the result obtained from the soil nutrient analysis. The first fertilizer application of 20kg NPK 15-15-15 was carried out before planting. The plants were side dressed with 4kg nitrogen a few days before flowering.

Weeds were controlled as and when it became necessary to do so. Weeding was carried out three weeks after planting and a second weeding was done just before flowering.

3.4. SEED HARVESTING AND DRYING

The pods were harvested when they were well dried on the plants. They were sun dried further for five days and the seed extraction was carefully done by hand. The seeds were sundried until a moisture content of about 8% was reached before the start of the laboratory work.

3.5. SEED ANALYSIS

3.5.1. Seed Moisture Content Determination

The moisture content of the seeds was determined by using the Low Constant Temperature Oven Method as described by the ISTA (2010). Hundred grams (100g) of seeds of each variety was weighed and oven dried for 17 hours at 103^0C±2. The difference between the initial and final weight was determined and was found to be in the 8% range or lower needed for okra seed storage.

3.5.2. Seed Purity Test

The seed purity of the three varieties of okra was determined as described by AOSA (1981). Working samples of 100g of seeds of each variety were weighed in four replications. The components were separated into four parts; pure seed, other crop seed, inert matter and weed seed. The various components were separated visually with the aid of a lens and then weighed. Percentage composition by weight of the pure seeds and the other constituents were then computed using the formula;

$$\textbf{Pure Seed} = \frac{\text{weight of pure seeds (g)}}{} * 100$$

Total weight of sample (g)

3.5.3. One Thousand Seed Weight

One hundred seeds of each of the three varieties were counted. This was carried out in eight replications and the means were calculated after weighing. The mean of each variety was multiplied by 10 to obtain the one thousand grain weight for that particular variety (CFLS, 2007).

3.6. ACCELERATED SEED AGEING

The seeds of the three okra varieties were subjected to controlled deterioration (ageing) as described by Chhetri (2009) by ageing the seeds at relative humidity ranging from 92% to 98% at 45^{o}C for 72 hours in an oven. Three plastic bowls of dimension 30cm x 20cm and 4cm deep had each one of them filled with 250ml distilled water. A wire mesh was firmly fitted on the lid of each of the bowls. 150g of seeds of each variety was spread in a single layer on the mesh. The seeds were covered with tissue paper to prevent condensed water vapour from dropping directly onto the seeds. The plastic bowls with the seeds were then placed in an oven and the temperature of 45^{0}C was set. The setup was kept in the oven for 72 hours.

3.7. PRIMING

3.7.1. Priming Agent Preparation

The seed priming agents; Ascorbic acid 50ppm (P1), Ascorbic acid 100ppm (P2), Ascorbic acid 150ppm (P3), Potassium chloride (KCl) 0.2% (P4), Potassium chloride (KCl) 0.3% (P5), Potassium chloride (KCl) 0.4% (P6), Sweet Orange juice extract 1:1 (P7), Sweet Orange juice extract 1:2 (P8), Sweet Orange juice extract 1:3(P9), *Moringa oliefera* leaf extract1:5 P(10),

Moringa oliefera leaf extract, 1:10 (P11) and *Moringa oliefera* leaf extract 1:15 (P12) which are readily available and widely used as priming agents were used in the experiment.

3.7.1.1. Ascorbic acid

An electronic balance was used to weigh 0.015g, 0.03g, 0.075g of ascorbic acid. The weighed ascorbic acid was each dissolved in 300ml of distilled water. These translate into 50ppm, 100ppm and 150ppm concentration of ascorbic acid.

3.7.1.1. Potassium Chloride (KCl)

The electronic balance was used to weigh 0.6g, 0.9g and 1.2g of KCl. These were each dissolved in 300ml of distilled water to form 0.2%, 0.3% and 0.4% KCl solution.

3.7.1.2. *Moringa oleifera* leaf extract

The *Moringa oliefera* leaf extract were obtained as described by Basra (2011). Fresh harvested *Moringa oleifera* leaves were obtained and 0.5kg of it was weighed with an electronic balance. The juice was extracted by blending the leaves with 250ml distilled water. Volumes of the extract were diluted at ratios of 1:5, 1:10 and 1:15 of the extract to distilled water.

3.7.1.3. Sweet orange juice extract

The sweet orange juice extract was obtained from eight oranges with an average weight of 225g with the aid of a juice extractor. A volume of 600ml was obtained. Volumes of the raw orange juice were diluted with distilled water at the ration of 1:1 1:2 and 1:3.

3.7.2. Seed Priming

Four hundred seeds of each of the three varieties were primed with 100ml ascorbic acid solution of concentrations 50ppm, 100ppm and 150ppm for 18 hours after 72 hours of accelerated ageing. Potassium chloride (KCl) solution of volume 100ml in concentrations of 0.2%, 0.3% and 0.4% was used to prime four hundred seeds of each of the three okra variety for 18 hours after 72 hours of accelerated seed ageing. Four hundred seeds of the three varieties aged were soaked in 100ml of the varying concentrations of sweet orange juice extract and *Moringa oleifera* leaf extract for 18 hours.

3.8. STANDARD GERMINATION TEST

A standard germination test was conducted between blotter papers to know the potential of the three varieties before the start of the accelerated ageing process. This was carried out using the process for standard germination test described in the ISTA rules for seed testing (ISTA, 1999). Three replications of one hundred seeds of each variety were used. Three blotter papers were used for each replication with two blotter papers below the seeds and one covering it with all the seeds placed on the blotter paper in a straight line. After the seeds were covered with the third blotter paper, the setup was wetted with distilled water. The samples were kept on shelves with occasional wetting with distilled water. The period of germination was 14 days. The setup was analysed during and after the germination period.

A standard germination test was also conducted between blotter papers for each variety after the accelerated seed ageing. One hundred seeds in three replications were used. Three blotter papers were used for each replication with two blotter papers below the seeds and one covering it with all

the seeds placed on the blotter paper in a straight line. After the seeds were covered with the third blotter paper, the setup was wetted with distilled water. The samples were kept on shelves with occasional wetting with distilled water. The period of germination was 14 days.

Samples of the primed accelerated aged seeds were put under running water for five minutes after the 18 hours of priming. The seed were shade dried for two hours. A standard germination test was carried out using one hundred seeds in three replications of each variety between blotter papers. Three blotter papers were used for each replication with two blotter papers below the seeds and one covering it with all the seeds placed on the blotter paper in a straight line. After the seeds were covered with the third blotter paper, the setup was wetted with distilled water. The samples were kept on shelves with occasional wetting with distilled water. The duration of germination was 14 days.

3.9 SEEDLING ANALYSIS

Seedlings of both the primed and unprimed accelerated aged seeds were analaysed to determine the percentage of normal seedlings, abnormal seedlings, dead/rotten seeds and fresh ungerminated seeds. This was done with the aid of the ISTA (2006) seedling evaluation manual.

3.9.1. Speed of Germination

One hundred seeds of each variety after accelerated ageing and priming were germinated in three replications between blotter papers. This was kept for 14 days with occasional wetting with distilled water. Number of seedlings emerging daily was counted from the day of planting to the

14th day. The germination index (G.I.) was computed by using the formula described by Gupta (1985).

$$\textbf{G.I} = \frac{\textbf{Number of seedlings emerging+...+…+ number of seedlings emerging}}{\textbf{Day after planting} \qquad \textbf{day of final count}}$$

The variety showing greater germination index was considered to be more vigorous.

