

MANAGEMENT OF POST HARVEST RIDGE BLACKENING OF OKRA
(*Abelmoschus esculentus* (L.) Moench) PODS

BY

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DEPARTMENT OF CROP SCIENCE

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DECLARATION

I, Katende Ronald hereby declare that this thesis is my own work and has not been submitted to any other University or institution for a degree award

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Dedication

To Mum and Dad

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Abstract

Okra (*Hibiscus esculentus*) has become a potential non-traditional agricultural export for Uganda since 1993. However, quality is still the biggest constraint and needs to be improved to successfully expand Uganda's export market. Ridge blackening is the most common quality problem of okra in Uganda. In an effort to manage ridge blackening of okra, three experiments were set up in 2003/2004 to develop a reliable method for determining the severity of ridge blackening on okra pods, to establish the relationship between frequency of handling of pods and severity of ridge blackening and to evaluate field packing as a feasible method for management of the problem.

An ordinal rating scale for determination of severity of ridge blackening was developed and its accuracy and precision was compared with the visual estimation scale based on Horsfall-Barratt. Using this scale, seven varieties of okra ("Pure luck", "Lucky five", "Greenie", "Nirali", "Pusa sawani", "Clemson Spineless" and "Ever lucky") were screened for varietal resistance/ tolerance to ridge blackening and two methods of postharvest handling of okra were investigated. Under the conventional (pack-house) method, okra pods were harvested and transported to a pack-house facility where sorting, grading, packing and cooling were carried out, while field packing involved sorting, grading and packing in the field, and transporting of the products to the pack-house cooling facility. The number of times the pods were handled, the severity of ridge blackening, weight loss of pods and microbial load on pods were recorded for the two handling methods.

The results of the study showed that the ordinal rating scale was more accurate in measuring ridge blackening of okra at all levels of severity (1-100%) compared to Horsfall-Barratt (1945) visual method which tended to overestimate severity below 25 %. Okra variety

significantly ($P < 0.05$) affected the severity of ridge blackening. Variety 'Pusa sawani' showed the lowest severity while variety 'Clemson spineless' and 'Nirali' showed horizontal resistance as a high incidence of ridge blackening but low severity. Variety 'Pure luck' and 'Ever lucky' showed very high severities of ridge blackening figures 3 a. and b). Field packing led to less handling of pods (35 times) compared to conventional packing (48-59 times). This resulted in significantly ($P < 0.01$) lower severity of ridge blackening, lower microbial load and lower rates of weight loss during storage.

It is recommended that growers adopt varieties with relatively higher resistance to ridge blackening and minimize the number of times the pods are handled and should consider field packing where applicable.

CHAPTER ONE

1.0 INTRODUCTION

1.1 The okra crop

Okra, *Abelmoschus esculentus* (L.) Moench, also known as *Hibiscus esculentus* L., ‘Lady's finger’ or ‘Gumbo’ is a native of the tropical parts of Africa. It is in the Mallow family (Malvaceae) and is a relative of cotton and the tropical flowering hibiscus (Tindall, and Proctor 1980). It is a widely grown vegetable crop in the tropics and sub-tropics, and also in warmer temperate areas (Kochhar, 1986). It can be found as an annual (primarily in the U.S.) or as a perennial in India and Africa (Lamont, 1999). In the United States, Mexico and Japan, the young fruiting pods are the edible portion, while young leaves and mature seeds may be consumed in other countries (Duzyaman, 1997).

Okra is a warm season crop and it requires a long warm growing season. It is quite susceptible to frost and will not thrive even when there is a continued cold spell. This vegetable grows in all types of soil, thriving best in a moist, friable well-manured soil with pH between 6.0-6.8 (Kochhar, 1986). Most okra cultivars produce green pods, but a few varieties produce yellow (cv. ‘Blondy’) or dark red (cv. ‘Burgundy’) pods. Usually, pods have 4 to 10 distinct ribs or ridges although some cultivars like ‘Emerald’ are completely round, with no ribs. Pods are prized for their unique flavor and high mucilaginous content (used as a thickening agent). Other names of Okra include *bhendi*, *bhindi*, *gumbo*, *gombo* and *quaio* (Perkins-Veazie, 2002).

1.2 Commercial importance of Okra in Uganda

Okra has been regarded as a potential non-traditional agricultural export (NTAE) crop for Uganda since 1993 (EPADU, 1993). Exports of fresh okra from Uganda have steadily increased from 19 MT in 1993 to a peak of 130 MT in 1998, down to 69 MT in 2002 (ADC/IDEA, 1999).

The small Ugandan grower can earn a net margin of U Shs. 247,400 per acre per crop (UShs. 611,325/Ha/crop) and since the crop can be cropped three time a year; its annual margin is triple this figure (UShs. 0.75 – 1.5 million/acre per year or UShs. 1.85 – 3.7 million per ha). This is comparable to annual gross margins of other high value crops like hot pepper and fresh green beans. A Ugandan Okra exporter can earn a net margin of over UShs. 373,000 for a 400 Kg shipment of green okra to the UK (ADC / IDEA, 2003).

For small grower production, the basic investment requirements are land and seed. Considering the estimated cost of production, it requires an estimated US \$ 352 per acre per crop (US \$ 870 per ha per crop) or US \$ 850 per acre per crop per year (US \$ 2150 per ha per crop per year). To ensure product quality, investment in cold storage is recommended (ADC / IDEA, 2003).

The European markets offer the most potential for the Ugandan Okra produce. Currently most okra of Uganda is exported to the UK and Netherlands and these are the two largest markets within the European Union. Other potential markets include Germany, Spain, France and

Belgium. In these markets, Okra is still considered an "Asian" vegetable and the average price range between U S \$ 2.60-4.30 per kg in the European Union and between £ 2.85-9.60 per kg in the United Kingdom (ADC/ IDEA, 2003).

1.3 Constraints of Okra production in Uganda

Although Okra can be grown very profitably in Uganda with minimal inputs, quality remains the biggest problem and needs to be improved to successfully expand Uganda's okra market share. Okra is a highly perishable vegetable and hence has a very short shelf life of 7-10 days at 7 to 10°C. Ridge blackening and dry stalks are the most common problems with Uganda's okra (ADC/ IDEA, 2003).

1.4 Justification of the study

Okra is well adapted to almost all the climatic areas and soil types in Uganda. The country has the potential to produce 200-250 MT per year (ADC/ IDEA, 2003), most of which can be exported to the European Union whose market demand is estimated at 500-800 MT per year, at an average price of US\$ 2.60-4.30/Kg.

Although okra is still being regarded as an 'Asian' vegetable in the European Union, it is regarded by most supermarket buyers as the Asian vegetable with the most potential for crossover into the mainstream markets and, therefore, Uganda can take advantage of this market opportunity.

There are many other okra exporting countries, particularly in the UK market, but none of these individual countries has yet emerged as a consistent and high quality producer of okra. The largest suppliers include Kenya, Thailand, Gambia, India, Zambia and Zimbabwe. Other competitors include Cyprus, Ethiopia, Mexico and Brazil. Uganda can easily gain a bigger share of the market and also emerge as the lead okra exporter to European Union market if her okra growers invest in appropriate postharvest handling techniques and facilities that ensure excellent quality.

Despite the high commercial potential of okra in Uganda, there has been no attempt to address the problem of ridge blackening, the major cause of low quality of Ugandan okra, hence the need for this research.

1.5 Objectives of the study

The main objective of this research was to develop postharvest handling procedures for management of ridge blackening of okra for Uganda. The specific objectives were to: -

- i. Develop a reliable method for determining the severity of ridge blackening on okra pods.
- ii. Establish the effect of variety on the incidence and severity of ridge blackening of okra,
- iii. Establish the relationship between frequency of handling of okra pods and severity of ridge blackening of okra, and
- iv. Evaluate field packing as a feasible method for management of ridge blackening of okra.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

Okra, probably a native of tropical Africa or tropical Asia is an annual herb that can grow up to 2 m in height. The stems are hairy and woody when mature and the leaves alternate up to 30 cm in length. The numerous cultivars vary in time to maturity, color of leaves, stem length, shape of fruit and other characters. The main groups are short and long duration cultivars (Kochhar, 1986).

The world okra production has been increasing since 1993. The estimated world area planted for harvest of okra is approximately 976,900. India leads with 360,000 ha under production, production of 3.5 Million Metric tones (MMT)/year and yield of 97 MT / ha. India is followed by Nigeria with 275,000 ha of Okra, a net production of 0.72 MMT and a yield of 26 MT /ha; followed by Pakistan, Ghana and Egypt in that order with 12,500, 18,000 and 6,072 ha under production, productions of 0.11, 0.10, and 0.085 MMT/year and yields of 8.8, 5.6, and 14 MT /ha, respectively (FAO, 2003).

Exports of fresh okra from Uganda have steadily increased from 19 MT in 1993 to a peak of 1998, down to 69 MT in 2002 (ADC/IDEA, 1999).

2.2 Production techniques of okra in Uganda

The crop is well adapted to almost all the climatic areas and soil types in Uganda. The most common planting system is by direct sowing. The seed is directly sown into beds and later thinned out where plants are too close. The recommended spacing is 30 cm between rows and 10 cm between plants. The size of the bed is 1 meter by 40 meters, giving a plant population of 1,200 plants per bed. Planting, amounts to 65 percent of area after removing walkways and dividing roads, giving a total plant population of 150,000 plants per hectare, which can yield 8 MT. Organic matter is available and an application of 30 - 40 kg per bed (approximately 0.75 – 1 Kg/m²) of composite is recommended. Commercial fertilizer in the form of NPK can also be applied at 40 to 60 kg per hectare or split application by side dressing with 20 - 30 kg per hectare. If the soil has a good moisture supply at planting, the young plants usually grow to a height of 8 - 15 cm before requiring supplementary irrigation. Adequate moisture during harvesting encourages the rapid development of pods (ADC/IDEA, 2003).

The export product should be of the same variety, showing similar shape, skin color, flavor and texture. The product should be soft, non-fibrous, and always free from shrivel. Harvested okra should be intact, sound, and free from dirt, foreign material, pests, and diseases. The market usually requires 9-11cm in length with fresh green stalks. No browning is allowed. Damage caused mechanically or by pests should not exceed 5 percent of the surface area. It is advisable not to harvest in the rain or when wet. For exporters without cold room facilities, okra should be harvested in the cool of the day and shipped the same or next day. Close liaison

with customers regarding size, variety and quality is essential to develop okra exports (ADC/IDEA, 2003).

Most varieties of okra are ready to pick 55 to 60 days after planting. Pods are harvested when they are 9 to 11 cm long. Generally, pods should be picked 4 to 6 days after flowering. Okra should be harvested when the fruit is bright green, the pod is fleshy and seeds are small. After that period, the pod becomes pithy and tough, and the green color and mucilage content decrease (Cantwell and Suslow, 2002). Okra pods are harvested when immature and high in mucilage, but before becoming highly fibrous; generally within 2 to 6 weeks after flowering. (Duzyaman, 1997).

During harvesting, pods can be snapped off or cut. Cutting of pod from the plant takes longer but produces a nicer product (Kemble and Mary, 1997). Pods are cut using a sharp knife and the pod is placed in a plastic ventilated container. All over-grown pods are always removed from the plant to encourage more flowers to form.

2.3 Quality indices of okra

Quality in produce can be defined as the composite of characteristics that differentiates individual items within a commodity and has a significant influence in determining the level of acceptance by the consumer (Dainello *et al.*, 2001). High quality okra pods are bright green and turgid. Seeds should not be protruding through the epidermis, and ridges should be free of blackening and bruising (Perkins-Veazie *et al.*, 1992). Okra pods should be tender and not

fibrous, and have a color typical of the cultivar (generally bright green). The pods should be well formed and straight, have a fresh appearance and not show signs of dehydration. Okra should be free of contaminants such as leaves, stems and broken pods and defects such as, insect/ pest damage, and mechanical injury. Damage caused by pests or mechanically should not exceed 5 % of the surface area. The product should be of the same variety, showing similar shape, skin color, flavor and texture. The product should be soft, non-fibrous and always free from shrivel (ADC/IDEA, 2003). The tender pods are easily damaged during harvest, especially on the ridges and this leads to unsightly brown and black discoloration. Quality losses that occur during marketing are often associated with mechanical damage, water loss, chilling injury, and decay (Cantwel Suslow, 2002). Okra is graded by size and absence of defects, decay, insects and dirt, shape, and tenderness. 'Fancy' pods are < 9 cm; Choice 9 to 11 cm; and Jumbo > 11 cm (Duzyaman, 1997).

2.4 Postharvest technology and handling

Fresh fruits, vegetables, and flowers must be in excellent condition and have excellent quality if maximum shelf life is desired. The best possible quality of any commodity exists at the moment of harvest. From that point on, quality cannot be improved, only maintained. Shelf life begins at harvest (Wilson *et al*, 1997).

