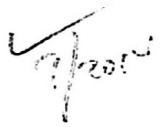
# THE EFFECT OF SEED FACTORS AND THE DURATION SEED REMAINS IN SOIL BEFORE THE ONSET OF RAINS ON ESTABLISHMENT OF MAIZE AND SORGHUM



BY

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**ABSTRACT**

A study was undertaken to: (a) assess the seed quality in commercial and farmers planting seed, (b) monitor the extent of seed ageing in storage and (c) investigate the effect of length of time seed remain in soil before onset of rains on establishment of maize (*Zea mays* (L) and sorghum (*Sorghum bicolor* (L).

Seed of three cultivars of maize (Staha, TMV-1, and Kito) and one sorghum cultivar (Tegemeo) were bought from Tanzania Seed Company (TANSEED), Morogoro branch, and from farmers around Morogoro Municipality. The bought seed was stored alongside TANSEED and farmer's seed. Initially, seed samples from each lot and each farmer, were taken to the laboratory for refrigeration to minimize ageing and hence to serve as control. Acquired seed was initially subjected to a germination test to assess its quality as a planting material. Germination test were conducted in a sandbox set at a matric suction of 1kPa.

The study on the effect of length of time seeds remain in soil before the onset of rains on establishment was conducted both in glasshouse and in the field using high, medium and low vigour seeds. High vigour seeds were the fresh / unaged seed samples from the seed lots. Medium and low vigour seeds were obtained by artificial ageing of fresh seed for 2 and 3 days respectively. Planting, both

in the glasshouse and in the field was done at an interval of 3 days, that is 0, 3, 6, 9, 12, 15 days. Watering was on the 15$^{th}$ day with an equivalent of 20mm of rainfall.

Seeds from TANSEED had initial germination percentage ranging from 93 to 100%, (maize) and 92 to 96% (sorghum). Seeds from farmers had germination percentage varying from 64 to 99% (maize) and 8 to 65% (sorghum). Overall sorghum seeds from TANSEED had relatively higher germination capacity than those from farmers. Seeds from farmers had high initial seed moisture content (SMC) than commercial seed. Sorghum had higher SMC than maize irrespective of the source. Initial SMC was about 10 and 11% for maize and sorghum respectively. At the end of the study, SMC had increased to an average of 12 and 14% for maize and sorghum respectively.

Time to 50% germination ($T_{50}$) increased with storage time for seeds obtained from TANSEED. $T_{50}$ values (in days) for maize cv Staha lot A were 2.2, (initially), 2.4 (after one month) and 2.7 after two months). Seeds from farmers showed no consistent trend.

In both field and glasshouse studies, sorghum seeds emerged earlier than maize seeds. Sorghum seeds started emerging 3 days after watering whereas for maize emergence started on the 4$^{th}$ day.

The length of time seed remained in the soil (dry

planting) had no effect on percentage emergence in the glasshouse experiment. Under field conditions percentage emergence decreased with the length of time seed remained in soil before watering.

High vigour maize seeds had relatively higher proportion of seeds which emerged than the other two vigour categories. In sorghum, medium and low vigour seeds performed better in terms of emergence than high vigour seeds.

The average shoot length for maize 10 days after watering varied from 157mm to 238mm and 90.7mm to 248mm for the glasshouse and field experiments respectively. Sorghum seedlings grown in the glasshouse had mean shoot lengths varying from 121mm to 172mm and the mean values recorded in the field varied from 63mm to 101mm.

## DECLARATION

I BARTHOLOMEW DONAT TARIMO, do hereby declare to the SENATE of Sokoine University of Agriculture that this dissertation is my own original work and it has not been submitted, in any other University for a degree award.

Signature.....

Date.....

## COPYRIGHT

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## LIST OF ABBREVIATIONS

AOSA = Assocation of Official Seed Analysis

HV = High Vigour

ISTA = International Seed Testing Association

LV = Low Vigour

MV = Medium Vigour

NORAD = Norwegian Agency for International Development

RH = Relative Humidity

SAT = Semi Arid Tropics

SMC = Seed Moisture Content

TANSEED = Tanzania Seed Company

TMV-1 = Tanzania Maize Variety

# CHAPTER ONE

## 1.0 INTRODUCTION

The desired end in crop production and silviculture is a high yield of high quality produce. To this end a good start is essential. A good start for plant populations grown from seed implies rapid, uniform and complete germination. The achievement of these ideals depends on a suitable environment for crop establishment and growth on one hand, and on the genetic, physiological and physical nature of the seeds on the other (Woodstock,1976).

Agricultural production is the principle source of well being for eight out of ten persons in African countries (Mascarenhas 1982). Frere (1982) estimated that 65% of African population is actively engaged in agriculture rising to more than 75% in 28 countries.

Crop establishment is a part of crop production system, it is the foundation on which all other factors affecting final crop yield are dependent (Hooke, 1987). Causes of poor establishment are complex involving interaction of seed, soil, climate, machinery management and soil flora and fauna factors (Rwehumbiza, 1994).

Most of the farmers in developing countries including Tanzania, suffer the problem of poor establishment of crops in the field leading to sub optimal plant stands, this is one of the major drawback of crop production in the Tropical and subtropical areas (Rwehumbiza, 1987).

Agronomically, one of the greatest hazards in agricultural production is sowing seeds which do not have the capacity to produce an abundant yield of the required cultivar. Planting seeds which possess those physiological traits for rapid, uniform emergence and optimum number of maturing plants (high germinability and vigour) is one of the surest ways of improving agricultural production (Mashauri, 1993).

Decrease in seed planting quality has been attributed to genotypic factors and/or to deterioration during seed development, harvesting, processing and storage leading to viability and vigour loss of the seeds. This may be due to degradation of cellular systems and functions, including membranes, nucleic acids and cellular organelles (ISTA, 1987).

Some of the consequences of seed deterioration are reduction in field emergence and stand establishment, retarded plant growth and reduced grain yield (Edje and

Burris, 1970; Heydecker, 1977; ISTA, 1987 ). The effect on stand establishment as influenced by emergence is one of the critical factors affecting grain production in cereals (Roberts, 1972; Pollock and Roose, 1972; Heydecker, 1977).

Maize (*Zea mays* (L) and Sorghum (*Sorghum bicolor* (L) Moench) are both important crops in the semi arid tropics (SAT). A number of studies have shown that their successful establishment may be limited by poor germination or poor emergence due to high temperature, moisture stress and poor seed quality (Gurmu and Naylor, 1991).

Seed viability and vigour are considered the major components and the most widely accepted parameters for assessing seed quality. Germination testing has become the universally accepted method for determining seed viability (ISTA, 1985). Seeds placed into storage will undergo natural ageing (Roberts, 1972) during storage time, that the vital systems and functions of the cell membranes are progressively impaired until they become incapable of supporting the resumption of growth.

Unsatisfactory emergence and establishment may occur because of a number of environmental constraints. Example of constraints include inadequate or excess moisture, unfavourable pH, high temperatures, soil-borne pathogens, soil crusting on silt soils, poorly prepared seedbeds or deeper planting (Powell, 1988). The impact of these adverse conditions can be severe and economically very damaging when low vigour seeds are planted. Apart from decline in the overall yield as a consequence of poor stand resulting from poor emergence (Hampton and Scott, 1982), emergence failure may occur, necessitating resowing, and this could mean a delay in harvest,resulting in a fall in market prices and lower profits from the harvest (Matthews and Powell, 1986).

As there is variability in vigour of individual seed (high, medium, low vigour and dead seeds) in a seed lot, variability in emergence rate is expected. The late emerging seedlings are at a competitive disadvantage and may result in weaker plants of doubtful survival until maturity (Tseng and Lin, 1962; Webster, 1966). The surviving medium or low vigour seedlings will inevitably cause variability in uniformity during plant growth and development (Perry, 1980; Adegbuyi and Burris,1989; Egli *et al*, 1990; Te Krony and Egli, 1991). This can potentially affect dry matter accumulation by plants and

thus potentially influence seed production.

Much research work has also been pursued in a quest of assessing the effect of seed vigour on seed production. Some research findings (Funk *et al*; 1962 Camargo and Vaughan, 1973; Burris, 1975) indicate that vigour effects may be carried over to influence grain yield. However, whether the reduced yield is due to seed vigour effect *per se*, or is simply because of reduced plant population is questionable. There is growing evidence showing that when plant population is not a factor, there are negative or no effects of seed vigour on grain yield (Johnson and Wax, 1981; Adegbuyi and Burris, 1989). Factors such as genotypic diversity, variability in vigour levels of the seed lots used, environmental interactions, and experimental techniques employed might be responsible for these conflicting seed vigour results.

Generally, loss of viability and seed vigour may result from deterioration process involved during seed ageing both pre and post-harvest. Seed ageing is now considered as a major cause of reduced vigour, germination rate and capacity as well as delayed emergence and poor field establishment in many crop species (Powell and Matthews,1984).

Planting can be done during the dry condition or after the first rain(s) when the soil is sufficiently moist. Dry planting is risky in the sense that seeds may deteriorate fast in the hot and humid soil conditions and thus may establish poorly or fail to germinate when rains finally come. Planting after the first rains also has drawbacks. Determining the amount of water from a single rainfall event which would be sufficient for germination and emergence of the sown seeds under a set of soil and weather conditions is usually complex. Prolonged dry spells between rainfall events often lead to germination failure of sown seeds or death of emerging seedlings due to water stress (Rwehumbiza,1994).

Because of erratic nature of rainfall in SAT, some farmers practice dry planting. The seed placement is done a week or two before the onset of the rains. Some seeds imbibe insufficient water and deteriorate. The seed vigour and the duration seed remains in the soil are factors which can greatly affect crop establishment, hence the need to be carefully studied. Seed can be of high vigour, but if remains too long in the soil before the onset of the rain, it will fail to germinate.

## 1.1 PROBLEM STATEMENT

The problem of ensuring proper germination of planted seed and subsequent establishment of seedlings is of general importance in agriculture (Hillel, 1972). On an individual farm, establishment difficulties may represent total crop failure in one season or insignificant losses in another. Establishment as a part of the crop production system, is a foundation on which all other factors affecting final crop yield are dependent (Hooke, 1987).

Low vigour seed succumb easily to adverse environmental conditions common in the SAT including Tanzania. The vigour of the seed remains an establishment problem since there is no vigour test in many countries before seed sowing. Planting of low vigour seeds is still wide spread in developing countries (ICRISAT, 1990).

In Tanzania where the main source of seeds is the TANSEED, and the storage conditions are not ideal (high temperature, relative humidity and seed moisture content) seed deterioration cannot be ruled out. Marketed seeds are sometimes stored for 2 - 3 seasons and that may be too long. This necessitate for the study of seed vigour as a factor which may affect crop establishment.

The duration the seed can stay in the soil before onset of rains is another crucial factor affecting establishment. There is no research that has been done to investigate the duration for which dry planted seeds (low, medium and high vigour) can stay in the soil before the onset of rains and still establish satisfactorily .

Timing of rainfall in the Semi Arid Tropical (SAT) is erratic and its amount is highly variable from year to year. Thus deciding on when to plant is a major challenge to the farmer. Therefore this study was set up with the following objectives:

## 1.2 OBJECTIVES

1. To determine the range of quality (vigour) of planting material (maize & sorghum) from commercial and farmers.

2. To assess the extent of (maize & sorghum) seed deterioration in storage.

3. To investigate the effect of the length of time seeds remains in the soil before onset of rains on establishment.

# CHAPTER TWO

## 2.0 LITERATURE REVIEW

### 2.1 Seed

A seed is a highly sophisticated, self contained living system. As a successful performance of the seed is related to its quality, it is important that this quality be preserved. In order to maximise its chances of producing a successful plant it needs to be treated with care during production, harvesting, processing and storage (Mashauri, 1993).

For many agricultural and horticultural crops, specified plant populations are recommended for maximising yield and/ or quality (Hampton and Coolbear, 1990). The first prerequisite in achieving the above goal is the use of seeds which possess those physiological traits for maximum yield and/or quality of the required cultivar. However, because of the interplay of many deteriorative factors affecting the seeds, from the time of inception at flowering of the parent plants until they germinate, emerge and establish in a complex soil environment, availability of such high quality seeds may become a limiting factor.

### 2.1.1 Standard germination and field emergence

The main method for determining the planting value of seeds and hence their value to producers, is seed testing for various aspects of seed quality. Seed viability is considered the major component and most widely accepted parameter for assessing seed quality and germination testing has become the universal method for determining seed viability (ISTA, 1987). The test reports the percentage of normal seedlings, abnormal seedlings which are probably produced from those seeds close to death (Roberts, 1986), and dead or ungerminated seeds in the seed lots. Germination results less than acceptable standard, for example < 90% for cereals usually indicate deterioration (Hampton and Coolbear, 1990).

There is often a good correlation between germination test results and field emergence under favourable conditions (Thompson, 1979; Roberts, 1984; Bekendam *et al*, 1987). A study by Bekendam *et al* (1987) showed that aged and unaged seed lots of maize had similar performance in the standard germination test, and that during favourable field conditions, the germination capacity showed the highest correlation with field emergence.

Under unfavourable conditions, howevere, the standard germination test often over-estimates the actual field performance of the seeds (Hampton and Coolbear, 1990). Bekendam *et al* (1987) demonstrated that although the standard germination results of both aged and unaged seeds were similar, aged seeds performed poorly in the cold test and conductivity test and emerged poorly in the field. Additionally, the cold test and conductivity test results showed higher correlation with field emergence than the standard germination.

The above observation can be attributed to two factors : (a) the standard germination test is not sensitive enough to distinguish small but important differences in the ageing or deterioration process and (b) that in the germination test the soil physical properties (temperature, water potential and strength) and biotic factors (insect pests and microorganisms) are either excluded or optimised. In the field, the physical and biotic factors are rarely completely optimal, and can reduce the level of field emergence and establishment to below that predicted by the standard germination test. Whereas the germination test assesses the maximum percentage of seed sown which can potentially germinate, emerge and establish, the actual field emergence essentially depends on the prevailing environmental

conditions. There will thus be differences in the field emergence between high germinating seed lots of the same cultivar due to differences in seed vigour (Hampton and Scott, 1982; ISTA, 1987).

The problem of ensuring proper germination of planted seed and subsequent establishment of seedlings is of general importance in agriculture (Hillel, 1972). On an individual farm, establishment difficulties may represent total crop failure in one season or insignificant losses in another.

Crop establishment is a part of crop production system, it is the foundation on which all other factors affecting final crop yield are dependent (Hooke,1987). Causes of poor establishment are complex involving interaction of seed, soil, climate, machinery management and soil flora and fauna factors (Rwehumbiza,1994).

Crop establishment is sequential process of germination, emergency and seedling growth, consequently many factors interact in a complex way to determine the final field establishment (Hooke, 1987).

Germination involves a complex sequence of biochemical, physiological and morphological changes in which certain

stages can be recognised. The first stage begins with the imbibition of water by the dry seed, the softening of the seed coverings and the hydration of protoplasm. The second stage begins with the initiation of cellular activities and includes the appearance of specific enzymes and a rise in respiration rate (Hartmann and Kester, 1968).

Cell elongation and emergence of the radical are events associated with the onset of germination. After the embryo has emerged from the seed coat germination is considered complete. However, the radical end of the hypocotyl and the plumule end of the hypogeal seedling must continue to develop, proliferate in the soil and emerge above the soil surface respectively. Both centres of growth are no longer protected by seed coat and now come into contact with the soil environment (Trouse, 1971).

### 2.1.2 Seed vigour

Seed vigour has been defined as those properties of a seed lot which determines its potential to rapidly produce a uniform and healthy plant stand under a wide range of field conditions (AOSA, 1983). Seed vigour may be viewed as a potential of a seed lot to germinate, emerge rapidly or store well under less than optimal environmental

conditions (Hampton and Coolbear, 1990). Maximum seed quality occurs at mass maturity, when maximum seed dry weight is attained, after which vigour and viability can deteriorate both pre- and post-harvest.

Loss of vigour may result from a matrix of inter-related deteriorative processes involved with seed ageing, which may be viewed as an inevitable consequences of initial membrane deterioration. As deterioration increases, both field emergence and storability decreases (Delouche and Baskin, 1973). Additionally seed lots will exhibit ageing symptoms including the slow rate of germination and emergence, poor seedling growth, decrease tolerance to sub optimal conditions, and enhanced solute leakage.

There are distinct though interacting factors which are considered to influence vigour potential through their effects on membrane integrity. They include genetic constitution, environmental conditions during seed development, tolerance/ susceptibility to mechanical or heat damage during harvesting, drying and cleaning, storage conditions and pathogens.

### 2.1.3 Vigour assessments and their relationship with field emergence

Seed lots passing the viability test, whilst all of acceptable and similar high levels of laboratory germination can sometimes show considerable differences in field emergence (Perry, 1972). It has been largely the absence of a consistent relation between germination in the laboratory and emergence in the field which has been responsible for the development of the concept of seed vigour (Powell and Matthews, 1978).

The differences in field emergence between seed lots which the standard germination test indicates are of similar quality, obviously require a more sensitive differential of potential seed performance to be able to predict field emergence and establishment with more accuracy. Although this can in theory be achieved by predictive simulation models frequently used by agriculture engineers and agronomists (Wood, 1972), this method is over complicated and unreliable as such simulation models require accurate information on the environmental conditions in the field (that are often variable, and hence unpredictable) and on the response of the seed lots to the environmental variables.

Seed vigour testing has become very important because it can often provide a better estimation of field emergence under stress conditions than the results of standard germination tests (Te Krony and Egli, 1977; Johnson and Wax, 1978; AOSA, 1983; ISTA, 1987; Hampton and Coolbear, 1990).

A variety of seed vigour test have been developed and AOSA (1983) categorised them as; (i) seedling growth and evaluation tests (seedling growth and speed of germination ), (ii) stress tests (cold test and accelerated ageing ) (iii) biochemical tests (conductivity test and respiration ).

### 2.1.4 Factors influencing seed vigour

Major factors which the International Seed Testing Association (ISTA) consider may cause variation in vigour were summarized by Perry (1980) and recently updated by Harty *et al*,(1987) as:

(i) genetic constitution (ii) environmental and nutrition of the mother plant (iii) stage of maturity at harvest (iv)seed size, weight, or specific gravity (v) mechanical integrity (vi) deterioration and ageing (vii) pathogens. Thus a reduction in seed viability and seed vigour, may result from incomplete seed development on the mother plant, injuries during harvest, improper processing and

storage, or ageing (Hartmann and Kester, 1968). With long storage, reduced viability is usually preceded by a period of declining vitality (Toole *et al* 1956).

The planted seeds are the end product of several steps. These include growing in the seed production fields, harvesting, processing, and storage (Justice and Bass, 1978). The conditions and practices the seeds encounter in these processes have their ultimate test when the seeds are planted in complex environment of the soil.

Soil moisture levels range from insufficient for seed germination and development to water saturated soil which can cause soaking injury. Water logged soils may also cause oxygen deficiency that can inhibit germination and seedling elongation.

A combination of decreased soil temperature and soil moisture content and an increased planting depth, can be critical to successful seedling emergence (Chopra and Chaudhary, 1981). This can reduce emergence rate, making the seeds more prone to soil pathogen attack causing a decrease in total emergence. The pH in agricultural soils normally varies from 3 to 8 while the levels of organic matter, amount of various ions and soil texture also differ greatly, and this too may affect germination (Cal

and Obendorf, 1972; Etherington, 1978; Harman, 1983).

Maximum germination and seedling growth rates for most kinds of seeds occur in pH ranging from 4 to 7 (Justice and Reece, 1954; ISTA, 1985). Soil compaction restricts penetration and growth of the root system and also shoot growth prior to emergence. This opposing force increases with decreasing pore diameter in the soil, levels of organic matter and water content (Currie, 1984). Without adequate vigour the elongating root experiences resistance or fails to penetrate compacted soils.

The greatest barrier to shoot elongation is a surface crust, formed when unstable soil, often with a too fine tilth, slakes on wetting and hardens on drying (Arndt, 1965a,b; Currie, 1984). Throughout this range of soil conditions there are numerous insects and about 1500 types of microorganisms and virus that can survive and adversely affect the germinating seed (Agarwal and Sinclair, 1987).

The uncertainty of environmental condition demands that the seed farmers must plant seeds of high vigour because the subsequent performance of seeds under adverse conditions usually hinges on the ability of the seeds to survive the wide range of environmental conditions. However, there are many factors which are considered to

influence vigour. These can be categorised as genetic effects, environmental condition during seed development, harvesting and processing techniques, pathogens and deterioration during storage (Ching and Cronstad, 1972; Burris, 1977; Bulisan and Warner, 1980; ISTA,1987; Bdliya and Burris, 1988; Mashauri *et al*, 1992). These factors can all be linked to seed ageing, due to the damage inflicted to the structural integrity of cell membranes during seed development, drying, handling and storage.

### 2.1.5 Seed storage and deterioration

#### 2.1.5.1 General aspects of seed storage

Generally the longevity of seeds in store is influenced by environmental temperature, moisture content of the seed and oxygen pressure (Roberts, 1972). Other factors include crop species and initial quality of the seed (Egli, *et al*, 1978).

In the majority of cases the lower the temperature and the lower the moisture content the longer the viability; while high oxygen pressure would shorten the period of viability (Roberts, 1972).

Considering seed moisture content and storage temperature, Harrington (1963) points out two rules of thumb for seed viability in store. With the exception of extreme

conditions, for each one percent decrease in moisture content and for every 5°C decrease in temperature, storage life is doubled. Oxygen pressure is not taken to be a seriously limiting problem probably because it cannot be easily alleviated in stores. It is generally accepted, however, that increase in oxygen tend to decrease the period of viability. Extreme storage conditions can be generalized for most crops. According to Roberts (1972) freezing injury will occur at very low temperatures if seeds are very moist, but many species will store better at temperatures as low as -20°C provided the moisture content is not high enough for freezing injury. Thus seed moisture content seems to play a major role in seed storage, probably a far greater role than storage or ambient temperature.

