KWAME NKRUMAH UNIVERSITY OF SCIENCE & TECHNOLOGY, KUMASI

SCHOOL OF GRADUATE STUDIES

DETERMINATION OF THE EFFECTS OF POSTHARVEST POD STORAGE ON SEED VIABILITY OF COCOA (*Theobroma cacao (L)*

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MARCH 2014

DECLARATION

I certify that all the work contained in this dissertation is my own except references made to other people's work which has been duly acknowledged, and that this research work has not been submitted before for any degree in any university or college.

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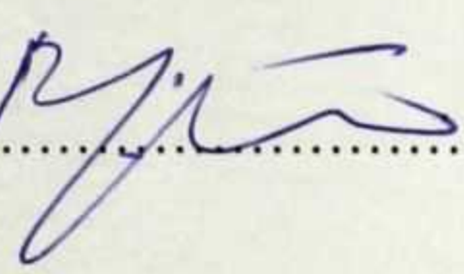

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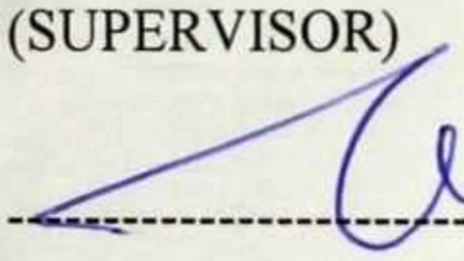

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DEDICATION

"This piece of Research work is dedicated to mybeloved family, especially Bettina Saajah (my daughter) and Margaret (my wife)

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The completion of this experiment and write up would not have been possible without God Almighty. I therefore give special thanks to Him for giving me sustained strength throughout the period of this work. May Hisname be blessed now and forever!

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ABSTRACT

This research was conducted at Appeadu near KNUST to determine how cocoa pod storage affects seed viability, when stored in containers for a specific period. The objectives were to determine the optimum storage period for maximum seed viability, determine the ideal storage container for maximum germination and finally determine the superior growth performance of the seedlings obtained. The design was a Randomized Complete Block Design (RCBD) in a factorial arrangement involving two factors: storage period and storage container. This arrangement produced interactions between the two factors and increased precision due to "Hidden replication". Pod were randomly drawn at 5daily intervals for up to 30 days and seed sowed to determine viability through sixteen (16) parameters, which included time to start and end germination, germination percentage, stem girth, canopy spread, shoot length, vigour index. The results generated from this experiment were in respect of interactions and simple effects of the two factors, on viability and seedling growth performance. Interaction effects were pronounced on five parameters which included time taken to start and end germination; vigour index; shoot height and leaf area. Germination speed and percentage were also significantly influenced by storage period. For growth parameters, superior performance ($p<0.05$), was obtained for variables such as leaves per plant, petiole length, internode length, within 0DAH - 15DAH period. In respect of the type of container used for storage, internode length and dry matter accumulation were significantly influenced. Storage temperature and relative humidity did not affect the results. In conclusion, viability was maximum within 0DAH -15DAH storage period and any of the storage containers (basket, jute sack or fertilizer sack) could be used to store pods without any significant differences in performance of the parameters. The growth and morphological properties of the seedlings, showed best performance, from pods stored in 0DAH -20DAH and this was irrespective of any of the three containers used.

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CHAPTER ONE

1.0 INTRODUCTION

*Cocoa (Theobroma cacao)*is a member of the familySterculiacae and genus Theobroma which is divided into six groups containing twenty-two species among which *Theobroma cacao* is widely cultivated (Opoku-Ameyaw *et al*, 2010), though Hammed (2011) argues that the crop has recently been reclassified as a member of *Malvaceae* instead of *Sterculiaceae* families.

The mature cocoa tree can grow up to 12 – 15 m high in the wild. It is an angiospermous plant and therefore bears flowers which are borne on small flower stalks in clusters on the trunk and branches, a habit referred to as cauliflorous or truncate. These flowers matureinto fruits commonly known as pods. An average pod is 10 – 32 cm long and contains 20 to 60 seeds with leathery seed shell which is embedded in an aromatic mucilaginous pulp. This mucilage contains a germination inhibitor inside the pod, but once the pod is opened, the mucilage decomposes rapidly and germination begins (Opoku-Ameyaw *et al*, 2010).

Cocoa cultivation remains a critical livelihood activity for hundreds of thousands of farmers in Ghana. Improvement in production and productivity are likely to have far reaching impact or consequences for many rural households' ability to meet their basic needs.

The economic importance of cocoa cannot be overemphasized: Cocoa is used forbeverages (not tea), foreign exchange earnings (in Ghana it is one of the major foreign exchange earners, apart from oil and gold.Sales of cocoa beans have been one of the major foreign exchange earners to Ghana throughout the years. In 2002, cocoa made up for 22.4 per cent (463 million US $) of the total foreign exchange earnings (Institute of Statistical, Social and Economic Research, ISSER, 2003) and also constituted 63% of the foreign export earnings from the agricultural sector

(ISSER, 2003). Cocoa is the only traditional export commodity whose export is taxed; in 1998, it contributed 14.5 per cent of total tax revenue in the country (ISSER, 2000). The total export receipts from cocoa (beans and products) in 2002 amounted to US$463.4million compared to US$381.1million in 2001, representing an increase of 17.8 per cent (ISSER, 2002). The cocoa sub-sector exhibited the most impressive performance in recent time. For instance, the cocoa sector grew at an outstanding rate of 16.4 per cent in 2002. This has been attributed to both increase in cocoa output and relatively better border price for the commodity (ISSER, 2003).

Other uses to which cocoa is put includeBlack soaps for spiritual or religious purposes; herbs for medicinal care;confectionary purposes as inChocolates,Ice cream and Cocoa juice production. Alcoholic beverages,as in Wine production, are other uses to which cocoa is put. Aside these benefits from cocoa, its by-products are applied in the cosmetic industry as Hair cream,Body cream and Toilet soaps. Fire wood, organic nutrient sources,wrapping of pap, employment generation, recreational / ornamental uses and income generation are some of the other uses to which cocoa is applied (Hammed, 2011).Cocoa is further used to extract cocoa butter, cocoa paste and cocoa powder which in large partsare consumed as chocolate confectionery and other cocoa-based food products (Opoku-Ameyawet *al*, 2010). Cocoa is acommodity that directly links consumption patterns of consumers in the developed world withthe overall well-being of farmers and rural workers in developing countries. The demand forthe product increases each year as a result of rising living standards, development of newproducts containing cocoa, advertising campaigns and reports of the health effects ofchocolate that reach the market in developed countries (ibid).

These numerous benefits of cocoa calls for raising the productivity and production levels of cocoa, particularly in Ghana, but to be able to increase the productivity and production on cocoa

farms, farmers require relevant and timely information and knowledge on production practices (Takame, 2002;Opoku-Ameyaw *et al*, 2010) which includeknowledge on appropriate postharvest handling of hybrid cocoa pods to obtain viable seed and for that matter good germination and vigorous seedlings.

The Ghana Cocoa Board and Ghana government have established the need to increase area (hectares) under cocoa production in order to increase cocoa production (yield), for increased foreign exchange and avoid the *Dutch Disease*, following Ghana's discovery of Oil. This involves among other factors, the provision of adequate planting materials (cocoa pods), which in Ghana isthe prerogative of only 26 Seed Production Unit centres (cocoa stations) under COCOBOD, as the only mandated body to produce seedlings. (Opoku-Ameyaw *et al*, 2010).

In view of the growing importance of cocoa, the demand for quality planting materials has increased many times throughout the country in the recent past. However the greatest bottleneck restrictingthe cocoa-area-expansion drive is the inadequacy of hybrid planting material of cocoa from the cocoa stations coupled with low germination of the seed when sowed. More often than not, farmers who get their planting materials from these sources (Seed gardens) go through long postharvest handling periods, which subsequently result in low germination of the seed from such pods (Hanson and Hunter, 1960). Contrary to what happens on famers fields, the Cocoa stations record higher percentage germination of seed sowed, due to the relatively short time for which pods are kept or stored after harvest.

These hybrid pods are obtained from crosses between parent clones of desirable qualities on a commercial scale in specially prepared fields called seed gardens (Opoku-Ameyaw, 2010). In the seed gardens, crossing of parent clones is made through hand pollination, also called manual pollination. The hybridization policy of these seed gardens is based on the self-incompatibility of

the selected clones used as the female and male parents. The two parent clones, which have been carefully selected, are planted in separate plots (monoclonal gardens). Such an arrangement offers possibilities for controlled crosses and flexibility in the choice of combinations which can be made (Possnette and Entwistle, 1957; Opoku- Ameyaw, 2010).

As a result of cross compatibility and segregation problems, farmers are always obliged to go back to the seed gardens to collect pods for propagation. Due to the limited number of seed gardens in the country vis-à-vis the greater demand for pods, farmers travel long distances to acquire these pods, resulting in long postharvest handling period. This long postharvest handling period subsequently result in low seed viability (Hanson and Hunter, 1960), presumably due to changes in postharvest physiology and other handling issues. In many situations farmers even break the pods and remove the seeds as a way of managing these long handling processes, but seeds so treated sometimes get fermented in the process.

This problem is thus causing great harm to the cocoa industry of the Ghana, which has the potential to expand and produce more than what is currently being produced.

Beyond the shores of Ghana, pods exported to Liberia (by sea) had viability problems at their destination in the year 2009, where seed sowed recorded low germination percentage due to a relatively long storage period (Unpublished SPU Reports, 2009).

In all these, not much scientific study has been carried out to determine the optimum time of postharvest pod storage for which podscan be stored to avoid low germination percentage when planted.

The targets of enhancing and increasing cocoa production in the coming years will therefore be achieved in part, through the production and distribution of healthy, genuine and high quality planting material (pods) stored within the maximumstorage period.

Postharvest pod management of cocoa has therefore become an area of concern to the Management of Ghana's Cocoa Industry and its clientele (the farmer), as it has a major effect on productivity and production. The manner in which the pods are managed after harvest (specifically the number of days pods are stored or kept after harvest and the containment material used to store the pods) have a perceived effect on the germination of seeds.

The statement of the problem is that prolonged storage of pods result in low seed viability, presumably as a result of postharvest physiological changes that occur after harvest.

This subsequently result in low germination of the seed when sowed, with its attendant costs to the farmer in terms of pod re-acquisition, additional transportation to seed gardens for more pods, small farm holdings and consequent lower cocoa production, which therefore result in low national income. This is a source of worry to the farmer and the national economy as a whole which depend on cocoa exports for foreign currency

This study is justified on the basis that, various studies into the postharvest quality of cocoa have been in the area of processed cocoa beans as raw materials for industrial processing purposes. However, not much work has been done in terms of postharvest pod quality management for subsequent propagation, to help farmers achieve efficiency in their production enterprise. A preliminary survey conducted by this researcher revealed that a 100% of farmers interviewed indicated that this is an area of much concern to them and by extension need to be worked on.

It is therefore hoped that this study would impact positively on management of the Cocoa Seed Gardens and its linkage to cocoa extension practitioners towards a sustainable cocoa industry.

Specifically;

- The outcome of the study will augment the very little knowledge on the subject and serve as a catalyst for further research on postharvest management of pods as well as the overall academic well-being of the nation.
- In addition, the findings of the study will be expected to help in informed-decision and policy making in the area of creation and distribution of more Seed Gardens to serve the larger interest of all stakeholders in Ghana's cocoa industry.
- Finally, it is hoped that the study will stimulate interest in the academia of Cocoa Research for further studies in cocoa pod management after harvest

The main purpose of the study was to assess the effect of postharvest pod storage on seed viability and early stages of growth of cocoa.

The specific objectives of this study were:

1. To categorize the harvesting and postharvest handling practices adopted for cocoa pod harvesting by the seed Gardens (Seed Production Unit)

2. To determine the optimum storage period for which pods can be stored for maximum seed viability.

3. To determine the ideal carriage and storage container with which pods can be stored for maximum seed viability.

4. To determine the growth and morphological properties exhibited by seedlings obtained from the above storage systems.

CHAPTER TWO

2.0 LITERATURE REVIEW

As an integral part of a seed production program, a good storage/ post-harvest handling is essential tokeep seeds alive and vigorous for subsequent sowings. The storability of many field crops isinfluenced by the type of packaging material or storage containers, which are decided by kind andamount of seed to be packed, type of package, duration of storage, storage temperature andrelative humidity *etc.* Research carried out on storage of cocoa seed and pods together with work on other related crops, are reviewed here; specifically, literature on effects of pod storage duration on viability, effects of storage container on seed viability as well as literature on general seed germination.

2.1 EFFECTS OF STORAGE DURATION ON SEED VIABILITY

2.1.1 Storage of Cocoa Seeds on Viability

According to Redshaw (1965), the cocoa bean is a non-dormant seed which is ready for germination as soon as the pods/ fruits are ripe, and that the cocoa seed is viable for a considerable period of time even before the pod is ripe. Hanson and Hunter (1960); Redshaw(1965), however maintains that germination capacity of cocoa appears to be short lived, and that viability is lost within 10-15 days after the seeds are harvested, unless they are placed under special storage conditions which permit their germination.

One of the earliest methods of storage was to maintain seeds within pods and this have remained the main form of storage to date, particularly in Africa, Onakoya (2011) and for that matter Ghana. He indicated that Cocoa seeds readily germinate when sowed and do not pass through a dormancy period. They however lose viability on extraction from the pod within five to seven days,

unless specially treated. He further opined that Cocoa seeds are therefore best stored in pods; where they remain viable for up to four weeks after harvesting. When it becomes necessary to extract the seeds from the pods for storage, the extracted seeds should be mixed with moist fine sand, moist sawdust or moist ground charcoal and the mixture should therefore be stored in a cool dry place and under such conditions, extracted seeds can be stored for two to three weeks. (Ibid).

The above notwithstanding, Redshaw, (1965) demonstrated that even seeds contained in immature pods are usually still viable after storage at 21 °C to 27°C for 8- 10 weeks; though mature pods are mostly harvested for seedling establishment in Ghana. This practice of use of mature pods for seedling establishment was originated by Posnette & Todd(1951) and confirmed by Ahenkora and Halm (1977); International Cocoa Research Conference, ICRC (2003) who asserted that immature pods of unspecified age recorded good seedling germination butthat the seedlings died shortly after germination.It was made clear by their study (Ahenkora and Halm (1977); ICRC, (2004) that pods heaped in the nursery should be broken and sown within the first nine days after harvesting. The period at which viability is maximum, is generally about six days after harvest, thereafter; there is rapid decline in viability.

Thompson (1950) had reported that some 5,000 cocoa seeds sent from Ghana to Malaya, Borneo and Sarawak, germinated satisfactorily, using charcoal as the packing material. But contrary to this, whole cocoa pods exported to Liberia by the Seed Production Unit of COCOBOD in 2009 recorded an unsatisfactory germination percentage when the seed were extracted and planted upon arrival (SPU Unpublished Report, 2009).

2.1.2 The Effects of Cold Storage on Cocoa Seeds

The desire to have cocoa seed stored for a relatively longer period resulted in some work which has been done on cold storage of seed as a way of maintaining seed viability. In this direction, the responses of cocoa seeds to storage factors including seed moisture, storage temperature and fungi have beeninvestigated. Such studies revealed that physiological, biochemical and structural changes associated with seed caused deathby dehydration in the air- conditioned room (22°C, 55% RH) and chilling at 1 °C, (Luan, 1984), rather than retaining seed viability.

Luan found that changes associated with seed dehydration damage and then chill injury of cocoa seeds were different and that germination and seedling growth were rapidly decreased in both cases, but axial respiration and protein synthesis were unaffected by the chill treatment , but were reduced significantly in axes moderately damaged by dehydration . He also revealed that loss of membrane integrity as evidenced by increased leachate conductivity also occurred in seeds moderately damaged by dehydration, but was not detected in chilled seeds until they were totally killed .

Progressive damages to cell organelles including cell membranes, mitochondria, ribosomes and nuclei were observed with increasing dehydration damage. Conversely, organelles were essentially unchanged in chilled seeds except for severe derangement of the plasmalemma and the tonoplast. It was further suggested that death caused by dehydration is progressive and involves damage to many biological processes including respiration, protein synthesis and function of cell organelles; culminating finally in total cell collapse. (Ibid)

It was also discovered by Luan (1984) that death caused by low temperature is more abrupt and may be triggered by only a few vital processes resulting mainly in severe degeneration of cell

membranes and their related functions, without affecting respiration, protein synthesis and other cell organelles.

This assertion had earlier been made by Boroughs and Hunter, (1961) and later Boroughs and Labarca, (1962) that subjection of cocoa seed to cold conditions causes a loss of viability of the cocoa seed.

Ibanez (1963a and b) also demonstrated that cocoa seeds lose their viability on immersion in water at 4 °C, for 10 minutes, but that loss of viability was however found to be reversible when such chilled seeds were immersed afterwards in water at 37 °C for 10 minutes. It was further stated that under such conditions, at least 85% of the seeds were restored to viability and produced healthy plants. But after 15 minutes of such a cold treatment, however, no length of time of post treatment could prevent ultimate death of the seed (Redshaw, 1965)

Subsequent work by Ibanez, (1964) demonstrated that the site of the cold effect was in the cotyledons and not in the embryonic tissue. Respiration rates in embryos of cocoa remained unchanged regardless of cold treatment, while cotyledonous tissue showed a large increase in endogenous respiration after cold treatment. In addition, embryonic tissue growing in sterile medium independent of the cotyledon material developed as well after chilling as the normally treated material. In all cases, growth over 2cm, leaf and chlorophyll production, were taken as criteria for viability. He however stated that it was uncertain as to whether this growth was due to mitotic division processes or solely to cell enlargement in embryonic leaves and roots.

The cold effects of the mitotic processes have been demonstrated by Moh (1963) and then Moh and Alan (1964) who have suggested that low temperature (cold) may inhibit the spindle

formation at metaphase leading to an inhibition of chromosome movement which ultimately affects germination.

(Ibanez 1963) has demonstrated that pigment leakage occurs from cold killed tissue but not from seeds that have been restored to viability by post-treatment for 10 minutes in water at 37°C.

It is interesting to note the presence of inhibitory effects on embryo survival and growth by the pigments released by cold killed seeds as demonstrated by Ibanez (1964)

Ibanez (1963) has said that these suggest the occurrence of a biological change in the cotyledon cells. It can be considered that the theory seems feasible and gains support from Kramer (1955), who has stated that permeability changes in cytoplasmic membranes may be caused by environmental factors such as low temperature conditions. In addition, it has been demonstrated by studies carried out by Casas and Ibanez (1963) that little or no damage occurs to the vascular tissue between the cotyledons and embryo following subjection of the cocoa seed to cold.Previous experiments on the storage and viability of cocoa beans by Pyke,(1993) included results on the influence of storage temperature on viability of seed from stored pods. It was concluded that desiccation, fungal decay and senescence were the factors involved in the deterioration of pods. In cool storage, the higher limit of the lethal temperature range was about 4.3°C, while at the optimum storage temperature germination remained perfect for 40 -50days.

It is not possible under the current seed (pod) production by the seed gardens and farmers in Ghana to arrange for a maintained temperature of such low magnitude for storage and transportation of pods. Because the average annual temperature is 28 °C (range 25 – 30°C) and also the cocoa bean is in a non-resting stage; the bean is therefore ready for germination when the pod is ripe.

2.1.3 Cocoa Pod Maturityand Storage duration on viability.

It has been stated by Ahenkora and Halm (1977) ; ICRC (1980) that, regardless of variety, pod age, and potting medium, the viability and growth performance of beans sown between the third (3^{rd}) andsixth (6^{th}) day (inclusive) after pod harvesting were found to be superior to those sown outside this period. They further observed that bean viability significantly declined after the seventh (7^{th}) day after harvest and most pods had rotted before the 13^{th} day of storage.

It has also been reported that viability of beans from pods harvested 7 days to the time of pod ripening was significantly superior ($p<0.01$) to those from pods harvested either 15 days to the time of pod ripening. This was also observed in the ripened pods and the over -ripened pods. (ibid)

As evident in earlier work (posnette & Todd, (1951); Martinson (1967) cocoa beans mature sometime before the pods ripens. Onakoya (2011) obtained almost 100% germination from full sized under-ripe pods 'whose beans were held in relatively hard pulp' but the viability of the beans from the under-ripe pods fell rapidly. Results from Evans (1950) Vaseline- smeared pods also indicated that whereas the Vaseline beneficially reduced water loss from the pods, it deleteriously impeded gaseous exchange. He concluded that : healthy unblemished pods to be transported to arrive at their destination in one –and- a half to two months should be packed in moist finely ground charcoal in perforated containers. The pods should be ripe pods in which the beans move slightly in the pod when the latter is shaken. If cocoa beans were to be transported to arrive in their destination in viable condition, the ripe seeds with pulp attached should be dispatched in relatively dry charcoal powder (moisture content about 30% but not exceeding 35% in containers with perforated sides.

Obviously, the above recommendations could be useful if relatively small sample weights were to be transported but certainly not for large pod consignments involving several thousands of pods. (This is the quantity of planting materials being handled by the seed gardens and cocoa farmers in Ghana).

Pods harvested 15 days to time of ripening had a longer viability rate but the average seedlings size over a six month period was lower than the more mature pods. The degree of maturity of pods significantly influenced the seedlings performance in the nursery (Ibid). At the point of their respective maximum viabilities the corresponding girth increase in the 7 day pod and the ripe pod was 78% and 28% respectively greater than the 15-day pod (ibid). Beans from the over-ripe pods when planted within the first four days of harvesting were just as good as those from pods harvested from seven days to time of ripening. They further revealed that the latter showed a high viability rate with superior seedlings performance even after the pods had been kept for more than ten days after harvesting.

2.1.4 Morphological properties of Seedlings obtained from stored cocoa pods

According to Ahenkora and Halm (1977) and ICRC (1980), most of the beans from stored pods did not germinate after 14 days of storage. They revealed that abnormalities of seedling morphological properties in terms of Leaf and stem abnormalities of seedlings were not common except on very few seedlings from the ripe and over-ripe pods planted on the 9^{th} and 11^{th} day respectively after harvesting.