Fresh vegetables are extremely perishable and have relatively short shelf lives. They are living, respiring tissue that are also senescencing and dying. Freshly harvested vegetables are mostly comprised of water with most having 90-95 % moisture content. Water loss after

harvest is one of the most serious post harvest conditions. Consequently, special effort is required to reduce the effects of these naturally occurring processes if quality harvested in the field will be the same at the consumer level (Dainello and Cotner, 2001).

The basic requirement in harvesting, storing and transporting of fresh horticultural produce regardless of how long they must be stored is to ensure that every product remains a living, transpiring and respiring organism. The techniques involved in harvesting, handling, moving and storing the crop to reduce losses and to keep them fresh is post-harvest technology; and the whole chain of movement and operations is post-harvest handling (Anon, 1998).

Food losses of extremely variable magnitude occur at all stages in the post-harvest system from the physical harvesting operation, through handling, storage, processing and marketing activities to final delivery to consumer. The extent of losses depends on a number of factors like perishability of the produce, environmental factors like ambient temperatures and relative humidity, length of time between harvesting and final consumption and post-harvest handling, storage and processing practices (Booth *et al*, 1987).

Losses in quality and quantity affect horticultural crops between harvest and consumption. The magnitude of post harvest losses in fresh fruits and vegetables is estimated at 5-25 % in developed countries and 20-50 % in developing countries depending on the commodity. To reduce these losses, producers and handlers must understand the biological and environmental factors involved in deterioration and use post harvest techniques that delay senescence and maintain the best possible quality (Kader, 1992).

2.5 Postharvest requirements of okra

Okra in good condition can be stored satisfactorily for 7-10 days at 7-10 °C and a relative humidity of 90 to 95%. At higher temperatures; dehydration, toughening, yellowing and decay are rapid. A relative humidity of 90-95 % is desirable to prevent shriveling. At temperatures below 7°C, okra is subjected to chilling injury, which is manifested by surface discoloration, pitting and decay. Weight loss is very high in immature okra pods and cultivars may vary in rate of water loss. A very high relative humidity (95-100%) is needed to retard dehydration, pod toughening, and loss of fresh appearance (Cantwell and Suslow, 2002). Okra bruises easily and the bruises blacken within a few hours. Packaging is always done in perforated film to help prevent wilting and physical injury during handling (Kemble and Musgrove, 1997).

Virtually every procedure used in handling of fresh produce can affect the microbial diversity of the fruit. Not only does wounding during harvesting, handling and packing provide infection points for plant pathogenic fungi, but it also provides colonization sites for food borne pathogens. Immature okra pods have a very high respiration rate and also bruise easily, which leads to a rapid deterioration of the cell walls and blackening of the pods in the packing house a few hours later (Vegetarian News letter, 2002).

2.6 Quality loss of Okra

2.6.1 Chilling and rots

Chilling and injury-enhanced rots are probably the most common causes of loss. Decay on okra can be due to various common bacterial and fungal organisms, but *Rhizopus*, *Geotrichum*

and *Rhizoctonia* fungal rots as well as bacterial decays due to *Pseudomonas* sp. have been reported to cause post-harvest losses (Kader, 1992).

Fresh okra bruises easily; the bruises blacken within a few hours. A bleaching type of injury may also develop when okra is held in hampers for more than 24 hours without refrigeration. Storage containers should permit ventilation. Prepackaging in perforated film is helpful to prevent wilting and physical injury during handling (Kemble *et al*, 1997).

2.6.2 Ridge blackening

Ridge blackening is a result of surface injuries, impact bruising and vibration bruising. These are major contributors to deterioration and that browning of damaged tissues results from membrane disruption, which exposes phenolic compounds to the polyphenol oxidase enzyme. On the okra pods, it appears as a black discoloration along the ribs of the pods and it becomes evident soon after harvest of the pods (Kader, 1983).

2.7 Preharvest and Postharvest handling of vegetables

Vegetables and fruits provide an abundant, cheap source of fiber, several vitamins and minerals. However, fresh vegetables have a relatively short shelf life before they begin to decay, which in turn reduces their quality (FAO, 1989).

Production practices have a tremendous effect on the quality of fruits and vegetables at harvest and on post-harvest quality and shelf life. It is well known that some cultivars ship better and have a longer shelf life than others. Environmental factors such as soil type; temperature, frost and rainy weather at harvest can have an adverse effect on storage life and quality. Management practices can also affect postharvest quality. Produce that has been stressed by too much or too little water, high rates of nitrogen or mechanical injury like scrapes, bruises and abrasions are particularly susceptible to post-harvest diseases (Bachmann and Earls, 2000). Bachmann and Earls, (2000) further observed that crops destined for storage should be as free as possible from skin breaks, spots, decay and other deteriorations. Bruises and other mechanical damages not only affect appearance but also provide entrance to decay organisms as well. Postharvest rots are more prevalent in fruits and vegetables that are bruised or otherwise damaged. Mechanical damage also increases moisture loss. Damage can be prevented by training harvest labor to handle the crop gently, harvest at proper maturity, harvest dry whenever possible, handling each fruit or vegetable not more than necessary (field packing if possible), installing padding inside bulk bins and avoid over or under packing of containers.

Virtually every procedure used in handling of fresh produce can affect the microbial diversity of the fruit. Not only does wounding during harvesting and handling during packing provide infection points for plant pathogenic fungi, but it also provides colonization sites for food borne pathogens, increases respiration rate and the rate of ethylene production. (Jager and Korsten, 2002.). Temperature is the single most important factor in maintaining quality after harvest. Refrigerated storage retards elements of deterioration in perishable vegetables like

aging due to ripening, softening, textural and color changes, undesirable metabolic changes and respiratory heat production, moisture loss and shriveling that results in spoilage due to invasion by bacteria, fungi and yeast (Hardenburg *et al*, 1986).

Okra like hot pepper can be collected during harvesting in picking aprons and transferred to plastic crates for transport to the packing house. Every puncture, abrasion or bruise is a potential site for decay. Vegetables with decay should not be put in picking aprons or field crates because they are a source of inoculums that can infect other healthy vegetables. During harvesting, all containers used should be light colored, ventilated and shallow. Covering containers with a light colored material will minimize absorption or radiation from sunlight and so limit heat build up. Grading and packing a fruit on the same day of harvest prevents over heating and the possibility of bacterial soft rot infection. Package must not be only of the correct size but must also be filled properly. Over filling causes bruising. Excessive bulging of the sides of the package leads to decreased compression strength. Under filling, on the other hand, causes fruit damage since fruits can be bruised as they move around inside the package during transportation and handling (Heiser and Smith, 1953).

Okra has the same general requirements as hot pepper, cucumber, sweet pepper and melongena. Therefore, these products can be stored together without deleterious effects. Ice should not be placed in contact with these commodities. All these produce are ethylene sensitive and therefore should not be stored or transported with fruits like passion fruit, mangoes and tomatoes (Jose and Mayberry, 1998).

CHAPTER THREE

3.0 DEVELOPMENT OF AN IMPROVED METHOD FOR DETERMINING SEVERITY OF RIDGE BLACKENING OF OKRA

3.1 Introduction

Marketing of Ugandan okra in the European markets like the United Kingdom and the Netherlands, is mostly hampered by the problem of ridge blackening and dry stalks (ADC, 1998). Ridge blackening is a black discoloration that occurs on okra pods after harvest. This defect normally occurs on bruised or damaged pods. It starts at the ridges or ribs and spreads to the other parts of the pod (Plate 1). Export market standards for okra stipulate that any damage caused mechanically or by pests should be minimal and not exceed 5% of the surface area (ADC, 2001).



Plate 1: Okra pods with signs of Ridge Blackening

The methods used in determination of severity of ridge blackening of okra are usually the visual methods similar to those used to assess disease severity. The most commonly used

visual method for severity estimation is direct visual estimation where the specimen is observed and assigned a severity value from 0 – 100 %. (Parker, *et al.*, 1995)

The other commonly used method of disease severity estimation is by means of visual estimation with the use of disease scale. A disease scale is a partition of the continuous severity values from 0 to 100% into a finite number of classes. Disease scales are very convenient and they are also advantageous where the rater is unable to distinguish severity values within a class (a range). The most common disease scale used today is the one based on Horsfall-Barratt (1945).

A number of studies (Parker, *et al.*, 1995; Beresford & Royle, 1991; Forbes & Jerger, 1987) accessing the reliability of visual methods in estimation of disease severity have observed that visual methods tend to overestimate severities below 25 %, and that there is no strong evidence that the estimates of disease severity on a two-dimensional surface would obey Horsfall-Barratt hypothesis. Results from these studies, confirmed that the greatest estimation bias in disease severity measurement using the visual methods occurred below 10% disease severity or 30-40 % senescence. Most estimates in these ranges were over estimates. It was further observed that the visual methods tend to overestimate severities below 10% and it was found that greatest over estimations occurred at disease severity levels below 25% using visual methods. Based on these observations, visual scale methods give inaccurate results if they are used in the estimation of the severity of ridge blackening of okra and hence there was an urgent need to develop or design a method, which would be more accurate than the visual methods at estimating small severities of ridge blackening of okra of as low as 5%.

It is common to measure severity as with an ordinal rating scale, where for most types of diseases or infections the focus is directed to measuring the surface area of the plant unit that is infected and express it as a proportion of the total surface area of the whole plant unit.

The objective of this study was, therefore, to develop and describe an ordinal rating scale for determination of severity of ridge blackening of okra.

3.2 Materials and methods

3.2.1 The plant material

Variety ‘Pusa Sawani’, the most widely grown okra variety in Uganda was used in this study. It is an open pollinated variety, which was bred for resistance to yellow vein mosaic virus prone areas/seasons. The pods are dark green with distinct ridges and their size is medium and uniform.

3.2.2 The study area

The okra pods were grown and obtained from Mairye Estates located off Gayaza Busiika Road just after Namulonge Agricultural Research Station, in Wakiso District.

The soils of this area are classified as Rhodic ferralsols of Buganda catena (MAAIF-Entebbe, 1999). They are reddish in colour with good physical properties of permeability and stable

structure. They are almost at their final stage of weathering and thus relatively low fertility, which is, however, boosted by high organic matter, making it look dark reddish at different spots. The reserve weatherable minerals are often less than 10 % of fine sand fraction. The clay fraction consists of mainly kaolinite minerals, free iron oxides, amorphous gels and some times small amounts of 2:1 clays (MAAIF-Entebbe, 1999).

Within the study area, day temperatures vary between 25-28°C. Rainfall is well distributed throughout the year with two maximas i.e. this climatic zone is characterized by a bimodal type of rainfall distribution. The two maximas are between March to June (Long rains) and August to November (short rains). The total annual rainfall ranges between 1500 to 1800 mm and the wettest months are April with ± 180 mm and November with ± 200 mm (MAAIF-Entebbe, 1999).

3.2.3 Sample preparation

Okra pods were harvested and handled using the conventional method as follows: Harvesting commenced at 50-55 days after planting and extended to about 100 days. It was done with sharp knives and the pods were placed in plastic perforated containers (25 x 40 x 20 cm). From the field the pods were taken to the vegetable pack-house where they were weighed and then placed in a humid cold room at 10°C and 98% relative humidity (RH) for at least two hours to remove field heat. From the humid cold room, the okra pods were sorted and graded into exportable and non-exportable quality according to surface area damage (bruising), disease incidence, soiling, dehydration, and by size as dictated by the market. The pods were

either pre-packed in polythene bags for direct sales to supermarkets in the UK or bulk packed in 5 kg boxes and placed in the cold room at 10°C and 60% RH.

3.2.4 Development of an ordinal test method for determining severity of ridge blackening of okra

Pods were picked at intervals of 5 days from the cold room at Mairye Estates and transported to the laboratory at the Department of Food Science and Technology, Faculty of Agriculture, Makerere University. Ridge blackening was determined using the following ordinal test method based on actual measure of severity on okra pods.

The severity of ridge blackening on the pod was measured as a proportion of the total surface area of the whole pod and it was done in two stages: determination of the total surface area of the okra pod, followed by determination of the proportion of the blackened area.

The pod was taken as a five-sided cylinder with a five sided conical tip (Plate 2)

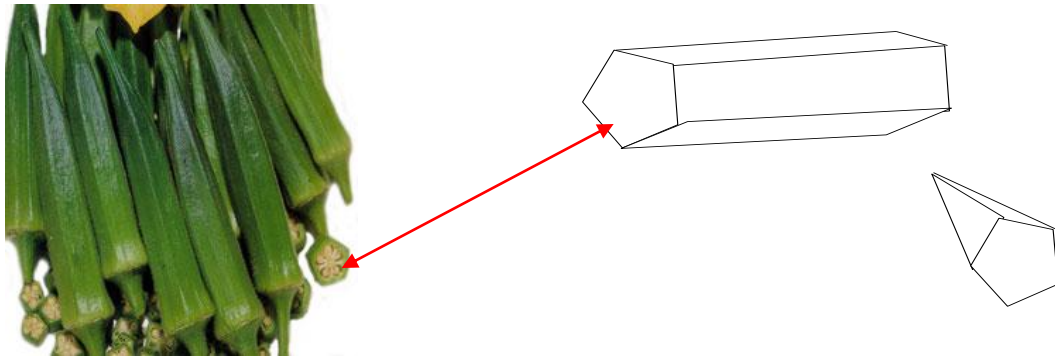


Plate 2: The shape of an okra pod

Using a kern dial vernier caliper, (0-150mm X 0.02 with positive Locking Screw, depth Measuring Blade- German make) various dimensions of the okra pod were measured (Figure 1), the first measurement was the length of the conical tip of the okra pod (a) and the width of each of the triangular faces of the cone (b) from the point at which the pod begins to taper towards the tip. The length (a) was taken as the height of any of the 5-triangular faces of the cone. The length of the cylindrical portion of the okra pod (d) was also measured from the same point as above to the stalk end of the pod. This length was taken as the length of any of the 5 rectangular faces of the cylindrical portion of the pod. The average width of any of the 5 rectangular faces of the cylindrical portion of the pod was calculated as the mean of length (c) and (b).