Douglas (1983) categorises storage responses to moisture content as follows:-

| | |
|---|---|
| Moisture content above 40-60% : | Germination occurs |
| Moisture content above 12-14% : | Mould grows on and in the seed |
| Moisture content above 10-12% : | Fumigants may hurt germination |
| Moisture content above 8-9% : | Sealed storage is unsafe |

Thus it would be most desirable to store seeds at moisture contents less than 10%. Too dry conditions, however, may also reduce seed longevity, through extreme desiccation (Roberts, 1972).

### 2.1.5.2 Importance of storage

The concept of storage enables agronomists and farmers to select seeds of good quality for both germination and storage longevity. A seed lot with high storability has seeds of high vigour and hence high germinability capacity. The latter predicts the field establishment and performance of seeds (AOSA, 1983; Humpton and Coolbear, 1990).

Storage knowledge helps to alleviate the unnecessary deteriorative factors during storage through controlled temperature, moisture, relative humidity and alterating weather conditions for long time storage of seeds. It is cautioned that, "for each $5^{0}$ C increase in seed temperature, the life of the seed is halved." Like wise, for each 1% increase in seed moisture content the life of the seed is halved (Harrington, 1963). As moisture content increases, storage fungi and insects are able to grow on seed and destroy its capacity to germinate (FAO, 1983).

### 2.1.5.3 Seed deterioration

Deterioration or ageing is an inherent biological process in any seed in store. Delouche and Baskin (1973) suggest that any consideration for storability of seed must encompass this complex process which begins soon after the seed has attained physiological maturity; and proceeds throughout the life of the seed. Loss of capacity to germinate is about the last thing that happens as seed deteriorates, and usually preceded by decrease in germination rate and increase in seedling abnormalities. Deterioration would occur at whatever condition, and is speeded up by increased temperature and moisture content.

Seed ageing has come to be recognised as a major cause of reduced vigour in many species. Ageing involves the accumulation of degenerative changes until eventually the ability to germinate is lost. Maximum seed quality occurs at physiological maturity, after which vigour and viability decline both before and after harvest (Delouche, 1980; Powell and Matthews, 1984). The existence of vigour differences among crop seed lots is a natural consequence of the way population of the seed die (Matthews, 1980), and is a reflection of production history of each lot. Quantification of the physiological age of a seed can be achieved by artificially ageing seed lots and analysing the serial germination tests to infer the value of the

seed lot constant; Ki, of the viability equation (Ellis and Roberts, 1980).

In an attempt to find means of slowing down seed deterioration or ageing, scientists have sought to understand the mechanism of ageing. Many agree that many physical or cytological, physiological and biochemical changes occur as seed deteriorates during storage (Egli, *et al*, 1978).

Various methods have been devised to measure the extent of seed deterioration. Among them include controlled deterioration and accelerated ageing which are also standard vigour tests (Delouche and Baskin,1973; Matthews and Powell, 1987). Both methods are similar in principle, they involve incubating seeds at high relative humidity at elevated temperature (usually 45°C) for a period of time.

Controlled deterioration differs from accelerated ageing essentially in that the former involves raising the initial seeds moisture content to the same level for all lots prior to the period of deterioration. In accelerated ageing, seed gain moisture (at 100% RH) during the initial period of ageing (Matthews and Powell, 1987) allowing different rates of moisture gain between lots.

### 2.1.5.4 Deterioration of seeds during storage

The duration seed are kept in storage (post harvest) until when taken up for sowing is referred to as "storage time." It has been scientifically proven that; seeds placed in store will undergo natural ageing (Berjak and Villier, 1970; Roberts, 1972, 1983).

Vital systems and functions of the cell membrane, organelles, nuclear materials and biochemical mechanisms that control the physiological processes involved in the resumption of growth is progressively impaired until they become incapable of supporting the resumption of growth (AOSA, 1983). Alternatively, microorganisms (storage fungi in particular) can infest the seeds during storage, and are also responsible for spoilage of seed quality (Christensen and Kaufmann, 1974). Temperature and relative humidity (RH), both influence the rate at which the seed will deteriorate and also control the activity of microorganisms. The higher the seed moisture content (SMC) and storage temperatures the higher the deterioration rate. Similarly,if the seeds are physically or mechanically damaged, or if storage pathogens (fungi, insects and mite) invade, seed quality loss may occur substantially and very quickly (Neergaard, 1977; Roberts, 1983; Agarwal and Sinclair, 1987; Mashauri, 1991).

Low SMC and temperature prolong seed storage life. Recent studies (Williams and Leopold, 1989; Bruni and Leopold, 1991, 1992a, 1992b) have shown that the cytoplasm of several seed species including maize and sorghum is in a glass state at low SMC and temperature storage. A glass is a liquid of high viscosity such that it stops or slows down all chemical reactions requiring molecular diffusion, and so prevents damaging interactions between cell components and thus assure quiescence and stability over time (Franks, 1985; Burke, 1986; Bruni and Leopold, 1992b). Although dry and cold storage conditions can increase storage life of seeds, the optimum SMC and temperature are still a subject of an ongoing debate (Ellis *et al.*, 1990, 1991; Vertucci and Ross, 1990, 1991). Too low SMC and temperatures can also be detrimental to the seeds. Too low moisture content would cause structural alteration as the intercellular bound water can be removed (Aksenow *et al.*, 1977). Bruni and Leopold, (1992b) suggested that too low SMC may cause crystallisation in the sugar matrix which in turn may perturb membranes, bringing an irreversible damage. The poor storage performance observed at extremely low SMC (Ellis *et al.*, 1990; Vertucci and Ross, 1990) could therefore be related to this event. At low temperature (5°C and below) although insects become inactive some microorganisms such as group members of *Fusarium,*

*Aspergillus, Penicillium* species can continue to degrade the seeds (Christensen and Kaufmann, 1974; Neergaard, 1977; Mashauri, 1991).

**2.1.6 The physiology of seed deterioration**

Loss of viability and vigour may result from deterioration process involved during seed ageing, both pre- and post harvest, and seed ageing is now considered as a major cause of reduced vigour in many species (Delouche, 1980; Powell *et al*, 1984).

Aged seeds exhibit various forms of physiological changes which are the measures of how far ageing has progressed. These are reflected as reduced rates of emergence and growth and decreased tolerance to suboptimal conditions (Roberts, 1972, 1983). These symptoms may or may not appear at one time in a single sample of seeds and some are peculiar to seeds of certain species of plants or one set of ageing conditions. Reduction in seedling growth, for example which either precedes or accompanies loss of germinability, does not necessarily occur in every case of seed deterioration. Anderson, (1970) suggested that germinability and seedling growth, although closely related, are regulated by different mechanisms which seem to operate independently during deterioration. Often the time which marks the first detectable loss of vigour or

viability does not coincide with the actual beginning of biochemical changes associated with deterioration (Harrington, 1973).

At a cellular level, there are several biochemical changes that can cause or contribute to seed deterioration. These may include; changes in membrane composition and integrity, enzyme changes, damage to protein and RNA synthesis, genetic damage, hormonal changes and accumulation of toxic metabolites (Abdul-Baki, 1980; Blowers *et al.*, 1980; Woodstock *et al.*, 1984; Dourado and Roberts, 1984; Francis and Coolbear, 1987; Priestly, 1986). There is no reason to assume that any critical type of physiological damage in any specie or under given set of ageing conditions may be very important in another species or set of ageing conditions. Probably it is best to regard all these mechanisms as a component of inter-related events of which the relative importance may depend on the exact conditions of the seeds both pre- and post harvest (Priestly, 1986; Coolbear, 1990)

### 2.1.7 Seed factors limiting crop establishment

#### 2.1.7.1 Seed quality

Seed factors acting alone or in combination with soil, biotic, climatic and management factors, are implicated with establishment problems (Rwehumbiza, 1994).

Good quality seed has the following characteristics: It is genetically true to species or cultivar, it has a capacity for high germination, it is free from diseases and insects and it is free from mixture with other crop seeds, weed seeds and inert and extraneous material (Hartmann and Kester, 1968). Seed testing provides information to meet legal standards determines seed quality and establishes the rate of sowing for a given stand of seedlings.

**2.1.7.2 Seed viability**

The germination test expresses the number of seedlings which can be produced by a given number of seed under optimum test conditions. . The procedure is rather arbitrary and in many cases does not simulate the actual environment so that it might often fail to predict field performance (Heslehurst and MacDonald, 1987; Isely, 1958). The artificial conditions provided in the laboratory and experimental areas (green houses) are different from real situation in the field. Crop establishment losses could be reduced by using "better quality" seed; as measured by standard germination test. Blacket (1987) suggest two germination checks to be undertaken, one after harvest and prior to seed grading or treatment and second prior to planting. He bases his suggestion on well established facts that seeds deteriorate at various stage of

processing. Blacket lists the major causes of seed deterioration as (i) weather damage (ii) seed stored at high moisture, resulting in heating and rapid deterioration (iii) seed stored in hot sealed and unaerated silos (iv) insect and fungal damage during storage (v) seed "cooked" during grain drying and (vi) old age.

**2.1.7.3 Seed vigour**

It has been largely the absence of a consistent relation between germination in the laboratory and emergence in the field which has been responsible for the development of the concept of seed vigour (Powell and Matthews, 1978). Since vigour testing is not yet a routine practice in many countries, means that establishment problems emanating from sowing low vigour seeds will remain for the fore seeable future even in developed countries (Harty *et al.* 1987).

**2.1.8 The time seed remains in soil before onset of rains**

Planting can be done during dry condition or after the first rains when the soil is sufficiently moist. Some farmers do practice dry planting because of erratic nature of rains in the rainfed agriculture. Soils which become very sticky after heavy rains encourage farmers to dry plant.

According to Manning (1956) sowing should be done as early as possible at the beginning or even before the break of rains in order that full benefits can be obtained from the rains during the crucial stages of growth.

Deciding on how long the seeds can stay in the soil without deterioration up to the onset of the rains is a major challenge to the farmer. In semi arid traditional agriculture, sowing is very often done before the rains, and seed may lie in the ground for periods from a few days to several weeks. The seed may deteriorate as a result or be lost through pests, birds and rodents (Dogget, 1988). Proper germination of planted seeds and establishment of seedlings are important in agriculture because they determine density of stand, influence the degree of weed infestation and in extreme situations limit yield (Hillel, 1972). Sown seeds must imbibe enough water to initiate germination. Similarly, seedling roots must absorb enough water to satisfy the seedlings needs for growth and development. Successful germination of seeds requires adequate supply of water and seed must absorb water at a sufficiently rapid rate to reach their critical germination water content before the effect of other environmental stresses, ( drying of the soil or fungal attack) prevent germination (So, 1987).

Stored seeds of different type vary in their air-dry moisture content. Trouse (1971) found that many agriculturally important seeds carrying viable, dormant plant embryos contain about 7 to 12 percent moisture. The water potential of air-dry seed is frequently below -50 MPa (Black, 1968). Thus, the soil water content need not be very high for imbibition to take place. All the same, there is evidence (Hunter and Erickson, 1952) that a certain minimum amount of water determined by seed species must be imbibed before germination is reinitiated.

# CHAPTER THREE

## 3.0 MATERIALS AND METHODS

The work reported in this dissertation was divided into two main studies: (a) Assessment of seed quality in commercial and farmers planting seed including monitoring of the extent of seed ageing in storage and (b) The study of the effect of length of time seeds remain in soil before onset of rains on establishment of maize and sorghum.

The second study was carried out first, in the glasshouse and later under field conditions. Some of the materials and methods used were common to all studies and are thus described under general materials or methods.

### 3.1 General materials

Seeds of both maize and sorghum; and soil were the main materials used in this study. Detailed descriptions of both seed and soil are given later in appropriate sections.

## 3.2 General methods

### 3.2.1 Seed and seed source

Seeds of three varieties of maize (Staha, TMV-1, and Kito) and one sorghum variety (Tegemeo) were bought from Tanzania Seed Company (TANSEED), Morogoro branch and from farmers in the rural areas around Morogoro.

### 3.2.2 Germination test

Acquired seed was initially subjected to a germination test to assess its quality as a planting material. Germination tests were conducted in a sandbox set at a matric suction of 1kPa. Seeds were germinated on top of a blotting paper placed on sand which was divided into four grids with a pencil mark to separate replications. The layout was designed such that each seed type was replicated four times and each replicate had 100 seeds. Seeds were covered on top with another blotter. Germination was considered complete when the radicle emerged from the seed and was about 4mm long.

### 3.2.3 Seed moisture content (SMC)

Seed moisture content, was determined each time seed was acquired and after every sampling using the MOTOMCO moisture meter (manufactured by DICKEY-John corporation PATERSON, NEW JERSEY).

The procedure involved placing 250g of seeds in the machine along with a thermometer. The reading obtained was applied to a calibration chart to read the percentage seed moisture content. The correction for temperature was applied to obtain the correct SMC in percentage. The exercise was repeated three time for each sample then the average was computed.

### 3.2.4 Data collection

Data collection started a day after starting the germination test and continued for seven days. Germination count, time to 50% germination and germination rate were the main parameters assessed in the study. Data on germination was recorded after every twenty four hours.

## 3.3 Experiment No. 1: The study of the extent of seed ageing in storage.

### 3.3.1 Storage and sampling techniques

Where available, seeds from each cultivar (cv) were obtained from different seed lots and farmers respectively. The bought seeds were stored alongside TANSEED and farmers seeds in their stores. Initially, seed samples from each lot were taken to the laboratory for refrigeration to minimize ageing. Refrigeration allowed the quantification of any deterioration in natural

storage. Every month for 3 months, seed samples were taken for germination tests as described in section 3.2.2

### 3.3.2 Data collection and management

Data similar to that in section 3.2.4 was collected and entered into a spreadsheet (Lotus, 1-2-3) from which graphs were produced.

Table 3.1 Seed and seed source

| source | cultivar (crop) | lot/farmer's name |
|---|---|---|
| TANSEED | Kito (maize) | A |
| | Kito (maize) | B |
| | Kito (maize) | C |
| | Staha (maize) | A |
| | Staha (maize) | B |
| | Staha (maize) | C |
| | TMV-1 (maize) | A |
| | TMV-1 (maize) | B |
| | TMV-1 (maize) | C |
| | Tegemeo (sorghum) | A |
| | Tegemeo (sorghum) | B |
| | Tegemeo (sorghum) | C |
| FARMERS | | |
| | Staha | Milando |
| | Staha | Mahava |
| | Staha | Mahundumla |
| | Kito | Shija |
| | Kito | Dongo |
| | TMV-1 | Omary |
| | Tegemeo | Salehe |
| | Tegemeo | Shija |

## 3.4 Experiment No. 2. The effect of length of time seeds remain in soil before the onset of rains on establishment of maize and sorghum.

The experiment was designed to assess the survival of high, medium, and low vigour seed categories with respect to length of the time seed remained in soil before the onset of rains on establishment.

### 3.4.1 Glasshouse experiment

The glasshouse study involved planting seeds in soil columns. Seeds were sown in an air dry soil (with an initial soil moisture content of 7.4% ).

The soil used in the study was randomly sampled from the site where the field experiment was later conducted. The soil was broken into small aggregates to remove the big clods and some big roots.

### 3.4.2 Packing of the soil columns

Soil columns were cylindrical PVC pipes of 20cm length, and 10.5cm internal diameter. The weight of the soil packed to a bulk density of 1.1g/cm$^3$ in the PVC pipes was calculated using the following formula:

**Mass of soil =Bulk density of soil x Volume of soil column**

In order to have that bulk density each soil column was packed with an average of 1.5kg of soil (this includes the percentage soil moisture content, that is 7.4% of the required soil weight). The soil columns were placed on the platform in the glasshouse and arranged as described in the layout (Appendix 3.1). The soil columns were labelled indicating length of time seeds remained in soil before onset of rains and vigour of the seeds.

### 3.4.3 Seeds

The seeds used in this experiment were maize cv Staha (lot b) and sorghum cv Tegemeo (lot c). Medium and low vigour seeds were obtained by artificially ageing (that is 1 and 2 days for maize and 2 and 3 days for sorghum).

#### 3.4.3.1 Artificial ageing of seeds

Seeds were artificially aged after testing different seed lots (experiment one) and found no significant differences in germination percentage. The target was to obtain medium and low vigour seed categories. Seed ageing was by the controlled deterioration (CD) method (Matthews, 1980). Two main steps were involved:

**(i) Increasing seed moisture content.**

The initial SMC was 10.8 and 11.5% for maize and sorghum respectively which was increased to 21%. Seed moisture

content was increased by placing weighed samples of each variety in open petri dishes containing moist seeds and covered with moist filter papers. Seeds were allowed to imbibe water to predetermined moisture content (mf). The approach to required moisture content was checked by frequent weighing. The required seed weight (sf) was calculated using the following equation:

$$Sf = Si \left[ \left( 1 + mf \right) / \left( 1 + mi \right) \right]$$

where, Sf = final seed weight after imbibition (at mf )

Si = initial seed weight (at mi )

mi = initial seed moisture content (dry weight ) g/g

mf = final seed moisture content (after imbibition) g/g

**(ii) The deterioration process**

The partially imbibed seed samples were heat sealed in aluminium foil packets and stored in a refrigerator for 24 hours to ensure an even distribution of moisture. The sealed packets were then incubated in a water bath at 45°C. The incubation period varied from 1 to 3 days. The aged seeds were germinated to obtain the germination percentage which allowed for selection of medium and low vigour categories (Table 3.3)

### 3.4.4 Planting

Packing of soil was designed such that 5cm and 3cm of the soil column for maize and sorghum respectively was left to be filled after sowing to account for the predetermined planting depth. Planting was done at an interval of 3 days, that is 0, 3, 6, 9, 12, and 15. Planting depth was 5cm and 3cm for maize and sorghum respectively. A total of 5 seeds were planted in each soil column. On day 15, all soil columns were watered with 20mm equivalent of rain which was equivalent to 173ml per soil column. The watering was done in instalment to avoid overflow. First, 100ml was applied and the remaining 73ml was applied after one hour.

### 3.4.5 Environmental conditions in the glasshouse

Temperature and evapotranspiration in glasshouse were monitored throughout the time of experiment. Temperature was measured by a normal thermometer which was graduated up to 50$^{0}$C (placed on a wall to measure air temperature). Evapotranspiration rate was estimated as follows: A pan of 25cm diameter was filled with soil then watered to make the soil wet. The pan was then weighed. The weighing was done every 24 hours to get the water loss. The soil was rewetted and the pan reweighed daily. The exercise was continued for 7 days to get the average water loss per day.

Formula for evapotranspiration rate

$$E = V/A$$

Where; E = Evapotranspiration (mm/day)

V = Volume of water lost ($cm^3$)

A = Area ($cm^2$) surface area from which water is being lost)

### 3.4.6 Layout and design

The study was a two factor experiment. There were 3 seed vigour categories and 6 length of time seed remained in soil. The treatments were replicated 3 times. The design was complete randomized design.

### 3.4.7 Data collection

Emergence of seedlings was observed and recorded daily for 8 days. Data on emergence were recorded after every twenty four hours. The main parameters investigated were emergence of seedlings, number of germinated seeds, seedlings which did not emerge, seeds which did not germinate, root and shoot length of each seedling that germinated and/or emerged.

**Table 3.2 Temperature and evapotranspiration during the experiment in the glasshouse.**

| Days | Air temperature (°C) | Evapotranspiration (mm/day) |
|---|---|---|
| 1 | 25 | 2.03 |
| 2 | 25 | 1.34 |
| 3 | 24 | 2.85 |
| 4 | 23 | 1.63 |
| 5 | 23 | 3.26 |
| 6 | 24 | 3.05 |
| 7 | 25 | 2.85 |
| 8 | 26 | 2.03 |
| Mean | 24.4±0.35 | 2.38±0.16 |

**Table 3.3 Germination percentage of the artificially aged seeds.**

| Cultivar | Duration of ageing (days) | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| Maize (cv Staha) | 95 | 84 | 50 |
| Sorghum (cv Tegemeo) | 87 | 86 | 76 |

### 3.5 Field experiment

#### 3.5.1 Location

The experimental site is situated at Sokoine University of Agriculture farm, at 6° 29′ S and 37° 9′ E and at an elevation of 526m above sea level. The site lies within the Usagaran system of basement complex. The soils of the area are believed to have developed from colluvial material derived from the Uluguru Mountains of the same complex, but also *in situ* decomposition of the original rocks (Shayo-Ngowi and Mtakwa, 1994). The average annual rainfall is 837mm, most of which occurs between October and May, with greater concentration in the months of March and April. The soils have been classified as Typic Acrorthox (Kasseba *et al.*, 1972). The land had been under grass fallow for over twenty years but was occasionally

being used for grazing cattle.

According to Shayo-Ngowi and Mtakwa, (1994) the bulk density of area range from 0.94g. $cm^{-3}$ to 1.50g. $cm^{-3}$. The mean bulk density of the soil was 1.27g. $cm^{-3}$. The total porosity and particle density ranged from 43 to 64% and 2.45 to 2.70 respectively.

**Table 3.4 Temperature and evapotranspiration during the experiment in the field.**

| Days | Air temperature (°C) | Evapotranspiration (mm/day) |
|---|---|---|
| 1 | 32 | 3.05 |
| 2 | 32 | 5.70 |
| 3 | 28 | 5.29 |
| 4 | 30 | 5.29 |
| 5 | 28 | 4.07 |
| 6 | 31 | 5.91 |
| 7 | 30 | 7.13 |
| 8 | 31 | 5.09 |
| Mean | 30.25±0.77 | 5.20±0.46 |

## 3.6 Methods

### 3.6.1 Land preparation

The field was prepared by clearing the bush followed by normal cultivation using hand hoe. The big clods were broken to enhance good contact between seeds and the soil.