They opined that the meanstem girth measurements with respect to the planting days to obtain a relationship between the individual planting days (of beans from the stored pods) and the

performance of the corresponding nursery seedlings produced a result that revealedthat beans sown between the fifth and seventh day after harvesting, gave the highest degree of variability than those sown thereafter. Similarly the total number of days for which various categories of harvested pods could be stored under the nursery conditions and still retain the optimum bean viability was computed from the respective equations of the fitted curves and the maximum viability peak for the 15- day to ripen, 7-day to ripen, ripe pod and over-ripe pods were 9, 7, 5 and 3 days respectively.

Previous experience by Posnette and Todd, (1951) showed a record of good germination from cocoa beans of immature pods of unspecified age, but the seedlings died later. The study on the influence of maturity of pod on seed viability in cocoa (Martinson, 1967) indicated that seedlings from immature pods developed abnormalities in leaf formation or general morphological peculiarities and hence lack of uniformity.

2.1.5 Factors Affecting or causing Lossof seed viability

Viability of seeds may be defined simply as the ability of seed to germinate. The causes of loss of viability in seeds are not well understood. For purposes of this study, the definition of viability was extended to cover the ability of the resulting seedlings to withstand normal nursery conditions up to 3 months or even time of transplanting the seedlings to the field. Dehydration of moist seeds could cause death yet some seeds can be dehydrated at low temperature and kept viable for years (Crockers and Barton, 1953). Exhaustion of food reserves or specific metabolic substrate necessary for early stage of germination before digestion of food reserves begins, causes loss of viability. Another possibility is the loss of enzyme activity, yet dead seeds

sometimes contain some active enzymes, (Stone 1957a). It has further been suggested by Avery & Blakeslee (1943) that the proteins of seed degenerate with age or that mutation occur in the nuclei which hinder or prevent germination. Gunthardt *et al* (1953) reported that chromosomal aberrations increase with increasing age of seeds.

Under natural conditions of 20°C and 60% RH, within dried and slowly rotting fruits, coffee seeds retain their viability for longer than 6 months (Velasco and Guitierrez, 1974) and by applying special storage conditions for each crop, coffee seeds can remain viable even for a longer time period. However, the water content of seeds in the naturally rotting fruits, as well as the water content of the coffee seeds stored as seed material, is far higher than that present in processed green coffees (11 %). Consequently, the much longer period of viability under natural conditions or for breeding purpose is explained by the significantly greater water potential in the seeds (Valio, 1976; Van der Vossen, 1980).

2.1.6 The effects of cocoa seed mucilage on viability or germination

Conventionally, local farmers plant cocoa beans either in the nursery or at stake with the mucilaginous covering on the body of the beans. This has been said not to encourage high percentage bean germination as the mucilage undergoes fermentation producing carbon dioxide and acid, which damage the embryo and retard germination process (ICRC 1980). The mucilage also forms a suitable substrate for fungal growth around the beans. This condition is detrimental to the life of the embryo and the germination process (Ashiru 1970). Earlier studies on cocoa bean germination had shown that mucilage in cocoa beans caused high germination percentage failure and bean loss (Atanda and Jacob, 1971). However, care should be taken in removing

mucilaginous covering on the beans to avoid damaging the emerging radical and hampering further germination process (Chinwuko and Lucas, 1986). Saw dust has been found to enhance germination in cocoa when seed is planted with mucilage (Ndubuaku and Oyekanmi, 2000), but the use of sawdust is not a usual practice in raising seedlings by farmers and even by the seed gardens.

ICRC, (1980) indicated that the cleaned beans (without mucilage) recorded higher percentage germination and fewer days to cotyledon drop than un-cleaned beans (with mucilage) in all the cocoa genotypes whose seed had been sown. He further revealed that there were no significant differences ($p>0.05$) in the percentage germination in both seed conditions. However, the un-cleaned beans differed significantly in their days to cotyledon drop in all the genotypes ($p<0.05$).

It has been found that the reasons for the lower percentage germination in the unclean beans could be due to the inhibitory effect ofmucilage which delayed germination and consequently led to the death of some beans in the soil as earlier observed by Ashiru (1970). The sawdust medium gave significantly faster and higher rate of germination irrespective of the seed condition. The faster and higher rate of germination obtained in the sawdust medium could be attributed to good aeration and drainage as a result of course particle size of sawdust as compared with the more compact and poorly aerated topsoil medium. Similar observations were made by Ndubuaku and Oyekanmi (2000).

2.2 EFFECT OF STORAGE CONTAINERS ON SEED VIABILITY DURING STORAGE

2.2.1 Storage containers

Seed storage is an integral part of seed production program since seeds of manyfield crops are produced with greater care and cost. Hence, a good storage is essential tokeep them alive and vigour until required for subsequent sowing season. Seed is said to be instorage in various stages from harvest to sowing, further the left over seeds are to be storedwithout appreciable decline in quality in order to meet the further demand.

A good number of containers are used for storing seeds but their suitability depends on the kind or type of seed and the protection the container can offer the seed in storage. Robbins and Shetha (1986) reported that un-extracted fruit seeds (as in cocoa pods) should not be stored in sealed containers or in deep piles. Classifying packaging materials, Agrawal (1995) categorized packaging/ storage materials into three; (1) moisture-vapour permeable containers (e.g. jute sack). (2) moisture-vapour resistant containers (e.g. Jute lined with polythene film) and (3) moisture-vapour proof containers (tin cans, polythene).

2.2.2 Container 1: Baskets (moisture-vapour permeable containers)

Baskets as storage containers for cocoa pods are especially usable for carting and occasional storage of pods during harvesting and storage. (Seed Production Unit (SPU) unpublished Report, 2008). In the humid tropics ventilation should be good, so baskets are not to be put close together or lined with any other material. (Oti-Boateng,1993.)

Baskets do not give enough protection against insects, but in certain traditions, especially in Northern Ghana, this can be improved by applying mud, clay or cow dung to the in- and outside.

However, the same effect is obtained by using a plastic bag inside the basket, which also makes storage airtight. If a basket is plastered, further ventilation is made impossible. If then, a too moist product stored, will go mouldy and rot quickly. Therefore one has to decide whether priority should be given to further protection againstinsects. (WFP, 1992)

However, with this storage method it is possible to use insecticides and with big baskets it is certainly advisable to dust the inside of the basket. This is mostly the case when grains are being stored.

The basket can be well-protected from the rain if it is made of grass or reed and kept in the house or some other dry building.

It is very suitable for storage of cereals, pulses, oil containing seeds, and potatoes for a period of 6 - 9 months; but temporarily for storage of pods and other planting materials on the farm.(Oti-Boateng, 1993)

As a result of the fact that gaseous exchange is highly taking place, respiratory activities is hastened when fresh produce like cocoa pods are stored in them. This is likely to cause deterioration of the pods in a relatively shorter period of storage.

2.2.3 Container 2: Jute sacks (moisture-vapour permeable containers)

These sacks are especially suitable for the dry tropics. In general jute sacks are cheaper than sacks made of cotton or sisal. Because of the danger of moisture uptake they should not be placed on concrete floors or on the ground, when they are used to store seed but on plastic sheets, waterproof canvas or on wooden pallets. Putting them on platform is preferred because it allows air to flow under the sacks. Do not stack sacks against the walls, as insects and termites can get

into the contents from the walls. Stack the sacks in a neat manner in not too big quantities on top of and against each other. Leave some space between the sacks so that air can move freely between them. Paths of about 40 cm wide should be left open between the stacks for inspection, cleaning and control of insects and rodents. (FAO-GTZ-CIRAD, 2001)

Advantages of jute sacks are that: The product can have slightly higher moisture content than when put into airtight storage, provided the sacks are stacked in such a way that air can move through the sacks for continued drying and cooling. (Ibid)

Sacks are also easy to handle and label. These sacks allow gasses to pass through and therefore insects may be controlled by using fumigants in a closed room or underneatha plastic sheet covering the stack.

Because gaseous exchange is common, respiratory activities is likely to be high when fresh produce like cocoa pods are stored in them

2.2.4 Container 3:Fertilizer/Plastic bags (moisture-vapoursemi/ or impermeable containers)

Plastic bags are suitable for storage in the humid and dry tropics. The product has to be dried well because during storage further drying is impossible, as not much air can enter the bag. Even in open plastic bags the product does not dry because there is no air circulation. If the plastic bags are closed well, airtight storage is obtained with all its advantages and disadvantages. Since air flow is very restricted, respiratory activities of fresh produce such as cocoa pods, is much reduced. This in turn may reduce the rate of respiration of food reserves in the beans within the pods.

Plastic bags do not offer much protection against rodents so extra attention is required.

2.2.5 Storage Containers and viability

The packaging materials used are decided by thekind and quantity of seed to be stored or packed,the type of package, duration of storage, storage temperature and relative humidity of thestorage area etc. Storage of orthodox group of seeds is done in different containers such asmoisture pervious and impervious containers.

Generally, seeds stored in moisture impervious sealed containers retain better qualitycompared to moisture previous containers under ambient conditions.

The prevailing relative humidity and temperature of the storage atmosphere influencegreatly on the longevity of seeds since moisture content of the seeds fluctuate more in themoisture pervious containers than the moisture impervious containers.

The ideal package material should protect seeds from high moisture, to withstand lowtemperature and preserve viability for longer periods (Appiah, F. and Kumah, P., 2009).

2.2.6 Comparative effects of viability of Polythene bag storage (impervious) to Cloth bag storage (impervious) on seeds

Vanangamudi and Karivaratharaaju (1988) observed higher field emergence andvigour index of field bean seeds stored in 700 gauge polythene bag compared to those incloth bags after 40 months of storage period.Dwivedi and Shukla (1990) opined that germination reduction (94.8 to 56.4%) anddevelopment of fungal colonies were less in chickpea seeds stored in polythene bags thanthose stored in cloth bags (94.8 to 51.2%) after 12 months of storage period.

Usha*et al*. (1990) stated that seeds of cowpea and horsegram treated with Malathionand stored in polythene bags retained significantly higher seed viability over a period of 8months as compared to seeds stored in cloth bag.Singh and Dadlami (1999) reported that there were ten times of

greater loss in seed weight andfour times as many eggs observed on seeds stored in cloth bags compared to those stored inpolythene bags at the end of eight months storage period of *Vignaradiata*seeds.Charjan and Gupta (1996) stated that storage of gram seeds in polythene bagsmaintained significantly higher germination and fewer invasions of fungi than those in gunny orcloth bags after 10 months of storage.

Patil (2000) reported that chickpea seeds stored in polythene bag recorded highergermination (68.36%), seedling dry weight (160 mg), vigour index (1369) and lower EC (1.45dSm-1) compared to those stored in cloth bag (64.10%, 141 mg, 1348, 1209 dSm-1respectively) at the end of 10 months period.Biradar (2001) recorded significantly higher germination (3.9%), shoot length (7.79cm), root length (8.44 cm) and lower EC (293.6 µmhos/cm) in greengram seeds stored inpolythene bag compared to those stored in cloth bag (79.8%, 6.37 cm, 6.94 cm and 305.8µmhos/cm respectively) at the end of 12 months period.

Tammanagouda (2002) revealed significantly higher germination (71.15%), rootlength (11.14 cm), shoot length (8.11 cm) and lower moisture content (9.21%) and seedinfestation (34.10%) in the greengram seeds stored in polythene bag as compared to those incloth bag at the end of 10 months storage period.

In a storage experiment conducted with two soybean cultivars PK-327 and JS-71-05in cloth bag and polythene bag (700 gauge), Singh and Dadlani (1999) reported thatgermination percentage of 94 per cent in JS-71-05, and 84 per cent in PK-327 wasmaintained for 14 months for seeds packed in polythene bag fell to three per cent and one percent respectively in seeds packed in cloth bag after 8 months.

Sushma (2003) concluded that garden pea seeds stored in 700 gauge polythene bagrecorded significantly less per cent of seed infestation, moisture content and more hundredseed weight than those in cloth bag at the end of 10 months of storage period.

2.3 PHYSIOLOGY OF SEED GRMINATION

Germination is believed to have several definitions, depending on who is proposing the definition. To the seed physiologist, germination is defined as the emergence of the radicle through the seed coat. Such a definition says nothing about other essential structures such as the epicotyl or hypocotyls that become the above ground parts of a successful seedling. To the seed analyst, germination is "the emergence and development from the seed embryo of those essential structures which, for the kind of seed in question, are indicative of the ability to produce a normal plant under favorable conditions" Miller (2010). This definition focuses on the reproductive ability of the seed, an essential objective in agriculture. Others consider germination to be the resumption of active growth by the embryo resulting in the rupture of the seed coat and emergence of a young plant. This definition presumes that the seed has been in a state of quiescence, or rest, after its formation and development (ibid). During this period of rest, the seed is in a relatively inactive state and has a low rate of metabolism. It can remain in that state until environmental conditions trigger the resumption of active growth. Regardless of which definition is preferred, it should be emphasized that one cannot actually see the process of germination unfolds. Therefore all definitions include some measure of seedling development, even though this occurs subsequent to the germination event. Specific definitions of germination

by some authorities are captured below and are reflective of both the "physiologist" and "analyst" perspectives of germination.

Germination is the resumption of active growth of the embryo initiated when the seed is subjected to favourable environmental conditions of moisture, temperature and oxygen, Gardner *et al* (1985) and Hadidi (1996). Some other authorities defined germination as the emergence and development of the seedling to a stage where aspects of its essential structures indicate whether or not it is able to develop further into satisfactory plant under favourable conditions in soil (Copeland and McDonald, 1995; Mathur *et al*, 2003). Basu (1990) also asserted that it is difficult to maintain germination capacity or the potential viability of seed especially in hot climates and acknowledged that germination results remain the prerequisites for assessing seed for planting or industrial purposes. According to Opeke (1982), mechanical or internal physiological barriers may prevent seed germination due to imposed dormancy. Madsen (1988), defined dormancy as the state in which seeds will not germinate despite favourable external conditions which may be due to endogenous or exogenous factors.

2.3.1 Factors Influencing Germination

Several factors have been identified that are said to influence seed germination. These factors include temperature, humidity, seed moisture, fungi pathogens, storage conditions and seed oil content among others. Copeland and McDonald (1995) documented that temperature, water, oxygen and light are important external conditions necessary for seed germination.

2.3.2Influence of Temperature on Germination.

Seed germination is a complex process involving many individual reactions and phases, each of which is affected by temperature. Temperature was reported by Gardner *et al* (1985) as a requirement for germination of non-dormant seeds. Madsen (1988), Copeland and McDonald

(1995) also reported that temperature as well as water, oxygen and light are an important external conditions necessary for seed germination. It has also been observed that high temperature during seed maturation may induce dormancy in seed, Driscoll (1990). It was further observed that the effect on germination can be expressed in terms of cardinal temperature: that is *minimum,optimum,* and *maximum* temperatures at which germination will occur. The minimum temperature is sometimes difficult to define since germination may actually be proceeding but at such a slow rate that determination of germination is often made before actual germination is completed. The optimum temperature may be defined as the temperature giving the greatest percentage of germination in the shortest time. The maximum temperature is governed by the temperature at which denaturation of proteins essential for germination occurs. The optimum temperature for most seeds is between 15°C and 30°C. The maximum temperature for most species is between 30°C and 40°C. Not only does germination have cardinal temperatures, but each stage has its own cardinal temperature; therefore, the temperature response may change throughout the germination period because of the complexity of the germination process.

Some seeds require vernalization (low temperature treatment) before they can germinate, grow and initiate flowers. Driscoll (1990) observed this when he reported that winter wheat seed requires 2°C treatment for six weeks before planting to induce flowering. On the contrary Gardner *et al* (1985), Copeland and McDonald (1995) stated that most tropical seeds are very sensitive to chilling during germination, especially at temperatures below 10°C. Simic *et al* (2007) also reported that the combined effect of high temperature and relative humidity accelerate seed deterioration independent of the initial seed quality.That the combined effect of high temperature and relative humidity accelerates seed deterioration independent of the initial seed quality.

The response to temperature depends on a number of factors, including the species, variety, growing region, quality of the seed, and duration of time from harvest (ibid).

2.3.3 Effect of Seed Moisture Content on Germination

High seed moisture is reported to affect seed quality. Between 40% - 60% moisture content, metabolic activities increase and seed germination is triggered off resulting in the death of the embryo. An earlier report indicated that seed with hard seed coat prevented oxygen and moisture entry into seed and prevented autoxidation of linoleic and linolenic acids which are responsible for degradation of cellular organelles (Cantliffe, 1998).

Water is a basic requirement for germination. It is essential for enzyme activation, breakdown, translocation, and use of reserve storage material. In their resting state, seeds are characteristically low in moisture and relatively inactive metabolically, Miller (2010), that is, they are in a state of quiescence. Thus, quiescent seeds are able to maintain a minimum level of metabolic activity that assures their long-term survival in the soil and during storage.

Moisture availability is described in various ways. *Field capacity* moisture is about optimum for germination in soil; however, germination varies among species and may occur at soil moistures near the *permanent wilting point.* Most seeds have critical moisture content for germination to occur. For example, this value in corn is 30%, wheat 40% and soybeans 50% (ISTA, 1993, 2007). Once that critical seed ~~moisture~~ content is attained in the seed, sufficient water is present to initiate germination and the seed is committed to that event and cannot turn back. If the internal moisture content decreases below the critical moisture content, seeds will essentially decay in the soil (Miller, 2010).

2.3.4 Influence of Air (Oxygen) on Seed Germination

Air is composed of about 20% oxygen, 0.03% carbon dioxide, and about 80% nitrogen gas. If one provides different proportions of each of these gases under experimental conditions, it soon becomes clear that oxygen is required for germination of most species. Carbon dioxide concentrations higher than 0.03% retard germination, while nitrogen gas has no influence.(Miller, 2010).

2.3.5 Morphology of Seed Germination.

Based on the fate of the cotyledons, two kinds of seed germination occur, and neither appears to be related to seed structure. These two types are illustrated by the germination of bean and pea seeds. Although these seeds are similar in structure and are in the same taxonomic family, their germination patterns are quite different, Miller (2010).

Epigeal Germination. Epigeal germination is characteristic of bean and pine seeds and is considered evolutionarily more primitive than hypogeal germination. During germination, the cotyledons are *raised above the ground* where they continue to provide nutritive support to the growing points (ibid).

Hypogeal Germination. Hypogeal germination is characteristic of pea seeds, all grasses such as corn, and many other species. During germination, the cotyledons or comparable storage organs *remain beneath the soil* while the plumule pushes upward and emerges above the ground (ibid). In hypogeal germination, the epicotyl is the rapidly elongating structure. Regardless of the

type,the cotyledons or comparable storage organs continue to provide nutritive support to the growing points throughout germination (Ibid).

2.4 Cocoa pod harvesting practices at Seed Gardens (Cocoa Stations)

Cocoa pods meant for propagation or sowing are made available to farmers through certain practices and procedures adopted by the Seed Gardens or Cocoa Stations. These procedures and practices are well-formalized within the Seed Garden establishment (SPU Seed Propagation Guide; unpublished) which serves as Standard Operational Procedures (SOP).

Hand pollination of the cocoa trees is done in May of every year. This takes five (5) months for the pods to reach physiological maturity. At this point in October, pod harvesting for propagation are done. A harvesting schedule for harvestings fortnightly is also prepared. For each harvesting day, pod harvesting is done in the morning, to reduce with field heat effect. Harvesters use harvesting hooks, cutlasses or secateurs to remove matured and ripened pods from the trees, in such a manner to avoid injuring the pod tissue and pre-disposing pods to rot organisms. Pods are then gathered at a central collection point, for sale to farmers. (Personal communication with Seed Gardens Managers)

CHAPTER THREE

3.0 MATERIALS AND METHODS

This storage experiment was conducted on Hybrid Cocoa varieties with different pod storage periods/ duration and storage containers to ascertain their influence on viability/ germination under ambient storage conditions under the supervision of the Department of Horticulture, Kwame Nkrumah University of Science &Technology, Kumasi, during the period November 2012- March 2013, and specifically involved 30- day pod storage. The details of materials used and the techniques adopted during the course of present investigations are described in this chapter.

3.1Sources of Data for the Study

Both primary and secondarydata were collected for the purpose of this research. For clarity, Saunders *et al*, (2007) define data as facts, opinions and statistic that have been collected together and recorded for reference or for analysis.

3.1.1Primary Data Source

Primary data is data that is used for a specific purpose for which it was gathered. For this study, it was obtained by taking recordings of the field experiments with the help of trained field assistants.

3.1.2Secondary Data Source

Secondary data is data that is used for a purpose other than for which it was originally obtained. It may be descriptive or explanatory (Saunders *et al*, 2007), raw (unprocessed) or summarized (Kervin, 1999). They can be categorized into documentary, multi-source or survey- based (Saunders et al, 2006).

Secondary data for the research were collected by reviewing textbooks, journals, articles, magazines, publications, internal records of Seed Production Unit (Seed Gardens)-(COCOBOD) and Cocoa Research Institute of Ghana, (CRIG) to gather or review information that is related to this study.

3.2 Experimental Site/Study Area

The study is a field research which was conducted at Appeadu, near KNUST, Kumasi, which lies between Latitude 6°745' N and longitude 01°36' W (Anon. 1977)`21`with an altitude of 261.4 meters above mean sea level..The original location of Pankesse was changed due to difficulty in obtaining cocoa pods at the Pankesse Cocoa Station in the Eastern Region as was previously planned.

The storage experiment was conducted for a period of five months (November 2012 to March2013) but specifically involved a 30 day pod storage period.

3.3 Climatic condition

The mean meteorological data were measured from November 2012 to February 2013and confirmed with figures collected from the Meteorological Station of the Animal Science Department, KNUST and presented inAppendix 4. During the pod storage period, the mean maximum temperature of 32.7°C was noticed during November and the mean minimum temperature was 19.7 during January 2013.The relative humidity during storage period was unstable: 77% - 96 % in November 2012to 17% - 91% in January2013 respectively.

