THE EFFECT OF SEED SIZE AND STORAGE CONDITIONS ON THE GERMINATION AND YIELD OF ONIONS (*Allium cepa* L).

BY

RACHAEL KEHINDE A. COLE-EGHAREVBA

Department of Plant Science,
Faculty of Agriculture,
Ahmadu Bello University,
Zaria.

A Dissertation submitted to the Faculty of Agriculture in partial fulfillment of the requirements for the degree of Doctor of Philosophy of Ahmadu Bello University, Zaria.

JULY, 1986

DECLARATION

I hereby declare that the whole of this work now being submitted as a Thesis for the Ph.D. degree of Ahmadu Bello University is the result of my own investigation . The work embodied in this thesis has not been submitted already in substance for any degree, and is not being concurrently submitted in candidature for any other degree.

Candidate: [signature] (M.I.)

Date: 30/7/86

The above declaration is confirmed by:

[signature]

Professor L.B. Olugbemi,
Major Supervisor.

Date: 31/7/86

JULY 1986.

DEDICATION

This Thesis is dedicated to my ONLY brother WILLIAM ADEYINKA IDOWU COLE (Ph.D. Vet. Microbiology, Illinois), Aged 39 years, who died on October 9th and was buried in Champaign, Illinois, U.S.A. on October 19th, 1985.

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ABSTRACT

Seeds of two local onion varieties: Maiduguri Improved and Ex Gayanawa were graded by width in May, 1982 into two sizes: less than 2.0mm and 2.0 - 2.5mm. The seeds were stored under six storage conditions, namely, Baft bags in room temperature; polythene bags in room temperature; Baft bags in the refrigerator; Polythene bags in the refrigerator, Polythene bags in the freezer and paper envelopes in the dessicator. Seeds from all the treatments, except for the two storage conditions identified as inferior (Polythene bags in room temperature and Baft bags in the refrigerator) were partially withdrawn from storage at the beginning of 1982/83 and 1983/84 dry seasons and used in field trials. The 1982/83 dry season trial was located at the A.B.U. Research Farm, Samaru, while the 1983/84 field trial was conducted at the A.B.U. Irrigation Research Station, Kadawa, near Kano. Each trial was designed as a 2 x 2 x 4 (variety, seed size and storage conditions) factorial experiment and replicated three times. Seed laboratory germination was tested after 2, 4, 6, 8 and 15 months of storage. In the field trials, attention was placed on yield of onion and its components as affected by the factors studied.

In 1984, two supplementary nursery trials were carried out at the Samaru College of Agriculture, A.B.U., Zaria to study the effects of seed size and storage conditions on

field emergence and seedling growth. Seeds of the Institute for Agricultural Research selection, "Composite-4" variety stored for four months wore used for this purpose and trials were designed as a 2 x 4 (seed size and storage conditions) factorial experiment, replicated four times.

Amongst the storage conditions studied, the baft bags in room temperature and the polythene bags both in the refrigerator and the freezer were identified as the best for seed storage. Baft bags in room temperature, Polythene bags in the refrigerator and polythene bags in the freezer had on the average 70%, 69%.5% and 68.6% laboratory germination respectively after 15 months of storage. Seed storage in the desiccator was significantly lower (65,2%) in germination only after 15 months compared to the best three treatments while the polythene bags in room temperature and baft bags in the refrigerator were discarded after 8 months of seed storage due to their low seed viability (60.9 and 54.0% respectively).

From the results obtained in the nursery trials, it is concluded that both field emergence and seedling growth are not significantly influenced by seed size and storage conditions. It should be emphasized, however, that seeds used in these trials were stored for four months only and under conditions identified earlier as good. Consequently, no significant influence of the factors studied on seed

laboratory germination was observed.

Prom the field trials, it is concluded that neither variety nor location influenced significantly onion growth and yield. However, a significant interaction between variety and location was observed. Ex Gayanawa which produced heavier seeds and maintained viability for longer period in storage was obviously better adapted to Kadawa growing conditions in terms of early maturity and yield than Maiduguri Improved variety.

Although larger seeds were more viable than the smaller ones in storage, they were not superior in field emergence, growth, maturity and total yield.

CERTIFICATION

We certify that this piece of investigation was carried out by Mrs. Rachael Kehinde A. Cole-Egharevba in the Department of Plant Science, Ahmadu Bello University, Zaria.

PROF. L.B. OLUGBEMI,
CHAIRMAN, SUPERVISORY
COMMITTEE.

DR. F. BEDNARZ,
MEMBER, SUPERVISORY
COMMITTEE.

DR. J.D. OLAREWAJU,
MEMBER, SUPERVISORY
COMMITTEE.

PROF. O.I. LELEJI,
HEAD, DEPARTMENT OF
PLANT SCIENCE.

PROF. G.E. OSUIDE,
DEAN, POST-GRADUATE
SCHOOL.

DATE: _____

AHMADU BELLO UNIVERSITY,
ZARIA.

THESIS APPROVAL

This Thesis entitled "The Effect of Seed Size and Storage Conditions on the Germination and Yield of Onions" by R.K.A. Cole-Egharevba (Mrs), meets the regulations governing the degree of Doctor of Philosophy of Ahmadu Bello University, Zaria and is approved for its contribution to scientific knowledge and literary presentation.

Internal Examiners

Prof. L.B. Olugbemi,
Department of Plant Science,
Ahmadu Bello University,
Zaria.

Dr. F. Bednarz,
Department of Plant
Science, Ahmadu Bello
University, Zaria.

Dr. J.D. Olarewaju
Department of Plant Science,
Ahmadu Bello University,
Zaria.

Prof. O.I. Leleji
Head, Department of Plant
Science, Ahmadu Bello
University, Zaria.

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CHAPTER ONE

INTRODUCTION

The onion, (Allium cepa L.) belongs to the family Alliaceae. It is a biennial plant which forms a bulb in the first season of growth and flowers in the second. The onion can be grown profitably on many soils but it does best on fertile and well drained, sandy, loam soils.

1.1. Origin and Distribution.

Although the origin of Allium cepa L. is not well known, some believe that it originated from western Asia in the area extending from Palestine to India (Jones and Mann, 1963). Joubert and Strydom (1968), also believe that the cultivation of onion dates back before the birth of Christ in Egypt. Very little is known about how and when the onion was introduced into different countries. Helm, (1956) indicated that the cooking onion was popular in Germany at the start of the middle ages. Also it is believed that the onion is one of the many crops for which the Americans are indebted to the old world. In Egypt the onion is mentioned as one of the funerary offerings as early as 2100 B.C. (Jones and Mann, 1963). The Indians believe that the onion is a medicinal crop for its usefulness to the eyes. The juice when mixed with honey and placed in the eyes was said to be useful to patients suffering from weakness of vision for white clouds and for incipient cataract, (Jones and Mann, 1963).

1.2. Importance of the Crop

The demand for onion as a vegetable is world wide. In Nigeria it forms part of an ingredient of main meals, being used mainly in flavouring and seasoning of a wide variety of dishes. It is also harvested in the green state and used as salads. Several authors have referred to the onion as having a traditional place in folk-lore medicine for many centuries (Grieve 1931, Tackholm and Drar 1954 Jones and Mann 1963, Ikram 1971 and Purseglove, 1975). They claimed that the onion could cure small pox by rubbing chopped bulbs on soles of the feet and that it acts as a remedy for hysteria if sniffed into the nostrils. It is also claimed that because of its favourable action on the elasticity of the blood vessels, some mixture of it is used to minimize high blood pressure (Sinnadurai and Abu, 1977). Ikram (1971) indicated that in Nigeria, onion has been used to cure ailments such as fever and earaches. When feverish, the juice is rubbed on the body or taken in with Palm-oil and pepper. The strong odour is also supposed to be effective in repelling snakes and it is common to see that people plant the crop near their homes for this purpose. Nutritionally, the onions compared with other fresh vegetables are relatively high in food energy (Calories); intermediate in protein content (Nitrogen), rich in minerals (Phosphorous and calcium) and some vitamins (Ascorbic acid). They also have some fats and carbohydrater which are all essential to daily living (Comin 1946 and Sherman, 1947).

The onion is an essential item of internal trade between the Northern and Southern parts of the country, because the southern parts rely entirely on the north for their supply of onions. Because of this demand and since onion production is restricted to a limited area of the country, it is essential that optimum cultural, management and protection practices be employed for maximum production of the crop.

1.3. Production

The production of onion world wide has increased significantly from 11.2m metric tons in 1975 to 19.5m metric tons in 1980. The 19.5m metric tons were produced from 1.6m hectares of land with an average yield of 12.2 tons/hectare (Anon 1981a). The United States of America, Japan, India and the Union of Soviet Socialist Republic are each said to produce over 1.5 million metric tons of onion annually. Total production for Africa and West Africa in 1980 were 1.5 million and 176,000 metric tons respectively (Anon, 1981a). West African countries producing considerable amounts include Niger, Senegal, Chad, Ghana and Nigeria.

According to Inyang (1966), onion has been in production in northern Nigeria for such a long time that it has become an inevitable commercial vegetable. Onion production in Nigeria is restricted to the Northern Guinea and Sudan Savannah areas by climatic factors which provide,

in the dry season, an initial cool condition necessary for early growth of the crop and later high temperature needed for bulb formation, ripening and maturation. The bulk of the onion crop in Nigeria is produced under irrigation in dry season and in low land fadama areas. Olayide et al (1972) reported that onion production in Nigeria rose from 69,000 metric tons in 1960 to 86,000 metric tons in 1970. Anon (1974) estimated the average annual output of onions in Nigeria as about 77,000 metric tons with an expected annual increase in production of about 2.6%. Of recent, there has not been any reliable data or statistics on onion production in Nigeria, but Iyang (1966) gave an estimated yield of 12 tons per hectare and that yield seldom exceeds 15 tons per hectare. Available experimental data by Green (1973) and Bednarz et al (1985) suggest that the yield of local onions is in the range of 10-40 tons per hectare with an average of 15-25 tons per hectare. If these figures of 15-25 tons per hectare are accepted, then onion yield in Nigeria compares favourably with those of other West African countries like Chad (20 tons/ha), Senegal (17.8 tons/ha) and Ghana (14 tons/ha) (Anon 1981a).

The yield is low when compared with some other parts of the world like Belgium (68.4 tons/ha), Netherlands (40.1 tons/ha), Japan (39.8 tons/ha) and United States of America (34.6 tons/ha) (Anon, 1981). This is despite the fact that in these countries, seeds were directly sown in the field. In Nigeria, and in many other developing

tropical and sub-tropical countries, seedlings are first raised in the nursery before being transplanted to the field. Other things being equal, transplants are expected to produce higher yields than directly seeded onions, transplants are already growing as plants and are therefore better able to withstand unfavourable environmental and soil conditions than if seeds were directly sown. Some of the reasons advanced for the low yield of onions in Nigeria include, poor quality of seeds, low transplant vigour as a result of poor stand establishment, low plant density, inadequate use of fertilizers and ineffective control of pests and diseases.

Onion seed has been reported to deteriorate quickly in hot humid weather (Myers, 1942; Gane, 1948; Gadia et al, 1964; Elbaradi, 1971; Harrington, 1973; and Minkov, 1974). This may be responsible for the poor stand establishment which may have been as a result of low seed viability due to poor storage. Green (1971), ascribed the poor yield of onions in Nigeria primarily to the use of seeds from bolted onion crop. Bolters are onion plants which flower prematurely and subsequently produce seeds instead of bulbs. Even if the flower stalks are removed to prevent plants from flowering the bulbs obtained are of inferior quality and not suitable for storage and/or planting. Seeds from bolters are indiscriminately used by farmers which Amstel, van (1982) observed to be smaller than normally produced seeds. The

use of these seeds which are usually of low viability, adversely affect the overall production of onion.

Because of the dietary and commercial importance of the onion and the convinction that the potential from bulb yield of the crop has not been fully exploited, continued efforts are being made to investigate some aspects of the factors that are responsible for the low yield of the crop. Some of these factors as previously indicated, are those of poor quality seeds and seed deterioration in storage. In Nigeria, the farmers know that the onion seed viability decreases after 6-8 months from harvest. Only about 20-30% of onion growers venture into onion seed production (Audu, 1985). The onion seed crop is produced in the dry season when temperature is sufficiently low to induce the development of inflorescences. Because rains are not available during the dry season the crop must be irrigated. This means that the land must be levelled properly, which is one of the limiting factors. Other limiting factors are shortage of mother bulbs, lack of means for effective control of pests and diseases and lack of satisfactory mechanization. The farmers believe that the benefits derived from seed production are less than the labour and management inputs. Since only few farmers produce seeds and they lack the technical knowledge of adequate storage methods, other farmers have to purchase these seeds at exorbitant prices of ₦80.00 - ₦100.00 per kilogram weight of seeds, every planting season.

To make a break through in onion production, Nigerian farmers will require good quality seeds to have better yield. The ability to retain seed viability for longer periods, which is still a vital problem to Nigerian onion producers, and ways of solving these are all part of this investigation.

1.4. Objectives

The objectives of the present investigation are two-folds:

i) To determine the effects of seed size on growth and yield of onions.

ii) To determine the effects of different methods of storage on viability and production of onion.

CHAPTER TWO

REVIEW OF LITERATURE

2.1. The relationship between seed quality and seed size

Seeds are the most conservative parts of plants since they are required all the time to perpetuate all plant species. According to van Wyk (1961) seed characteristics include dimensions, structure of seed coat, presence or absence of hairs, chemical content etc., all of which are believed to affect seed germination.

Seed quality is therefore a collective term used to describe the potential performance of a large quantity of seeds. Seeds should be true to type, free from diseases and mechanical damage and should have high viability. As reported by Schwass and Allo (1973), viability of newly harvested seed should be 90 per cent or higher. Good quality seeds enhance increased yield per hectare. Owen (1956) observed that mechanical damage can occur during harvesting, threshing and drying of onion seeds and this will affect seed quality. It was emphasized by Dobrovsky (1962) that "seeds should be handled more like eggs and not like stones", since it is possible to have very low seed germination due to microscopic breakages in seeds. There is the obvious fact that micro-organisms appear to attack the seeds at the injured places and so lower seed quality. Injury to seeds can occur during the use of chemical (for insects or fungi control) at high rates of application, especially when seed moisture is high, the

storage is prolonged and there is inadequate ventilation (Debrovsky, 1962). As a result, such seeds have their viability greatly reduced, faster than non-treated seeds under the same adverse storage conditions. Moreover, during drying, the injured seed coats may be subjected to high temperature. This will also reduce seed germination.

Very important parameters that can be used to assess seed quality are colour, size and shape. Another parameter as emphasized by Mukhin (1979) is seed weight. For instance, for skopinsky mestny variety of onion, the number of seeds per gram varied from 320 to 590, while the relative weight in grams per cubic centimeter was 0.85-1.15. Mukhin (1979) therefore concluded that, to a certain limit, the bigger the onion seed weight, the more suitable it is for sowing. The use of high quality seeds has been recommended by Joshua and Singh (1981) to increase the benefits derived from the effective use of expensive inputs such as tractor services, fertilizers, chemicals and labour in a crop production programme. Of all these seed quality characteristics, seed size is one of the most obvious and it can be expressed by three dimensions: length, width and thickness. The onion seed has been described by Mukhin (1979) to have a width of 1.4-2.9 mm, length of 2.2-3.7 mm and thickness of 1.1-1.9mm.

As mentioned earlier, the number of seeds per gram of one variety may vary greatly from another variety of the

same crop. Mukhin (1979) observed that graded carrot seeds required 3.5 kilograms to plant one hectare of land as against the 5-6 kilograms of ungraded and non-uniform seeds. This is an indication that when seeds are graded into sizes, less number of seeds could be used to plant a hectare of land as this will bring about better field emergence and uniform seedling sizes. Also Litynski (1982) reported that since emergence and seedling quality were better from graded than ungraded seeds, the onion crops were expected to give two to three times higher yields if graded seeds were used. If in future, it is necessary for Nigerian farmers to mechanise transplanting, it may be necessary to have seedlings of about the same size to give way for efficient transplanting processes. The use of high quality seeds is one of the ways of enhancing food production in less developed countries.

2.2. Effect of seed size on Crop Production

The effect of seed size upon the subsequent growth and ultimate yield of crops has engaged the attention of research workers for many years. However, despite the fact that an enormous body of literature on the subject is available, the absence of a general consensus on the effect of seed size on growth and yield of some crops indicates the need for further investigation.

From the available literature, it can be concluded that seed size may influence germination, field emergence, seedling vigour; plant establishment, growth and yield of a crop. Because there is little information on the effect of seed size on onion growth and yield, references will be made sometimes to similar small seeded vegetables. Hewston (1964) reported that the enhanced emergence from large onion seeds offered only an initial advantage which does not reach bulb formation. But Brewster et al (1974) while studying seed weight and plant density on onion yield assumed from his data that the use of different seed sizes may influence final bulb size. Also Austin and Longden (1967) found that larger carrot seeds emerged better, produced heavier seedlings and higher root yields.

(i) Effect of seed size on germination

There has been much discussion on seed size as a determining factor in germination of many vegetables and grasses, yet no consensus has been arrived at, possibly due to inability to clearly distinguish between germination and emergence. Germination, for all practical purposes, according to Gill and Singh (1979) is the rupture of the testa by an extruding radicle whereas Kaufmann and Macfaden (1963) defined the appearance of the first aerial organ above the soil surface as emergence. It could therefore be visualized that most field trials which attempted to measure the effect of seed size on germination more likely

could have been measuring its effect on emergence. In this investigation, germination test was performed in the laboratory which was based on the appearance of the radicle whereas the emergence which was observed on the field was based on the appearance of the seedlings.

Germination from large seeds proved to be significantly higher than from small seeds of onion (Brewster et al, 1974). This view is supported by many investigators on different similar vegetable crops such as radish and carrots, Cummings, 1914, Dhesi et al, 1965, Marie et al, 1967, and Austin and Longden 1967). Also Joubert and Rappard (1970) noted that crops from larger seeds of carrots and cauliflower became established quickly and were able to withstand unfavourable weather conditions more than the smaller seeds.

(ii) Effect of seed size on seedling emergence

The extent to which seeds of different crop species are able to emerge from the soil, as stated by Dhillion and Kler (1976), is affected by a number of factors, among which are size of the seed sown, depth of sowing, soil moisture and soil type. Although the effects of these factors cannot be very much separated due to their interaction on emergence, emphasis will be placed here on seed size as a factor. Hegarthy (1971), Bedford and Mackay (1973) who worked on onion and carrots respectively found that the field emergence is usually much lower than

laboratory germination. Similar views were expressed by Mukhin (1979) when he compared onion emergence in the laboratory, Green house and field and found that while the laboratory test gave 75% emergence, the green house and field emergence were 65% and 44% respectively. These are lower than laboratory germination since environmental conditions on a field scale cannot be predicted or fully controlled and many factors can operate against the germination of the seed and emergence of the seedling on the field. Examples of such factors are soil temperature, soil moisture content and soil mechanical factors such as soil crusts. Mukhin (1979) therefore recommended two to three times more of seeds for field planting than the calculated amount based on the laboratory test. He also presented data to show that the various small seeded vegetables differ in the number of days from sowing to emergence as some are slower than others in emergence. He showed that while it took radish and cabbage only 5-6 days, onion and carrots did not emerge until 12-14 days after sowing.

Hansen (1926) studying vegetable seeds observed that seedling emergence was higher for large than for small seeds. Similarly, Hewston (1964) reported a striking increase in onion percent emergence as seed size increased. More recently Brewster et al (1974) and Usik (1980) showed that large onion seeds emerged better than smaller ones and according to the latter, the difference was 10-20%.