### 3.6.2 Field layout and design

Small plots of 1m x 1m were prepared as indicated in the experimental layout (Appendix 3.1). Each plot was labelled indicating the length of time seeds remained in soil before watering, type and vigour of the seeds.
The study was a two factor experiment. There were 3 seed vigour categories and 6 length of time seeds remained in soil. The treatments were replicated 3 times. The design was complete randomized design.

### 3.6.3 Planting in the field

Seeds were hand planted (at a depth of 10cm and 6cm for maize and sorghum respectively). Planting holes were made using a small handhoe.

Planting of all vigour categories (low, medium and high) was designed such that seeds would remain in the soil for 0, 3, 6, 9, 12, and 15 days. On day 15, all the plots were watered uniformly with 40mm equivalent to rain water.

A total of 20 seeds were planted in each plot.

### 3.6.4 Environmental conditions at planting

#### 3.6.4.1 Soil moisture content

Soil moisture content was determined gravimetrically. At planting four soil samples were randomly taken from the experimental area and was used for soil moisture estimation.

#### 3.6.4.2 Determination of matric suction

Matric suction of soil at each planting was determined using the filter paper technique (Fawcet and Collis-George 1967). Calibrated filter papers (Whatman No. 42) were placed between two layers of the sampled soil in a sealed container and left for four days to equilibrate. The weight of the container and filter paper was determined, and then dried in the oven at 105$^{0}$C for twenty four hours. The containers were removed and placed into a desiccator to cool for another twenty four hours. The moisture in the calibrated filter papers were calculated gravimetrically. Matric suction was obtained by interpolation from the calibrated curve for the batch of filter papers used. The average soil matric suction and soil moisture content is presented on (Fig. 3.1)

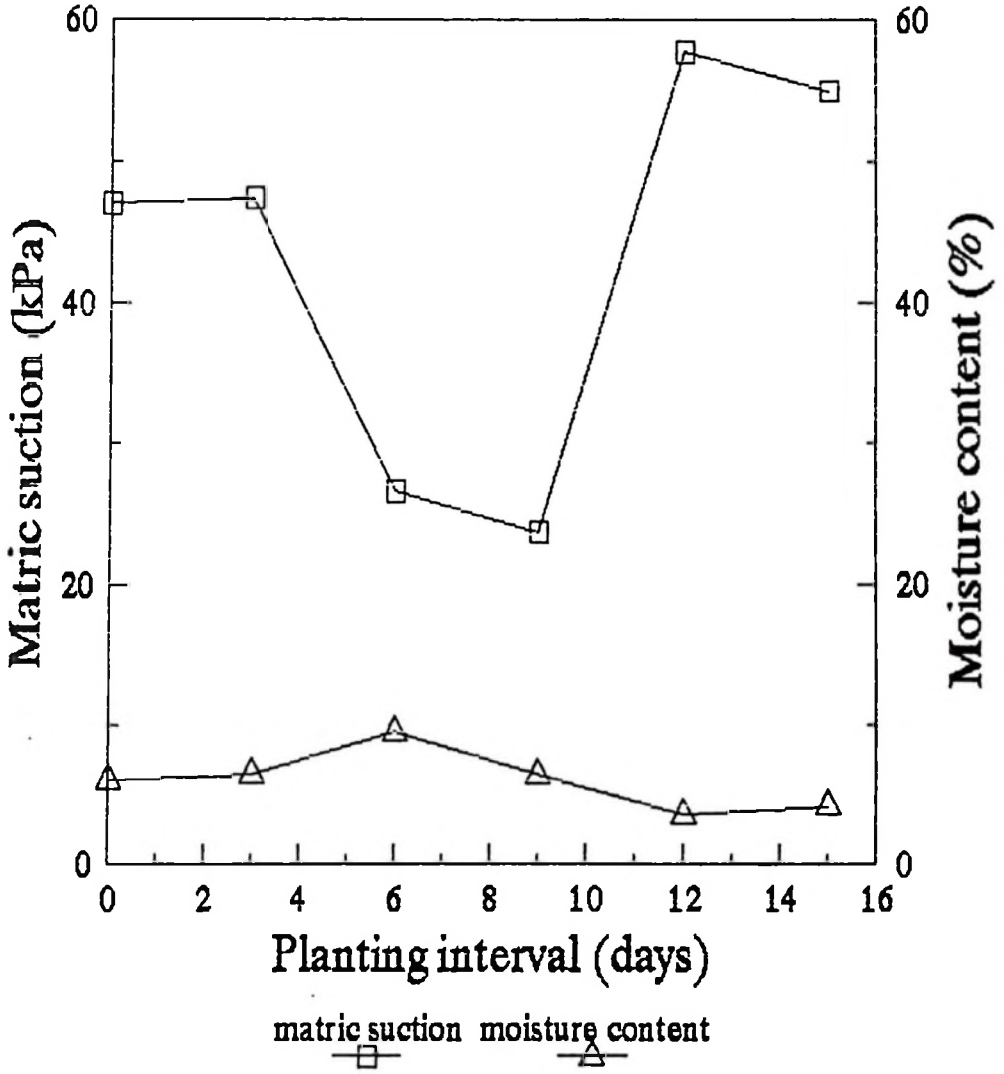



Fig. 3.1 Soil matric suction and moisture content on each planting day

### 3.6.5 Data collection

Emerged seedlings were recorded daily. Data was recorded for ten days when there were no further emergence. Seedlings were considered emerged when the plumule appeared from the soil surface.

# CHAPTER FOUR

## 4.0 RESULTS

### 4.1 EXPERIMENT ONE:

**Assessment of seed quality in commercial and farmers planting seed and monitoring of the extent of seed ageing in storage**

#### 4.1.1 Percentage germination

Seeds obtained from TANSEED had germination percentage ranging from 88 to 100% (Table 4.1). Some of the seeds from farmers had their germination percentages below the acceptable level of 85% and 75% for maize and sorghum respectively (Table 4.2).

Table 4.1 Germination percentage for maize and sorghum seeds obtained from TANSEED as affected by storage time.

| Crop cultivar | Sampling regime | | |
|---|---|---|---|
| | Time zero | After one month | after two months |
| Maize cv Staha, lot A | 99 | 99 | 96 |
| Maize cv Staha, lot B | 100 | 96 | 93 |
| Maize cv Staha, lot C | 97 | 100 | 96 |
| Maize cv TMV-1, lot A | 97 | 97 | 100 |
| Maize cv TMV-1, lot B | 97 | 99 | 98 |
| Maize cv TMV-1, lot C | 94 | 96 | 97 |
| Maize cv Kito, lot A | 98 | 96 | 92 |
| Maize cv Kito, lot B | 93 | 94 | 90 |
| Maize cv Kito, lot C | 100 | 98 | 96 |
| Sorghum cv Tegemeo, lot A | 90 | 93 | 91 |
| Sorghum cv Tegemeo,lot B | 96 | 96 | 92 |
| Sorghum cv Tegemeo, lot C | 92 | 96 | 88 |

**Table 4.2 Germination percentage for maize and sorghum seeds obtained from farmers as affected by storage time**

| Crop (cv), farmer | Sampling regime | | |
|---|---|---|---|
| | Time zero | After one month | After two months |
| Maize cv Staha, (Milando) | 88 | 83 | 88 |
| Maize cv Staha, (Mahava) | 95 | 92 | 90 |
| Maize cv Staha, (Mahundumla) | 64 | 69 | 57 |
| Maize cv TMV-1, (Omary) | 97 | 98 | 100 |
| Maize cv Kito, (Dongo) | 99 | 94 | 89 |
| Maize cv Kito, (Shija) | 89 | 81 | 90 |
| Sorghum cv Tegemeo, (Salehe) | 65 | 55 | 50 |
| Sorghum cv Tegemeo, (Shija) | 8 | 0 | 1 |

All maize and sorghum cultivars from TANSEED had high germination capacity and the values obtained were above the minimum values set by Tanzania Official Seed Certification Agency (TOSCA) that is > 85% for maize and > 75% for sorghum. Some maize seeds from the farmers also had germination percentage above the minimum acceptable values set by TOSCA except for the Staha obtained from farmer Mahundumla. Both sorghum lots had germination percentage below the acceptable level (Table 4.2 and Appendices 4.5 - 4.8).

Overall sorghum seeds from TANSEED had relatively higher germination capacity than those from farmers.

Basing on the germination capacity there was no significant differences (p=0.05) between sampling times in both seed sources (Table 4.1 - 4.3). The reason for such result could be the short period in sampling interval (one month). Thus the time was too short to give significant differences.

Table 4.3 Average number of seeds which germinated (out of 100 seeds planted) as affected by seed lot and sampling regimes.

| Sampling | Staha lot A | Staha lot B | Staha lot C |
|---|---|---|---|
| 1 month | 97± 1.88a | 100±0.0a | 97±1a |
| 2 months | 99± 1a | 96± 2.8ab | 100± 0b |
| 3 months | 98 ±1.12a | 93± 1.88b | 96± 0a |
| LSD at P=0.05 | 4.52 | 6.28 | 1.84 |
| | Kito lot A | Kito lot B | Kito lot C |
| 1 month | 93± 2.4a | 97± 3a | 100± 0a |
| 2 months | 96± 1.6a | 94± 2a | 98± 1.12ab |
| 3 months | 92± 2.28a | 90± 2a | 94± 2b |
| LSD at P=0.05 | 6.96 | 7.6 | 4.24 |
| | TMV-1 lot A | TMV-1 lotB | TMV-1 lot C |
| 1 month | 97± 1.88a | 97± 1a | 95± 1a |
| 2 months | 97± 1a | 98± 1a | 97± 1.88a |
| 3 months | 100± 0a | 99± 1.12a | 97± 1a |
| LSD at P=0.05 | 3.96 | 3.36 | 4.36 |
| | Tegemeo lot A | Tegemeo lot B | Tegemeolot C |
| 1 month | 91± 3.76a | 96± 1.6a | 92± 1.6ab |
| 2 months | 93± 2.48a | 96± 2.28a | 96± 2.28a |
| 3 months | 91± 3a | 92± 1.6a | 88± 2b |
| LSD at P=0.05 | 10.04 | 6 | 4.24 |

Means within the same column followed by the same letter are not significantly different at P=0.05 according to Duncan's New Multiple Range Test.

### 4.1.2 Time to 50% germination

Sorghum seeds started germination earlier than maize seeds (Table 4.4 and 4.5). Time to 50% germination ($T_{50}$) was estimated by interpolation in the cumulative germination curves. Maize seeds from both farmers and TANSEED, differed in their germination rate. Maize seeds from TANSEED had a consistent trend where the germination rate decreased with storage time. Sorghum seeds started germination earlier than maize probably because smaller seeds require less water than larger ones to initiate germination (Table 4.4 and 4.5. and Appendices 4.1 - 4.8). Sorghum seeds from farmers had comparatively lower germination percentage than those from TANSEED. The sorghum seed from farmer Shija for example had a germination of less than 10% (Table 4.2).

$T_{50}$ for seeds obtained from TANSEED showed very little variation with storage time (Table 4.4 and Appendices 4.1 - 4.4). Overall $T_{50}$ increased with storage time. The differences were not significant and this might be attributed to short period assigned to the sampling interval (one month). Seeds from local farmers did not follow any trend with respect to $T_{50}$ (Table 4.5). Sorghum cv Tegemeo obtained from Shija had the lowest proportion of viable seeds (8, 0, and 1% for sampling after 1, 2 and 3 months respectively)

Table 4.4 Time in (days) to 50% germination for the seeds obtained from TANSEED as affected by storage time.

| Crop-cultivar | Sampling regime | | |
|---|---|---|---|
| | time zero | After one month | After two months |
| Maize cv Staha, lot A | 2.2 | 2.4 | 2.7 |
| Maize cv Staha, lot B | 2.3 | 2.5 | 2.8 |
| Maize cv Staha, lot C | 2.2 | 2.5 | 2.8 |
| Maize cv TMV-1, lot A | 2.4 | 2.5 | 2.8 |
| Maize cv TMV-1, lot B | 2.7 | 3.1 | 3.1 |
| Maize cv TMV-1, lot C | 2.7 | 3.0 | 3.0 |
| Maize cv Kito, lot A | 2.5 | 2.7 | 2.8 |
| Maize cv Kito, lot B | 2.4 | 2.6 | 2.8 |
| Maize cv Kito, lot C | 2.5 | 2.7 | 2.7 |
| Sorghum cv Tegemeo, lot A | 1.6 | 1.6 | 2.7 |
| Sorghum cv Tegemeo, lot B | 1.5 | 1.7 | 1.7 |
| Sorghum cv Tegemeo, lot C | 1.5 | 1.6 | 1.6 |

**Table 4.5 Time in (days) to 50% germination for the seeds from farmers as affected by storage time.**

| Crop-Cultivar (farmer) | Sampling regime | | |
|---|---|---|---|
| | Time zero | After one month | After two months |
| Maize cv Staha, (Milando) | 2.6 | 2.6 | 2.5 |
| Maize cv Staha, (Mahava) | 2.5 | 2.5 | 2.5 |
| Maize cv Staha, (Mahundumla) | 3.0 | 2.7 | 2.9 |
| Maize cv TMV-1, (Omary) | 2.5 | 2.3 | 2.4 |
| Maize cv Kito, (Dongo) | 2.5 | 2.3 | 2.7 |
| Maize cv Kito, (Shija) | 2.6 | 2.4 | 2.5 |
| Sorghum cv Tegemeo, (salehe) | 1.8 | 2.2 | 3.1 |
| Sorghum cv Tegemeo, (Shija) | Not applicable because germination was zero | | |

Table 4.6 Average time in (days) to 50% germination for the seeds obtained from TANSEED as affected by seed lot and sampling regime

| Sampling | Staha A | Staha B | Staha C |
|---|---|---|---|
| 1 | 1.95±0.06a | 2.22±0.08a | 2.22±0.08ab |
| 2 | 2.30±0.04b | 2.50±0.04b | 2.37±0.04ab |
| 3 | 2.67±0.07c | 2.77±0.04c | 2.75±0.06b |
| LSD at P=0.05 | 0.197 | 1.95 | 0.216 |
| | Kito A | Kito B | Kito C |
| 1 | 2.5±0.04a | 2.52±0.06ab | 2.47±0.05ab |
| 2 | 2.72±0.06b | 2.67±0.08ab | 2.5±0.0ab |
| 3 | 2.95±0.06c | 2.95±0.06b | 2.7±0.04b |
| LSD at P=0.05 | 0.211 | 0.229 | 0.138 |
| | TMV-1 A | TMV-1 B | TMV-1 C |
| 1 | 2.52±0.04a | 2.65±0.11a | 2.7±0.1a |
| 2 | 2.65±0.09ab | 3.07±0.04bc | 2.92±0.02bc |
| 3 | 2.8±0.03b | 3.12±0.14bc | 2.95±0.03bc |
| LSD at P=0.05 | 0.197 | 0.355 | 0.197 |
| | Tegemeo A | Tegemeo B | Tegemeo C |
| 1 | 1.65±0.03a | 1.5±0.03a | 1.7±0.06a |
| 2 | 1.65±0.03a | 1.7±0.0bc | 1.7±0.06a |
| 3 | 1.72±0.04a | 1.75±0.05bc | 1.7±0.0a |
| LSD at P=0.05 | 0.116 | 0.106 | 0.150 |

Means within the same column followed by the same letter are not significantly different at P=0.05 according to Duncan's New Multiple Range Test.

### 4.1.3 Change in seed moisture content (SMC) with storage time

Seed moisture content was increasing with storage time (Table 4.7.). Seeds from farmers had high initial SMC than commercial seed. Sorghum had high SMC than maize irrespective of the source. Initial SMC varied from 10.27 to 11.25% and 11.26 to 11.52% for maize and sorghum from TANSEED respectively. The range for seeds from farmers was 11.60 to 12.70% and 12.18 to 15.02% for maize and sorghum respectively.

## Table 4.7 Change in SMC with storage time

| Crop-cultivar/lot | Seed moisture content (%) | | |
|---|---|---|---|
| | Time zero | After one month | After two months |
| **Seeds from TANSEED** | | | |
| Maize cv Kito, lot A | 10.86 | 11.19 | 11.62 |
| Maize cv Kito, lot B | 10.74 | 11.86 | 11.90 |
| Maize cv Kito, lot C | 10.87 | 11.95 | 12.06 |
| Maize cv Staha, lot A | 10.74 | 11.91 | 12.15 |
| Maize cv Staha, lot B | 10.81 | 11.51 | 11.86 |
| Maize cv Staha, lot C | 11.25 | 12.66 | 12.71 |
| Maize cv TMV-1, lot A | 10.54 | 11.97 | 12.25 |
| Maize cv TMV-1, lot B | 10.80 | 11.70 | 11.95 |
| Maize cv TMV-1, lot C | 10.27 | 11.62 | 11.89 |
| Sorghum cv Tegemeo, lot A | 11.52 | 12.23 | 12.64 |
| Sorghum cv Tegemeo, lot B | 11.26 | 12.30 | 12.80 |
| Sorghum cv Tegemeo, lot C | 11.50 | 12.60 | 13.08 |
| **Seeds from local farmers. (Farmer)** | | | |
| Maize cv Staha, (Milando ) | 11.60 | 12.04 | 12.68 |
| Maize cv Staha, (Mahava ) | 11.96 | 12.05 | 12.96 |
| Maize cv Staha, (Mahundumla) | 11.88 | 12.12 | 12.58 |
| Maize cv Kito, (Shija) | 12.70 | 12.98 | 13.25 |
| Maize cv Kito, (Dongo) | 11.62 | 12.10 | 12.70 |
| Maize cv TMV-1, (Omary) | 11.75 | 11.99 | 12.15 |
| Sorghum cv Tegemeo, (Salehe) | 12.18 | 13.19 | 13.98 |
| Sorghum cv Tegemeo, (Shija) | 15.02 | 16.13 | 16.88 |

## 4.2 EXPERIMENT TWO: The effect of the length of time seeds remains in soil before onset of rains on establishment

### 4.2.1 Seedling emergence

Emergence of seedlings as affected by the length of time seed remained in soil before watering is presented on (Table 4.1 and 4.2 and Appendices 4.9 and 4.10)

Sorghum seeds emerged earlier than maize seeds. Sorghum seeds started emerging 3 days after watering whereas emergence for maize started on the 4$^{th}$ day after watering (Table 4.1 and 4.2 and Appendices 4.11 and 4.12). More maize seedlings emerged early (day 4 - 5) in high vigour seeds compared to medium and low vigour categories (table 4.8).

In the field, emergence of both maize and sorghum followed the same trend as that of glasshouse experiment. Sorghum emerged earlier than maize regardless of the vigour groups. Sorghum emerged on the 3$^{rd}$ day after watering whereas maize emerged on the 4$^{th}$ day (Table 4.9 - 4.10) and Appendices 4.11 - 4.12).

Emergence for maize seeds which had stayed in the soil for 15 days was first observed on the 5$^{th}$ day after watering for all vigour groups of maize. Sorghum seeds even those which had stayed in soil for 15 days, started emerging on the 3$^{rd}$ day after watering. The high vigour (HV) maize seeds had more emerged seedlings on the 4$^{th}$ day compared to medium vigour (MV) and low vigour (LV) seeds (Table 4.9 and 4.10).

For the glasshouse experiment, the length of time seed remained in the soil seem to have had no effect on percentage emergence (Table 4.8 and 4.9). Under field conditions, percentage emergence decreased with length of time seed remained in soil before watering (Table 4.10 and 4.11).

The proportion of both sorghum and maize seeds which emerged, seeds which germinated but failed to emerge and seeds which did not germinate are shown in (Table 4.12 and 4.13).

Table 4.8 Cumulative percentage emergence of maize (cv Staha) as affected by vigour and the length of time seeds remained in soil columns before watering (Glasshouse)

| Days after watering | Length of time seed remained in soil before watering — Days | | | | | |
|---|---|---|---|---|---|---|
| | 0 | 3 | 6 | 9 | 12 | 15 |
| **High Vigour seed** | | | | | | |
| 4 | 20 | 30 | 20 | 20 | 20 | 94 |
| 5 | 80 | 86 | 66 | 74 | 60 | 100 |
| 6 | 94 | 94 | 74 | 100 | 94 | 100 |
| 7 | 100 | 94 | 74 | 100 | 94 | 100 |
| 8 | 100 | 94 | 74 | 100 | 94 | 100 |
| **Medium Vigour seed** | | | | | | |
| 4 | 20 | 0 | 0 | 20 | 0 | 0 |
| 5 | 46 | 46 | 60 | 60 | 46 | 74 |
| 6 | 86 | 66 | 94 | 74 | 86 | 94 |
| 7 | 86 | 66 | 94 | 80 | 86 | 94 |
| 8 | 94 | 74 | 94 | 80 | 94 | 94 |
| **Low Vigour seed** | | | | | | |
| 4 | 0 | 60 | 0 | 0 | 0 | 0 |
| 5 | 30 | 74 | 40 | 40 | 26 | 34 |
| 6 | 80 | 100 | 60 | 86 | 74 | 80 |
| 7 | 86 | 100 | 80 | 86 | 86 | 86 |
| 8 | 86 | 100 | 80 | 86 | 94 | 94 |

NB. Days 1 to 3 had no emergence of seedlings hence skipped.

