ASSESSMENT OF PHYSICAL QUALITY AND HEALTH OF FARMER SAVED PIGEON PEA (*Cajanus cajan*) SEEDS IN BABATI AND KARATU DISTRICTS

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DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTERS OF SCIENCE IN CROP SCIENCE OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA.

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ABSTRACT

An assessment of quality parameters of farmer saved pigeon pea seeds was conducted in Babati and Karatu Districts in northern Tanzania. Pigeon pea seed samples were collected from 80 households (farmers), 40 from each district; for testing of their physical and health quality status with respect to three post-harvest handling practices (storage, pre storage seed treatment and seed sorting) following ISTA procedures. Results were then compared with national standards of pigeon peas seeds in Tanzania. Very few of the samples (15% in Babati and 12.5% in Karatu Districts) met the minimum quality standards for pigeon peas seed purity which is 97%. About 60 % of the samples from Babati and 55% from Karatu Districts met the minimum standards of moisture content (which is 10%). Similarly, 97.5 % of the samples from Babati and 82.5% from Karatu Districts met the minimum standard for germination capacity which is 70%. *Fusarium udum* which is a pathogen of seed health significance in pigeon peas was detected in 33 samples from Babati (equivalent to 82.5%) and 36 samples from Karatu Districts (equivalent to 90% of the samples). Eleven other seed infesting fungi were also observed, with *Rhizopus spp* appearing in all samples and having the highest incidence of 23.2% for Karatu and 16.1% for Babati District. Significant correlation existed between seed purity and incidence of *Cladosporium spp* and between seed moisture content and incidence of *Fusarium moniliforme*; but the correlation with purity was positive against expectation. Further study is suggested of scenarios of farmers′ seeds and quality.

DECLARATION

I, Tarmo, Theophili do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work done within the period of registration and that it has neither been submitted nor being concurrently submitted to any other institution.

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The above declaration confirmed

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Prof. D.G. Msuya Date

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P. J. Njau (Ph.D) Date

(Supervisor)

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I am also grateful to my mother and younger brothers and sisters for their encouragement during long period of this study.

DEDICATION

I dedicate this work to the ALMIGHTY GOD for keeping me healthy and strong enough to accomplish this study.

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LIST OF ABBREVIATIONS

CV	Coefficient of Variation
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organization Statistics
GERM	Germination
ISTA	International Seed Testing Association
LSD	Least Significance Difference
MC	Moisture Content
SE	Standard Error
SG	Standard Germination
SIMLESA	Sustainable Intensification of Maize-Legume Cropping Systems for Food Security in Eastern and Southern Africa
SUA	Sokoine University of Agriculture
TP	Top of Paper
TOSCI	Tanzania Official Seed Certification Institute
URT	United Republic of Tanzania

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

The Pigeon pea [*Cajanus cajan* (L.) Millsp] is a perennial legume in the family Fabaceae. It is an erect shrub often grown as an annual crop which can reach up to 4 m in height (Valenzuela and Smith, 2002). Pigeon pea is an important grain legume in northern Tanzania and has gained considerable national economic significance in recent years. In many parts of the country, pigeon pea is often grown as a cash crop by small-scale farmers and also used as an occasional food legume (Monyo and Laxmipathi, 2014). Pigeon pea offers multiple benefits including protein rich seed (approximately 21% protein), fuel, fodder, fencing material, improvement of soil fertility and erosion control (Saxena *et al*., 2010a).

The use of farm-saved, untreated seed in the smallholder farming sector is a common practice in Tanzania (Amare *et al.,* 2012). These seeds are always not protected before storage. The storage techniques used are also poor that may allow infestation of the grains by storage insect pests especially bruchids (Dasbak *et al.,* 2009). Seed borne fungi are a major constraint faced by small scale farmers (Patil *et al.,* 2012). The storage fungi such as *Aspergillus, Penicillium* and *Rhizopus* do not only spoil seeds but they may also produce toxins and chemicals that may affect human health when the infested grains are used for food (Bankole *et al.,*1995).

1.2 Justification

Currently, low production of pigeon peas has been observed in different parts of Tanzania (Mponda et *al*., 2013). Production trends (FAOSTAT, 2013) show that between 1999 and

2013, pigeon pea area under cultivation increased from 124.6 to 290 hectares (132.7%) and output from about 81 to 210 tons (159.2%). On the other hand, the crop's yield remained relatively constant at about 0.65 and 0.72 tons/ha, respectively which is below the crop′s potential of up to 4.6 ton/ha (Odeny, 2007).This implies that the gain in production over the said period have been attributable to area expansion and not productivity increase.

High incidences of wilt has been a major problem which causes a great yield loss of up to 90% of pigeon peas (Datta and Lal, 2012). Lack of timely availability of quality seeds of improved varieties, ecological (terminal drought) and edaphic factors (acidic soils), cultivation on marginal and sub-marginal lands with low inputs, lack of appropriate pigeon pea production and protection technologies, lack of basic information related to pests' biology, and poor post-harvest technology are other reasons for low yield of the crop (Sharma *et al*., 2010).

Use of improved quality seeds could solve some of the yield problems. Contrarily, however, about 96% of pigeon pea farmers use their own saved seeds whose quality status is not known (Shiferaw *et al.,* 2005). The seed supply is dominated by informal system such as borrowing from neighbours/relatives, exchanging or purchasing stored food grains to be used as seeds (Monyo and Laxmipathi, 2014). Such un- improved quality seeds could have high genetic variability and incidences of severe diseases and insect pest susceptibility. High genetic variability leads to indeterminate maturity dates of pigeon pea crop which leads to improper management hence affecting yield (Deshmukh and Mate, 2013). Also, differential susceptibility to disease and insect pest and non-uniform harvested grains greatly reduce yield (Sharma *et al*., 2010). In addition, majority of the farmers store their grains/seeds in bags/jute sacks and the seeds are not protected against storage pests hence get easily infested with storage pests which can cause a lot of physical and physiological damage to the grains or seeds rendering them un-germinable or germination with very low vigour. Therefore, there is a concern about physical quality and health of farmers own saved seeds. To ascertain the status of farmers' seeds, quality tests are required. This study aimed at substantiating the status of the physical quality and health of the farmers' own pigeon pea seeds with the view of recommending appropriate management practices to produce good quality seeds and improve pigeon pea production in the study area.

1.3 Objectives

1.3.1 Overall objective

To improve pigeon pea production through strategies to reduce disease incidence, impurities and post-harvest handling problems of farm saved seeds.

1.3.2 Specific objectives

i. To establish physical quality status of farm saved pigeon pea seeds in relation to different post-harvest handling techniques used by farmers.
ii. To establish presence of seed-borne, other pathogenic and saprophytic fungi of importance on collected farm-saved pigeon pea seeds.
iii. To determine the relation of intercepted seed borne fungi with germination and other physical quality attributes of the collected pigeon pea farm saved seeds.
iv. To identify different production characteristics and their relation to quality attributes of farm-saved pigeon pea seed.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction of the Crop

2.1.1 Origin and botanical description

Pigeon pea [*Cajanus cajan* (L.) Millspaugh] is an erect perennial legume that is widely grown in the tropics and subtropics and belongs to the family Fabaceae. The crop is said to have originated from India at least 3,500 years ago (Van der Maesen, 1990). Its seeds have become common food grain in Asia, Africa and Latin America (Kassa *et al*., 2012). It is largely consumed in South Asia and is a major source of protein for the population residing in this region. Pigeon pea is a shrub that can grow to 4m but usually grows 90cm to 183cm. Its deep tap root is fast-growing. The stem grows upright and is covered in short, soft hairs (pubescent) and is woody at the base. The pubescent, stalked leaflets are 5–10 cm long and 2–4 cm wide, with minute resinous glands underneath (Sheahan, 2012).

2.1.2 Ecology

Pigeon pea is said to have wide adaptability in different climatic and soil condition (Odeny, 2007). It grows well on a broad range of well-drained soils, from sands to clays over sedimentary, igneous and metamorphic parent materials. The crop is tolerant to pH that ranges between 4.5 and 8.4 and some varieties tolerate 6 to 12mmhos/cm of salinity. Pigeon pea grows well in areas receiving between 600-1000 mm of rain. Pigeon pea is different from other legumes that rapidly close their stomata, they allow for stomata adjustment in response to water stress, which allow osmotic adjustment until a critical internal water status is attained. In addition, solutes and other compounds in pigeon pea help to maintain integrity of the cells, preventing protein denaturation (Odeny, 2007). The ability of pigeon pea to tolerate drought is also contributed by its morphology; deep root which allows extraction of moisture from deep layers of the soil making it a crop that produces a big biomass through utilization of residual moisture (Porter and Didlack, 2011).

However, the crop does not grow well in water logged condition and frost but producing seed profusely under dry zone conditions, as it matures early and the incidence of pest damage is low (Odeny, 2007).

Pigeon pea is more or less photoperiod-sensitive; short days decrease time to flowering. Under humid conditions pigeon pea tends to produce luxuriant vegetative growth and it is affected by rain during the time of flowering which causes defective fertilization and permits attack by pod-caterpillars. The plant is remarkably hardy to both low temperatures (as low as 10°C to 5°C) and high temperatures (up to 40°C). For this case pigeon pea is an ideal crop to fit into different cropping systems in many parts of the world. The crop does not tolerate shade but it can tolerate only the moderate condition. Pigeon pea does well in full sun on bare ground although it can also grow with side shade or broken shade from trees and a low cover of grass and forbs. Growth is moderately slow during the first 2 months to 3 months of life during which time seedlings are not competitive with grass and weeds; afterwards pigeon pea competes well with vegetation equal or lower in height (Van der Maesen, 1990).