3.4 Source of Pods/ Seed for the Investigation

Physiologically matured and ripped pods were harvested fresh, from hand pollinated hybrids cocoa (*Akokorabedi*) at Fumso Cocoa Station in the Ashanti Region. The seeds were extracted and planted fresh whenever planting was due out.

3.5 Pod Storage Method

After harvesting the pods during the morning at the Fumsu Cocoa multiplication stations or seed garden, asper the harvesting schedule, 66 pods each were packed in (i) basket, (ii) fertilizer sack and (iii) jute sack separately. These were then stored under ambient conditions of temperature and relative humidity, up to 30 days from November 2012 to early part of December 2012 in a well-ventilated shed/ room at the study site. Some pictures showing cocoa pod storage are as shown on the following page:

Figure 3.5 Hybrid Cocoa Pods stored in the 3 storage containers under investigation

3.6 Research Design and Treatments

The research design of this study was a Randomized Complete Block Design (RCBD) in a Factorial arrangement, involving two factors: 1. effects of storage period 2. effects of storage container.

The choice of a Factorial Experiment helpedsave time and resources and also helped the researcherobtained the interactions between the two factors; asa two-way design enables the examination of thejoint(or interaction) effect of the independent variables on the dependent variable. Factorial design can also lead to more powerful test by reducing the error variance (IDL, 2009, Hort. 558)

3.7 Details of Field Experimentation

3.7.1 Treatment details

The experiment consisted of a total of 21 treatment combinations involving three storage containers and seven storage periods or duration which were replicated three times. The details of the experiment are provided below.

Factor – I: Storage Container (C)
C1 – Basket
C2 – Fertilizer sack
C3 – Jute sack

Factor – II: Storage period (P)
P1 – 0 Days after Harvesting (DAH)
P2 – 5 Days after Harvesting (DAH)
P3 – 10Days after Harvesting (DAH)
P4 – 15Days after Harvesting (DAH)
P5 – 20Days after Harvesting (DAH)
P6 – 25Days after Harvesting (DAH)
P7 – 30Days after Harvesting (DAH)

3.7.2 Treatment combinations

C1P1	C2P1	C3P1
C1P2	C2P2	C3P2
C1P3	C2P3	C3P3
C1P4	C2P4	C3P4
C1P5	C2P5	C3P5
C1P6	C2P6	C3P6
C1P7	C2P7	C3P7

NB: These were then replicated three times, giving a total of sixty three treatment combinations. Each combination contained fifty (50) poly bags, which then sum the polybags up to three thousand, one hundred and fifty polybags (3,150)

3.7.3 Planting / Sowing of Seeds

Three thousand, one hundred and fifty (3,150) polythene bags of standard cocoa bag size (12.5 x 20) were used for this experiment. They were filled with solarized top soil.

The filled polybags werethen arranged to form 3 replicates or blocks of the seven storage periods and the three storage containers. The arrangement was done to ensure uniform sunlight entry across the blocks or replicates. Daily temperature readings were recorded throughout the study.

The poly bags were arranged in batches of fifty in a Randomized Complete Block Design, involving a Factorial set up of 7 storage period levels (spaced at 5 days intervals) and 3 storage containers (Basket, Jute sack and Fertilizer sack).

The experiment was set up in a nursery constructed under artificial shade of Bamboo post and palm frond matting, with an incident light intensity estimated to be about 20% full daylight. This was done before the pods were harvested

200 mature pods of similar physiological maturity at Fumso Cocoa Station in the Ashanti Region were used. The harvested pods were weighed using a weighing scale to determine the weight whilst a Tape measure was used to measure the length and girth of the pods at the Centre, the proximal and the distal ends of the pods to ensure that uniform pod size were selected. The pod weight ranged from 1.02 kg to 1.09kg, whilst the length also ranged from 20cm to 20.4 cm. The girth also ranged from 30 cm to 30.1 cm.

The pods were then put into the respective storage/ carriage containers the same day. Four pods were taken from each category and broken open by knocking pod against the other.

The beans were extracted from the middle portion of the pods to ensure uniform germination (according to Onakoya (2011). The beans were planted with the mucilage (farmers' method) and were sown on their flat sides at the depth of about 2cm below the surface of the planting media (top soil).

The planting media were thoroughly watered the day before sowing and a routine watering was subsequently carried out every other day and so continued to the end of the experiment.

Figure3.7.3: Arrangement of filled Polybags for sowing of seed

3.7.4 Cultural Practices/ Maintenance Regime

Agronomic practices carried out during the study period included weeding, irrigation, and pest/disease control. The nursery was kept weed-free through manual pulling out of weeds. As has already been indicated, supplementary water application or irrigation was carried out every other day to keep the soil sufficiently moist during the study. An insecticide spray of "*Akate Master*" was separately complemented with Fungi-kill (fungicidal spray) using a pneumatic Knapsack sprayer, towards the controlof pest (caterpillars) and fungal infection that occurred on the leaves of the plants within 2-3 months upon emergence.Diagrammatic view of the planting out and serial germination are depicted below:

I II III IV

Figure 3.7.4A I-V: Cross-section of germinated seedlings involving storage periods (DAH)

I II III

Figure 3.7.4B I-III Cross-section of germinated seedlings in Replications depicting storage containers

3.8 Parameters for Assessments

The polybags were checked and monitored every morning to make observations on seed viability parameters as: date of germination, number of seedlings germinated and the date of cotyledon drop. To ensure adequate data is collected, both germination data and morphological data such as stemheight and stem diameter among nine otherswere measured, about 3 months after germination, with a tape / meter rule and a Vernier caliper, whilst some were counted or derived from formulae.

3.8.1 Data collected during the study or investigation included:

3.8.2Germination Related Parameters such as

3.8.2.1 Time from sowing to start of germination (days)

The sown seed were monitored daily to observe germination counts, which commenced at 10 Days after Sowing (DAS)

3.8.2.2 Time from start of germination to the final germination (days)

Germination count was monitored from beginning and continued till the end of germination, which ranged between 17 DAS and 24 DAS.

3.8.2.3Time taken to drop cotyledons (days)

The number of days taken from germination to cotyledon drop was recorded for each storage-container and storage period seedlings

3.8.2.4 Germination percentage.

Germination tests were carried out on the stored pod lots (containers) for 30 consecutive days. Daily germination counts were taken and recorded up to the 2 weeks (twenty -eighth day; time after which no seed was observed to have germinated) per each lot of 50 polybags and storage period. The results were calculated as percentage normal seedlings (ISTA, 1979).The normal seedlings were the number of seedlings that emerged at least 4 cm above the soil surface on the

14th day thereafter, after sowing were counted and average was expressed as per cent field emergence.

The abnormal seedlings and dead seeds percentages were also computed.

The germination counts commenced at 10 Days After Sowing (DAS) and continued till, 17 DAS and 24 DAS. It was measured in percentage (%) through this relation -

$$\frac{\text{No of bean germinated} \times 100}{\text{Total no of beans planted}}$$

3.8.2.5 Speed of germination

Speed of germination of the sown seed was estimated using the following formula by ***Maguire*** (1962):

$$SG = \frac{N1}{D1} + \frac{N2}{D2} + \frac{N3}{D3} + \frac{Nn}{Dn}$$

Where,

SG = Speed of germination, N1, N2, N3----------Nn = Number of seedlings emerged on D1, D2, D3-------and Dn days after Sowing, respectively

This is a coefficient that tells the rate at which germination mechanisms facilitate emergence of seedlings and provides a measure of how fast the seedling emerges from the soil. It gives an indication of how much energy is available for emergence (Valio, 1979)

3.8.3 SeedlingGrowth & Morphological Parameters include:

3.8.3.1 Seedling Vigour Index

Two determinations were made to assess seed vigour and growth rate: The first aspect was carried out on the fourteenth day after seedling emergence and repeated after 2 months, averaged and vigour index then computed.

The seedling vigour index was computed by adopting the following formula as suggested by Abdul-Baki and Anderson (1973) and expressed in number.

Vigour index = Germination (%) x Seedling length (cm).

The growth rate was however done by visual observation of the seedlings on a weekly basis.

3.8.3.2 Seedling Shoot height/length (cm)

From the germination test, ten normal seedlings were selected randomly from each treatment and the plant height was measured from the soil surface to the tip of the plant, one month after emergence, and repeated on the second month after emergence, using a metre rule and the mean shoot length was expressed in centimetre.

3.8.3.3 Seedling Stem girth (cm)

The mean stem girth of the sample plant was measured using an ESAL Vernier caliper. The diameter was measured 2cm from the soil surface, at the same time that the stem heights were measured. This measurement indicates stem lateral growth.

3.8.3.4Number of leaves per plant within first 2-3 months

The leaves on the sample plant were counted and recorded.The mean number of leaves at3 months after emergence was recorded for each treatment. Only fully developed or expanded leaves were counted during such leave count exercise which was carried out in the mornings between 7am and 9am.

3.8.3.5 Seedling Leaf Area (cm^2)

The leaf area (LA) was estimated for each treatment involving ten (10) plants each, at 3 months after emergence, with an empirical relationship by Adenikiju's derived formula, (Adenikiju, 1974), viz:

$Y= 93.0+ 19.2X_1 -124.4X_2 + 109.0X_2$, where Y = Leaf area; X_1= seedling height from ground to apex; X_2 = leaf number per seedling; X_2 = seedling age (weeks) after planting.

3.8.3.6 Leaf Petiole Length (cm)

Leaf Petiole length of the plant or seedlings was measured. The measurement was carried out on four true leaves per seedling. This was done when the seedlings were3 months old.

3.8.3.7 Stem Nodes per plant

Stem nodes were observed, counted and recorded at 3 month of the seedlings. Careful observation was made to include blind nodes (i.e. nodes other than at sites of leaf axils).

3.8.3.8 Stem Internode Length (cm)

Mean internode length of the plant was recorded during the third month of emergence as an indicator of stem growth. A 30cm rule was used to record the lengths. The exact distance between the alternate leaves was measured and recorded.

3.8.3.9 Seedling Plant Canopy (cm)

Plant canopy was measured at 3months after emergence. Two perpendicular distances covered by the plant canopy were measured using a 30 cm rule and recorded. The average of the two measured lengths gave the diameter of the canopy.

3.8.3.10 Seedling Root/ Hypocotyl Length (cm)

The root length of four seedlings for each treatment combination was measured from collar region to thetip of primary root of seedlings used in measuring shoot length and the average root length was expressed in centimetre.

3.8.3.11Seedling Dry Weight (Total Dry Matter) (g/seedling)

Four seedlings per treatment combinations at age 3 months, which were used for root length measurement wereput in A4 envelop and kept in an oven (wagtech brand at KNUST) maintained at 80°Cfor 24 hours, according to Dwapanyin and Frimpong, (2003). After drying, the seedlings were left to cool and the seedling dry weight was recorded and expressed in grams.

3.9 Data Collection, Entry and Statistical Analysis of the primary experimental data.

Primary data on germination and seedling morphology were collected on a daily basis with the help of the Trained Assistants. Data collectedwere vigorously crosschecked to ensure reliability,

accuracy, completeness and consistency. Field data resulting from this quality procedure were analyzed using Statistical Analysis System (SAS) package (Version 9.1) for such data, with data means separated by the LSD at 5%. Other data (percentages and count data less than 10) weretransformed into Square Root transformation values(Snedecor and Cochran, 1967) which were thenprocessed and analyzed using ANOVA, to generate information presented by inferential and descriptive statistics, i.e. was analyzed statistically by adopting the procedure described by Sundarajan *et al.* (1972) and significant differences were calculated at 5 percent level, whereverp< 0.05. Means were differentiated with alphabets or letters, with means having the same letter identified as not being significantly different.For interactions between the two factors at the various levels, significance was determined by comparing the standard deviation of each interaction to the Decision Rule Standard Deviation (SD) of 2.00: whenever the interaction standard deviation was higher than the Decision Rule Standard Deviation of 2.00, then such an interaction was considered significant (SAS Package). It is worthy of note that this test controls the Type I comparison-wise error rate, not the experiment-wise error rate.

CHAPTER FOUR

4.0 EXPERIMENTAL RESULT

Studies onDetermination of the effects of Postharvest Pod Storage on Seed Viability of Cocoa (*Theobroma cacao, L*) were conducted at Apeadu, near KNUST, Kumasi from November 2012 to February 2013. The results generated on various seed quality parameters *viz*., Time (Days) from sowing to start of germination, Time (Days) from start of germination to the final germination, Time to drop cotyledons, Germination percentage, speed of germination and then seedling morphological data such as Seedling Vigour Index, Plant Height Stem Girth, Number of Leaves per Plant, Leaf Area, Leaf Petiole Length, Stem Nodes per Plant, Stem Internode Length, Plant Canopy spread, Seedling Root/ Hypocotyl Length and Seedling Dry Weight (Total Dry Matter) of Hybrid Cocoa (*Akokora Bedi*) are presented in this chapter. It should be noted that results which were found to be insignificant have been attached in **Appendix5**

4.1 GERMINATION DATA

4.1.1 Time from sowing to start of germination (Days)

The results of Time from sowing to start of germination as influenced by Storage Period and Storage Container and their interactions are presented under the various effects as below:

4.1.1.1 Effects of Storage Period on the Time to start Germination

The effects of Cocoa pod storage period on the time taken by the cocoa seed to start germination, resulted in the seed taking 10 days to 18 days (grand mean of 11.51 days) to start germination. The storage periods had highly significant effects ($p<0.005$) on the time taken to start germination, at 5% Level of significance. There were significant differences between 5DAH &10DAH, 10DAH &15DAH, 15ĐAH &20DAH, 20DAH & 25DAH and then 25DAH and

30DAH, and thus produced significant differences in the time taken for the seed to start germination, as indicated within Table 4.1.1Abelow:

Table 4.1.1A. Effects of Storage period on Time taken from sowing to start of Germination

DAH	Mean No of days taken to start germination
0	10.11a
5	10.00a
10	15.00b
15	13.22c
20	10.56ad
25	11.22d
30	10.44ae

Alpha = 0.05; Least Significant Difference = 0.7816; CV = 7.128780

Means with the same letter are not significantly different

4.1.1.2 Effects of Storage Container on the Time taken from sowing to start Germination

As in Storage period effects, the time taken to start germination, as a result of the three storage containers, ranged from 10 days to 18 days with a grand mean of 11.51 days. The effect of the Storage Containers showed no significant differences ($p>0.05$), at 5% Level of significance, among the three storage containers (Basket, Jute sack and Fertilizer sack).

4.1.1.3 Interactive effects of Storage Container & Storage Period on the Time to start Germination The interactive effect was significant ($P< 0.05$ i.e. 0.0148), resulting in an indication of strong evidence that storage period and container interactions have had an effect on time taken to start germination by the seed. The individual interactions which were found to be significant include; 20DAH &Fertilizer sack interaction (4.1% effect), with a standard deviation

of 2.082 (Standard deviation greater than 2.00) and 30DAH & Jute sack interaction, with a Standard deviation of 2.31 (15.5% effect) as indicated in the Table 4.1.1B below:

Table 4.1.1B Interaction effects for Time taken to Start Germination

Level of DAH	Level of STORAGE	Decision Rule SD	Mean	Std Dev
0	BASKET	2	3.18	0.00
0	Fert_Sac	2	3.23	0.09
0	Jute_Sac	2	3.18	0.00
5	BASKET	2	3.18	0.00
5	Fert_Sac	2	3.18	0.00
5	Jute_Sac	2	3.18	0.00
10	BASKET	2	3.80	0.08
10	Fert_Sac	2	3.75	0.00
10	Jute_Sac	2	4.09	0.19
15	BASKET	2	3.62	0.00
15	Fert_Sac	2	3.71	0.08
15	Jute_Sac	2	3.62	0.00
20	BASKET	2	3.18	0.00
20	Fert_Sac	2	3.42	2.08
20	Jute_Sac	2	3.18	0.00
25	BASKET	2	3.38	0.08
25	Fert_Sac	2	3.33	0.00
25	Jute_Sac	2	3.38	0.08
30	BASKET	2	3.18	0.00
30	Fert_Sac	2	3.18	0.00
30	Jute_Sac	2	3.37	2.31

4.1.2 Time from start of germination to the final germination (Days)

The results of Time taken from start to final germination as influenced by Storage Period and Storage Container and their interactions are presented under the various effects as below:

4.1.2.1 Effects of Storage Period on the Time taken from start to end of Germination

The time taken from start to end of germination, as a result of storage period effect, ranged from 4 days to 20 days with a grand mean of 13.89.

Storage period had significant effects ($p<0.005$) on time taken from start to end of germination at 5% Level of significance.

There was significant difference between 20DAH and 25DAH but the set of 0DAH to 20DAH

were not significantly different, so was 25DAH and 30DAH as shown in Table 4.1.2A below:

Table 4.1.2A Effects of Storage period on Time taken to end Germination

DAH	Mean No of days taken to end of germination
0	12.11a
5	13.44a
10	13.22a
15	12.11a
20	14.00a
25	16.11b
30	16.22b

Alpha = 0.05; Least Significant Difference = 2.695; CV = 20.36670

Means with the same letter are not significantly different.

4.1.2.2 Effects of Storage Container on the Time from start to end of Germination (days)

The time taken from start to end of germination, in respect of storage containers, ranged from 4 days to 20 days with a grand mean of 13.89 days.

Storage Containers had significant effects ($p<0.05$) on time from start to end of germination at 5% Level of significance, as the P-value is small enough to justify the rejection of the assertion that the means were the same or similar. The effect of Jute sack storage was significantly different from Fertilizer sack effects (16.8% higher) and therefore ended germination earlier indicated within Table4.1.2B on the next page.

Table 4.1.2B. Effects of Storage Container on Time taken to end Germination

Storage Container	Mean No of days taken to end germination
Basket	14.10 a
Jute sack	12.52a
Fertilizer Sack	15.05b

Alpha = 0.05; Least Significant Difference = 1.7643; CV = 20.36670

Means with the same letter are not significantly different.

4.1.2.3 Interactive effects of Storage Container & Storage Period on Time taken from start to end Germination (days)

The interaction effects between storage period and containers had P< 0.05 (i.e. 0.0038), resulting in strong evidence that the interactions between storage period and storage containers have had an effect on time taken from start to end of germination.

Out of the 21 interactions, those found to be significant were 0DAH & Basket interaction (15.4%), 5DAH & Basket interaction (50%), 10DAH & Basket interaction (25.8%), 10DAH & Fertilizer Sack interaction (100%), 10DAH & Jute sack interaction (over 10%), 15 DAH & Fertilizer sack interaction (over 100%) , 15DAH & Jute sack interaction (20%) , 20DAH & Basket interaction (over 75%), 20DAH & Fertilizer sack interaction (50%), 20DAH & Jute sack interaction (over 25%), 25DAH & Jute sack interaction (over 100%), 30 DAH & Fertilizer sack interaction (25%) and then 30 DAH & Jute sack interactions (4.1%), since their respective standard deviation figures are above the decision rule standard deviation of 2. 000 as indicated in Table 4.1.2C on the next page.

Table 4.1.2C Interaction effects for Time taken to end Germination

Level of DAH	Level of STORAGE	Decision Rule SD	Mean	Std Dev.
0	BASKET	2	3.42	2.31
0	Fert_Sac	2	3.53	1.00
0	Jute_Sac	2	3.53	0.08
5	BASKET	2	3.74	3.40
5	Fert_Sac	2	4.01	0.22
5	Jute_Sac	2	3.23	0.08
10	BASKET	2	3.83	2.52
10	Fert_Sac	2	4.25	4.12
10	Jute_Sac	2	2.59	2.65
15	BASKET	2	2.90	0.10
15	Fert_Sac	2	3.66	2.65
15	Jute_Sac	2	3.77	3.24
20	BASKET	2	3.58	3.56
20	Fert_Sac	2	3.79	3.06
20	Jute_Sac	2	3.83	2.52
25	BASKET	2	4.29	0.07
25	Fert_Sac	2	3.97	0.14
25	Jute_Sac	2	3.77	3.04
30	BASKET	2	4.33	0.06
30	Fert_Sac	2	3.92	2.52
30	Jute_Sac	2	3.83	2.08

4.1.3 Time to drop cotyledon (Days)

The results of Time taken to drop cotyledons of seedlings, as influenced by Storage Period and Storage Containers and their interactions are presented under the various effects as below:

4.1.3.1 Effects of Storage Period on the Time taken to drop Cotyledons (days)

The time taken for the seedlings to shed their cotyledons, as a result of storage period, ranged between a minimum of 12 days to a maximum of 16 days, with a grand mean of 13.81 days.

However, these effects had $p > 0.05$ (i.e. 0.4454), resulting in insufficient evidence that storage periods had significant impact on time taken to shed cotyledons by the seedlings.

4.1.3.2 Effects of Storage Containers on the Time taken to drop Cotyledons (days)

The effect of the Storage Containers had $p > 0.05$ (i.e. 0.3978), resulting in insufficient evidence

that storage containers (Basket, Jute sack and Fertilizer sack) have had an insignificant effect on time taken by the seedlings to drop cotyledons.

4.1.3.3 Interactive effects of Storage Container & Storage Period on Time taken to shed cotyledons (days)

The interactive effect of the Storage Containers and Storage Period had P> 0.05 (i.e. 0.9610), resulting in insufficient evidence that storage period and storage containers interactions were significant in producing an effect on time taken to start germination.

4.1.4 Germination percentage

The results of germination percentage as influenced by Storage Period and Storage Container and their interactions are presented under the various effects as below:

4.1.4.1 Effects of Storage Period on Germination Percentage

Recorded range of germination percentage had a minimum of 6.7% to a maximum of 100%, with a mean of 56.31. Germination Percentage recorded due to the effects of storage periods were found to be significantly different ($p<0.005$), at 5% Level of significance. There were significant differences among 10DAH and 15DAH, 15DAH and 20DAH 10DAH and 25DAH, with 25DAH producing a germination percentage of 17.8% higher than the effects of 10DAH. The pairwise comparisons of LSD (5%) are indicated within Table 4.1.4A on the following page.