3.9.2. Seed Vigour Index (S.V.I)

This was computed by determining the germination percentage and seedling length of the okra seeds. While evaluating the number of normal seedlings, 5 randomly selected seedlings had their lengths measured at the time of final count. The seed vigour index was calculated by multiplying the mean seedling length in mm and germination percentage. The variety showing the higher seed vigour index was considered as the more vigorous variety as stated by Abdul-Baki and Anderson (1973).

3.10. STATISTICAL ANALYSIS

The data collected were summarised using Microsoft Excel software. Percentages and averages were calculated using Microsoft Excel. Tables, bar charts and graphs were used to present the data. GenStat Statistical Software (12.0 edition) was used for analysis of variance. Means were separated using Fisher's unprotected LSD (5%)

CHAPTER FOUR

RESULTS

4.1 SEED ANALYSIS

4.1.1. Seed Physical Purity

CRI-K-P11-11 recorded the highest seed physical purity with a pure seed weight of 97.90g per

100g of seed. Asontem and Manpeali recorded purity values of 92.05g and 96.66g respectively. The values recorded by CRI-K-P11-11 and Manpeali had no significant difference between them but differed highly significantly (P<0.01) from the value recorded by Asontem. No other crop seeds or weed seeds were found in the seed samples (Table. 4.1).

Table 4.1: Analysis of Seed Physical Purity of 100g of seeds and One Thousand Seed Weight

Variety	Pure Seed (g)	Other Crop Seed (g)	Inert Matter (g)	Weed Seed (g)	One thousand seed weight (g)
CRI-K-P11-11	97.90a	0	2.1b	0	47.53b
Asontem	92.05b	0	7.95a	0	37.6c
Manpeali	96.66a	0	3.34b	0	53.6a

4.1.2. One Thousand Seed Weight (TSW)

Manpeali had the highest one thousand seed weight, with TSW of 53.6g. CRI-K-P11-11 and Asontem had one thousand seed weight values of 47.525g and 37.6g respectively. All these values differed highly significantly (P<0.01) from each other.

4.2. EVALUATION OF VARIETIES BEFORE ACCELERATED SEED AGEING

CRI-K-P11-11 recorded the highest germination percentage (91.0%) before the start of accelerated seed ageing. This value was significantly different from the values recorded by Asontem (81%) and Manpeali (83%) at P<0.05. CRI-K-P11-11 recorded the highest speed of germination, seed vigour index and the highest number of normal seedlings before the start of the experiment. There were no significant differences between the percentages of normal seedlings recorded among the three varieties. The speed of germination of CRI-K-P11-11 (22.39) differed significantly (P< 0.05) from Manpeali (17.18) but there was no significant difference between the speed of germination of Asontem (19.15) and Manpeali (17.18) (Table 4.2)

Table 4.2: Evaluation of Varieties before Accelerated Seed Ageing

Variety	Germination (%)	Speed of Germination (GI)	Seed Vigour index	Normal seedlings (%)	Abnormal Seedlings (%)	Dead seeds (%)
CRI-K-P11-11	91.00a	22.39a	8887a	89.0a	2a	9.0a
Asontem	81b	19.15ab	7405a	79.0a	2a	15.67a
Manpeali	83b	17.18b	7423a	81.0a	2a	17.0a

4.3. EVALUATION OF VARIETIES AFTER ACCELERATED SEED AGEING WITHOUT SEED PRIMING

There were significant differences ($p< 0.01$ and $p<0.05$) between the varieties for germination percentage, speed of germination(GI), seed vigour index, normal seedlings, abnormal seedlings and dead seeds after 72 hours of accelerated seed ageing without seed priming.

CRI-K-P11-11 recorded the highest mean germination percentage of 43.00% after 72 hours of accelerated seed ageing. This value differed highly significantly from the 17.0% and 14.0% recorded by Asontem and Manpeali. There was no significant difference between the values recorded by Asontem and Manpeali.

Table 4.3: Evaluation of the Varieties of Okra after 72 hours of Accelerated Seed Ageing without Seed Priming.

Variety	Germination (%)	Speed of Germination	Seed Vigour index	Normal seedlings (%)	Abnormal seedlings (%)	Dead seeds (%)
CRI-K-P11-11	43.00a	11.36a	3642a	29.67a	13.33a	57.0b
Asontem	17.00b	3.925b	1119b	9.0b	8a	76.67a

Manpeali	14.00b	3.581b	1489b	6.0c	8a	72a

The speed of germination value of 11.36 recorded by CRI-K-P11-11 after 72 hours of accelerated seed ageing, differed highly significantly ($p<0.01$) from the 3.925 and 3.581 recorded by Asontem and Manpeali. There was no significant difference between the values recorded by Asontem and Manpeali. These values relatively are very low (Table. 4.3).

The seed vigour index of CRI-K-P11-11 (3642) differed highly significantly from that of Asontem (1119) and Manpeali (1489) after 72 hours of AA at $p<0.01$. There was however no significant difference between the seed vigour index values of Asontem and Manpeali (Table. 4.3).

CRI-K-P11-11 recorded the highest number of normal seedlings with a normal mean seedling percentage of 29.67% after the period of accelerated seed ageing. This value differed significantly ($P<0.1$) from the values recorded by Asontem (9) and Manpeali (6).

72 hours of accelerated seed ageing without seed priming, saw the varieties record high numbers of abnormal seedlings. CRI-K-P11-11 recorded the highest number of abnormal seedlings with an abnormal seedling percentage of 13.33%. This value did not differ significantly from the 8% abnormal seedlings recorded by Asontem and Manpeali.

After 72 hours of accelerated seed ageing without seed priming, very high numbers of dead seeds were recorded. Asontem recorded the highest number of dead seeds with a dead seed percentage of 76.67%. This value was highly significantly different ($P<0.01$) from the value recorded by CRI-K-P11-11(57%). Asontem and Manpeali recorded 6 and 14 hard seeds respectively. (Table 4.3)

4.4. THE EFFECT OF SEED PRIMING ON GERMINATION PERCENTAGE OF THE OKRA VARIETIES AFTER 72 HOURS OF ACCELERATED SEED AGEING.

Seventy two hours of accelerated seed ageing and seed priming afterwards resulted in highly significant differences in germination percentage between the varieties, the effect of the seed primers and the interaction between the varieties and primers at $p<0.01$. CRI-K-P11-11 recorded the highest mean germination percentage of 49.61% among the varieties. Asontem recorded the least mean germination percentage with a mean germination percentage of 15.89%.

Ascorbic acid 150 ppm was the best performing seed primer with mean germination percentage 39.33%. The best performing organic seed primers was *Moringa oleifera* leaf extract 1:15 with mean germination percentages of 33.78%. The worst performing primer was sweet orange juice extract 1:1 with a mean germination percentages of13.56 %. The interaction between CRI-KP11-11 and Ascorbic acid 100 ppm, Ascorbic acid 150 ppm and KCl 0.3 % produced the highest germination percentage with values; 65.67 %, 68.0% and 64.33% recorded respectively. There were no significant differences between them. The interaction between CRI-K-P11-11 and *Moringa oleifera* leaf extract 1:15 produced the highest germination percentage between a variety and an organic seed primer. Their interaction produced a germination percentage of 50.00%. The worst interactions occurred between sweet orange juice extract 1:1 and Asontem and Manpeali. Their interaction recorded a germination percentage of 10.00% and 11.00% respectively (Table 4.4).