2.2 Importance of the Crop

Pigeon pea is an important crop in the developing tropical and subtropical countries (Vange and Moses, 2009). It has several nutritional, medicinal and other uses. For the small scale farmers in northern and eastern Tanzania it is an important cash crop that many farmers rely on for their income (Infonet-biovision, 2013). The leaves are used to feed animals, the stems are used as fencing material, fuel and building materials for some communities and the grains are used for food. Due to its ability to fix atmospheric nitrogen, pigeon pea can utilize somehow low fertility land and still produce good yield. The crop can fix about 70 kg N/ha per season by symbiosis until the mid-pod-fill stage. This is around 88% of the total nitrogen content of the plant at that stage of growth. The residual effect on a following cereal crop can be as much as 40 kg N/ha (Phatak *et al.*, 1993).

For optimum production the crop requires a supply of mineral nutrients, the most important of which is nitrogen. Exhausted soils are often low in nitrogen, meaning that farmers are obliged to apply inorganic fertilizers. However, as fertilizer costs increase, farmers struggle to obtain good yields. This problem can be addressed by incorporating pigeon peas into the cropping system. Leguminous plants have a special relationship with nitrogen-fixing bacteria (*Rhizobium*). By biologically fixing nitrogen levels in the soil, legumes provide a relatively low-cost method of replenishing nitrogen in the soil, thus improving soil fertility and boosting subsequent crop yields (Saxena *et al*., 2010a).

The protein content of commonly grown pigeon pea cultivars ranges between 17.9 and 24.3 g/100 g for whole grain samples, and between 21.1 and 28.1 g/100 g for split seed (Sheahan, 2012). The high-protein genotypes also contain significantly higher amount (about 25%) of sulphur-containing amino acids, namely methionine and lysine which assists in breakdown of fats thereby preventing the build-up of fat in the arteries, as well as assisting with the digestive system (Oluwaseun, 2013). Pigeon pea seeds contain about 57.3% to 58.7% carbohydrate, 1.2% to 8.1% crude fibre, and 0.6% to 3.8% lipids (Hassan *et al*., 2013). Since pigeon peas contain high protein value they supplement the diets for millions of people, especially traditional cereal- banana- or tuber-based diets of resourcepoor farmers that are generally protein-deficient. The perennial nature of pigeon pea allows farmers to take multiple harvests with surpluses traded in both local and international markets (Odeny, 2007).

Pigeon peas can also be used in other various ways, for example, the green seeds (and pods) serve as vegetable while ripe seeds are a source of flour, used split (dhal) in soups or eaten with rice, also the ripe seeds may be germinated and eaten as sprout. Tender leaves are rarely used as a potherb. The crop has also been widely used as a traditional folk medicine. The leaves have been reported to arrest blood flow, relieve pain and kill worms. They can be used to cure measles, dysentery, jaundice, diarrhoea, cough, sore, bronchitis, bladder-stones, diabetes and many other illnesses (Saxena *et al*., 2010b).

2.3 Growth and Management of Pigeon Pea

Pigeon pea seeds are normally sown directly into prepared land. For germination the crop requires the optimum temperature of 29°C-36°C). The crop is a slow-growing crop and mostly cultivated during the rainy season. In most cases pigeon pea suffers from early weed infestation as it fails to compete with weeds at the early stage of development. Therefore, it is necessary to keep the crop weed-free during the early stages of growth period (4-6 weeks) (Reddy, 1990).

In many pigeon pea growing areas the crop is largely grown as a rain-fed crop; however, the flower initiation and pod setting stages are the most crucial to drought stress. At this stage therefore, irrigation is important (Chauhan *et al*., 1988). However, Excessive moisture is detrimental to pigeon pea as it promotes vegetative growth and enhances incidences of *Phytophthora* and *Alternaria* blights. Therefore, irrigation should be done only when the crop experiences drought stress after flowering and at pod filling stage.

2.4 Current Situation of Pigeon Pea Production in Tanzania

Currently, the pigeon pea production is hampered mainly by diseases, pests and poor post-harvest handling techniques (Monyo and Laxmipathi, 2014). The most devastating disease is *Fusarium* wilt which is both soil and seed borne (Patil *et al*., 2012). The diseases can cause yield loss of up to 90 % (Datta and Lal, 2013). Insect pests that affect the crop are of two categories, field insect pests such as pod borers, pod suckers and pod bugs, while the others are storage insects especially bruchids (Dasbak *et al*., 2009). Post-harvest handling techniques are the most important factors for quality grains used as food and seeds as well (Sallam, 2014).

2.5 Constraints to Pigeon Pea Production

Although pigeon pea is among the important crops in Tanzania and Eastern African region in general, little research effort has been directed at either crop improvement or technology transfer situation which causes slow production growth of pigeon pea as compared to other pulses like common beans and cowpeas (Lyimo and Myaka, 2001). The production of pigeon pea has remained more or less static over the last several years to the extent that many farmers were abandoning pigeon pea cultivation (Odeny, 2007). As different needs and opportunities surface, pigeon pea breeders need to incorporate new genetic sources using various breeding methods aided with modern tools such as biotechnology.

Other factors like traditional landraces area also responsible for low crop yields in farmer’s fields in Tanzania. Year after year use of these traditional landraces, which frequently suffer from different biotic and abiotic stresses due to lack of quality seeds results into decrease in productivity of pigeon pea. Poor production practices such as low plant densities, low soil fertility, insufficient weeding and inappropriate use of fungicides and herbicides also limit the production. Pigeon pea is also mostly underutilized as compared with other legumes like common beans and cowpeas, a situation which lead into low production rate of the crop (Akande, 2007). Abiotic factors such as drought, soil with poor water holding capacity; and socio-economic factors like infrastructure, marketing and exploitation by middlemen also affect pigeon pea productivity in major growing regions of the crop in Tanzania.

2.5.1 Diseases and insect pests

The most serious disease reported in the recent years is Fusarium wilt caused by *Fusarium udum* (A soil and seed borne fungus). Wilt incidence of up to 100% was reported in Kilosa district in 1988 cropping season which was a major pigeon pea constraint for the farmers' fields (Kiprop *et al.,* 2005). The disease was quite devastating for the local varieties of the crop than improved ones. The study done in Babati has shown that 96% of the farmer who grew local varieties of pigeon peas reported fusarium wilt in their farms (Shiferaw *et al.,* 2005) where as for the improved varieties (ICAP 00053 and ICEAP 00040) growers it was only 13% to 15% who reported the infestation of the wilt. Grain loses of up to 57% was reported by local varieties growers where as 3% to 4% of loses was reported by improved varieties growers of pigeon pea in 2002/03 growing season. Pod borers are the major pigeon pea pests in the study area; others are aphids, pod suckers, blister beetles, termites, pod bugs and pod flies (Shiferaw *et al.,* 2005). Other pathological problems are sterility mosaic disease (SMD), leaf spot (*Mycovellosiella cajani*), *Macrophomina* stem canker, rust and to a lesser extent powdery mildew (*Leveillulata urica*) (Prasanthi *et al*., 2009; Dialoke *et al*., 2010; Kamlesh and Choure, 2012).

The quality of seeds is highly affected by diseases, pests and mismanagement or poor post harvest handling practices of the seeds (FAO & ICRISAT 2015). Diseases kill the important germinating part of the seed making it ungerminable. Pests such as *Helicoverpa armigera* feed on pods which cause it to produce unhealthy seeds and hence decrease their vigour (Kapasi *et al.*, 2013).

Although there are measures for fusarium wilt control such as using the newly released resistant varieties, adoption of them by the farmers was very low, other measure like crop rotation was not practiced mainly because more than 90% of the available land is cultivated. Awareness of the disease was quite low to farmers such that the previously infested land were continued to be cultivated for planting the crop (Shiferaw *et al*., 2005).

2.5.2 Unstable pigeon pea seed system

As in other pigeon peas growing regions of Africa, the majority of farmers in Tanzania get their seeds mainly from informal channels which include farm saved seeds, seed exchanges among farmers and/or local grain/seed market. These channels contribute more than 96% of pigeon peas seed supply in Tanzania (Monyo and Laxmipathi, 2014). Because of unavailability and inaccessibility of the improved seeds, majority of farmers use their own saved seeds which are comparatively cheaper and readily available (Sintowe *at al.*, 2011).

2.6 Efforts to Improve the Production of Pigeon pea in Tanzania

So far, major effort has been centred in overcoming Fusarium wilt incidence by breeding for the disease resistant varieties such as Mali (ICEAP 00040), Tumia (ICEAP 00068) and Komboa (ICPL 87091) (Monyo and Laxmipathi, 2014). However, availability and accessibility of the improved varieties is a problem to most of the small scale farmers because private seed companies are not willing to invest in such crop seed business due to low returns (Sintowe *et al.,* 2011). This makes farmers to continue relying on their low quality local seeds.

2.7 Seed Quality

Seed quality is the possession of seed with required genetic and physical purity that is accompanied with physiological soundness and health status (Icishahayo *et al*., 2009). There are several advantages of using quality seeds which are:

- To ensure genetic and physical purity of the crops;
- To give desired plant population;
- Capacity to withstand the adverse environmental conditions and produce seedlings that are more vigorous;
- Fast growing and can resist pest and disease incidences to certain extent;
- Ensure uniform growth and maturity of pigeon peas and
- Develop root system that will be more efficient in absorption of nutrients and respond well to added fertilizer and other inputs resulting in higher yield.