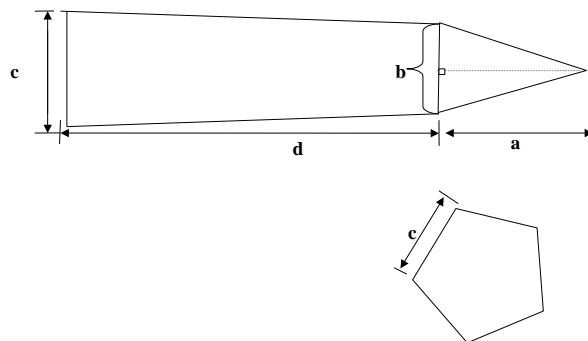


Figure 1: Determination of total surface area of okra pods

The total surface area of the okra pod was calculated using the formula below:-

$$\text{Total surface area} = \left\{ \left[\left(\frac{c+b}{2} \right) \times d \right] + \left[\frac{1}{2} \times \left(\frac{c+b}{2} \right) \times a \right] \right\} \times 5$$

The blackened area on the okra pod was measured by carefully smearing the blackened patches with a light film of clean oil using a thin fiber of cotton (cotton swab). The pod was then impressed on a clean graph paper. The graph paper used was composed of small squares each of 0.04 cm² and 25 of these made up 1 cm². The squares with the oil impressions were counted and summed up immediately before the oil spread. The total number of squares covered with oil was calculated as a percentage of the total surface area of the pod to give the severity of ridge blackening on the pod.

3.2.5 Determination of the accuracy and precision of the ordinal test method

The level of accuracy and precision of the ordinal test method in measuring the severity of ridge blackening of okra pods was determined by comparing it with the visual estimation scale based on Horstfall-Baratt (1945) using the same sample of okra pods.

The precision of the estimates obtained by the two methods was measured by the coefficient of determination (R²). The relative accuracy of these two methods was determined using regression where by the closeness of the slope to unity and of the intercept to zero meant the closer of this method to a perfect severity assessment. Thus, a perfect assessment would have

an R^2 of 100%, a slope of 1 and an intercept of zero. To determine if there was a statistically significant difference between the two sets of data, an ANOVA was run and the F -test was calculated at $P < 0.05$.

3.3 Results

Severity of ridge blackening of okra was significantly ($p < 0.05$) greater using the Horsfall-Barrat (1945) visual scale compared to severity estimated using the ordinal test method based on measurement of actual severities (Table 1 and 2). There were significant differences ($P < 0.05$) in the use of the visual method based on Horsfall-Baratt scale and the ordinal test method (base on measurement of actual severities) for the determination of severity of ridge blackening of okra.

Table 1: Analysis of variance for comparison of assessment for the two methods used to collect data on the severity of ridge blackening

Source of variation	df	Severity (mean squares)	CV (%)
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Method	1	9.6891**	27.7
Residual	20	0.3689	
Total	23		
Method			Mean Severity (%)
Horsfall-Barrat visual method			2.83 (8.44)
Ordinal Test method (Measurement of actual severity)			1.58 (2.63)
LSD _{0.05}			0.517 (2.87)

** Significant at P<0.01

Table 2: Efficiency of Horsfall-Barrat (1945) visual scale and the ordinal test method based on measurement of actual severity in determining severity of ridge blackening of okra

Values in brackets are the actual values

The comparison of the regression lines from data from the two methods (Figure 2) indicated that the coefficient of determination (R^2) for data generated by the designed method was greater than that generated using the Horsfall-Brarrat (1945) visual scale. In addition, the slope of the regression line generated from the ordinal test method was closer to unity than the slope of the regression line generated with the visual scale method although both slopes were positive.

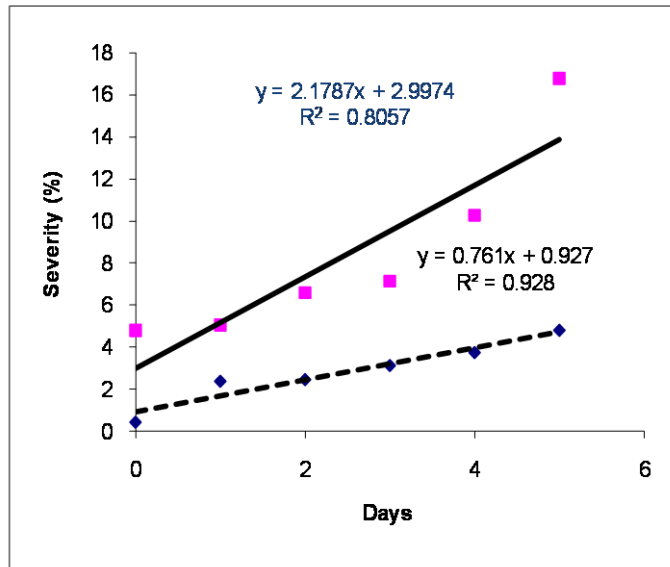


Figure 2: Comparison of data collected by the ordinal test method (based on measurement of actual severities (broken line) and the Horsfal-Barrat (1945) visual method (solid line). Data were \sqrt{x} transformed prior to analysis.

The regression line from data generated from the ordinal test method had an intercept of 0.7617, which was closer to zero than the intercept of the regression line of 2.1787 generated from data got using the Horsfal-Barrat visual scale.

3.4 Discussion

Accuracy describes how close the mean of an estimate is to the true value of the quantity of the disease assessed, while precision describes the repeatability or variation associated with an estimate regardless of the average value (Martin, 1971).

The regression line from the data generated using the test ordinal test method based on measurement of actual severity was closer to the state of affairs than the regression line from data generated from the visual method. The ordinal test method described here was

significantly ($P < 0.05$) more precise and accurate in determining severity of ridge blackening of okra than the visual method. The intercept of the regression line generated using the ordinal test method was closer to zero than the regression line generated using the visual scale indicating that the test method was more accurate than the visual scale method. The precision of the severity estimates was measured using the coefficient of determination (R^2) and it was also observed that the ordinal test method had an R^2 closer to 100% than the visual scale method. This indicates that the ordinal test method is more precise than the visual scale method in determining the severity of ridge blackening of Okra pods (Figure 2).

The Horsfall-Barratt (1945) scale is based on two assumptions; the first assumption is that there is a logarithmic relationship between intensity of a stimulus (reflected light from a diseased specimen) and sensation (perceived/estimated) area diseased. The other assumption is that when an object consisting of two components (healthy portion of specimen and the diseased), is observed, the observer focuses on the component that is of a smaller size. This assumption implies that severity ranges shrink above 50%.

The Horsfall-Barratt (1945) visual method had a tendency to over estimate severities below 10 % whereas the ordinal test method was generally more accurate at all levels of severities. This observation is consistent with previous work on the assessment of infectious disease for brown rust of barley by Beresford and Royle (1991). They observed that overestimation often occurred at low disease severities. In a study using disease diagrams, Forbes and Jeger (1987) also found that greatest overestimation occurred at disease severity levels below 25%.

In another study done to assess the reliability of visual estimates of disease severity on cereal leaves by Parker *et al*, (1995); visual estimates of wheat disease severity were compared with actual severities determined using image analysis of tracings of diseased leaves. Observer (visual) estimates were widely scattered about the actual severities (i.e. they were imprecise), differed substantially from the actual severities even after averaging (i.e. they were inaccurate), and varied considerably over short time scales. Relative bias decreased with increasing disease severity. In some treatments during this study, visual assessment errors altered the conclusions of the experiment. Two treatments were statistically indistinguishable on the basis of visual severity estimates, while estimates obtained by image analysis showed that one treatment was twice as effective as the other.

The major advantage of the ordinal test method based on measurement of actual severity was its ability to estimate the severity of ridge blackening uniformly from zero to 100% unlike the visual method where assessments made over a number of dates did not fall on a common regression line; that is the severity estimates were not consistent on different occasions. The scatter of points around $Y=0$ decreased as the actual severity increases towards the point of 8 % for visual estimation (Fig. 3). This implied that estimates became more accurate and precise as actual severity increased to 50%. Therefore, the designed ordinal test method was objective in disease severity estimation.

In spite of the objectivity of the ordinal test method in severity estimation, it took more time to generate results than when using the visual scale. Assessment of the different dimensions of each okra pod, making the oil impressions and counting the squares and the various

computations took more time to obtain the actual severity than if one was using the visual scale method. Because of this, sample size had to be drastically reduced. However, using the appropriate number of samples is critical, but with severity measurements, the sample size issue is ignored and the focus is placed on measuring plant units (individual leaves, roots, pods etc) in the available sample.

CHAPTER FOUR

4.0 EFFECT OF VARIETY ON THE INCIDENCE AND SEVERITY OF RIDGE

BLACKENING OF OKRA

4.1 Introduction

Most varieties of okra are ready to pick 55 to 60 days after planting. Generally, pods should be picked 4 to 6 days after flowering. Pods can be snapped off or cut. Cutting takes longer but produces a nicer product. Okra deteriorates rapidly and is normally stored only briefly to hold for marketing or processing. Okra has a very high respiration rate at warm temperatures and should be promptly cooled to reduce field heat and subsequent deterioration (Kemble *et al.*, 1995).

Okra, which is in good condition, can be stored satisfactorily for 7 to 10 days at 45 to 50 degrees F (7 °C to 10 °C). At higher temperatures, toughening, yellowing, and decay are rapid (Kemble *et al.*, 1995). A relative humidity of 90 to 95 percent is desirable to prevent shriveling. Fresh okra bruises easily; the bruises blacken within a few hours. A bleaching type of injury may also develop when okra is held in hampers for more than 24 hours without refrigeration. Storage containers should permit ventilation. Prepackaging in perforated film is helpful to prevent wilting and physical injury during handling (see section 3.2.1).

The objective of this experiment was to screen for varietal resistance or tolerance to ridge blackening within the okra varieties grown in Uganda. Five of these were being introduced for the first time on the market and their performance in terms of incidence and severity to ridge

blackening were generally not known. It has been shown that there is variation in the storage potential of different cultivars of the same crop and each variety of a horticultural crop has a limited storage life even under optimum storage conditions (FAO, 1989). Some cultivars have greater storage-life potential than others Cantwell and Suslow (1999).

4.2 Materials and methods

4.2.1 The study area

The experiment was conducted at Mairye Estates, one of the few horticultural enterprises, which grows okra on a commercial scale in Uganda.

4.2.2 The okra varieties

Experimental treatments constituted seven okra varieties arranged in Complete Randomized Design (CRD) and replicated four times. The seven okra varieties were “Pure luck”, “Lucky five”, “Greenie”, “Nirali”, “Pusa sawani”, “Clemson Spineless” and “Ever lucky”.

‘Pure Luck’ is an F1 hybrid. It is an early variety and prolific in growth. Plants are medium tall and vigorous in habit. Pods are uniform, slender, smooth and spineless. It sets pods quickly and starts producing on lower parts of the plant.

‘Lucky Five’, also an F1 hybrid is a medium-dwarf, vigorous plant with small deep-serrated leaves and it is also early setting. This hybrid has smooth, five-angled pods, which are green and spineless.

‘Greennie’ is also an early plant and vigorous with small parted leaves. Fruit-set begins on the 7-8th node when it is sown under high temperature conditions (30-35 °C) or on the fourth node when it is sown under lower temperatures (about 20 °C).

‘Ever Lucky’: The plants are vigorous, prolific and medium-tall. The petioles are green with occasional purple stripes. Pods are five-ridged, shiny dark green, and spineless (Know-You Seed Company Limited, 2003).

‘Clemson Spineless’ is a uniform spineless - medium dark green, angular pods 8-12 cm long with large diameter. The plant can grow to a height of 1 to 2 meters and it is very productive. This is the most commonly available variety (Kemble *et al.*, 1995).

‘Nirali’ has dwarf, well branched plants which start bearing 40 days after sowing. Fruits are tender, very attractive dark green, short (8-9cm) with blunt tip. It has thick flesh with very good transport, keeping and cooking quality. It is also a high yielder (Namdhari Seeds Pvt. Ltd, 2003).