Table 4.9 Cumulative percentage emergence of sorghum (cv Tegemeo) as affected by vigour and the length of time seeds remained in soil columns before watering (Glasshouse experiment).

| Days after watering | Length of time seed remained in soil before watering (Days) | | | | | |
|---|---|---|---|---|---|---|
| | 0 | 3 | 6 | 9 | 12 | 15 |
| | High Vigour seed | | | | | |
| 3 | 46 | 40 | 66 | 80 | 66 | 60 |
| 4 | 66 | 66 | 72 | 94 | 86 | 66 |
| 5 | 80 | 80 | 86 | 94 | 94 | 66 |
| 6 | 80 | 80 | 100 | 94 | 94 | 66 |
| 7 | 80 | 80 | 100 | 94 | 94 | 66 |
| 8 | 80 | 80 | 100 | 94 | 100 | 66 |
| | Medium Vigour seed | | | | | |
| 3 | 46 | 74 | 54 | 40 | 30 | 46 |
| 4 | 72 | 86 | 72 | 54 | 46 | 80 |
| 5 | 72 | 94 | 72 | 66 | 54 | 94 |
| 6 | 86 | 94 | 72 | 66 | 54 | 94 |
| 7 | 86 | 94 | 80 | 66 | 54 | 94 |
| 8 | 86 | 94 | 80 | 66 | 54 | 94 |
| | Low Vigour seed | | | | | |
| 3 | 46 | 66 | 40 | 40 | 66 | 34 |
| 4 | 72 | 94 | 66 | 60 | 80 | 54 |
| 5 | 94 | 94 | 86 | 80 | 80 | 60 |
| 6 | 94 | 94 | 100 | 86 | 80 | 66 |
| 7 | 100 | 94 | 100 | 86 | 80 | 66 |
| 8 | 100 | 94 | 100 | 86 | 86 | 66 |

NB.Days 1 to 2 had no seedling emergence hence skipped.

**Table 4.10 Cumulative percentage emergence of maize (cv Staha) as affected by vigour and the length of time seeds remained in the soil (field) before watering.**

| Days after watering | Length of time seed remained in soil before watering — Days | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 3 | 6 | 9 | 12 | 15 |
| | **High Vigour seed** | | | | | |
| 4 | 40 | 60 | 74 | 46 | 40 | 0 |
| 5 | 100 | 86 | 86 | 80 | 86 | 60 |
| 6 | 100 | 86 | 86 | 80 | 86 | 66 |
| 7 | 100 | 94 | 86 | 80 | 86 | 66 |
| 8 | 100 | 94 | 86 | 80 | 86 | 66 |
| | **Medium Vigour seed** | | | | | |
| 4 | 20 | 26 | 40 | 30 | 20 | 0 |
| 5 | 86 | 86 | 80 | 86 | 54 | 40 |
| 6 | 86 | 86 | 86 | 86 | 74 | 40 |
| 7 | 86 | 100 | 94 | 86 | 74 | 46 |
| 8 | 86 | 100 | 94 | 86 | 74 | 46 |
| | **Low Vigour seed** | | | | | |
| 4 | 40 | 0 | 20 | 0 | 0 | 0 |
| 5 | 60 | 60 | 26 | 20 | 20 | 20 |
| 6 | 60 | 60 | 46 | 40 | 46 | 20 |
| 7 | 66 | 66 | 74 | 66 | 46 | 26 |
| 8 | 66 | 74 | 74 | 66 | 60 | 26 |

NB. Days 1 to 3 had no emergence of seedlings hence skipped.

Table 4.11 Cumulative percentage emergence of sorghum (cv Tegemeo) as affected by vigour and the length of time seeds remained in soil (field) before watering.

| Days after watering | Length of time seed remained in soil before watering — Days | | | | | |
|---|---|---|---|---|---|---|
| | 0 | 3 | 6 | 9 | 12 | 15 |
| | **High Vigour seed** | | | | | |
| 3 | 40 | 26 | 46 | 40 | 20 | 20 |
| 4 | 54 | 46 | 60 | 40 | 20 | 54 |
| 5 | 54 | 46 | 60 | 40 | 30 | 54 |
| 6 | 54 | 46 | 60 | 40 | 30 | 54 |
| 7 | 54 | 46 | 60 | 40 | 30 | 60 |
| 8 | 54 | 46 | 60 | 40 | 30 | 60 |
| | **Medium Vigour seed** | | | | | |
| 3 | 74 | 46 | 40 | 34 | 20 | 34 |
| 4 | 74 | 74 | 54 | 46 | 46 | 46 |
| 5 | 74 | 74 | 54 | 46 | 46 | 46 |
| 6 | 74 | 74 | 54 | 46 | 46 | 46 |
| 7 | 74 | 74 | 60 | 46 | 54 | 46 |
| 8 | 74 | 74 | 60 | 46 | 54 | 46 |
| | **Low Vigour seed** | | | | | |
| 3 | 40 | 60 | 60 | 34 | 40 | 30 |
| 4 | 40 | 74 | 80 | 34 | 40 | 30 |
| 5 | 46 | 74 | 80 | 34 | 40 | 46 |
| 6 | 46 | 74 | 80 | 34 | 40 | 46 |
| 7 | 54 | 80 | 80 | 46 | 40 | 46 |
| 8 | 54 | 80 | 80 | 46 | 40 | 46 |

NB.Days 1 to 2 had no seedling emergence hence skipped.

**Table 4.12 Percentage of maize and sorghum seeds which emerged as was affected by vigour in the glasshouse study.**

| Vigour category | Emerged | Germinated not emerged | Failed to germinate |
|---|---|---|---|
| **Maize:** | | | |
| High vigour | 94.4 | 4.4 | 1.1 |
| Medium vigour | 87.8 | 10 | 2.2 |
| Low vigour | 91 | 6.6 | 2.2 |
| **Sorghum:** | | | |
| High vigour | 85.5 | 0 | 14.4 |
| Medium vigour | 80 | 0 | 20 |
| Low vigour | 88.8 | 0 | 11 |

High vigour maize seeds both in glasshouse and in the field had relatively high proportion of seeds which germinated and emerged than LV and MV seeds (Table 4.12). The proportion of seeds which germinated but failed to emerge and seeds which did not germinate was also relatively lower in HV than in the other two vigour categories.

In sorghum and for low vigour seeds, relatively more seeds emerged compared to the other two vigour categories
The results are contrary to those observed in maize due to the fact that the MV and LV groups performed better in terms of emergence and growth than the HV seeds. This can be seen in (Table 4.13) where the MV had a proportion of 57.7 seeds which emerged and 42.2 seeds which did not germinate compared to 46.6 and 52.2 for HV category.
There was overall reduction in percentage emergence under field condition as compared to glasshouse study.

Table 4.13 Percentage of maize and sorghum seeds which emerged as was affected by vigour in the field study.

| Vigour category | Emerged | Germinated not emerged | Failed to germinate |
|---|---|---|---|
| Maize: | | | |
| High vigour | 84.4 | 2.2 | 13.3 |
| Medium vigour | 82.2 | 3.3 | 14.4 |
| Low vigour | 63.3 | 5.5 | 31.1 |
| Sorghum: | | | |
| High vigour | 46.6 | 0 | 52.2 |
| Medium vigour | 57.7 | 0 | 42.2 |
| Low vigour | 56.6 | 0 | 43.3 |

### 4.2.2 Root and shoot length for glasshouse and field experiments.

Mean root and shoot Lengths in both glasshouse and the field studies are shown in (Table 4.14 and 4.15)

**Table 4.14 Mean maize and sorghum root and shoot length as affected by length of time seed remained in soil before watering for glasshouse (G) and field (F) experiments.**

| Length of time (days) | Maize | | | Sorghum | | |
|---|---|---|---|---|---|---|
| | Root (G) | Shoot (G) | Shoot (F) | Root (G) | Shoot (G) | Shoot (F) |
| 0 | 154.9ab | 184.8a | 133.3c | 103.2a | 143.7ab | 90.1a |
| 3 | 153.1ab | 190.3a | 129.0c | 96.4a | 154.8c | 84.3a |
| 6 | 160.5c | 210.9a | 133.0c | 107.1a | 147.9ab | 86.9a |
| 9 | 145.6a | 197.5a | 124.0ab | 103.3a | 148.0ab | 88.3a |
| 12 | 147.0ab | 191.2a | 105.0a | 92.2a | 136.0a | 74.5a |
| 15 | 150ab | 202.1a | 132.0c | 102.7a | 141.8ab | 85.3a |
| LSD (P=0.05) | 14.0 | 30.2 | 20.8 | 20.9 | 21.4 | 15.8 |

Means within the same column followed by the same letter are not significantly different at P=0.05 according to Duncan's New Multiple Range Test.

Table 4.15 Mean maize and sorghum root and shoot length as affected by vigour categories for glasshouse (G) and field (F) experiments.

| Vigour Group | Maize | | | Sorghum | | |
|---|---|---|---|---|---|---|
| | Root (G) | Shoot (G) | Shoot (F) | Root (G) | Shoot (G) | Shoot (F) |
| High vigour | 157.0a | 221.4a | 150.8a | 104.ab | 155.4b | 88.5a |
| Medium vigour | 148.0a | 193ab | 135.0b | 108.6a | 145.3ab | 86.0a |
| Low vigour | 150a | 174.3ab | 92.0c | 90.3b | 136.9a | 80.3a |
| LSD P=0.05 | 9.9 | 21.3 | 14.7 | 14.8 | 15.1 | 11.1 |

Means within the same column followed by the same letter are not significantly different at P=0.05 according to Duncan's New Multiple Range Test.

#### 4.2.2.1 Maize root and shoot lengths.

When the means for root were separated by multiple range test (MRT) for the number of days seeds remained in soil columns before watering, only root length on day 9 and day 6 showed significant differences (p=0.05). The difference in other treatments were non significant (NS). Generally there were no consistent trend in maize root length with either vigour category or length of time seeds remained in soil columns before watering (Table 4.14 and 4.15, Appendix 4.13).

There were no significant differences (p=0.05) for maize shoot length with respect to vigour categories as well as length of time seeds remained in soil columns before watering (Table 4.14 and 4.15). Shoot lengths for maize grown in the field differed significantly (P=0.05) from that in the glasshouse and especially between HV and LV (Table 4.14 and 4.15). This trend can also be observed in (Appendix 4.18). Again there were no consistent trend for the length of time seeds remained in soil before watering (Table 4.14 and Appendix 4.17).

Root and shoot lengths for maize and sorghum (grown in both glasshouse and in the field) as affected by vigour category and length of time seed remained in soil before watering are shown in (Table 4.16 and 4.17).

#### 4.2.2.2 Sorghum root and shoot lengths

The root lengths measurement for the sorghum grown in the soil columns showed significant differences (p=0.05) between MV and LV categories (Table 4.15 and Appendix 4.16). No trend was observed with regard to the length of time seeds remained in soil columns before watering (Table 4.14 and Appendix 4.15)

Shoots for sorghum seedlings grown in soil columns were significantly longer (P=0.05) for HV as compared to MV and LV (Table 4.15). Seedlings from HV seeds had longer shoots followed by MV and LV respectively. There was no consistent trend for shoot length to vary with the length of time seeds remained in soil before watering (Table 4.14 and Appendix 4.16).

Sorghum seedlings grown in the field showed no significant differences (P=0.05) in shoot length both with respect to seed vigour categories and for the length of time seeds remained in soil before watering (Table 4.14 and 4.15).

Table 4.16 Maize root and shoot length (grown in both glasshouse and in the field) as affected by vigour category and length of time seed remained in soil before watering.

| Length of time seed remained in soil | 0 | 3 | 6 | 9 | 12 | 15 | LSD at P= 0.05 |
|---|---|---|---|---|---|---|---|
| **Maize root length (glasshouse)** | | | | | | | |
| High vigour | 168.4a | 152.6a | 164.3a | 142.4a | 163.6a | 151a | 32.36 |
| Medium vigour | 152.6a | 156a | 152.4a | 140a | 135.1a | 152.4a | 24.48 |
| Low vigour | 143.6a | 150.8a | 164.7a | 154.6a | 142.4a | 148a | 32.19 |
| LSD at P=0.05 | 22.56 | 25.36 | 38.98 | 46.63 | 26.23 | 35.11 | |
| **Maize shoot length (glasshouse)** | | | | | | | |
| High vigour | 200.1a | 207.3a | 243.3a | 228.8a | 233.3a | 215a | 62.71 |
| Medium vigour | 192.9a | 178.4a | 195.7a | 181.1a | 201.4a | 207.8a | 80.43 |
| Low vigour | 161.6a | 185.3a | 193.8a | 182.7a | 139a | 183.1a | 62.19 |
| LSD at P=0.05 | 67.47 | 68.58 | 67.93 | 117 | 49.48 | 77.24 | |
| **Maize shoot length (field)** | | | | | | | |
| High vigour | 153.3a | 152.8a | 160.9a | 140.6a | 146.9a | 150.6a | 30.74 |
| Medium vigour | 141a | 137.5a | 140a | 142.3b | 105.5c | 147.5b | 35.6 |
| Low vigour | 105.8a | 97.3a | 100.2a | 90.5a | 64.9a | 98.2a | 57.19 |
| LSD at P=0.05 | 82.75 | 23.28 | 25.44 | 42.74 | 34.68 | 52.59 | |

Values sharing the same letter in the same row are not significantly different at P=0.05.

Table 4.17 Sorghum root and shoot length (grown in both glasshouse and in the field) as affected by vigour category and length of time seed remained in soil before watering.

| Length of time seed remained in soil | 0 | 3 | 6 | 9 | 12 | 15 | LSD at P=0.05 |
|---|---|---|---|---|---|---|---|
| **Sorghum root length (glasshouse)** | | | | | | | |
| High vigour | 82.5a | 102b | 116.9c | 114.8c | 99.8b | 105b | 28.61 |
| Medium vigour | 131.7a | 106.2a | 107.4a | 109.3a | 92.8a | 104.6 | 53.99 |
| Lowm vigour | 95.5a | 81.1a | 97.2a | 85.8a | 84.2a | 98.6a | 29.5 |
| LSD at P=0.05 | 88.8 | 34.1 | 27.76 | 33.0 | 17.0 | 20.0 | |
| **Sorghum shoot length (glasshouse)** | | | | | | | |
| High vigour | 155.9a | 143.2a | 158.5a | 160.9a | 159.5a | 154.7a | 34.27 |
| Medium vigour | 153.4a | 168.7b | 152.8a | 140.6a | 119.2c | 137.6a | 46.70 |
| Low vigour | 122.0a | 161.5b | 132.5c | 142.5c | 130.1c | 133.1c | 34.19 |
| LSD at P=0.05 | 51.13 | 39.47 | 42.48 | 43.65 | 46.97 | 36.26 | |
| **Sorghum shoot length (field)** | | | | | | | |
| High vigour | 92.3a | 89.4a | 95.1a | 98.3a | 63.3a | 92.5a | 44.24 |
| Medium vigour | 90.6a | 79.5a | 86.9a | 92.9a | 78.4a | 88.0a | 19.14 |
| Low vigour | 87.5a | 84.0a | 78.8a | 73.8a | 81.8a | 75.6a | 20.93 |
| LSD at P=0.05 | 24.24 | 15.75 | 14.0 | 30.44 | 66.4 | 24.44 | |

Values sharing the same letter in the same row are not significantly different at P=0.05.

### 4.2.3 Number of lateral roots for maize and sorghum grown in the soil columns

#### 4.2.3.1 Maize seedlings

At harvest the number of lateral roots varied from 2 to 15 with an average of 6 roots for all the vigour categories. There was no clear trend for the number of lateral roots to vary with either vigour category or the length of time seeds had remained in soil before the application of water. For example, LV seedling whose seed remained in the soil for zero days had 10 lateral roots compared to 6 and 7 for HV and MV respectively.

#### 4.2.3.2 Sorghum seedlings

The count of lateral roots in sorghum at harvest showed a similar trend to that for maize. That is, there was no trend for the number of lateral roots to vary with either vigour category or the length of time seeds remained in the soil before watering.

### 4.2.4 Number of leaves for maize and sorghum grown both in soil columns and in the field.

#### 4.2.4.1 Maize seedlings in the soil columns.

The number of leaves at harvest varied from 2 to 4 with an average of 3 leaves in all vigour categories. No consistent trend was observed for the number of leaves to

vary with either vigour or the length of time the seed remained in the soil before watering.

#### 4.2.4.2 Sorghum seedlings in the soil columns

At 10 days after the application of water, the seedlings had 2 to 3 leaves with an average of 3 leaves. Again no consistent trend was observed for this parameter to vary with vigour groups or the time seed remained in soil before the application of water.

#### 4.2.4.3 Maize seedlings in the field

The number of leaves for maize seedlings varied from 2 to 4 with an average of 3 leaves for all vigour groups. No trend was observed for the number of leaves to vary with either vigour or the length of time the seed remained in the soil before watering.

#### 4.2.4.4 Sorghum seedlings in the field

Sorghum seedlings had an average of 3 leaves regardless of vigour group and the length of time seeds remained in soil before watering.

# CHAPTER FIVE

## 5.0 DISCUSSION

### 5.1 Experiment one: Assessment of seed quality in commercial and farmers planting seed and monitoring of the extent of seed ageing in storage.

Sorghum seeds from TANSEED had higher germination capacity than those from farmers. Sorghum seeds from farmers might have been destroyed during processing and storage where by cell membranes, organelles,nuclear materials and other mechanisms involved in the resumption of growth were impaired making them incapable of supporting the resumption of growth (AOSA, 1983). Germination was 0% for sorghum cv Tegemeo obtained from farmer Shija during the second sampling. Alternatively microorganisms (storage fungi) might have infested the seeds during storage which spoiled the seed quality (Christensen and Kaufmann,1974). The activity of these microorganisms which were observed during the germination test could have been favoured by high temperatures and relative humidity in farmers' stores which also influence the rate of seed deterioration. The effect of seed deterioration has been described by Delouche and Baskin (1973) as slow rate and decreased germination capacity, poor emergence and seedling growth, decreased tolerance to suboptimal conditions and low

oxygen uptake during early stage of germination.

The germination capacity, in practice is the best general indicator of a seed lot's ability to grow in the field and lot's of low capacity should be rejected (Thompson, 1979). The importance of high germination to farmer is obvious but in practice the full potential is seldom realised and the number of seedlings established in the field is less than germination capacity would indicate, for conditions in the field are not usually favourable. Nevertheless, the higher the germination capacity the better the field establishment (higher germination capacity is an indicator of field establishment). Thus the results from this study showed that all seeds from TANSEED had the germination capacity above the acceptable level. One out of six maize varieties from farmers and all two sorghum varieties also from farmers had the germination capacity below the acceptable level.

The importance of $T_{50}$ to farmers is obvious since the rate of moisture loss and development of high soil strength are limiting factors to crop establishment. The early germinating seeds utilise the available moisture and hence emerge before surface crusts are formed. The formed soil surface crust prevent emergence of the late germinated seedlings.

The germination rate for sorghum was observed to be lower than that for maize. This could be due to the fact that sorghum seeds are attacked by more pests and diseases than maize seeds. The seeds with low vigour are associated with low viability and low germination rate and percentage (Hartman and Kester, 1968). Normally sorghum seeds have lower germination rate as well as capacity as compared to maize seeds (Dogget, 1988). Sorghum seeds obtained from farmers had low viability potentials as well as vigour due to the factors such as poor handling of seeds during harvesting, processing and storage. These might cause reduction of vigour and viability and hence lower the germination rate.

ISTA (1987) and Bodliya and Burris (1988) linked the factors such as poor handling of seeds from mother plants; harvesting, processing and storage to seed ageing due to the structural integrity of cell membranes during seed development, drying, handling and storage. Seeds with high germination rate are of advantage to farmers because they emerge sufficiently rapid before the effect of other environmental stress factors for example drying of the soil or fungal attack prevent germination (So, 1987)

Seed moisture content increased with storage time. This was evidence that the moisture content in seed stores was

higher than the initial SMC hence seeds absorbed more moisture for the purpose of equilibration.

Roberts (1972) pointed out that seeds' moisture content seems to play a major role in seed storage probably a far greater role than storage or ambient temperature. The higher the SMC and temperature, the higher the deterioration rate and if the seeds are physically or mechanically damaged or if storage pathogens (fungi, insects and mites) invade, seed quality loss may occur substantially and very quickly (Neergaard, 1977; Roberts, 1983; Agarwaal and Sinclair, 1987; Mashauri, 1991) Generally the longevity of seeds in store is influenced by environmental temperature, moisture content of the seed and oxygen pressure (Roberts, 1972) and also by crop species and initial quality of the seed (Egli, *et al.* 1978)

Considering SMC and storage temperature, Harrington (1963) pointed out two rules of thumb for seed viability in store; that except in extreme conditions, for each one percent decrease in SMC and for every $5^{0}C$ decrease in temperature seed storage time is doubled. Thus it would be most desirable to store seeds at moisture content less than 10%. Too dry conditions, however may also reduce seed longevity, through extreme desiccation (Roberts,

1972).

Although dry and cold storage conditions can increase storage life of seeds, the optimum SMC and temperature are still a subject of ongoing debate (Ellis *et al.*, 1990, 1991, Vertucci and Ross, 1990, 1991). Storage knowledge helps to alleviate the unnecessary deteriorative factors during storage through controlled temperature, moisture and relative humidity.

### 5.1.1 Seed sources

Seed from TANSEED was more superior than that from farmers. TANSEED is a parastatal organisation which is responsible for the production, processing and selling of the seeds directly to farmers or through the stockists in Tanzania. The production and handling of the seeds is relatively superior as compared to farmers because of the control imposed at different stages of production, processing and storage. Storage conditions in TANSEED, Morogoro branch are improved as compared to farmers. The godowns are well ventilated so as to allow free air circulation which lowers the storage temperature. The seeds are stored at the SMC ranging from 10 to 12% which allows minimum deterioration or destruction by the pathogens and storage pests. Seeds are dressed with (storage) chemicals to avoid destruction by storage pests.