Similar conclusions were reported by Austin and Longden (1967) and Mackay (1970) on small seeded vegetables who observed higher emergence and higher number of seedlings from large carrot seeds than small ones, partly due to the smaller seeds having a proportion of incomplete embryos. Contrary to the above, Bedford and Mackay (1973) working with onion seeds, noted that the emergence periods for both large and small seeds were the same.

(iii) Effect of seed size on seedling vigour and growth

The effect of seed size on various aspects of plant growth has been reported by many investigators for a number of crops. Such reports include small seeded vegetable crops, Cummings (1914) and Gelmond (1972); small grains, Kisselbach (1924) and oil seeds; Dhillion and Kler (1976).

Cummings (1914) observed that plants obtained from large seeds started better, grew more vigorous as shown by their greater height, had more branches and greater leaf area than plants from small seeds.

Schmidth (1921) similarly found that large vegetable seeds exhibited more rapid growth habit than the small ones. Besides, he observed that the dry weight of plants from heavier seeds was higher than those from small seeds. Black (1956) and 1957) concluded that there is a direct relationship between seed weight and both dry weight and

leaf area in the early plant growth stages. He explained that seedlings from larger seeds have greater initial photosynthetic area leading to increase in dry weight during the early part of the vegetative phase. These views were supported by Alam and Locascio (1965), and Austin and Longden (1967).

It would seem from the foregoing that large seeds show superiority over small seeds in producing vigorous seedlings at least at the initial stages. This is probably due to the presence of large food reserves in the large seed. As such, this superiority was much pronounced in the case of deeper planting or unfavourable conditions in the early stages of growth when seedlings had greater dependence on food reserves of the seed. Under favourable condition and/or with advance in growth stage, the differences are generally less marked, diminishing and in certain cases completely disappearing (Austin and Longden 1967 and Harper and Obeid 1967).

(iv) Effect of seed size on Crop Yield

Brenchley (1923) showed that the initial better growth from large seeds in several crops did not lead to higher yield. Similar view was expressed by Hewston (1964) on cauliflower when he reported that seedlings from large seeds with an initial overall advantage of better germination and growth of seedlings attained similar size and yield at maturity. Similarly, Grapinski et al (1977),

Gill and Singh (1979) showed that the use of various seed sizes of radish had no appreciable effect on crop quality or yield. Hatridge-Esh and Bennett (1980) did not record differences in yield between onion plants from smaller and larger seeds except that plants from the heavier seeds exhibited leaf colapse two days earlier. However, Frappel (1973), while investigating plant spacing in onions, reported a yield decrease of 10% by small sized seeds when all seeds were drilled rather than hand planted. Usik (1980) obtained similar results, as above.

Contrary views were expressed by other investigators. For instance, Semicastinova (1968) showed that yields of radish and lettuse were related to seed size, maximum yield being produced by large seeded plants. Similar results were reported by Lee and Nicholas (1978) on radish and recently, Smittle (1982) observed on small seeded vegetables that the number and size of the non-bolters (marketable bulbs) were much higher in large than small seeded crops. Also Scaife and Jones (1970), Tompkins (1965) Alam and Locascio (1966) and Joubert and Rappard (1970) observed that yields of vegetable crops were higher as seed sizes increased.

Generally, it could be concluded that the available information relating to the effect of seed size on yield in vegetables is inconsistent. In most cases the plants

from larger seeds normally mature early, yield higher while in others, the contrary is the case. As explained by Dhillion and Kler (1976), these differences and inconsistencies may be due to the type of crop grown, the environmental condition, viability state of the seeds used and the type of management practices utilized.

2.3. The effect of seed storage conditions

Seeds are stored to preserve or maintain their physiological qualities for a period of time, usually till the next growing season. The period for which a seed can retain its viability depends on the species and on the storage conditions. Like any other form of life, seeds do not retain their vital spark and vigour indefinitely. Delouche et al (1973) showed that seeds are stored for varying lengths depending upon their intending usage. For example, they could be stored for one to nine months to be planted next season, for eighteen to twenty-four months under specific storage conditions in crops that lose viability quickly and in some cases for up to ten years to provide materials for breeders and geneticists. Various investigators such as Beattie and Boswell (1939), Myers (1942), Barton (1961) and Harrington (1973) have shown the optimum storage conditions under which most field and vegetable seeds are able to maintain their viability. Such optimum storage conditions include cold storage, use of moisture proof bags or other sealed containers and drying of seeds to low moisture content of about 6 - 7%.

Takayanagi (1973) showed that seeds of most field and vegetable crops may retain their viability for a long time (about five to ten years) if they are dried and stored in air tight containers. Gadia et al (1964) described that heating up to 30 - 60°C for up to 2 hours has no detrimental effect on germination percentage of seeds with low moisture content but the germinating capacity of seeds with high moisture content of 11-15 per cent would reduce under such temperature treatment.

It is generally known that the onion seed is one of the shortest lived vegetables as there is such a marked loss of viability in storage (Ganc, 1948), yet the success in onion production depends on good and viable seeds. After seeds are produced, they must be dried, processed and stored in a suitable environment to maintain their viability and vigour.

(i) Environmental factors affecting seed viability during the storage period

Several authors have concluded that relative humidity, seed moisture content and temperature are the most important environmental factors affecting the viability of seed in storage (Anon, 1954; Owen, 1956; Bartan, 1961; James et al, 1964; Litynski, 1966; Delouche, 1968; Christensen and Kaufmann, 1969 and Harrington, 1973). Of these three factors, relative humidity is the most important because of its direct relationship to seed moisture content.

Other factors affecting seed viability are physical condition of the seed and storage atmosphere.

Seed injuries may reduce germination and make seeds more susceptible to attack by organisms. Seeds can be injured during harvesting, threshing, cleaning, grading, etc. Kuperman (1950) found that even with small cracks in seeds of wheat and oats, their field germination was reduced by 16%.

The composition of the storage atmosphere is also important. If the amount of oxygen necessary for respiration is reduced in storage atmosphere, respiration slows down. According to Milner and Gedes (1954), any storage condition which reduces storage respiratory activity tends to prolong seed viability. However, in Africa as investigated by Dobrovsky (1962), viability may be lost as the seeds go through high rate of respiration and become exhausted due to high temperature and high moisture content of the seed in such an environment. Seeds high in moisture content respire more than dry seeds, especially when the temperature is high. Hence low seed moisture content, low relative humidity and temperature will help to prolong onion seed viability (Barton, 1961).

In seed storage, there is also an interaction between moisture content and relative humidity. This is so because the moisture content that seeds assume

during storage is a function of relative humidity and temperature of the air surrounding the seeds. Delouche et al (1973) reported that high seed moisture encourages the growth and reproduction of storage molds and insects which will weaken or kill the seeds. In humid, tropical areas, seeds of many crops attain maturity and are harvested at a high moisture content. These seeds may go into storage insufficiently dried, and as seed moisture is high, the rate of deterioration becomes high. According to Anon (1954), a state of equillibrium is reached between the moisture in the seed and the surrounding air as the seeds absorb or lose moisture. As a result, at lower relative humidity, the moisture content attained by seeds is less than at higher relative humidity. Christensen and Kaufmann (1969) observed that if the seed moisture content exceeds 10-13%, sprouting, fungal invasion and/or heating can quickly destroy seed viability. They therefore suggested adequate drying of vegetable seeds to low moisture content before storage. Thus Barton (1961), Delouche (1963) and Harrington (1973) concluded that high seed moisture content and high relative humidity combined make up the greatest single cause of loss of viability and vigour in seeds.

The temperature at which seeds are stored also affects viability and vigour. According to Harrington (1963a), the longevity of seeds in storage is approximately doubled for

each 5.5°C, decrease in temperature, other conditions being equal. This is so because as the temperature of the seeds increases, the biological activities of the seeds also increase. Even though, cold storage (0 - 5°C) of seeds is desirable, Harrington (1972) observed that unless the seeds are sealed in moisture proof containers, the storage relative humidity at low temperatures will be high. This is so since most sub-zero or cold stores have a high relative humidity and after a period of storage, the seeds gain moisture and ice crystals form. Only seeds with less than 14% moisture content do not form ice crystals. As reported by Heydecker (1974), crystallization would damage seed cells causing loss in viability.

Delouche (1968) and Harrington (1972) both concluded that the effect of moisture content and temperature on seed longevity are inter-related. They presented data to show that if moisture content is 45-60%, germination usually occures. However, moisture content of above 18-20% will increase respiration in stored seeds and heating can occure when aeration is low. This spontaneous heating can raise the temperature high enough to kill the seeds. Also, between 12-14% and 18-20% moisture content, mold growth occure infecting the seed especially in cracked areas. Above 10% moisture content, insects become a serious problem in stored seed. These authors further showed that the higher the moisture content of the seed, the more they are adversely affected by temperature.

Beattie and Boswell (1939) observed that high germination and good stands cannot be expected from onion seed stored more than one year under high relative humidity and high temperatures in tropical areas.

Boswell et al (1944), stored onion seeds in the laboratory at 0°C and in six to eight months later, the onion showed marked loss in germination. Toole and Gorman (1948) sampled onion seeds having original laboratory germination of 94% and 13.2% moisture content, which they stored at 26.7°C and 30% relative humidity. They found that within three weeks, germination decreased by 12 per cent and at nine weeks all the seeds were almost dead. However, when seeds were subjected to reduced temperature of 10°C and relative humidity of 50%, germination was higher. This shows that the life of onion seed may be prolonged by storage at low temperature as well as maintaining low moisture content with low relative humidity.

Brison (1942), Sandhu et al (1972), Rusev (1974) Singh et al (1976) also observed that when seeds are dried to low moisture content and left in sealed air-tight containers at low temperatures the viability of stored onion seeds will be maintained. Similar views were expressed by Toole and Gorman (1948), Weibull (1955); Barton (1966) and Harrison and Carpenter (1977) who found that onion seed life could be prolonged by use of cold

temperatures of 0°C to 20°C with seeds of 4-6% moisture content. Gane (1948) also reported that the viability of vegetable seeds were prolonged over two and half to three years under a low temperature of 0°C and relative humidity of 70%, but as temperature increased to 10°C, the onion seeds began to deteriorate even at the same humidity. Jones and Mann (1963) observed that for high viability to be maintained in freshly harvested onion seeds, there must be both low seed moisture content and low storage temperature. Elbaradi (1971) observed that onion seeds remained viable for longer than one year when dried to 6.5% moisture content and stored in air-tight containers, but seeds with high moisture content of 9.5 to 13% would lose viability within ten and three months respectively. From all the above results, it can be concluded that loss of viability in onion seeds was progressively faster with increase in temperature, relative humidity and moisture content of the seeds.

(ii) Effect of different storage methods and containers

It is advisable to keep seeds in containers so as to maintain low moisture content during storage. Barton (1935, 1949) and Brison (1942) compared the influence of storage conditions using different containers on the germination of onion seeds. They concluded that onion seeds stored in sealed glass jars or tin cans with air-tight lids at room temperature remained viable twenty-four months longer than when stored in unsealed or open containers such as paper envelopes. Also, they observed that seeds

with both low moisture content of 3.5 to 6.5 per cent and temperature of 5°C or lower were viable for longer period than those with high moisture content of 10 to 12%.

Harrington (1973) investigated the resistance of eight different containers to moisture. Containers used to store onion seeds ranged from kraft paper bags to enamel lined tins. The moisture content used was classified as high, medium and low at 9.98, 8.73 and 7.06 per cent respectively. Temperatures used ranged from 17.8°C to 37.8°C. His results suggested that alluminium foil and enamel tin cans should be used as these were completely water proof and kept seeds viable longest. The results further indicated that polythene containers were unsuitable. Miyagi (1966) used different seed bags - metal foils, plastic films and paper bags to store onion seeds under room temperature for the periods of nine, seventeen and twenty-two months respectively. He observed that metal foils were completely impermeable to moisture and so seeds stored there retained both vigour and germinating capacity for twenty-two months.

Paper envelopes are commonly used by seedsmen to store their seeds before they are sent to wholesale or retail markets. Barton (1949) stored onion seeds in paper envelopes at room temperature of 30°C and at 76% relative humidity and in the desiccator with moisture

content adjusted from 10.6 to 3.5% respect.vely. The seeds maintained viability for twelve months. However, those stored at 10.6% moisture content produced weak seedlings at three months and by six months, the seeds lost viability completely. This meant that reduction in moisture content can prolong the life of seed stored in paper envelopes. Harrington (1963b) used several containers including paper bags to store seeds at variable temperatures and he suggested that kraft paper bags should not be used for seed storage as it showed no resistance to moisture vapour transmission. Also, Gadia et al (1964) stored seeds of 6.5 per cent moisture content in paper bags and germination dropped to less than 20 per cent in four months and by the eleventh month germination was zero. On the other hand, Miyagi (1966), stored onion seeds in paper bags in room temperature but observed that germinating capacity was reduced in nine months because such containers were permeable to moisture.

Cloth bags have also been shown by Harrington (1963b) to show no resistance to moisture vapour transmission. Brison (1942) stored onion seeds in cloth bags at cold temperatures of -1.1°C to 4.4°C and the seeds germinated fairly well (72.4%) after forty-four months. In contrast, under a higher temperature of 32.2° to 35°C, viability was 71% at twenty months but no seed germinated between twenty to twenty-seven months. Myers (1943) observed

that bagged seeds in natural storage can achieve 50% germination even after 15 months. The seedlings will however be low in vigour which will result in poor yield. While in cold storage, bagged onion seeds will germinate up to at least two and half years of storage if sown immediately after removal from the cold treatments. Gadia et al (1964) stored onion seeds with low moisture content under room temperature in cloth bags and observed that germinating vigour dropped off by the eleventh month.

The purpose of using moisture proof polythene bags for seeds is to maintain high germination as long as possible. Brison (1942) used cellophane bags to store onion seeds both in room and in cold temperatures respectively. He observed that at room temperature, only 28.2% germinated in twenty months, but no germination was recorded between twenty to twenty-seven months of storage. In cold storage, 86.2% germination after thirty-two months and 54.2 per cent after thirty-nine months. Polythene was observed by Harrington (1963a) to be more resistant to moisture vapour transmission at low temperatures. However, he indicated that some moisture does penetrate the plastics as it is not completely impermeable to water.

Plastic films were used by Miyagi (1966) to store some vegetables and the results obtained showed that onion seeds retained vigour after nine months but lost germinating

capacity after twenty-two months since these plastic films were not completely impermeable to moisture. Boros and Hadnagy (1968) used paper alluminium foil and laminated polythelene bags as containers to store seeds at cold temperature 5°C and at room temperature for two years. They observed that the most suitable container to prolong seed viability was a laminated polyethelene and that the cold temperature was better than the room temperature storage.

Some investigators which include Beattie and Boswell (1939), Anon (1954), Roberts (1973) and Minkov (1974) observed that the onion seeds would not maintain high germination capacity for more than one year in natural condition or room temperature, hence they recommended the use of desiccators to further reduce the moisture content of dried seeds but the amount of moisture removed should not be such that would damage the seeds and cause injury to such seeds. Barton (1943) stored onion seeds with an initial germination of 98% in desiccators at 20°C with 35% relative humidity. At the end of fifty-two weeks, 81 per cent of the seeds germinated but at increased relative humidity of fifty-five per cent, seeds deteriorated rapidly after twenty weeks storage at which time the seeds had attained moisture content of 11%. At 76 per cent relative humidity, germination after forty weeks was only 7% with an increase in moisture content to 15%. This

indicates that high relative humidity levels can be very harmful to seed viability while in storage.

Nutile (1959) worked on the effects of desiccation on seed viability following several years of storage. He found that vigour was not impaired significantly in different grasses and vegetable crops when moisture content was reduced to 4 per cent. However, the rate of sprouting or number of seedling emergence was greatly reduced. He therefore concluded that extreme drying in itself had a harmful effect on seedling development. There was a positive correlation between decreasing seed moisture (2% or less) and period of storage. Most of the injury observed from desiccation were revealed as abnormal sprouts and stubby roots and shoot. Also Newhall and Hoff (1960) preserved onion seeds in a desiccator over calcium chloride at room temperature and after twenty-two years, germination was as high as 75% but the resulting bulbs were small in size and not marketable. They therefore reported that excessive drying changes the physical and chemical structure of the protoplasm and after re-moistening it is unable to establish its original condition for normal metabolic activities.

It may be concluded that seeds must be stored in a suitable environment to maintain good viability and vigour. Temperature, relative humidity and seed moisture content

at time of storage are the main factors that must be controlled to ensure safe seed storage. Generally, the lower the relative humidity and temperature, the longer the storage life of seeds. Also low level of oxygen in the storage environment prolongs seed viability by reducing its rate of respiration. According to Anon (1954), good quality onion seeds held at low moisture level will retain its viability for many years without serious loss. From the available evidence so far, plastic films are superior to paper envelopes and cloth bags for maintaining onion seed viability in storage.

CHAPTER THREE

MATERIALS, METHODS AND ENVIRONMENTAL CONDITIONS OF THE TRIALS

The study was carried out under irrigation in the dry seasons of 1980/81 to 1983/84 at the Ahmadu Bello University Farm, Samaru and at the Kadawa Irrigation Station of the Institute for Agricultural Research, Ahmadu Bello University. Samaru is in the Northern Guinea Savannah, on latitude 11° 11' North, longitude 07°38' East and 686 m above mean sea level. Kadawa is in the Sudan ecological zone, on latitude 11°39' North, longitude 08°02' East and 500 m above mean sea level, (Valleto and Ibanga, 1984). The locations of the experimental stations are shown in Figure 1.

3.1. Seed Multiplication and Processing

Seven local varieties namely, Maiduguri Improved, Ex Mubi I, Ex Mubi II, Ex Gayanawa, D.S. 79/B2, Ex Kano and Bama Improved and one foreign variety, Early Texas Grano were transplanted at the University Research Farm, Samaru between December, 1980 to April, 1981 to produce mother bulbs. The bulbs were harvested in April 1981 and air dried under the shade for 7 days while the leaves were later severed off..