Table 4.4: The effect of seed priming on germination percentage of the okra varieties after 72 hours of Accelerated Seed Ageing.

Variety	Ascorbic Acid 50ppm	Ascorbic Acid 100ppm	Ascorbic Acid 150ppm	KCl 0.2%	KCl 0.3%	KCl 0.4%	Orange juice extract 1:1	Orange juice extract 1:2	Orange juice extract 1:3	*Moringa oleifera leaf extract* 1:5	*Moringa oleifera leaf extract* 1:10	*Moringa oleifera leaf extract* 1:15	**Mean**
CRI-KP11-11	55.67 c	65.67 ab	68.0 a	52.00 cd	64.33 ab	61.33 b	19.67 ijkl	45.67 e	46.00 e	21.33 hijk	45.67 e	50.00 de	**49.61 a**
Asontem	16.33 lmno	20.33 hijkl	22.0 hij	14.33 mnop	16.33 lmno	17.00 klmno	10.00 p	13.00 op	13.67 nop	13.33 op	13.00 op	21.33 hijk	**15.89 c**
Manpeali	20.67 hijkl	23.67 ghi	28.0 fg	23.00 hij	24.67 gh	18.33 jklmn	11.00 p	18.67 jklm	18.33 jklmn	16.33 lmno	20.33 hijkl	30.00 f	**21.08 b**
Mean	**30.89 e**	**36.56 b**	**39.33 a**	**29.78 e**	**35.11 bc**	**32.22 de**	**13.56 h**	**25.78 f**	**26.00 f**	**17.00 g**	**26.33 f**	**33.78 cd**	

4.5. THE EFFECT OF SEED PRIMING ON SPEED OF GERMINATION (GI) OF THE OKRA VARIETIES AFTER 72 HOURS OF ACCELERATED SEED AGEING.

The speed of germination of the three okra varieties was accessed after 72 hours of accelerated seed ageing and seed priming with the twelve seed primers.

Highly significant differences in speed of germination occurred between the varieties, seed primers and the interaction between the varieties and primers at $p<0.01$ after 72 hours of accelerated seed ageing. CRI-K-P11-11 recorded the highest mean speed of germination with a GI of 13.78 among the varieties. Manpeali recorded the least mean speed of germination with a mean speed of germination 4.395. This GI value was however not significantly different from the GI of Asontem. Ascorbic acid 100 ppm, Ascorbic acid 150 ppm and KCl 0.3% were the best performing seed primers with mean speed of germination of 9.412, 10.14 and 7.617 respectively. There were no significant differences between them. However the GI of Ascorbic acid 100 ppm and KCl 0.3% were not significantly different ($P>0.05$) from the GI of KCl 0.4 %.

The best performing organic seed primers was *Moringa oleifera* leaf extract 1:15 with mean speed of germination of 8.41. The worst performing primer was sweet orange juice extract 1:1 with a mean speed of germination of 3.544. The interaction between CRI-K-P11-11 and Ascorbic acid 100 ppm, Ascorbic acid 150 ppm, KCl 0.3 % and KCl 0.4 % produced the highest speed of germination with values of 17.86, 18.67, 17.53 and 16.95 recorded respectively. There were no significant differences between them. The interaction between CRI-K-P11-11 and *Moringa oleifera* leaf extract 1:15 produced the highest speed of germination between a variety and an organic seed primer. Their interaction produced a speed of germination of 13.45. The worst interaction occurred between sweet orange juice extract 1:1 and Manpeali. Their interaction recorded a speed of germination of 2.204 (Table 4.5).

Table 4.5: The effect of seed priming on the speed of germination (GI) of the okra varieties after 72 hours of accelerated ageing

Variety	Ascorbic Acid 50ppm	Ascorbic Acid 100ppm	Ascorbic Acid 150ppm	KCl 0.2%	KCl 0.3%	KCl 0.4%	Orange juice extract 1:1	Orange juice extract 1:2	Orange juice extract 1:3	*Moringa oleifera leaf extract* 1:5	*Moringa oleifera leaf extract* 1:10	*Moringa oleifera leaf extract* 1:15	**Mean**
CRI-KP11-11	15.13 bc	17.86 a	18.67 a	14.08 cd	17.53 ab	16.95 ab	5.301 fghi	11.73 de	12.97 cd	9.868 e	11.84 de	13.45 cd	**13.78 a**
Asontem	4.210 fghij	5.451 fgh	5.879 fg	4.246 fghij	3.915 ghij	3.943 fghij	3.129 hij	2.793 ij	3.279 hij	9.993 e	3.196 hij	5.332 fgh	**4.614 b**
Manpeali	4.344 fghij	4.921 fghi	5.886f g	4.522 fghij	4.878 fghi	3.854 ghij	2.204 j	4.014 fghij	3.844 ghij	3.460 ghij	4.371 fghij	6.446 f	**4.395 b**
Mean	**7.895 cd**	**9.412 ab**	**10.14 a**	**7.617 cde**	**8.777 abc**	**8.249 bc**	**3.544 f**	**6.181 e**	**6.697 de**	**7.774 cd**	**6.469 de**	**8.410 bc**	

4.6. THE EFFECT OF SEED PRIMING ON SEED VIGOUR INDEX (SVI) OF THE OKRA VARIETIES AFTER 72 HOURS OF ACCELERATED SEED AGEING.

The seed vigour index (SVI) of the three okra varieties was accessed after 72 hours of accelerated seed ageing and seed priming with the twelve seed primers.

Seventy two hours of accelerated seed ageing and seed priming afterwards resulted in highly significant differences in seed vigour index between the varieties, seed primers and the interaction between the varieties and primers at $p<0.01$. CRI-K-P11-11 recorded the highest mean seed vigour index among the varieties with an SVI of 6043. Asontem recorded the least mean seed vigour index with a mean SVI of 1571. Ascorbic acid 150 ppm and KCl 0.4 % were the best performing seed primers with mean SVI of 4345 and 4180. There was no significant difference between their SVI values.

The best performing organic seed primers was *Morenga oleifera* leaf extract 1:15 with a mean SVI of 3822. The worst performing primer was sweet orange juice extract 1:1 with a mean SVI of 1380. The interaction between CRI-K-P11-11 and Ascorbic acid 150 ppm, KCl 0.3%and KCl 0.4 % produced the highest seed vigour index with values of 7956, 8235 and 8403 recorded respectively. There were no significant differences between them. The interaction between CRIK-P11-11 and *Morenga oleifera* leaf extract 1:15produced the highest SVI between a variety and an organic seed primer. Their interaction produced an SVI of 6365. The worst interaction occurred between sweet orange juice extract 1:1 and Asontem. Their interaction recorded an SVI of 769. This was not significantly different from the SVI of the interaction between Manpeali and sweet orange juice extract 1:1 (Table 4.6).

Table 4.6: The effect of seed priming on seed vigour index (S.V.I) of the varieties of okra after 72 hours of accelerated seed ageing.