Seeds from TANSEED are well packed to minimize the risk of mixing one cultivar with another.

Farmers differ in the way they handle their seeds from production, processing and storage. Obviously there is no control during production since different farmers plant different cultivars within the same field hence no control on pollination. Some farmers store their seeds in poorly ventilated houses at the same time these houses are used as kitchen where the temperatures are very high. This does not agree with the study by FAO (1983) which cautioned that for every 5°C increase in seed temperature the life of the seed is halved and like wise for each 1% increase in seed moisture content the life of the seed is also halved (Harrington, 1963).

Farmers from whom the seeds were obtained did not dress their seeds with chemicals to prevent destruction by storage insects, hence most of their seeds were bored by storage pests. Mechanical damage to the seeds was also observed indicating poor processing techniques practised by the farmers. All these drawbacks observed from farmers indicate a need for the relevant authorities to intervene so as to enhance crop establishment and growth. The poor storage condition in the farmers stores was reflected in the study where some farmers had seeds with germination

rate and capacity below the standard set by TOSCA. This also reflected in poor establishment in the field.

## 5.2 Experiment Two: The effect of the length of time seeds remains in soil before onset of rains on establishment

In both glasshouse and field experiments sorghum seeds started emerging 3 days after watering where as for maize emergence started on the 4$^{th}$ day after watering. This is probably because the sorghum seeds are small in size than maize which provides large surface area for imbibition of water during germination process than the maize seeds. Possibly sorghum did take up water rapidly than did maize, thus sorghum had seed coat which allowed moisture to enter into the seeds relatively quicker than did the seed coat for maize. The early emergence confirms the rapid moisture uptake by sorghum as opposed to maize. Normally smaller seeds require less water than larger ones to initiate germination.

From the results (Table 4.7) sorghum had SMC higher than that of maize, this also could contribute to earlier emergence of sorghum as compared to maize because sorghum in this case needed less moisture to initiate germination. The reduced emergence rate by MV and LV could be because aged seeds do show marked decrease in enzyme activity

especially that of Super Oxide Dismutase SOD, as it was advocated by Anderson (1970). All the same, one has to note that reduced vigour does always result from general damage to the entire spectrum of enzymes (Ross, *et al* 1988). MV and LV maize seeds had exhibited ageing symptoms that is slow germination rate and slow emergence rate (Delouche and Baskin, 1973).

In addition, MV and LV maize seeds had lost their viability potential due to ageing and thus could not germinate and emerge rapidly. Cell membrane do deteriorate with ageing of seeds (Hampton and Coolbear, 1990). Thus when the seed is aged its emergence and storability become reduced as it was the case with MV and LV maize seeds which were artificially aged.

Due to ageing MV and LV maize seeds might have their endogenous auxins reduced. The above is a growth promoter in plants, so if this hormone is reduced germination capacity and rate are reduced as well (Coolbear, 1990).

During favourable conditions (such as optimum temperature, evapotranspiration, absence of microbes and other insect pests eg. environment in the glasshouse) both aged and unaged seeds showed similar performance. These results agreed with the study performed by Bekendam *et al*. (1987)

which showed that aged and unaged seed lots of maize had similar performance in the standard germination test, and during favourable field conditions.

Relatively more seeds germinated and emerged from low vigour sorghum seeds compared to the other two vigour categories. Probable explanations include the fact that normally sorghum varieties have inherent seed dormancy which reduces germination capacity and rate (ISTA, 1985). The artificial ageing of the seeds might have broken the inherent seed dormancy, hence made the LV category to germinate and emerge earlier than fresh seeds (HV) and MV seeds which still had the inherent seed dormancy. ISTA (1985) demonstrated that sorghum seeds need prechilling to break the inherent seed dormancy so as to germinate and emerge early. For the same reason it can be observed from (Table 4.10) for the HV and MV sorghum seeds the number of seeds which could not germinate is relatively higher compared to LV sorghum seeds.

**5.3 Comparison between glasshouse and field experiments.**

Maize seeds germinated and emerged 4 days after watering in both glasshouse and the field. The number of the seedlings emerged on the 4$^{th}$ day was relatively higher in the glasshouse than the field due to the artificial and more favourable conditions created in the glasshouse. The temperature in the glasshouse was relatively low, with an average of 24°C. This temperature created artificial micro climate which favoured germination and emergence of seedlings. The temperature in the field during experimentation was relatively high. The average temperature was 30°C. This temperature speeded up the rate of evapotranspiration which resulted into increased rate of water loss. The evapotranspiration rates were 2.4mm and 5.2mm per day for the glasshouse and in the field respectively. The rate of evapotranspiration in the field was double that of the glasshouse and this could be related to double rate of water loss in the field which could be the cause of observed impaired germination and emergence rate in the field. Sorghum seeds germinated and emerged 3 days after the application of water, for both glasshouse and the field. Again more seedlings emerged on the 3$^{rd}$ day in glasshouse experiment as compared to the field experiment. The reasons could be the same as those given above for maize.

### 5.3.1 Seedling emergence count

In the glasshouse experiment out of total maize seeds planted for each vigour category, the proportion of seeds which germinated and emerged was 94.4, 87.8 and 91 for HV, MV and LV respectively. In the field, the proportions were 84.4, 82.2 and 63.3% for HV, MV and LV respectively (Table 4.12 and 4.13).

The above results confirm the inherent differences in performance between vigour categories under favourable and unfavourable conditions. Hence, germination results from controlled environment should not be used to recommend seed lots as being fit for planting before being tested in the field.

The proportion of maize seeds which failed to germinate under glasshouse conditions varied from 1.1 to 2.2% across vigour categories. In the field experiment the proportins increased and varied from 13.3 to 31.1%. This also elaborates the difference between the two environments. These trends were also observed in sorghum (Table 4.12 and 4.13).

### 5.3.2 Shoot length

The average shoot length in the glasshouse, at 10 days after watering varied from 157mm to 238mm long. Whereas in the field, for the same duration the shoot length varied from 90.7mm to 248mm.

Sorghum also follow the trend observed in maize. The mean shoot length varied from 121mm to 172mm and 63mm to 101mm for glasshouse and the field experiments respectively. The reason for the above variation is the differences in the two environments (glasshouse and the field conditions).

# CHAPTER SIX

## 6.0 CONCLUSIONS AND RECOMMENDATIONS

In view of the results obtained in this study, the following conclusions and recommendations can be made:

### 6.1 CONCLUSIONS

(a) As far as seed quality is concerned, commercial seed (TANSEED) ranked much higher than seed from farmers. Use of commercial seed by farmers can thus reduce incidences of poor crop establishment and especially for sorghum.

(b) Germinability of the maize and sorghum seeds is influenced by the length of storage time. The longer the storage time the lower the germination percentage and the longer the $T_{50}$. Therefore the seeds for field planting should not be stored longer than one season.

(c) Low germination percentage could be attributed to poor storage conditions which cause accelerated ageing of seed. This was observed in the sorghum and maize seeds obtained from local farmers. Farmers in the rural areas faced poor crop establishment due to poor handling of their seeds, including poor storage conditions (high temperatures,

relative humidity and high seed moisture content) which result into lowered seed vigour.

(d) High vigour maize and sorghum seeds survived in the soil for more than 15 days and still germinated and emerged well on the application of water. The longer poor quality seeds (low vigour) remained in the soil before watering, the slower and lower the germination and emergence.

(e) Overall, the glasshouse experiment showed a superior difference in terms of performance from field experiment and this was probably due to the difference in conditions which existed in both experiments. Thus results from glasshouse experiments should not be used to arrive at recommendations meant for farmers because the conditions in the field are not always favourable and therefore results from glasshouse become unrealistic.

## 6.2 RECOMMENDATIONS

(a) Where as the current study lasted for only six months, TANSEED stores seed for 2-3 seasons. Thus long term and monitoring of the extent of seed ageing in stores is required so as to draw meaningful conclusions. Such studies need to be carried hand in hand with pathological experiments because the incidences of pathological

symptoms like fungal growth were observed in the germination test conducted in the laboratory.

(b) Most farmers cannot afford or do not use certified seeds, instead they rely on the seed from the previous season which is usually kept under conditions that cause deterioration. Further studies should target appropriate seed storage techniques for farmers.

(c) Government intervention in terms of subside and other assistance to farmers could encourage them to go for commercial seeds and as a result improve crop establishment.

## REFERENCES

**Abdul-Baki, A.A.** (1980) Biochemical aspects of seed vigour. *Horticultural Science* 15(6), 765-771.

**Adegbuyi, E. and Burris, J.S.** (1989) Effect of seed vigour on crop characters in uniform and reduced population of corn *(Zea mays* L.). *Journal of Agronomy and Crop Science* 162, 10- 20.

**Agarwal, V.K. and Sinclair, J.B.** (1987) *Principles of Seed Pathology*, Vol. 1 and 2.CRC Press, Florida.

**Aksenow, S.I. and Golovina, E.A.** (1977) State of water in seed of different qualitative composition and change of it under temperature influences. *Soviet Plant Pathology* 24, 1007-1015.

**Anderson, D.J.** (1970) Physiological and biochemical differences in deteriorating barley seeds. *Crop Science* 59, 610-614.

**Anon.** (1985) International Rule for Seed Testing (1985). *International Seed Association, Seed Science and Technology* 13, 356 - 513.

**Arndt, W.** (1965a) The nature of the mechanical impedance to seedlings by soil surface seals. *Australian Journal of Soil Research* 3, 45-54.

**Association of Official Seed Analysis (AOSA)**, (1983) *Seed Testing Handbook,* AOSA Contribution No. 32

**Bdliya, P.M. and Burris, J.S.** (1988) Diallel analysis of drying injury of seed corn. *Crop Science* 28, 935-938.

**Bekendam, J.; Kraak L, and Vos, J.** (1987) Studies on field emergence and vigour of onion, sugar beet, flax and maize seed. *Acta Horticulturae* 215, 83-94.

**Berjak, P. and Villiers, T.A.** (1970) Ageing in plant embryos. The establishment of normal sequence of development in the root cap up on germination. *New Phytology* 69, 929-939.

**Black, C.A.** (1968) *Soil- Plant Relationship.* Wiley, New York.

**Blacket, D.S.** (1987) Improving crop emergence with management and agronomy. In: *Crop Establishment Problems in Queensland.* Occasional Publications No. 34 (*edited by Wood I.M.; Hazard, W.H. and From, F.R.*). pp 192 - 207. Australian Institute.

**Blowers, l.E.; Stormonth, D.A. and Bray, C.M.** (1980) Nucleic acid and protein synthesis-loss of vigour in germinating wheat embryos. *Planta* 150, 19-25.

**Bruni, F. and Leopold , A.C.** (1991) Glass transitions in soybean seed. Relevance to anhydrous biology. *Plant Physiology* 96, 660-663.

**Bruni, F. and Leopold, A.C.** (1992a) Cytoplasmic glass formation in maize embryos. *Seed Science Research* 2, 251-253.

**Bruni, F. and Leopold, A.C.** (1992b) Pools of water in anhydrobiotic organisms. A thermal stimulated depolarization current study. *Biophysics Journal* 63, 663-672.

**Bulisan, E.A. and Warner, R.L.** (1980) Seed protein and nitrogen effects up on seedling vigour in wheat. *Agronomy Journal* 72, 657-662

**Burke, M.J.** (1986) The glass state and survival of anhydrous biological systems. · pp. 358-364. In: *Membranes Metabolism and Dry Organisms*. (edited by A.C. Leopold). Ithaca, Cornell University Press.

**Burris, J.S.** (1975) Seedling vigour and its effect in field production of corn. *Proceedings of the 30th Corn and Sorghum Research Conference* 185-193.

**Burris, J.S.** (1977) Effect of location of production and maternal parentage on seedling vigour in hybrid maize. *Seed Science and Technology* 5, 703-708.

**Cal, J.P. and Obendorf, R.L.** (1972) Imbibitional chilling injury in *Zea mays* L. altered by initial kernel moisture and maternal parent. *Crop Science* 12, 369-373.

**Camargo, C.P. and Voughan, C.E.** (1973) Effect of seed vigour on field performance and yield of grain sorghum ( *Sorghum bicolar*). *Proceedings of the Association of Official Seed Analysts* 63, 135- 147

**Ching, T.M. and Kronstad, W.E.** (1972) Varietal differences in growth potential, adenylate energy level and energy change of wheat. *Crop Science* 12, 785-789.

**Chopra, U.K. and Chaudhary, T.N.** (1981) Seedling emergence of wheat and grain in relation to soil water potential, temperature and seedling depth. *Journal of Indian Society of Soil Science* 29, 437-440.

**Christensen, C.M. and Kaufmann, H.H.** (1974) Microflora. In: *Storage of Cereal Grains and Their Products*. (*edited by C.M. Christensen*). American Association of Cereal Chemists, Minnesota. pp. 158-182.

**Coolbear, P.** (1990) Seed Physiology. *Lecture Notes*, Seed Technology Centre, Massey University.

**Currie, J.A.** (1984) The physical environment in seed-bed. *Aspects of Applied Biology* 7, 33-54.

**Delouche, J.C.** (1980) Environmental effects on seed development and seed quality. *Horticultural Science*

15, 775-580.

**Delouche, J.C. and Baskin, C.C.** (1973) Accelerating ageing techniques for predicting the relative storability of seed lots. *Seed Science and Technology* 1(2), 427-452.

**Doggett, H.** (1988) Sorghum (2nd edition). Longman Scientific and Technical, New York.

**Dourado, A.M. and Roberts, E.H.** (1984) Chromosome aberrations induced during storage in barley and pea seeds. *Annals of botany* 54, 767-779.

**Douglas, J.E.** (1983) Seed storage and packing. In: *Cereal Seed Technology.* Food and Agriculture Organisation of the United Nations; Rome, Italy; pp. 87-105.

**Edje, O.T. and Burris, J.S.** (1970) Physiological and chemical changes in deteriorating soybean seed. *Proceedings of the Association of Official Seed Analysts* 60, 158-166.

**Egli, D.B; G.M. White and D.M. TeKrony** (1978) Relationship between seed vigour and the storability of soybean

seed. *Journal of Seed Technology* 3, 1-12

**Egli, D.B. ; TeKrony, D.M. and Wiralaga, R.A.** (1990) Effect of soybean seed vigour and size on seedling growth. *Journal of Seed Technology* 14, 1-12.

**Ellis, R. H.; and Roberts, E. H.** (1980) Improved equations for the prediction of seed longevity. *Annals of Botany* 45, 13-30.

**Ellis, R.H.; Hong, T.D. and Roberts, H.E.** (1991) Seed moisture content, storage, viability and vigour. *Seed Science Research* 1, 275-277.

**Ellis, R.H.; Hong, T.D.; Roberts, E.H. and Tao, K.** (1990) Low moisture content limits to relations between seed longevity and moisture. *Journal of Experimental Botany* 65, 493-504.

**Etherington, J.R.** (1978) Plant physiological ecology. *Studies in Biology* No. 98. Edward Arnold, Southhampton.

**Food and Agriculture Organization (FAO)** (1983) *Technical Guidance for cereal Seed Testing*. United Nations, Rome.

**Fawcet, R. G. and Collis-George N.** (1967) A filter paper method for determining the moisture characteristic of soil. *Australian Journal of Experimental Agriculture and Animal Husbandry* 7, 162-167.

**Francis, A. and Coolbear, P.** (1987) A comparison of changes in germination responses and phospholipid composition of naturally and artificially aged tomato seeds. *Annals of Botany* 59, 167-172.

**Franks, F.** (1985) *Biophysics and Biochemistry at Low Temperatures*. Cambridge University press.

**Funk, C.R.; Anderson, J.C.; Johnson, M.W. and Atkinson, R.W.** (1962) Effect of seed source and seed age on field and laboratory performance of field corn. *Crop Science* 2, 318-320.

**Frere, M.** (1982) Use of climatic information for land use planning and crop diversification. In: *Proceedings of the Technical Conference on Climate* africa WMO No. 596, 190 - 193.

**Gurmu, M. and Naylor, R.E.L.** (1991) Effects of low water availability on germination of two sorghum cultivars. *Seed Science and technology* 19, 373 - 383.

**Hampton, J.G. and Coolbear, P.** (1990) Potential versus actual field performance -can vigour test provide an answer? *Seed Science and Technology* 18, 215-228.

**Hampton, J.G. and Scott, D.J.** (1982) Effect of seed vigour on garden pea production. *New Zealand Journal of Agricultural Research* 25, 289-294.

**Harman, G.E.** (1983) Mechanism of seed infection and pathogenesis. *Phytopathology* 73, 326-329.

**Harrington, J.F.** (1963) Practical instructions and advice on seed storage. *Proceeding of International Seed Testing Association* 28, 989-994.

**Harrington, J.F.** (1973) The biochemical basis of seed longevity. *Seed Science and Technology* 1, 453-461.

**Hartmann, H.T. and Kester, D.E.** (1968) *Plant Propagation*. Principles and practices (2nd edition) Prentice-Hall, Inc. Englewood Cliffs, New Jersey.

**Harty, R. L., Heslehurst, M. R., and McDonald, J.** (1987) Seed vigour. In: *Crop Establishment Problems in Queensland:* Occasional Publication No. 34 (*edited by Wood, I. M., Hazard, W. H. and From, F. R.*). pp 79-87. Australian Institute of Agricultural science.

**Heslehurst, M.R. and McDonald, J.** (1987) Seed vigour In: *Crop Establishment Problems in Queensland:* Occasional Publications No. 34 (*edited by Wood I.M., Hazard W.H. and From F.R.*). pp. 79 - 87 Australian Institute of Agricultural Science.

**Heydecker, W.** (1977) Stress and seed germination: An agronomic view. pp. 237-276. In: *The Physiology and Biochemistry of Seed Dormancy and Germination.* (*edited by A.A. Khan*).

**Hillel, D.** (1972) Soil moisture and seed germination. In: *Water Deficits and Plant Growth* (edited by Kozlowski, T.T.) Vol. III pp. 65 - 89. Academic Press, New York.

**Hooke, M.H.** (1987). How do we tackle crop establishment problems? In: *Crop Establishment Problems in Queensland:* Occasional Publications No. 34 (*edited by Wood I.M., Hazard, W.H. and From F.R.*). pp. 136 - 140. Australian Institute of Agricultural Science.

**Hunter, J. R. and Erickison, A. E.** (1952) Relation of seed germination to soil moisture tension. *Agronomy Journal* 44 (3), 107-109.

**ICRISAT,** (1990) Annual Report for 1989. *Patencheru Andra Pradesh*, India.

**International Seed Testing Association (ISTA)** (1985) International rules of seed testing. *Seed Science and Technology* 13, 299-355.

**International Seed Testing Association (ISTA)** (1987) *Handbook of Vigour Testing Methods*. Zurich, Switzerland.

**Isely, D.** (1958) Preliminary report on moisture level control in seed testing. *Proceedings of the Association of Official Seed Analysis* 48, 125 - 131.

**Johnson, R.R. and Wax, L.M.** (1978) Relationship of soybean germination and vigour tests to field performance. *Agronomy Journal* 70, 273-276.

**Johnson, R.R. and Wax, L.M.** (1981) Stand establishment and yield of corn as affected by herbicides and seed vigour. *Agronomy Journal* 73, 859-863.

**Justice, O.L. and Bass, L.N.** (1978) *Principles and practices of Seed storage.* Science and Education Federal Research, Agricultural Handbook, No. 506.

**Justice, O.L. and Reece, M. H.** (1954) A review of literature and investigation on the effects of hydrogen-ion concentration on the germination of seeds. *Proceedings of the Association of Official Seed Analysts* 34, 144-149.

**Kasseba, A., Pitlado J. R. and Uriyo A. P.** (1972) Trend of soil classification in Tanzania. The experimental use of the 7$^{th}$ approximation. *Journal of Soil Science* 23, 235-247.

**Kramer, P.J.** (1972) *Plant and Soil Water Relationships* A modern synthesis. McGraw Hill, New York.

**Manning, H.L.** (1956). Planting date and cotton production in the Buganda Province of Uganda. *Experimental Agriculture* 17, 245 - 258.

**Mascarenhas, A.C.** (1982) Climatological aspects of human settlements in Africa In: *Proceedings of the Technical Conference on Climate*. Africa WMO NO. 596, 460 - 477. Geneva Switzerland.

**Mashauri, I. M.** (1991) Relationship between initial seed moisture content, processing, damage and storage on the quality of maize (*Zea mays* L.) seeds. Diploma of Agricultural Science. Thesis, Massey University.

**Mashauri, I.M.; Coolbear, P. and Hill, M.J.** (1992) Interactions between seed moisture and sheller speed during small-scale processing on the subsequent seed quality of maize *(Zea mays* L.). *Journal of Applied Seed Production* 10, 84-87.

**Mashauri, I. M.** (1993) Effects of seed vigour on seed production and quality in *Zea mays* L. cv Illini. M.Sc thesis in Seed Technology. Massey University. Palmerston North New Zealand.

**Matthews, S. and Powell, A.A.** (1986) Environmental and physiological constraints on field performance of seeds. *Horticultural Science* 21 (5), 1125-1128.

**Matthews, S. and Powell, A.A.** (1987) Controlled deterioration testing. In: *Handbook of vigour test methods,* (2nd edition). ISTA, Zurich pp. 49-56.

**Matthew, S.** (1980). Controlled deterioration: A new vigour test for crop seeds. In: *Seed Production (edited by Hebblethwaite, P.D.).* pp. 647 - 670 Butterworths.