For each variety, 50 bulbs per bag of good quality were selected and stored on well ventilated wooden racks

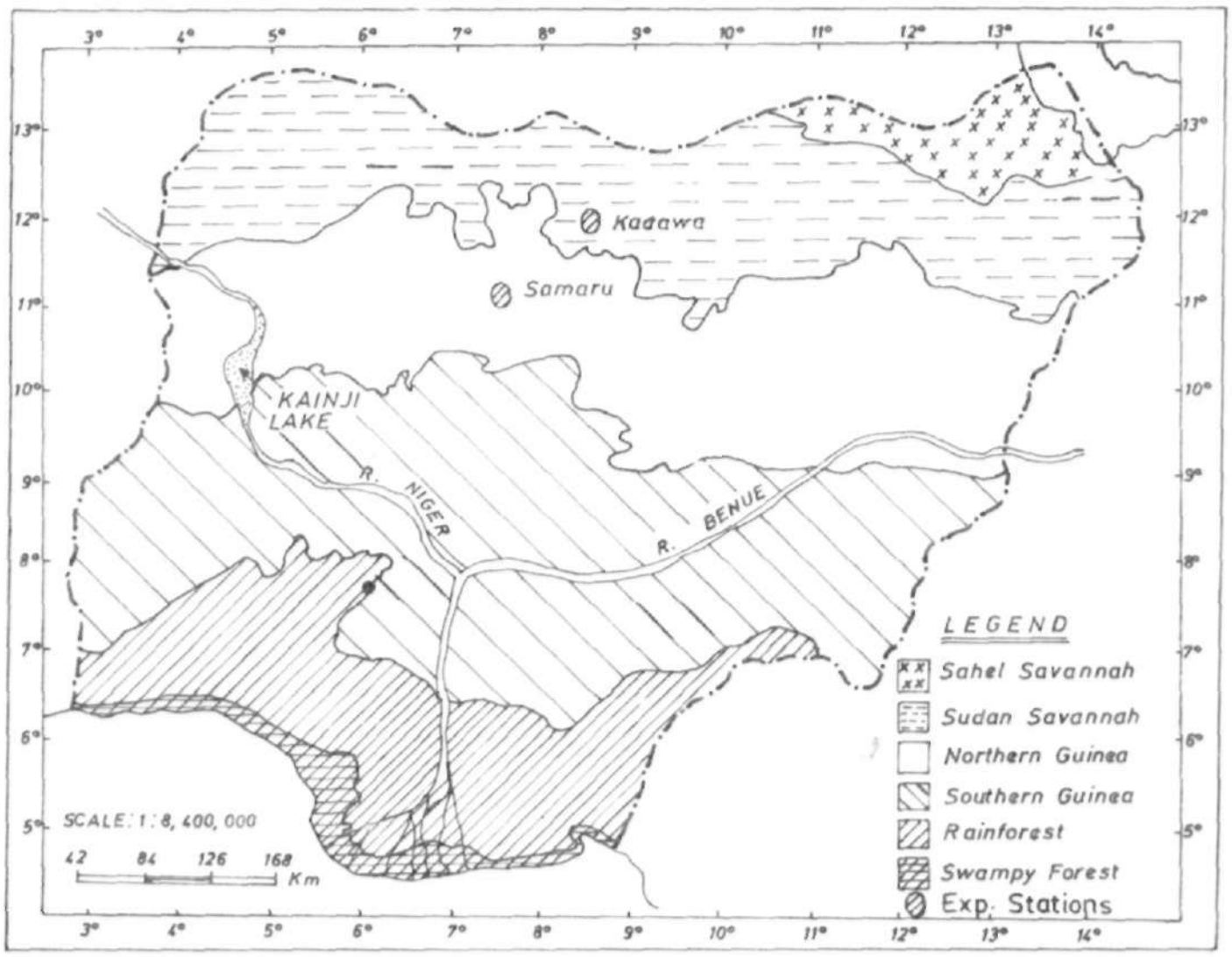


FIG.1 MAP OF NIGERIA SHOWING THE MAIN ECOLOGICAL ZONES. AND EXPERIMENTAL STATIONS

at the Horticultural Section of the Institute for Agricultural Research, Ahmadu Bello University Farm, Samaru from May to November 1981. A total of 10,084 bulbs were therefore stored. In November 1981, the mother bulbs of the seven varieties were planted in the Ahmadu Bello University Farm, Samaru to produce seeds under spatial isolation. Management practices carried out were as outlined by Green (1973), and as detailed under "Land Preparation and Cultural Practices".

Floral umbels of only two varieties namely - Maiduguri Improved and Ex Gayanawa were selected for the trials as these produced seeds abudantly. The seed umbels were harvested in the middle of April 1982 and were sun dried for a week, threshed and cleaned by hand. Sun dried seeds usually have high moisture content of about 18-20% hence it was necessary to further dry the seeds to an acceptable moisture content of 6-7%. To achieve this, the seeds were dried artificially at a temperature of 105^{O}C for 16 hours. During the drying, the seed moisture content was determined in accordance with the International Testing Associational Rules (1966), i.e. I.S.T.A. rules as outlined below.

(i) Determination of Moisture Content

50 grams of seeds were placed in crucibles (porcelain dishes) and initial weight was taken. Two samples were taken as test. The dish was placed on top of its cover

in an electrically heated oven, heated earlier on to 105°C and allowed to remain there for 16 hours. The electrically heated oven had a thermostatic control and removable perforated shelves. The seeds were weighed frequently as seed samples were being taken continuously every 1-2 hours to monitor seed moisture content, until a constant weight of 6.5% was arrived at for that lot. As soon as desired moisture content was achieved, seeds were placed in the desiccators to cool. The seed moisture content was calculated in accordance with the following International Seed Testing Association 1966 formula :

$$Mc = \frac{M_1 - M_2}{M_1} \times 100$$

where Mc = percent moisture content

M_1 = the weight of seed sample in grams before drying

M_2 = the weight of seed sample in grams after drying.

(ii) Seed Grading

Seeds were then graded into two different sizes. "Endecotte" test sieve separators, which have round holes, were used for this purpose. Large seeds were designated as those with more than 2.0mm sieve size but not more than 2.5 mm while small seeds were those with less than 2.0 mm sieve size. After grading, the seeds were subjected to artificial, corrective drying to 6.5% moisture content. This was done because the exposure of a sample into

an open mixing tray may cause a change in the moisture content.

After grading, seeds were put into the different storage containers. These included moisture proof polythene bags, baft bags and paper envelopes (Plates 1-6). The polythene bags were of 17.5 x 28 cm and 0.25 mm width and the baft bags were 20 x 28 cm. The storage equipment used were a refrigerator, a deep freezer, a pyrex desiccator and a well ventilated cool room.

3.2. Experimental Procedures

Seeds of Maiduguri Improved and Ex Gayanawa varieties, after being graded and dried as described above, were stored at different storage conditions (for seventeen months) and used for the major field trials carried out during the 1982/83 and 1983/84 dry seasons. Each trial was designed as a 2 x 2 x 4 factorial experiment (variety, seed size and storage conditions respectively). The treatments were replicated three times in a randomized block. The first trial of 1982/83 was carried out at Samaru, while that of 1983/84 was at Kadawa.

(1) Seed Storage Trial

Seeds were graded, redried to 6.5 per cent moisture content and placed in desiccators. For each seed size category, the weight of 1,000 seeds was assessed in



PLANTE 1 : Seed Storage:condition 1



PLATE 2 : Seed Storage:condition 2



PLATE 3 : Seed Storage:condition 3



PLATE 4: Seed Storage : condition 4



PLATE 5 : Seed Storage :condition 5



PLATE 6: Seed Storage: Condition 6

accordance with the I.S.T.A. rules (1966); the number of seeds/gram was also calculated from these data.

On May 20, 1982, after the initial laboratory seeds germination test, the seeds of both sizes were each subjected to the following storage conditions:

1. Polythene bags in room temperature.
2. Baft bags in room temperature.
3. Polythene bags in the refrigerator.
4. Baft bags in the refrigerator.
5. Paper envelopes in the desiccator over calcium chloride.
6. Polythene bags in the freezer.

During storage, seed germination tests according to I.S.T.A. rules (1966) were carried out at two monthly intervals from July 1982 to January 1983, and also in August 1983.

a) Viability test on Onion seeds

7 On each date, 100 onion seeds were taken from each storage treatment for germination tests. Each petri dish containing 9 cm whatman's filter paper was soaked with 10 ml distilled water. The 100 onion seeds were then uniformly distributed in each petri dish by use of forceps. A completely randomised design was used with 4 replications. The petri dishes were placed in room

temperature in the laboratory. Seedlings with normal roots measuring at least 2 mm or more in length were considered germinated when checked 9 and 14 days after planting. After 8 months of storage, two storage treatments, namely polythene bags in room temperature and baft bags in refrigerator were discontinued because of accelerated loss in seed viability.

(ii) The Nursery Trials

Two supplementary trials were carried out towards the end of September through to the beginning of November 1984, to find the effects of seed size and storage [illegible] conditions on field emergence and quality of seedlings. Seeds from the main storage trials had been utilised for the field trials, therefore, seeds of "Composite 4" variety stored for four months only were used for the nursery trials. Experimental procedures during the storage of the seed lot were the same as in the main seed storage trial, but only four storage conditions identified previously as the best were compared. There was inadequate time to store the seeds for longer periods of time since all nursery establishments were started between September and October of the trial years (Table 1). Both trials were designed as a 2 x 4 factorial experiment (seed size and storage conditions, respectively) and replicated four times in a complete randomised block.

In the first trial, 100 seeds were planted, 4 rows/ plot, on 18 September 1984. Each row was one meter long and the rows were 0.25 meter apart. Date of full seedling emergence, which was counted fourteen days after sowing, was recorded.

In the second trial, the plot size was 0.60 m x 0.80 m and 8 grams of seeds were drilled on 22 September 1984 in each plot consisting of 4 rows spaced at 16.0 cm apart. This gave 15.15 grams of seeds per square meter. The number of seeds per gram assessed before sowing was 360 and 308 for small (less than 2.0 mm) and large (2.0 to 2.5 mm) size respectively. Only the two central rows of each plot were used for plant stand assessments and seedling quality evaluation. Plant stands were counted after one and five weeks from field emergence. On the latter date, one hundred seedlings were taken at random for their quality evaluation. The number of transplantable seedlings were counted based on vigour and health of the seedlings. The number of true leaves (longer than 2 cm) per plant was determined on twenty-five plants, taken at random. Finally, fresh and dry matter of all the one hundred seedlings were determined. The freshly harvested seedlings were washed in distilled H_{20} and were dried in a ventilated oven at 65 - 70^{o}C for 36 hours, and then weighed to the nearest milligram. Each treatment was replicated four times. The above method was in accordance with the Association of official analytical chemists (A.O.A.C.), 1975.

(iii) Field Trials

Some seeds were removed from storage after five and seventeen months of storage and used for the first and second field trials respectively. The experimental details are given in Table 1. The second trial which was carried out at Kadawa was sown in the nursery one week earlier than at Samaru (Table 1). The seedlings planted at Kadawa later proved to be of better quality than those planted at Samaru. Both field trials were of complete randomised block design (2 varieties x 2 seed sizes x 4 storage conditions) and replicated three times.

During the growing season, number of leaves per plant was counted and plant height measured, seven, ten and thirteen weeks after transplanting. On each of these dates, ten plants taken at random from the four central rows of each plot were used for the tests.

Plants were harvested at a 75% foliar fall over, When about ¾ of the number of leaves per plant dropped down from the bulb neck of the plant. It is the characteristics of fallen onion leaves to become partially dried up. Foliar fall over refers only to non-bolting plants. As observed by Bednarz (1982), bolted plants will fall over only after the seeds formed are matured. Therefore both bolters and non-bolters do not exhibit same foliar fall over as bulbs mature and ripen for harvest. Plant stand

Table 1 : Experimental Details of the Field Trials

Operations	Location and Year	
	Samaru (1982/83)	Kadawa (1983/84)
Period of seed storage	5 months	17 months
Sowing date	22/10/82	15/10/83
Date of full emergence	31/10/82	24/10/83
Age of transplants	54 days	50 days
Transplanting date	24/12/82	13/12/83
Spacing	0.20 x 0.20m	0.20 x 0.20m
Plot size (sunken beds)		
Total	2.9 x 3.7m	2.7 x 3.1m
Planted area	2.4 x 3.4m	2.2 x 2.8m
Planted/total plot area ratio	0.760	0.736

was counted shortly before harvest and date of harvest recorded. After harvesting, bulbs were cured and dried for one week under shade and then separated into bolters, healthy mature bulbs, splits, diseased bulbs and immature bulbs. Yields were calculated in tons per hectare.

Indices used for yield analysis include:

1. Total yield of bulbs in tons/hectare.
2. Bolters, rotten bulbs and splits as percentage by weight of bulbs harvested.
3. Marketable yield in tons/hectare. Marketable yield is defined as healthy, mature bulbs of all sizes as well as healthy bolters. Thus splits, diseased bulbs and immature bulbs were excluded.

3.3. Environmental conditions of the Trials and Production Practices.

(i) Microclimate conditions in the seed storage trials

Due to lack of facilities such as thermohydrographs and other weather instruments, only daily temperatures were recorded in three storage chambers, namely, the refrigerator, the freezer and the seed store. With the exception of the freezer, whose temperature was recorded only once a day, i.e., at noon, as the temperature there was fairly constant, the other temperatures were recorded at 8.00 a.m., 12.00 noon and 4.00 p.m. Mean daily

temperatures were calculated on a monthly basis and are shown in Table 2. The night temperatures, although not determined, were usually lower than the day temperatures, especially during the dry season period (October to February).

From Table 2, it can be seen that the daily room remperatures ranged from 21°C to 27°C the highest being recorded between March and July of each year. In comparison with the room temperature, the refrigerator temperatures were lower by about 12.2 to 17.4°C and varied at a range of 3.4°C to 11.5°C, the lowest temperatures being recorded in December in both years. The temperatures in the freezer were at a range of 2 to 12°C below zero. When compared with the room temperatures, the reduction in temperatures of both the refrigerator and freezer were not consistent because of electricity fluctuation, especially in June in both years. On some days in this month, the temperatures in the refrigerator were only a few degrees lower than those in the seed store, while the temperatures in the freezer were sometimes a few degrees above zero. This is not reflected in the table as averages only are shown for each month.

Due to lack of appropriate measuring devices, air humidity in the storage chambers was not recorded. From data presented in Tables 3 and 4, it may however

Table 2 : Mean Monthly Temperatures (^{O}C) in Seed Storage Chambers in Samaru in 1982 and 1983 Trial Periods

Year and Month	Refrigerator	Freezer	Room Temperature
1982			
May	10.2	-9.8	26.5
June	13.1	-5.7	25.8
July	9.2	-12.1	24.2
August	8.3	-9.7	23.3
September	10.4	-8.2	23.7
October	11.8	-5.3	24.0
November	12.0	-8.0	23.2
December	4.8	-11.4	22.1
1983			
January	5.9	-11.5	21.8
February	9.9	-10.3	23.3
March	11.7	-8.3	25.1
April	11.3	-6.2	26.7
May	13.2	-7.8	26.5
June	14.5	-3.9	25.2
July	8.3	-10.4	25.3
August	5.5	-12.2	24.4
September	9.2	-8.8	23.8
October	10.0	-2.3	23.4
November	8.2	-10.1	22.2
December	3.4	-11.8	20.8

however be estimated that the relative air humidity in the seed store was at a range of 11-21% in the driest part of the years (November to April) and between 60-80% in the rainy season months (May to September). The relative air humidity was certainly higher in the refrigerator and freezer than in the other storage conditions, especially during the rainy months.

(ii) Nursery and Field Trials:

Weather Conditions

The weather conditions during the periods of the nursery and field trials are presented in Table 3 and 4. Seedlings for both field trials in 1982 and 1983 were produced at Samaru from the later part of October till the middle of December. Only slight differences can be detected in weather conditions between both years during that time (Table 3). On the average, the air temperatures were similar in both years, though in 1983, the differences between the maximum and minimum temperatures were somewhat higher than in 1982. In October 1982, in contrast to 1983, some rainfall was recorded and relative air humidity was two times higher. However, the rains occurred at the beginning of the month and thus were unlikely to affect seedling emergence. On the other hand, in November and December, after seedling emergence, the weather conditions for the growth of onion transplants seemed to be more favourable in 1983 than in the previous year. This was as a result of more hours of sunshine, weaker winds and lower evaporation.

Table 3: 1982/83 and 1984 Meteorological Data for Samaru

Period of time	Sunshine (hours)	Windrun (km/day)	Evap. (mm)	Temp. °C Max.	Temp. °C Min.	RH %	Rain Fall (mm)
1982							
May	8.2	206.71	8.7	33.5	21.8	56.8	72.1
June	7.3	197.13	7.6	30.8	21.0	66.4	113.9
July	6.6	167.85	5.5	29.5	19.9	71.4	168.9
August	6.6	134.38	4.9	28.0	19.5	76.3	190.7
September	7.1	105.70	5.2	29.6	19.5	70.7	117.6
October	8.0	101.26	6.1	31.1	18.7	60.2	45.8
November	8.0	112.37	9.6	30.1	13.3	20.9	0.0
December	8.4	139.38	11.2	30.0	13.6	14.9	0.0
1983							
January	3.5	253.54	10.1	23.6	13.8	18.5	0.0
February	8.1	173.78	13.3	32.4	18.1	10.8	0.0
March	7.7	197.22	15.1	33.0	17.0	13.6	0.0
April	7.7	155.00	13.7	37.5	19.9	17.6	0.0
May	8.6	240.30	10.9	34.7	21.6	51.1	72.3
June	6.9	230.70	7.6	31.9	19.6	62.4	74.3
July	6.7	186.70	5.4	28.8	23.4	72.7	107.5
August	6.7	116.40	5.4	28.4	16.7	75.6	259.7
September	7.4	98.00	4.6	29.9	17.3	68.4	95.2
October	7.5	91.00	6.1	31.8	14.3	30.5	0.0
November	9.3	73.90	8.4	32.0	12.6	17.4	0.0
December	8.6	90.00	10.0	32.0	12.9	16.2	0.0
1984							
May	7.7	225.2	7.9	31.9	21.3	67.4	98.9
June	7.3	201.1	6.9	31.5	20.5	70.8	55.4
July	6.4	160.4	6.3	28.9	19.2	79.0	173.8
August	8.1	143.6	6.1	29.8	19.5	77.1	158.1
September	6.9	90.00	5.4	29.5	19.2	70.8	189.0
October	6.7	67.00	5.3	30.5	18.6	60.6	178.0
November	7.7	87.00	5.7	31.2	13.6	22.4	0.0

Source: Irrigation Research Programme 1983-1984 and 1985, IAR, A.B.U., Zaria.

Table 4: 1983/84 Meteorological data for Kadawa

Period of time	Windrun (km/day)	Evap. (mm)	Temp. °C Max.	Temp. °C Min.	RH %	Rainfall (mm)
1983						
December	129.5	7.2	30.4	13.9	34	0.0
1984						
January	147.0	7.2	26.4	12.2	43	0.0
February	138.2	7.3	30.3	14.9	42	0.0
March	129.6	9.3	36.3	19.6	34	0.0
April	129.8	10.5	37.5	22.7	41	Trace
May	225.2	7.1	31.5	21.3	59	98.9

Source: Progress Report (1983/84), Irrigation Research Programme, IAR, A.B.U., Zaria.

(a) Weather conditions of the Nursery Trials

The nursery trials for seedling quality evaluation were also carried out at Samaru. However, these seeds were sown in September, 1984, about one month earlier than those of the nursery establishment used as transplants for the field trials. Consequently, the weather conditions during the nursery trials were more humid than during the time of seedling production for field trials (Table 3). In September and October 1984, the amount of rainfall was significantly higher while the amount of evaporation was much lower than during the respective months of the previous two years. The drop in evaporation may be related to lower solar radiation and relatively slow

winds as both the air temperature and air humidity were average.

(b) Weather conditions of the Field Trials

It is not possible to make comprehensive comparison between the weather conditions after transplanting for both field trials because data on number of sunshine hours for Kadawa were not available. However, from other meteorological data covering the time from December to April, it may be concluded that on the average the weather conditions at Kadawa (1983/84) were more favourable for onion growth than those at Samaru (1982/83), Tables 3 and 4). At Kadawa, in particular, the winds were not so strong, evaporation was considerably lower and relative air humidity higher than at Samaru.

(iii) Soil Conditions

The nursery trials were carried out at the Horticulture Section of the College of Agriculture, Samaru; while the first field trial was carried out at the University Research Farm, Samaru and the second at Kadawa Irrigation Research Station. The experimental fields at Samaru had deep, well drained soils with 40-60 cm thick sandy loam surface horizons. The subsoils were clay loams at 100-200 cm depth. Occasionally, iron pans occurred below 150 cm from soil surface (Valette and Ibanga, 1984).