Variety	Ascorbic Acid 50ppm	Ascorbic Acid 100ppm	Ascorbic Acid 150ppm	KCl 0.2%	KCl 0.3%	KCl 0.4%	Orange juice extract 1:1	Orange juice extract 1:2	Orange juice extract 1:3	*Moringa oleifera leaf extract* 1:5	*Moringa oleifera leaf extract* 1:10	*Moringa oleifera leaf extract* 1:15	**Mean**
CRI-KP11-11	6235 cd	7664 b	7956 ab	6552 c	8235 a	8403 a	2399 hij	5618 e	4981 f	2122 ijkl	5982 de	6365 cd	**6043 a**
Asontem	1666 lmno	1815 klmn	2046 jklm	1405 nopq	1737 klmno	1926 jklm	769 r	1374 nopq	1314 nopq	1267 opqr	1144 pqr	2390 hij	**1571 c**
Manpeali	2087 jkl	2587 ghi	3034 g	2024 jklm	2171 ijkl	2211 hijk	972 qr	1815 klmn	1412 nopq	1532 mnop	1668 lmno	2710 gh	**2019 b**
Mean	**3329 d**	**4022 bc**	**4345 a**	**3327 d**	**4047 bc**	**4180 ab**	**1380 g**	**2936 e**	**2569 f**	**1640 g**	**2931 e**	**3822 c**	

4.7. EVALUATION OF NORMAL SEEDLING PERCENTAGE AFTER ACCELERATED SEED AGEING AND SEED PRIMING

The evaluation of germination after 72 hours of accelerated seed ageing with seed priming saw CRI-K-P11-11 record the highest normal seedling percentage with a mean normal seedling percentage of 43.28%. This value differed highly significantly ($P< 0.01$) from the normal seedling percentage of Asontem (10.56%) and Manpeali (16.25%). Ascorbic acid 150ppm recorded the highest primer mean normal seedlings percentage with a mean normal seedling percentage of 34.67%. This value was highly significantly different from the percentage of normal seedlings recorded by the other primers.

The interaction between CRI-K-P11-11 and Ascorbic acid 150 ppm recorded the highest number of normal seedling percentage (63.0%) and the worst interaction was between sweet orange juice extract 1:1 and Asontem (5.0%) but the value was not significantly different from the value recorded between Manpeali and orange juice extract 1:1(6.0%). The worst performing primer was sweet orange juice extract 1:1 with a mean normal seedling percentage of 7.56%. *Moringa oleifera* leaf extract 1:15 was the organic primer with the highest mean normal seedling percentage of 28.11%. The interaction between *Moringa oleifera* leaf extract 1:15 and CRI-KP11-11 recorded the highest number of normal seedlings between a variety and an organic seed primer (43%). (Table 4.7)

Table 4.7: The effect of seed priming on the normal seedling percentage of the varieties of okra after 72 hours of accelerated seed ageing

Variety	Ascorbic Acid 50ppm	Ascorbic Acid 100ppm	Ascorbic Acid 150ppm	KCl 0.2%	KCl 0.3%	KCl 0.4%	Orange juice extract 1:1	Orange juice extract 1:2	Orange juice extract 1:3	*Moringa oleifera leaf extract* 1:5	*Moringa oleifera leaf extract* 1:10	*Moringa oleifera leaf extract* 1:15	**Mean**	
CRI-K-P11-11	48.67 c	60.67 ab	63.00 a	47.00 cd	59.33 ab	57.33 b	11.67 lmno	38.67 ef	38.00 f	12.33 lmno	39.67 ef	43.00 de	**43.28 a**	
Asontem	9.33 nopq	14.33 jklm	18.00 ijk	8.33 opq	10.33 mnop	12.00 lmno	5.00 q	8.00 opq	5.67 pq	11.33 mno	8.00 opq	16.33 ijkl	**10.56**	**c**
Manpeali	14.67 jklm	17.67 ijk	23.00 gh	19.00 hij	20.67 ghi	16.33 ijkl	6.00 pq	13.67 klmn	11.33 mno	11.33 mno	16.33 ijkl	25.00 g	**16.25 b**	
Mean	**24.22 d**	**30.89 bc**	**34.67 bc**	**24.78 h**	**30.11 ef**	**28.56 f**	**7.56 g**	**20.11 e**	**18.33 c**	**11.67**	**21.33**	**28.11**	**d**	**b** **a**

4.8. EVALUATION OF ABNORMAL SEEDLING PERCENTAGE AFTER ACCELERATED SEED AGEING AND SEED PRIMING

Seventy two hours of accelerated seed ageing and seed priming saw all the primers record a mean abnormal seedling percentage between 2% and 9%. The mean abnormal seedling percentage of CRI-K-P11-11, Asontem and Manpeali were 6.33, 5.33 and 4.86. There were significant differences ($P < 0.05$) between the mean values recorded by all three varieties. The interactions between the varieties and primers recorded percentages of abnormal seedlings ranging from 2.0% to 9% with the worst interaction occurring between *Moringa oleifera* leaf extract 1:5 and CRI-K-P11-11. There were no significant differences in most of the values recorded. (Table 4.8)

Table 4.8 : Percentage of abnormal seedlings after 72 hours of accelerated seed ageing and priming of the three okra varieties.

Variety	Ascorbic Acid 50ppm	Ascorbic Acid 100ppm	Ascorbic Acid 150ppm	KCl 0.2%	KCl 0.3%	KCl 0.4%	Orange juice extract 1:1	Orange juice extract 1:2	Orange juice extract 1:3	*Moringa oleifera leaf extract* 1:5	*Moringa oleifera leaf extract* 1:10	*Moringa oleifera leaf extract* 1:15	**Mean**
CRI-K-P11-11	7.0 c	5.0 f	5.0 f	5.0 f	5.0 f	4.0 g	8.0 b	7.0 c	8.0 b	9.0 a	6.0 d	7.0 c	**6.333 a**
Asontem	7.0 c	6.0 d	4.0 g	6.0 d	6.0 d	5.0 f	5.0 f	5.0 f	8.0 b	2.0 h	5.0 f	5.0 f	**5.333 b**
Manpeali	6.0 d	6.0 d	5.333 e	4.00 g	4.0 g	2.0 h	5.0 f	5.0 f	7.0 c	5.0 f	4.0 g	5.0 f	**4.861 c**
Mean	**6.667 b**	**5.667 d**	**4.778 g**	**5.0 f**	**5.0 f**	**3.667 h**	**6.0 c**	**5.667 d**	**7.667 a**	**5.333 e**	**5.0 f**	**5.667 d**	

4.9. EVALUATION OF DEAD SEEDS PERCENTAGE AFTER ACCELERATED SEED AGEING AND SEED PRIMING

High numbers of dead/ rotten seeds were recorded at the end of the germination period after 72 hours of accelerated ageing and seed priming. Asontem recorded the highest percentage of dead seeds with a mean dead seed percentage of 81.47%. The least was CRI-K-P11-11 with a dead seed percentage of 50.39%. The varietal means differed significantly ($P< 0.05$) from each other. The interaction between *Moringa oleifera* leaf extract 1:5 and Asontem recorded the highest number of dead seeds (86.0%). Orange juice extract 1:1 was the worst performing seed primer with a mean dead seeds percentage of 82.78%. This value was significantly different from the values recorded by the other seed primers. The primer with the least mean number of dead seeds after 72 hours of accelerated ageing was Ascorbic acid 150ppm with a dead seed percentage of 59.67% (Table 4.9).