Seed quality has different types of quality attributes (Ibid). These include the following; Physical qualities of the seed in the specific seed lot, Physiological qualities which refers to aspects of performance of the seed, Genetic quality which relates to specific genetic characteristics of seed variety, Seed Health which refers to the presence or absence of diseases and pests within a seed lot. Well-developed and high density seeds have higher quality. Seed physical integrity is related to mechanical harvest, seed cleaning, transportation and storage. Seeds without mechanical damage maintain high quality. Seed moisture content regulates all biological processes in seed.

In most cases farmers have been using their own saved seeds which are not certified hence their quality status are not known (FAO & ICRISAT. 2015). Farmers have been using high seed rates of seeds that are substandard which highly contributes to low production of pigeon peas. Since farmers use the stored grains for planting, sorting of seeds is mainly not common practice for most farmers making seeds to contain a lot of physical impurities (Mponda *et al.*, 2013).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Seed Sample Collection

One kilogram of farmer-saved pigeon pea seeds was collected from each farmer using the sampling procedures (Rita, 2013) for quality testing. All tests were performed at the African Seed Health Centre (ASHC) seed testing laboratories in Morogoro, following the International Seed Testing Association (ISTA, 2005a, b) and then results compared with minimum quality standards for pigeon pea seed certification for validation of quality standard as specified by Tanzania Official Seed Certification Institute (TOSCI) procedures (URT, 2007).

3.2 Seed Quality Test

The collected seeds were grouped according to post-harvest handling and treatment of seeds, cropping system and varieties. Working samples for laboratory tests were replicated as it is the rule for seed testing (ISTA, 2005a).

3.2.1 Purity test

From the collected seeds 300g portions were used for physical purity analysis with three replications. The components were separated into pure seed, inert matter, weed seed and other seeds and each component was weighed using an analytical balance. Finally, the percentage composition of the seed lot was calculated based on the weight of each component.

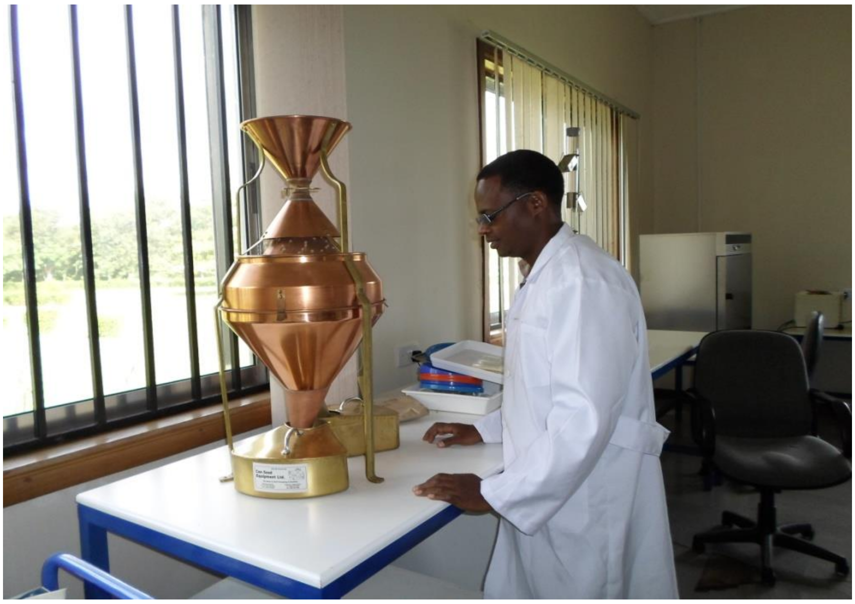

Plate 1: Pigeon pea seed samples mixing for purity testing

3.2.2 Moisture content determination

For this test, high constant temperature oven dry method (130-133ºC for about one hour) was used. The moisture content as a percentage by weight was calculated to one decimal place following the standard formula as specified by ISTA (2005a).

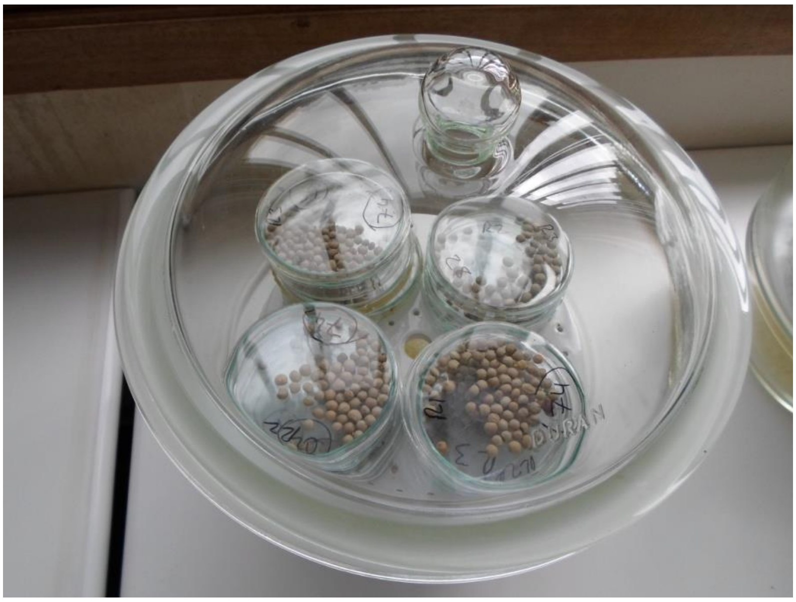

Plate 2: Moisture content determination by oven dry method

3.2.3 Germination capacity

For standard germination (SG) test, four hundred seeds from pure seed components of each sample were divided into four replicates of one hundred (100) seeds and each germinated using top of paper (TP) method. Seeds were then incubated at temperature of 25ºC; first and final counts were made on 4th and 10th days respectively after incubation as specified by ISTA. At the end of the SG test, germinated seeds were divided into normal and abnormal seedlings while un-germinated ones were grouped as dead seeds and the percentage of each component calculated. Germination percent was assessed as the percentage of seeds producing normal seedlings.

3.3 Seed Health Test

Seed samples were studied for the presence or absence of seed-borne fungi. Identification of different seed-borne pathogens was done by using a standard blotter method as described by (ISTA, 2005b). A pair of sterile white blotter papers of 8.5 cm diameter was soaked in sterile distilled water and placed in pre-sterilized Petri dish of 90 mm diameter. Ten seeds of test sample per Petri dish were then placed at equal distance on moist blotter in the Petri dish. Two hundred seeds were examined per each sample. The Petri dishes were incubated at 28ºC ± 2ºC under diurnal conditions. At the end of incubation period, each seed was thoroughly examined under different magnification of compound and stereo-microscopes for identification of fungal contamination. Identification was made based on morphological characteristics of the pathogens (colony characteristics, conidiophores, shape and septation of conidia and other structures) and comparison with appropriate literature. Percentage of infected seeds by individual fungal species was calculated for each sample following the ISTA procedures.

3.4 Correlation Analysis

Pearson's correlation analysis was performed to establish relationship between the intercepted fungal pathogens with quality attributes (Purity, Germination and Moisture content) of collected farm saved pigeon pea seeds.

3.5 Production Characteristics as Related to Farmer Saved Seed Quality

3.5.1 Description of the Study Area

The study was conducted in Babati and Karatu Districts in northern zone of Tanzania.

Babati District is in Manyara Region, located at 04°13′S 035°45′E, East Africa. The district covers an area of 606,900ha, a large proportion (10.5%) of which is covered by the water bodies of Lake Babati, Lake Burunge and Lake Manyara. About 90% of the population of Babati District live in the rural areas and depend on agriculture for their livelihood. Mixed crop-livestock, mostly maize-based systems are widely found in the district that are intercropped with varying species, such as common beans, pigeon peas and sunflowers, according to altitude and rainfall availability (Shiferaw *et al.*, 2005).

Karatu District on the other hand is located at 3° 20' 0" S, 35° 40' 0" E. It is bordered by the Ngorongoro District to the north, the Shinyanga Region to the west, the Monduli District to the east, and the Manyara region to the south and southeast. The District has an area of 102 573 ha arable land for cultivation which constitutes 31.1% of the total area. In 2015/2016 the District actual hectors cultivated were 48 197.1 ha for food crops and 27 782.5 ha of cash crops. Apart from growing other crops, about 95% of the farmers in the area also grow pigeon peas mainly for cash and in small amount for food (Shetto and Owenya, 2007).

3.5.2 Field data collection (farmer interview)

All pigeon pea growing villages from the two districts were listed and twenty (ten from each district) District selected. The villages that were involved are Orngadida, Qash, Endanoga, Gedamar, Galapo, Endagile, Mamire, Endakiso, Sangara and Riroda in Babati District and Kambi ya Faru, Getamock, Basodawish, Endamarariek, Rhotia, Qaru, Kansay, Endabash, Endanyawet and Ayalaliyo in Karatu District. In each village, four farmers were selected and visited in their homes based on significant production and accessibility or closeness to roads for easy sampling. Then each farmer was interviewed to gather several information about their seeds as stipulated below;

- Information about the cropping system(whether intercropped or sole cropped);
- Number of seeds they plant per hole (seed/hill);
- Whether they spray crop in the field or not;
- Whether they treat or don't treat their seeds before storage;
- The storage techniques they use (Containers, bags, or others); and
- Whether they sort or don't sort their seeds before storage.