The soil of the experimental field at Kadawa was deep (over 152 cm), unmottled, sandy soil over relatively impermeable mottled alluvial horizon. The colour of the top soil was pale brown to yellowish brown and there was no mottling seen. The subsoil was sandy clay loam, light gray with iron and manganese mottles, while the top soil was loamy (I.A.R. Irrigation Programme, 1983). Thus, the soils at Samaru was poorer than those at Kadawa.

(iv) Land Preparation and Cultural Practices

Standard land preparation and cultural practices were applied to both nursery and field trials in accordance with the current AERLS recommendations (Anon 1981b) and as detailed below.

(a) Transplant Production

The field was ploughed during the first week of October in both years. One week after ploughing, sunken beds (basins) were made for transplants to be used for the field trials. Plot size for the nursery seedlings was 2.0 m x 2.0 m and seeds were drilled in rows 15 cm apart. Each plot was planted with 30 grams of seeds. Nursery beds were mulched with dry grass for fifteen days and watered throughout this establishment by use of cans. The nurseries were hand weeded regularly before transplanting to the field.

For the nursery trials on seedling quality and evaluation of growth analysis, smaller sized beds, 1 sq.m and 0.60 x 0.80 m respectively were used. Well rotted farm yard manure at a rate of 2 kg/m^2 and superphosphate at a dose of 21 g/m^2 were applied as basal dressings. The soil was then worked into a fine tilth. Seeds were treated with Dithane M-45 at 4 g/kg of seeds and sown thinly (7-10 gms/m^2) at a depth of 1.0 - 1.3 cm and covered with fine soil. Mulching and watering were done as above. Weeds were hand pulled when noticed. Three weeks after emergence, 14 grams of Ammonium sulphate in 4.5 liters of water was applied to two square meters of the soil bed area. At the time of transplanting, the seedlings were about 15-22 cm in height.

(b) Bulb Production

The fields were ploughed two weeks to transplanting at both locations. Farm yard manure at the rate of 12 tons per hectare with a base dressing of 250 kilograms per hectare of superphosphate were harrowed into the fields in both locations one week before transplanting. Seedlings were transplanted on basins at a square spacing of 20 cm x 20 cm. Calcium Ammonium Nitrate at the rate of 250 kg/ha was applied as two equally split top dressings, 3 and 6 weeks after transplanting.

Check basin irrigation was given two times a week and reduced to once a week at 9-10 weeks after transplanting.

Irrigation was stopped during the first week of April to allow for proper maturation and ripening of the bulbs. Light watering was resumed two days to harvest to allow for effective lifting of the bulbs from the soil. Also 50% malathion at 2250 cc in 225 liters of water per hectare was applied two times at two weekly intervals of 5 and 7 weeks (after transplanting) to control thrips. The field was shallowly cultivated three times with the use of small, special, onion hoes to control weeds.

CHAPTER FOUR

RESULTS

4.1. Results of the seed storage trial

4.1.1. Initial onion seed quality

There was no significant difference in the initial laboratory germination of ungraded seeds between the two varieties studied (Table 5).

Table 5: Initial laboratory germination of ungraded onion seeds

Variety	Seed Germination %
Maiduguri Improved	96.5
Ex Gayanawa	97.5
LSD 0.05	n.s

Foot Note: In this and other tables giving the results of laboratory germination test, the figures have been expressed as percentages because 100 seeds were used for each test.

From the grading, it was observed that for both size categories seed weight and number of seeds/gram differed. Seeds of Ex Gayanawa were heavier than seeds of Maiduguri Improved (Table 6). The difference was quite remarkable as the smaller sized seeds of Ex Gayanawa were heavier by 11.1% in comparison with those of Maiduguri Improved, while for the larger sized seeds, the difference in favour of Ex Gayanawa reached 19.4%.

Table 6: Seed weight and number in relation to variety and seed size category

Variety	Seed Size (mm)	Initial weight 1000 seeds (g)	Mean no. of seeds per gram
Maiduguri Improved	Less than 2.0	2.53	395
	2.0 - 2.5	3.15	317
Ex Gayanawa	Less than 2.0	3.02	331
	2.0 - 2.5	3.50	286

4.2. Laboratory seed germination during storage

Each of the three factors studied, (variety, seed size and storage conditions) significantly influenced laboratory seed germination at least at some sampling dates.

(i) The effect of Variety

At the last sampling dates, laboratory seed germination of Ex Gayanawa variety was significantly higher than that of Maiduguri Improved (Table 7). This could be due to the heavier seeds exhibited by Ex Gayanawa (Table 6) which made it superiod to Maiduguri Improved, (Figure 2).

Table 7: The effect of variety on onion seed laboratory germination (%)

Variety	Months in Storage				
	2	4	6	8	15
Maiduguri Improved	92.6	90.8	84.8	78.8	67.4
Ex Gayanawa	93.8	92.1	85.8	80.6	69.2
LSD at 0.05	n.s	n.s	n.s	1.1	1.6

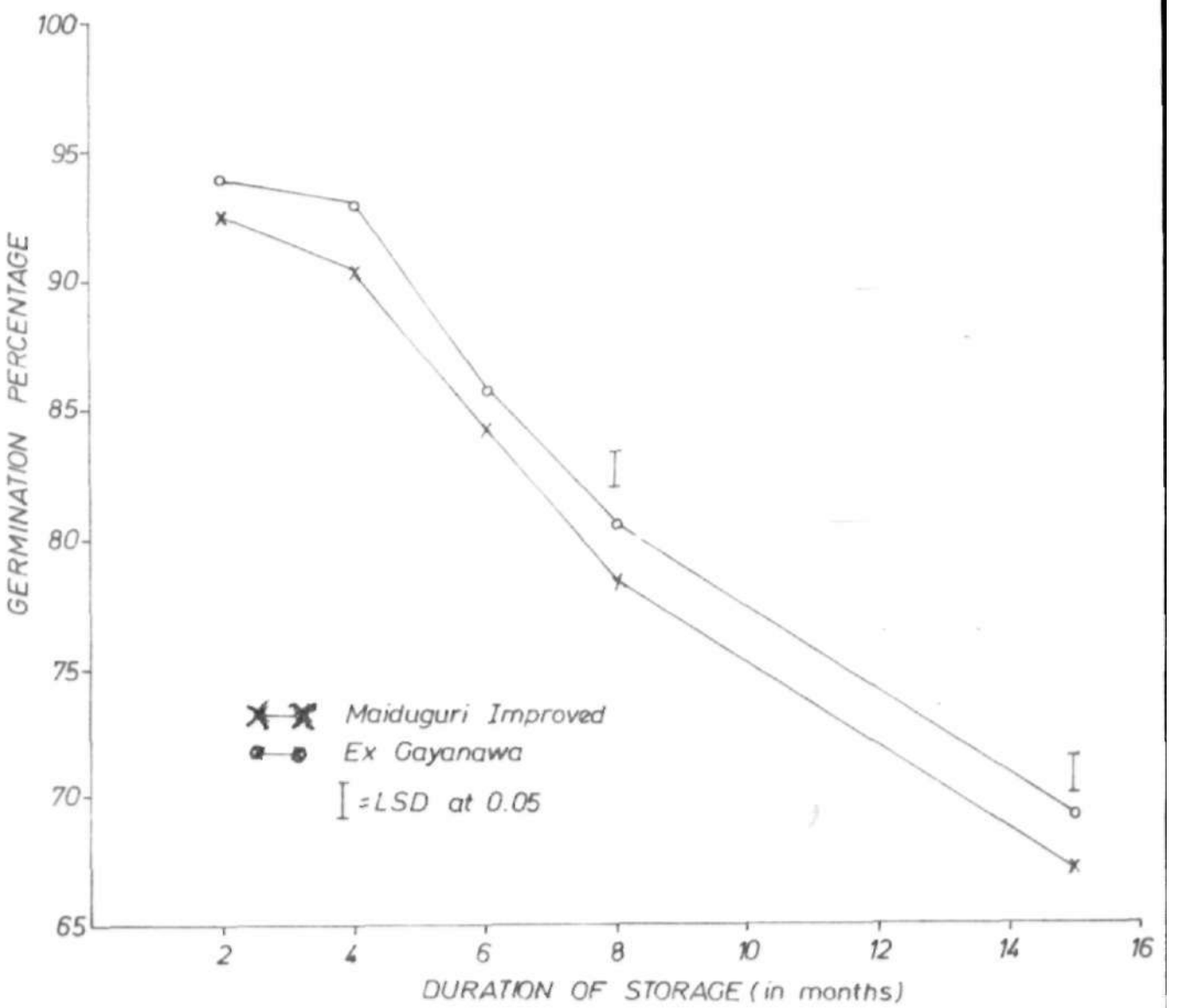


Fig. 2 Percent laboratory germination of two onion varieties.

For both varieties studied, seed germination declined with successive sampling dates (Figure 2), especially after four months of storage. However, Ex Gayanawa variety performed somewhat better.

(ii) Effect of Seed Size

At most sampling dates and especially toward the end of the storage period, seed germination was significantly higher for the larger seeds than for the smaller ones (Table 8). For this reason, the germination of Ex Gayanawa which had heavier seeds than Maiduguri Improved was higher than that of the latter (Figure 2).

Table 8: The effect of seed size on onion seed laboratory germination (%)

Factors Seed Size	Months in storage 2	4	6	8	15
Less than 2.0 mm	92.2	91.1	84.4	78.8	66.3
2.0 - 2.5 mm	94.1	91.9	86.1	80.7	70.4
LSD at 0.05	1.3	n.s	1.2	1.1	1.6

Figure 3 indicates that there was a decline in seed germination with storage periods in both sizes. The larger seeds performed significantly better throughout the storage period. As evidenced in figure 3, there was also a gradual decrease in seed germination at 2 - 4 months of storage. This decrease was however less in the small sized seeds which had initial lower seed viability.

After 4 months of storage, both seed sizes followed almost the same pattern of reduction in viability. At the end of the storage period, the germination rate of the larger seeds was 70.4% while that of the smaller seeds was 66.3%.

(iii) The Effect of Storage Conditions

Three of the storage conditions, namely baft bags in room temperature, polythene bags in the refrigerator and polythene bags in the freezer were the best in onion laboratory seed germination and were not significantly different after 15 months of storage (Table 9).

Seeds stored very well in the desiccator during the first eight months but after 15 months of storage, their germination was significantly lower than those in the treatments mentioned above. Considerably lower laboratory germination was recorded for seeds stored in polythene bags in room temperature and baft bags in the refrigerator after 4 months of storage (Figure 4) with the later storage treatment being significantly worse.

The two storage treatments, namely beft bags in the refrigerator and polythene bags in room temperature were discarded after 8 months of storage due to low germination rate (Table 9).

In figure 4, storage methods 2 (Baft bags in room temperature), 3 (Polythene bags in the refrigerator) 6 (Polythene bags in the freezer) and later 5 (Paper

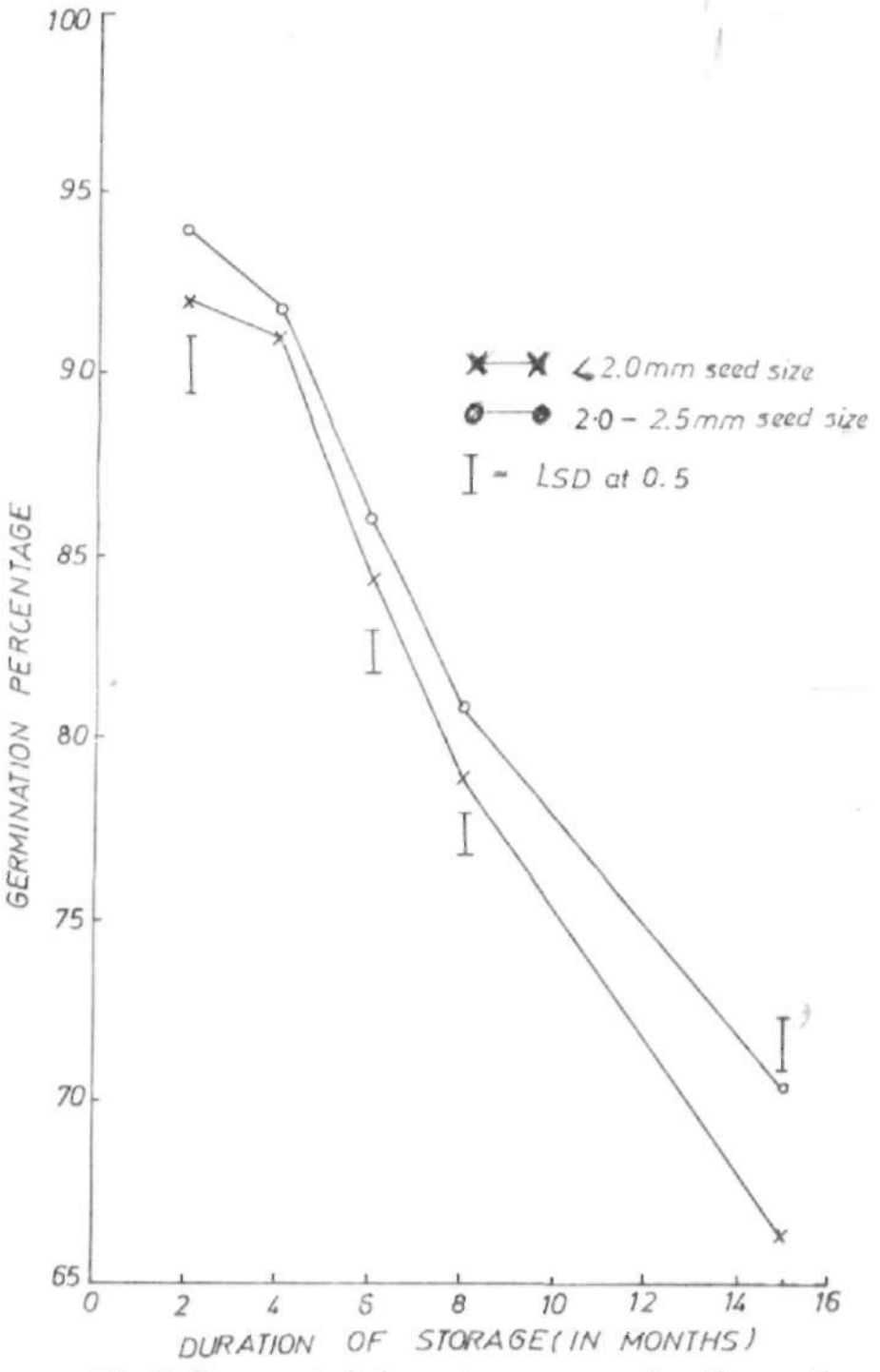


Fig.3 Percent laboratory germination of two onion seed sizes.

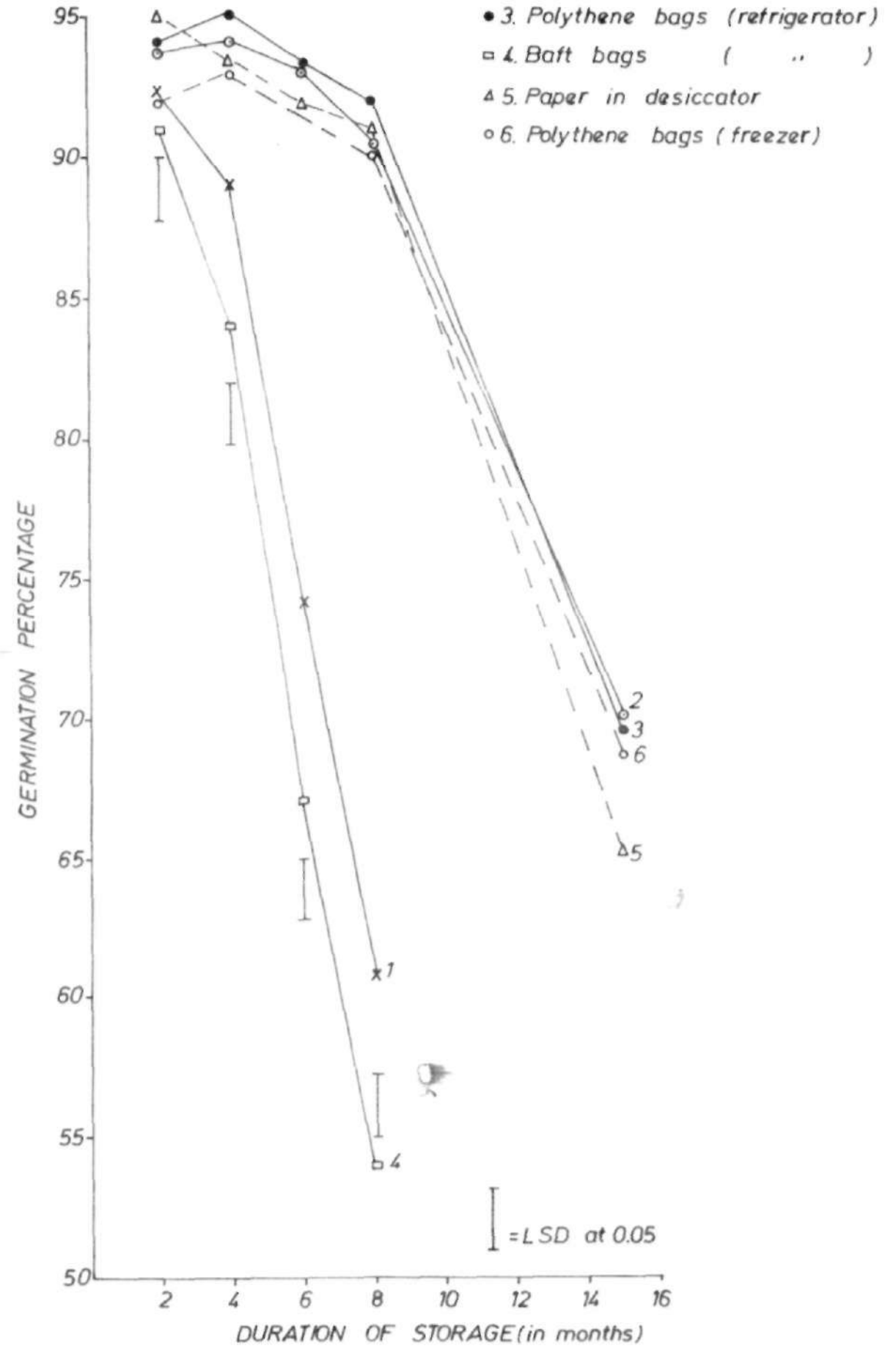


Fig. 4 Percent laboratory germination of onion seeds under different storage conditions

envelopes in the desiccator) behave almost in the same way. The decrease in seed germination was gradual up to 8 months of storage after which there was an accelerated decline in germination of all the four storage methods mentioned above. However, there was an accelerated decline in seed germination rates of storage methods 1 (polythene bags in room temperature) and 4 (baft bags in the refrigerator) right from the beginning to the end of the storage period. Also increase in moisture content of all seeds in the various storage conditions was observed (Table 10).

Table 9: The effect of storage conditions on laboratory seed germination of onion (%)

Storage Conditions	Duration of storage (months)				
	2	4	6	8	15
Polythene bags (Room Temp.)	92.3	89.0	74.2	60.9	-
Baft bags (Room Temp.)	93.6	94.0	93.0	90.5	70.0
Polythene bags (Refrigerator	94.2	95.0	93.4	92.0	69.5
Baft bags (Refrigerator)	91.8	84.2	67.0	54.0	-
Paper envelopes in the desiccator	95.0	93.6	92.0	91.0	65.2
Polythene bags (Freezer)	92.0	93.0	92.4	90.0	68.6
LSD at 0.05	2.2	2.4	2.1	2.0	2.2

It was observed that the treatments with low seed germination (polythene bags in room temperature and Baft bags in the refrigerator) also had higher moisture content at 5 months (October 1982) of storage (Table 10).