Table 4.1.4 Effects of Storage Period on Germination Percentage

DAH	Mean germination percentage
0	4.3066 a
5	4.12 a
10	3.22 a
15	3.99 b
20	3.96 ac
25	3.92c
30	4.13c

Alpha = 0.05; Least Significant Difference = 0.3335; CV = 8.871223

Means with the same letter are not significantly different.

4.1.4.2 Effects of Storage Container on Germination Percentage

Recorded range of germination percentage had a minimum of 6.7% to a maximum of 100%, with a mean of 56.31. There were no significant differences (P> 0.05) in percentage germination due to the effects of storage containers (Basket, Jute sack and Fertilizer sack).

4.1.4.3 Interactive effects of Storage Container and storage period on Germination Percentage

The interactive effects of storage period and Containers produced insignificant effect in percentage germination of the seedlings, as none of the interactions had standard deviation greater than 2.00, to suggest significant impact.

4.1.5 Speed of germination

The results of speed germination as influenced by Storage Period and Storage Container and their interactions are presented under the various effects as below:

4.1.5.1 Effects of Storage Period on Speed of Germination

The minimum speed recorded for germination was 0.13 whilst the maximum speed was 4.58, with a mean of 2.02. There was significant influence of storage period on the speed of germination, from start up to completion of germination. The storage effect of 10 DAH was significantly different from the effects of 0DAH &15DAH. 15DAH &20DAH were also significantly different. There were no significant differences within the set 15 DAH to 30DAH. Those set were however significantly different from each of the other DAHs. The pods stored for 0 days recorded numerically higher (2.80) speed of germination (and therefore germinated faster) compared 5-day storage (2.48) to 20-day storage (2.21) and through to 10- day of storage (0.89), as revealed in Table 4.1.5 below:

Table 4.1.5 Effects of Storage Period on Speed of Seedling Germination

DAH	Mean co-efficient of speed of seedling germination
0	2.80a
5	2.47a
10	0.89b
15	1.88c
20	2.21ac
25	1.69c
30	2.19c

Alpha = 0.05; Least Significant Difference = 0.6936; CV = 36.078

Means with the same letter are not significantly different.

4.1.5.2 Effects of Containers on Speed of Germination

The minimum speed recorded for germination was 0.13 whilst the maximum speed was 4.58, with a mean of 2.017. There was no significant influence of containers on the speed of

germination of the seedlings. The pods stored in Basket recorded numerically higher (2.13) speed of germination and therefore geminated relatively faster than pods in the other containers. This was followed by Jute sack (2.05) and Fertilizer sack (1.89).

4.1.5.3 Interactive effects of storage period and Container interactions on Speed of germination.

None of the interactions between Storage period and Containers did record significant impact on the speed of germination.

The interaction due to 0DAH and Basket recorded highest speed of germination whilst 20DAH and Basket recorded lowest speed of germination.

4.2 SEEDLING MORPHOLOGICAL DATA

4.2.1 Seedling Vigor Index

The results of vigour index at 3 months old, ranged from 0.91 to 24.01, with a mean value of 10.27 which has been influenced by Storage Period, storage containers and their interactions, as presented below:

4.2.1.1 Effects of Storage Period on Seedling Vigour Index

There was significant difference in storage period effect ($p<0.05$) between the 5th and 10th and also between the 10th day storage and 15th day storage on vigour index. The set of 15DAH, 20DAH, 25DAH and 30DAH did not have significant differences within them but were also significantly different from 10DAH, with 25DAH effect being 22.7% higher than the effect of 10DAH and about 1% higher than the LSD value or cut-off point of 3.5762, as indicated in the Table 4.2.1A on the next page.

Table 4.2.1A Effects of Storage Period on Seedling Vigour Index

DAH	Mean seedling vigour index
0	15.89a
5	12.59a
10	4.93b
15	10.67c
20	10.54c
25	8.54c
30	8.70c

Alpha = 0.05; east Significant Difference = 3.5762; CV = 36.564

Means with the same letter are not significantly different

4.2.1.2 Effects of Storage Container on Vigour Index

Vigour index statistically did not differ on account of seedlings obtained from storage containers ($p>0.05$) with an absolute figure of 0.6338. Numerically, there were differences in vigour index, with Jute sack recording the highest (10.66) and Fertilizer sack recorded the lowest (9.63), but these differences were not significant.

4.2.1.3 Interactive effects of Storage period and Container on Seedling vigour index

Vigour index due to interaction of storage period and containers was statistically significant. the interactions which were significantly influential on seedling vigour index were 0DAH & Fertilizer sack, 0DAH & Jute sack, 5DAH &Basket, 5DAH &Jute sack, 10DAH & Fertilizer sack, 15DAH &Basket, 15DAH & Fertilizer sack, 15DAH & Jute sack, 20DAH & Jute Sack, 20DAH & Fertilizer sack and then 30DAH & Jute sack. Their interactions gave a vigour index above a standard deviation of two as in Table 4.2.1 on the following page.

Table 4.2.1 Interaction effects for Seedling Vigour Index

Level of DAH	Level of STORAGE	Decision Rule SD	Mean	Std Dev.
0	Basket	2	15.90	0.89
0	Fert_Sac	2	13.27	8.59
0	Jute_Sac	2	18.51	2.73
5	Basket	2	9.70	4.32
5	Fert_Sac	2	15.46	7.75
5	Jute_Sac	2	12.62	5.13
10	Basket	2	6.88	1.93
10	Fert_Sac	2	5.87	2.31
10	Jute_Sac	2	2.05	1.58
15	Basket	2	12.06	3.94
15	Fert_Sac	2	8.94	5.35
15	Jute_Sac	2	11.01	2.17
20	Basket	2	10.84	1.05
20	Fert_Sac	2	8.51	5.83
20	Jute_Sac	2	12.26	3.38
25	Basket	2	9.03	1.28
25	Fert_Sac	2	7.85	1.39
25	Jute_Sac	2	8.74	1.16
30	Basket	2	9.18	1.11
30	Fert_Sac	2	7.51	2.11
30	Jute_Sac	2	9.42	2.39

4.2.2 Seedling Shoot Height or Length (cm)

The data on Plant shoot height/ length at 3 months old, ranged between 12.5 cm and 24.5 cm with an overall mean of 17.73cm is influenced by storage period, storage containers and their interactions are presented as follows:

4.2.2.1 Effects of Storage Period on Seedling Stem Height or Length (cm)

Seedling stem height at 3 months old ranged between 12.5 cm and 24.5 cm with an overall mean of 17.73 cm. Storage period had a significant effect ($P< 0.05$) on the Seedling shoot height. Shoot heights were significantly different in seedlings produced from pods stored between 5DAH & 10DAH, then 25DAH and 30DAH, as shown in Table 4.2.2A on the next page.

Table 4.2.2A Effects of Storage Period on Plant Shoot Height/ Length

DAH	Mean seedling shoot length
0	20.56a
5	19.23a
10	16.48b
15	18.33b
20	18.64b
25	17.07b
30	13.78c

Alpha = 0.05; Least Significant Difference = 2.0506; CV = 12.141

Means with the same letter are not significantly different.

4.2.2.2 The Effects of Containers on Seedling Stem Height/ Length (cm)

The shoot/ stem length was non-significantly influenced by containers ($p>0.05$). However it was numerically higher (18.04cm) with the pods stored in Jute sack followed by Basket (17.74 cm) and lowest (17.40cm) in Fertilizer sack for the 30 day storage.

4.2.2.3 Interactive effects of Storage period and Container on Seedling Shoot/ stem Height (cm)

The interactions of storage period and containers were significant on shoot length during the 3 months of storage. Seven of the twenty-one interactions were found to be significant, as their standard deviations were higher thanthe Decision Rule standard deviation of 2.00. The shoot length in 0DAH & Basket was highest (20.56), through to 14.13 for 30DAH & Jute sack, as the lowest numerically, as is indicated in Table 4.2.2B on the following page.

Table 4.2.2B Interaction effects for Seedling Shoot Height

Level of DAH	Level of STORAGE	Decision Rule SD	Mean	Std Dev.
0	BASKET	2	20.57	0.81
0	Fert_Sac	2	19.20	3.77
0	Jute_Sac	2	21.90	1.49
5	BASKET	2	18.17	1.10
5	Fert_Sac	2	20.13	4.92
5	Jute_Sac	2	19.40	2.75
10	BASKET	2	17.73	1.08
10	Fert_Sac	2	16.53	3.62
10	Jute_Sac	2	15.17	1.88
15	BASKET	2	18.10	0.46
15	Fert_Sac	2	17.33	2.06
15	Jute_Sac	2	19.57	0.92
20	BASKET	2	18.47	1.69
20	Fert_Sac	2	18.17	4.26
20	Jute_Sac	2	19.30	0.79
25	BASKET	2	17.40	0.92
25	Fert_Sac	2	17.00	2.17
25	Jute_Sac	2	16.80	0.56
30	BASKET	2	13.77	0.21
30	Fert_Sac	2	13.43	1.12
30	Jute_Sac	2	14.13	1.76

4.2.3 Seedling Stem Girth/ Diameter (cm)

The data on Seedling Stem Girth/ Diameter ranged between 0.28 cm and 0.44cm with an overall mean of 0.37 cm, at 3 months old, as influenced by storage period and containers and their interactions are presented below:

4.2.3.1 Effects of Storage Period on Seedling Stem Girth / Diameter (cm)

Seedling stem diameter ranged between 0.28cm and 0.44cm with an overall mean of 0.37 cm at 3 months old. Storage period had no significant effect ($p>0.05$), on seedling stem diameter, as p-value was 0.0789.

4.2.3.2Effects of Storage Containers on Seedling Stem Girth / Diameter (cm)

The Seedling girth/ diameter was non-significantly influenced by containers ($p>0.05$). However there were numerical differences which was higher (0.37 cm) with seedlings from the pods stored in Basket followed by seedlings from pods stored in Jute sack (0.36cm) and lowest (0.35cm) for seedlings from pods stored in Fertilizer sack.

4.2.3.3 Interactive effects of Storage period and Container on Seedling stem girth/ diameter (cm)

The interactions of storage period and containers were insignificant ($p>0.05$ and standard deviation below 2.00) on seedling stem girth/ diameter. The shoot length in 10DAH & Basket interaction was highest (0.403), through to 0.333 for 0DAH & Jute Fertilizer sack, as the lowest numerically.

4.2.4 Number of Leaves per Plant

The results of the Number of Leaves per Plant ranged between 2.11 and 2.45 with an overall mean of 2.25 leaves per seedling, at 3 months old, as influenced by Storage Period and Storage Container and their interactions are presented as follows:

4.2.4.1 Effects of Storage Period on Leaf Production (Number of Leaves)

The number of leaves produced at 3 month ranged between 2.11 and 2.45 with an overall mean of 2.25 leaves per seedling. There was significant difference in leaf production as a result of storage period effects: the effects of 10DAH on leaf production were significantly different from the other remaining DAH effects, with 0DAH for instance being 3.9% higher than 10DAH, as indicated in Table 4.2.4 on the following page.

Table 4.2.4 Effects of Storage Period on Number of Leaves per Plant

DAH	Mean number of leaves per plant
0	2.42a
5	2.28a
10	2.33b
15	2.26a
20	2.26a
25	2.13a
30	2.10a

Alpha = 0.05; Least Significant Difference = 0.0769; CV = 3.578

Means with the same letter are not significantly different.

4.2.4.2 Effects of Storage Container on Leaf Production (Number of Leaves)

There were no significant differences (P> 0.05) in Number of Leaves per plant, due to the effects of storage containers (Basket, Jute sack and Fertilizer sack).However, Jute sack effect produced the highest number of 2.27, followed by Basket effects of 2.26 leaves per plant, whilst Fertilizer sack effect produced 2.23 leaves per plant.

4.2.4.3 Interactive effects of Storage period and Container on Leaf Production (Number of Leaves)

The effects of interactions were insignificant on Number of Leaves produced per seedling, since none of the interactions recorded a standard deviation above the Decision Point SD of 2.00. The leaves per plant in 0DAH & Basket interactions were highest (2.467), through to 30DAH & Fertilizer sack interaction, which ~~both~~ recorded the lowest figure (2.025) numerically.

4.2.5 Seedling Leaf Area (cm^2)

The results of Leaf Area ranged from 23.04 cm^2 and 275.68 cm^2, with a mean of 141.95 cm^2, at 3 months old, is influenced by Storage Period, Storage Container and their interactions as

explained below:

4.2.5.1 Effects of Storage Period on Seedling Leaf Area (cm^2)

There were significant differences in leaf area as a result of storage period effect ($p<0.05$), specifically 0DAH was significantly different (49% lower) from 10DAH. The remaining DAHs were not significant. The pods stored for 25 days after harvest recorded seedlings with the highest Leaf Area (194.79cm^2) whilst 0DAH recorded the lowest (96.12cm^2), as indicated in Table4.2.5A below:

Table 4.2.5A Effects of Storage Period on Seedling Leaf Area (cm^2)

DAH	Mean Seedling leaf area
0	96.12 a
5	151.73 b
10	99.36 b
15	150.00 b
20	155.97 b
25	194.79 b
30	145.69 b

Alpha = 0.05; Least Significant Difference = 52.883; CV = 39.101

Means with the same letter are not significantly different.

4.2.5.2 Effects of Storage Container on Seedling Leaf Area (cm^2)

There were no significant differences ($P> 0.05$) in Leaf Area resulting from the effects of storage containers (Basket, Jute sack and Fertilizer sack). Values of 148.14 cm^2 for Fertilizer sack, 144.72cm^2 for Jute sack and 133.01cm^2 for Basket effects, were less than the LSD value of 34.62.

4.2.5..3 Interactive effects of Storage Container and storage period on Leaf Area (cm^2)

The interactive effects of storage period and Containers produced significant effects ($p<0.05$) in Leaf Area for all the interactions (each interaction had a standard deviation above the Decision Point of 2.000) of the seedlings as indicated in Table4.2.5B below:

Table 2.4.5B Interactioneffects for Seedling Leaf Area

Level of DAH	Level of STORAGE	Decision Rule SD	Mean	Std Dev.
0	Basket	2	68.48	15.52
0	Fert_Sac	2	125.81	18.42
0	Jute_Sac	2	94.08	28.67
5	Basket	2	113.47	76.35
5	Fert_Sac	2	171.25	116.40
5	Jute_Sac	2	170.48	52.79
10	Basket	2	90.76	65.24
10	Fert_Sac	2	115.44	69.55
10	Jute_Sac	2	91.89	32.59
15	Basket	2	145.52	8.80
15	Fert_Sac	2	130.80	39.55
15	Jute_Sac	2	173.68	17.74
20	Basket	2	152.56	32.49
20	Fert_Sac	2	146.80	81.78
20	Jute_Sac	2	168.56	15.24
25	Basket	2	256.48	17.60
25	Fert_Sac	2	165.87	63.42
25	Jute_Sac	2	162.03	61.96
30	Basket	2	103.79	69.11
30	Fert_Sac	2	180.99	21.05
30	Jute_Sac	2	152.29	82.82

4.2.6 Leaf Petiole Length (cm)

The results of Leaf petiole length ranged from 1.6cm to 5.5cm, with an overall mean of 2.47cm, at age of 3 months. This was influenced by Storage Period, Storage Container and their interactions as presented below:

4.2.6.1 Effects of Storage Period on Seedling Leaf Petiole Length (cm)

Seedling /Plant petiole length in Table 4.2.6showed significant variability in storage period effects ($p<0.05$), with $p = 0.0080$. The 0DAH storage period effect was significantly different

from the set of 5DAH -30DAH, on petiole length. Petiole length of seedlings from pods of 0 days storage was 3.02 cm at 2 months old and produced 19.3% higher effects in respect of the LSD value. It was also 0.49 cm and 16.2% longer than petiole length produced by plants from pods stored for 20 days, which in turn was 1.00cm longer than plants from pods stored for 5 days, as shown in Table4.2.6 below:

Table 4.2.6 Effects of Storage Period on Seedling Leaf Petiole Length (cm)

DAH	Mean leaf petiole length
0	3.02a
5	2.43b
10	2.42b
15	2.23b
20	2.53b
25	2.41b
30	2.24b

Alpha = 0.05; Least Significant Difference = 0.4099; CV = 17.406

Means with the same letter are not significantly different.

4.2.6.2 Effects of Storage Containers on Seedling Leaf Petiole Length (cm)

There was no significant differences recorded for Seedling /Plant petiole length from pods stored in any of the Containers ($p>0.05$), specifically with a p-value of 0.3292. Petiole length of seedlings from pods stored in Jute sack was 0.0857 cm longer than that produced by plants from pods stored in Fertilizer sack,in numerical terms, which in turn was 0.114 cm longer than plants from pods stored in Basket; the two differences being lower than the LSD value of 0.2683 at 5% level of significance.

4.2.6.3 Interactive effect of Storage Periods and Containers on Seedling Leaf Petiole Length (cm)

There was no significant differences recorded for Seedling /Plant petiole length as a result of the interaction effect of seedlings obtained from pods stored in the Containers for the Seven Storage periods ($p>0.05$; Standard Deviation, SD > 2.00), specifically with a p-value of 0.1821.No interaction had a standard deviation figure higher than 2.00. The highest SD value was 1.66 and lowest SD value was 0.12

4.2.7 Stem Nodes per plant

The results of Number of Nodes per Plant at 3 months old, ranged from 4 to 8 nodes per plant, with an average mean of 5.65 are influenced by Storage Period, Storage Container and their interactions are briefly presented below:

4.2.7.1 Effects of Storage Period on Stem Nodes per Plant

The number of nodes per seedling was found to be significantly different, as the p-value of 0.0042 is less than 0.05($P< 0.05$), due to the effects of number of days pods were stored. Effects of 30DAH were significantly different from the effects of 0DAH, 5DAH, 10DAH, 15DAH, 20DAH and 25DAH, within which set there were no significant differences.

Stem nodes per plant, resulting from pods stored for 20 days was 6.56 and 0.67 higher than that produced by plants from pods stored for 10 & 15 days, which in turn was 0.44higher than plants from pods stored for 5,0 & 25 days, as shown in Table 4.2.7 on the page that follows this current page.

Table 4.2.7 Effects of Storage Period on Stem Nodes per Plant

DAH	Mean number of nodes per plant
0	5.44a
5	5.44a
10	5.89a
15	5.89a
20	6.56a
25	5.44a
30	4.89b

Alpha = 0.05; Least Significant Difference = 0.76; CV = 14.21

Means with the same letter are not significantly different.

4.2.7.2 Effects of Storage Container on Stem Nodes per Plant

The number of nodes per seedling resulting from the effects of Containers used for storage (Basket, Jute sack and Fertilizer sack) was found to show insignificant differences,(P> 0.05).

Numerically, stem nodes per plant, was higher in seedlings from pods stored in Jute sack (5.81), and followed by Fertilizer sack (5.62) which was 0.095 higher than that of the Basket storage.

4.2.7. 3 Interactive effects of Storage Periods and Containers on Stem Nodes per Plant

There was no significant effects recorded for Stem Nodes per Seedling, which has been occasioned by interactions of pods stored in the three Containers for the seven storage periods (p>0.05).

4.2.8 Stem Internode Length (cm)

The results of Stem Internode Length at 3 months old, as influenced by Storage Period, Storage Container and their interactions are presented below:

4.2.8.1 Effects of Storage Period on Stem Internode Length (cm)

Seedling internode length of *T. cacao*as a result of the period for which it was stored (seven storage periods) at 5% level of significance was estimated. Results of the effects of storage period (DAH), was insignificant ($p = 0.2209 > 0.05$) and there were thus no significant differences in petiole length as a result of storage period.

4.2.8.2Effects of Storage Container on Stem Internode Length (cm)

Plant internode length of *T. cacao* due to storage containeris shown in Table 4.2.8. Plants from pods stored in Basket, Jute sack and Fertilizer sack produced significantly different internode lengths. The effects of Basket storage were significantly different ($p < 0.05$) from the effects of fertilizer storage (a difference of 0.28cm; which is 38.5% higher than the LSD value of 0.2029) but 23.5% longer than the internode length produced by fertilizer sack -stored pod seedlings. Jute sack effect was also different from Fert. Sack, as shown in Table 4.2.8 below:

Table 4.2.8 Effects of Storage Containers on Stem Internode Length

Storage container	**Mean stem internode length**
Basket	1.48a
Jute sack	1.37a
Fertilizer sack	1.19b

Alpha = 0.05; Least Significant Difference = 0.20; CV = 24.140

Means with the same letter are not significantly different.

4.2.8.3 Interactive effects of Storage Periods and Containers on Stem Internode Length

There was no significant differences ($p>0.05$) recorded for Stem Internode Length, as a result of interaction effects of pods stored in the Containers and the Storage periods, with a specific p-value of 0.053 and standard deviation less than Decision Rule SD of 2.00.

4.2.9 Plant Canopy Spread (cm)

The results of Plant/ Seedling Canopy Spread at 3 months old, ranged from 7cm to 28cm and averaged 21.02cm, as influenced by Storage Period, Storage Container and their interactions are presented below:

4.2.9.1 Effects of Storage Period on Seedling Canopy spread (cm)

There was significant difference in Seedling canopy spread of plants (3 months old) from pods stored for the various storage periods ($P<0.05$). Effects of 30 day storage were significantly different (25.7% and 20.9% respectively lower and narrower) from those of 0 day storage and 20 day storage, as presented in Table 4. 2.9 Below: Plants from pods from the other storage periods did not produce differences in canopy spread.

Table 4.2.9 Effects of Storage Period on Seedling Canopy spread

DAH	Mean seedling canopy spread
0	23.67a
5	18.91b
10	22.11a
15	21.09b
20	22.78b
25	19.72b
30	18.83c

Alpha = 0.05; Least Significant Difference = 3.5214; CV = 17.586

Means with the same letter are not significantly different.