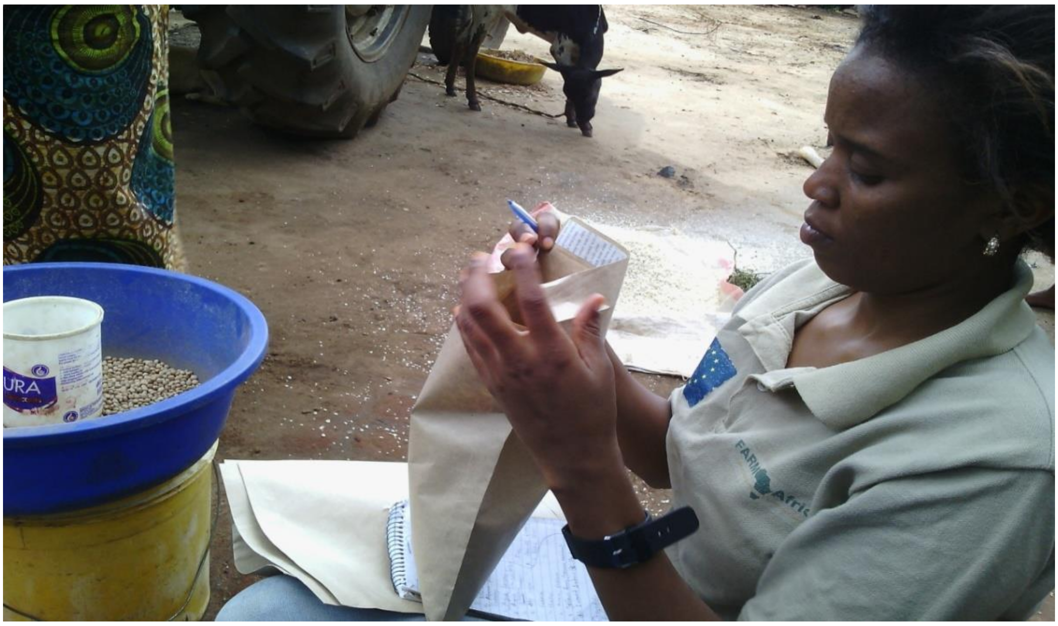

Plate 3: Pigeon pea seed samples collection in one of the village of Babati district

Plate 4: Pigeon pea seed samples store in bags (jute sacks/sulphate bags) in Karatu

3.6 Data Analysis

Descriptive statistical methods were used to compute means and percentages. Additionally to discern important patterns of influence, data collected relating physical quality attributes and post harvest handling practiced by farmers were grouped according to handling practices and subjected to analysis of variance. The analysis of variance (ANOVA) was performed using the Statistical Analysis stem computer software: GenStat. Treatment means were separated using Least Significance Difference (LSD).

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Results

4.1.1 Physical quality status of farm saved pigeon pea seeds in relation to different post-harvest handling techniques used by farmers

4.1.1.1 Quality status

Results of the various physical quality attributes of the pigeon pea farm-saved seeds in the survey area are presented in Tables 1 and 2. Overall in both Babati and Karatu Districts, very few of the samples (6 samples from Babati District equivalent to 15% and 5 samples from Karatu District equivalent to 12.5%) met the minimum standard for purity, which is 97% according to TOSCI. Majority of the samples, however, were of acceptable quality in terms of germination capacity. Out of 40 samples in Babati District it was only one sample that was sub-standard in germination, meaning that about 97.5% of the samples' germination capacities were TOSCI acceptable (70%). Similarly, in Karatu District, as many as 82.5% of the samples were TOSCI acceptable in terms of germination capacity.

As regards moisture content, in Babati District 24 samples equivalent to 60% of the samples had moisture content not exceeding 10% therefore they were of acceptable quality. This was followed by Karatu samples, with about 55% of the samples meeting the moisture quality standard. Combining germination, purity and moisture content; certification declaration for the farmers' seeds across the study area would be that about 92.5% of the samples were sub-standard, most of them due to failure in purity.

Table 1: Test results for physical quality attributes of pigeon pea seeds collected from the crop farmers in Babati District

Sample No.	Purity (%)	MC (%)	GERM (%)
1	89.9	10.3	97.0
2	74.5	9.3	97.0
3	87.4	10.3	82.0
4	95.5	11.3	85.0
5	89.4	10.0	96.0
6	93.4	8.3	93.0
7	92.5	11.0	82.0
8	90.6	10.0	94.0
9	96.5	8.7	76.0
10	91.2	11.7	94.0
11	84.9	11.0	87.0
12	92.8	11.0	77.0
13	85.9	8.3	86.0
14	92.9	10.3	96.0
15	89.9	10.0	76.0
16	97.2	10.0	94.0
17	94.3	8.7	85.0
18	84.1	7.7	91.0
19	95.4	10.3	77.0
20	96.8	9.7	75.0
21	93.2	10.7	83.0
22	88	8.7	95.0
23	90	9.3	93.0
24	92.7	8.7	62.0
25	94.8	8.3	97.0
26	97.4	11.3	89.0
27	88	9.3	70.0
28	86	9.0	95.0
29	92.1	8.7	76.0
30	85.2	9.7	76.0
31	96.3	10.3	76.0
32	98	8.7	81.0
33	86	9.7	74.0
34	98	12.0	93.0
35	97.8	11.0	84.0
36	92.3	11.3	74.0
37	88	11.3	95.0
38	92.5	9.0	82.0
39	97.2	9.7	94.0
40	91	9.7	75.0
TOSCI Standard[a]	97	10.0	70.0

Source: URT (2007)

Table 2: Test results for physical quality attributes of pigeon pea seeds collected from the crop farmers in Karatu District

Sample No.	Purity (%)	MC (%)	GERM (%)
41	97.7	9.3	98.0
42	77.7	7.7	77.0
43	85.1	9.3	70.0
44	94.1	11.3	86.0
45	92.8	9.3	86.0
46	93.1	9.7	62.0
47	95.4	11.0	95.0
48	90.0	10.3	68.0
49	95.9	10.3	84.0
50	88.2	10.3	83.0
51	96.9	11.7	84.0
52	92.5	9.7	68.0
53	93.5	9.7	72.0
54	97.3	8.7	81.0
55	84.0	11.3	70.0
56	98.4	9.0	79.0
57	89.7	11.7	66.0
58	96.3	9.0	71.0
59	97.4	10.3	84.0
60	92.3	10.3	77.0
61	94.2	11.7	67.0
62	90.0	11.0	77.0
63	82.7	9.7	89.0
64	89.4	9.0	95.0
65	94.7	10.3	69.0
66	81.4	8.7	95.0
67	97.7	10.7	75.0
68	89.9	9.7	81.0
69	89.3	9.0	69.0
70	92.7	10.7	90.0
71	84.6	8.7	85.0
72	93.1	10.3	87.0
73	93.5	9.0	87.0
74	94.0	11.0	75.0
75	95.1	8.7	72.0
76	89.1	10.3	78.0
77	95.5	11.0	97.0
78	89.3	9.3	98.0
79	93.3	8.7	78.0
80	88.9	9.0	92.0
TOSCI Standard	97.0	10.0	70.0

Source: URT (2007)

4.1.1.2. Handling practices

Table 3 shows the various post-harvest handling practices and proportion of farmers practising them from both Districts together with combination of storage techniques with treatment of the seeds against storage insects and sorting. Generally bag storage dominated against container storage. It was observed that 77.5% of farmers in Babati and 65% of farmer in Karatu Districts used bags to store their seeds. Frequencies of farmers treating their seeds against storage insects against those who did not were almost equal, whereby 52.5% of farmers in Babati and 55% from Karatu applied storage insecticides in their stored seeds/grains. Majority of farmers indicated that they were not practicing seed sorting. It was observed that only 17.5% of farmers in Babati and 35% from Karatu Districts were practicing seed sorting. Great majority of farmers who stored the seeds in bags were not sorting before storage, only 15% and 22.5% of farmers in Babati and Karatu Districts respectively did sort their seeds before storage in bags. While in Babati District 20% of farmers who stored their seeds in containers also treated them against storage insects, in Karatu District the same proportion (20%) who stored the seeds in containers did not treat them with insecticides.

Table 3: Post-harvest pigeon pea seed handling practices in Babati and Karatu Districts and proportion of farmers practicing them.

Handling practice	Babati District (%)	Karatu District (%)
Bag	77.5	65
Container	22.5	35
Treated	52.5	55
Untreated	47.5	45
Sorted	17.5	35
Unsorted	82.5	65
Bag-Treated	32.5	40
Bag-untreated	45	25
Bag –sorted	15	22.5
Bag – unsorted	62.5	42.5
Container-treated	20	15
Container-Untreated	2.5	20
Container-sorted	2.5	12.5
Container – unsorted	20	22.5

4.1.1.3 Physical quality in relation with post-harvest seed handling practices

Results relating physical quality of seeds and post-harvest handling practiced on the pigeon pea seeds used by farmers in Babati and Karatu Districts are presented in Tables 4 – 11.

Tables 4 and 5 show relation of the post-harvest handling practices upon the farm-saved pigeon pea seed with physical quality status. It can be observed that there is extensive variation of quality with handling practice, but it is difficult to discern the pattern of influence.