**Naylor, R.E.L. and Gurmu, M.** (1990) Seed vigour and water relations in wheat. *Annual of Applied Biology* 117, 441 - 450.

**Neergaard, P.** (1977) *Seed Pathology,* Vol. 1 and 2. MacMillan Press, London.

**Perry, D.A.** (1972). Interaction effects of seed vigour and environment on seedling establishment. Panel discussion. Pre-sowing seed treatments. In : *Seed ecology (edited by Heydecker, W.).* pp. 311 - 323 19th Easter School in Agriculture Science University of Nottingham.

**Perry, D. A.** (1978) Report of the vigour test committee, 1974-1977. *Seed Science and Technology* 6, 159-181.

**Perry, D.A.** (1980) Deterioration in barley seeds and its effects on field performance. In: *Seed Production*. (*edited by P.D.Hebblethwaite*). Butterworths, London.

**Pollock, B.M. and Roose, E.E.** (1972) Seed and seedling vigour. pp. 313-387. In: *Seed Biology*. (*edited by T.T. Kozlowoski*). Academic Press, New York.

**Powell, A.A.** (1988) Seed vigour and field establishment. *Advances in the Research and Technology of Seeds* 11, 29-61.

**Powell, A.A. and Matthews, S.** (1978) The damaging effect of water on dry pea embryos during imbibition. *Journal of Experimental Botany* 29, 1215-1229.

**Powell, A.A. and Matthews, S.** (1984) Application of the controlled deterioration vigour test to detect seed lots of Brussels sprouts with low potential for storage under commercial conditions. *Seed Science and Technology* 12, 649 - 657.

**Priestley, D.A.** (1986) *Seed Ageing.* Implication for seed storage and persistence in the soil. Cornstock, Ithaca, USA.

**Roberts, E.H.** (1972) Storage environment and the control of viability. In: *Viability of Seeds.* (*edited by E.H. Roberts*). Chapman and Hall, London.

**Roberts, E.H.** (1972) Dormancy: A factor affecting seed survival in the soil. In: *Viability of Seeds* (*edited by E.H. Roberts)*. Xhapman and Halls Ltd. London pp. 321 - 357.

**Roberts E.M.** (1973) Loss of viability : Ultrastructural and physiological aspects. *Seed Science and Technology*. 1, 529-545.

**Roberts, E.H.** (1983) Loss of viability during storage. In : *Advances in Research and Technology of Seeds* 8, 9-34.

**Roberts, E.M.** (1986) Quantifying seed deterioration. In: *Physiology of Seed Deterioration,* 101-123. (*edited by M.B. MacDonald and C.J. Nelson*). CSSA, Madison, Wisconsin.

**Rwehumbiza, F.B.** (1987) Plant water status and grain yield of maize in relation to soil water status at Morogoro, Tanzania. MSc. Thesis SUA.

**Rwehumbiza, F.B.** (1994) The effect of seed and soil physical conditions on establishment of sorghum Ph.D. Thesis Aberdeen University.

**Shayo-Ngowi, A. J and Mtakwa, P. W.** (1994) Progress report on the SADC experiments on the impact of soil erosion on crop yield. (November 1993 to December 1994) pp 16.

**So, H. B.** (1987) soil physical factors limiting crop establishment. In: *Crop Establishment Problems in Queensland:* Occasional Publications. No 34 (*edited by Wood, I. M., Hazard, W. H. and From, F. R.*). pp. 154-165. Australian Institute of Agricultural Science.

**TeKrony, D.M. and Egli, D.B.** (1977) Relationship between laboratory indices of soybean vigour and field emergence. *Crop Science* 24 (17), 573-577.

**TeKrony, D.M. and Egli, D.B.** (1991) Relationship of seed vigour to crop yield: a review. *Crop Science* 31, 816-822.

**Tanzania Official Seed Certification Authority (TOSCA)** (1987) *Rules, Regulations and Certification procedures*. Established under seeds regulation of standards. Act. of 1973 and weed seed order of 1975.

**Thompson, J.R.** (1979) *An Introduction to Seed Technology*. Leonard Hill, pp. 251.

**Toole, E.H., Hendricks, S.B., Borthwick, H.A., and Toole,V.K.** (1956) Physiology of seed germination. *Annual Review of Plant Physiology* 7, 299-324.

**Trouse, A.C.** (1971) Soil conditions as they affect plant establishment root development and yield. Effect of soil temperature on plant activities pp. 269 - 276 In: K.K. Barnes *et al* compaction of Agricultural Soil Monograph ASAE St.

**Tseng, S.T. and Lin, C.I.** (1962) Studies on the physiological quality of pure rice seed. *Proceedings of the International Seed Testing Association* 27, 459-474.

**Vertucci, C.W. and Roos, E.E.** (1990) Theoretical basis of protocols for seed storage. *Plant Physiology*. 94, 1019-1023.

**Vertucci, C.W. and Roos, E.E.** (1991) Seed moisture content, storage viability and vigour. *Seed Science Research* 1, 277-279.

**Webster, R.E.** (1966) Effect of size of seed on plant growth and yield of Ford hook 242 Bush lima bean. *Proceedings of the American Society of Horticultural Science* 84, 327-333.

**Williams, R.J. and Leopold, A.R.** (1989) The glassy state in corn embryos. *Plant Physiology* 89, 977-981.

**Wood, I.M.** (1972) Seed quality effects on establishment and productivity, with particular reference to crop production in Queensland. *Proceedings of the 4th Australian Seed Research Conference* 99-104.

**Woodstock, L. W.** (1969) Seedling growth as a measure of seed vigour. *Proceedings of the International Seed Testing Association* 34, 273-280.

**Woodstock, L.W.; Furman, K. and Soloman, T.** (1984) Changes in respiratory metabolism during ageing in seeds and isolated axes of soybean. *Plant Cell Physiology* 25, 15-26.

**Woodstock L. W** (1976) Progress repot on seed vigour tests. *Association of Official Seed Analysts* North America News letter 50

## Appendix 3.1 Experimental layout for field and greenhouse experiments

a) plots for maize.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| T3 | LV | T0 | LV | T6 | LV | T12 | LV | T15 | LV | T9 | LV |
| T12 | HV | T9 | HV | T15 | HV | T3 | HV | T0 | HV | T6 | HV |
| T15 | MV | T6 | MV | T0 | MV | T9 | MV | T12 | MV | T3 | MV |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| T12 | HV | T6 | HV | T3 | HV | T15 | HV | T9 | HV | T0 | HV |
| T12 | MV | T15 | MV | T9 | MV | T0 | MV | T3 | MV | T6 | MV |
| T0 | LV | T9 | LV | T12 | LV | T3 | LV | T6 | LV | T15 | LV |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| T9 | HV | T15 | HV | T0 | HV | T12 | HV | T3 | HV | T6 | HV |
| T15 | LV | T6 | LV | T3 | LV | T9 | LV | T0 | LV | T12 | LV |
| T0 | MV | T9 | MV | T15 | MV | T6 | MV | T12 | MV | T3 | MV |

(b)plots for sorghum.

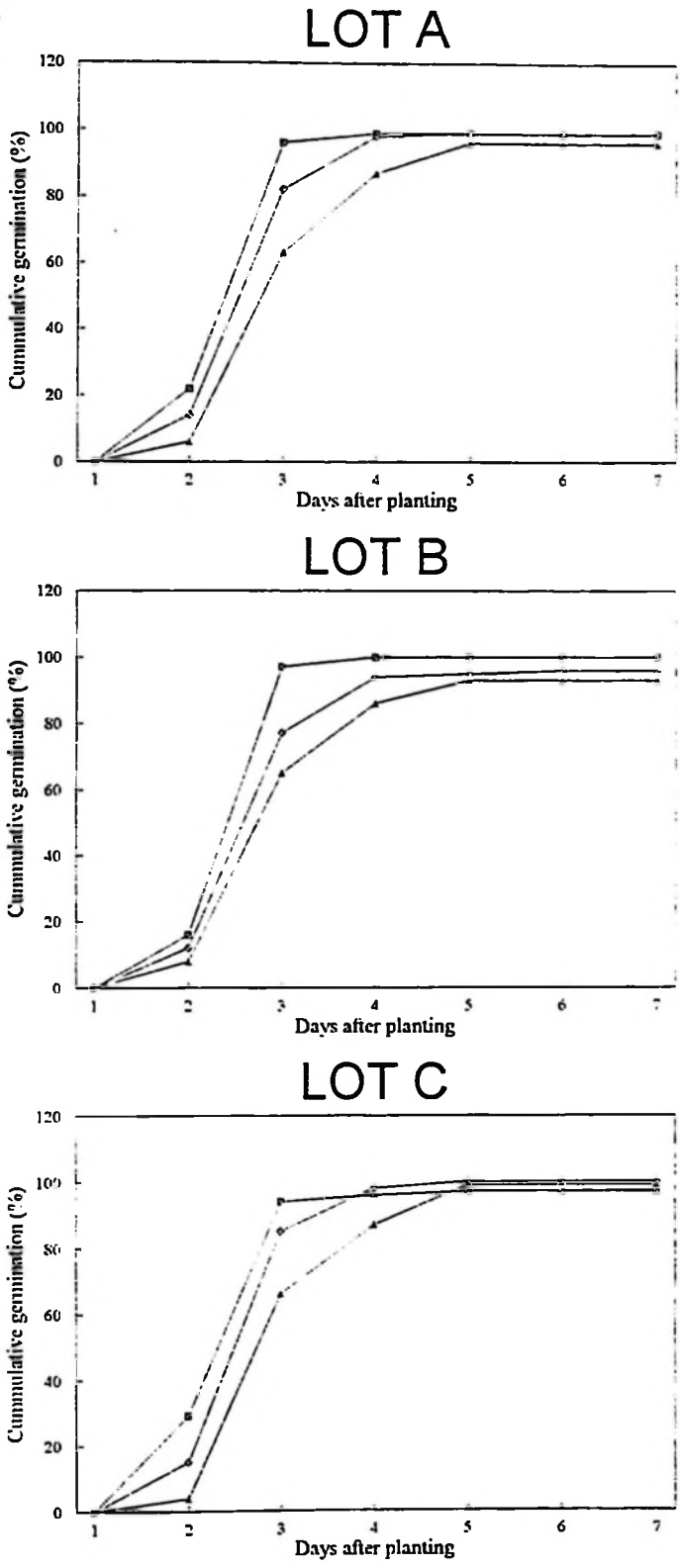
| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| T3 | LV | T0 | LV | T6 | LV | T12 | LV | T15 | LV | T9 | LV |
| T12 | HV | T9 | HV | T15 | HV | T3 | HV | T0 | HV | T6 | HV |
| T15 | MV | T6 | MV | T0 | MV | T9 | MV | T12 | MV | T3 | MV |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| T12 | HV | T6 | HV | T3 | HV | T15 | HV | T9 | HV | T0 | HV |
| T12 | MV | T15 | MV | T9 | MV | T0 | MV | T3 | MV | T6 | MV |
| T0LV | LV | T9 | LV | T12 | LV | T3 | LV | T6 | LV | T15 | LV |

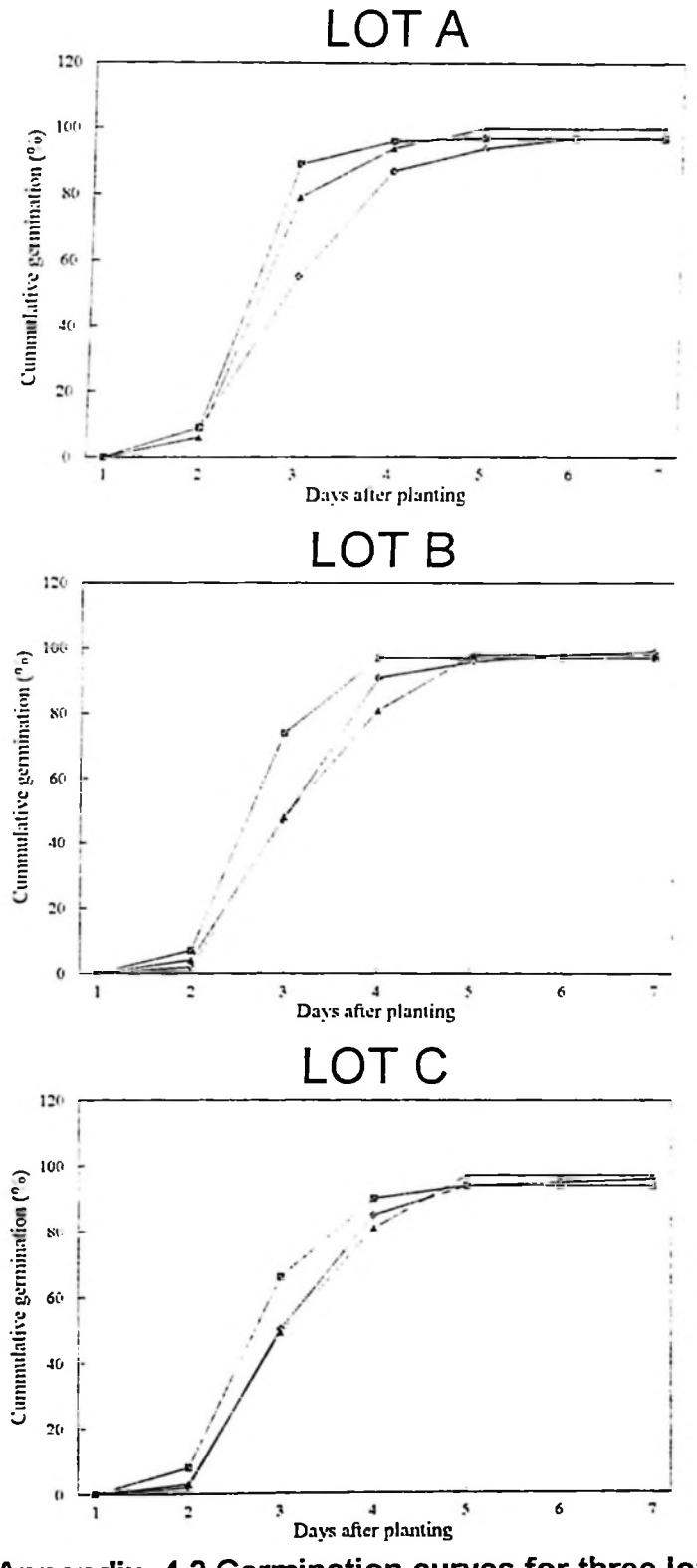
| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| T9 | HV | T15 | HV | T0 | HV | T12 | HV | T3 | HV | T6 | HV |
| T15 | LV | T6 | LV | T3 | LV | T9 | LV | T0 | LV | T12 | LV |
| T0 | MV | T9 | MV | T15 | MV | T6 | MV | T12 | MV | T3 | MV |

key: T0,T3, T6 -- - - - number of days seeds remain in the soil before watering/moisture supply

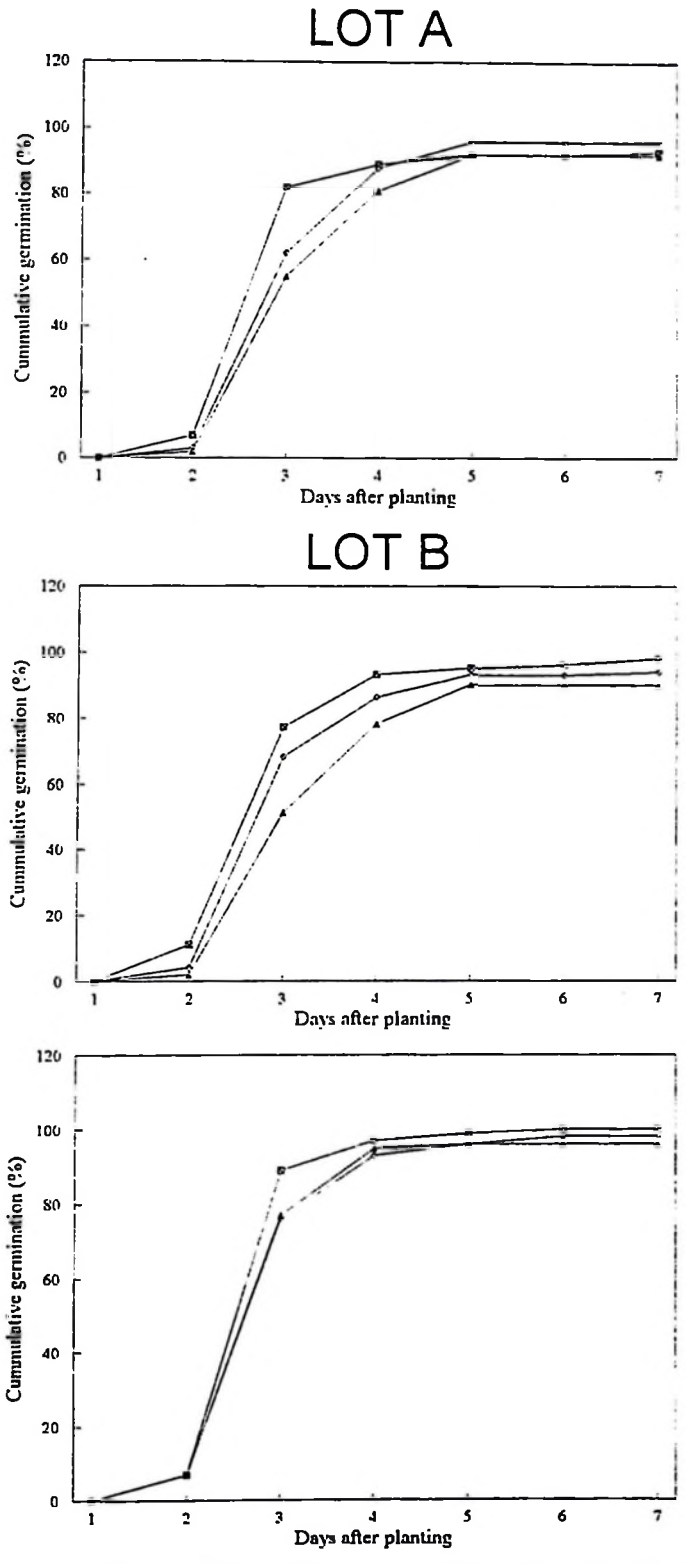
H.V. High vigour seeds M.D. Medium vigour seeds L.V. Low vigour seeds



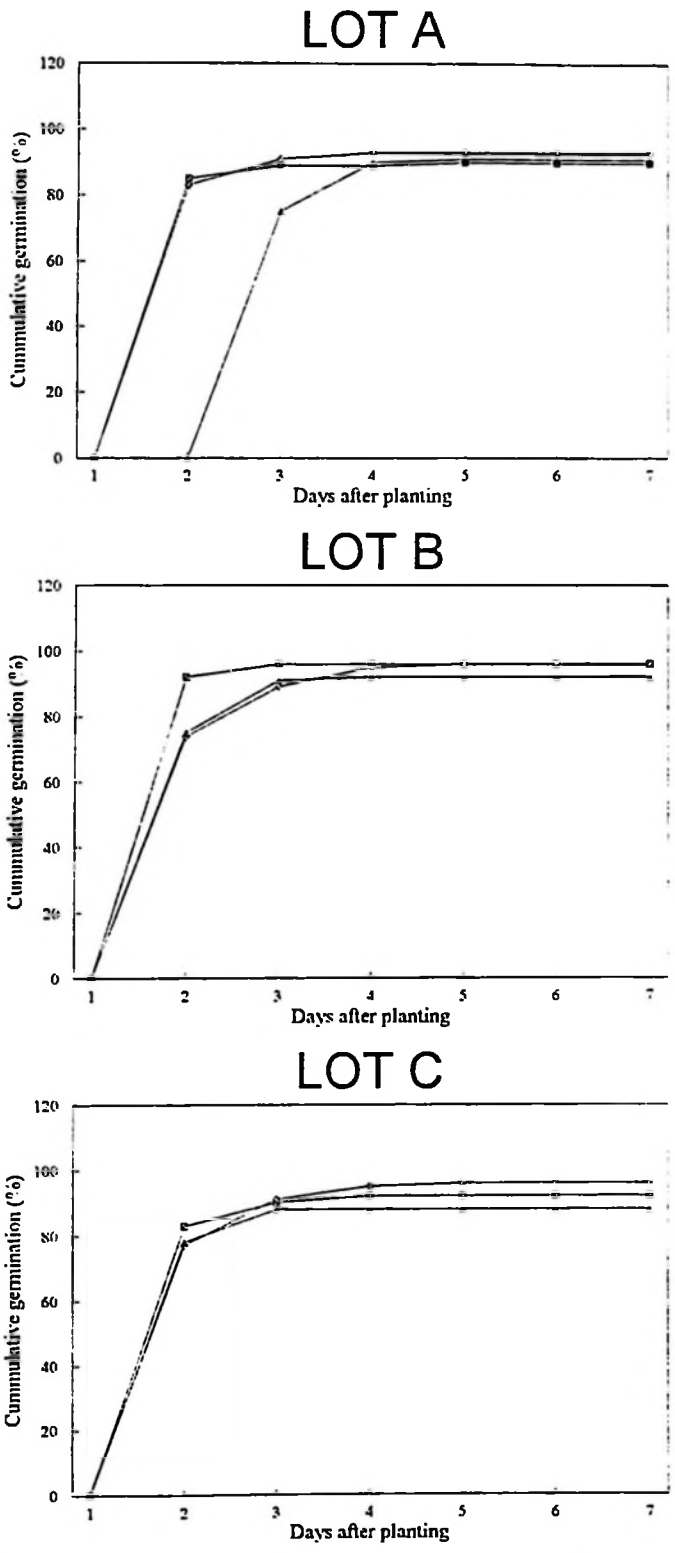

**Appendix 4.1 Germination curves for three lots of Maize (cv Staha ) as affected by duration of storage. At the begining of storage programme (■ ), one month (◆ ), and two month later (▲ ).**