Table 10: Moisture content of onion seeds in relation to storage conditions and duration of storage

Storage Conditions	% moisture content May 1982	Oct. 1982	Aug. 1983	Oct. 1983
1 Polythene bags (Room Temp.)	6.5	9.2	-	-
2 Baft bags (Room Temp.)	6.5	6.9	7.5	9.1
3 Polythene bags (Refrigerator)	6.5	7.1	8.2	8.8
4 Baft bags (Refrigerator)	6.5	11.8	-	-
5 Paper envelopes in desiccator	6.5	5.8	4.6	4.4
6 Polythene bags in freezer	6.5	7.6	8.7	9.9

The differences between varieties and seed sizes were negligible, therefore only averages for seed storage conditions are presented.

Shortly before the seeds were discarded, mould growth was observed on seeds stored in polythene bags at room temperature while some of the seeds stored in baft bags in the refrigerator showed visible sprouting (Plates 7 and 8). From Table 10, it can be seen that storage in the desiccator allowed the seeds to be drier than they were originally and this may account for its lower seed germination after 15 months of storage in comparison to the other three storage conditions (Figure 4).

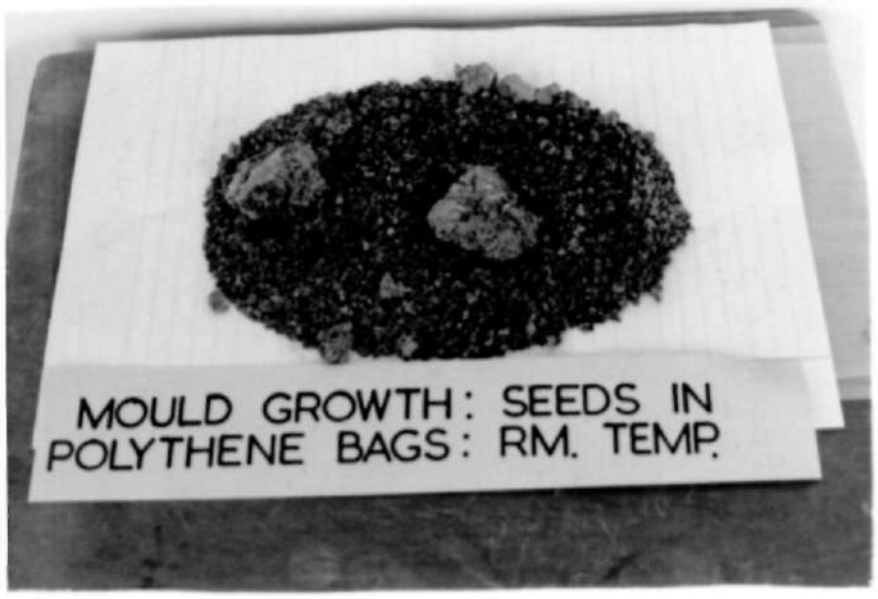


PLATE 7 : Seed Storage after 8 months in Condition 1



PLATE 8: Seed storage after 8 months in Condition 4

(iv) Interactions of Factors Studied

With the exception of the first sampling date (after 2 months), no significant interaction was observed for all the three main factors, namely, variety, seed size and storage conditions as they affect seed laboratory germination. However, on some sampling dates, significant interactions were found for the three pairs of factors, (Tables 11, 12 and 13). Amongst these three pairs of factors, the interaction between storage condition and variety (Table 12) as well as between storage conditions and seed size (Table 11) were most persistent.

(a) Effect of seed size and storage conditions

During the first 8 months of storage, with the exception of the second sampling date, significant interaction was observed between the storage conditions and seed size as they affect seed germination in the laboratory (Table 11). Initially, seed storage in baft bags in the refrigerator and polythene bags in the freezer were less favourable for the small than the large seeds. At later sampling dates, it was observed that the small seeds stored in baft bags in the refrigerator or in polythene bags at room temperature showed consistently lower germination percentage than the large seeds stored at the same conditions.

However, when the two worst storage conditions were discarded, there was no significant interaction between all the other storage conditions and seed size.

Table 11: The interaction between seed size and storage conditions on onion seed laboratory germination (%)

Size and Storage conditions	Duration of storage (months) 2	4	6	8	15
Less than 2.0 mm					
Polythene bags (Room Temp)	93.5	89.0	72.0	57.8	-
Baft bags (Room Temp.)	93.5	96.0	94.0	91.0	67.0
Polythene bags (Refrigerator)	93.5	94.0	92.9	92.0	69.5
Baft bags (Refrigerator)	88.0	88.5	65.0	51.0	-
Paper envelopes in the desiccator	95.5	93.0	92.0	92.0	63.5
Polythene bags in freezer	89.5	93.0	91.0	89.0	65.8
2.0 - 2.5 mm					
Room Temp. (Polythene bags	91.1	90.0	76.5	64.0	-
Baft bags (Room Temp.)	93.8	93.0	92.0	90.0	73.0
Refrigerator (Polythene bags)	95.0	96.0	94.0	92.0	70.0
Refrigerator (Baft bags)	95.5	85.0	69.0	57.0	-
Paper envelopes in the desiccator	94.5	94.0	92.0	90.0	67.0
Polythene bags in freezer	94.5	93.0	93.0	91.0	71.5
LSD at 0.05	3.1	n.s	3.0	2.8	n.s

(b) Effect of Variety and Storage Conditions

Similar pattern described above was observed for the interaction between variety and storage conditions but not as pronounced as in (Table 12). After 8 months of storage in the polythene bags at room temperature, and

baft bags (Refrigerator) significantly lower laboratory seed germination was recorded for Maiduguri Improved, the variety that had lighter seeds.

Table 12: The interaction between variety and storage conditions on onion seed germination (%)

Storage and Variety	Duration in months 2	4	6	8	15
Maidiguri Improved					
Polythene bags (Room Temp)	92.6	88.0	71.0	58.0	-
Baft bags (Room Temp.)	94.8	94.0	93.0	91.0	69.0
Polythene bags (Refrige-rator)	93.0	95.0	93.5	91.0	68.5
Baft bags (Refrigerator)	88.5	81.5	66.0	53.0	-
Paper envelopes in desiccator	96.0	94.0	93.0	91.0	64.0
Polythene bags in freezer	90.5	93.0	92.0	89.0	68.2
Ex Gayanawa					
Polythene bags (Room Temp)	92.0	90.0	77.5	63.8	-
Baft bags (Room Temp.)	92.5	95.0	93.0	90.0	71.0
Polythene bags (Refrige-rator)	95.5	95.0	93.2	93.0	70.5
Baft bags (Refrigerator)	95.0	87.0	68.0	55.0	-
Paper envelopes in desiccator	94.0	93.0	91.0	91.0	66.5
Polythene bags in freezer	93.5	93.0	91.0	91.0	69.0
LSD at 0.05	3.1	n.s	3.0	2.8	n.s

(c) Effect of Variety and Seed Size

The interaction between these two factors, was significant at the beginning of storage only (Table 13 and Figure 5).

Table 13: The interaction between variety and seed size on onion seed germination (%)

Variety and Seed Size	Months in Storage 2	4	6	8	15
Maiduguri Improved					
Less than 2.0 mm	90.7	89.7	83.5	78.0	65.5
2.0 - 2.5 mm	94.4	92.0	86.0	79.7	67.2
Ex Gayanawa					
Less than 2.0 mm	93.8	92.5	85.5	79.6	69.0
2.0 - 2.5 mm	93.7	91.8	86.2	81.7	71.5
LSD at 0.05	1.8	2.0	n.s	n.s	n.s

At most sampling dates, larger seeds germinated better than smaller seeds for both varieties studied. At 2 - 4 months of storage (Table 13), the germination of large seeds of Maiduguri Improved was significantly higher than that of its smaller seeds. Such was not the case with Ex Gayanawa variety which had almost the same rate of germination for both seed sizes.

(v) The interaction of onion variety, seed size and storage conditions

Significant interaction of all the three factors studied as they affect seed germination in the laboratory

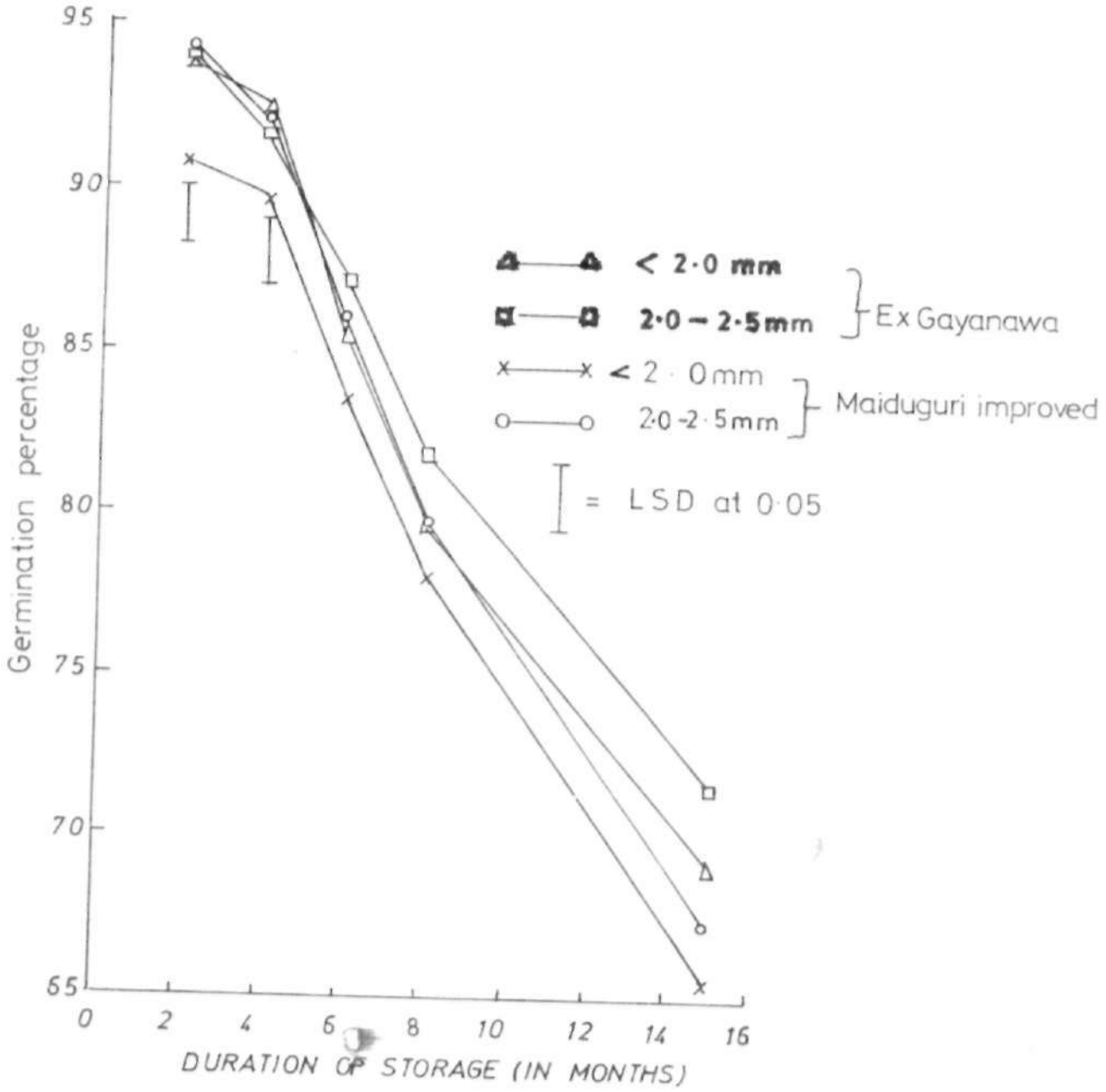


Fig.5. Percent laboratory germination of onion seeds as influenced by varieties and seed size.

was recorded only for the first sampling date i.e. after two months of storage (Table 14). This interaction is only of little importance as onion seeds are supposed to be stored for much longer period than two months. The differences in laboratory seed germination between all treatments studied were comparatively small, being at a range of 7% only.

Table 14: The interaction of variety, seed size and storage conditions on laboratory seed germination after 2 months storage (%)

Storage Conditions	Seed Sizes	
	Less than 2.0 mm	2.0-2.5mm
Maiduguri Improved		
Polythene bags (Room Temp.)	92.0	93.2
Baft bags (Room Temp.)	97.0	92.5
Polythene bags (Refrigerator)	92.0	94.0
Baft bags (Refrigerator)	82.0	95.0
Paper envelopes in desiccator	96.0	96.0
Polythene bags in freezer	85.0	96.0
Ex Gayanawa		
Polythene bags (Room Temp.)	95.0	89.0
Baft bags (Room Temp.)	90.0	95.0
Polythene bags (Refrigerator)	95.0	96.0
Baft bags (Refrigerator)	94.0	96.0
Paper envelopes in desiccator	95.0	93.0
Polythene bags in freezer	94.0	93.0
LSD at 0.05	4.4	

4.3. Results of the Nursery Trial

Initial germination of ungraded seeds of Composite 4 was 98.2%. After seed grading it was found that average weight of 1000 seeds was 2.78 grams for the small seeds and 3.25 grams for the large seeds respectively. Moisture content at the commencement of the trial was 6.5% for all the treatments.

The data on laboratory germination after 4 months of storage as related to seed size and storage conditions are shown in Table 15. There was no significant effect between seed size and storage conditions in laboratory seed germination. Also the differences in seed moisture content were not significant.

Table 15: Onion seed of Composite 4, germination and moisture content after 4 months of storage

Seed size and Storage conditions	Seed Laboratory germination (%)	Moisture content (%)
Less than 2.0 mm		
Baft bags (Room Temp.)	96.2	6.9
Polythene bags (Refrigerator)	96.3	7.1
Polythene bags (Freezer)	95.8	7.3
Paper envelopes (desiccator)	95.9	6.2
2.0 - 2.5 mm		
Baft bags (Room Temp.)	95.9	7.0
Polythene bags (Refrigerator)	96.0	7.3
Polythene bags (Freezer)	96.2	7.5
Paper envelopes (desiccator)	95.8	6.3
LSD at 0.05	n.s	n.s

(i) Field emergence of onion as influenced by seed storage conditions and seed size

As shown in table 16, field emergence of onion was about 50% and was not significantly influenced by seed storage conditions, or seed size, neither was there any significant interaction between these two factors.

Table 16: Field emergence of onions in relation to storage conditions and seed size

Treatments	Emergence at 2 weeks after sowing (%)
Storage Conditions	
Baft bags (Room Temp.)	50.2
Polythene bags (Refrigerator)	48.2
Polythene bags (Freezer)	48.5
Paper envelopes (Desiccator)	49.8
LSD at 0.05	n.s
Seed Size	
Less than 2.0 mm	49.8
2.0 - 2.5 mm	50.4
LSD at 0.05	n.s

(ii) The effect of storage conditions and seed size on the efficiency of transplant production

No significant interaction was observed between seed storage conditions and seed size on the number of seedlings per unit area or the seedling growth parameters. Also none of the factors had significant influence on number of seedlings per unit area, percentage of transplantable seedlings or seedling quality (Table 17).

Table 17: The effect of storage condition and seed size on emergence and quality of onion seedlings

Treatments	No. of seeds sown per m^2	Field emergence (%)	No. of seedlings/m^2 days after emergence		35 days after emergence			
			7	35	% of transplantable seedlings	Mean No. of leaves per plant	Mean wt. of 100 seedlings (g) Fresh matter	Dry matter
Storage Conditions								
Baft bags (Room Temp.)	5060	47.0	2380	1503	31.2	2.4	24.9	3.3
Polythene bags (Refrigerator)	5060	46.7	2361	1684	33.3	2.3	24.3	3.3
Polythene bags (Freezer)	5060	49.3	2520	1667	32.9	2.4	23.7	3.0
Paper Envelopes (Desiccator)	5060	47.8	2419	1706	33.7	2.3	23.2	3.0
LSD at 0.05		n.s	n.s	n.s	n.s	n.s	n.s	n.s
Seed size								
Less than 2.0 mm	5454	46.3	2524	1724	31.6	2.4	24.3	3.2
2.0 - 2.5 mm	4666	49.6	2315	2315	33.3	2.4	23.7	3.1
LSD at 0.05		n.s	n.s	n.s	n.s	n.s	n.s	n.s

Foot Note: No significant interaction of the factors was found. The average number of seeds sown over both seed sizes was 5060/m^2, The average number of seedlings as % of seeds sown was 48.0 and 32.4 after 7 and 35 days from field emergence respectively.

Averaging for all treatments, field emergence was about 48% (Table 17) which was close to that in the first nursery trial (Table 16). As the number of small seeds sown per unit area was higher by about 17% as compared with the larger ones, they produced about 9% higher number of seedlings/m^2 than the larger seeds. This difference, however, was statistically insignificant (Table 17).

About one third of the seedlings died between the first and fifth week after emergence (Table 17). Seedling survival, however, was not significantly influenced by the factors studied.

4.4. Results of the field trials

(i) The effect of variety, seed size and storage conditions on onion growth and maturity

On average for both locations and all the treatments studied, number of leaves per plant and plant height increased significantly between 7 and 13 weeks after transplanting (Table 18, Figures 6 and 7). However, onion growth in Samaru trial was markedly slower in comparison to the other trial at Kadawa (Table 19 and Figures 8 and 9).

Figures 6 and 7 are growth patterns of the onion plant some weeks after transplanting. It can be seen that onion growth in 7-13 weeks after transplanting was very vigorous. Between the consecutive sampling dates, there were significant increases in number of leaves/plant and in plant height.

Table 18: Number of leaves/plant and plant height in onion after transplanting

Weeks after transplanting	No. of leaves per plant	Plant height (cm)
7	5.9	24.0
10	7.5	43.0
13	8.8	53.7
LSD 0.05	1.03	2.22

Table 19: Number of leaves/plant and plant height (cm) at both locations

Location	Weeks after transplantating 7	10	13	LSD at 0.05
No. of leaves/plant				
Samaru	3.9	6.2	8.8	1.46
Kadawa	7.9	8.8	8.8	
Plant height (cm)				
Samaru	16.3	37.9	55.4	3.15
Kadawa	31.7	48.2	52.0	

The number of onion leaves/plant at Kadawa were significantly higher than at Samaru at 7 and 10 weeks after transplanting. By 13 weeks after transplanting, the growth pattern seemed to be the same for both locations.

The increases in plant height of onion was more significant at Kadawa 7-10 weeks after transplanting than at Samaru (Figure 9). However, the interaction between plant height and location ceased to exist at 13 weeks after transplanting.