Further scrutiny of the data to establish relationship is presented in subsequent Tables 6, 7, 8, 9, 10 and 11. This scrutiny involved strenuous grouping of the data according to handling practice to have groups that were subjected to analysis of variance to establish statistically verifiable handling practice effects on the seeds' quality attributes.

Table 4: Post-harvest seed handling practices corresponding to laboratory physical seed quality in pigeon pea seed samples collected in Babati District

	Handling practices			Quality test results		
Sample No.	**Storage**	**Treatment**	**Sorting**	**Germination (%)**	**Purity (%)**	**MC (%)**
1	Container	Treated	Sorted	97.0	89.9	10.3
2	Bag	Untreated	Unsorted	97.0	74.5	9.3
3	Bag	Untreated	Sorted	82.0	87.4	10.3
4	Bag	Untreated	Unsorted	85.0	95.5	11.3
5	Container	Treated	Unsorted	96.0	89.4	10
6	Bag	Treated	Unsorted	93.0	93.4	8.3
7	Bag	Treated	Unsorted	82.0	92.5	11.0
8	Bag	Treated	Unsorted	94.0	90.6	10.0
9	Bag	Untreated	Unsorted	76.0	96.5	8.7
10	Container	Treated	Unsorted	94.0	91.2	11.7
11	Bag	Untreated	Sorted	87.0	84.9	11.0
12	Container	Treated	Unsorted	77.0	92.8	11.0
13	Bag	Treated	Unsorted	86.0	85.9	8.3
14	Bag	Untreated	Unsorted	96.0	92.9	10.3
15	Bag	Untreated	Sorted	76.0	89.9	10.0
16	Bag	Untreated	Unsorted	94.0	97.2	10.0
17	Bag	Untreated	Unsorted	85.0	94.3	8.7
18	Bag	Untreated	Unsorted	91.0	84.1	7.7
19	Bag	Treated	Unsorted	77.0	95.4	10.3
20	Bag	Treated	Unsorted	75.0	96.8	9.7
21	Bag	Untreated	Unsorted	83.0	93.2	10.7
22	Bag	Untreated	Unsorted	95.0	88.0	8.7
23	Bag	Untreated	Unsorted	93.0	90.0	9.3
24	Bag	Treated	Unsorted	62.0	92.7	8.7
25	Container	Untreated	Unsorted	97.0	94.8	8.3
26	Bag	Untreated	Unsorted	89.0	97.4	11.3
27	Bag	Untreated	Unsorted	70.0	88.0	9.3
28	Bag	Treated	Unsorted	95.0	86.0	9.0
29	Container	Treated	Unsorted	76.0	92.1	8.7
30	Bag	Treated	Sorted	76.0	85.2	9.7
31	Container	Treated	Unsorted	76.0	96.3	10.3
32	Bag	Treated	Unsorted	81.0	98.0	8.7
33	Bag	Treated	Sorted	74.0	86,0	9.7
34	Bag	Treated	Unsorted	93.0	98.0	12.0
35	Bag	Treated	Unsorted	84.0	97.8	11.0
36	Bag	Untreated	Unsorted	74.0	92.3	11.3
37	Bag	Untreated	Sorted	95.0	88.0	11.3
38	Container	Treated	Unsorted	82.0	92.5	9.0
39	Container	Treated	Unsorted	94.0	97.2	9.7
40	Bag	Untreated	Unsorted	75.0	91.0	9.7

Table 5: Post-harvest seed handling practices corresponding to laboratory physical seed quality test results in pigeon pea seed samples collected in Karatu District

	Handling practices			Quality test results		
Sample No.	**Storage**	**Treatment**	**Sorting**	**Germination %**	**Purity (%)**	**MC (%)**
1	Container	Treated	Unsorted	98.0	97.7	9.3
2	Bag	Untreated	Unsorted	77.0	77.7	7.7
3	Bag	Treated	Unsorted	70.0	85.1	9.3
4	Container	Treated	Sorted	86.0	94.1	11.3
5	Bag	Treated	Sorted	86.0	92.8	9.3
6	Container	Untreated	Unsorted	62.0	93.1	9.7
7	Container	Untreated	Unsorted	95.0	95.4	11
8	Bag	Untreated	Unsorted	68.0	90.0	10.3
9	Bag	Treated	Unsorted	84.0	95.9	10.3
10	Bag	Treated	Unsorted	83.0	88.2	10.3
11	Bag	Untreated	Unsorted	84.0	96.9	11.7
12	Container	Untreated	Sorted	68.0	92.5	9.7
13	Bag	Treated	Unsorted	72.0	93.5	9.7
14	Bag	Treated	Sorted	81.0	97.3	8.7
15	Bag	Untreated	Unsorted	70.0	84.0	11.3
16	Container	Untreated	Unsorted	79.0	98.4	9.0
17	Container	Treated	Sorted	66.0	89.7	11.7
18	Container	Untreated	Unsorted	71.0	96.3	9.0
19	Bag	Treated	Unsorted	84.0	97.4	10.3
20	Bag	Untreated	Sorted	77.0	92.3	10.3
21	Container	Untreated	Unsorted	67.0	94.2	11.7
22	Bag	Treated	Unsorted	77.0	90.0	11
23	Bag	Untreated	Unsorted	89.0	82.7	9.7
24	Container	Untreated	Sorted	95.0	89.4	9.0
25	Bag	Treated	Unsorted	69.0	94.7	10.3
26	Bag	Treated	Unsorted	95.0	81.4	8.7
27	Bag	Treated	Unsorted	75.0	97.7	10.7
28	Bag	Treated	Unsorted	81.0	89.9	9.7
29	Container	Untreated	Sorted	69.0	89.3	9.0
30	Container	Treated	Unsorted	90.0	92.7	10.7
31	Bag	Untreated	Sorted	85.0	84.6	8.7
32	Bag	Untreated	Sorted	87.0	93.1	10.3
33	Bag	Treated	Sorted	87.0	93.5	9.0
34	Bag	Treated	Unsorted	75.0	94.0	11.0
35	Container	Treated	Unsorted	72.0	95.1	8.7
36	Bag	Treated	Unsorted	78.0	89.1	10.3
37	Bag	Untreated	Sorted	97.0	95.5	11.0
38	Bag	Treated	Sorted	98.0	89.3	9.3
39	Container	Treated	Unsorted	78.0	93.3	8.7
40	Bag	Untreated	Sorted	92.0	88.9	9.0

Tables 6, 7, and 8 show a summary of analysis of variance results to show effects of handling practice on the physical quality attributes of the seeds measured. Table 6 shows effect of storage practice on germination, purity and moisture content, which are important physical quality attributes. Beyond any statistical doubt, storage practice influenced the tested physical quality attributes of germination and purity. Level of confidence for effect on germination was higher than 99.9% ($P < 0.001$) and on purity it was higher than 95% ($P < 0.05$).

Table 6: Mean sum of square Analysis of variance values for effects of storage practice on pigeon pea seed germination, purity and percent moisture content of the seeds

Source of variation	Df	Germination	Purity	Moisture content
Sample	21	353.64***	118.94***	3.488***
Storage	2	1585.53***	186.06*	0.884
Sample x Storage	42	326.99***	42	3.424***
Replication	3	0.401	821	0.068
Error	197	2.586	56.02	0.559

*** Significant at 0.001 * Significant at 0.05

Table 7 shows effects of storage pesticide treatment of the seeds as practiced by the survey area farmers. The treatment had significant effects on germination capacity and also significantly ($P < 0.001$) influenced the moisture content of seeds

Table 7: Mean sum of square analysis of variance values for effects of storage insecticide application on pigeon pea seed germination and other physical attributes

Source of variation	Df	Germination	Purity	Moisture content
Sample	20	330.96***	54.26	3.48***
Treatment	2	355.8***	102.36	7.53***
Sample x treatment	40	457.33***	86.15**	2.98***
Replication	2	0.079	412.21**	0.643
Error	188	2.473	46.07	0.64

*** Significant at 0.001 ** Significant at 0.01

Table 8 shows effects of seed sorting. The practice effect was highly significant (P < 0.001) on germination capacity and moisture contents of the seeds but not on purity

Table 8: Mean sum of square analysis of variance values for effects of seed sorting on pigeon pea seed germination and other physical attributes

Source of variation	Df	Germination	Purity	Moisture content
Sample	20	330.74***	79.57*	3.64***
Sorting	2	801.24***	52.82	9.35***
Sample x Sorting	40	388.2***	68.71	2.92***
Replication	2	0.496	615.57	0.07
Error	188	2.549	46.38	0.55

*** Significant at 0.001 * Significant at 0.05

Throughout the analyses of variance presented in Table 6, 7 and 8, the various samples collected from farmers demonstrated to be significantly different in the tested quality attributes, with some exceptions in purity. Interaction between sample and handling practice was also significant in most instances, again with some exceptions in purity.

Table 9, 10 and 11 show the patterns of influence of the handling practices on the quality attributes of the seeds. Table 9 present effects of storage where we see that bag storage was best practice in preserving germination capacity of the seeds, but this was only so in Babati. In Karatu District bag stored seeds were slightly poorer in germination capacity than seeds stored in containers.