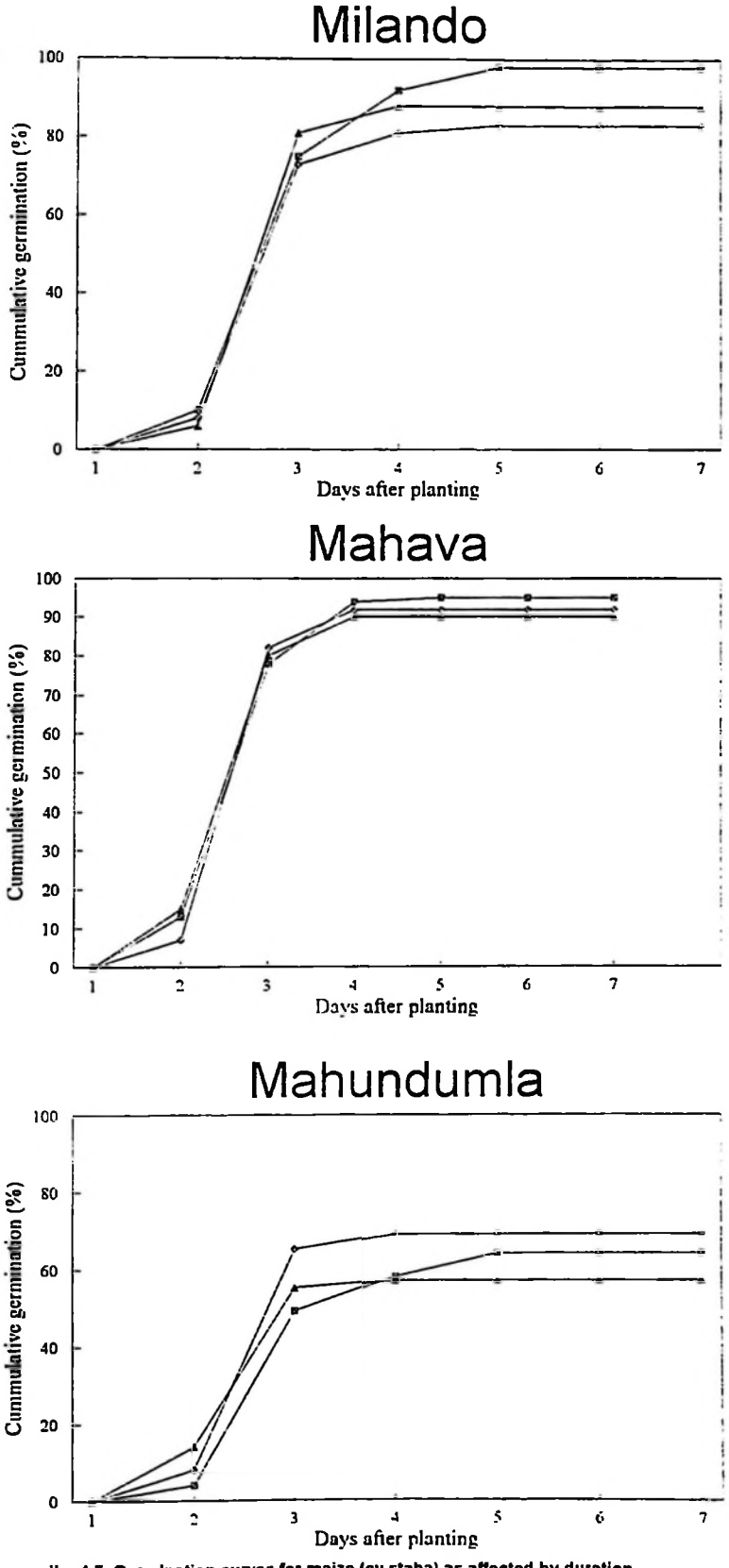

**Appendix 4.2 Germination curves for three lots of Maize (cv TMV-1) as affected by duration of storage. At the begining of storage programme (■ ), one month (♦ ), and two month later (▲ ).**



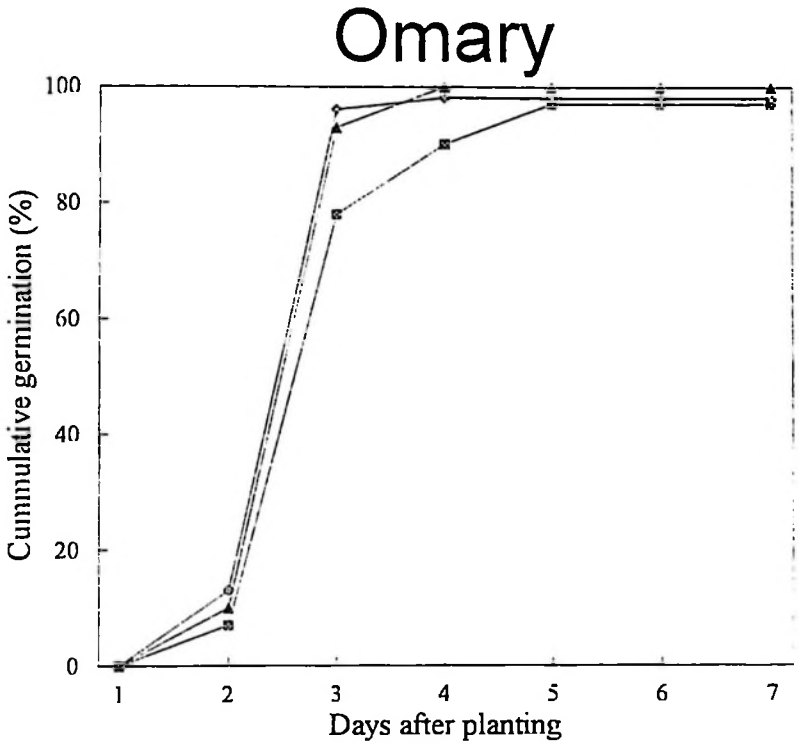

**Appendix 4.3 Germination curves for three lots of Maize (cv Kito) as affected by duration of storage. At the begining of storage programme (■ ), one month ( ♦ ), and two month later ( ▲ ).**



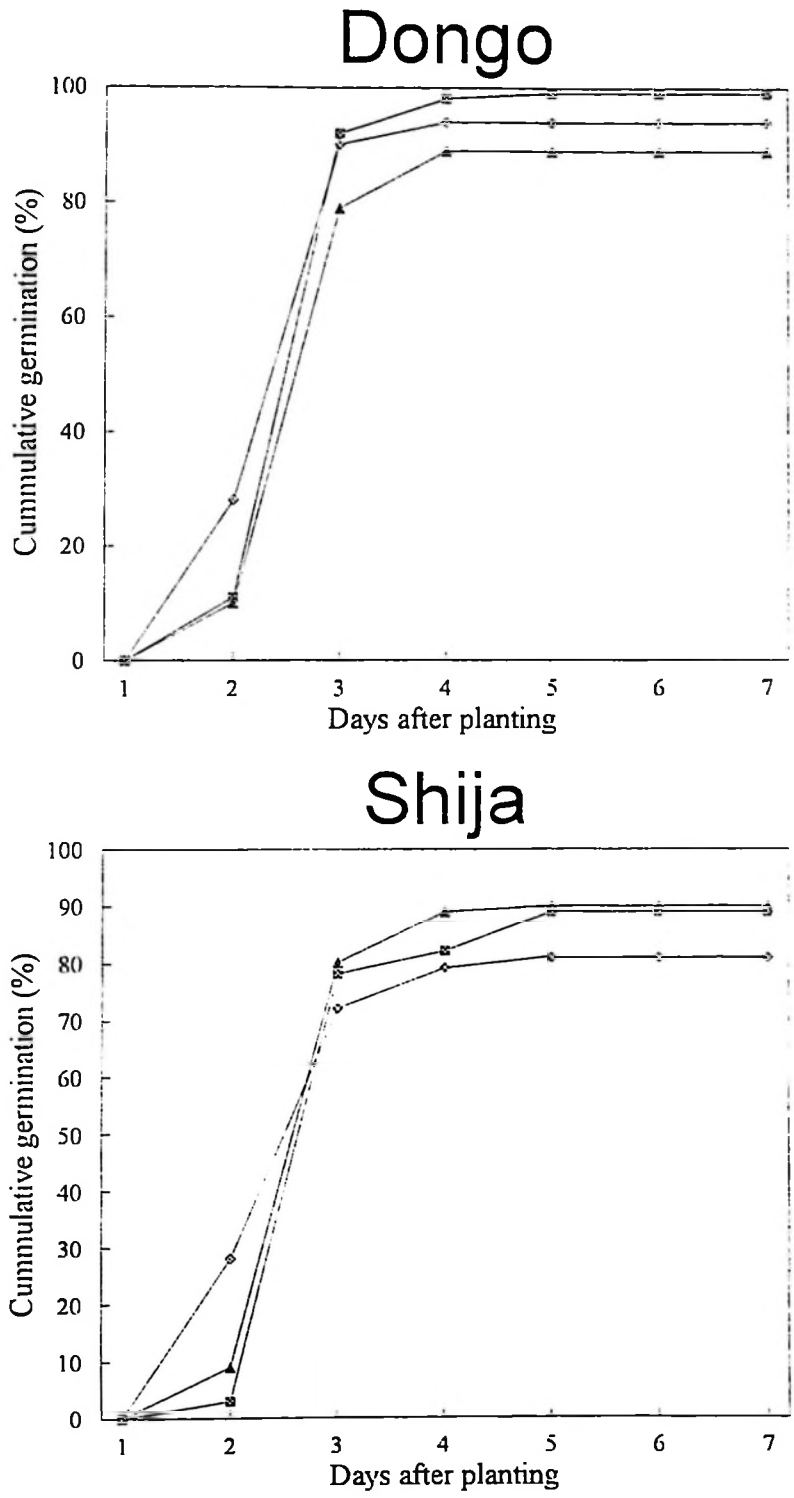

**Appendix 4.4 Germination curves for three lots of sorghum (cv Tegemeo ) as affected by duration of storage. At the begining of storage programme (■), one month (♦), and two month later (▲).**



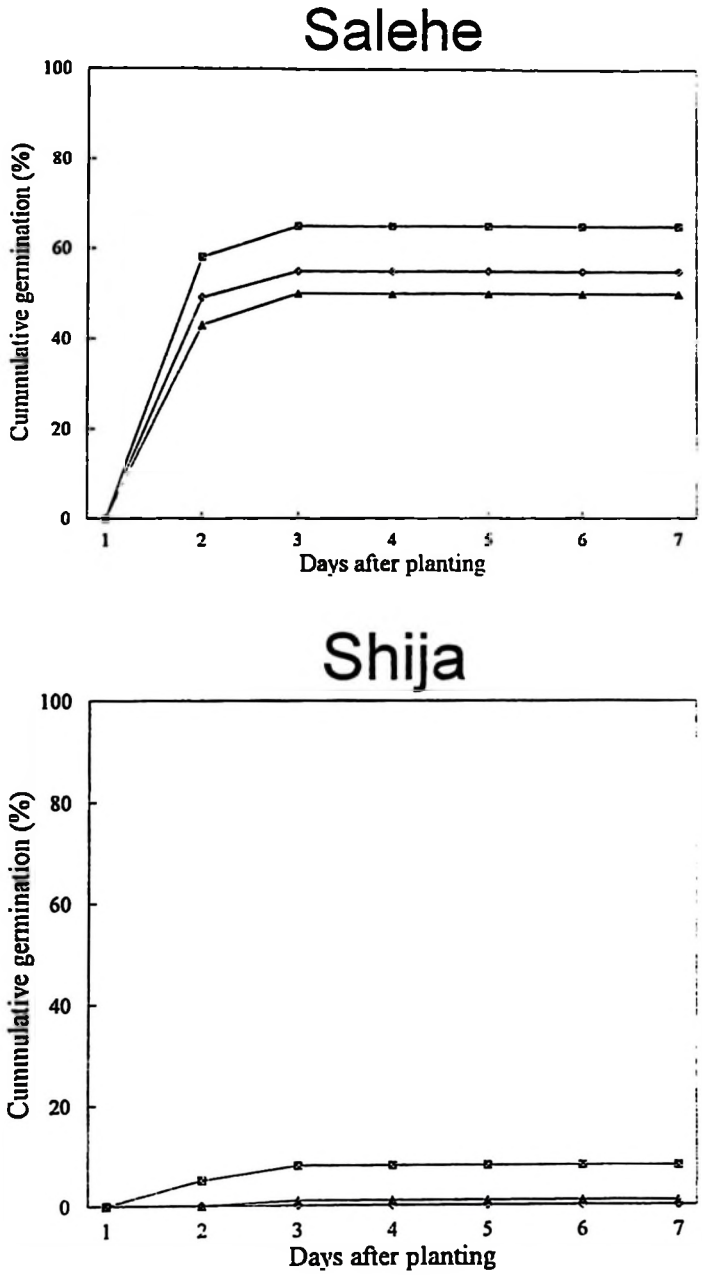

**Appendix 4.5 Germination curves for maize (cv staha) as affected by duration of storage. At the begining of storage programme (■), one month (◆) and two month later (▲).**



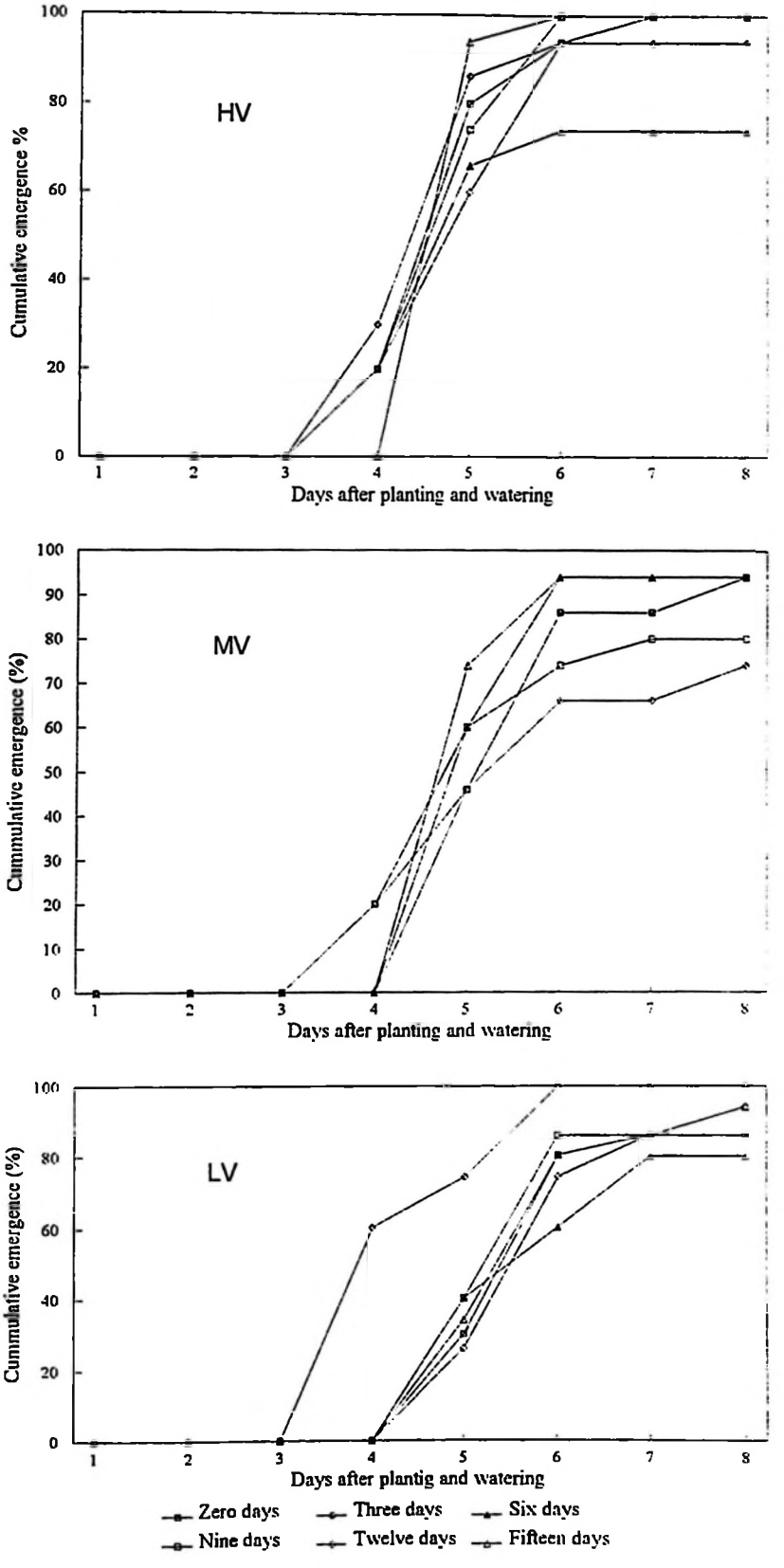

**Appendix 4.6 Germination curves for maize (cv TMV-1) as affected by duration of storage. At the begining of storage programme ( ■ ), one month ( ◆ ) and two month later ( ▲ ).**



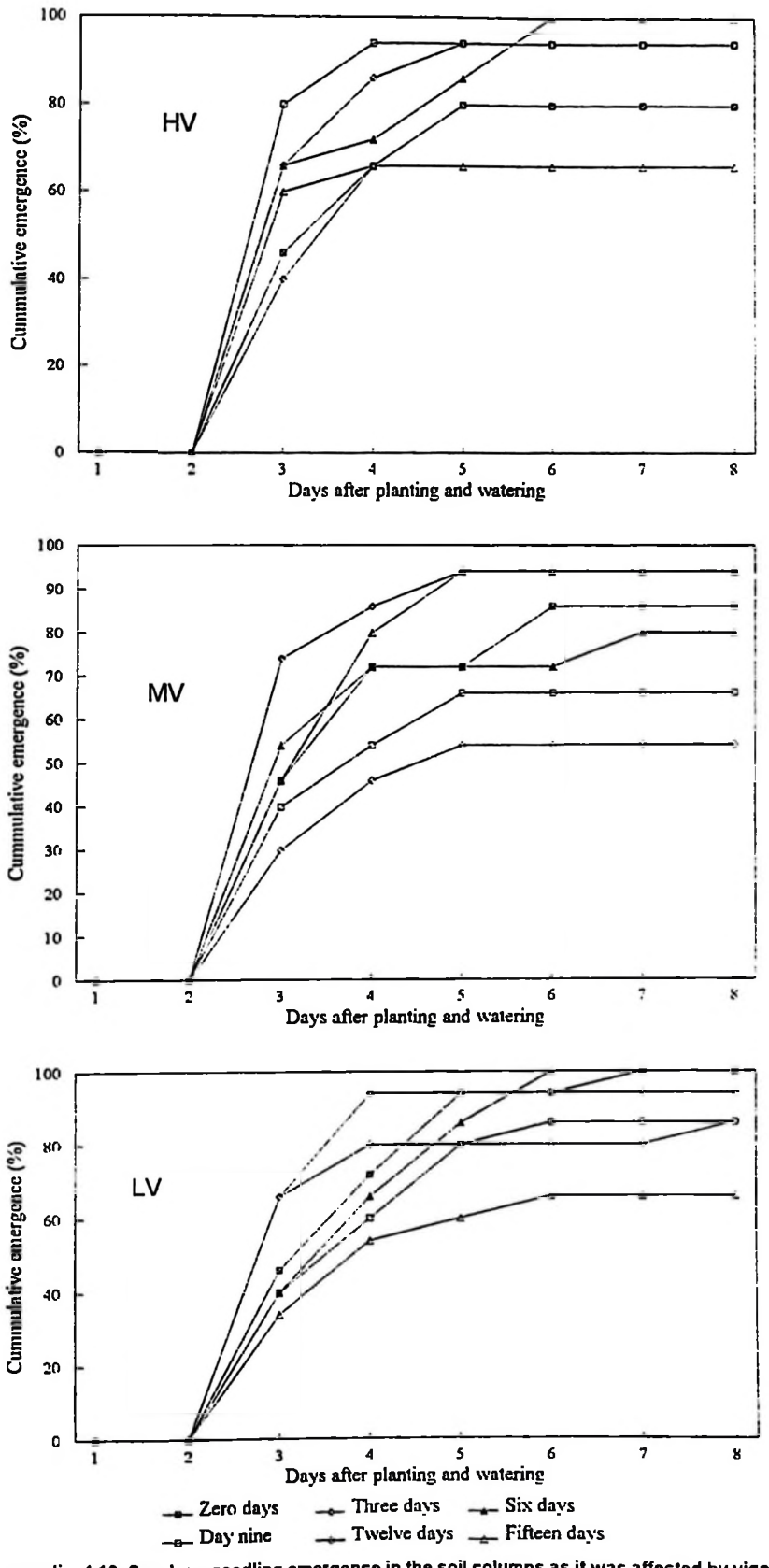

**Appendix. 4.7 Germination curves for maize (cv Kito) as affected by duration of storage. At the begining of storage programme ( ■ ), one month ( ◆ ) and two month later ( ▲ ).**