None of the three factors studied had significant effect on number of leaves per plant (Table 20). Seed size and storage conditions did not have any significant

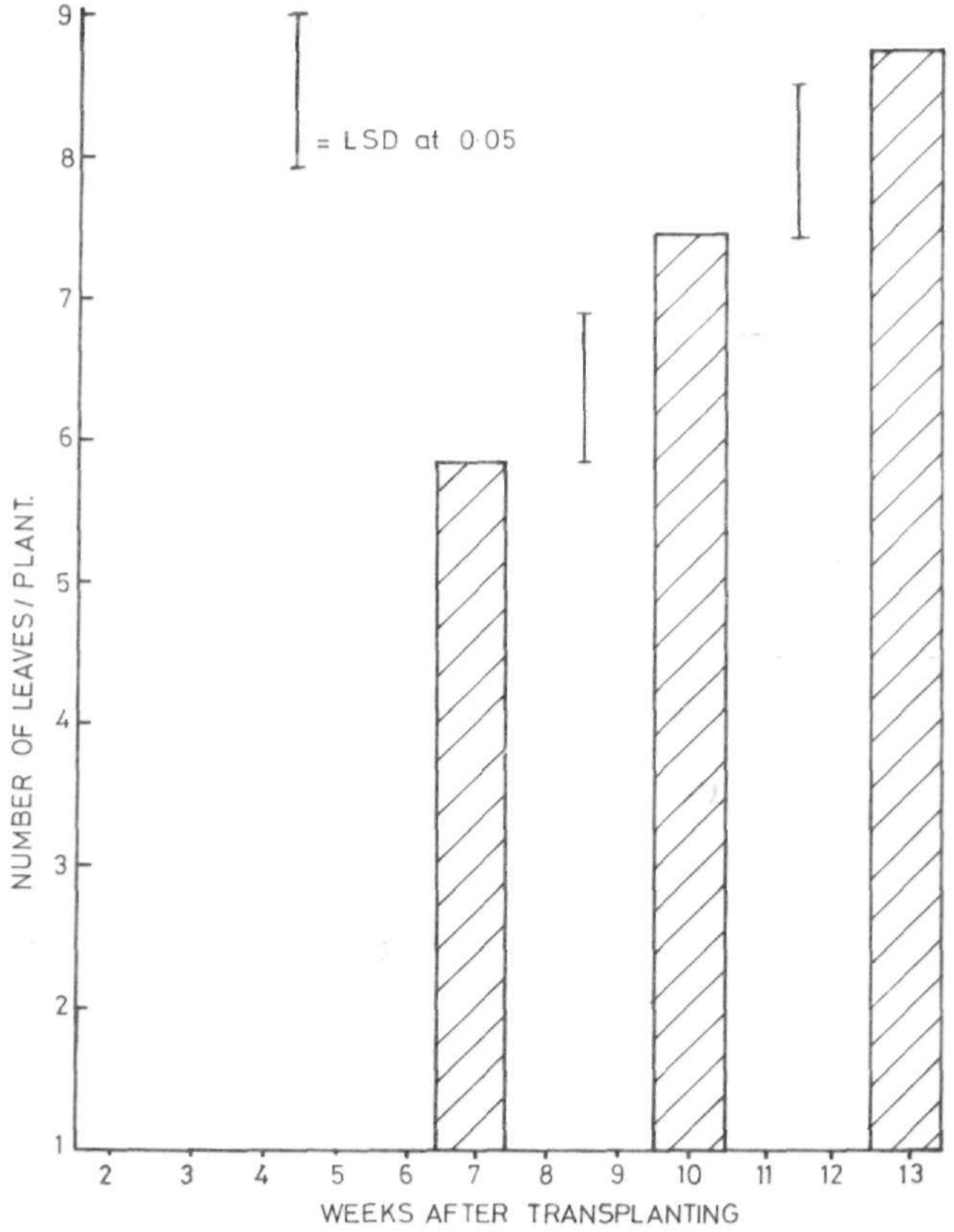


Fig.6. Number of onion leaves/plant after transplanting.

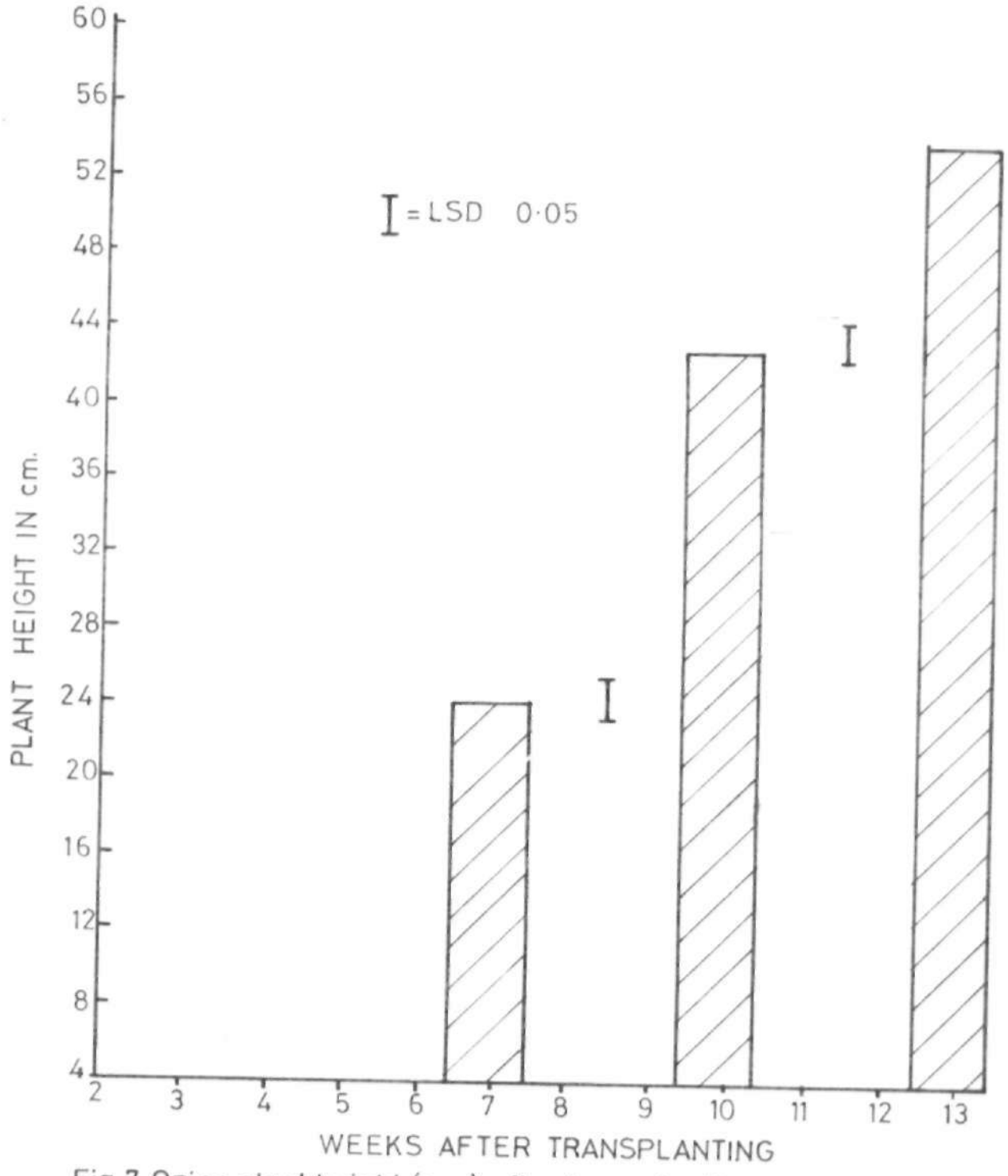


Fig. 7. Onion plant height (cm) after transplanting.

effect on plant height but plants of Ex Gayanawa were significantly taller than those of Maiduguri Improved (Table 20).

Table 20: The effect of variety, seed size and storage conditions on number of leaves and plant height (cm) 7 - 13 weeks after transplanting

Treatments	Number of leaves per plant	Plant height (cm)
Variety		
Maiduguri Improved	7.5	38.9
Ex Gayanawa	7.3	41.6
LSD at 0.05	n.s	1.82
Seed Size		
Less than 2.0 mm	7.6	39.9
2.0 - 2.5 mm	7.2	40.6
LSD at 0.05	n.s	n.s
Storage Conditions		
Baft bags (Room Temp.)	8.2	41.9
Polythene bags (Refrigerator)	7.2	38.9
Polythene bags (Freezer)	6.9	39.2
Paper envelopes (desiccator)	7.3	41.0
LSD at 0.05	n.s	n.s

This significant effect in height was observed only at Kadawa (Table 21), the location close to the source of origin of Ex Gayanawa variety. Plants obtained from seeds

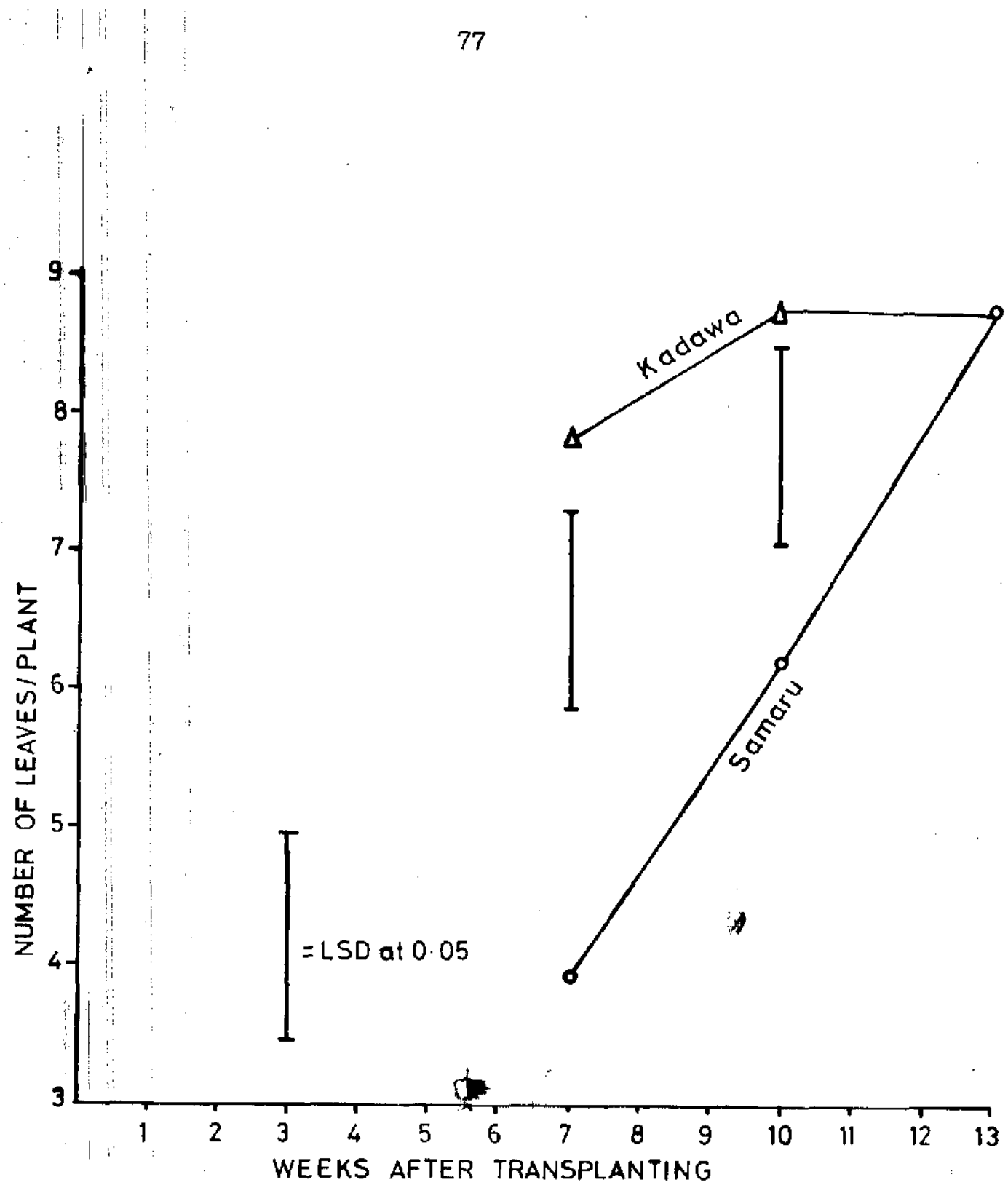


Fig.8. Number of onion leaves/plant at 2 experimental locations

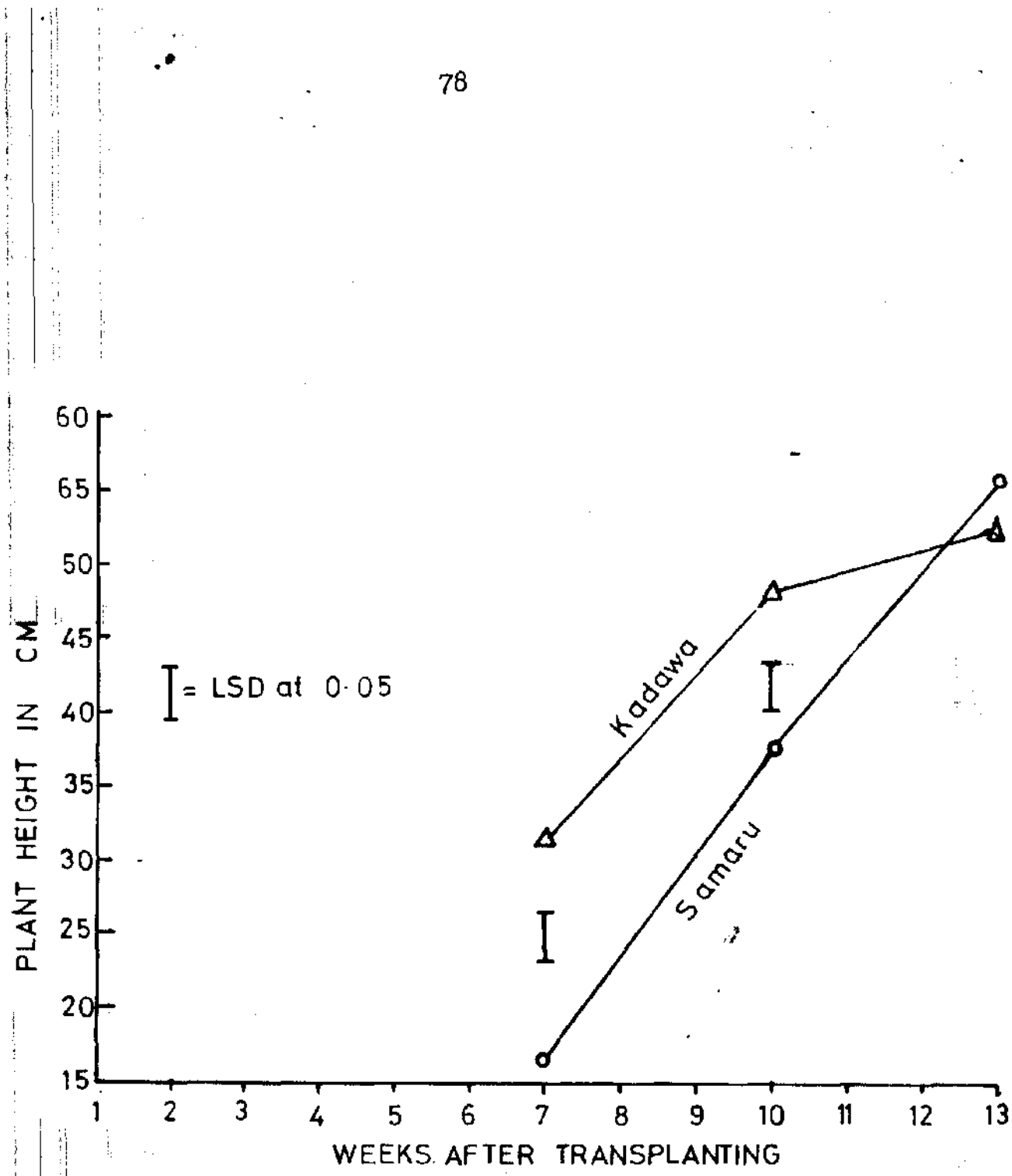


Fig.9. Onion plant height (cm) at 2 experimental locations.

stored in baft bags (room temperature) and paper envelopes (desiccator) were taller than those stored under other conditions.

Table 21: The interaction between location and variety as they affect onion plant height (cm) 7-13 weeks after transplanting

Location	Variety		LSD at 0.05
	Maiduguri Improved	Ex Gayanawa	
Samaru	35.72	36.39	2.57
Kadawa	41.04	46.89	

No significant interaction between variety, seed size or seed storage conditions on number of leaves per plant or plant height was found. Also, interactions between pairs of these factors were insignificant. However, there were interactions between varieties, location and plant height.

Plants from small seeds stored in polythene bags in the refrigerator and large seeds stored in the freezer were significantly shorter than those from seeds of both sizes stored in baft bags in room temperature or those from large seeds stored in the desiccator (Table 22).

Table 22: The interaction between seed size and storage conditions on plant height (cm) 7-13 weeks after transplanting

Storage conditions	Seed Size		LSD at 0.05
	Less than 2.0 mm	2.0 - 2.5 mm	
Baft bags (Room Temp.)	42.24	41.55	3.63
Polythene bags (Refrigerator)	37.27	40.65	
Polythene bags (Freezer)	40.80	37.55	
Paper envelopes (desiccator)	39.17	42.85	

Seed storage in freezer reduced, significantly, height of plants of Maiduguri Improved variety while seed storage in refrigerator equally had adverse effect on height of Ex Gayanawa variety plants (Table 23).

Table 23: The interaction between variety and storage conditions on plant height (cm) at 7 and 13 weeks after transplanting (for both locations)

Storage conditions	Plant height (cm)		LSD at 0.05
	Maiduguri Improved	Ex Gayanawa	
Baft bags (Room Temp.)	39.32	44.48	3.63
Polythene bags (Refrigerator)	40.56	37.36	
Polythene bags (Freezer)	35.13	43.23	
Paper envelopes (desiccator)	40.53	41.49	

The two varieties reached maturity stage almost at the same time at Samaru but at Kadawa, it was observed that Ex Gayanawa matured 5 days earlier than Maiduguri Improved (Table 24). The effects of seed size and storage conditions on onion maturity were not significant.

Table 24: The length of onion growing season (days) as influenced by location and varieties

Treatment	Age of Transplants (days)	From Trans-planting to maturity	Total length of growing season
Location and Variety			
Samaru (1982/83)			
Maidiguri Improved	54	124	178
Ex Gayanawa	54	124	178
Kadawa (1983/34)			
Maiduguri Improved	50	124	174
Ex Gayanawa	50	119	169

(ii) The interaction of variety, seed size and storage conditions on onion bulb yield

There was no significant interaction of variety, seed size, storage conditions and location, in their combined influence on total bulb yield and its components. However, there was a significant interaction between variety and location with respect to total yield (Table 25). Ex Gayanawa variety which was close to its place of origin had significantly better yield at Kadawa than Maiduguri Improved variety.

Table 25: The effect of variety on bulb yield at two different locations

Location	Yield(in tons/ha)		LSD at 0.05
	Maiduguri Improved	Ex Gayanawa	
Samaru	11.53	9.68	2.82
Kadawa	9.72	12.68	

At Samaru (Table 25) the difference between these two varieties was insignificant, but at Kadawa Ex Gayanawa gave significantly better yield than Maiduguri Improved. This interaction, however, was not significant for proportion of bolters, rotten bulbs or splits on total yield as seen in Table 26, and Plates 9, 10, 11, 12, and 13.

The main effect of the factors studied are shown in Table 26. Significant effect was observed only for location on total onion yield and its components.