4.2.9.2 Effects of Storage Container on Seedling Canopy spread (cm)

Plants from pods stored in Basket, Jute sack and Fertilizer sack did not produce significant

differences ($p>0.05$) incanopy spread. Numerically, plants produced from Basket stored pods produced the higher canopy spread of 22.12cm, followed by Jute sack (21.13 cm) and lowest was Fertilizer sack (19.80 cm).

4.2.9.3 Interactive effects of Storage Periods and Containers on Seedling Canopy spread (cm)

Interactions effects of seedling canopy spread was insignificant ($p>0.05$), with a specific p-value of 0.9097 and standard deviation of less than 2.000. (Appendix 5)

4.2.10 Seedling Root/ Hypocotyl Length (cm)

The results of Seedling Root/ Hypocotyl Length at three (3) months old, as influenced by Storage Period and Storage Container and their interactions are presented as follows:

4.2.10.1 Effects of Storage Periods on Seedling Root/ Hypocotyls Length (cm)

Root length was significantly influenced ($p< 0.05$) by storage periods. Root length of seedlings resulting from 15DAH, 25DAH and 30DAH were significantly different from the mean of seedlings for 0DAH, 5DAH 10DAH and 20DAH. Root length of seedlings produced from 0DAH were thus 23% longer than that of 25DAH seedlings, whilst 10DAH seedlings being 19.4% longer than that of 25DAH. It was observed that numerically, pods stored for zero days of storage produced seedlings with longest root length of 9.79 cm whilst the shortest root length was recorded by seedlings from pods stored for 25DAH (7.71cm), as indicated in Table 4.2.10 on the next page.

Table 4.2.10 Effects of Storage Period on Seedling Root/ Hypocotyls Length (cm)

DAH	Mean seedling root length
0	9.79a
5	9.01a
10	9.21a
15	8.57b
20	9.17a
25	7.71b
30	8.10b

Alpha = 0.05; Least Significant Difference = 0.9854; CV = 11.759

Means with the same letter are not significantly different.

4.2.10.2 Effects of Storage Containers on Seedling Root/ Hypocotyls Length (cm)

Root length was non-significantly influenced ($p > 0.05$) by containers throughout the storage period of 0 up to 30 days storage. It was however numerically higher with plants from pods stored in Basket (8.89cm) followed by plants from pods stored in Jute sack (8.86cm) and lowest in Fertilizer sack storage (8.64cm).

4.2.10.3 Interactive effects of Storage Periods and Containers on Seedling Root Length (cm)

There were no significant interactions ($p>0.05$) recorded for Seedling Root/ Hypocotyl length, since the p- value of 0.232 was higher than 0.05 whilst all interactions standard deviation was lower than the 2.00.

4.2.11 Seedling Dry Weight (Total Dry Matter- g/seedling)

The results of Seedling Dry Weight (Total Dry Matter) at 3 months old, as influenced by Storage Period and Storage Container and their interactions, ranged between 1.71g/ seedling and

13.93g/seedling, with an overall mean of 3.712g/seedling, as presented below:

4.2.11.1Effects of Storage Periods on Seedling Dry Weight (Total Dry Matter) (g/seedling)

Pods stored for 15 DAH produced plants with the highest TDM of 4.90g/seedling, whilst pods stored for 0DAH produced plants with the lowest TDM of 2.90g/seedling. TDM was insignificantly influenced ($p > 0.05$) by storage periods.

4.2.11.2 Effects of Storage containers on Seedling Dry Weight (Total Dry Matter) (g/seedling)

The influence of containers on TDM (dry weight) of seedlings was significant ($p<0.05$) at 5% level of significance, as in Basket and Fertilizer sack storage effects. The effects of Basket storage thus resulted in 41.9% accumulation of dry matter above that of Fertilizer sack storage as indicated in Table 4.2.11 below:

Table 4.2.11 Effects of Storage Period on Seedling Dry Weight (Total Dry Matter)

Storage Container	Mean seedling dry weight
Basket	4.37a
Jute sack	3.69a
Fertilizer sack	3.079b

Alpha = 0.05; Least Significant Difference = 0.9787; CV = 42.269

Means with the same letter are not significantly different.

4.2.11.3 Interactive effects of Storage Periods and Containers on Seedling Dry Weight (TDM)

The interactions between Storage periods and storage containers were insignificant ($p>0.05$) on seedling dry weight. The p- value of was 0.434 whilst none of the interactions had a standard deviation above 2.00.

4.3 CORRELATION ANALYSIS & RELATIONSHIPS AMONG THE 16 VARIABLES

For purposes of this study, determination of degree of association or strength of a relationship is based on Bruce Ratner's DM STAT-1 series (see Appendix 2), and is as follows: correlation coefficient value of 0 indicates no linear relationship; +1 indicates a perfect positive linear relationship: as one variable increases in its values, the other variable also increases in its values via an exact linear rule; -1 indicates a perfect negative linear relationship: as one variable increases in its values, the other variable decreases in its values via an exact linear rule. Values between 0 and 0.3 (0 and -0.3) indicate a weak positive (negative) linear relationship via a shaky linear rule; Values between 0.3 and 0.7 (-0.3 and -0.7) indicate a moderate positive (negative) linear relationship via a fuzzy-firm linear rule whilst values between 0.7 and 1.0 (-0.7 and -1.0) indicate a strong positive (negative) linear relationship via a firm linear rule.

4. 3.1 Correlation between the Speed of germination and the other 15 variables

Three types of relationships were identified according to the degree of association through the correlation coefficient values as follows:

a).A positive and strong correlation relationship (r = 0.7-1.0). This involved speed of germination, which increased as seedling vigour also increased. The relationship was highly significant, as $p < 0.05$(i.e. 0.0001).

b). A positive and weak correlation relationship (0 to 0.3) of speed of germination with the other variables as Leaf Area, time taken to end germination, germination percentage, the number of nodes per seedling, seedling internode length, number of leaves per plant, seedling height/ length, seedling canopy spread, Hypocotyl or root length and then Total Dry Matter. These associations were not significantly different from zero ($P>0.05$)

c).A negative and weak correlation relationship (0 – 0.3) with the other variables. This type of relationship existed between speed of germination and seedling stem girth, time taken to start germination, time taken to drop cotyledons and petiole length. With the exception of petiole length relationship with speed of germination, which was found to be statistically significant ($p<0.05$), the other relationships in this class of association were statistically insignificant, ($p>0.05$).

4.3.2 Correlation between the Seedling Vigour Index and the other variables

Two types of relationships were identified according to the degree of association as follows:

1. Same direction but weak correlation association ($r = 0 – 0.3$). The relationship of this nature occurred between vigour index and other variables as seedling plant height, time taken to start germination, time taken from start to end of germination, Leaf Area, the number of leaves per plant, seedling stem girth, germination percentage, the number of nodes per seedling, seedling canopy spread, seedling internode length, Hypocotyl or root length and then Total Dry Matter. All relationships involved in this category were statistically non-significant ($p>0.05$) and therefore statistically speaking, did not exist.

2. A negative and weak correlation relationship (r falls from 0 – 0.3). This type of association existed between seedling vigour index the time taken to drop cotyledons and then petiole length, but statistically did not exist.

4.3.3 Correlation between the Seedling Leaf Area and the other variables

As was the previous case of vigour index, two types of relationships were identified as follows:

1. Same direction but weak correlation association with variables as seedling stem girth, time taken to start germination, leaf petiole length, seedling internode length, number of leaves per

plant, and the number of stem nodes per plant, seedling canopy spread, Hypocotyl or root length and then Total Dry Matter.

However, these relationships were not statistically significant. ($p>0.05$), hence no relationship existed.

2. Opposite direction but weak correlation association. As seedling leaf area increases, each of the other variables such as plant height, the time taken to end germination, time taken to drop cotyledons, germination percentage and then petiole length, decrease. The above notwithstanding, no statistically significant linear relationships existed between Leaf area and these other variables

4.3.4 Correlation between the Number of Leaves per plant and the other variables

Three types of relations hips were identified according to the degree of association as follows:

a).A positive (same direction) and moderate correlation relationship ($r = 0.3$ to 0.7).

Typical examples are found in the relationships between Number of leaves and plant height and also with Hypocotyl or root length. These relationships were statistically significant, as $P< 0.05$ and therefore linear relationship existed.

b). A positive but weak correlation relationship. Relationship of this nature occurred between the number of leaves per plant and: time taken to drop cotyledons, germination percentage, seedling internode length, seedling stem girth, time taken to start germination, number of stem nodes, seedling canopy spread, petiole length and then Total Dry Matter. All these relationships were not statistically significant and were therefore not real.

c).A negative and weak association between number of leaves per plant and time taken to end germination. The relationship was statistically significant ($p<0.05$) and therefore really existed.

4.3.5 Correlation between the Seedling stem girth and the other variables

Three types of associations were identified according to the degree of association as follows:

a).A positive and moderate (r =0.3 to 0.7) relationship between stem girth relationship with time taken to start germination which was statistically significant ($p < 0.05$)

b).A positive but weak correlation relationship with the other variables. This occurred between the number of seedling stem girth and: plant height, petiole length, number of stem nodes, seedling canopy spread, internode length, Hypocotyl or root length and then Total Dry but all these relationships were not statistically significant.

c).A negative (opposite direction) and weak association. Examples under this correlation relationship existed between stem girth and time taken to end germination, time taken to drop cotyledons and then percentage germination. It was only the time taken to shed cotyledons that had a significant relationship with seedling stem girth; the other two were not statistically significant.

4.3.6 Correlation between Seedling Height and the other variables

As in the case of the other analysis, three types of relationships were identified according to the degree of association as follows:

1).Same direction but moderate correlation association occurred between plant height and germination percentage. The relationship involving germination percentage was significantly different but not same with plant height.

2. Same direction but weak correlation association with the other variables. This type of relationship occurred with the other variables such as the seedling canopy spread, stem nodes per plant and then Hypocotyl or root length. These relationships were not statistically significant.

3. Opposite direction but weak correlation association. This type of association existed between plant height and the time taken to start germination, the time taken to end germination, time taken to drop cotyledons, petiole length, stem internode length and then Total Dry Matter. All the relationships were not statistically significant ($p > 0.05$) except the association involving the time taken to start germination.

4.3.7 Correlation between Time taken to start germination and the other variables

Three types of relationships were identified according to the degree of association as follows:

1).Same direction but weak correlation association with the other variables. Typical relationships with time to start germination included nodes per plant, seedling canopy spread, petiole length, stem internode length, Hypocotyl or root length and then Total Dry Matter. Two (relationships involving Stem internode length and Total Dry Matter) out of the six relationships in this category are statistically significant, as each have ($p < 0.05$).

2. A moderate and inverse correlation association with the other variables. This type of association existed between the time taken to start germination and percentage germination. This association was highly statistically significant.

3. A weak and inverse correlation association with the other variables. This type of association existed between the time taken to start germination and: time taken to end germination and then time taken to drop cotyledons. These two relationships are not statistically significant ($p > 0.05$).

4.3.8 Correlation between Time taken to end germination and the other variables

Two types of relationships were identified and include:

1).Same direction but weak correlation association. Examples of these relationships with time to end germination included time taken to shed cotyledons, germination percentage and then

petiole length. The relationship involving petiole length was statistically significant ($p<0.05$) but the rest were not.

2. A weak and inverse correlation association with the other variables. This type of association existed between the time taken to end germination and the number of nodes per plant, seedling canopy spread, internode length, Hypocotyl length and Total Dry Matter. Apart from internode length, none of the other variables had significant relationships.

4.3.9 Correlation between Time taken to drop Cotyledons and the other variables

An opposite direction and weak correlation association with the other variables was found. Examples of relationships here included germination percentage, stem nodes per seedling, seedling canopy spread, petiole length, internode length, Hypocotyl length and then Total Dry Matter, with Time to drop cotyledons. The relationship involving total dry matter was the only one statistically significant ($p<0.05$).

4.3.10 Correlation between germination percentage and the other variables

Two types of relationships were identified according to the degree of association as follows:

1).Same direction but weak correlation association. Typical relationship with germination percentage was that involving seedling Hypocotyl length. None of the relationships in this category was significant.

2. A weak and inverse correlation association with the other variables. This type of association existed between germination percentage and the number of nodes per plant, seedling canopy spread, petiole length, internode length and then Total Dry Matter.

None of these relationships was significant and were therefore the same as zero (0)

4.3.11 Correlation between Number of Nodes per seedling and the other remaining variables

As in the case of some other analysis, two types of relationships were identified:

1).A positive direction but moderate association with the other variables. Example of this relationship was found between Number of Nodes per seedling and seedling canopy spread. This relationship was statistically found to be highly significant ($p = 0.0005$).

2. Same direction but weak association of Number of nodes per plant with the other variables as Stem Internode Length, the Hypocotyl or root length and then Total Dry Matter. All of these relationships were insignificant ($p > 0.05$).

4.3.12 Correlation between Seedling Canopy spread and the other variables

Two types of relationships were identified according to the degree of association:

1).A positive but moderate relationship. Typical relationships with seedling canopy spread involved variables such as internode length and Hypocotyl length. Relationship with Hypocotyl length was significant but that of stem internode length was not significant.

2). A positive and weak relationship, which involve seedling canopy spread with variables as petiole length and then Total Dry Matter. These two variables, statistically speaking, do not have linear associations with the seedling canopy spread.

4.3.13 Correlation between petiole length and the other variables

1).Same direction but weak association with the other variables. A typical relationship involved seedling Hypocotyl length. This relationship is however, not significant ($p>0.05$)

2. A weak and inverse association with the other variables. This type of association existed between petiole length and stem internode length and then Total Dry Matter.These relationships were not significant ($p>0.05$)

4.3.14 Correlation between Stem Internode Length and the other variables

Two types of relationships were identified according to the degree of association:

1). A positive but moderate relationship. A typical relationship with stem internode length involved stem length and Hypocotyl length. This relationship was highly statistically significant.

2). A positive but weak relationship. Typical relationship with stem internode length involved variable Total Dry Matter. The relationship was statistically non-significant.

4.3.15 Correlation between Hypocotyl/ Root Length and Total Dry Matter

The only relationship found here is one between Hypocotyl Length and Total Dry Matter. The association was however, non-significant ($p>0.05$)

4.4 EFFECTS OF STORAGE CONDITIONS ON THE 16 PARAMETERS OF THE EXPERIMENT

The extent to which the prevailing storage conditions (temperature and relative humidity) within the storage containers during the storage period had on the parameters of the experiment have been analyzed by correlating the storage conditions (Temperature range of 27.1°C -32°C and Relative Humidity range of 82% - 93.6%)with the quantities (means) obtained in respect of the 16 variables or parameters of the experiment. Determination of whether the correlation coefficient (r) and its associated probability value (p) resulted in a significant impact or not, on the variables was assessed with a benchmark or cut-off point of p (0.05). (see Appendix 3)

Details of the variable-by-variable analysis are outlined, with the Correlation Table subsequently attached, as below:

4.4.1Correlation between the time taken to start to germination and storage conditions (Relative Humidity and Temperature)

The relationship existing between the time taken to start germination and the two storage conditions of relative humidity and temperature were found to move in the same direction (r = 0.3308 - 0.4076). However, those associations were statistically insignificant, as p >0.05(0.3652 – 0.4686) and therefore did not have a significant impact on the time taken to start germination.

4.4.2 Correlation between the time taken from start to end of germination and storage conditions (Relative Humidity and Temperature)

The relationship existing between the time taken from start to end of germination and the two storage conditions of relative humidity and temperature were found to move in the same direction(r = 0.2646 to 0.4115) but statistically insignificant, as p >0.05 (0.3591 – 0.5663) and therefore did not have a significant impact on the time taken by seedlings to end germination.

4.4.3 Correlation between the time taken to shed cotyledons and storage conditions (Relative Humidity and Temperature)

The relationship existing between the time taken from start to end of germination and the two storage conditions of relative humidity and temperature were found to move in the opposite direction (r = -0.4313-0.0.4308). However, those associations were statistically insignificant, as p >0.05 (0.3346 – 0.4537) and storage conditions thereforedid not have a significant impact on the time taken by seedlings to shed the cotyledons.

4.4.4 Correlation between germination percentage and storage conditions (Relative Humidity and Temperature)

The relationship existing between germination percentage and the two storage conditions of relative humidity and temperature were found to move in the opposite direction (r = -0.4572 – 0.5144) but were statistically insignificant, as p >0.05 (0.2376 – 0.3024) and therefore the recorded storage conditions did not have a significant impact on germination percentage.

4.4.5 Correlation between speed of germination and storage conditions (Relative Humidity and Temperature)

The relationship existing between speed of germination and the two storage conditions of relative humidity and temperature were found to move in the opposite direction (r = 0.5597 - 0.6018) but were statistically insignificant, as p >0.05 (0.1528 – 0.1914) hence no impact on speed of germination.

4.4.6 Correlation between seedling stem girth and storage conditions (Relative Humidity and Temperature)

The relationship existing between seedling stem girth and the two storage conditions of relative humidity and temperature were found to move in the same direction (r = 0.3860 – 0.4584) and were statistically insignificant, as p >0.05 (0.3009- 0.3924) had no impact on seedling stem girth.

4.4.7 Correlation between seedling vigour index and storage conditions (Relative Humidity and Temperature)

The relationship existing between seedling vigour index and the two storage conditions of relative humidity and temperature were found to move in the opposite direction(r = 0.7094-0.7566) However, with the exception of the impact of relative humidity within basket storage

which had significant effects on seedling vigour index, the other associations were statistically insignificant, as p >0.05 (0.0585- 0.0742).

4.4.8 Correlation between seedling height and storage conditions (Relative Humidity and Temperature)

The relationship existing between plant height and the two storage conditions of relative humidity and temperature had some aspects moving in the same direction and others were found to move in the opposite direction (r = 0.4875 – 0.5671) but were statistically insignificant, as p >0.05 (0.1843- 0.2671).

4.4.9 Correlation between seedling canopy spread and storage conditions (Relative Humidity and Temperature)

The relationship existing between seedling canopy spread and the two storage conditions of relative humidity and temperature were found to move in the opposite direction (r = -0.5467 – 0.6010) but those associations were statistically insignificant, as p >0.05 (0.1535- 0.2041), thusdid not have any impact.

4.4.10 Correlation between Leaf Area and storage conditions (Relative Humidity and Temperature)

The relationship existing between leaf area and the two storage conditions of relative humidity and temperature were found to move in the same direction(r =0.4834 – 0.5840) but were insignificant, (p >0.05)because P ranged from 0.1686 to 0.2718 and therefore did not have any impact.

4.4.11 Correlation between Hypocotyl (Root) Length and storage conditions (Relative Humidity and Temperature)

The relationship existing between Hypocotyl length and the two storage conditions of relative humidity and temperature were found to move in the opposite direction(r = 0.4991 – 0.6445) and were statistically insignificant, as p >0.05 (0.1167 – 0.2541), thusdid not have a significant impact on Hypocotyl length

4.4.12 Correlation between Total Dry Matter and storage conditions (Relative Humidity and Temperature)

The relationship existing between dry matter and the two storage conditions of relative humidity and temperature were found to move in the same direction (r = 0.1568 – 0.2326) but were statistically insignificant, as p >0.05 (0.0.6158 – 0.7371), thus had no impact on Dry Matter.

4.4.13 Correlation between Number of Leaves per plant and storage conditions (Relative Humidity and Temperature)

The relationship existing between Number of Leaves per plant and the two storage conditions of relative humidity and temperature were found to move in the opposite direction (r = 0.5416 – 0.6906) and were statistically insignificant, as p >0.05 (0.0858 -0.2093) and therefore did not have impact.

4.4.14 Correlation between Petiole Length and storage conditions (Relative Humidity and Temperature)

The relationship existing between Petiole Length and the two storage conditions of relative humidity and temperature were found to move in the opposite direction (r = 0.8868 – 0.9277)but those associations were statistically significant, (p < 0.05) and therefore had an impact on petiole length.

4.4.15 Correlation between Stem Internode Length and storage conditions (Relative Humidity and Temperature)

The relationship existing between Stem Internode Length and the two storage conditions of relative humidity and temperature were found to move in the opposite direction ($r = 0.1036 – 0.1758$) but were statistically insignificant ($p > 0.05$). P ranged from 0.7042 to 0.8251.

4.4.16 Correlation between Stem Nodes per plant and storage conditions (Relative Humidity and Temperature)

The relationship existing between stem nodes per plant and the two storage conditions of relative humidity and temperature were found to move in the same direction ($r = 0.5631 – 0.6228$) but were statistically insignificant, ($p > 0.05$).

CHAPTER FIVE.

5.0 DISCUSSION

Cocoa belongs to *Sterculaceae* (and currently reclassified as M*alvaceae*) family and is a major cash crop of the world.

The Ghanaian economy continues to receive great foreign exchange earnings from this commercial crop known as "The Golden Pod". The quality of seed or bean is highest when the pod completes structural and functional development and attains physiological maturity on the plant itself. Seed viability maintenance especially under storage conditions and their field performance has gained importance in the present context. Since cocoa planting is season bound, with seed gardens and pods being unavailable to all farmers at time of raising nurseries, the storage of pods has become inevitable for the farmer, the seed producer(SPU, COCOBOD) and the breeder as the case may be.

The required quantity of seed samples were sown and observations on time (days) to start germination, time (days) to complete germination, germination percentage, speed of germination, time (days) to drop cotyledons, internode length, number of nodes per plant, number of leaves per plant, Leaf Area, petiole length, root length, shoot length, vigour index, seedling dry weight were made and the results of the study are discussed in this chapter.