Table 9: Mean physical quality test results of pigeon pea seeds as influenced by storage practice in Babati and Karatu Districts

Storage	Germination (%)	Purity (%)	Moisture content (%)
Container storage	80.8	93.6	10.1
Bag storage Babati	87.5	91.1	9.8
Bag storage Karatu	79.7	90.6	9.9
Mean	82.7	91.8	9.9
S.E. $\pm$	0.243	1.303	0.13
CV %	1.94	8.15	7.55
$LSD_{0.05}$	0.507	2.72	ns

Ns=non- significant

Table 10 presents influence of storage insecticide application on germination and the other tested attributes. Treated seeds in Babati District were significantly best (P < 0.05) in germination but these were awkwardly followed by the untreated seeds. Treated seeds in Karatu District were significantly poorer in germination capacity than untreated seeds. On moisture content, the untreated seeds were significantly poorer in quality than both of the treated seed categories.

Table 10: Mean physical quality test results of pigeon pea seeds as influenced by storage insecticide treatment of the seeds in Babati and Karatu Districts

Treatment	Germination (%)	Purity (%)	Moisture content (%)
Treated Babati	84.3	92.4	9.7
Treated Karatu	80.3	92.3	9.9
Untreated	82.6	90.2	10.3
Mean	82.4	91.6	10.0
S.E. ±	0.281	1.21	0.14
CV %	1.91	7.41	8.0
$LSD_{0.05}$	0.59	ns	0.29

Ns=non-significant

Table 11 presents influence of sorting on the physical quality expression of the seeds. Unsorted seeds in Babati were significantly best overall in germination but sorted seeds were significantly better (P < 0.05) in germination than the unsorted seeds in Karatu. Unsorted seeds of Karatu were also significantly poorer in moisture content based quality than the sorted seeds or unsorted seeds of Babati. Sorting did not show any significant effects on seed purity.

Table 11: Mean physical quality test results of pigeon pea seeds as influenced by practice of seed sorting in Babati and Karatu Districts

Sorting	Germination (%)	Purity (%)	Moisture content (%)
Sorted	81.6	90.2	9.7
Unsorted Babati	86.5	91.7	9.9
Unsorted Karatu	80.8	91.8	10.4
Mean	82.97	91.2	10.0
S.E. ±	0.247	1.213	0.13
CV %	1.92	7.47	7.4
$LSD_{0.05}$	0.52	ns	0.27

Ns=non-significant

4.1.2 Seed Heath

Results of micro-organisms specifically fungi infestation detected from the seeds used by farmers in the two districts where study was conducted are presented in Tables 12 and 13 for Babati and Karau Districts respectively and the incidence of each species detected from the samples presented in Table 14. Of greatest interest in seed health was *Fusarium udum* which is a serious pathogen of the crop and seed-borne. Four other *Fusarium* species (or belonging to *Fusarium* group) were also intercepted in the seeds. These were *F. moniliforme*, *F. pallidoroseum*, *F. equiseti* and *F. poae*. Other species of essentially saprophytic fungi detected were *Rhizopus spp*, *Penicillium spp*, *Cladosporium spp*, *Botrytis cinerea*, *Aspergillus flavus*, *Aspergillus niger*, and *Curvularia lunata*. Among the *Fusarium spp*, *F. moniliforme* appeared in greatest frequency (100% of samples in Babati and 97.5% of samples in Karatu Districts) followed by *F. pallidoroseum* and *F. equiseti* whose frequencies were respectively > 80%. In Karatu District, *F. moniliforme* was missing in one of the samples. Each sample in both Districts was infested with at least 7 of the fungal species. Least infested was sample number 14 from Gedamar and No. 27 from Mamire villages in Babati District. Nevertheless, sample No. 14 was still not free from *F. udum*. Samples free from *F. udum* were sample numbers 7, 11, 22, 24, 27, 30 and 31 in Babati District (Table 12) and numbers 25, 28, 33 and 37 in Karatu District (Table13).

Table 12: Microbial contamination of seeds of pigeon pea collected from farmers in various villages of Babati District

Sample No.	Village	*Rhizopus spp*	*Fusarium. moniliforme*	*F.poae*	*F.udum*	*F.equiseti*	*F.pallidoroseum*	*Penicillium spp*	*Cladosporium spp*	*Apergillus flavus*	*A.niger*	*Curvularia lunata*	*Botrytis cinerea*
1.	Orgadida	+	+	+	+	+	+	+	-	+	+	+	+
2.	″	+	+	+	+	+	+	-	-	-	+	-	-
3.	″	+	+	-	+	-	-	+	+	-	+	-	-
4.	″	+	+	-	+	+	-	+	+	+	-	-	-
5.	Qash	+	+	+	+	+	+	+	+	+	+	+	+
6.	″	+	+	+	+	+	+	+	+	+	+	+	+
7.	″	+	+	+	-	+	+	+	+	+	+	+	-
8.	″	+	+	-	+	-	-	-	-	-	+	-	-
9.	Endanoga	+	+	-	+	+	+	+	+	+	+	+	+
10.	″	+	+	-	+	-	+	+	-	+	+	-	-
11.	″	+	+	+	-	+	+	+	+	+	+	-	-
12.	″	+	+	+	+	+	+	+	-	+	+	+	-
13.	Gedamar	+	+	-	+	-	+	+	-	+	+	+	-
14.	″	+	+	-	+	-	+	-	-	+	+	+	-
15.	″	+	+	-	+	+	+	+	-	+	+	-	+
16.	″	+	+	-	+	+	+	+	-	+	+	+	-
17.	Galapo	+	+	-	+	+	-	+	-	+	+	-	+
18.	″	+	+	+	+	+	+	+	+	+	+	+	+
19.	″	+	+	+	+	+	-	+	+	+	+	+	+
20.	″	+	+	-	+	+	-	+	-	+	+	-	+
21.	Endagile	+	+	-	+	+	+	+	+	+	+	-	+
22.	″	+	+	+	-	+	+	+	+	+	+	+	+
23.	″	+	+	+	+	+	+	+	+	+	+	+	+
24.	″	+	+	-	-	+	+	+	+	+	+	+	+
25.	Mamire	+	+	+	+	+	+	+	+	+	+	+	+
26.	″	+	+	-	+	+	+	+	+	+	+	+	+
27.	″	+	+	-	-	+	+	+	-	+	+	-	-
28.	″	+	+	+	+	+	+	+	+	+	+	+	+
29.	Endakiso	+	+	-	+	+	+	+	+	+	+	+	+
30.	″	+	+	+	-	+	+	+	-	+	+	+	+
31.	″	+	+	+	-	+	+	+	+	+	+	+	-
32.	″	+	+	-	+	-	+	+	+	+	+	-	-
33.	Sangara	+	+	+	+	-	+	+	+	-	+	-	-
34.	″	+	+	+	+	+	+	+	+	+	+	+	+
35.	″	+	+	-	+	+	+	+	+	+	+	+	+
36.	″	+	+	-	+	+	+	+	+	+	+	+	+
37.	Riroda	+	+	-	+	+	+	+	+	+	+	+	+
38.	″	+	+	-	+	+	+	+	+	+	+	+	+
39.	″	+	+	-	+	+	+	+	+	+	+	+	+
40.	″	+	+	+	+	+	+	+	+	+	+	+	+

+ = intercepted, - = not intercepted

Table 13: Microbial contamination of seeds of pigeon pea collected from farmers in various villages of Karatu District

Sample No.	Village	*Rhizopus spp*	*Fusarium. moniliforme*	*F.poae*	*F.udum*	*F.equiseti*	*F.pallidoroseum*	*Penicillium spp*	*Cladosporium spp*	*Apergillus flavus*	*A.niger*	*Curvularia lunata*	*Botrytis cinerea*
1	Rhotia	+	+	+	+	+	+	+	+	+	+	+	-
2	″	+	+	+	+	+	+	+	+	+	+	+	+
3	″	+	+	-	+	+	+	+	+	+	+	+	+
4	″	+	+	-	+	-	-	+	-	+	+	+	-
5	Qaru	+	+	+	+	+	+	+	+	+	+	+	+
6	″	+	+	+	+	+	+	+	+	+	+	-	+
7	″	+	+	-	+	+	+	+	+	+	+	+	+
8	″	+	+	-	+	-	+	+	-	+	+	-	+
9	Kansay	+	+	+	+	+	+	+	+	+	+	+	+
10	″	+	+	+	+	+	+	+	+	+	+	+	+
11	″	+	+	+	+	+	+	+	+	+	+	+	+
12	″	+	+	+	+	+	+	+	+	+	+	+	+
13	Endabash	+	+	+	+	+	+	+	+	+	+	+	+
14	″	+	+	+	+	+	+	+	+	+	+	+	+
15	″	+	+	-	+	+	+	+	-	+	+	+	+
16	″	+	+	+	+	-	+	+	+	+	+	+	+
17	Endanyawet	+	+	+	+	+	+	+	+	+	+	-	+
18	″	+	+	+	+	+	+	+	-	+	+	+	+
19	″	+	+	-	+	+	+	+	+	+	+	+	+
20	″	+	+	-	+	-	+	+	+	+	+	-	+
21	Ayalaliyo	+	+	+	+	-	+	+	+	+	+	+	+
22	″	+	+	-	+	+	+	+	+	+	+	-	-
23	″	+	+	-	+	+	+	+	-	+	+	+	+
24	″	+	+	+	+	+	+	+	+	+	+	+	-
25	Kambi ya Faru	+	+	-	-	+	+	+	+	-	+	+	+
26	″	+	+	-	+	+	+	+	+	+	+	+	+
27	″	+	+	-	+	-	+	+	+	+	+	-	+
28	″	+	+	-	-	+	+	+	+	+	+	+	+
29	Basodawish	+	+	-	+	+	+	+	+	+	+	+	+
30	″	+	+	-	+	+	+	+	+	+	+	-	+
31	″	+	+	-	+	+	+	+	-	+	+	+	+
32	″	+	+	+	+	-	+	+	+	+	+	+	-
33	Getamock	+	-	-	-	-	-	+	+	+	+	-	-
34	″	+	+	-	+	+	+	+	+	+	+	+	+
35	″	+	+	-	+	+	+	+	+	+	+	+	+
36	″	+	+	-	+	+	+	+	+	+	+	+	+
37	Endamarariek	+	+	-	-	+	+	+	+	+	+	+	+
38	″	+	+	-	+	-	+	+	+	+	+	+	+
39	″	+	+	-	+	+	+	+	+	+	+	-	+
40	″	+	+	-	+	+	+	+	-	+	+	+	+

+ = intercepted, - = not intercepted

Table 14 shows extensiveness of the fungal infestation in the samples tested in terms of incidence equated with number of seeds infested out of 200 seeds tested in each sample. From the Table it can be observed that percent incidence for *F. udum* was 2% in Babati District and 3.1% in Karatu District. This was generally low even though frequencies of interception of the pathogen in the tested samples were high. Fungi whose observed incidences were highest were *Rhizopus spp* and *Aspergillus flavus*. Mean incidence averaged over the two Districts was about 19.7% for *Rhizopus* and 18% for *A. flavus*. Species with lowest incidence was *F. poae* (0.9%) followed by *F. udum* (2.5%).