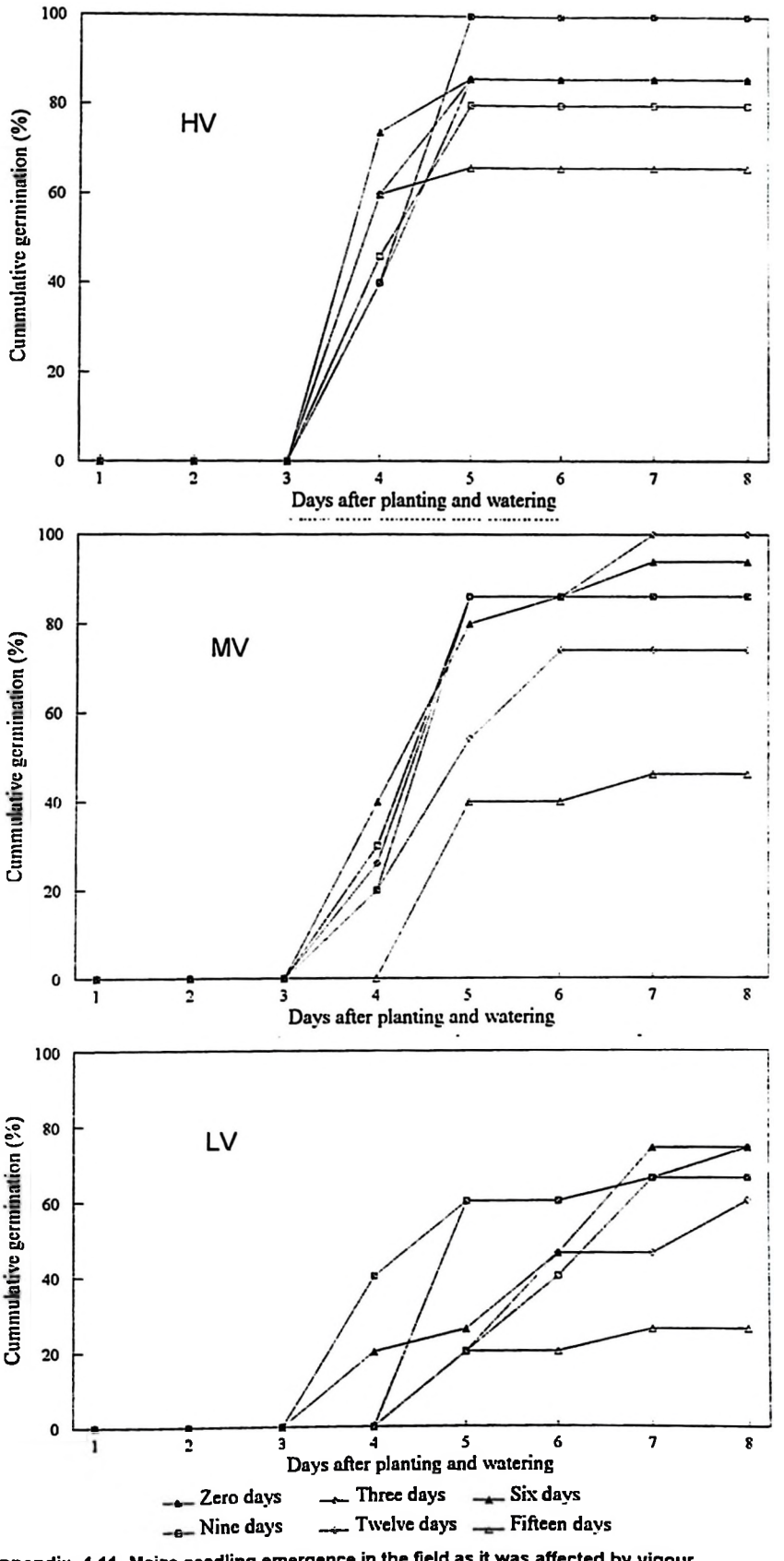

**Appendix 4.8 Germination curves for sorghum (cv Tegemeo) as affected by duration of storage. At the begining of storage programme (■), one month (♦) and two month later (▲).**



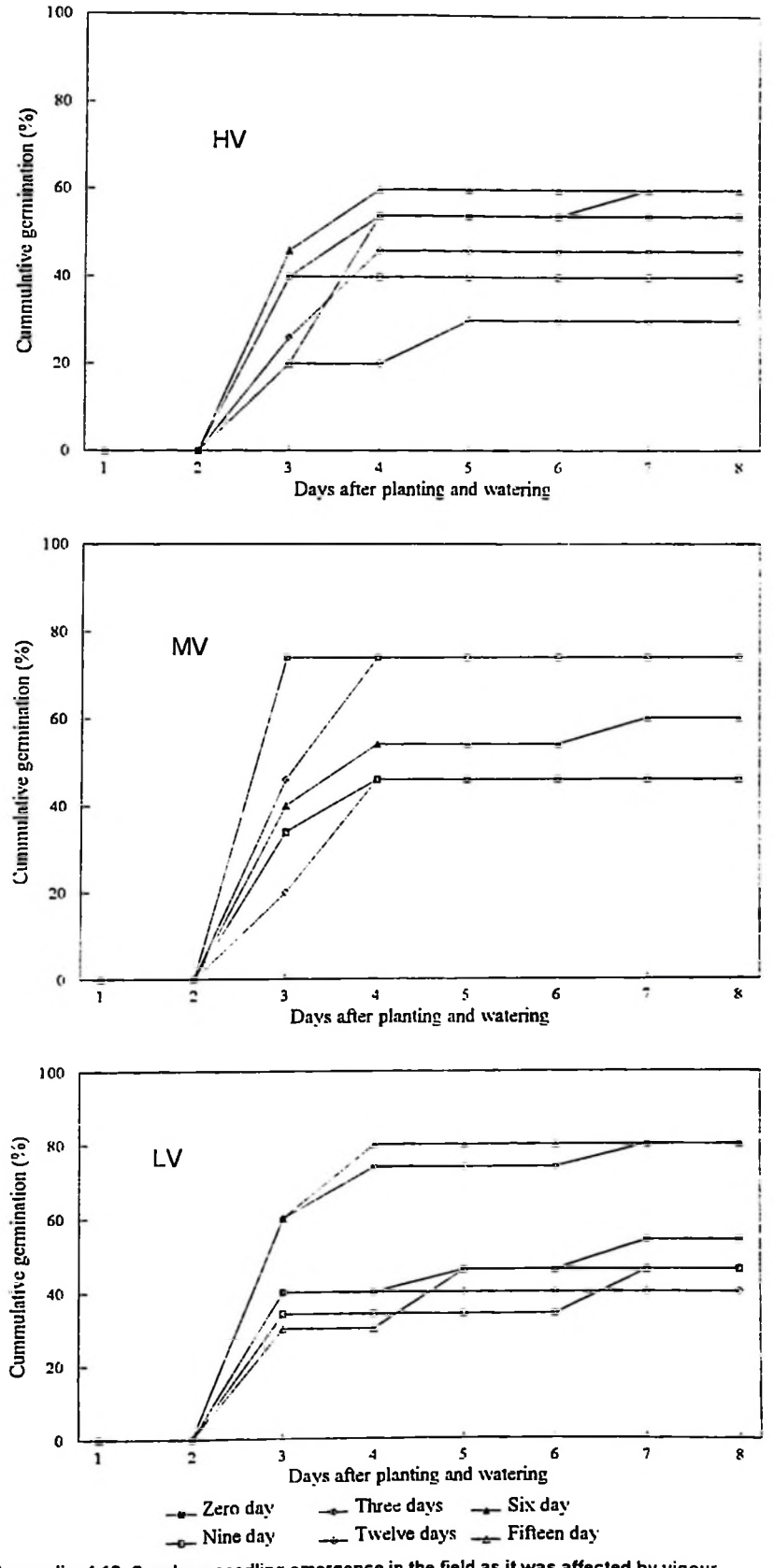

**Appendix 4.9 Maize seedling emergence in the soil columns as it was affected by vigour and length of time seeds remained in soil before watering.**



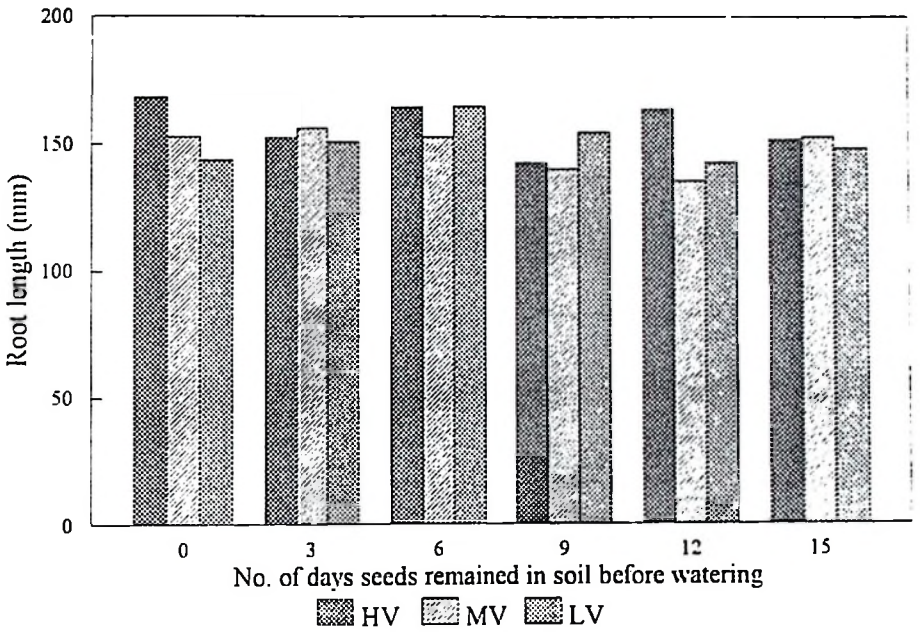

**Appendix 4.10 Sorghum seedling emergence in the soil columns as it was affected by vigour and length of time seeds remained in soil before watering.**



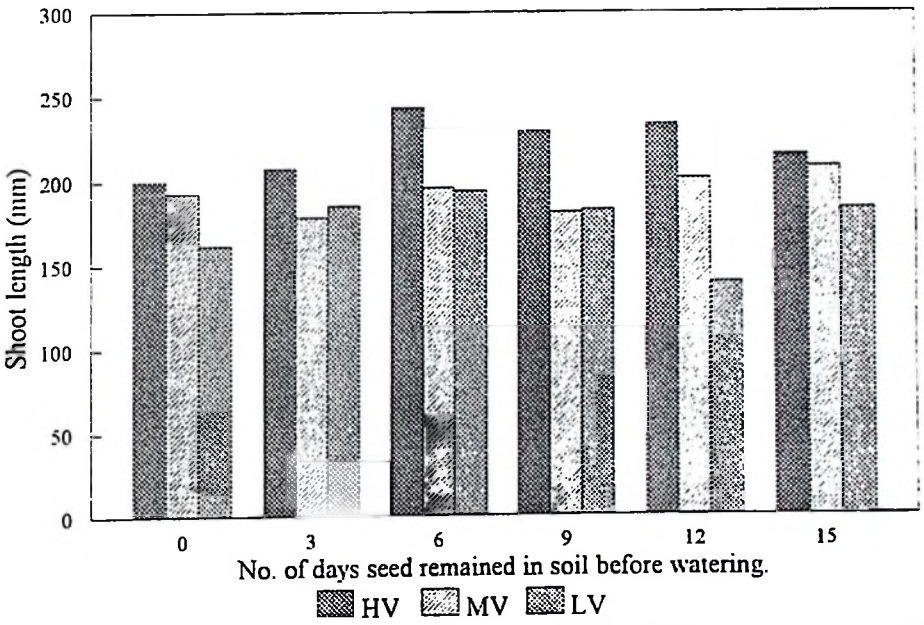

**Appendix 4.11 Maize seedling emergence in the field as it was affected by vigour and length of time seeds remained in soil before watering.**



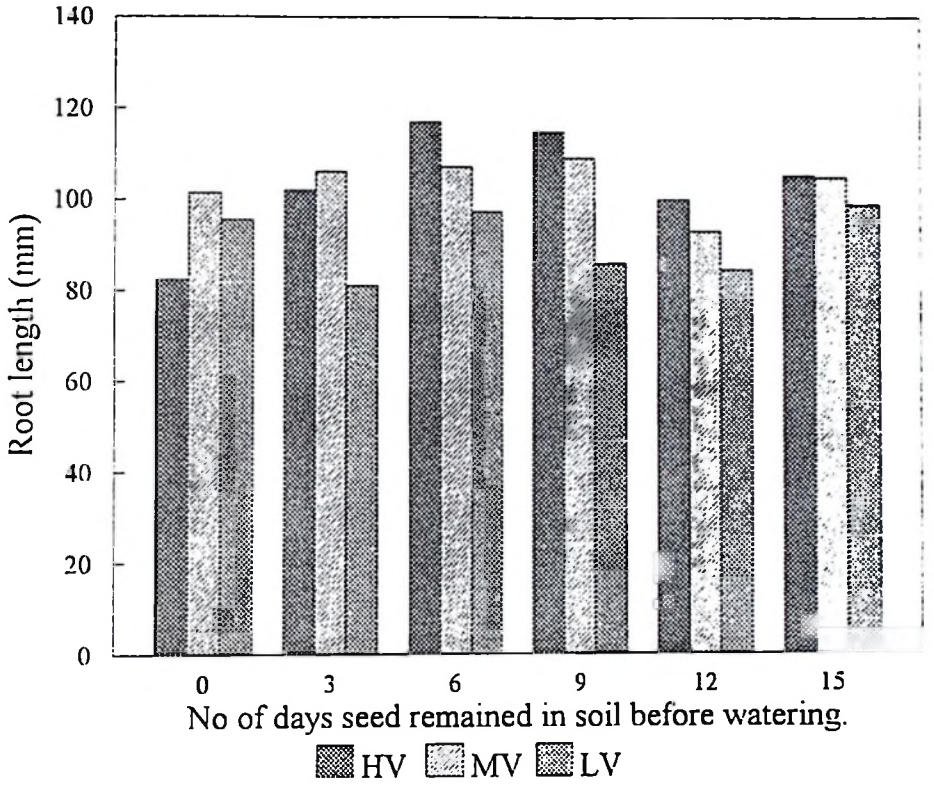

**Appendix 4.12 Sorghum seedling emergence in the field as it was affected by vigour and length of time seeds remained in soil before watering.**



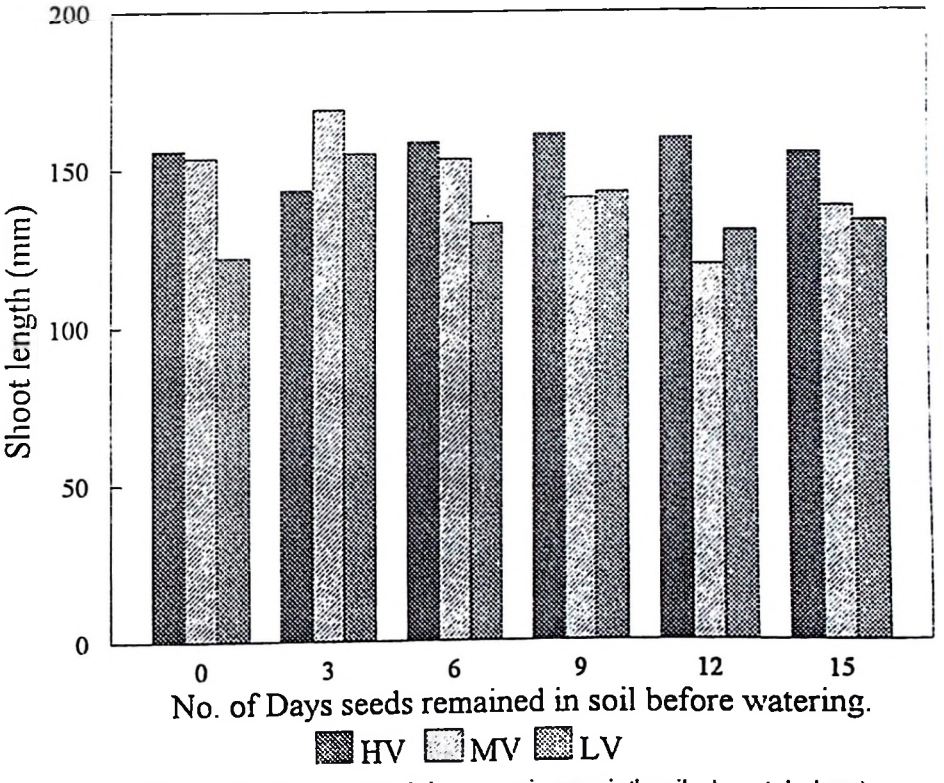

Appendix 4.13 Root length in three maize seed vigour categories grown in the soil columns (glasshouse)



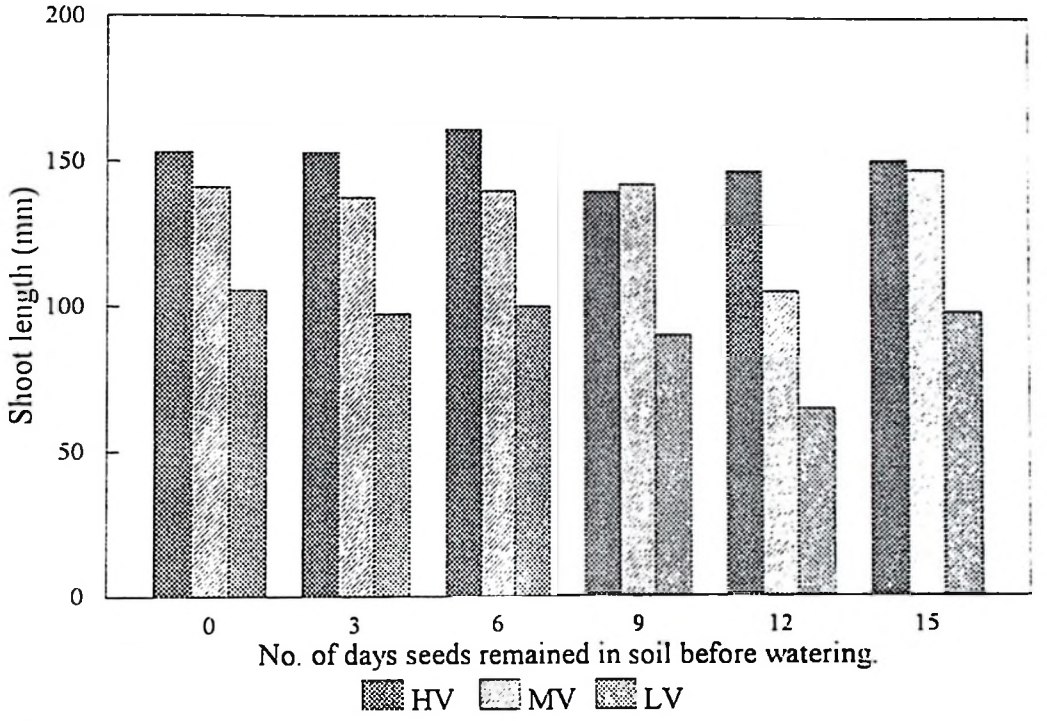

Appendix 4.14 Shoot length in three maize seed vigour categories grown in the soil columns (glasshouse)



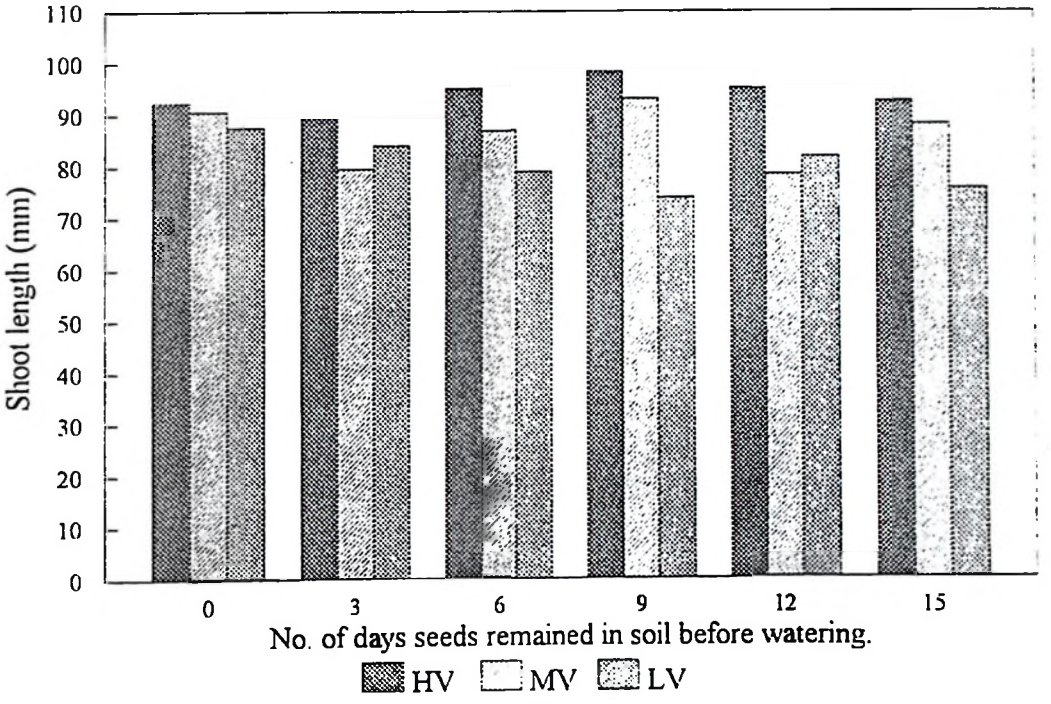

Appendix 4.15 Root length in three sorghum seed vigour categories grown in the soil columns (glasshouse)




Appendix 4.16 Shoot length in three sorghum seed vigour categories grown in the soil columns ( glasshouse)




Appendix 4.17 Shoot length in three maize seed vigour categories grown in the field.




Appendix 4.18 Shoot length in three sorghum seed vigour categories grown in the field.