'Pusa Sawani' is the most common variety being grown in Uganda. It is an open pollinated variety, which was bred for resistance to yellow vein mosaic virus prone areas/seasons. In India, this variety replaced all other local varieties for cultivation all over India (Sidhu, 2003).

These varieties are well known in the European markets and most of the Mexican, American and Caribbean okra is centered on some of these varieties (ADC/IDEA, 1998). These varieties have been recommended for export production in Uganda from the trials carried out by the USAID ADC/IDEA Project (Mairye Estates Vegetable Research Annual Report, 2002).

4.2.3 Experimental setup

Okra seeds of each of the seven varieties were directly sown in three rows on a 1.8m bed center to center and 40 cm apart. Each row was 25 m in length giving plots of 25 by 1.8 m. The seed rate used was 8-10 kg per hectare and plants were later thinned to a spacing of 25 cm between rows and 10 cm between plants.

Weeding, fertilizer application and irrigation was done according to the schedules of Mairye Estates Limited. These included an application of NPK 19:19:19 at a rate of 25 kg/ ha when plants were 15 to 20 cm tall, repeated two to three weeks later. From flowering onwards, Magnesium sulphate, Calcium sulphate and Potassium sulphate were applied at a ratio of 1:1:1 once a week at 20-30kg/ha. Irrigation was done at a rate of 2 liters per m² daily during the dry season and at least twice a week in the rainy season.

Okra was harvested and handled using the conventional method as described in chapter 3 (section 3.2.3). For each okra variety, four (4) samples of twenty pods were selected, prepared and placed in the cold room. The incidence and severity of ridge blackening was estimated at 5 days interval, for 2-4 weeks using destructive sampling. One sample for each variety was selected every 5 days and the incidence and severity of ridge blackening was determined. The incidence of ridge blackening was determined by counting all pods with sign of ridge blackening, expressed as a percentage of the total number of pods in the sample. The severity of ridge blackening was determined using the ordinal test method developed in chapter 3.

The average weight of the pods was also measured using a digital weighing scale every five days for all samples and the average weight loss was calculated as a percentage of the previous weight of the pods.

Data obtained was analyzed by ANOVA using GENSTAT statistical package. Differences between means were separated using Fisher's Protected Least Significance Difference (LSD) test at 5 % level of significance.

4.3 Results

The analysis of variance for the incidence and severity of ridge blackening and weight loss on selected okra varieties is shown in Table 3. Variety significantly ($P < 0.01$) affected the severity of ridge blackening, but it had no effect on the incidence of ridge blackening and weight loss

of okra. Storage duration significantly affected the incidence ($P<0.01$) and severity ($P<0.01$) of ridge blackening and weight loss ($P<0.05$) of okra pods.

Table 3: Analysis of variance for incidence, and severity of ridge blackening and loss in pod weight of okra at Mairye Estates Limited in Uganda (April 2003)

Source of variation	df	Mean squares		
		Incidence	Severity	%Pod Weight loss
Variety	6	0.1836 ^{NS}	1.7855**	1.3332 ^{NS}
Storage duration	4	1.20539**	2.4117**	2.5539*
Residual	265			
Total	275			

The incidence and severity of ridge blackening and loss in pod weight loss increased with storage duration for all varieties (Figure 3 a, b and c). Although there were no significant differences ($P<0.01$) in the incidence of ridge blackening and pod weight loss between these varieties, there were significant ($P<0.01$) differences in the severity of ridge blackening between the okra varieties. Cultivar 'Pusa Sawani' showed the least severity of ridge blackening while 'Pure luck' showed most severity (Table 4).

There was positive relationship between severity of ridge blackening and pod weight loss (Figure 4) with a coefficient of determination of 76.16 %. Variety 'Pure Luck' with the highest incidence and severity of Ridge blackening also had the highest level of percentage

weight loss while ‘Pusa Sawani’ with the lowest incidence and severity of ridge blackening also showed low percentage weight loss (Table 4).

Rotting was observed within 10 days of storage on varieties ‘Nirali’ and ‘Clemson Spineless’, while shrinking and softening were observed for ‘Pusa Sawani’ and other varieties.

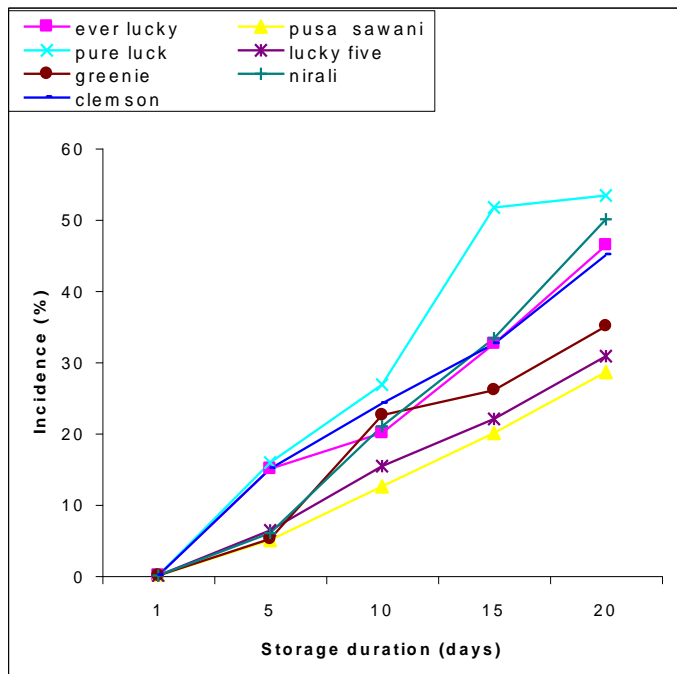


Figure 3 a: Effect of variety and storage duration time on the incidence of ridge blackening of okra.

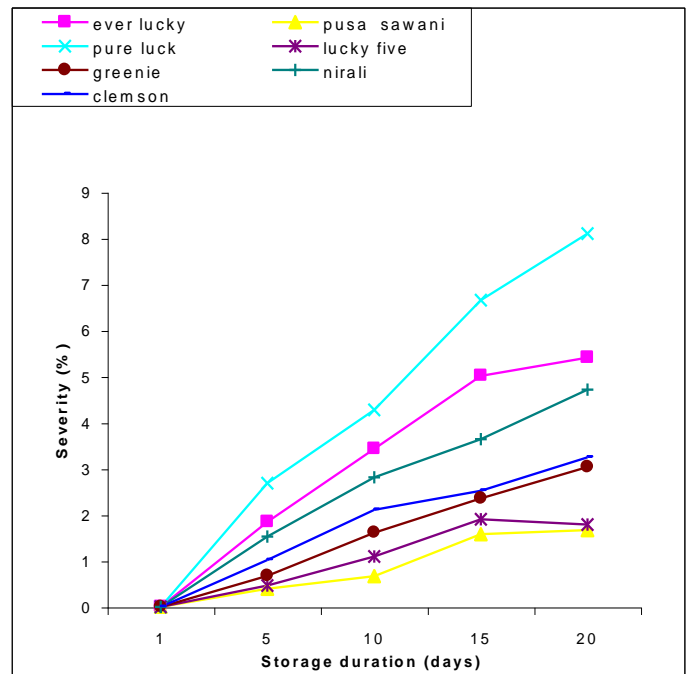


Figure 3 b: Effect of variety and storage duration on the severity of ridge blackening of okra

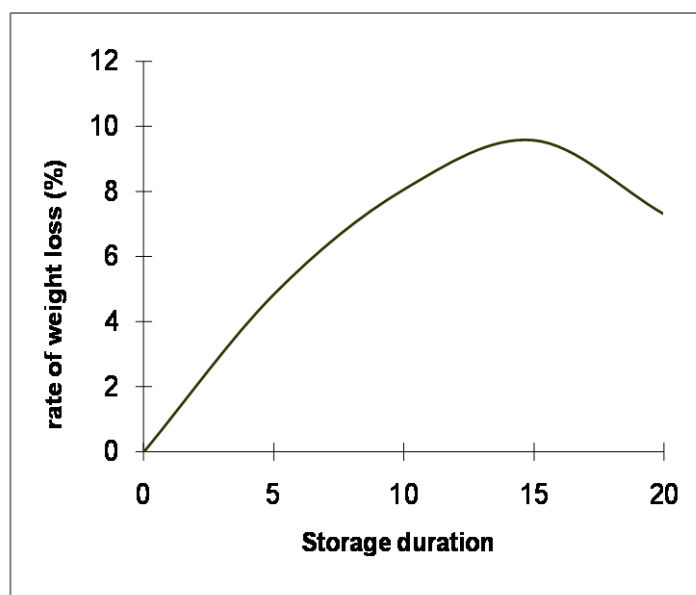


Figure 3 c: Effect of storage duration on rate of weight loss of okra pods

Table 4: Incidence and Severity of ridge blackening and pod weight loss of seven okra varieties in Uganda

Variety	Incidence ^A %	Severity ^B %	Pod weight loss (%) ^B
Pure Luck	34.5 (1.453)	5.05 (2.174)	3.42 (13.02)
Ever Lucky	27.3 (1.387)	3.57 (1.815)	2.76 (8.04)
Nirali	26.7 (1.265)	2.68 (1.573)	2.92 (9.02)
Clemson Spineless	26.9 (1.375)	2.08 (1.370)	2.62 (7.92)
Greenie	20.3 (1.207)	1.65 (1.211)	2.80 (8.25)
Pusa Sawani	14.8 (1.086)	1.28 (1.051)	2.21 (5.41)
Lucky Five	16.9 (1.150)	1.16 (1.029)	2.76 (8.04)
Lsd_{(0.05)*} (0.01)**	NS	1.409 (0.445)**	NS

^A Values in brackets were log₁₀ transformed prior to analysis
^B Values in brackets were $\sqrt{(x)}$ transformed prior to analysis

NB. Pods were stored at 7 to 10°C and the parameters were measured every 5 days

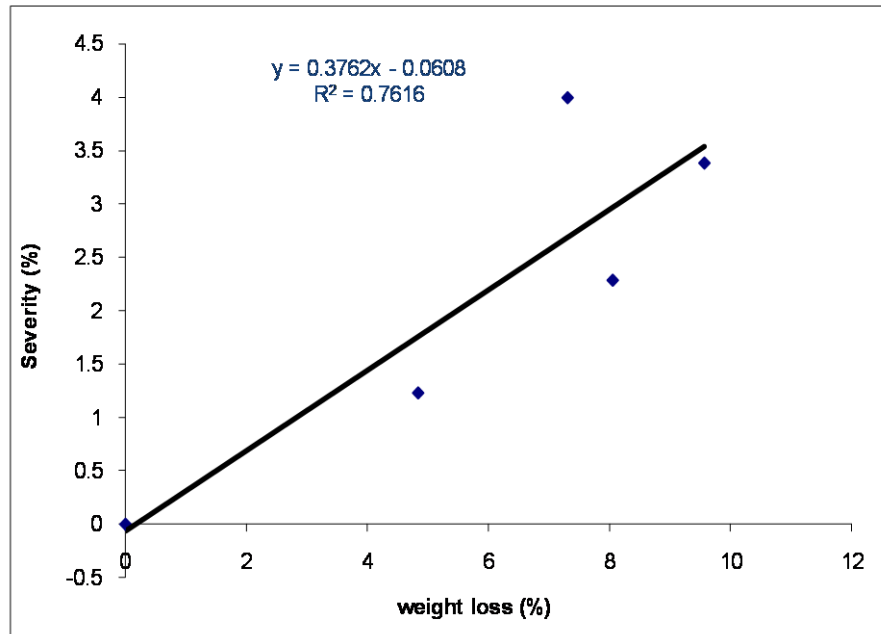


Figure 4: Relationship between severity of ridge blackening and weight loss of okra pods

4.4 Discussion

Ridge blackening; a black coloration observed on okra pods after harvesting is highly suspected to be caused by bruising or wounding of okra pods. The incidence of ridge blackening was not affected by the okra variety and all okra varieties in this experiment were handled in the same way. This could have been the reason for the lack of difference in incidence of ridge blackening for all the varieties tested in this study.

The variety significantly affected the severity of ridge blackening of okra. This could be attributed to the difference in the shelf lives of these okra varieties, which probably has a direct bearing with the genetic make up of the different varieties. There is variation in the storage potential of different cultivars of the same crop and each variety of a horticultural crop

has a limited storage life even under optimum storage conditions (FAO, 1989). The potential storage life is partly under genetic control and can be manipulated by breeding. In their study on tropical yams, Martin and Degras, (1978) observed that yam varieties differed in storability from a week to several months. Some cultivars have greater storage-life potential than others (Cantwell and Suslow (1999). Okra from Uganda has to be stored for a day or two to achieve the required export volumes, and it undergoes long distance shipping to the European Union. From this study, variety 'Pusa Sawani' with the lowest incidence, severity and weight loss would be the best okra variety for Uganda. It is recommended that if long distance shipping or storage was an integral to a marketing strategy in commercial vegetable production, then consideration should be made for appropriate cultivar selection, especially if controlled atmospheres are not being used (Toivonen and Forney, 2003).