5.1 General Discussion on the Influence/ Effects of Storage Period on the variables.

5.1.1 Germination variables

The observed significant differences in the time taken to start seedling emergence/ germination among the seven (7) storage periods revealed that 0DAH and 5DAH took the shortest time to start germination. The effect of respiration that may have reduced the bean size was not pronounced and therefore did not reduce the surface area of the beans. The large surface area may have provided higher imbibition rate to increase the metabolic activity within the bean. This reduction in time associated with 0DAH and 5DAH, possibly due to larger seed surface area, has been reported in the various plant species like *Acacia biotic* (Mandal *et al*, 1997), pegion pea, (Vanangamudi*et al*,1988), cowpea (Sighn and Rai,1988) and Sorghum (Cortes, 1988). The increased time to start germination under the 10DAH -30DAH could be the result of frequent respiration and dehydration through evaporation of the pods as a result of constant exposure to high temperature.

The time taken to end germination from 0DAH to 20DAH were relatively shorter compared to 25DAH to 30DAH which took a relatively longer time to complete germination. Thought the 25DAH to 30DAH took the longest time to complete germination, 25DAH took a very short time to start germination. This could be due to greater food reserves at the early part of the storage, which was catalyzed and metabolized to provide the needed energy to quicken the germination process. However with continued storage, the stored food reserves in the beans could have been used up through respiration in storage and therefore during germination could not be readily available by the seedling to emerge.

Time to drop cotyledons by the seedlings was not significantly different irrespective of the storage period or the container. Thus, the food reserves within the cotyledons which is supposed to be used by growing seedling were not affected by the degree of storage (DAH) and the container within which such pods (for that matter the seeds) were stored. This provided the energy needs of the growing seedlings for some time, till the reserves were used up, and switched the supplementary food reserves produced by the growing seedlings which become photosynthetic.

The 0DAH – 10DAH storage beans recorded higher percentage germination than 15DAH-30DAH stored beans. The lower percentage and speed of germination in the 15DAH -30DAH stored beans could be due to increase in metabolic activity which leads to increased respiration rate, which in turn leads to more utilization of food reserves, Meena *et al.*, (1998). It could also be due to the inhibitory effect of mucilage which delayed germination and subsequently led to the death of some of the beans in the soil as earlier observed by Ashiru (1970). The higher and faster rate of germination (speed of germination) generally obtained in respect of 0DAH - 10DAH could be attributed to the available food reserves utilized by the growing seedling as compared with the 15DAH -30DAH which do not have ready access to the stored food reserves due to exhaustion of food reserves or specific metabolic substrate necessary for early stage of germination before digestion of food reserves begins. Similar observations were made by Ndubuaku and Oyekanmi (2000). Another possibility is the loss of enzyme activity, yet dead seeds sometimes contain some active enzymes, (Stone 1957a).

5.1.2 Growth & Morphological Variables/ Parameters

Cocoa seedling growth parameters studied in this experiment varied significantly ($p>0.05$) due to pod storage period. Seedling vigour was highest with 0DAH -5DAH, and then fell drastically in respect of 10DAH. It then increased with 15DAH and 20DAH and subsequently declined in seedlings from pods stored for 25DAH and 30DAH. The slight increase within the first five days storage, followed by a dramatic decrease in vigour for the 10DAH storage and an equally sharp rise of vigour in the 15DAH and 20DAH except 25DAH and 30DAH(Table4.2.1A.). The decrease in vigour over the 10DAH storage period and subsequently 25DAH and 30DAH elicits the probable influence of the cumulative respiratory effects under storage conditions and pathogenic degenerative effect of the fungi associated, as the pods had started to rot. The loss of vigour during storage has been hypothesized to depletion theory of food reserves by Oxley (1950). The decrease also confirms the fact that, loss of vigour is inherently inexorable and occurs faster and earlier than viability in seeds, Gastel *et al.*, (1996). In this experiment, the storage temperature and relative humidity of 27.1 -32°C and 82%- 93.6% respectively did not interact to reduce seedling vigour, just as with germination percentage, speed of germination and other variables. These findings were thus contrary to Kwoseh (1994) and Cantliffe (1998) which indicate that high moisture and relative humidity in storage interact to reduce germination and seed vigour and will decrease faster at high temperatures. This could be due to the fact that these conditions had direct effect on the cocoa pods but not the seed within the pods.

Seedlings from 0DAH and 5DAH storage produced taller plants /stem heights (Table 4.2.2), bigger stems; nodes per plant (Table 2.4.7); more leaves per plant (Table 2.4.2) with longer petiole length (Table 2.4.6), internode length but with a generally an inverse and relatively smaller leaf sizes, which got bigger with increasing storage period. A similar trend was also

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exhibited by seedlings from the various storage periods in respect of seedling canopy spread, which were higher for 0DAH, then low for 5DAH, then higher again 10DAH-20DAH and subsequently declined. These situation in respect of these experimental variables irrespective of the storage conditions of 27.1 -32°C andrelative humidity of 82%- 93.6%. This could be attributed to high seedling vigour observed (Table 2.4.1A) and the presence of cotyledons which could have served as sources of food reserves for active growth, which then resulted in more photosynthetic activities. This finding is similar to a report by Cantliffe (1998) that vigorous seeds and seedlings germinated rapidly and produced normal seedlings within a wide range of environmental conditions.

These results could also mean that plants/ seedlings raised from pods stored for 0DAH -10DAH channeled the photosynthates towards height, girth, nodes, internode and petiole and leaf development. The utilization of photosynthates for structural development and influenced by the environment was reported by Gardner *et al*., (1985). The higher leaf area for the longer storage periods seedlings could be the result of compensation for the reduction in leaf area s. Leaves may tend to enlarge, elongate and produce more chlorophyll per unit area to compensate for the loss in numbers so as to improve photosynthetic activities. (Ndubuaku et al, 2000). These findings were also similar to those observed by Ahenkora and Halm, (1977) and were not impacted by the storage conditions of 27.1°C -32°C andrelative humidity of 82%- 93.6%.

The general reduction of stem diameter/girth, internode length, height, Leaf number per plant, leaf area, petiole length, nodes per plant for the longer storage periods as a result of reduced photosynthetic rates reduced vigour and slowed growth. The little metabolite produced is usually used for maintenance respiration more than vegetative growth.

The root or hypocotyl length for the storage period (Table 4.2.10) was generally longer for the storage periods 0DAH -20DAH, albeit in a reducing order. The production of longer root length for the early days after storage could be a physiological effort to raise the developing plumule or plant to a height that it could get direct solar radiation from the sun. Root/Hypocotyl length decrease with storage period in cocoa pods is similar to the observation in seedlings of *Pinusthunbergii* and *P. rigida*(Kim*et al*, 1978)

Length of storage did not affect significantly dry matter accumulation in seedlings from the pods stored for the respective periods. However, just as with the other variables, the first few days had higher numerical values than the long storage pods. The higher accumulation for the 0DAH to 15DAH could be possibly due to the initial early and active germination and growth of the seedlings for such storage periods, which helped to start early accumulation of dry matter and it agrees with the observations made in *Eucalyptus citriodora (*Aguiar and Nakane, 1983) and in *Pisumsativum* (Kant, 1986). This might have happened as a result of the higher leaf chlorophyll found to be associated with leaves from seedlings obtained from pods but not affected by storage temperatureof 27.1°C -32°C and relative humidity of 82%- 93.6%.

5.2 General Discussion on theInfluence/ Effects of Storage Containers on the variables.

5.2.1 Germination parameters of the experiment in respect of storage containers.

Cocoa seed exhibited epigeal type of germination (Opoku-Ameyaw *et al,* 2010*);* Gardner *et al*., 1985). Time taken to start germination by seeds of cocoa was high but did not differ ($p < 0.05$) among the three storage containers. This could be due to the fact that at physiological maturity seeds have high germination potential (Gardner *et al*., 1985) irrespective of 27.1oC -32°C storage

temperature and 82%- 93.6% relative humidity. No statistical differences in germination meant that stored cocoa pods/ seed will germinate well at the storage condition of temperature within 27.1°C -32°C and relative humidity of 25-93.6%; irrespective of any of the three (3) storage containers used. This means that any degenerative processes, such as metabolic activities which often cause degradation of seed quality including germination (Neergaard, 1979) may not have caused any affected.

However, the time taken from start to end of germination was found to be significantly influenced by the type of storage container used. Specifically, the Jute sack storage significantly influenced time taken to end germination of seedling when compared with Fertilizer sack. Thus, Jute sack ended germination in a relatively shorter period of 12.5 days which was significantly different from the 15.04 days taken by pods from Fertilizer sack storage to end germination. Basket and Jute sack or Basket and Fertilizer sack storage did not result in any significant differences in time taken to complete germination. This could be due to the insufficient supply of air (oxygen) for normal respiration of pods, which could have resulted in anaerobic respiration that had alcohol as its end product. The alcohols generated from such a metabolic activity could have hampered enzymatic action necessary to catalyze the germination process, hence the longer period of 15.04 days taken to end germination by beans from pods stored in Fertilizer sack.

Relative to cotyledon drop, containment did not produce any significant differences, though, numerically, Basket storage effects resulted in a relatively shorter period to drop cotyledons. This, as explained in the previous section could be due to the depletion of food reserves in the cotyledons, making them redundant and occasioned their shedding by the seedlings, which was irrespective of the storage container used and the storage conditions of temperature and relative humidity (27.1°C -32°C and 82%- 93.6%.)

Basket, Jute sack and Fertilizer sack storage did not result in any significant differences in percentage germination and speed of germination, though basket storage resulted in numerically higher germination percentage and speed of germination. The storage conditions within these three containers did not have any effect on germination, which run contrary to Kwoseh (1994), presumably because it was cocoa pod and not direct seed that were stored. The composition of the internal environment of the pod was not affected by the storage environment within the containers (Olympio and Kuma, 2009).

Secondly, favourable soil moisture content regime provided as prescribed by ISTA (2007) might have contributed to the uniform germination percentages and germination speed from the three containers and good seedlings development observed during the experiment. It must be emphasized that though the difference among the three storage containers were significant, numerically, 80% of desirable effects on germination related variables occurred with Basket storage, whilst 20% occurred with Jute sack storage, with none on Fertilizer sack storage.

5.2.2 Morphological parameters of the experiment in respect of storage containers

The eleven (11) seedling growth and morphological parameters studied in this experiment varied insignificantly ($p>0.05$) due to storage containers, with the exception of stem internode length and Seedling dry weight/ dry matter. They were also not significantly impacted by storage conditions of temperature and relative humidity of 27.1oC -32°C and 82%- 93.6% respectively.

Though not significantly different, 54.5% of desirable effects on eleven (11) morphological related variables occurred with Basket storage, 36.4% with Jute sack storage whilst 9.1% occurred with Fertilizer sack storage. Basket storage effect was numerically highest with better

performance for variables/parameters as seedling stem girth, number of leaves per plant, stem internode length, seedling canopy spread, Root length and seedling dry weight or dry matter. Jute sack had highest positive effects and showed superior performance in respect of variables as seedling height, petiole length, number of nodes per plant and seedling vigour; whilst Fertilizer sack positive storage effect had to do with only leaf surface area, which as explained in the section on storage period effect, could be due to seedlings from such storage adapting physiologically to expand and elongate in order to be able to have optimum access to solar radiation for photosynthesis (Ndubuaku, 2000). What these mean is that seedlings from Basket-stored pods channeled greater part of the photosynthate to stem growth (lateral and vertical growth of the stem), leaf production and its spread, root development and dry matter accumulation; whilst seedlings produced from Jute sack-stored pods diverted most of its photosynthate towards seedling elongation, leaf petiole elongation and general seedling vigour.

The only two variables which showed significant differences in terms of storage container effects were both related to Basket storage producing the desired effect. This could be due to the non-accumulation of deleterious products of respiratory activities of pods within the storage container (Basket) andhence the slightly superior performance of seedlings from basket stored pods as against the Jute sack and Fertilizer sack.

5.3 Discussion of Interaction effects (storage period x containers) on Experimental Variables.

Generally, five (5) out of the sixteen (16) experimental parameters/ variables representing 31.25% of the experimental variables recorded significant interactions between storage period and storage containers and these happened independent of storage conditions of temperature and

relative humidity of 27.1°C -32°C and 82%- 93.6%. Thus, more than half of the total experimental variables did not record significant interactions.

But specifically, 40% (2 out of 5) of germination related variables recorded significant interactions and these are the time taken by the seed to start germination and time taken to end germination whilst 27.3% (3 out of 11 parameters) of the growth and morphological related variables also recorded significant interactions.

The growth parameters which were found to have had significant interactions included seedling vigour index,stem height or length and seedling Leaf Area.

On the two parameters concerning germination, 2 out of the 21 interactions regarding time to start germination were significant; and included 20DAH & Fertilizer sack interactions and 30DAH & Jute sack. Though storage effect on time to start germination was insignificant, its (Fertilizer sack and Jute sack) interaction with storage period was significant at 20DAH and 30DAH respectively. The interaction resulted in the reduction of the time to start germination from an individual Fertilizer sack effect of 11.76 days to 11.67 and that of Jute sack from 11.54days to 11.33 days, thus projecting the two standard deviations above 2.0. Hence the interactions reduced the number of days that seed from pods stored in Fertilizer sack and Jute sack would have taken to germinate. The reverse was the case involving storage period effects, which took lesser time to start germinations as compared with the interaction effects.

Regarding the time taken from start to end of germination (Table 4.1.2) 13 out of the 21 individual interactions (61.9%) were significant and thus had an overall effect reducing the time taken to end germination by the seedlings. As in the case of the time taken to start germination, in seven (7) of the interactions (0DAH & Basket; 10DAH& Jute sack; 20DAH & basket; 20DAH & Fertilizer sack; 25DAH & Jute sack; 30DAH &Jute sack and 30DAH& Fertilizer

sack) the interactions resulted in relatively lesser time to end germination as compared with both individual effects of storage periods (0DAH – 30DAH) and storage containers. In the remaining six (6) interactions, there was a reduction in time taken to end germination relative to either storage period or storage container.

Among the interactions between storage period (0DAH -30DAH) and container (Basket, Jute sack & Fertilizer sack) on seedling vigour, 13 out of 21 interactions were also found to be superior in recording significantly higher (11.01 – 18.5) vigour: six (6) interactions had vigour means being higher than both of the individual means in respect of storage period and storage containers. The remaining seven (7) interactions showed superior performance on seedling vigour with either storage period or storage container but not both. Therefore, it is evident from the results that storing cocoa pods in the three containers for a period up to 30 days, particularly early days storage (0-10) in Jute sack and Fertilizer, lead to responses that help build vigour in the resulting seedlings.(Table 4.2.1). This is different when individual factors are considered; resulting in basket storage producing superior performance of seedling vigour.

Focusing on Plant height, there were seven (7) out of 21 interactions (33.3%) which were found to be significant in producing superior performance in terms of plant height. In two of the seven significant interactions (5DAH &Jute sack and 5DAH &Fertilizer sack), plant height resulting from these interactions (19.4 cm and 20.13cm) were both higher than plant heights obtained from the separate effects of the seven storage periods and the three storage containers used(19.23cm and 18.0cm) respectively. The other five (5) significant interactions were again superior over either storage period or storage container. These significant interactions were more pronounced with Fertilizer sack containment and somehow Jute sack containment; which runs contrary to what prevailed when the two separate container effects were analyzed, which had

basket storage producing superior plant height. (Table 4.2. 6). As explained earlier the combined beneficial influence of 5DAH and Jute &Fertilizer sacks on plant height clearly indicates the protection against detrimental physiological and biochemical changes. Therefore, it is evident from the results that seed/seedlings from container storage differ in response to how long they were stored in the containers and the type of containers used and these results are in conformity with Patil (2000) in chicken pea.

Leaf Area was found to be 100% significantly influenced by storage period and container interactions. In order words, all the 21 interactions in relation to leaf area were all significant. In six (6) out of these 21 interactions (5DAH & Jute sack; 5DAH &Fertilizer sack; 15DAH & Jute sack; 20DAH & Jute sack; 30DAH & Jute sack and then 30DAH & Fertilizer sack), the interactions resulted in larger leaf area above the separate leaf area figures resulting from the storage period or the storage containers. The remaining interactions were either superior in respect of storage container or storage period for the leaf area values. The interactions therefore lead to larger leaf area of the seedlings which resulted in greater exposure to solar radiation for photosynthate production, seedling vigour and rapid dry matter accumulation.

Generally, the storage period and container interactions helped maintain viability in respect of these five (5) variables for the entire storage period of 30 days, particularly when stored in Jute and Fertilizer sacks, which was not so with the separate factors of storage period and storage containers, where viability in respect of the sixteen variables were generally not maintained throughout the 30 day storage period.

However, the superior performance of the variables emanating from the interactions was not realized in respect of the eleven remaining variables: three germination –related variables

(germination percentage, speed of germination and time to drop cotyledons) and then eight growth/ morphological parameters (Stem girth, Leaves/plant, Leaf petiole length, Nodes/plant, Seedling Canopy spread, Root or Hypocotyl length, Stem internode length and Seedling dry weight or Dry Matter), as no significant interactions occurred, hence the separate or individual factors (storage period and storage container) effects were separately assessed, as in the previous sections.(5.1.1, 5.1.2, 5.2, 5.2.1, 5.2.2)

CHAPTER SIX

6.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

6.1 SUMMARY

The results generated from this storage experiment entitled "Determination of postharvest pod storage on seed viability of Cocoa" conducted from November 2012 to March 2013 are summarized below:

The experiment consisted of two factors: storage period and storage containers which were replicated three times. The storage periods were (0DAH, 5DAH, 10DAH, 15DAH, 20DAH 25DAH and 30DAH) whilst the storage containers were 3 (Basket, Jute sack and Fertilizer sack). Cocoa pods were obtained and stored in the three containers for the storage period of 0-30 Days-After- Harvest (DAH).

Pod samples were then taken at 5daily intervals for seed sowing and ascertaining the seed viability parameters *viz*., time to start germination, time to end germination, germination percentage, speed of germination, time taken to shed cotyledons, seedling stem girth, stem internode length, number of nodes per plant, seedling canopy spread, number of leaves per plant, leaf petiole length, Leaf area, root length and shoot length, vigour index, seedling dry weight/ dry matter.

Among the storage period, generally, 0DAH – 15DAH resulted in a relatively shorter time to start germination, to end germination, higher germination percentage and speed of germination whilst time taken to shed cotyledons were not significantly different and thus average or uniform time was used to shed cotyledons irrespective of 0DAH-30DAH.

In the case of the growth/ morphological parameters, superior performance in respect of variables such as seedling vigour, shoot length/height, nodes per plant, leaves per plant, petiole length, internode length, except leaf area occurred with 0DAH -5DAH. However, root length and Seedling Dry weight / Dry Matter had superior performance with the period 0DAH -20DAH. It must be stressed that with all these dynamics, the storage conditions of temperature and relative humidity did not affect the results obtained.

Among the storage containers, however, results obtained were generally insignificant in respect of the 16 parameter of the study. Specifically, out of the 5 germination related data, only the time taken to end germination was significantly different between Basket and Fertilizer sack, with basket and jute sack taken a relative shorter time to end germination. Out of the eleven (11) growth and morphological parameters, stem internode length and seedling dry weight or dry matter were significantly influenced.

Among the interactions between storage period and storage containers, five (5) out of the 16 (31.25%) parameters recorded significant interactions. With the specifics, two out of five (40%) parameters of germination- related: time to start germination and time to end germination were found to have had significant interactions. Reference to the growth and morphological variables/parameters, three (3) out of eleven (27.3%) recorded significant interactions and these included seedling vigour index, stem/ shoot length and Leaf Area.

These interactions resulted in ~~superior~~ performance of these variables or parameters than the individual factors of storage period and storage containers. The early storage period and mostly Fertilizer sack and then Jute sack produced such superior performance, as against individual Basket storage which produced superior performance for these parameters, whose occurrence

was independent on the storage conditions of 27.1°C -32°C storage temperature and 82%-93.6% relative humidity

6.2 CONCLUSION

Cocoa seeds from pods harvested from the Cocoa Stations or Seed Gardens under the control of the Seed Production unit of COCOBOD are hybrids. These are produced and harvested under well-established standard practices to retain viability within acceptable periods of time, if well-handled after harvest. The identified practices for pre-harvesting included preparation of a harvesting schedule for fortnightly harvesting, acquisition of proper harvesting tools (harvesting hooks, cutlasses or secateurs), harvesting in the morning (up to 10 am), and post harvest practices involve protection of pods against sun shine to reduce with field heat effect, reducing damage to pod tissues using harvesting hooks with bags to avoid injuring the pod tissue and pre-disposing pods to rot organisms and then gathering of pods to a central shady collection point, for sale to farmers of pods. Harvesters use to remove matured and ripened pods from the trees, in such a manner. The results indicated of the experiment that freshly harvested cocoa pods and seeds extracted from yellow-ripe physiologically matured pods are good for planting. Seed from pods stored from 0DAH -15DAH generally produced superior performance in most of the parameters measured, and therefore has been considered as the optimum period for which pods can be stored for maximum viability.

The traditional storage containers (i.e. Basket, Jute sack and Fertilizer sack), could be used to store pods without any significant differences in performance of the parameters.

The growth and morphological properties of the seedlings, showed best performance, as far as the three containers are concerned. These best performances were however restricted to pod storage from 0DAH -20DAH.

6.3 RECOMMENDATION

1. Farmers should continue carting and storing cocoa pods in in their traditional storage containers of Basket, Jute sack and Fertilizer.

2. The hybrid pods meant for propagation ideally should not be stored beyond 15 days after harvest (15DAH), but preferably up to 10Days –After-Harvest.

3. To meet this ideal storage period of 10DAH, farmers should get their poly bags filled with top soil before looking for pods to sow seed.

6.3.1 Suggestion for Possible/Further Research

Postharvest physiological and biochemical changes that occur within cocoa pods and seed during storage are likely factors affecting cocoa seed viability and variability within each variable (up and down continuously with increasing storage period) and the extent to which that happens should be investigated and thoroughly discussed.