Table 26: The effects of location, variety, seed size and storage conditions on bulb yield

Treatments	Total yield (tons/ha)	Percentage by weight of total yield		
		Bolters	Rotten bulbs	Splits
Location				
Samaru	10.6	52.1	8.0	0.1
Kadawa	11.2	19.5	1.8	1.2
LSD at 0.05	n.s	3.6	3.9	0.5
Variety				
Maidiguri Improved	10.6	37.0	4.7	0.8
Ex Gayanawa	11.2	34.5	5.1	0.5
LSD at 0.05	n.s	n.s	n.s	n.s
Seed Size				
Less than 2.0 mm	11.0	34.4	4.9	0.5
2.0 - 2.5 mm	10.8	37.2	4.9	0.8
LSD at 0.05	n.s	n.s	n.s	n.s
Storage Conditions				
Baft bags (Room Temp.)	11.8	34.4	3.2	1.1
Polythene bags (Refrigerator)	10.1	35.5	8.0	0.2
Polythene bags (Freezer	10.6	35.5	5.1	0.8
Paper envelopes (desiccator)	11.2	37.7	3.2	0.5
LSD at 0.05	n.s	n.s	n.s	n.s



Plate 9: Onion Bulb: Transverse sections of Bolters.



Plate 10: Onion Bulb: Transverse sections of Non-Bolters.

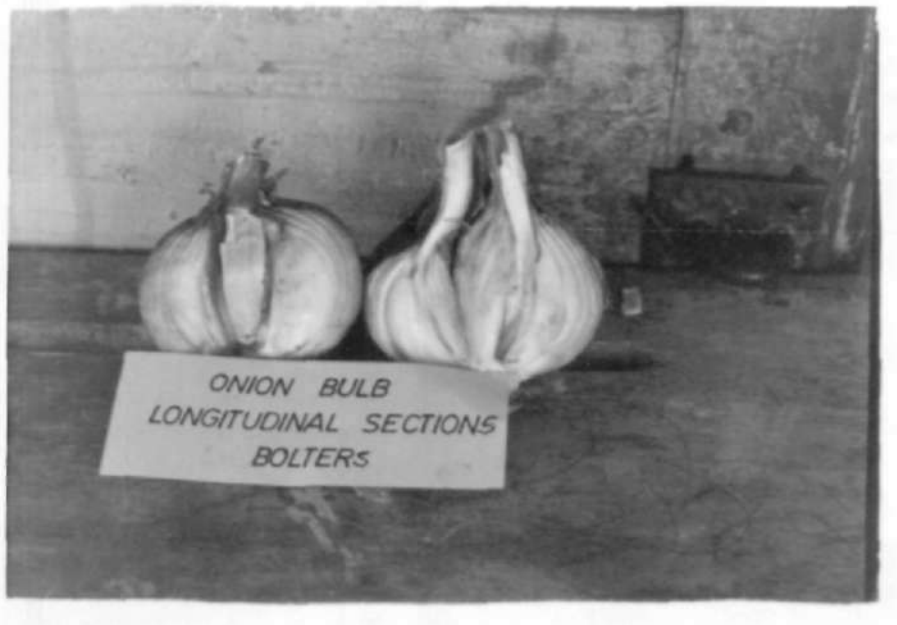


PLATE 11: Onion Bulb: Longitudinal sections of Bolters



PLATE 12: Onion Bulb: Longitudinal sections of Non-Bolters.



PLATE 13: Split Onion bulbs.

The quality of the products at Kadawa was considerably higher than at Samaru. At the later location, there were high rates of bolters, rotten bulbs and splits. Total yield and its components were not significantly influenced by variety, seed size or storage conditions.

Maiduguri Improved variety had higher percent bolters than Ex Gayanawa although of statistical insignificance. The large sized seed also had higher percentage of bolters than the smaller ones. Similarly, seeds stored in paper envelopes in the desiccator had higher percentage of bolters than other storage treatments while seeds stored in cold temperatures (refrigerator and freezer) had higher percentage of rotten bulbs (Table 26).

CHAPTER FIVE

DISCUSSION

5.1. Storage Trials

The onion seed has been reported by Barnejee (1978) to be fairly susceptible to adverse storage conditions especially as the seed is notoriously short lived. It has also been observed by Barton (1961) that the containers used and the conditions of storage influence the germinability of onion seed considerably.

(i) Variety

There was no difference between the two varieties studied in quality and germination prior to storage treatments (Table 5). However, after 8 months of storage or more, Ex Gayanawa seeds proved more viable than Maiduguri Improved variety on the basis of the results of the laboratory seed germination tests (Table 7). It is possible for Ex Gayanawa variety to have greater efficiency in transferring reserve materials to the embryo axis. Similar view was expressed by Bremner *et al* (1963) when they reported that embryo growth may be limited by lack of an energy supply directly after germination. It was observed in this investigation, that although the two varieties were graded into the same seed sizes, the seed weight and number of seeds per gram of one variety differ from those of the other variety. (Table 6).

There are evidences of Bedford and Mackay (1973), Brewster et al (1974), Hatridge-Esh and Bennett, (1980) to show that onion varieties may differ in seed size but it is not clear if this affects their laboratory germination. Bedford and Mackay (1973) could also find no correlation between mean seed weight of several onion cultivars and their emergence. The present investigation seems to suggest that onion varieties with larger seeds may retain viability for longer time than those with smaller seeds, which may be due to genetical, physiological and mechanical characteristics. James et al (1967) observed that while seeds of some onion varieties stored in identical conditions were dead or of low viability, others maintained a high degree of viability which was ascribed to their genetic trait. This view was also confirmed by Roberts (1972) when he reported that loss of viability in stored seeds of some onion varieties may be attributed to the accumulation of injurious mutations in the surviving seeds. It is possible also for loss of viability in seeds of some varieties to be environmental. This was observed by James et al (1964) when he mentioned that seeds may decline rapidly in vigour due to unfavourable weather conditions which resulted in poor ripening and harvesting conditions such as when one or two rains fall on seed umbels shortly before harvesting. Clark (1948) also investigated loss in seed viability which he attributed to

mechanical damage during harvesting and seed threshing which may result in fragmented seeds and scar tissue and if planted, such seeds produce misshapen seedlings. All these investigation show that varieties well adapted to a given environment may still differ in viability. Maiduguri Improved variety may be less adapted to the environment of Samaru than Ex Gayanawa whose source is nearby. For this reason, Ex Gayanawa produced larger and more viable seeds. It should be borne in mind that seeds of different onion varieties may differ not only in size but in shape. If such a situation occurs, grading according to dimension only (i.e. width) may not be sufficient to get comparable seed grades of different varieties. Therefore, the grading method according to weight may be more accurate.

(ii) Seed Size

In this investigation, seeds were graded into two sizes (less than 2.0 mm and 2.00 to 2.5 mm) by width (Table 6). In this case, it can be assumed that the grading of seeds into different sizes obviously tends to improve the resistance of large seeds to unfavourable weather conditions than smaller seeds. The same view as above was expressed by Heydecker (1969) when he reported that not only will larger seeds germinate or emerge earlier than smaller seeds, but their physiological and pathological conditions are better. It is

evident from the results presented in Table 6 that the one thousand seed weight of the different size grades of onions showed a close association with the size of the seeds since it is possible for a larger seed elsewhere to have smaller weight than a smaller seed in some other place. The size grading of onions has made one to realize that seeds from the same plant may differ in weight depending on where the seeds are produced on the plant. The larger seeds with more food reserve will allow for earlier field emergence than the smaller seeds. This agrees with the earlier observations by Black (1957) and Gelmond (1972). As shown in Table 6, Ex Gayanawa variety had heavier seeds and this may have contributed to the superiority of this variety over Maiduguri Improved in seed germination. There are evidences of Perry (1972), Gill and Singh (1979), who reported that larger or bigger seeds showed higher germination and emergence over smaller seeds which might be due to low vigour contributing to slow emergence of small seeds.

In this investigation, it was observed that at most sampling dates, especially towards the end of storage, seed germination was significantly higher for the larger than for the smaller onion seeds (Table 13). The high percentage of germination and field emergence recorded for large sized viable seeds (even at 8 months sampling period) could be ascribed to the large food

reserves contained in them. Also since living things respire; the larger seeds are supposed to store longer than the smaller ones which respire very quickly leading to loss in seed viability when seeds are stored for some period of time. The result of this investigation confirms the findings of Cummings (1914) on some vegetable crops such as broccoli (Alam and Locascio, 1965); radish (Marie et al, 1967); small seeded vegetables, (Joubert and Rappard, 1970); onions, (Brewster et al, 1974 and Kazakova, 1978). They all reported that germination from larger seeds were significantly higher than from smaller seeds. Hewston (1964) also reported that the lower values obtained for the small sized seeds could be due not only to the initial food reserve being small, but partly due to the inclusion of higher proportion of shrivelled and immature seeds resulting from incomplete seed development.

(iii) Storage Conditions

Results of the storage treatments showed that onion seeds stored in baft bags in room temperature and in polythene bags both in the refrigerator and freezer gave the best germination in laboratory tests (Table 9). These were followed by seeds stored in the desiccator which became significantly inferior to these only after 15 months of storage.

Two seed storage treatments, namely polythene bags in room temperature and baft bags in the refrigerator were the worst and had to be discarded at the end of the eighth month of storage. In these storage treatments low seed germination was accompanied by increase in seed moisture content (Table 10). At the fifth month, the seed moisture content had risen from 6.5% to 11.8% and to 9.2 in baft bags in the refrigerator and polythene bags in the room temperature respectively. Seeds in polythene bags (room temperature) continued to respire and since there was no out-let for the accumulated moisture within the polythene bags, there was bound to be increase in seed moisture content which contributed to the losses in viability observed. Similar views as above were expressed by Dobrovsky (1962), who reported that when the moisture content of a seed is high, the damage is greater and faster. It was also observed by Harrington (1960) that if polythene bags are used to store seeds, moisture content should not be higher than 4-8% or else deterioration rate will be fast. In the case under investigation the seeds had reached 9.2% moisture content just after five months of storage (Table 10), and so respiration was therefore rapid especially as the polythene bags were sealed which provided no outlet, for the end product, which included water and carbondioxide. It has been

reported too by Barton (1966) that increase in seed moisture may further speed up respiration and its end product, carbondioxide, may be injurious to stored seeds if in higher concentration.

For effective storage therefore, it is very important that any excess water or end products of respiration should not be allowed to accumulate within the containers. The sealed polythene bags also had reduction in oxygen content, and low oxygen may cause anaerobic respiration to take place which Gadia et al (1964) observed to be toxic to living tissues. It has been established by Villiers and Edgecumbe (1975) that stored seeds have a high mutation rate and so rapidly lose viability if their moisture content is raised. This would seem to explain what happened to seeds in the baft bags placed in the refrigerator. Also some of the seeds stored in this condition showed visible sprouting and mould growth.

It has been reported by Harrington (1973) that reduction in temperature to $0^{\circ}C$ and below is beneficial for seed storage because it reduces the rate of respiration and so prolongs the life of seeds. The problem is that cold storages have a high relative humidity thus the seed gains a high moisture content and when it is brought out from storage for planting, it rapidly losses vigour and germination. This view was expressed

by Mathes et al (1969), who observed that if temperature is only reduced and the seeds are not protected against moisture (by use of moisture proof containers like polythene bags or other air-tight containers), respiration rate may still be quite high and growth of mould may occur. That was exactly the case in this investigation when baft bags were used in the refrigerator. In baft bags, water was able to condense freely on seed surfaces from the surrounding atmosphere, because of fluctuation in the temperature within the refrigerator. This condensation increased seed moisture content and as seeds were weakened or killed, mould growth appeared. It is therefore probable that the cold temperature reduced viability of the seeds in baft bags at high moisture levels. This reduced viability could have resulted from cellular damage which occurred when the high moisture content seeds were still stored at low temperature. It was observed that sprouting even occurred when temperature was low.

Similar low seed germination as observed in the refrigerator in this study, was reported by Delouche (1968) and Harrington (1972) who both used cloth bags. They observed mould growth as a result of high moisture content.

The use of baft bags in room temperature in this investigation maintained germination at a level of 70% for fifteen months, (Table 9). Since the baft bags were not fully air-tight, there was free movement of air within the seeds which allowed for reduction in both seed moisture content and respiration of the seeds. Several investigators such as Brison (1942), Myers (1943) and Gadia et al (1964) presented data to show that viability of onion seeds so stored lasted from eleven to twenty months of storage. It should be noted too that the relative humidity recorded in Samaru during the seed storage period ranged from 11-20% during the dry season and from 52-76% in the rainy season (Table 3). This data may suggest that the relative humidity in the room where the seeds were stored in Samaru, was not too high to cause quick damage to the seeds stored in baft bags under room temperature. The moisture content of seeds stored here was as low as 9.1% even after 15 months of storage period since the perforations in baft bags helped immensely in the exchange of moisture between the seed and the atmosphere.

Seeds stored in polythene bags in the refrigerator and in the freezer maintained viability of 69.5% and 68.6% respectively for 15 months. These two methods ranked second and third respectively (after baft bags in room temperature). The use of air-tight polythene

bags prevented moisture from reaching the seeds. The same was true to a lesser extent under the freezer condition. Though the temperature in the freezer (-2 to -12°C) is much lower than that of the refrigerator (3.4 to 14.5°C) (Table 2), the continuous freezing and thawing due to electricity fluctuations, may have caused internal injuries to the seeds in the freezer which contributed to its third ranking in seed viability. Mathes et al (1969) observed that most cold temperature storages in warm climates have high relative humidities so that seeds acquire dangerously high moisture level during storage which can cause internal injuries. These internal injuries as reported by Osbourne et al (1974) could be that when seeds aged in storage, the machinery for synthesis of the enzymes and hormones needed for proper seedling growth is greatly impaired and may lead to reduced growth rate or loss of seedlings. The moisture content of seeds stored in the refrigerator increased from 6.5% to 8.8% while in the freezer, it increased from 6.5% to 9.9% within the 17 months of storage period. This also supports the findings of Weibull (1955), Harrington (1963a), Barton (1966), Rusev (1974) and Harrison and Carpenter (1977) who suggested that both low temperature and low seed moisture content could prolong seed viability of onions from 20 to 30 months. The present investigation was terminated after 17 months of storage and 15 months of laboratory seed germination test due to the rapid deterioration of the seeds at that time.

Seeds in the desiccator maintained good viability at all sampling dates except at 15 months of storage when it has 65% germination rate (Table 9). This rate was therefore significantly lower than other treatments at the end of the sampling period (15 months). The moisture content of seeds stored in the desiccator dropped from 6.4% to 4.4% in 17 months of storage. This would have suggested that seeds under this low moisture condition would have retained their viability for a longer period of time because they possessed a very low metabolic rate but the contrary was the case. Temperature in the desiccators were higher (34-37°C) than room temperatures (21-27°C) which may explain the deterioration of the stored seed under this storage condition. Mathes et al (1969) observed that it is also possible for the desiccant to add heat to the storage compactment as a result, there was positive correlation between injury to viability of seeds with decreasing seed moisture. Nutile (1959) discovered that excessive drying changes the physical and chemical structure of the protoplasm. He also reported that if very dried seeds are remoistened at planting, they are unable to re-establish their original condition for normal metabolic activities and growth. If it happens, they are abnormal sprouts. Barnajee (1978) also presented data to show that it is possible for extreme dryness to induce dormancy in some vegetable seeds.

This once more agrees with Harrington's (1963a), views that temperature and moisture content are the two most important factors affecting the viability of stored seeds. Barton (1943), Newhall and Hoff (1960) stored seeds for a period of 25 months in the desiccator under a moisture content of 3.5%. It is most probable that the temperature inside the desiccator used by these investigators (though higher than room temperature) was lower in temperate countries than in tropical countries where this investigation was carried out.

From the above, it would appear that under Northern Nigerian climatic conditions, (Guinea and Sudan zones) onion seed storage in baft bags in room temperature(well ventilated stores) is most practical for small scale farmers, since they rarely have cooling devices (refrigerators and freezers). Even where these are available blackouts are frequently encountered. There may be tremendous improvement in vegetable production in Nigeria when the farmers as a co-operative group may want to multiply seeds in large quantities in future. These seeds will in turn be marketed by large seed companies. It is therefore recommended that small scale farmers should store their onion seeds in baft bags in room temperature. On the other hand, large seed companies or future farmers co-operatives could store properly dried seeds in air tight containers in cool stores.

(iv) The interaction between variety, seed size and storage conditions on germination

In this investigation, a significant interaction of all the three factors (variety, seed size and storage conditions), on onion germination was found only at two months of seed storage (Table 14). This finding was however, not observed in further germination tests carried out after 4, 6, 8 and 15 months of storage. As such, it is of little practical importance for two reasons:

(a) The difference in laboratory seed germination between all the treatments studied were comparatively small, i.e., at a range of 7% only.

(b) The interaction was not significant on later sampling dates and therefore is of little importance as onion seeds are supposed to be stored for such longer period than two months.

(1) Interaction of Variety and Storage

Throughout the storage period (except for the first 2 months) seeds stored in polythene bags at room temperature and baft bags in the refrigerator has lower germination for Maiduguri Improved (variety with lighter seeds) throughout the storage period than for Ex Gayanawa (Table 12). This supports the earlier observation that lighter seeds are likely to lose viability sooner than the bigger ones when stored in adverse environmental conditions.

(2) Seed Size and Storage

Results showed that some storage treatments, namely baft bags in the refrigerator and polythene bags in room temperature and initially polythene bags in the deep freezer were less favourable for the small than for the large seeds (Table 11). This shows that in adverse storage conditions, the larger seeds performed better than the smaller ones. This decline in germination of small seeds following storage in cold and room temperatures may be attributed to the genotypes of the seeds, the grade or effectiveness of the moisture proof containers and fluctuation in the storage conditions due to frequent power failures.

(3) Variety and Seed Size

This interaction between variety and seed size indicates that after two to four months of storage (figure 5) larger seeds of Maiduguri Improved germinated significantly better than its smaller ones while no significant difference in germination was noticed between the two seed sizes of Ex-Gayanawa for the same period (Table 13). This effect between variety and seed size described above, however, ceased to exist at later sampling dates. In this connection, Ex Gayanawa variety which had heavier seeds than Maiduguri Improved tolerated all the storage conditions better and obviously for this reason germinated better towards the end of the storage

period (Figure 2 and Table 13). It is also possible for smaller seeds of Maiduguri Improved variety to become more dormant in storage than those of Ex Gayanawa would. This view was earlier expressed by Harrison and Carpenter (1977) when they studied that some onion varieties may produce fewer dormant seeds while others produced up to 50% dormant seeds. From the above, it can be concluded that use of light seeds (with empty or immature embryos) may become critical for seed germination after a long storage period.

5.2. The Nursery Trials

Field emergence in both nursery trials was about 49% which was much lower than the initial laboratory germination of 97% (Tables 5 and 16). Barton (1961) had observed that a high initial germination percentage of seed provides no assurance for its field emergence. In this investigation, additional losses occurred in the nursery trial from the time of emergence (first week) to the time of transplanting (fifth week), (Table 17). Further losses at transplanting could be as a result of what Abdallah and Roberts (1968) observed to be the possibility of seeds accumulating certain materials which could cause damage to the seeds while in storage for long periods of time. Also Roberts (1972) expressed the view that seedlings produced from old seeds showed a large number of deleterious mutations resulting in losses in growth of seedlings.

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Some of these losses were also due to either insect damage or adverse environmental conditions in October to November during the early stages of growth of the crop. In the investigation under review, it was observed that one-third of viable seeds sown are likely to become transplantable seedlings (Table 17) if seeds are treated against diseases and insects and later placed under good management of the nursery. It may be concluded that for planting purposes in this environmental condition, it may be important to know that about three times more of viable seeds should be sown than the number of seedlings required. This allowance is necessary to compensate for the losses encountered between sowing and field emergence and between field emergence and transplanting time (Table 17).

These results confirmed the findings of Hegarthy (1971) and Bedford and Mackay (1973) who found that onion seed emergence was lower in the field than in the laboratory. In the open field, seeds are often subjected to unfavourable conditions like inadequate moisture, high or low temperatures, soil pathogens and mechanical obstacles such as soil crusts. Also environmental conditions strongly influence the percentage of seedling (suitable temperature, texture etc.) that field emergence may be high as laboratory germination.