Appearance of new RNA and protein species in wounded tissues provides evidence for genomic control of the response of ridge blackening and many factors such as species and variety, stage of physiological maturity, extent of wounding, temperature, oxygen and carbon dioxide concentrations, water vapor pressure, and various inhibitors (Hurst *et al.*, 1993) may affect the intensity of the wound response in fresh tissues.

Darker-colored varieties of okra namely 'Pusa Sawani', 'Greenie' 'Lucky Five' and 'Clemson Spineless' exhibited a higher level of resistance to ridge blackening than light colored varieties like 'Nirali', 'Pure Luck' and 'Ever Lucky'. This observation emphasizes differences in genetic make up and suggests that dark-colored varieties are probably more tolerant or resistant. Some physiological disorders in okra that accentuate spoilage and cause pod

blackening could be delayed by cultivar selection and these disorders are more visible in light - colored varieties such as 'Blondy', and they were reduced by using dark coloured varieties like 'Clemson spineless' (Bachmann and Earles, 2000).

The differences in thickness of the dermal system (outer protective coverings) of the different okra varieties may offer another explanation for the varietal difference in the severity of ridge blackening between varieties. The thickness of the pod epidermis could have affected the response of the different varieties. The cuticle is composed of surface waxes, cutin embedded in wax, and a layer of mixtures of cutin, wax, and carbohydrate polymers. The thickness, structure, and chemical composition of the cuticle vary greatly among commodities and among developmental stages of a given commodity (Hardenburg *et al.*, 1986).

There was a positive correlation between severity of ridge blackening and pod weight loss (76.16 %). The varieties that showed the highest severity of ridge blackening also showed corresponding high levels of percentage weight loss in storage. Rough handling of fresh produce causes bruising and injury. Bruising of pods accelerate the rate of respiration and transpiration of the pods and also contribute to ridge blackening of okra pods (Kader, 1992). Water is lost rapidly from surface cracks and the tissues around injuries, so incorrect handling will also cause increased water loss and shrinkage of the product (Raghupathy, 2000).

The weight of okra pods decreased with storage duration for all okra varieties. The pod weight loss could be due to transpiration, which is influenced by internal, or commodity factors (such as morphological and anatomical characteristics, surface-to-volume ratio, surface injuries, and

maturity stage). External or environmental factors like the storage temperature, relative humidity, air movement, and atmospheric pressure also affected transpiration (Grierson and Wardowski, 1978). Water loss through transpiration is a main cause of deterioration in fresh produce because it results not only in direct quantitative losses (loss of saleable weight), but also loss in appearance (wilting and shriveling) (Kader, 1983).

Weight loss may also be due to respiration. During respiration stored organic materials like carbohydrates, proteins, and fats are broken down into simple end products with a release of energy. Loss of stored food reserves in the commodity during respiration means hastening of senescence as the reserves that provide energy to maintain the commodity's living status are exhausted, reduced food value (energy value) for the consumer is reduced, and salable dry weight is lost. The rate of deterioration (perishability) of harvested vegetables is generally proportional to the respiration rate (Kader, 1983).

CHAPTER FIVE

5.0 RELATIONSHIP BETWEEN FREQUENCY OF HANDLING AND SEVERITY OF RIDGE BLACKENING AND MICROBIAL LOAD OF OKRA PODS

5.1 Introduction

The trend is increasing toward field packing of fruit vegetables whereby grading, sorting, packing, and palletizing are carried out in the field and the products are then transported to a central cooling facility. Field packing operations entail much less handling of products than in pack houses and this reduces product damage and, therefore, increases packout yield of products. Handling costs are also reduced in field packed operations although there is need for increased supervision to maintain a consistent quality in the packed product (Kader, 1992). Field packing generally provides greater marketable yields because of reduced mechanical damage. Wrapped and unwrapped lettuce, celery, cauliflower, broccoli, and spinach are mostly field packed, though the latter three are still packed in packinghouses by a few shippers in the USA. (Kasmire and Cantwell, 2002).

Losses in quality and quantity affect horticultural crops between harvest and consumption and this is because they are susceptible to mechanical injury and also to attack by bacteria and fungi resulting into pathological breakdown (Kader, 1992). The inner tissues of healthy plants and animals are free of microorganisms. They become contaminated when exposed to the microorganisms. The magnitude of this microorganism contamination depends upon various factors such as the microbial population of the environment from which the food was taken,

the condition of the raw product, the method of handling the food and the conditions of storage (Maruthi, 2001).

Microbial contamination or cross-contamination of fresh produce during pre-harvest and harvest activities may result from contact with soils, fertilizers, water, workers, and harvesting equipment. Any of these may be a source of pathogenic microorganisms (USDA, 2001). Fresh fruits and vegetables normally carry a surface flora of microorganisms of soil saprophytes and some plant parasites. Some of these microorganisms will play an important role in any subsequent spoilage (Harrigan and McCance, 1990).

The objectives of this study were to establish the relationship between the frequency of handling of okra pods and severity of ridge blackening and to evaluate field packing as a feasible post harvest handling method for management of ridge blackening of okra.

5.2 Materials and methods

Two varieties of okra, 'Pusa Sawani' and 'Nirali' were used. These two varieties showed the lowest and highest severity to ridge blackening respectively, in experiment described in chapter four. These varieties were field grown as in Chapter four. During harvesting and postharvesting, two methods of handling were used; the conventional pack-house handling method (described in Chapter four) and field packing as described below.

Field packing involved harvesting and packing of okra pods in the field. Only export quality pods (i.e. pods with fresh green stalks and 7-9 cm in length showing similar shape, skin colour, flavour and texture, non fibrous, free from shrivel, intact, sound and free from dirt; foreign material, pests and diseases, with no browning or blackening, and with mechanical or pest damage not exceeding 5% of the surface area) were harvested using a sharp knife. The harvested pods were placed in 1 kg boxes and the boxes were taken to the pack house. From the pack-house, the boxes were stored in a cold room at 7°C and 60% RH for two hours to remove field heat.

The number of times the okra pods were handled for each method was monitored and recorded as follows: When a pod or a container with pods was either lifted, placed down, or moved a distance from one spot to another, each of these activities was recorded as a separate episode of handling.

The field packed and the conventional (pack house) packed boxes were all kept in the cold room at 7 – 10 °C and relative humidity of above 80 %, and samples were selected every five (5) days for determination of severity of ridge blackening and pod weight loss as in Chapter three and four. Treatments were replicated four times and the experiment was repeated twice.

Microbial load determination was carried out at the Food Microby laboratory of Department of Food Science and Technology; Faculty of Agriculture, Makerere University using the surface colony count method by Miles and Misra (1938). Three pods were selected from each

handling method/treatment. Microorganisms were isolated from pod surfaces by placing these pods in a conical flask, with 100 ml of 0.1 % peptone water diluent and shaking this mixture 25 times with an excursion of 30 minutes. Dilution series (up to 10^{-6}) were prepared and plated on potato dextrose agar media, and each dilution was replicated three times for each treatment. Total plate counts and microbial identification were done 24 hours after incubation at 37°C. Dilutions which yielded fewer than 300 colonies per plate were considered since with colonial concentrations exceeding this the count would be depressed to unknown degree by over crowding and microbial antagonism. In addition, dilution plates, which had colonies less than 30, were also discarded since the statistical error involved in counting fewer than 30 colonies becomes overwhelmingly great.

The number of spores (Colon Forming Units-c.f.u) present in the original sample (per pod of okra) was calculated using the formular below:

Average number of counts x 100

3 x Dilution factor (10^x)

Through visual means based on colony morphology, the counted colonies were separated into bacterial and fungal colonies, isolated using a sterile needle and placed on a microscope slide for final microbial identification.

5.3 Results

5.3.1 Effect of frequency of handling on severity of ridge blackening of okra

Using the conventional pack-house method, okra was handled 48 and 59 times for loose and pre-packed pods, respectively, while using the field packing method, the pods were handled only 35 times (Table 5, 6 and 7).

Table 5: Frequency of handling of okra for the two packing methods at Mairye Estates Limited (2002)

Handling method	Frequency of handling
Conventional	48 (Loose/bulk packing) 59 (pre-packing)
Field packing	35

Using the conventional pack-house method, the pods are cut and placed in a plastic ventilated container, carried by the harvester. When the plastic container is full, it is placed in another bigger container in a shade adjacent to the field. From the shade, the tray is picked up and placed on a tractor, which takes it to the pack house. Okra pods are thus handled six (6) times during field activities.

At the pack house, the trays are lifted from the tractor and are taken inside the pack house and placed on a table. They are lifted from the table and placed on a weighing scale to record the weight of the total in-coming produce. From the weighing scale, the pods in trays are taken

and placed into a pre-cooler at 7 °C for two hours. Up to this point, the pods have been

Type of Handling	Conventional packing	Field packing
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handled 11 times.

From the pre-cooler, the trays are taken to the grading room and placed on the grading table, and the pods are poured onto the grading table. Up to this point the pods have been handled 14 times.

1. Cutting pod from the plant	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
2. Placement of pod in plastic container / Box	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
3. Carrying of container / Box from field to shade	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
4. Placement of plastic container in tray in the shade	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
5. Picking the tray /box up	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
6. Placing the tray / Box on the tractor	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
7. Driving tractor to pack-house	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
8. Lifting tray / Box from tractor	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
9. Taking tray / Box inside pack-house	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
10. Placing tray / Box on the table	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
11. Picking up the tray / Box from the table	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
12. Placing of tray / Box on weighing scale	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
13. Removing excess pods from the box	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
14. Lifting from the weighing scale	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
15. Taking tray to pre-cooler	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
16. Placing tray down in the pre-cooler	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
17. Lifting tray up from pre-cooler floor (after 2 hours)	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
18. Moving tray from pre-cooler to grading hall	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
19. Placing tray on grading table	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
20. Pouring pods on grading table	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
21. Export quality pods picked up	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
22. Export quality pods place on one side of grading table	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
23. Sorted pods picked up from one side of the table	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
24. Pods placed in 5 Kg boxes	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
25. Box lifted from grading table	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
26. Box placed on weighing Scale	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
27. Box lifted from weighing scale	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
28. Box placed on grading table	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
29. Box covered with the lid	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
30. Box labeled	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
31. Box lifted up from grading table	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
32. Box moved to cold room	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
33. Box placed down in the cold room	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
34. Box lifted from cold room floor (loading process)	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
35. Box thrown to other person in cold room	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
36. The box is received by the person	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
37. Box placed on conveyor belt	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
38. Box moving on conveyor belt	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
39. Box picked from conveyor belt outside cold room	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
40. Box thrown inside truck to first person	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
41. First person receives it	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
42. First person throws box to second person in truck	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
43. Second person receives it	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
44. Second person throws to third person in the truck	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
45. Third person receives it	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
46. Third person throws the box to forth person	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
47. Forth person receives it	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
48. Forth person throws the box to the fifth person	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
49. Fifth person places the box in the truck.	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
TOTAL	48	35

Table 6: Types and frequency of handling of okra pods using conventional and field packing methods at Mairye Estates, 2002

Table 7: Additional handling of pre-packed okra using the conventional method at Mairye Estates, 2002

Type of Handling	Conventional packing
50. Pods picked from grading table	☑
51. Pods placed in polythene bags	☑
52. Bags are placed on the grading table	☑
53. Bags are picked up	☑
54. The bags are placed on weighing scale	☑
55. Bags picked up from weighing scale	☑
56. Bags are taken to sealing machine	☑
57. Pre-packs are sealed	☑
58. Pre-packs are placed on the grading table after sealing	☑
59. Pre-packs picked up from grading table	☑
60. Pre-packs place in 5 Kg box	☑
Total	11

On the grading tables, each pod is handled singly and sorted by hand. Pods, which conform to the export standard or quality, are placed on one side of the table. From this point onwards, pods are handled separately depending on whether they are to be bulk or loose packed or to be pre-packed. For loose/bulk packing, the pods are picked from the grading table and placed in 5kg carton boxes. The boxes are lifted and placed on a weighing scale and from the weighing scale; the boxes are placed down on the grading table. Up to this point, the loose packed pods have been handled 21 times. For pre-packs, the okra pods are picked from the grading table and placed in perforated polythene bags. The bags are placed on the weighing scale, picked up again and taken to the sealing machine, sealed and then placed down on the grading table. The pre packs are later picked from the grading table and placed in boxes. There is an additional

eleven times of handling. Therefore for pre-packed okra up to this point; the pods are handled thirty four times (Table 7).

Boxes with pre-packs or loose packs are picked up from the grading table, and taken to the cold room. During loading, two people handle the packed boxes in the cold room. The first person picks up the box, throws it to the second person who then places the box onto the conveyor belt. At the end of the conveyor belt just outside the pack house, the refrigerated truck is always packed adjacent to the conveyor belt with four people inside. One pack-house worker standing outside the truck picks the box from the conveyor belt, throws it up the truck to the first worker just at the entrance of the truck. This person then throws it to the second person, the second person does like wise to the third, fourth, and the fifth worker places the box down in the refrigerated truck. From the grading table to the cold room and during loading, the pods in pre-packs or in boxes are handled twenty five times. Up to this point, the loose or bulk packed pods had been handled forty eight (48) times while the pre-packed pods would have been handled fifty nine times (59) (Table 6).