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APPENDIX 1

Table 4.1 ANOVA TABLE for Time taken to start Germination

Source	DF	ANOVA SS	Mean Square	F Value	Pr> F
REPS	2	0.4126984	0.2063492	0.31	0.7377
DAH	6	193.3015873	32.2169312	47.87	<.0001
STORAGE	2	2.8888889	1.4444444	2.15	0.1302
DAH*STORAGE	12	20.2222222	1.6851852	2.50	0.0148
Model	22	216.8253968	9.8556999	14.64	<.0001
Error	40	26.9206349	0.6730159		
Corrected Total	62	243.7460317			

R-Square = 0.889555; CV = 7.128780; Root MSE = 0.820375; Mean = 11.50794

Table 4.2 ANOVA TABLE for Time taken to end Germination

Source	DF	ANOVA SS	Mean Square	F Value	Pr> F
REPS	2	8.6031746	4.3015873	0.54	0.5883
DAH	6	156.2222222	26.0370370	3.25	0.0106
STORAGE	2	68.2222222	34.1111111	4.26	0.0210
DAH*STORAGE	12	295.1111111	24.5925926	3.07	0.0038
Model	22	528.1587302	24.0072150	3.00	0.0012
Error	40	320.0634921	8.0015873		
Corrected Total	62	848.2222222			

R-Square =0.622666; CV = 20.36670; Root MSE =2.828708; Mean = 13.88889

Table 4.3 ANOVA TABLE for Time taken to drop Cotyledons

Source	DF	ANOVA SS	Mean Square	F Value	Pr> F
REPS	2	7.52380952	3.76190476	2.98	0.0621
DAH	6	7.49206349	1.24867725	0.99	0.4454
STORAGE	2	2.38095238	1.19047619	0.94	0.3978
DAH*STORAGE	12	5.84126984	0.48677249	0.39	0.9610
Model	22	23.23809524	1.05627706	0.84	0.6661
Error	40	50.47619048	1.26190476		
Corrected Total	62	73.71428571			

R-Square = 0.315245; CV = 8.134570; Root MSE = 1.123345; Mean = 13.80952

Table 4.4 ANOVA TABLE for Seedling Germination Percentage

Source	DF	ANOVA SS	Mean Square	F Value	Pr> F
REPS	2	0.35431145	0.17715573	1.45	0.2477
DAH	6	6.45003584	1.07500597	8.77	<.0001
STORAGE	2	0.32604212	0.16302106	1.33	0.2759
DAH*STORAGE	12	3.40271687	0.28355974	2.31	0.0235
Model	22	10.53310629	0.47877756	3.91	<.0001
Error	40	4.90262660	0.12256566		
Corrected Total	62	15.43573289			

R-Square =0.682385; C V = 8.871223; Root MSE =0.350094; Mean = 3.946398

Table 4.5 ANOVA TABLE for Speed of Germination

Source	DF	ANOVA SS	Mean Square	F Value	Pr> F
REPS	2	0.62905079	0.31452540	0.59	0.5572
DAH	6	20.59371111	3.43228519	6.48	<.0001
STORAGE	2	0.58031746	0.29015873	0.55	0.5827
DAH*STORAGE	12	6.45846032	0.53820503	1.02	0.4535
Model	22	28.26153968	1.28461544	2.42	0.0073
Error	40	21.19854921	0.52996373		
Corrected Total	62	49.46008889			

R-Square = 0.571401; CV = 36.07861; Root MSE = 0.727986; Mean = 2.017778

Table 4.6 ANOVA TABLE for Seedling Vigour Index

Source	DF	ANOVA SS	Mean Square	F Value	Pr> F
REPS	2	57.4761556	28.7380778	2.04	0.1434
DAH	6	640.6143937	106.7690656	7.58	<.0001
STORAGE	2	12.9976603	6.4988302	0.46	0.6338
DAH*STORAGE	12	162.3408730	13.5284061	0.96	0.0458
Model	22	873.429083	39.701322	2.82	0.0022
Error	40	563.586244	14.089656		
Corrected Total	62	1437.015327			

R-Square =0.607808; CV= 36.56405; Root MSE=3.753619; Mean = 10.26587

Table 4.7 ANOVA TABLE for Plant Shoot Height/ Length

Source	DF	ANOVA SS	Mean Square	F Value	Pr> F
REPS	2	24.8926984	12.4463492	2.69	0.0804
DAH	6	261.6485714	43.6080952	9.41	<.0001
STORAGE	2	4.2831746	2.1415873	0.46	0.6331
DAH*STORAGE	12	33.5657143	2.7971429	0.60	0.0459
Model	22	324.3901587	14.7450072	3.18	0.0007
Error	40	185.2939683	4.6323492		
Corrected Total	62	509.6841270			

R-Square= 0.636453; CV =12.14132; Root MSE = 2.152289; Mean =17.72698

Table 4.8 ANOVA TABLE forSeedling Stem Girth/ Diameter

Source	DF	ANOVA SS	Mean Square	F Value	Pr> F
REPS	2	0.00889841	0.00444921	3.66	0.0346
DAH	6	0.01506032	0.00251005	2.07	0.0789
STORAGE	2	0.00245079	0.00122540	1.01	0.3736
DAH*STORAGE	12	0.00854921	0.00071243	0.59	0.8397
Model	22	0.03495873	0.00158903	1.31	0.2250
Error	40	0.04856825	0.00121421		
Corrected Total	62	0.08352698			

R-Square =0.418532; C V = 9.523923; Root MSE= 0.034845; Mean = 0.365873

Table 4.9 ANOVA TABLE forNumber of Leaves per Plant

Source	DF	ANOVA SS	Mean Square	F Value	Pr> F
REPS	2	0.00432151	0.00216076	0.33	0.7194
DAH	6	0.66176905	0.11029484	16.95	<.0001
STORAGE	2	0.01323854	0.00661927	1.02	0.3708
DAH*STORAGE	12	0.15107760	0.01258980	1.93	0.0591
Model	22	0.83040670	0.03774576	5.80	<.0001
Error	40	0.26032247	0.00650806		
Corrected Total	62	1.09072917			

R-Square = 0.761332; C V= 3.578320; Root MSE =0.080673; Mean = 2.254482

Table 4.10 ANOVA TABLE for Seedling Leaf Area

Source	DF	ANOVA SS	Mean Square	F Value	Pr> F
REPS	2	4573.06450	2286.53225	0.74	0.4825
DAH	6	63697.11049	10616.18508	3.45	0.0077
STORAGE	2	2644.83547	1322.41773	0.43	0.6540
DAH*STORAGE	12	39953.45298	3329.45441	1.08	0.4013
Model	22	110868.4634	5039.4756	1.64	0.0867
Error	40	123237.8990	3080.9475		
Corrected Total	62	234106.3624			

R-Square= 0.473582; CV=39.10178; Root MSE= 55.50628; Mean = 141.9533

Table 4.11 ANOVA TABLE for Leaf Petiole Length

Source	DF	ANOVA SS	Mean Square	F Value	Pr> F
REPS	2	2.48380952	1.24190476	6.71	0.0031
DAH	6	3.80634921	0.63439153	3.43	0.0080
STORAGE	2	0.42285714	0.21142857	1.14	0.3292
DAH*STORAGE	12	3.23269841	0.26939153	1.46	0.1821
Model	22	9.94571429	0.45207792	2.44	0.0069
Error	40	7.40285714	0.18507143		
Corrected Total	62	17.34857143			

R-Square=0.573287; C V = 17.40691; Root MSE=0.430199; Mean = 2.471429

Table 4.12 ANOVA TABLE for Stem Nodes per Plant

Source	DF	ANOVA SS	Mean Square	F Value	Pr> F
REPS	2	11.55555556	5.77777778	8.97	0.0006
DAH	6	14.76190476	2.46031746	3.82	0.0042
STORAGE	2	0.88888889	0.44444444	0.69	0.5076
DAH*STORAGE	12	9.33333333	0.77777778	1.21	0.3120
Model	22	36.53968254	1.66089466	2.58	0.0045
Error	40	25.77777778	0.64444444		
Corrected Total	62	62.31746032			

R-Square= 0.586347; C V= 14.20638; Root MSE =0.802773; Mean = 5.650794

Table 4.13 ANOVA TABLE for Stem Internode Length

Source	DF	ANOVA SS	Mean Square	F Value	Pr> F
REPS	2	1.04666667	0.52333333	4.94	0.0120
DAH	6	0.91936508	0.15322751	1.45	0.2209
STORAGE	2	0.84666667	0.42333333	4.00	0.0261
DAH*STORAGE	12	2.51111111	0.20925926	1.98	0.0533
Model	22	5.32380952	0.24199134	2.29	0.0113
Error	40	4.23333333	0.10583333		
Corrected Total	62	9.55714286			

R-Square =0.557050; CV= 24.14038; Root MSE = 0.325320; Mean =1.3476

Table 4.14 ANOVA TABLE for Plant Canopy Spread

Source	DF	ANOVA SS	Mean Square	F Value	Pr> F
REPS	2	358.2222222	179.1111111	13.11	<.0001
DAH	6	199.8263492	33.3043915	2.44	0.0420
STORAGE	2	56.8688889	28.4344444	2.08	0.1381
DAH*STORAGE	12	80.0155556	6.6679630	0.49	0.9097
Model	22	694.933016	31.587864	2.31	0.0104
Error	40	546.431111	13.660778		
Corrected Total	62	1241.364127			

R-Square = 0.559814 CV = 17.58694; Root MSE = 3.696049; Mean = 21.01587

Table 4.15 ANOVA TABLE forSeedling Root/ Hypocotyl Length

Source	DF	ANOVA SS	Mean Square	F Value	Pr> F
REPS	2	7.20012381	3.60006190	3.37	0.0446
DAH	6	27.45149841	4.57524974	4.28	0.0020
STORAGE	2	0.79309524	0.39654762	0.37	0.6926
DAH*STORAGE	12	17.29561587	1.44130132	1.35	0.2316
Model	22	52.74033333	2.39728788	2.24	0.0130
Error	40	42.79160952	1.06979024		
Corrected Total	62	95.53194286			

R-Square=0.552070 C V= 11.75921; Root MSE =1.034307; Mean = 8.795714

Table 4.16 ANOVA TABLE forSeedling Dry Weight (Total Dry Matter, TDM)

Source	DF	ANOVA SS	Mean Square	F Value	Pr> F
REPS	2	16.63215556	8.31607778	3.38	0.0441
DAH	6	20.78085397	3.46347566	1.41	0.2360
STORAGE	2	17.54735556	8.77367778	3.56	0.0377
DAH*STORAGE	12	30.68755556	2.55729630	1.04	0.4345
Model	22	85.64792060	3.89308730	1.58	0.1022
Error	40	98.48151110	2.46203780		
Corrected Total	62	184.1294317			

R-Square = 0.465151 C V = 42.26997 Root MSE =1.569088; Mean=3.712063

APPENDIX 2

Pearson Correlation Coefficients, N = 63
Prob> |r| under H0: Rho=0

	GERM_SPEED	VIGOUR	LEAF_AREA	LEAVES	GIRTH	PLTHT	START_GERM	END_GERM
GERM_SPEED	1.00000	0.91264	0.20616	0.08064	-0.03035	0.05100	-0.05209	0.12872
<.0001 0.1050	0.5298	0.8134	0.6914	0.6852	0.3147			
VIGOUR	0.91264	1.00000	0.20884	0.20179	0.14324	0.07869	0.01352	0.03360
<.0001	0.1005	0.1127	0.2627	0.5398	0.9162	0.7937		
LEAF_AREA	0.20616	0.20884	1.00000	0.03878	0.18785	-0.07580	0.15593	-0.11516
	0.1050	0.1005		0.7629	0.1404	0.5549	0.2223	0.3688
LEAVES	0.08064	0.20179	0.03878	1.00000	0.09590	0.44574	0.09559	-0.28549
	0.5298	0.1127	0.7629		0.4547	0.0003	0.4561	0.0233
GIRTH	-0.03035	0.14324	0.18785	0.09590	1.00000	0.18407	0.34398	-0.18283
	0.8134	0.2627	0.1404	0.4547		0.1487	0.0058	0.1515
PLTHT	0.05100	0.07869	-0.07580	0.44574	0.18407	1.00000	-0.26290	-0.15606
	0.6914	0.5398	0.5549	0.0003	0.1487		0.0374	0.2219
START_GERM	-0.05209	0.01352	0.15593	0.09559	0.34398	-0.26290	1.00000	-0.23850
	0.6852	0.9162	0.2223	0.4561	0.0058	0.0374		0.0598
END_GERM	0.12872	0.03360	-0.11516	-0.28549	-0.18283	-0.15606	-0.23850	1.00000
	0.3147	0.7937	0.3688	0.0233	0.1515	0.2219	0.0598	
COTYLEDON	-0.09153	-0.16871	-0.05889	0.17382	-0.29400	-0.01432	-0.15596	0.01066
	0.4756	0.1862	0.6466	0.1731	0.0193	0.9113	0.2223	0.9339
GERM_PCT	0.19425	0.19156	-0.05622	0.13824	-0.04600	0.48881	-0.64127	0.17827
	0.1271	0.1326	0.6617	0.2799	0.7204	<.0001	<.0001	0.1621
Nodes seedling	0.18194	0.18894	0.04976	0.05401	0.07416	0.10433	0.22860	-0.10197
	0.1535	0.1381	0.6985	0.6742	0.5635	0.4158	0.0715	0.4265
Seedling canopy	0.06432	0.14478	0.05866	0.04659	0.16893	0.00683	0.13724	-0.11908
	0.6165	0.2576	0.6479	0.7169	0.1857	0.9576	0.2835	0.3526
Petiole length	-0.26201	-0.17273	-0.10252	0.05119	0.07856	-0.11232	0.11555	0.26874
	0.0380	0.1758	0.4240	0.6903	0.5405	0.3808	0.3671	0.0332
Internode length	0.15839	0.22232	0.14310	0.13793	0.17167	-0.14616	0.26885	-0.25397
	0.2150	0.0799	0.2632	0.2810	0.1785	0.2530	0.0331	0.0446
MSL_HYPOCOT	0.15704	0.24284	0.11206	0.36471	0.16656	0.16032	0.13301	-0.17157
	0.2190	0.0552	0.3819	0.0033	0.1920	0.2094	0.2987	0.1788
DRY_MATTER	0.09633	0.16487	0.03480	0.05656	0.10356	-0.08403	0.26554	-0.23600
	0.4526	0.1966	0.7865	0.6597	0.4193	0.5126	0.0354	0.0626

CORRELATION TABLE (CONTINUED)

	COTYLEDON	GERM_PCT	Nodes_ seedling	seedling_ canopy	Petiole_ length	Internode_ length	MSL_ HYPOCOT	DRY_ MATTER
GERM_SPEED	-0.09153 0.4756	0.19425 0.1271	0.18194 0.1535	0.06432 0.6165	-0.26201 0.0380	0.15839 0.2150	0.15704 0.2190	0.09633 0.4526
VIGOUR	-0.16871 0.1862	0.19156 0.1326	0.18894 0.1381	0.14478 0.2576	-0.17273 0.1758	0.22232 0.0799	0.24284 0.0552	0.16487 0.1966
LEAF_AREA	-0.05889 0.6466	-0.05622 0.6617	0.04976 0.6985	0.05866 0.6479	-0.10252 0.4240	0.14310 0.2632	0.11206 0.3819	0.03480 0.7865
LEAVES	0.17382 0.1731	0.13824 0.2799	0.05401 0.6742	0.04659 0.7169	0.05119 0.6903	0.13793 0.2810	0.36471 0.0033	0.05656 0.6597
GIRTH	-0.29400 0.0193	-0.04600 0.7204	0.07416 0.5635	0.16893 0.1857	0.07856 0.5405	0.17167 0.1785	0.16656 0.1920	0.10356 0.4193
PLTHT	-0.01432 0.9113	0.48881 <.0001	0.10433 0.4158	0.00683 0.9576	-0.11232 0.3808	-0.14616 0.2530	0.16032 0.2094	-0.08403 0.5126
START_GERM	-0.15596 0.2223	-0.64127 <.0001	0.22860 0.0715	0.13724 0.2835	0.11555 0.3671	0.26885 0.0331	0.13301 0.2987	0.26554 0.0354
END_GERM	0.01066 0.9339	0.17827 0.1621	-0.10197 0.4265	-0.11908 0.3526	0.26874 0.0332	-0.25397 0.0446	-0.17157 0.1788	-0.23600 0.0626
COTYLEDON	1.00000	-0.02675 0.8351	-0.00281 0.9826	-0.18615 0.1441	-0.11865 0.3544	-0.08396 0.5130	-0.16518 0.1958	-0.25094 0.0473
GERM_PCT	-0.02675 0.8351	1.00000	-0.10167 0.4279	-0.04669 0.7163	-0.09625 0.4530	-0.09175 0.4745	0.12814 0.3169	-0.16439 0.1979
Nodes seedling	-0.00281 0.9826	-0.10167 0.4279	1.00000	0.42551 0.0005	0.07516 0.5582	0.17815 0.1624	0.21327 0.0933	0.04626 0.7188
Seedling canopy	-0.18615 0.1441	-0.04669 0.7163	0.42551 0.0005	1.00000	0.20769 0.1024	0.33375 0.0075	0.31711 0.0113	0.13815 0.2803
Petiole length	-0.11865 0.3544	-0.09625 0.4530	0.07516 0.5582	0.20769 0.1024	1.00000	-0.04848 0.7059	0.15778 0.2168	-0.11881 0.3537
Internode length	-0.08396 0.5130	-0.09175 0.4745	0.17815 0.1624	0.33375 0.0075	-0.04848 0.7059	1.00000	0.35295 0.0045	0.13602 0.2878
MSL_HYPOCOT	-0.16518 0.1958	0.12814 0.3169	0.21327 0.0933	0.31711 0.0113	0.15778 0.2168	0.35295 0.0045	1.00000	0.09945 0.4381
DRY_MATTER	-0.25094 0.0473	-0.16439 0.1979	0.04626 0.7188	0.13815 0.2803	-0.11881 0.3537	0.13602 0.2878	0.09945 0.4381	1.00000

APPENDIX 3

STORAGE CONDITION (RELATIVE HUMIDITY & TEMPERATURE) ON STUDY VARIABLES

	BASKET_RH	BASKET_TE	FERT_RH	FERT_TEMP	JUTE_RH	JUTE_TEMP
START_GER	0.3711	0.3308	0.4067	0.4006	0.3863	0.3573
	0.4125	*0.4686*	*0.3652*	*0.3732*	*0.3921*	*0.4314*
END_GERM	0.4115	0.3869	0.3207	0.2646	0.3547	0.3375
	0.3591	*0.3912*	*0.4831*	*0.5663*	*0.4350*	*0.4591*
COTYLEDON	-0.4308	-0.3918	-0.4302	-0.3413	-0.4153	-0.3833
	0.3346	*0.3847*	*0.3354*	*0.4537*	*0.3541*	*0.3960*
GERM_PERC	-0.4727	-0.4572	-0.4930	-0.5144	-0.4766	-0.4713
	0.2841	*0.3024*	*0.2609*	*0.2376*	*0.2795*	*0.2857*
SPEED_GER	-0.6002	-0.5597	-0.6018	-0.5896	-0.5923	-0.5680
	0.1542	*0.1914*	*0.1528*	*0.1636*	*0.1611*	*0.1834*
STEM_GIRT	0.4060	0.3860	0.4584	0.4389	0.4355	0.4037
	0.3662	*0.3924*	*0.3009*	*0.3245*	*0.3287*	*0.3692*
VIGOUR	-0.7566	-0.7189	-0.7360	-0.7094	-0.7376	-0.7095
	0.0490	*0.0687*	*0.0593*	*0.0742*	*0.0585*	*0.0741*
PLT HT	0.5471	0.5224	-0.4875	-0.5423	-0.5671	-0.5223
	0.2081	*0.2201*	*0.2671*	*0.2085*	*0.1843*	*0.2291*
CANOPY SPR.	-0.6002	-0.6010	-0.5467	-0.5711	-0.5772	-0.5894
	0.1542	*0.1535*	*0.2041*	*0.1805*	*0.1749*	*0.1637*
LEAF AREA	0.5840	0.5717	0.5441	0.4834	0.5587	0.5527
	0.1686	*0.1799*	*0.2068*	*0.2718*	*0.1923*	*0.1982*
HYPOCOTYL	-0.6465	-0.5917	-0.5767	-0.4991	-0.6030	-0.5648
	0.1167	*0.1617*	*0.1753*	*0.2541*	*0.1518*	*0.1865*
DRY MATTER	0.1568	0.1840	0.2326	0.2118	0.1952	0.2026
	0.7371	*0.6928*	*0.6158*	*0.6484*	*0.6748*	*0.6631*
NUMBER_LE	-0.6906	-0.6514	-0.6203	-0.5416	-0.6485	-0.6143
	0.0858	*0.1129*	*0.1373*	*0.2093*	*0.1151*	*0.1422*
PETIOLE_L	-0.9277	-0.9063	-0.9168	-0.8868	-0.9257	-0.9039
	0.0026	*0.0049*	*0.0037*	*0.0078*	*0.0028*	*0.0052*
INTERNODE	-0.1442	-0.1770	-0.1036	-0.1756	-0.1318	-0.1758
	0.7577	*0.7042*	*0.8251*	*0.7064*	*0.7782*	*0.7062*
STEM_NODE	0.5963	0.5631	0.6228	0.5892	0.6180	0.5843
	0.1576	*0.1881*	*0.1352*	*0.1639*	*0.1391*	*0.1683*