Table 4.9: Percentage of dead seeds after 72 hours of accelerated seed ageing and seed priming

Variety	Ascorbic Acid 50ppm	Ascorbic Acid 100ppm	Ascorbic Acid 150ppm	KCl 0.2%	KCl 0.3%	KCl 0.4%	Orange juice extract 1:1	Orange juice extract 1:2	Orange juice extract 1:3	*Moringa oleifera leaf extract* 1:5	*Moringa oleifera leaf extract* 1:10	*Moringa oleifera leaf extract* 1:15	**Mean**
CRI-KP11-11	44.33 p	34.33 qr	32.00 r	48.00 op	35.67 qr	38.67 q	80.33 bcdefg	54.33 n	54.00 n	78.67 defghi	54.33 n	50.00 no	**50.39 c**
Asontem	83.67 abc	79.67 cdefgh	78.00 efghi	80.67 bcdef	80.67 bcdef	80.00 cdefgh	85.00 ab	83.00 abcd	83.33 abcd	82.00 abcde	86.00 a	75.67 ghijk	**81.47 a**
Manpeali	75.33 hijk	72.33 jkl	69.00 lm	74.00 ijk	71.33 kl	77.67 efghi	83.00 abcd	77.33 efghi	78.67 defghi	80.67 bcdef	76.67 fghij	65.00 m	**75.08 b**
Mean	**67.78 c**	**62.11 ef**	**59.67 f**	**67.56 c**	**62.56 e**	**5.44 cd**	**82.78 a**	**71.56 b**	**72.00 b**	**80.44 a**	**72.33 b**	**63.56 de**	

CHAPTER FIVE

DISCUSSION

5.1 SEED ANALYSIS

5.1.1. Seed Physical Purity

The three okra varieties used for the experiment had very high purity values. CRI-K-P11-11 recorded purity values 97.9g per 100g of seeds, Asontem 92.05g per 100g of seeds and Manpeali 96.99g per 100g of seeds. Seed analytical purity is one of the most important multiple component of seed purity analysis (Powell, 2010). Schmidt (2000) defined seed physical purity as an expression of how clean a seed lot is. Schmidt (2000) further explained that it is never possible to achieve a completely clean or pure seed lot by mechanical seed processing because the physical characters of inert matter or other seed parts may be similar to those of the seeds in question that separation is impossible. Seed lots that can be placed onto the market are determined by the quality of seeds and its viability. Since pure seed may include dead, empty seed and damaged seeds, purity does not tell anything about viability (Milosevic *et al*., 2010).

5.1.2. One Thousand Seed Weight

Mahadevappa and Nandisha (1987) stated that heavier seeds produce vigorous seedlings responsible for high grain yields but a different observation was made in this study. CRI-K-P1111 recorded one thousand seed weight value of 47.525g, Asontem(37.6g) and Manpeali (53.6g) . Though Manpeali had the highest one thousand seed weight it was not the best performer in the parameters that were studied. This suggests that varietal characteristics and genetic potential of a variety influences its performance. Zecchnelli (2010) indicated that only the use of good quality (physical

and varietal) seeds will lead to the return expected before the application of other means of crop production are achieved.

5.1.3. Evaluation of Varieties before Accelerated Seed Ageing

CRI-K-P11-11 recorded high; germination percentage (91%), speed of germination (22.39), seed vigour index (8887) and percentage of normal seedlings (89%). These values differed significantly ($P<0.05$) from the values recorded by Asontem and Manpeali. This could be attributed to the improved nature of that variety. Desh *et al*. (2013) made similar observations that improved varieties of okra perform better in vigour tests and produce better seedlings. Asontem and Manpeali equally recorded high values because the vigour tests were carried out just after the seeds were harvested and dried to the required moisture content. Kumar (2010) stated that okra seeds stored for longer periods loses viability and are less vigorous. Field conditions are rarely favourable and the emerging seedlings suffer from stresses. Seed lots having similar laboratory germinations may give wide differences in field emergence (Gupta, 1995).

5.2. THE EFFECT OF ACCELERATED SEED AGEING ON THE THREE OKRA VARIETIES WITHOUT SEED PRIMING.

The ISTA categorizes Okra seeds as low vigorous seeds. Seventy two hours of accelerated seed ageing saw the best performing variety; CRI-K-P11-11 had its germination percent drop from 91% to 43%. This is in line with the results, earlier reported by Seiadat *et al*. (2012) which shows negative effect of accelerated seed ageing on germination. Similar results were recorded by Ramos *et al*. (2004), Tunes *et al.* (2009) in seeds of rocket, barley and ryegrass, respectively. They found that the stress caused by the accelerated ageing test for a period of 72 hours caused significant reduction in the germination of the seeds.

Reduction in the speed of germination was also observed in all the varieties under study after 72 hours of accelerated seed ageing without priming. The best performing variety that is, CRI-KP11-11 had its speed of germination drop from 22.39 to 11.36. Murata *et al.* (1980) suggested that the reduction is the speed of germination after accelerated seed ageing is due to the reduction in the germinability of the seeds.

The seed vigour indices of the unprimed seeds of all the three varieties of okra decreased after the time of accelerated seed ageing. The worst performing variety that is, Asontem had its seed vigour index drop from 7405 to 1119. This score was not significantly different ($P>0.05$) from the seed vigour index recorded by Manpeali (1489) after 72 hours of accelerated seed ageing without priming. This can be attributed to a reduction in germination and seedling length after accelerated seed ageing. The germination percentage and seedling length are used in the computation of the seed vigour index. Farhadi *et al*., (2012) observed that root and shoot lengths were greatly reduced with an increase in the duration in the ageing environment.

5.3. THE EFFECT OF SEED PRIMING ON GERMINATION AFTER ACCELERATED SEED AGEING (AA) OF THE OKRA VARIETIES.

Seventy two hours of accelerated seed ageing and priming, saw CRI-K-P11-11 record relatively high germination percentages (49.61%). This value was highly significantly different ($P<0.01$) from the varietal means recorded by Asontem (15.89%) and Manpeali (21.08%). This could be attributed to the improved nature of the variety. The FAO (2010) studies conducted in parts of Africa and Asia indicated that primed corn seeds flowered sooner, emerged earlier, required less weeding, fewer cultivation, produced grain faster and matured earlier than using dry seeds sown at the same time. Reports of seed priming improving emergence, grain yield, stand establishment, straw yields and harvest index have been recorded by Farooq *et al.*, (2008) in wheat. Selvarani and Umarani (2011) observed an increase in days for 50% germination, percentage of radicle protrusion, days for maximum germination and germination percentage in seeds of carrot and onion after seed priming.

The low germination percentages recorded by Asontem and manpeali could be attributed to the nature of theses varieties. Reports by Abdalla and Roberts, (1968) indicates that barley and pea seeds treated with combinations of accelerated ageing treatment showed genetic damage and the amount of genetic damage was exclusively due the loss of viability. This observation is also in line with what Desh *et al.* (2013) observed that, ageing treatment of okra seeds showed deleterious effect on germination and other quality traits. A study by Desh *et al.* (2013) saw the germination percentage of all the okra varieties studied decreased after accelerated ageing at 40±1^{o}C for 72 hours. Similar results were recorded in okra by Narwal (1995).