5.3.2 Effect of handling method on incidence and severity of ridge blackening of okra

The analysis of variance for the effect of handling methods on variety and storage duration on the incidence and severity of ridge blackening and pod weight loss of okra is shown in Table 8. For both handling methods, the incidence and severity of ridge blackening and pod weight loss increased with storage duration.

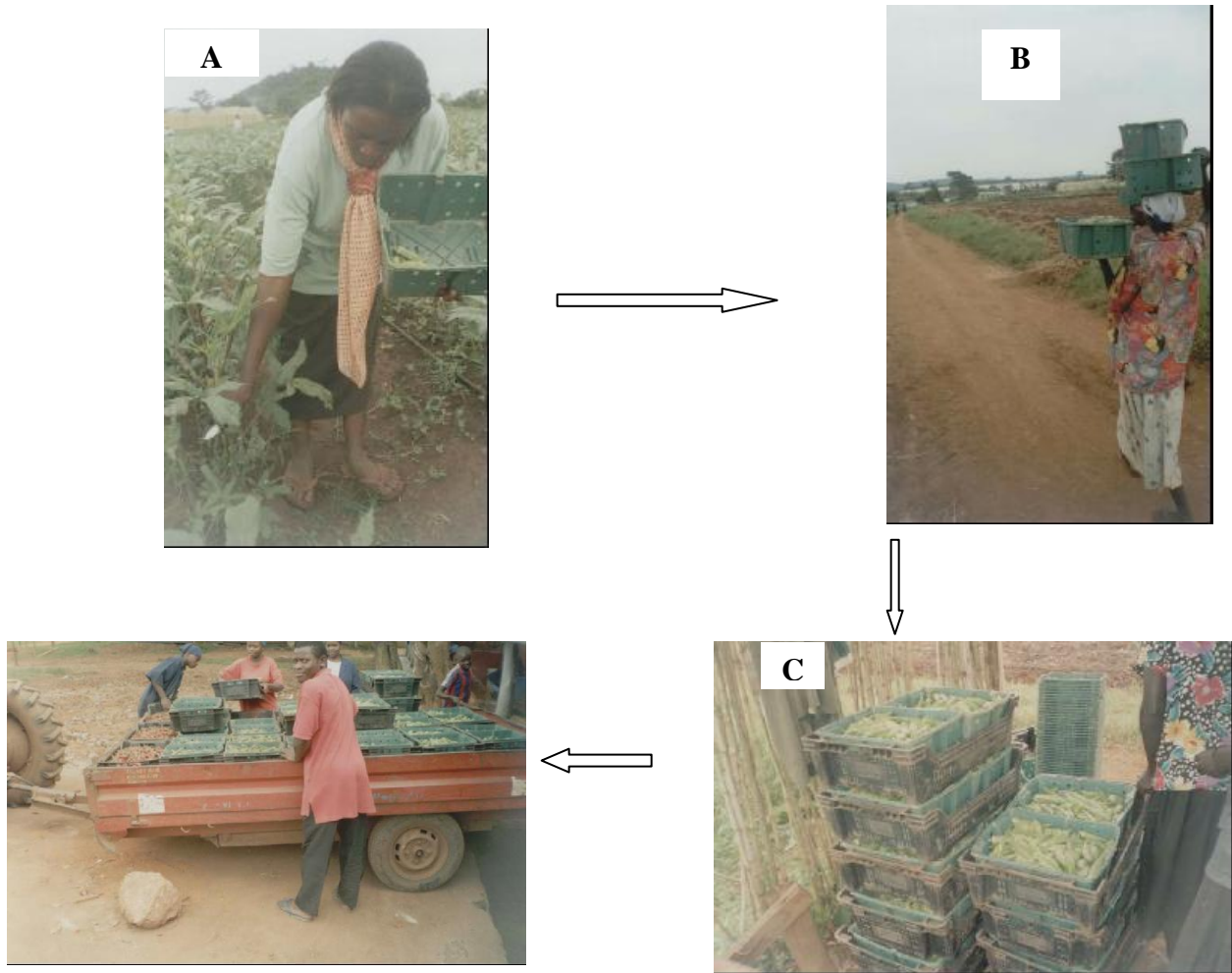


Plate 3: Some handling steps of okra from the field up to the pack house with A-harvesting in field, B-carrying to field shed, C-crates of Okra in field shed and D-Offloading okra from tractor-trailer at pack-house.

Table 8: Analysis of variance for the effect of handling method, variety and storage duration on incidence, severity and % weight loss on okra pods

Source of variation	df	Mean squares		
		Incidence	Severity	% Weight loss
Handling method	1	1.86604**	3.7511**	2.0985**
Storage duration	4	1.17318**	5.7655**	0.5614 ^{NS}
Variety	1	0.13034 ^{NS}	6.831**	1.1995*
Residual	192			
Total	198			

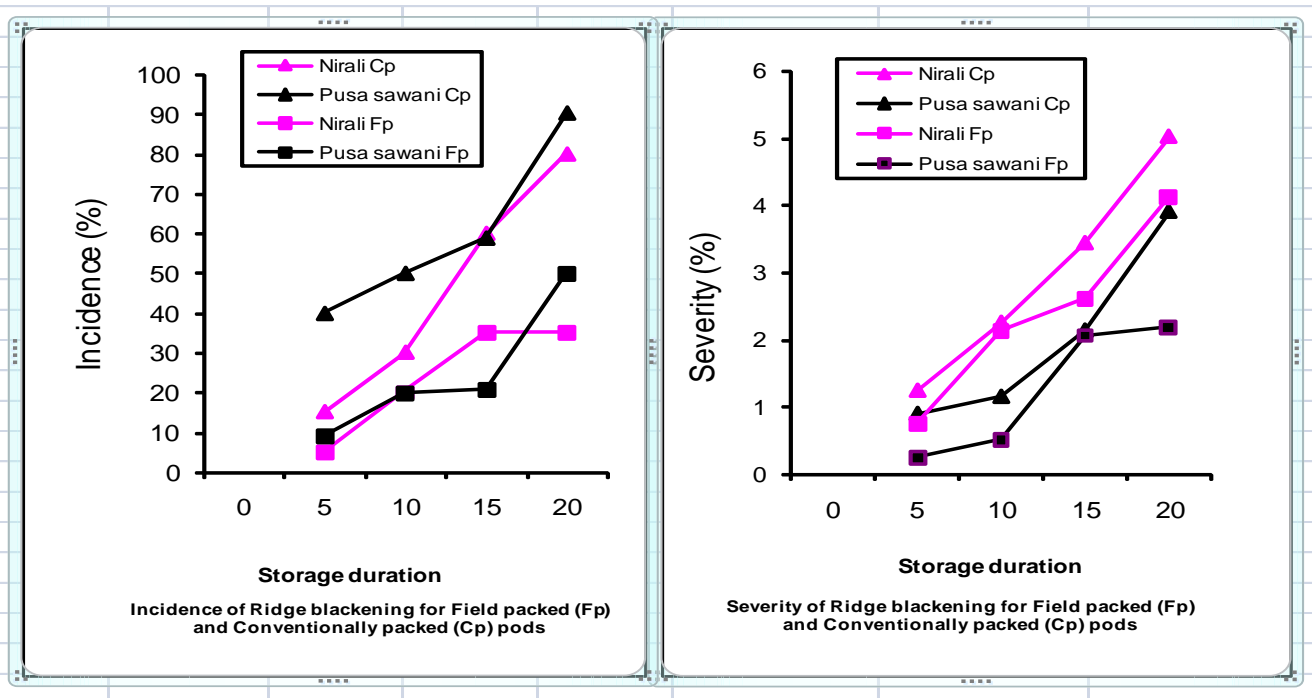


Figure 5: Effect of storage duration on the incidence and severity of ridge blackening of field packed and conventionally packed okra pods

Handling method affected incidence and severity of ridge blackening and pod weight loss of okra. The conventional handling method resulted in significantly higher incidence ($P < 0.01$)

and severity ($P<0.01$) of ridge blackening and pod weight loss ($P<0.01$) of okra pods compared to field packing method (Table 9).

Variety significantly ($P<0.01$) affected severity of ridge blackening and weight loss ($P<0.05$), variety ‘Nirali’ showed significantly ($P<0.01$) higher severity of ridge blackening and pod weight loss during storage compared to ‘Pusa Sawani’. For both varieties, the conventional handling method resulted in higher severity compared to field packing method (Table 9).

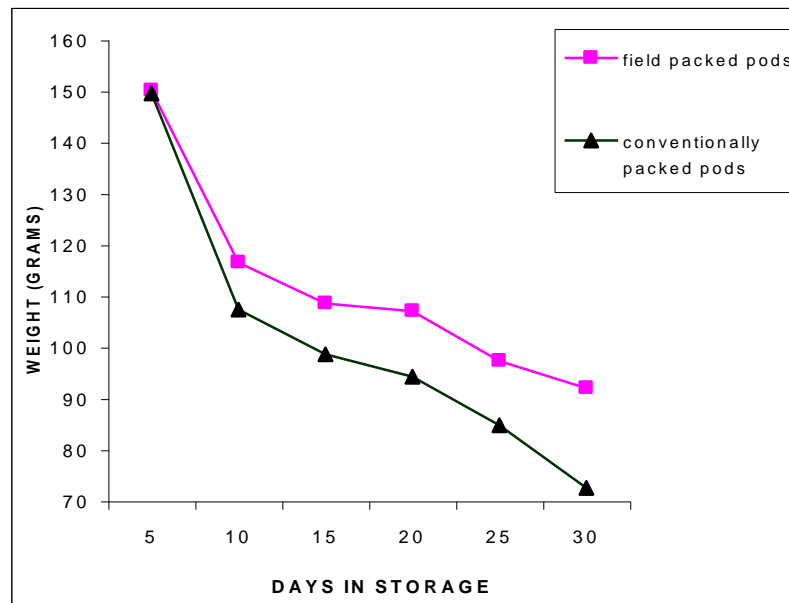


Figure 6: Effect of storage time on weights of okra pods for conventionally and field packed pods

The handling method ($P<0.01$) affected weight loss of pods with the conventional method resulting in significantly ($P<0.05$) higher weight loss than the pods that were field packed (Table 9). Field packed pods lost weight at a lower rate during storage compared to conventionally packed pods (FIG. 6)

Table 9: Effect of handling method and variety on the incidence and severity of ridge blackening and weight loss of okra pods

ASPECT	Incidence ^A (%)	Severity ^B (%)	%Pod weight loss ^B
Handling method			
Conventional Handling	58.4 (1.737)	1.993 (1.342)	2.998 (7.50)
Field Packing	39.2 (1.543)	1.339 (1.067)	2.203 (6.43)
LSD_{0.01}	5.30 (0.0551)	0.3556 (0.1318)	0.726 (0.1343)
Variety			
Nirali	48.1 (1.620)	2.148 (1.376)	7.74 (2.664)
Pusa Sawani	50.5 (1.671)	1.101 (1.006)	6.62 (2.509)
LSD_{0.05}	NS	0.3344 (0.1266)	0.736 (0.1358)

^A Log₁₀ transformed prior to analysis

^B $\sqrt{(x)}$ transformed prior to analysis

5.3.3 Effect of handling method on microbial load on okra pods

The analysis of variance for the effect of handling method and variety on microbial load on okra pods is shown in Table 10. Handling method significantly ($P < 0.01$) affected the total abundance of microorganisms ($P < 0.01$) in particular on okra pods. However, the okra variety significantly ($P < 0.01$) affected only the fungal population on okra pods.

The conventional handling method resulted in significantly ($P < 0.05$) higher abundance of microorganisms (7.008 Total Plate Counts (TPC)) on okra pods, and in particular of bacteria pathogens (4.752 TPC) compared to the field packing method with 6.579 TPC (Table 11). The okra varieties did not significantly ($P > 0.05$) affect the total abundance of microorganisms present on okra pods, but variety ‘Nirali’ had significantly ($P < 0.01$) more fungi (3.6 TPC) compared to variety ‘Pusa sawani’ with 3.2 TPC (Table 11).

All the okra samples tested under the two handling methods had similar types of microorganisms. The only difference was their relative abundance. Conventionally packed pods had a higher microbial load than field packed ones for the all the microorganisms identified (Table 12).