Table 14: Fungal species intercepted in samples of pigeon pea seeds collected from farmers in Babati and Karatu Districts and their incidences

Fungal species intercepted	Incidence		
	Babati District	Karatu District	Mean
Fusarium udum	2.0	3.1	2.55
F. moniliforme	8.5	9.6	9.05
F. poae	1.1	0.7	0.9
F. pallidoroseum	6.0	6.7	6.35
F. equiseti	4.5	3.5	4.0
Rhizopus spp	16.1	23.2	19.7
Aspergillus flavus	15.7	20.3	18.0
Penicillium spp	10.1	12.3	11.2
Aspergillus niger	10.1	13.0	11.55
Cladosporium spp	7.6	13.7	10.65
Curvularia lunata	3.5	2.3	2.9
Botrytis cinerea	3.2	3.7	3.45

4.1.3 Relation of intercepted seed borne fungi with germination and other physical attributes of the collected seeds

Table 15 relates fungal incidences of seed infestation with physical quality attributes of seeds tested during this study. No very conclusive observations, however, have been realized on expected relationship between infestation and quality. Established correlation coefficients showed in-existence of any significant ($P \leq 0.05$) relationship between germination capacity of the seeds and microbial infestation (incidence).

Among the physical quality attributes significant correlations existed only between Purity and incidence of *Cladosporium spp* (r = 0.274*) and between Moisture content and *F. pallidoroseum* (r = 0.249*). The rest of significant correlations were between the fungal species amongst themselves. All of these correlations were positive. Correlations between *A. flavus* and *Penicillium spp*; between *F. equiseti* and *F. moniliforme*; between *B. cinerea* and *A. flavus*; *B. cinerea* and *F. equiseti*; *C. lunata* and *F. equiseti*; *C. lunata* and *B. cinerea*; and between *F. poae* and *C. lunata* were highly significant ($P < 0.01$). *F. udum* did not have significant correlation with any of the physical quality attributes nor with any of the other fungal species.

Table 15: Correlation between physical quality attributes and fungal species incidences, and amongst the fungal species infesting tested pigeon pea seeds

	PURITY	M.C.	GRMNN	RHIZOP	F-MNLFM	PENCLM	F- PAL	CLODOSP	A-NGR	A-FLVS	F-EQST	BCNR	CVLNT	FPOAE	F-UDUM
PURITY	1.000														
M.C.	0.262*	1.000													
GRMNN	-0.080	0.046	-1.000												
RHIZOP	-0.088	-0.104	-0.011	1.000											
F-MNLFM	0.124	0.165	-0.033	0.040	1.000										
PENICLM	0.113	-0.038	-0.010	0.059	0.217	1.000									
F-PAL	-0.009	-0.249*	0.021	-0.073	0.220	0.247*	1.000								
CLDOSP	0.274*	-0.015	-0.052	0.135	0.185	0.037	0.147	1.000							
A-NGR	-0.004	0.158	0.010	0.150	0.111	0.248*	0.078	0.081	1.000						
A-FLVS	0.038	-0.141	-0.083	0.211	0.053	0.313**	0.267*	0.129	0.192	1.000					
F-EQST	0.092	-0.109	-0.099	0.012	.341**	00.134	0.202	0.005	0.108	0.119	1.000				
B-CNREA	0.092	-0.144	-0.113	0.108	0.129	0.197	0.271*	0.246*	0.290*	0.363**	0.308**	1.000			
C-LNATA	0.139	-0.121	0.128	0.066	0.177	0.259*	0.070	0.150	0.197	0.089	0.302**	0.308**	1.000		
F-POAE	0.039	-0.125	0.045	0.062	0.214	0.207	0.155	-0.081	0.054	0.089	0.247*	0.183	0.398**	1.000	
F-UDUM	0.195	-0.061	-0.077	0.028	-0.071	0.049	-0.078	0.017	0.112	0.178	-0.185	0.108	-0.097	-0.009	1.000

Number of observations: 80 * Significant at 0.05 level ** Significant at 0.01 level
GRMNN=Germination, RHIZP=Rhizopus, F-MNLFM= *Fusarium moniliforme*, PENCLM=Penicillium, F-PAL=Fusarium pallidoroseum, CLDOSP=Cladosporium, A- NGR=*Aspergillus niger*, A-FLVS=*Aspergillus flavus* , F-EQST=*Fusarium equiseti* , BCNR=*Botrytis cinerea* , CVLNT=*Culvularia lunata*, FPOAE=*Fusarium poae* F-UDUM=*Fusarium udum*

4.1.4 Description of the production characteristics as related to farmers own saved pigeon pea seeds

Results for the pigeon pea crop production characteristics according to the study survey are summarized in Table 16. Overall, majority of the interviewed farmers were planting seeds of local varieties. In Karatu district as many as 70% of the farmers indicated that they were using local varieties, against 30% that were using improved variety of the pigeon pea seeds. In Babati District, 62.5% used local varieties.

Sowing practice for pigeon pea was usually multiple seeds per hole, the number of seeds sown per hole was found to range from 3 to 5 seeds per hill in the surveyed area. Majority of farmers in Babati District (35%) were planting 3 seeds per hill while in Karatu District 45% of farmers were planting 4 seeds per hill.

One of the commonest features of pigeon pea cultivation is sowing the crop as an intercrop companion, usually with maize. Overall, majority of the farmers were practicing intercropping when sowing the pigeon pea crop. As many as 95% of farmers in Babati District were sowing the crop intercropped with maize. Similarly, for Karatu the proportion of farmer who intercropped pigeon pea with maize reached 82.5% just little lower than Babati. In contrary about 17.5% of the farmer in Karatu District practiced sole cropping system against 5% of farmers in Babati District.

The study has shown that insect pest control in the field is a remote activity in pigeon pea cultivation especially in Karatu District. It was observed that only 5% of farmers in Karatu and 32.5% in Babati Districts sprayed the crop in the field with insecticides. Post-harvest, on the other hand, almost equal proportion of farmers was observed between those who treated their seeds before storage against those who did not. It was observed that 52.5% of farmers in Babati District treated their crop with storage insect pest against 47.5% who did not. In Karatu District, 55% of farmers treated their seeds against 45% who did not treat them. The type of chemicals used to protect seeds against storage insects were mainly in form of powder or dusts that was mixed with seeds before storing them in either bag or container.

The predominant storage techniques of harvested grains were use of bags against the alternative using containers such as drums, metal tins or plastics buckets. It was observed that 77.5% and 65% of farmer used bags against 22.5% and 35% who used containers in Babati and Karatu Districts respectively.

Sorting of seeds was not a common practice across the study area. Only 17.5% in Babati and 35% in Karatu districts sorted their seeds.

Table 16: Percent distribution of various pigeon pea production characteristics among different growers in Babati and Karatu Districts

Characteristics	Characteristics variables	Distribution	
		Babati District	Karatu District
Variety used	Improved	37.5	30.0
	Local	62.5	70.0
Sowing practice of seeds	3 seeds per hill	35.0	32.5
	4 seeds per hill	32.5	45.0
	5 seeds per hill	32.5	22.5
Cropping system	Intercropping	95.0	82.5
	Sole cropping	5.0	17.5
Insecticide spraying	Sprayed	32.5	5.0
	Unsprayed	67.5	95.0
Storage techniques	Container	22.5	35
	Bag	77.5	65
Treatment against storage insects	Treated	52.5	55.0
	Untreated	47.5	45.0
Sorting farm saved seeds	Sorted	17.5	35.0
	Unsorted	82.5	65.0

4.2 Discussion

4.2.2 Physical quality status of the seeds

It seems from the study results that farmers can hardly achieve certification of quality standard for purity and to variable extent moisture content of their seeds in terms of commercialization. It is more natural, however, that so long as they save the seeds for subsequent season planting, they strive and are experienced to safeguard germination capacity of the seeds. This may explain why the tested seeds samples were better in achieving minimum standards for germination (example 97.5 % of samples in Babati District). Many farmers, however, may not be aware that proper drying of seeds is one of strategies to safeguard germination; otherwise high certification standard for germination would be always alongside high standard for moisture content. One important characteristic of moisture content is, however, equilibrial fluctuation with weather (exposure to air moisture content) and this depends on storage practice and packaging containers of the seed.