The best performing seed primer in germination percentage in the study period was Ascorbic acid 150ppm (39.33%). This differed highly significantly (P<0.01) from the values recorded by the other primer concentrations. Desh *et al*. (2013) made a similar observation in okra where hydration with ascorbic acid (100 ppm for 6 hours) in combination with hydration (6 hours) with water, proved beneficial for enhancing standard germination significantly. KCl 0.3% also recorded high mean germination percentages (35.11%) when used as a seed primer. Basra *et al.*, (1989) reported that priming corn seeds using polyethylene glycol or potassium salt resulted in rapid germination. Lemrasky and Hosseini (2012) reported that seed priming with KCl had significantly positive effect on the rate of germination. *Moringa oleifera* leaf extract 1:15 was the best performer in germination percentage (33.78%) among the organic seed primers. This value differed highly significantly (P<0.01) from the values recorded by the other organic primer concentrations. A similar observation was made by Basra *et al.,* (2011), the study indicated that seed priming with fresh *Moringa oleifera* leaf extract1:30 was the most effective concentration for hybrid seed maize as depicted by early seedling growth and higher emergence rate. Nouman *et al.*,(2012) stated that all of the priming treatments with *Moringa oleifera* leaf extract significantly affected the germination rate and uniformity of all seeds of range grasses. Very low germination percentage values were recorded in all three varieties when primed with sweet orange juice extract 1:1. Its primer mean germination was 13.56%. Its interactions with some varieties were lower than the germination percentages of the unprimed seeds. This could be attributed to the high pH of the primer at that level of concentration. Similar observations were made by Powers (2004) who concluded that lettuce seeds did not germinate at pH levels lower than 5 using lime solutions or ascorbic acid. Reports by Jansen and Cronin (1953) indicates that pH values lower than three and higher than

eight inhibit germination. Dorna and Szopinska (2014) stated that some priming treatments even decreased germination compared with untreated seeds.

5.4. THE EFFECT OF SEED PRIMING ON SPEED OF GERMINATION (GI) AFTER ACCELERATED SEED AGEING (AA) OF THE OKRA VARIETIES.

Speed of germination values recorded after 72 hours of accelerated seed ageing were low regardless of the variety involved though the values of CRI-K-P11-11(13.78) were relatively higher and differed highly significantly from the values recorded by Asontem(4.614) and Manpeali (4.395). This shows that CRI-K-P11-11 was the more vigorous variety. Compared to the unprimed seeds after accelerated seed ageing, the values recorded were better. Tabatabaei (2013) reported that, catalase and ascorbat peroxidases which are essential for germination in sesame seeds decreased after ageing, but priming increases enzyme activity in seeds after ageing hence a faster rate of germination. Umarani and Selvarani (2011) stated that onion and carrot seeds showed significant differences in seed germination and the speed of germination regardless of the seed priming methods. Primed seeds are brought to a stage where the metabolic processes are already initiated, giving it a starting point over the unprimed seed. Upon further imbibitions, the primed seed can take off from where it has left of completing the remaining steps of germination faster than the untreated seed (Varier *et al.*, 2010). Typical responses to priming are wider temperature range of emergence, faster and closer spread of times to emergence over varying seedbed environments, better crop stand, hence enhanced yield and harvest quality, especially under unfavourable and stress conditions in the field (Halmer, 2004). Primed seeds mostly germinate more rapidly than non primed seeds, even under low temperatures (Murray, 1990). Rajpar *et al.*, (2006) reported that compared to control, primed seed took significantly fewer days to emerge. The low speed of germination of Asontem (4.614) and Manpeali (4.395) could be

attributed to the loss of viability and low vigour after the period of accelerated seed ageing. Bailly (2004) made similar suggestions that there is loss of viability and a decreased in enzyme activities in aged seeds. Ferguson *et al.,* (1990) stated that if two lots of seed have the same germination percentage but one is of high vigour and the other is of low vigor, a difference in the germination speed, seedling growth, or emergence can be seen after ageing.

Priming of the seeds positively influenced the speed of germination with ascorbic acid 150ppm as the seed primer with the highest mean speed of germination (10.14). KCl 0.3% also recorded high speed of germination (8.777). These values were not significantly different (P>0.05%). Foliar application and seed priming with ascorbic acid have been reported to increase growth and improve yields in various crops (Jyotsna and Srivastava, 1998). Misra and Dwibedi, (1980) reported that potassium chloride (KCl) introduced as an osmoticum has shown good potential to enhance growth, grain yield, germination and emergence of wheat. Lemrasky and Hosseini (2012) made similar observations in wheat. Sweet orange juice extract 1:1 (P7) as a primer, recorded were low speed of germination (3.544) and this could be attributed to the low pH of the primer. Powers (2004) stated that at extremely low pH lower than four, the seeds of lettuce did not germinate within six days, hence a low speed of germination values were recorded. *Moringa oleifera* leaf extract 1:15 (P12) was the best organic seed primer as far as the speed of germination (8.41) of the three okra varieties were concern. Nouman *et al.,* (2012) made a similar observation in rangeland grasses.

5.5. THE EFFECT OF SEED PRIMING ON SEED VIGOUR INDEX (SVI) AFTER ACCELERATED SEED AGEING (AA) OF THE OKRA VARIETIES.

Low seed vigour indices which differed highly significantly (P<0.01) were recorded for all the three varieties after 72 hours of accelerated ageing and seed priming but the values were relatively

better compared to the unprimed seeds. CRI-K-P11-11 recorded relatively high seed vigour index (6043), Asontem (1571) and Manpeali (2019). This confirms the ISTA (2005) categorization of okra seeds as a moderate storer. Henckel (1961) stated that the beneficial effect of priming is known to occur due to higher mitochondrial activity, formation of more high energy compounds and vital bio-molecules. Halopriming increases the growth and germination parameters of safflower compared with non primed seeds (Elouaer and Hannachi, 2012). The relative high seed vigour index was also influenced by the improved root and shoot length. Significant improvement in root and shoot length may seen in primed seeds as against un-primed seeds. This may be attributed to earlier germination (Farooq *et al*. 2005), which resulted in vigorous seedlings with better shoot and root length. These results also confirms findings by Stofella *et al*., (1992) who reported that priming of pepper seeds saw a significant improvement in radicle length hence the development of vigorous seedlings. Vigour index was increased in primed compared to unprimed maize seeds **(**Yohannes and Abraha, 2013). Similar results were reported by Ruan *et al.,* (2002) in rice which primed rice seeds showed a higher vigour index than non-primed ones.

CRI-K-P11-11 was the variety with the best mean seed vigour index (6043) in the study. This could be attributed to the improved nature of the variety.

Varieties primed with ascorbic acid 150 ppm recorded very high seed vigour index (4345). The primer mean however was not significantly different from the mean SVI recorded by KCl 0.4% (4180). Liu *et al.,* (2002) found similar results in maize when seeds primed with KCl showed improved germination percentage. Ajirloo *et al.,* (2013) stated that seed priming had significant positive effects on seedling characters such as seedling length, germination percentage, radicle dry weight, and the rate of germination. Willenborg *et al.,* (2005) also reported that the greater effect

of osmohardening with KCl is probably related to the osmotic benefit that K+ has in improving cell water saturation which acts as co-factors in the activities of enzymes leading to faster rate of germination and seedling growth. The seed vigour index of all the varieties primed with sweet orange extract 1:1 (1380) was very low. Chinnusamy *et al*., (2005) recorded similar results and stated that the factors that affect seed priming response include osmotic potential and solution composition. *Moringa oleifera* leaf extract 1:15 (3822) was the best performing organic seed primer in the seed vigour index of the three varieties of okra. This value differed highly significantly from the primer means of the other seed primers. *Moringa oleifera* leaf extract is rich in amino acids, potassium, calcium, iron, ascorbate, and growth hormones like zeatin hence ideal plant growth enhancement (Makkar and Becker, 1996)

5.6. EVALUATION OF GERMINATION AFTER ACCELERATED SEED AGEING WITHOUT SEED PRIMING

CRI-K-P11-11 recorded the highest percentage of normal seedlings (29.67%), abnormal seedling percentage (13.33%) and the least percentage of dead seeds (57.0%). Asontem recorded 9.0% normal seedling, 8.0% abnormal seedling and the highest percentage of dead seeds (76.67%). Manpeali recorded 6.0 % of normal seedlings, 8.0 % of abnormal seedlings and 72.0% of dead seeds. There was highly significant ($P<0.01$) between the varieties for normal seedling percentage.