Table 10: Analysis of variance for effect of handling method and variety on microbial load on total plate counts, bacterial and fungal loads on okra pods

Source of Variation	df	Total Plate counts	Fungi	Bacteria
Handling method	1	0.7367*	0.22133 ^{NS}	3.20589**
Variety	1	0.0018 ^{NS}	0.59548**	0.0700 ^{NS}
Residual	29			
Total	31			

Table 11: Effect of handling method and variety on microbial load on okra

ASPECT	Total plate count	Fungi	Bacteria
Handling method			
Conventional Handling	7.008	3.522	4.752
Field Packing	6.579	3.287	3.856
LSD_{0.05(*)}	0.3752*	0.2906^{NS}	0.2011**
	0.01(**)		
Varieties			
Nirali	6.780	3.598	4.31
Pusa Sawani	6.80	3.212	4.44
LSD_{0.05(*)}	NS	0.1943**	NS
	0.01(**)		

Table 12: Relative abundance of the organisms isolated on the okra pods under the two handling methods

Microorganisms	Field packed		Conventionally packed	
	Log c.f.u	Frequency (%)	Log c.f.u	Frequency (%)
<u>Fungal</u>				
<i>Rhizoctonia Solani</i>	0.818	15.158	0.901	14.577
<i>Aspergillus niger</i>	0.473	08.771	0.676	10.937
<u>Bacterial</u>				
<i>Botryodiplodia theobromae</i>	0.863	16.002	0.978	15.823
<i>Pseudomonas Spp.</i>	2.914	54.033	3.096	50.089
<i>Erwinia Spp.</i>	0.325	06.026	0.530	08.575
Total	5.393	100.00	6.181	100.00

5.4 Discussion

Deterioration of fresh commodities can result from physiological breakdown due to natural ripening processes, water loss, temperature injury, physical damage, or invasion by microorganisms. All of these factors can interact, and all are influenced by temperature (Wilson *et al.*, 1995). Post-harvest handling has a decisive effect on the extent of post-harvest losses, final quality, and the market value of horticultural crops. Owing to their tender texture

and high moisture content, fresh fruits and vegetables are very susceptible to mechanical injury and poor handling, unsuitable containers, improper packaging and transportation can easily cause bruising, cutting, breaking, impact wounding, and other forms of injury (Liu, 1999). Problems of rough handling and poor temperature management are compounded when poor sanitation practices exist in the post harvest environment (Dainello *et al*, 2001).

Field packed pods are handled fewer times because sorting, grading and packing are done in the field and the only activities that are carried out at the pack-house are weighing, labeling and loading. During weighing, excess pods are removed and the boxes are covered with lids and labeled. At the end of the handling line, it is observed that the field packed pods had been handled less times (only 35 times) compared to pack-house handling which are handled more frequently (49 times) (Table 5).

Handling methods had a significant effect ($P < 0.05$) on the incidence and severity of ridge blackening of okra pods and the microbial load on the pods. Okra pods handled under the conventional pack-house method had significantly higher incidence and severity of ridge blackening and microbial load than those pods that were field packed. Conventional pack-house handling involved handling pods more times (48 to 59 times) compared to the pods that were field packed (35 times). The more frequently the pods are handled the higher the incidences of bruising especially on the ridges which later turn black hence the high incidence and severity of ridge blackening. Field pack operations entail much less handling of products than in packinghouses and this reduces product damage and, therefore, increases pack-out yield of the product (Kader, 1992; Kasimire and Cantwell, 2002). Various types of physical

damage (surface injuries, impact bruising and vibration bruising) are major contributors to deterioration. Browning of damaged tissues result from membrane disruption, which exposes phenolic compounds to the polyphenol oxidase enzyme and also mechanical injuries not only are unsightly but also accelerate water loss, provide sites for microbial infection, and stimulate carbon-dioxide and ethylene production by the commodity (Kader, 1983). Careful handling of vegetables at all stages is recommended to prevent physical damage, especially in hot arid climates (Schnitzler, 1999) while careful handling of sensitive vegetables like eggplants is recommended because even slight bruising disfigures their skin (Sargent, 1998).

Okra pods handled under the conventional pack-house method had higher microbial load than pods that were field packed indicating that handling procedures contribute to the increase in microbial load on the okra pods. Conventional pack-house handling entails more damaging of the okra pods and hence creates more avenues for microbial contamination. The okra varieties had no significant effect ($P < 0.05$) on the microbial load probably due to the fact that the microbial load was from the environment and the handling procedures these okra varieties were exposed to and, therefore, the microbial load was not variety specific.

Postharvest rots on fruits and vegetables are more prevalent in fruits and vegetables that are bruised or otherwise damaged (Bachmann and Earls, 2000) and, therefore, the findings in this study compliment these earlier findings. Attack by most organisms follows physical injury or physiological breakdown of the commodity. In a few cases, pathogens can infect apparently healthy tissues and become the primary cause of deterioration. In general, fruits and vegetables exhibit considerable resistance to potential pathogens during most of their post-

harvest life but the onset of senescence in all commodities, renders them susceptible to infection by pathogens, stresses, such as mechanical injuries, chilling, and sunscald, lower the resistance to pathogens (Kader, 1983).

Yeasts, molds and bacteria are naturally present in the soil, water, and air around us. They can be adequately controlled by cleanliness in food handling (Mel Moench, 1975). Microorganisms can enter the horticultural environment from many sources including faecally contaminated irrigation water, use of improperly composted manure, fertilizers, wild or domestic animals and runoff from contaminated sites, such as stockyards (Premier and Behrsing, 2000). These organisms (yeasts, molds and bacteria) can readily contaminate fresh produce during any number of operations associated with the production, handling, packaging, processing, distribution, and preparation of produce for consumption (Dainello *et al.*, 2001).

Most microbial contamination is on the surface of fruits and vegetables and that microbial contamination or cross-contamination of fresh produce during pre-harvest and harvest activities result from contact with soils, fertilizers, water, workers, and harvesting equipment (Brecht *et al.*, 1999). In a survey of North Carolina packing lines, Carballo *et al.*, (1994), observed that rot problems in bell peppers (an indication of handling and hygiene practices) were similar when packing in the field or in the packinghouse. This observation is similar to the results from this study, the same types of microorganisms were found on okra pods under both handling methods. Incidence studies in tomato packing houses indicate that the microflora in tomatoes are most likely derived from soil (Senter *et al.*, 1985) indicating a need to improve the washing and disinfectant operations.

Handling method significantly ($P < 0.01$) affected the abundance of bacteria on okra pods. Okra pods that were handled conventionally had significantly ($P < 0.05$) higher bacterial load than those pods that were field packed. This indicates that bacteria affect more the bruised okra pods than the un-bruised ones since conventional handling method exposed the okra pods more to bruising than field packing method. However, the relative abundance of bacteria indicated that *Pseudomonas* species dominated over the *Erwinia* species. This probably indicated that deterioration was more due to this species than *Erwinia* species. When cut lettuce was inoculated with the dominant bacterial group present on the leaf surface, it was observed that when *Pseudomonas* species was inoculated, browning after 48 hours was more rapid and severe compared to lettuce inoculated with other bacterial species (Behrsing *et al.*, 2000). They further observed that sampling directly from the field and testing the microbiological levels on vegetables showed that numbers of microorganisms varied considerably within a field and between farms.

In all the treatments (handling methods and okra varieties), bacteria were more abundant than fungi on the okra pods that were handled using the two methods. This could have been probably because the okra pods had nutrients that favored the growth of more bacteria than fungi. Vegetables are more susceptible to bacteria because of their slightly high pH being 5.0 to 7.0 and, therefore, they are less in sugar than fruits whose pH is lower and they have more sugar and, therefore, more susceptible to fungi (Maruthi, (1975).

Handling methods had a significant effect ($P < 0.01$) on okra pod weight loss in storage. The conventionally pack-house handled okra pods underwent significantly ($P < 0.05$) higher percentage weight loss than pods that were field packed. Field packed pods lost weight at a lower rate during storage (Fig. 6) probably because they were less bruised and therefore the rate of water loss was minimal. Mechanical damage increases moisture loss of fresh vegetables, the rate of moisture loss can be increased by as much as 400% by a single bad bruise on an apple, while skinned potatoes could lose three to four times as much weight as non-skinned potatoes (Bachmann and Earls, 2000). The same authors conclude that damage could be prevented by training harvest labor to handle the crop gently; harvesting at proper maturity; harvesting dry whenever possible and handling each fruit or vegetable no more than necessary (i.e. field pack if possible).

The general decrease in weight of okra pods with storage duration could have been due to increased rates of transpiration and respiration which are both continuous processes. Water loss through transpiration is the main cause of deterioration in fresh produce and results not only in direct quantitative losses (loss of saleable weight), but also in loss of appearance (wilting and shriveling) (Kader, 1983). Fresh produce are living tissues which are continuously respiring and through this process, stored organic materials like carbohydrates, proteins, and fats are broken down into simple end products with a release of energy. The rate of deterioration (perishability) of harvested vegetables is generally proportional to the respiration rate (Kader, 1983) and loss of stored food reserves in the commodity during respiration means hastening of senescence as the reserves that provide energy to maintain the

commodity's living status are exhausted, food value (energy value) for the consumer is reduced and loss of salable dry weight.

Generally, all okra pods whether handled by the conventional pack-house method or field packing method showed similar incidence of ridge blackening. This could have been due to the mode with which they were taken to the pack house since they were transported on a tractor and the road to the pack house was full of potholes. Transport from field to packinghouse could be a source of injury to fresh vegetables, and it is recommended that roads should be maintained in good condition, the springs and shock absorbers on trucks and trailers must be properly maintained and that drivers should always exercise care and remember that they are transporting living material (Dainello *et al.*, 2001).

The okra variety had a significant ($P < 0.05$) effect on severity of ridge blackening of okra with variety 'Nirali' having greater severity than variety 'Pusa sawani'. This was probably because once ridge blackening is initiated by the handling procedures, the rate of its intensification on the pods is variety specific and hence the differences in severity for each variety.

Variety significantly ($P < 0.01$) affected the abundance of fungi with variety 'Nirali' having significantly ($P < 0.05$) more fungal load than variety 'Pusa Sawani'. This indicates that there is variation in the susceptibility of the varieties to the proliferation of fungi. Handling method did not significantly ($P < 0.05$) affect the abundance of fungi although the pods that were handled conventionally had higher fungal load than those pods that were field packed.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

The results of this study have shown that the designed ordinal scale is relatively more reliable and more accurate in measuring ridge blackening of okra from at all levels of severities compared to the visual methods which tend to over estimate the severities below 25%.

Okra variety significantly affects the severity of ridge blackening. Variety 'Pusa Sawani', the most common variety grown in Uganda showed the lowest severity of ridge blackening and Variety 'Clemson Spineless' and 'Nirali' showed some form of horizontal resistance with a high incidence of ridge blackening followed by a generally low severity. Varieties 'Pure luck' and Ever Lucky showed the highest severity of ridge blackening.

Severity of ridge blackening significantly increases with storage time and the net weights of okra pods also decrease with storage duration probably due to increase respiration and loss of moisture via the damaged tissue.

Field packing entails much less handling of the pods, which leads to less physical damage and, therefore, reduced ridge blackening and reduced microbial attack, reduced water loss and higher marketable yields.

In view of the above findings, the following recommendations are made:

- a) Okra growers should adopt varieties like ‘Pusa Sawani’, ‘Clemson spineless’ and ‘Nirali’ with relatively high resistance to ridge blackening while varieties like ‘Lucky Five’ which are very susceptible should be avoided.
- b) The number of times the pods are handled should be reduced and the method of field packing should be adopted since this entails much less handling of products compared to the conventional (pack house) method. Field packing reduces product damage, reducing handling costs and leads to more pack house out put of marketable product.
- c) Transport from field to packinghouse can be a source of injury, therefore, roads should be maintained in good conditions. Drivers should exercise care and remember that they are transporting living material. The springs and shock absorbers on trucks and trailers of tractors must be properly maintained. The packing line itself should have as few drops and shears as possible. Shears that are essential should be designed properly.
- d) Contamination of produce occurs from a wide number of sources (for example from water, manure, equipment and even workers) therefore sanitation is of prime importance, as follows.
 - **Manure:** Only properly treated manure and biosolids should be used to fertilize vegetables. Situate, if practical, vegetable production fields away from other potential sources of contamination such as nearby composting or manure storage areas, livestock or poultry operations, nearby municipal wastewater or biosolids storage, treatment or disposal areas, and high concentrations of wildlife in the growing and harvesting and packing environment.

- **Sanitary facilities and personal hygiene:** Producers should have the appropriate number of toilets for the number of workers, proper hand washing facilities, maximum worker to restroom distance, know how often such a facility should be cleaned, and how the waste is to be disposed-of in order to avoid contamination of the workers and produce.
- **Field stations:** Attempts should be made to prevent cross-contamination of fresh produce during pre-harvest and harvest activities that may result from contact with soils, fertilizers, water, workers, and harvesting equipment. Clean harvest containers (preferably use white ones) and storage facilities prior to use, periodically clean field containers and bulk load equipment, discard broken or damaged bins, remove as much dirt as possible in the field, and maintain harvest equipment.
- **Packing sheds:** Maintain buildings, fixtures, and other physical facilities, and their grounds. Practice good sanitation within the packing shed. Clean pallets, rest rooms, containers, grading and packing lines daily. Develop a vigorous pest control program.
- **Pack house:** Problems of rough handling and poor temperature and relative humidity management are compounded when poor sanitation practices exist in the post harvest environment. Packing sheds and storerooms should always be clean and neat. Products left on the floor under machinery will rot and contaminate the air with spores of decay-causing organisms that may then infect other commodities. The packing line itself should be left free of produce each day and cleaned regularly. Bulk bins, storage buckets, and other containers should be cleaned and disinfected regularly.