APPENDIX 4

WEATHER DATA DURING THE THREE (3) MONTH STUDY

DATE	NOVEMBER 2012				DECEMBER 2012				JANUARY 2013			
	TEMPERATURE		RH	RAINFALL	TEMPERATURE		RH	RAINFALL	TEMPERATURE		RH	RAINFALL
	MAX©	MIN©	%	MM	MAX	MIN	%	MM	MAX	MIN	%	MM
1	33.0	23.2	84	0.0	33.0	23.2	84	0.0	33.5	15.5	37	0.0
2	33.0	23.3	84	0.0	33.0	23.2	80	34.5	33.5	17.2	38	0.0
3	33.0	23.2	81	0.0	30.0	21.3	87	0.0	33.0	15.2	44	0.0
4	32.8	23.2	79	0.0	30.8	23.3	84	0.0	32.8	16.5	49	0.0
5	33.0	23.2	80	0.0	31.0	23.2	88	0.0	33.5	17.0	47	0.0
6	33.5	23.2	87	0.0	32.0	23.2	92	0.0	33.5	13.5	40	0.0
7	32.8	23.0	81	0.0	32.0	22.6	84	0.0	33.5	13.5	48	0.0
8	32.8	22.6	77	0.0	31.5	23.2	92	0.0	36.0	16.5	60	0.0
9	32.0	22.6	77	0.0	33.0	23.2	83	0.0	33.0	22.2	80	0.0
10	32.8	23.2	77	4.0	31.5	23.3	84	14.5	35.0	22.3	83	0.0
11	32.5	21.6	82	0.0	31.8	21.2	84	11.0	35.0	23.2	85	0.0
12	32.0	22.3	78	0.0	31.0	22.3	92	0.0	35.0	22.6	73	0.0
13	32.8	23.2	78	0.0	32.5	20.6	76	0.0	35.5	21.8	83	0.0
14	32.8	23.1	77	0.0	32.0	22.6	88	0.0	35.0	22.2	80	0.0
15	32.5	22.6	84	0.0	31.5	23.2	84	0.0	35.0	22.6	87	0.0
16	35.0	23.2	81	0.0	31.5	23.3	84	0.0	35.0	18.6	87	0.0
17	33.5	23.2	87	0.0	32.0	23.3	86	0.0	35.0	18.6	87	0.0
18	33.0	23.3	82	0.0	32.0	22.6	90	0.0	33.5	18.5	78	0.0
19	34.0	23.2	86	24.0	31.5	23.2	86	0.0	36.0	18.0	91	0.0
20	32.5	21.6	82	0.0	31.5	18.5	53	0.0	33.5	21.3	85	0.0
21	32.0	22.3	92	1.0	31.8	19.2	87	0.0	35.0	23.6	77	0.0
22	30.8	22.2	87	0.0	32.8	22.2	92	0.0	35.0	23.6	77	0.0
23	32.0	23.2	79	0.0	33.0	22.3	86	0.0	35.0	23.6	77	2.0
24	32.8	23.3	77	11.5	33.0	23.2	82	0.0	35.0	23.6	86	0.0
25	32.5	21.2	96	0.0	32.5	23.6	85	0.0	34.0	232	86	0.0
26	31.8	22.2	88	0.0	32.5	23.6	84	0.0	34.0	23.3	86	0.0
27	32.5	21.8	82	0.0	33.0	23.2	85	0.0	34.0	23.6	75	0.0
28	32.5	22.3	86	0.0	32.8	21.8	88	0.0	34.0	23.6	17	0.0
29	32.5	23.2	81	0.0	34.0	17.6	83	0.0	35.3	14.2	45	0.0
30	33.0	23.2	77	0.0	32.0	18.6	71	0.0	36.0	17.5	59	0.0
31	-	-	-	-	32.5	17.5	34	0.0	36.0	18.5	77	0.0
Total	**981.7**	**682.9**	**2469**	**40.5**	**995.0**	**683.3**	**2258**	**60.**	**1070.1**	**612.5**	**2124**	**2.0**
Mean	**32.7**	**22.8**	**82**		**32.1**	**22.0**	**83**		**34.5**	**19.7**	**69**	

APPENDIX 5: NON-SIGNIFICANT EFFECTS OF STORAGE ON VARIABLES

Effects of storage period on Time to start of germination

Storage Container	Mean
Basket	3.35869 a
Jute sack	3.42805 a
Fertilizer sack	3.40048 a

Alpha = 0.05; Least Significant Difference = 0.0718; CV= 3.388124

Means with the same letter are not significantly different

Effects of storage period on Time taken to drop cotyledon

DAH	Mean
0	3.78308 a
5	3.79610 a
10	3.70868 a
15	3.72322 a
20	3.67855 a
25	3.66131 a
30	3.73618 a

Alpha = 0.05; Least Significant Difference = 0.1437CV = 4.046834

Means with the same letter are not significantly different

Effects of storage container on Time taken to drop Cotyledons

Storage Container	Mean
Basket	3.69482 a
Jute sack	3.72686 a
Fert.sack	3.75852 a

Alpha = 0.05; Least Significant Difference = 0.0941CV = 4.046834

Means with the same letter are not significantly different

Interaction Table for Time to drop Cotyledon

Level of DAH	Level of STORAGE	Decision Rule SD	Mean	StdDev
0	BASKET	2	3.79562314	0.19966845
0	Fert_Sac	2	3.79862173	0.07556082
0	Jute_Sac	2	3.75499667	0.00000000
5	BASKET	2	3.79562314	0.19966845
5	Fert_Sac	2	3.83924820	0.20064877
5	Jute_Sac	2	3.75342024	0.13324681
10	BASKET	2	3.61763144	0.13825403
10	Fert_Sac	2	3.70979519	0.07829127
10	Jute_Sac	2	3.79862173	0.07556082
15	BASKET	2	3.66283292	0.15963229
15	Fert_Sac	2	3.79862173	0.07556082
15	Jute_Sac	2	3.70821876	0.15385209
20	BASKET	2	3.66459370	0.07829127
20	Fert_Sac	2	3.70821876	0.15385209
20	Jute_Sac	2	3.66283292	0.15963229
25	BASKET	2	3.61763144	0.13825403
25	Fert_Sac	2	3.74866088	0.26704393
25	Jute_Sac	2	3.61763144	0.13825403
30	BASKET	2	3.70979519	0.07829127

30	Fert_Sac	2	3.70645798	0.20797561
30	Jute_Sac	2	3.79228593	0.27901809

Effects of Storage containers on *Germination* percentage

Storage Container	Mean
Basket	4.0475 a
Jute sack	3.9058 a
Fert sack	3.8859 a

Alpha = 0.05; Least Significant Difference =0.2184C V = 8.871223

Means with the same letter are not significantly different

Interaction Table of Percentage Germination

Level of DAH	Level of STORAGE	Decision Rule SD	Mean	StdDev
0	BASKET	2	4.35362939	0.05292609
0	Fert_Sac	2	4.09935627	0.60431885
0	Jute_Sac	2	4.43684903	0.15064342
5	BASKET	2	3.92936560	0.35409469
5	Fert_Sac	2	4.28645505	0.26486809
5	Jute_Sac	2	4.13459946	0.25189704
10	BASKET	2	3.64805758	0.23908989
10	Fert_Sac	2	3.54949028	0.17610402
10	Jute_Sac	2	2.46376397	0.70928059
15	BASKET	2	4.16594956	0.37185468
15	Fert_Sac	2	3.76951667	0.74008795
15	Jute_Sac	2	4.02575408	0.16215949
20	BASKET	2	4.08023229	0.01940856
20	Fert_Sac	2	3.65028712	0.68829225
20	Jute_Sac	2	4.13120259	0.29396466
25	BASKET	2	3.95298191	0.15372677
25	Fert_Sac	2	3.83754389	0.07624472
25	Jute_Sac	2	3.95643075	0.11484995
30	BASKET	2	4.20221987	0.12275118
30	Fert_Sac	2	4.00897726	0.20204446
30	Jute_Sac	2	4.19170022	0.12712942

Effects of storage containers on speed of germination

Storage Container	Mean
Basket	2.1162 a
Jute sack	2.0495 a
Fertilizer sack	1.8876 a

Alpha= 0.05; Least Significant Difference =0.4541; CV =36.07861

Means with the same letter are not significantly different

Interaction Table for Speed of Germination

Level of DAH	Level of STORAGE	Decision Rule SD	Mean	Std Dev
0	Basket	2	2.82000000	0.44676616

0	Fert_Sac	2	2.36000000	1.13318136
0	Jute_Sac	2	3.22333333	1.03471413
5	Basket	2	1.86666667	0.56092186
5	Fert_Sac	2	2.85333333	1.57671600
5	Jute_Sac	2	2.68333333	0.52003205
10	Basket	2	1.20666667	0.23028967
10	Fert_Sac	2	1.13333333	0.29737743
10	Jute_Sac	2	0.32000000	0.27874720
15	Basket	2	2.15666667	0.76008771
15	Fert_Sac	2	1.69333333	1.00808399
15	Jute_Sac	2	1.80000000	0.41797129
20	Basket	2	2.57000000	0.57087652
20	Fert_Sac	2	1.51000000	1.18621246
20	Jute_Sac	2	2.53666667	0.67485801
25	Basket	2	1.81333333	0.41064989
25	Fert_Sac	2	1.64000000	0.24248711
25	Jute_Sac	2	1.61000000	0.38000000
30	Basket	2	2.38000000	0.33286634
30	Fert_Sac	2	2.02333333	0.54720502
30	Jute_Sac	2	2.17333333	0.57448528

Effects of storage container on seedling vigour index

Storage Container	Mean
Basket	10.511 a
Jute sack	10.657 a
Fertilizer sack	9.629 a

Alpha= 0.05; Least Significant Difference 2.3412;CV=36.56405

Means with the same letter are not significantly different.

Effects of Storage Container on Shoot height / Length

Storage Container	Mean
Basket	17.7429 a
Jute sack	18.0381 a
Fertilizer sack	17.4000 a

Alpha = 0.05; LSD = 1.3424; CV = 12.14132

Means with the same letter are not significantly different

Effects of storage period on Seedling Stem Girth

DAH	Mean
0	0.34889 a
5	0.36000 a
10	0.39222 a
15	0.38111 a
20	0.36889 a
25	0.34556 a
30	0.36444 a

Alpha = 0.05; LSD =0.0332; CV = 9.523923

Means with the same letter are not significantly different

Effects of storage container on Seedling stem Girth

Storage Container	Mean
Basket	0.37381 a
Jute sack	0.36524 a
Fertilizer sack	0.35857 a

Alpha = 0.05; LSD = 0.0217; CV = 9.523923

Means with the same letter are not significantly different

Interaction Table for Seedling stems Girth

Level of DAH	Level of STORAGE	Decision Rule SD	Mean	StdDev
0	BASKET	2	0.37666667	0.01154701
0	Fert_Sac	2	0.33333333	0.03511885
0	Jute_Sac	2	0.33666667	0.02081666
5	BASKET	2	0.38333333	0.04509250
5	Fert_Sac	2	0.34333333	0.02886751
5	Jute_Sac	2	0.35333333	0.03055050
10	BASKET	2	0.40333333	0.02309401
10	Fert_Sac	2	0.38000000	0.08717798
10	Jute_Sac	2	0.39333333	0.01154701
15	BASKET	2	0.39666667	0.02081666
15	Fert_Sac	2	0.37666667	0.02516611
15	Jute_Sac	2	0.37000000	0.01000000
20	BASKET	2	0.37333333	0.03055050
20	Fert_Sac	2	0.36000000	0.04582576
20	Jute_Sac	2	0.37333333	0.02516611
25	BASKET	2	0.34000000	0.04582576
25	Fert_Sac	2	0.34000000	0.03000000
25	Jute_Sac	2	0.35666667	0.04041452
30	BASKET	2	0.34333333	0.02081666
30	Fert_Sac	2	0.37666667	0.05686241
30	Jute_Sac	2	0.37333333	0.04163332

Effects of Storage Container on Number of Leaves per Plant

Storage Container	Mean
Basket	2.26420 a
Jute sack	2.26525 a
Fertilizer sack	2.23399 a

Alpha = 0.05; LSD = 0.0503;CV = 3.578320

Means with the same letter are not significantly different.

Interaction Table for Number of Leaves per Plant

Level of DAH	Level of STORAGE	Decision Rule SD	Mean	Std Dev
0	BASKET	2	2.46981781	0.00000000
0	Fert_Sac	2	2.32881791	0.12210949
0	Jute_Sac	2	2.46981781	0.00000000
5	BASKET	2	2.25831796	0.00000000

5	Fert_Sac	2	2.32881791	0.12210949
5	Jute_Sac	2	2.25831796	0.00000000
10	BASKET	2	2.39931786	0.12210949
10	Fert_Sac	2	2.25831796	0.00000000
10	Jute_Sac	2	2.32881791	0.12210949
15	BASKET	2	2.25831796	0.00000000
15	Fert_Sac	2	2.25831796	0.00000000
15	Jute_Sac	2	2.25831796	0.00000000
20	BASKET	2	2.25831796	0.00000000
20	Fert_Sac	2	2.25831796	0.00000000
20	Jute_Sac	2	2.25831796	0.00000000
25	BASKET	2	2.02484567	0.00000000
25	Fert_Sac	2	2.18049386	0.13479529
25	Jute_Sac	2	2.18049386	0.13479529
30	BASKET	2	2.18049386	0.13479529
30	Fert_Sac	2	2.02484567	0.00000000
30	Jute_Sac	2	2.10266977	0.13479529

Effect of Storage container on Seedling Leaf Area

Storage Container	Mean
Fertilizer sack	148.14 a
Jute sack	144.72 a
Basket	133.01 a

Alpha = 0.05; LSD = 34.62; CV =
Means with the same letter are not significantly different

Effect of Storage container on Leaf Petiole Length

Storage Container	Mean
Basket	2.3667 a
Jute sack	2.5667 a
Fertilizer sack	2.4810 a

Alpha = 0.05; LSD = 0.2683; CV = 17.486
Means with the same letter are not significantly different

Interaction Table for Seedling Petiole Length

Level of DAH	Level of STORAGE	Decision Rule SD	Mean	Std Dev
0	Basket	2	2.56666667	0.20816660
0	Fertiliz	2	3.60000000	1.66433170
0	Jute	2	2.90000000	0.17320508
5	Basket	2	2.83333333	0.15275252
5	Fertiliz	2	2.03333333	0.37859389
5	Jute	2	2.43333333	0.51316014
10	Basket	2	2.16666667	0.35118846
10	Fertiliz	2	2.43333333	0.05773503
10	Jute	2	2.66666667	0.47258156
15	Basket	2	2.30000000	0.17320508
15	Fertiliz	2	2.20000000	0.34641016
15	Jute	2	2.20000000	0.52915026
20	Basket	2	2.33333333	0.11547005
20	Fertiliz	2	2.56666667	0.40414519
20	Jute	2	2.70000000	0.17320508
25	Basket	2	2.23333333	0.20816660
25	Fertiliz	2	2.33333333	0.35118846
25	Jute	2	2.66666667	0.32145503
30	Basket	2	2.13333333	0.32145503

30	Fertiliz	2	2.20000000	0.17320508
30	Jute	2	2.40000000	0.52915026

Effects of storage containers on Stem Nodes per Plant

Storage container	Mean
Jute sack	5.8095 a
Fertilizer sack	5.6190 a
Basket	5.5238 a

Alpha = 0.05; LSD = 0.5007; CV = 14.20638

Means with the same letter are not significantly different

Interaction Table for Stem Nodes per plant

Level of DAH	Level of STORAGE	Decision Rule SD	Mean	Std Dev
0	Basket	2	5.00000000	0.00000000
0	Fertiliz	2	5.33333333	1.52752523
0	Jute	2	6.00000000	1.00000000
5	Basket	2	4.66666667	0.57735027
5	Fertiliz	2	6.00000000	1.00000000
5	Jute	2	5.66666667	0.57735027
10	Basket	2	6.00000000	1.00000000
10	Fertiliz	2	6.00000000	0.00000000
10	Jute	2	5.66666667	2.08166600
15	Basket	2	6.00000000	0.00000000
15	Fertiliz	2	5.00000000	0.00000000
15	Jute	2	6.66666667	0.57735027
20	Basket	2	6.66666667	1.52752523
20	Fertiliz	2	6.33333333	0.57735027
20	Jute	2	6.66666667	1.15470054
25	Basket	2	5.66666667	1.52752523
25	Fertiliz	2	5.66666667	0.57735027
25	Jute	2	5.00000000	0.00000000
30	Basket	2	4.66666667	0.57735027
30	Fertiliz	2	5.00000000	0.00000000
30	Jute	2	5.00000000	1.00000000

Effects of Storage Period on seedling internode Length

DAH	Mean
0	1.4000 a
5	1.1222 a
10	1.4889 a
15	1.3889 a
20	1.4778 a
25	1.2889 a
30	1.2667 a

Alpha = 0.05; L S D = 0.3099; CV = 24.14038

Means with the same letter are not significantly different.

Interaction Table for Seedling Internode Length

Level of DAH	Level of STORAGE	Decision Rule SD	Mean	StdDev
0	Basket	2	1.46666667	0.50332230
0	Fertiliz	2	1.40000000	0.36055513
0	Jute	2	1.33333333	0.28867513
5	Basket	2	1.53333333	0.05773503
5	Fertiliz	2	0.83333333	0.28867513
5	Jute	2	1.00000000	0.00000000
10	Basket	2	1.90000000	0.36055513
10	Fertiliz	2	0.90000000	0.69282032
10	Jute	2	1.66666667	0.57735027
15	Basket	2	1.50000000	0.50000000
15	Fertiliz	2	1.00000000	0.50000000
15	Jute	2	1.66666667	0.57735027
20	Basket	2	1.50000000	0.00000000
20	Fertiliz	2	1.60000000	0.17320508
20	Jute	2	1.33333333	0.28867513
25	Basket	2	1.23333333	0.15275252
25	Fertiliz	2	1.36666667	0.15275252
25	Jute	2	1.26666667	0.05773503
30	Basket	2	1.20000000	0.26457513
30	Fertiliz	2	1.26666667	0.25166115
30	Jute	2	1.33333333	0.11547005

Effects of storage container on Plant Canopy Spread

Storage Container	Mean
Basket	22.119 a
Jute sack	21.129a
Fertilizer	19.800 a

Alpha = 0.05; L S D = 2.305; CV = 17.58694

Means with the same letter are not significantly different

Interaction Table for Seedling Canopy Spread

Level of DAH	Level of STORAGE	Decision Rule SD	Mean	Std Dev
0	Basket	2	23.6666667	1.30940108
0	Fertiliz	2	22.1666667	1.79511288
0	Jute	2	25.1666667	1.07226391
5	Basket	2	19.5000000	0.61437828
5	Fertiliz	2	17.6666667	1.71253486
5	Jute	2	19.5666667	1.93494381
10	Basket	2	24.1666667	1.32916406
10	Fertiliz	2	20.6666667	1.11010093
10	Jute	2	21.5000000	0.32287566
15	Basket	2	21.3333333	0.15470054
15	Fertiliz	2	19.7666667	1.23792045
15	Jute	2	22.1666667	1.32916406
20	Basket	2	23.0000000	1.00000000
20	Fertiliz	2	22.3333333	1.04145188
20	Jute	2	23.0000000	2.00000000
25	Basket	2	22.0000000	1.64575131
25	Fertiliz	2	16.6666667	1.61880215
25	Jute	2	20.5000000	0.50000000

30	Basket	2	21.1666667	1.04083300
30	Fertiliz	2	19.3333333	1.08166600
30	Jute	2	16.0000000	1.64575131

Effects of storage container on Seedling Root Length

Storage Container	Mean
Basket	8.8933 a
Jute	8.8552 a
Fertilizer	8.6386 a

Alpha = 0.05; L S D = 0.645; CV = 11.75921

Means with the same letter are not significantly different

Interaction Table for Seedling Root / Hypocotyl Length

Level of DAH	Level of STORAGE	Decision Rule SD	Mean	StdDev
0	Basket	3	10.5000000	1.41091269
0	Fert	3	8.7833333	0.46457866
0	Jute	3	10.0866667	0.88635960
5	Basket	3	8.7400000	0.56000000
5	Fert	3	9.4366667	0.99228692
5	Jute	3	8.8566667	0.53538148
10	Basket	3	10.2933333	1.59550410
10	Fert	3	9.3100000	1.74192422
10	Jute	3	8.0333333	0.83864971
15	Basket	3	8.6300000	0.93674970
15	Fert	3	8.6266667	0.45346812
15	Jute	3	8.4600000	1.06056589
20	Basket	3	8.5866667	1.91066306
20	Fert	3	9.0866667	0.50560195
20	Jute	3	9.8333333	1.28290036
25	Basket	3	7.5866667	0.18876794
25	Fert	3	7.2166667	0.40722639
25	Jute	3	8.3366667	0.31722757
30	Basket	3	7.9166667	1.46486632
30	Fert	3	8.0100000	0.20808652
30	Jute	3	8.3800000	0.25000000

Effects of storage period on Seedling Dry Weight (Total Dry Matter)

DAH	Mean
0	2.9033 a
5	3.6411 a
10	3.7778 a
15	4.9022 a
20	3.3111 a
25	3.5400 a
30	3.9089 a

Alpha = 0.05; L S D = 1.4949; CV = 42.26997

Means with the same letter are not significantly different.

Interaction Table for Seedling Dry Weight (Total Dry Matter)

Level of DAH	Level of STORAGE	Decision Rule SD	Mean	StdDev
0	Basket	2	3.15666667	1.27582653
0	Fert	2	2.38666667	0.71234355
0	Jute	2	3.16666667	0.78014956
5	Basket	2	3.58333333	0.16165808
5	Fert	2	3.15666667	0.28867513
5	Jute	2	4.18333333	0.56765600
10	Basket	2	4.78666667	2.21488901
10	Fert	2	3.36333333	0.41307788
10	Jute	2	3.18333333	0.80033326
15	Basket	2	5.23000000	1.51165472
15	Fert	2	4.15666667	1.67398726
15	Jute	2	5.32000000	1.36275456
20	Basket	2	3.25666667	0.34078341
20	Fert	2	3.16333333	1.15768447
20	Jute	2	3.51333333	0.49652123
25	Basket	2	3.82666667	0.25501634
25	Fert	2	2.98000000	0.46000000
25	Jute	2	3.81333333	0.79425017
30	Basket	2	6.76000000	6.24281187
30	Fert	2	2.35000000	0.16093477
30	Jute	2	2.61666667	0.33321665