Similar results were recorded by Chetri (2009) which proved that accelerated ageing test showed highly significant differences in the quality of seeds among sixty seed lots of rice. GhassemiGolezani *et al.,* (2014) also made similar observations which showed that seed ageing had significant effect on mean emergence percentage ($P \leq 0.01$) of lentil. Decreased seedling length and dry weight were recorded after accelerated ageing by Nagarajan *et al.* (2004) and Doijode (1999) in okra. Seed ageing led to significant effects on the germination traits of seedlings and electrical conductivity in seeds of cotton (Sayed *et al.*, 2011). The high percentage dead/rotten seeds could be attributed to the seeds loosing viability. Basra *et al.*,(2003) reported that the failure of aged seeds to germinate might be due to mitochondrial dysfunction, less ATP production and lipid peroxidation (Copland and McDonald, 1995).

5.7. EVALUATION OF GERMINATION AFTER ACCELERATED SEED AGEING AND SEED PRIMING

CRI-K-P11-11 recorded the highest percentage of normal seedlings (43.28%), abnormal seedling percentage (6.33%) and the least percentage of dead seeds (50.39%). Asontem recorded 10.56% normal seedling, 5.33% abnormal seedling and the highest percentage of dead seeds (81.47%). Manpeali recorded 16.25% of normal seedlings, 4.86% of abnormal seedlings and 75.08% of dead seeds. These values differed highly significantly ($P<0.01$) from each other.

Ascorbic acid 150pmm was best seed primer with the highest percentage of normal seedlings (34.67%) and the least percentage of dead seeds (59.67%). *Moringa oleifera* leaf extract 1:15 was the best performing organic seed primer with a normal seedling percentage of 28.11%, abnormal seedling percentage (5.66%) and the least percentage of dead seeds (63.56%).

This is in line with what Desh *et al.*, (2013) stated that varieties recover after priming. Several seed priming methods have been used to reduce the damage of ageing and invigorate seedling performance in several crops (Farooq *et al.*, 2008). Significant effects of seed priming treatment were observed in the seedling establishment of caper (Khaninejad, 2012). Applying ascorbic acid in an exogenous manner has been found to induce mitotic activity in several crops, including maize (Kerk and Feldman, 1995). Ascorbate has been shown to play these roles in plant growth; cell wall expansion, cell division, and other developmental processes (Pignocchi and Foyer, 2003). Dolatabadian and Modarressanavy (2008) reported that ascorbic acid increased root and shoot length in treated seeds. Increases in root and shoot length by ascorbic acid might be due to the cell division and differentiation (Liso *et al.*, 1988). Ajirloo *et al.*, (2013) observed that the maximum seedling length of wheat was obtained from seeds primed in KCl 4%. Tavili and Biniaz (2009) observed that maximum germination was obtained when *H. vulgare* was primed with KCl. *Moringa oleifera* leaf extract 1:15 performed relatively well among the primers.

Hosaaini (2012) made similar observation in *Vigna radiate* primed with *Moringa oleifera.* During priming with *Moringa oleifera* leaf extract, which is rich in calcium, potassium and ascorbate, most of the N and Ca^{2}+ appeared to be move to embryo, which enhanced seedling emergence and subsequent growth of maize seedlings (Farooq *et al.*, 2010). Priming with *Moringa oleifera* leaf extract and ascorbate not only improved seedling emergence but also enhanced seedling vigour

(Basra *et al.*, 2011). The high numbers of abnormal seedlings and dead seeds recorded in all the three varieties could be attributed to the poor storage potential of okra. Okra seeds lose viability at a fast rate leading to poor germination and establishment

(Desh *et al.*, 2013).

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1. CONCLUSIONS

Based on the findings of this study, the following conclusions were made;

CRI-K-P11-11 was the best performing variety, recording the best seedling characteristics after accelerated seed ageing and priming with varietal mean germination percentage of 49.61%, speed of germination of 13.78 and seed vigour index of 6043 which differed highly significantly ($P< 0.01$) from the values recorded by Asontem and Manpeali. CRI-K-P11-11 also recorded the best seedling characteristics when seeds were not primed after accelerated seed ageing recording a

varietal mean germination percentage of 43.0%, speed of germination 11.36 and seed vigour index of 3642. This shows that CRI-K-P11-11 will store for a longer period when put in storage. The results obtained by Manpeali and Asontem show they will store poorly.

Moringa oleifera leaf extract 1:15 was the best performing organic seed primer, recording the best seedling characteristics after accelerated seed ageing with primer mean germination percentage of 33.78%, speed of germination of 8.41 and seed vigour index of 3822. Comparing these values to the values recorded when the seeds were not primed suggests that organic primers improve germination and seedling characteristics of Okra.

Ascorbic acid 150ppm was the best performing seed primer on the three varieties of Okra with a germination percentage of 39.33%, speed of germination of 10.14 and seed vigour index of 4345. These values were highly significantly different ($P<0.01$) from the means of the other primers except for speed of germination where it was not significantly different from the value recorded by Ascorbic acid 100ppm.

Without seed priming after 72 hours of accelerated ageing, CRI-K-P11-11 had dropped in germination percentage of 48%, speed of germination of 11.03, Seed Vigour Index of 5245 and mean normal seedling percentage of 59.33%. Asontem had dropped in germination percentage of 64%, speed of germination of 15.225, Seed Vigour Index of 6286 and mean normal seedling percentage of 70%. Manpeali had dropped in germination percentage of 69%, speed of germination of 13.599, Seed Vigour Index of 5934 and mean normal seedling percentage of 75.0%. These values suggest that accelerated ageing has deleterious effect on okra seeds.

6.2 RECOMMENDATIONS

1. Ascorbic acid 150ppm is highly recommended for okra seed priming and for organic priming purposes, *Moringa oleifera* leaf extract 1:15 is highly recommended.

2. It is also recommended that the number of varieties be increased and proximate analysis carried out on the okra seeds before and after accelerated ageing to observe the changes that occur in the seeds.