Based on the findings of this study, the following areas may be pursued for further studies:

- A study on the “effect of the relative levels of nitrogen, phosphorus potassium and other nutrients on the over all shelf life of okra pods”. This is because certain physiological disorders originate from pre-harvest nutritional imbalances.
- The “effect of different packaging materials and packaging types on the incidence and severity of ridge blackening of okra pods”. This is because packaging of fresh fruits and vegetables has a great significance in reducing the wastage. Packaging provides protection from physical damage during storage, transportation and marketing.
- Effect of plant age on the shelf life of pods. During this study, it was observed that the age of the plant from the sowing date probably has an effect on the shelf life of the okra pods harvested from it. It seemed that during the early stages of the plant, the harvested pods seemed to have a shorter shelf life than those pods that were harvested later as the okra plants became older. Further research is needed to address this.

REFERENCES

Agribusiness Development Center (ADC) Commercialization Bulletin # 7 - Okra, 1998.

Agribusiness Development Center of the USAID-funded. Uganda's Investment in Developing Export Agriculture (IDEA) Project.

Agribusiness Development Center (ADC) Commercialization Bulletin # 7 - Okra, May 2001.

Agribusiness Development Center of the USAID-funded. Uganda's Investment in Developing Export Agriculture (IDEA) Project.

Agribusiness Development Center (ADC) Commercialization Bulletin # 7 - Okra, 2003.

Agribusiness Development Center of the USAID-funded. Uganda's Investment in Developing Export Agriculture (IDEA) Project.

Anon. 1998. Specialty and Minor Crops Handbook. 2nd ed. Small Farm Center. University of California, Publication 3346. Division of Agriculture and Natural Resources, Communication Services—publications 6701 San Pablo Avenue Oakland, CA 94608-1239

Bachmann, J and Earles R, 2000. Postharvest Handling of Fruit & Vegetables. ATTRA Ozark Mountains at the University of Arkansas in Fayetteville. P.O. Box 3657, Fayetteville, AR 72702. NCAT Agriculture Specialists.

Beresford, R. M. and Royle, D. J. (1991). The assessment of infectious disease for brown rust (*Puccinia hordei*) of barley. *Plant Pathology* **40**: 374-381.

Booth R. H, A, J. Toet and Bevan L., 1987. Investing in sustainable post-harvest programs: guidelines for the development of post-harvest efforts to improve food supply based on 10 years experience of the FAO special action program. Food and Agricultural Organization of the United Nations Rome. pp 1 – 5

Brecht, Ritenour, and Sargent, (1999). *Vegetarian new letter* **99-12**.

Cantwell M. and Suslow, T., 2002. Department of Vegetable Crops, University of California, Davis, CA 95616. Recommendations for Maintaining Postharvest Quality. Postharvest Technology Research Information Center, Department of Pomology University of California One Shields Ave., Davis, CA 95616-8683.

Dainello F and Cotner S, , 2001. *Vegetable Growers' Hand Book*. Web Edition. Department of the Horticulture Industry, January 1992. Foods & Agriculture Organization of the United Nations (FAO).

Duzyaman, E. 1997. Okra: Botany and horticulture. In: J. Janick (ed) *Hort. Rev.* 29:41-72.

FAO (2003). FAOSTAT statistics database (URL: <http://apps.fao.org/default.htm>).

Forbes G.A. and Jeger M. J., 1987. Factors affecting the estimation of disease intensity in simulated plant structures. *Zeitschrift für Pflanzenkrankheiten und Pflanzenschutz* **94**, 113-20

Grierson, W. and W.F. Wardowski. 1978. Relative Humidity Effects on the Postharvest Life of Fruits and Vegetables. *HortScience* 13:570-74.

Hardenburg, R.E., A.E. Watada, and C.Y. Wang. 1986. The Commercial Storage of Fruits, Vegetables, and Florist and Nursery Stocks. U.S. Dept. of Agriculture, Agricultural Handbook No. 66. 130 pp.

Harrigan, F.W. and McCance, M. E., 1990. Laboratory Methods in Food and Dairy Microbiology. Academic Press, London.

Heiser, C.B. and Smith, P.B. (1953). "The Cultivated *Capsicum* peppers", *Economic Botany*, 7, pp. 214-221.

Horsfall, J. G. and Barrat R. W., 1945. An improved grading system for measuring plant diseases. In: *Horsfall JG, Cowling EB, eds. Plant Disease: An advanced Treatise. Vol II. How Disease develops in Populations*. London: Academic Press, 119-36

Hurst C. W, Reynolds E A., George A. S and Christian J A., September 1993. Maintaining Food Quality in Storage. Bulletin 914/September, 1993. The University of Georgia and Ft. Valley State College, the U.S. Department of Agriculture.

Jager, E.S. De and Korsten, L., 2002. Microorganisms associated with Litchi fruit and packinghouses in South Africa. *Department of Microbiology and Plant Pathology, University of Pretoria, Pretoria, 0002*

Jose L. Aguiar and Keith S. Mayberry (University of California cooperative Extension advisors), 1998. Vegetable research and information center, vegetable production series, division of agriculture and Natural resources, publication number 7210

Kader A. A., (ed.). 1992. *Postharvest Technology of Horticultural Crops*. Uni. of Calif., Div. of Agri. and Natural Resources. Oakland, California, USA. 296 pp.

Kemble J, and Mary B, 1997. ANR-1062, News Aug 1997. Department of Horticulture, Auburn University. Kader, A. A. 1983. Postharvest quality maintenance of fruits and vegetables in developing countries. In *Post harvest physiology and crop preservation*, ed. M. Lieberman, 520-36. New York: Plenum.

Kemble J. M., Sikora E. J., Zehnder G. W. and Patterson M. G., September, 1995. Guide To Commercial Okra Production, The Alabama Cooperative Extension System . ANR-0959

Kemble, J, Musgrove, M B,, 1997. Horticulture Notes: Soil Temperature Conditions For Vegetable Seed Germination. Auburn University, ANR-1061.

Know-you seed Company Limited, 2003. <http://www.harbest.com/seeds/okra.htm>,
<http://Knownyou.com/English/button2/product/okra/1292.html>.

Kochhar S. L., 1986. Tropical crops: a textbook of economic botany, 2nd Edition. University of Delhi, Macmillan publishers.

Lamont, W. 1999. Okra - A versatile vegetable crop. HortTechnology 9:179-184.

Liu F W, 1999. Postharvest handling in Asia. Food and fertilizer Technology center. Department of Horticulture, National Taiwan University, Wenchow St., R.O.C Taipei 10616 Taiwan

Mairye Estates small grants program vegetable research annual report June 2001-July 2002. Okra trails September 2001/2002. Tracking No. C 11- IDEA- 008. Pp 1-3

Martin B.R., 1971. *Statistics of Physicists*. London: Academic press.

Martin F.W., Degras L. 1978. Tropical yams and their potential. Part. 5. *Dioscorea trifida*. Agricultural handbook No 522 Science and education administration, U.S. Department of Agriculture (USDA) and U.S.A.I.D. Washington, USA.

Maruthi AVASN , 2001. Industrial waste management, enviromental microbiology. department of environmental studies, college of engineering gandhi institute of technology and management (GITAM), visakhapatnam (affiliated to Andhra university), India

Mel Moench, 1957. FOOD AFTER PRODUCTION: in Planet earth home, The ultimate self-sufficient home for any location in the world.

Miles, A. A. and Misra, S. S., (1938). The estimation of the bactericidal power of the blood. *J. Hyg., Camb.*, 38, 732.

Ministry of Agriculture Animal, Industry and Fisheries (MAAIF) Entebbe, 1999.

Namdhari Seeds Pvt. Ltd., 2003. <http://www.namdhariseeds.com/newokra.htm>

Parker, S. R., Shaw, M. W. and Royle, D. J., 1995. The reliability of visual estimates of disease severity on cereal leaves. Department of Agricultural Sciences, University of Bristol, Institute of Arable Crops Research, Long Ashton Research Station, Bristol BS18 9AF, UK.

Perkins-Veazie, P.M. and J.K. Collins. 1992. Cultivar, packaging, and storage temperature differences in storage temperature differences in postharvest shelf-life of okra. *HortTechnology* 2:350-352.

Poleman, C.M., and N. Peckenpaugh. 1991. Nutrition essentials and diet therapy. W.B. Saunders. Co.

Raghupathy R, 2000. Good Handling Practices For Fresh Produce Industry. Department of Science and Technology (DST) and Technology and Federation of Indian Chamber of Commerce and Industry (FICCI) project. New Dheli, India.

Sargent Steve, 1998. Handling Florida Vegetables – Eggplant. Department of Horticultural Sciences, Institute of Food and Agricultural Sciences (UF/IFAS). Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, 32611.

Schnitzler W H., 1999. Postharvest Issues for Protected Agriculture Production; Postharvest Handling and Monitoring of Quality for Vegetables Produced in Greenhouses in Hot, Arid

Climates. Institute for Vegetable Science, Technische Universität München, Freising, Germany.

Senter S. D., Cox N.A., Bailey J.S., Forbus Jr. W.R.,. 1985. Microbiological changes in fresh market tomatoes during packing operations [a research note]. *Journal of Food Science*: 50:254-5.

Sidhu A. S, 2003. Current Status of Vegetable Research in India. Punjab Agricultural University Regional Research Station, Bathinda, Punjab Indai.

Tindall, H.D., and F.J. Proctor. 1980. Loss Prevention of Horticultural Crops in the Tropics. *Prog. Food Nutr. Sci.* 4(3-4): 25-40.

Toivonen P M. A. and Forney C, 2003. Broccoli, Agriculture and Agri-Food Canada. Pacific Agri-Food Research Centre Summerland, British Columbia, Canada and Atlantic Food and Horticultural Research Centre, Kentville, Nova Scotia, Canada.

U.S. Dept. of Agriculture [USDA], Agricultural Marketing Service. 2001. Protecting perishable foods during transport by truck. Washington: USDA, AMS, Transportation and Marketing Division.

Vegetarian News letter, April 2002. A vegetable Crops Extension Publication. Vegetarian 02-04; University of Florida Institute of Food and Agricultural Sciences Cooperative Service.

Wilson, C.L., A. El Ghaouth, B. Upchurch, C. Stevens, V. Khan, S. Dorby, and E. Chalutz. 1997. Using an on-line UV-C apparatus to treat harvested fruit for controlling postharvest decay. *HortTechnology* 7,3: 278-282.

Wilson, L.G., M.D, Boyette and E.A. Estes, 1995. Postharvest Handling and Cooling of Fresh Fruits, Vegetables and Flowers for Small Farms, Part III: Handling, North Carolina State University Extension Horticulture Information Leaflet 804.

Wolford R and Banks D, 2003. (Extension Educators in Urban Horticulture and Gardening and Nutrition and Wellness respectively). Urban Programs Reserve Network, University of Illinois Extension.

World fertilizer use manual, 2002. Okra under tropical / subtropical conditions. International Fertilizer Industry Association (IFA) (1996-2004).

Zook Sylvia W- Nutritionist, 2001. In *All About Okra* by Ravi Kochhar; Department of Physiology, University of Wisconsin 1300 University Avenue Madison, WI 53706.

Appendix 1: World production of okra 1993-2002

Country	Parameter	Year									
		1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
India	Area (Ha)	376000	300,000	420000	380000	370000	320000	330000	350000	360000	360000
	Yield (Kg/Ha)	63963	101000	92857	100000	100000	100312	102424	97714	97222	97222
	Production (MT)	2405000	3030000	3900000	3800000	3800000	3210000	3380000	3420000	3500000	3500000
Nigeria	Area (Ha)	260000	260000	260000	260000	260000	245000	275000	275000	275000	275000
	Yield (Kg/Ha)	21923	23077	24231	25000	24980	25020	26145	26145	26145	26145
	Production (MT)	570000	600000	630000	650000	612000	638000	719000	719000	719000	719000
Pakistan	Area (Ha)	11090	10870	11345	12075	12405	12400	12400	12500	12500	12500
	Yield (Kg/Ha)	82851	81533	85318	87719	87719	87903	87903	88000	88000	88000
	Production (MT)	91882	88626	96793	108815	108815	109000	109000	110000	110000	110000
Ghana	Area (Ha)	25000	26000	27000	28000	28000	28000	28000	18000	18000	18000
	Yield (Kg/Ha)	56000	55769	55556	53571	53571	53571	53571	55556	55556	55556
	Production (MT)	140000	145000	150000	150000	150000	150000	150000	100000	100000	100000
Egypt	Area (Ha)	5000	5100	5565	5388	5400	5500	6450	6000	6072	6072
	Yield (Kg/Ha)	134000	132353	135833	135278	137037	136364	150574	126667	140375	140375
	Production (MT)	67000	67500	75591	72888	74000	97120	76000	85236	85236	85236

Source: Derived from Data Supplied By Food and Agricultural Organization of the United Nations; 2003