Among the three quality attributes, however, germination can be considered to be more critical. Under normal circumstances the level of germination reached in a seed test (for non-dormant seeds) cannot be improved. It is a biological threshold phenomenon. In the contrary, quality of seed based on purity and moisture content can be easily improved by cleaning (purity) and drying (moisture content).

4.2.3 Post-harvest handling

Storage, insecticide application and sorting of seeds as variably practiced by farmers are indeed of paramount significance in safeguarding quality of seed or its potential worth for sowing. The study has shown that especially germination was consistently significantly influenced by the three post-harvest handling practices. Germination is a delicate quality component of seed that presents a biological threshold between aliveness and death of the embryonic plant in the seed. Definitely, therefore, improper environment created by storage practice such as dampness, heating, access and multiplication of storage insect pests, will adversely influence ability of the seed to retain germination. Attack by storage insect pests is particularly important in maintaining seed value of grain. Insect damage on seed usually progresses towards destruction of the seed embryo. Once the embryo is damaged germination of the seed is at stake depending on extent of the damage. Treatment of seed with protective chemical substances as it has been demonstrated by majority of farmers in the study area is an un-avoidable practice.

There is evidence from data generated during this study that there is significant difference of influence of post-harvest handling practice between Karatu and Babati Districts. Even though purity and moisture content of seeds did not show significant differences between the two Districts no matter what was handling practice tested, germination capacities of seeds from the two Districts in relation to handling practice were consistently different ($P \leq 0.05$). Germination capacities of seeds from Babati were all the time statistically better than those from Karatu whenever there was comparison between the two Districts. That is, bag stored, treated and unsorted seeds in Babati respectively were significantly better in germination capacity than their counterparts in Karatu. Why Karatu samples germination capacities were lagging behind may not be easily explained. Perhaps there may also be significant environmental differences. When seeds were unsorted, which presents essentially no difference in intricate implementation of the practice; still seeds from Babati were significantly much better in germination. As regards storage, bag storage was observed to predominate throughout the study area. Bags are cheaper and more convenient to handle. Bags need smaller space in the store and can be easily arranged and overlapping each other, something that is not easy for containers since they are of different shapes and need more space.

4.2.4 Intercepted seed borne fungi and their relation to the quality attributes of farm saved seed

Fungal infestation may reduce or influences physical quality of the seed especially germination. It is usual to expect microbial reduction of seed germination capacity; in the other way round high seed moisture content could be expected to increase frequency and incidence of fungal infestation of seeds. It is also possible that presence of several species of fungi in the seed may influence incidences of the fungi amongst each other.

Even though incidence within the tested seed samples was generally low, prevalence of F. *udum* in the study area was high. More than 85% of the farmer-collected seed samples throughout the study area were found to contain the pathogen. *F. udum* is the most important known pathogen of pigeon peas and is seed-borne and soil-borne. Because of its potential to be transmitted through seed it is of great seed health significance.

A total of 12 different fungal species or groups of species were detected during this study with a minimum of seven species or groups of species in each sample. In other words, no sample was found to be infested with less than 7 different fungi. *Rhizopus spp* was most abundant, appearing in all samples. None of the detected fungi other than *F. udum* is of any serious seed health significance. Apart from *F. udum*, other fungi reported to be pathogenic in pigeon pea according to Sheela (2016) include *Colletotrichum cajanae*, *Diplodia cajani*, *Macrophomina phaseoli*, *Phoma cajani*, *Phaseolus manihotis*, *Phyllostica cajani*, *Phytophthora spp*, *Cercospora spp*, *Corticium solani*, *Leveilula taurica*, *Rhizoctonia bataticola*, *Rosellinia spp*, *Sclerotium rolfsii* and *Uredo cajani*; economic damages of which is reported to be negligible (Ibid). Furthermore, there is one bacterial species, *Xanthomonas cajani*, reported to cause disease in pigeon pea; and two viral infections: Sterility mosaic virus and Yellow mosaic virus (Ibid; Duke, 1981). Several species or groups of species detected during this study have been detected in pigeon peas previously. Sheela (2016) reported detection of 32 different species of fungi belonging to 15 genera, from 10 samples of pigeon pea seed collected from seed market. Among those are some species which have also been currently detected during this study. These are: *F. moniliforme*, *F. equiseti*, *Penicillium spp*, *Cladosporium spp*, *A. flavus*, *A. niger* and *Rhizopus spp*.

The observed incidences of the various fungi in the tested samples must naturally have meaning and implications. Most often, however, meaning and implications can only be predictable (predicted syntheses). Actual implication may be a matter of more research. Comparatively very high incidence of highly saprophytic fungi like *Rhizopus spp*; for example, may simply mean that the seeds were having high quantities of plant debris particles some of them decaying or decayed. This simply means purity was low and inert matter present was mostly plant debris. Indeed purity was low and sub-standard for the great majority of the samples. Considerably also high incidences of the storage fungi *A. flavus, A. niger* and *Penicillium spp*; may imply that the seeds reached the stores in considerably dry condition, drier than conditions that would support field inhabiting saprophytes which need wetter conditions. Under dry store conditions, field fungi like *Fusarium spp*; *Cladosporium, Curvularia* and *Botrytis spp* would not thrive competitively very well with the more dry condition-adapted storage fungi. In another prediction, presence of *Botrytis cinerea* in some of the samples may suggest that among intercropping practices there was intercropping with sunflower (*Helianthus annuus*). *B. cinerea* is an important pathogen of *H. annuus* and in presence of infection of the crop with *B. cinerea*, intercropping may be a source of plant debris particles with *B. cinerea* accompanying the pigeon pea seeds.

Correlation analysis, nevertheless, did not show very pronounced association between incidence of the seed infesting microflora and quality attributes of the seeds. Seemingly the microflora did not influence germination; only significant correlations existed between *Cladosporium spp* and purity; and between *F. pallidoroseum* and moisture content. Ideally high purity would discourage incidences of the debris-loving fungi, since there would be less inert matter. Consequently therefore predictable significant correlation would be negative. Contrarily the correlation was positive, meaning that increasing cleanness of seeds increased incidence of the fungus *F. pallidoroseum*. Ironically here it may be suggested that it is seed purity that is dependent variable, that the purity is increased by increasing incidence of the fungus. This may be sensible if we say that the microbe upon its saprophytic activity on decaying plant inert matter increases the pure seed fraction of seed purity.

Predictions may also be said about observation that all observed significant correlations among incidences of the different fungi were positive. This eliminates any existence of competitive growth or infestation of the seed by the fungi and contrarily suggests synergistic action. It may be indeed assumed that the fungi excreted combined damage or stress on the seed and each microbe's weakening ability of the seed tissues to resist colonization by the fungus increased opportunity for the other microbe to establish.

4.2.1 Production characteristics

Production characteristics reported from the survey relate to some extent with quality of the seed. It was found from the study, for example, that majority of farmers were using seeds of local varieties. Use of local informal varieties is an important avenue towards use of sub-standard quality seed, because there usually are no any measures to control quality of such seeds. Such are the same farmers who plant several seeds per hill because of suspicion of quality status of the seed. When majority of the farmers plant as many as 4 seeds/hill, it is a reflection of bad occasional experiences of poor germination of the seeds in the field.

Having majority of farmers using local varieties is common especially for a crop like pigeon pea. Many commercial seed companies cannot profitably invest in such crop seeds because of low and unpredictable demand of the seeds. Low demand on the other hand can be attributed to popularity of the crop among consumers and low adoption rate of released improved varieties. With exception of a small export market and a limited purchase by local domestic commercial food processors; pigeon pea in Tanzania is essentially a subsistence crop. Important strategies of subsistence crop producers include ability to source the seed on their own therefore local traditional varieties or at most seed saving. This greatly accounts for low adoption rates of improved crop varieties in subsistence or predominantly subsistence economies (Shiferaw *et al.,* 2005).

Another very important production characteristic reported from the survey was intercropping, which almost all farmers (nearly 91.3%, averaged over both districts) were practicing. Perhaps unknowingly and predominantly based on other benefits of intercropping (increased land productivity, increased diversity of products thus meeting dual demand of both intercrop components [or in other words more nutritional security], improving soil fertility), farmers exercising intercropping were also averting potentials of disease infestation of the crop; and especially infection with *Fusarium udum*. (Sheela, 2016) reports that intercropping pigeon pea with cereals specifically sorghum reduces the wilt problem caused by *F. udum*. This means it potentially reduces seed-borne inoculum of the disease. Post-harvest handling practices reported as production characteristics are much more directly related with seed quality.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

This study has shown that majority of the seed samples collected and hence being used by farmers posed a hazard of transmitting *Fusarium udum.* Only few samples from both Districts were free from the infectious pathogen; or in other words majority of the farmers′ farm saved seeds were potentially hazardous.

Additionally the study showed that great majority of seed samples were substandard in purity according to commercial seed quality control criteria.

Even though farm-saved seeds may be localized with the practicing farmer or within a restricted locality, generally it is suggested that there should be more study on scenarios of farmers′ seeds and quality. It is further suggested that in those areas where seed borne pathogens are endemic and farm-saved seeds is predominant farmers' awareness on Fusarium wilt disease should be created. It is also suggested that farmers should be trained how to reduce seed transmission of the diseases at least by rouging the infected plants in the field and selective harvesting the crop to be used as seed.

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