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APPENDICES

Appendix 1: Germination Percentage of the varieties before AA

REP	CRI-K-P11	Asontem	Manpeali
1	94	81	86
2	90	77	82
3	89	85	80
MEAN	**91**	**81**	**83**

Appendix 2: Seed Purity Test

variety	sample 1	sample 2	sample 3	sample 4	mean
Asomtem	91.8	90.9	93.2	92.3	**92.05**
Manpeali	96.6	96.3	95.91	97.8	**96.6525**

CRI-KP11	98.6	98.9	97.2	96.9	**97.9**

Appendix 3: One Thousand Seed Weight

variety	sampl 1	sample 2	sample 3	sample 4	sample 5	sample 6	sample 7	sample 8	Mean	TSW
Asomtem	3.81	3.78	3.71	3.88	3.69	3.9	3.46	3.85	3.76	37.6
Manpeali	5.46	5.62	5.71	5.41	4.91	5.31	5.44	5.02	5.36	53.6
CRI-KP11	5.06	4.78	4.5	5.13	4.33	5.03	4.68	4.51	4.7525	47.525

Appendix 4: Seedling evaluation after 72 hours of AA without Seed Priming

VARIETY	MEAN GEM	Normal seedling	Abnormal	Hard seed	Fresh seeds	Dead seeds
V1	43	30	13	0	0	57
V2	14	6	8	6	0	86
V3	17	9	8	14	0	83

Appendix 5: CRD Analysis of variance of Germination of the varieties after 72 hours of AA without seed priming

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
VARIETY	2	1526.00	763.00	65.40	<.001
Residual	6	70.00	11.67		
Total	8	1596.00			

Appendix 6: CRD Analysis of variance of Speed of Germination of the three varieties after 72 hours of AA without seed priming

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
VARIETY	2	115.885	57.942	17.86	0.003
Residual	6	19.464	3.244		
Total	8	135.348			

Appendix 7: CRD Analysis of vari ance of Seed Vigour Inde of the three varieties after 72 hours of AA without seed priming

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
VARIETY	2	11137838.	5568919.	60.77	<.001

Residual	6	549866.	91644.		
Total	8	11687704.			

Appendix 8: CRD Analysis of varia

ıce of Germination of the varieties after 72 hours of AA and seed priming

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
variety	2	23736.056	11868.028	1370.85	<.001
Priming	11	5826.472	529.679	61.18	<.001
variety.Priming	22	3723.056	169.230	19.55	<.001
Residual	72	623.333	8.657		
Total	107	33908.917			

Appendix 9: CRD Analysis of varia priming

ıce of S eed vigour Ind ex of the varieties after 72 hours of AA and seed

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
variety	2	436627254.	218313627.	2184.51	<.001
Priming	11	93317588.	8483417.	84.89	<.001
variety.Priming	22	65533122.	2978778.	29.81	<.001
Residual	72	7195457.	99937.		
Total	107	602673420.			

Appendix 10: CRD Analysis of vari seed priming

ıce Sp eed of Germin tion of the three varieties after 72 hours of AA and

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
variety	2	2067.521	1033.761	430.56	<.001
Priming	11	296.127	26.921	11.21	<.001
variety.Priming	22	358.751	16.307	6.79	<.001
Residual	72	172.869	2.401		
Total	107	2895.268			

Appendix 11: CRD Analysis of variance of abnormal seedlings of the varieties after 72 hours of AA and seed priming

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Priming	11	99.435185	9.039562	976.27	<.001
variety	2	40.685185	20.342593	2197.00	<.001
Priming.variety	22	108.203704	4.918350	531.18	<.001

Residual	72	0.666667	0.009259		
Total	107	248.990741			

Appendix 12: CRD Analysis of vari

nce of dead seeds of the varieties after 72 hours of AA and seed priming

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Priming	11	5124.630	465.875	54.04	<.001
variety	2	19401.685	9700.843	1125.34	<.001
Priming.variety	22	4210.981	191.408	22.20	<.001
Residual	72	620.667	8.620		
Total	107	29357.963			

Appendix 13: CRD Analysis of var priming

ance of normal seedlings of the varieties after 72 hours of AA and seed

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Priming	11	6379.806	579.982	66.99	<.001
variety	2	22004.056	11002.028	1270.82	<.001
Priming.variety	22	4727.722	214.896	24.82	<.001
Residual	72	623.333	8.657		
Total	107	33734.917			

Appendix 14: CRD Analysis of vari

nce of abnormal seedlings of the varieties before AA

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
VARIETY	2	0.000	0.000	0.00	1.000
Residual	6	8.000	1.333		
Total	8	8.000			

Appendix 15: CRD Analysis of variance of dead seeds of the varieties before AA

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
VARIETY	2	110.22	55.11	2.61	0.153
Residual	6	126.67	21.11		
Total	8	236.89			

Appendix 16: CRD Analysis of variance of germination percentage of the varieties before AA

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
VARIETY	2	168.00	84.00	8.40	0.018
Residual 6 60.00 Total 8 228.00			10.00		

Appendix 17: CRD Analysis of variance of normal seedlings of t

ıe varieties before AA

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
VARIETY	2	168.00	84.00	7.88	0.021
Residual 6 64.00 Total 8 232.00			10.67		

Appendix 18: CRD Analysis of variance of seed vigour index of the vari

eties before AA

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
VARIETY	2	4343873.	2171936.	3.93	0.081
Residual	6	3318018.	553003.		
Total	8	7661891.			

Appendix 19: CRD Analysis of variance of speed of germination (GI)

of the varieties before AA

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
VARIETY	2	41.571	20.786	7.13	0.026
Residual	6	17.493	2.916		
Total	8	59.065			

Appendix 20: CRD Analysis of variance of abnormal seedlings of the varieties after 72 hours of AA without seed priming

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
VARIETY	2	56.89	28.44	2.23	0.189
Residual	6	76.67	12.78		
Total	8	133.56			

Appendix 21: CRD Analysis of var priming

iance of dead seeds of the t hree varieties after 72 hours of AA without

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
VARIETY	2	1320.22	660.11	41.84	<.001
Residual	6	94.67	15.78		
Total	8	1414.89			

Appendix 22: CRD Analysis of variance of normal seedlings of the varieties after 72 hours of AA without seed priming

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
VARIETY	2	996.222	498.111	344.85	<.001
Residual	6	8.667	1.444		
Total	8	1004.889			

Appendix23: Ranking of varieties and primers for the various parameters

	Highest	Not significantly different from highest but lower	second	Not significantly different from second but lower	Third	Not significantly different from third but lower
Ranking	10	9	8	7	6	5

Appendix 24: Variety scores after AA

Parameter	CRI-K-P11-11	Asontem	Manpeali
Germination	10	6	8
Normal seedlings	10	6	8
Seed vigour index	10	6	8
Speed of germination	10	8	6
TOTAL	**40**	**26**	**30**

Appendix 25: scores of top three primers and top two organic primers after AA

	p2	p3	p5	p6	p8	p10	p11	p12
Germination	8	10	7	6	6		8	10
Normal seedlings	8	10	6	7	7		8	10
Seed vigour index	8	10	8	9	8		8	10
Speed of germination	9	10	9	8	6	9	8	10
TOTAL	**33**	**40**	**30**	**30**	**27**	**9**	**32**	**40**

Appendix 26: CRD Analysis of variance for Thousand Grain Weight of the three okra varieties

Source	DF	SS	MS	F	P
VARIETY	2	391.450	195.725	199.74	<0.001
Error	6	5.879	0.980		
Total	8	397.329			

Appendix 27: CRD

nalysis of var ance for Seed urity of the three okra varieties

Source	DF	SS	MS	F	P
VARIETY	2	75.9490	37.9745	44.13	<0.001
Error	9	7.7451	0.8606		
Total	11	83.6941			

Appendix 28: CRD Analysis of variance for Inert Matter of the three okra varieties

Source	DF	SS	MS	F	P
VARIETY	2	75.7270	37.8635	43.13	<0.001
Error	9	7.9011	0.8779		
Total	11	83.6281			