From the results obtained in this investigation on seedling emergence and quality of onion (Tables 16 and 17) there were no statistical significance of the combined effects of the four storage conditions and seed sizes. The seeds were stored for four months only and the storage methods employed were those indicated as the best in the main storage trial namely, baft bags in room temperature, polythene bags both in the refrigerator and the freezer and seeds in paper envelopes in the desiccator over calcium chloride. Consequently no significant differences between the storage methods were noticed in laboratory germination in field emergence or seedling quality. It may be postulated that significant differences in field emergence and seedling quality arise only when the duration of storage is long enough to produce significant differences in seed laboratory germination between treatments studied.

Regarding seed sizes (Table 17), the larger sized seeds gave higher field emergence (49.6%) and higher transplantable seedlings (33.3%) when compared with the smaller sized seeds. However, the differences were not statistically significant. Franklin (1970) reported that smaller seeds may not emerge quickly due to inadequate food reserve and that rapidity of leaf development was directly related to seed size. Austin (1963) also found a positive correlation between final plant

population and the mean seed weight of onion seeds. On the other hand Bedford and Mackay (1973) found no correlation between mean seed weight of different onion genotypes and their field emergence.

5.3. Field Trials

There were significant differences in plant growth and yield of onion between the 2 locations, Samaru and Kadawa. The main factors studied, i.e. variety, seed size and seed storage conditions showed no significant influence on onion growth and yield. Interactions of some pairs of factors in onion growth were significant, but were not persistent enough to be reflected in yield data.

5.3.1. Onion Growth

In this investigation, parameters observed on onion growth were limited only to number of leaves/plant and plant height between the 7th and 13th weeks after transplanting. For this reason, the discussion here is only an indication of onion performance on the field.

(i) Experimental Location and Plant Growth

Figures 8 and 9 indicate that onion growth (number of leaves/plant and plant height) was markedly slower and was significant so at 7 and 10 weeks at Samaru than at Kadawa. However, after 13 weeks of growth (from transplanting), these differences in growth were no

longer significant. This may be due to better growing conditions at Kadawa as by the meteorological data (Tables 3 and 4). The soils at Kadawa were also of better quality than those at Samaru as indicated by Vallette and Ibanga (1984). Seedling growth of Ex Gayanawa variety must have been more vigorous than that of Maiduguri Improved. Hatridge Esh et al (1977) working with onion contended that it is possible for one onion variety to emerge from any depth of planting at a faster rate than another variety, grown in the same location if environmental conditions are suitable.

(ii) Variety and Plant Growth

It is well known that varieties of same crop may differ in growth rate, duration of growth and yield (Jones and Mann 1963, Singh et al 1976, Brewster 1977 and Kazakova 1978). In this investigation, it was observed that plants of Ex Gayanawa were significantly taller than those of Maiduguri Improved (Tables 20 and 21). It may be that the seedlings of Ex Gayanawa variety has a higher level of food reserves in its cotyledons than Maiduguri Improved variety. Moreover, it is possible for seedlings of Ex Gayanawa (the variety with large seeds) to emerge earlier due to a faster growth rate of their embryos just after the onset of germination as compared with those of Maiduguri Improved variety. Bremner et al (1963) observed that embryo

growth may be limited by lack of an energy supply directly after germination, this could therefore be due to the greater efficiency of Ex Gayanawa seeds in transferring material to the embryo axis. It was also observed that Ex Gayanawa grew better, matured 5 days earlier and gave heavier bulb yields at Kadawa than Maiduguri Improved variety, while at Samaru, both varieties performed equally well (Table 19). Since Ex Gayanawa originated close to Kadawa while the other variety originated from Borno State, it can be concluded from the results that onion varieties perform better at locations that are closer to their sources. Larger seeded plants are expected to bulb early (Joubert and Rappard, 1970) and this may have contributed directly to early bulbing and maturity of Ex Gayanawa plants compared with Maiduguri Improved variety which had lighter seeds.

(iii) Seed Size and Plant Growth

There was no significant effect between the two seed sizes used on onion plant growth. Onions are small seeded crops. Wellington (1970) maintained that for most plants with small seeds, size of seeds will in most cases not affect plant yield. He presented data to show that at the beginning of growth, the two sizes were growing at about the same rate (although the larger size had a little edge) but the growth of plants from the larger seeds declined because competition began to

operate amongst the larger plants due to over crowding. Harrington (1974) once observed that growth declined amongst the large seeded plants in an over crowded situation as the individual plants were unable to develop to their full potential. Gelmond (1972) also presented data to show that there was a higher mortality rate among seedlings grown from lighter seeds than among those from heavier seeds.

(iv) Storage conditions and Plant Growth

Seed storage conditions did not show any significant effect on onion growth and yield in this study (Tables 20 and 26). However, it should be mentioned that the worst storage conditions (polythene bags in the room and baft bags in the refrigerator) had been discarded before the commencement of the field trial. Storage conditions selected for the field trials were identified as the best. No significant differences were observed among them in laboratory seed germination at the first field trial, while at the second field trial, only the desiccator treatment was slightly inferior (Table 9 and Figure 4).

Seeds stored in baft bags in room temperature tended to produce more leaves and taller plants than other treatments (Table 20). This storage condition is among the three designated the best in this study, which not only prolonged seed viability longest but is the simplest and cheapest of all the storage methods.

Seeds stored in polythene bags in the freezer, produced fewer number of leaves and shorter plants. This may be an indication of the adverse effect of very cold storage which requires a period of rewarming for germination and emergence. Roberts (1979) reported that it is possible for the seeds of some onion varieties to become susceptible to injury at very low temperatures and hence produce shorter seedlings. Barton (1961) also observed that it is possible for seeds with high moisture content to decay or if planted to produce weak and stunted seedlings. The investigation of Harrison and Carpenter (1977) also indicated that the consequence of seedling deterioration from onion seeds stored at low temperature is cytological abnormalities which were shown as chromosomal aberrations and point mutations.

Figures 6 and 7 are gr wth parameters of the onion plant 7 - 13 weeks after transplanting. It was observed that the plants were more vigorous, number of leaves and plant height increased significantly as plants grew. This is as a result of the physiological factors inherent in all seeds whereby plant growth progresses slowly from ground growth, t slow growth and steady stage which culminates in maturity. The number of onion leaves/ plant and plant height at Kadawa were significantly higher than those at Samaru at 7 and 10 weeks after transplanting (Table 19). This may be due to better

growing conditions at Kadawa as shown by the Meteorological data and soil factors (Valette and Ibanga, 1984). However, at the last sampling date, 13 weeks after transplanting, the differences mentioned above were no longer significant. This was to be expected when plants begin to ripen and mature there can be no further increase in number of leaves or plant height. In order words, by 13 weeks after transplanting, the number of leaves per plant and plant height had reached maximum and there were no significant differences between the two locations.

There was a significant interaction between location and varieties (Table 21). In both varieties, increase in plant height was remarkable at Kadawa. However, Ex Gayanawa variety had taller plants (Table 21), matured earlier (Table 21) and gave significantly higher bulb yield at Kadawa (Table 25) than Maiduguri Improved variety. But at Samaru, the respective differences between these two varieties were insignificant.

As previously pointed out, Ex Gayanawa, due to its inherent genetical characters was better adapted to the environmental conditions prevailing in its place of origin, i.e. in Kadawa. Barnejee (1978) reported that the plumule and radicle of some stored onion varieties are tissues responsible for seed deterioration in storage.

There was also a significant interaction between seed size and storage condition in this investigation, (Table 22). Plants from small seeds stored in the refrigerator and large seeds stored in the freezer were significantly shorter than those from seeds of both sizes stored in the room temperature or those from large seeds stored in the desiccator. Since these two treatments with shorter plants are due to cold temperatures, it is necessary to sow seeds immediately after removal from the cold storages. If not done exactly, Roberts (1979) reported that cold storage seeds would have condensation of moisture on them, and as seeds warm up, respiratory rate increases rapidly and the seeds will drastically decline in viability, hence these cold storages may develop shorter plants. It is also possible for seeds from cold storages to remain dormant for sometime and so will not germinate at the same time as other storage treatments. This will eventually affect plant height of such cold storage seeds. Smaller seeds of baft bags in room temperature as well as larger seeds in paper envelopes in the desiccator on average, produced the tallest plants during the period of study. These two storage conditions could have been recommended as the most ideal but the local farmers may not be able to afford desiccators or know how to use them.

There was a significant interaction between variety and storage conditions as they affect plant height (Table 23). It was observed that seeds stored in the freezer reduced significantly the height of Maiduguri Improved plants while seeds stored in the refrigerator equally had adverse effect on Ex Gayanawa plants. This confirms views by Beattie and Boswell, (1939) who observed that low temperature might be expected to so retard life processes that very little amount of respiration would be involved. There may also be increase frequencies of chromosome aberration which Sax and Sax (1964) reported to have occurred with increase in age of stored onion seeds.

5.3.2. Yield of Onion

There were no significant effects of variety, seed size and seed storage conditions on yield or its components (Table 26). There were also no significant interactions between the factors concerned.

(i) Yield of Onion and the Location

There was no significant difference in total yield between the two locations (Table 26) but the quality of yield was significantly better in Kadawa than at Samaru. This is in agreement with the earlier observation on growth which showed that leaf development (leaf number per plant and plant height) was much better in Kadawa than in Samaru. Total percentage yield of bolters and

rotten bulbs were highly significant at Samaru than at Kadawa. But the total percent split bulbs were slightly significant at Kadawa than at Samaru. With the environmental growing condition being superior at Kadawa than at Samaru, it is not surprising that the quality of the yield components was better at Kadawa than at Samaru. The significant differences in yield components between these two locations were, however, not large enough to bring about significant differences in total yield.

(ii) Yield of Onion and Variety

Total yield and yield components were not significantly influenced by variety (Table 26). However, Maiduguri improved variety had higher percentage bolters and splits than Ex Gayanawa variety. This is probably due to the fact that Ex Gayanawa variety which had heavier seeds had more food reserves and better yield in both locations. It was also observed that Ex Gayanawa variety had more but insignificant amount of rotten bulbs, (Table 26). This can be ascribed to the production of large sized bulbs which are easily susceptible to fungus attack than the smaller bulbs produced by Maiduguri Improved variety.

(iii) Yield of Onion and Seed Size

There was no significant influence of seed size on onion yield. Interactions of pairs of factors,namely seed size and yield components were observed but they

were not reflected in the total yield.

In this investigation, plants from larger seeds produced higher yield components (bolters and splits) than those from smaller seeds (Table 26), although not significant. This again could be attributed to the effect of more food reserve which triggered early germination and resulted in early maturity. Consequently, the larger seeded plants produced higher yield components but were not reflected in total yield. Also the onion has been characterized as a long growing seasonal vegetable as observed by Wood et al (1977), crops of small seeds with long growing season have no effect on the ultimate size of the bulbs. This is because, in general, seedlings from the large seeds (within the seed lot) of a variety may show a distinct initial advantage, but this was likely to be lost by the time plant maturity was reached.

(iv) Yield of Onion and Storage Conditions

Total yield and yield components were not significantly influenced by storage conditions. It was observed in this investigation that seeds stored in polythene bags both in the refrigerator and freezer produced more rotten bulbs (Table 26), although statistically insignificant. These seeds absorbed moisture content from 6.5% to 8.8% and 9.9%, respectively, (Table 10). Barton (1961) observed that the weak and stunted character of the seedlings which resulted from seeds of

high moisture content could be carried forward to bulb production due to physiological as well as genetical reasons.

Also seeds stored in the desiccator over calcium chloride were observed to produce higher percent bolters (Table 26), although statistically insignificant. Purkar and Barnejee (1979) believed that it is possible the dryness of these seeds could affect the membrane properties of the cells and this could lead to variability in population, some of which are heritable. Also Faulkner and Jackson (1980) observed that small seeds of low moisture content if stored in desiccators can develop hard-seededness so that such seeds do not germinate as quickly (normal germinative responses were inhibited) as do seeds stored in other treatments. They also observed that undesirable yield components may be produced by desiccated seeds.

It has been observed in this investigation that seeds in baft bags in room temperature produced more but insignificant splits which may be due to physiological (inherent characteristics within the seeds) or environmental (when the growing conditions favour the splitting of onion bulbs of this particular storage condition) factors. This storage condition also gave the highest but insignificant total yield. This can be attributed to its good storage environment such as adequate perforation for exchange of gases and moisture.

CHAPTER SIX

SUMMARY

Onion seeds of two varieties, namely Maiduguri Improved and Ex Gayanawa were stored for 17 months in six different conditions, polythene bags in room temperature, baft bags in room temperature, polythene bags in the refrigerator, baft bags in the refrigerator, polythene bags in the freezer and seeds in paper envelopes in the desiccator over calcium chloride. The varieties were each separated into two seed sizes (less than 2.0mm and 2.0 to 2.5 mm in width) by the use of Endecotte sieve separators. By the 8 months of storage, two storage treatments namely, polythene bags in room temperature and baft bags in the refrigerator were discarded due to accelerated decline in germination which was also accompanied by mouldiness and sprouting. The remaining four storage conditions were continued up to 17 months after which the investigation was terminated.

Results of the storage trial in the laboratory showed no significant interactions between all the 3 main factors studied (variety, seed size and storage conditions) except the effect of pairs of factors studied. Maiduguri Improved which had lighter seeds gave lower germination in polythene bags stored in room termperature than Ex Gayanawa variety. On the interaction of variety and seed size, after 2 and 4 months of storage, larger seeds of Maiduguri Improved variety gave significantly higher germination than the smaller seeds. This difference

ceased later. However, such effect was not noticed for the 2 seed sizes of Ex Gayanawa variety. In this connection, it was observed that Ex Gayanawa with heavier seeds was superior to Maiduguri Improved in laboratory seed germination right through to the end of the storage period. Moisture content increased steadily during storage especially in seeds stored in polythene bags in room temperature and baft bags in the refrigerator while seeds in the desiccator had lower moisture content.

Results of each of the factors studied showed no significant difference in initial seed germination between the 2 varieties but after 8 months of storage, Ex Gayanawa was significantly superior to Maiduguri Improved. The larger seed size was significantly higher in seed germination at all sampling dates (except at 4 months) to the smaller sized seeds thus suggesting that bigger seeds can maintain seed viability for longer periods of time than smaller seeds. Amongst the storage conditions studied, baft bags in room temperature and polythene bags in the refrigerator and freezer were the best for onion seed storage.

It would appear that the only option opened to the Nigerian small scale farmers is to store their seeds in baft bags in well ventilated rooms, since they do not have cooling devices such as refrigerators and freezers.

Results of both nursery trial indicated that field emergence was about 19%, compared with initial laboratory seed germination of 97%. Emergence and seedling growth were not affected significantly by seed size or storage

conditions. About one - third of the number of seedlings that emerged after 7 days were dead at transplanting, as such it may be concluded that in tropical environmental conditions such as in Nigeria, about 3 times more of viable seeds than required should be sown to make allowance for the loss of seedlings by transplanting time.

Results of the field trials indicate that plant height and number of leaves per plant grew more vigorous at Kadawa than at Samaru during the first ten weeks after transplanting but these significant differences were not observed 13 weeks after transplanting. Usually when plants attain maturity, increase in vegetative growth pattern such as number of leaves per plant and plant height cease and their energy resources are devoted to the filling and ripening of their reproductive structures. No significant interactions were found between the 3 factors studied except the effect of pairs of factors. In the interaction of variety and location, it was observed that at Kadawa, Ex Gayanawa variety grew more vigorously, matured 5 days earlier and gave significantly higher bulb yield than Maiduguri Improved variety. Kadawa is however, close to Kura the main source of Ex Gayanawa variety. In Samaru, the differences in these two varieties were insignificant. However some significant interactions of pairs of factors occurred during the growth of the onion after transplanting.

CHAPTER SEVEN

CONCLUSIONS

The following conclusions are drawn from this investigation:

1. In comparison with Maiduguri Improved, Ex Gayanawa variety produced heavier seeds at Samaru and maintained its seed viability in storage for longer periods.

2. The varieties did not differ significantly in their growth, time of maturity and bulb yield at Samaru, but at Kadawa, Ex Gayanawa grew more vigorously, matured 5 days earlier and gave significantly higher bulb yield than Maiduguri Improved. Ex Gayanwa's source was Kura village close to Kadawa, which explains the superiority of this variety over Maiduguri Improved (which originated from Borno State) at that location.

3. Although larger seeds (2.0 to 2.5 mm seed size) were more viable after storage than the smaller ones of less than 2.0 mm seed size, no significant differences were noticed between these two seed sizes in field emergence, growth, maturity date and total bulb yield and its components. The use of large seeds is probably only advantageous in crops of short duration and not in the onion which is a long duration crop.

4. Among the storage conditions studied, the baft bags in room temperature and the polythene bags both in the refrigerator and freezer were the best and

equally good for seed storage. Seed storage in the desiccator was as good to these after 8 months but became significantly inferrior after 15 months of storage. Polythene bags in room temperature and baft bags in the refrigerator gave significantly low laboratory seed germination accompanied by increase in seed moisture content and other mould growth.

5. Little or no significant interaction between all the three factors studied (variety, seed size and storage condition) was noticed in seed laboratory germination, field emergence, plant growth and bulb yield.

6. Significant interaction between the respective pairs of factors were quite frequent especially during seed storage in particular, under adverse storage conditions, larger seeds maintained their viability longer than the smaller ones. No significant interactions were noticed in field emergence and seedling growth. Some significant interactions occurred during subsequent onion growth after transplanting but none of them was significant in total bulb yield and bulb quality.

7. Best seed quality and bulb yields could be obtained if farmers select the best available local strains within the boundaries of distinct ecological onion production areas.

8. Seed grading according to size may be of advantage for varieties which are known to produce small seeds.

9. Small scale Nigeria farmers should continue to store their onion seeds in the traditional method i.e. in baft bags in a well ventilated and fairly cool store.

10. For commercial onion seed growers and vegetable seed companies, seed pre-conditioning (drying to 6.5% of moisture content), cooling devices (refrigerators and freezers) and air tight containers are essential for successful onion seed storage under Nigerian environmental condition.

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APPENDIX

Table A. 1: Number of mother bulbs obtained from 1980/81 dry season production

S/No.	Variety	Bolters	Non-bolters	Twin bulbs	Rotten bulbs	Total
1	Maiduguri Improved	1394	1799	[illegible]	[illegible]	3347
2	Early Texas Grano	675	602	40	12	1329
3	Ex Mubi I	975	820	24	6	1825
4	Ex Mubi II	1124	1066	31	8	2229
5	DS/79/B2	494	603	6	21	1124
6	Ex Gayanawa	1149	1780	0	2	1058
7	Ex Kano	1815	2841	29	132	4817
8	Bama Improved	450	593	31	0	1058
	Total	8,076	10,084	182	307	18,656

Foot note: Only the non-bolters of 10,084 bulbs were good enough to continue the experiment with. These were stored from May 1981 through November 1981.

Table A.2: Effect of storage on onion mother bulbs (from May 1981 - November 1981) used in seed multiplication for all experiments

S/No.	Variety	Total stored	Losses, sprouts & rotted bulbs	Survival	% Survival
1.	Maiduguri Improved	1799	780	1019	56.6
2.	Ex Mubi I	820	592	228	27.8
3.	Ex Mubi II	1066	986	80	7.5
4.	DS/79/B2	603	415	188	13.2
5.	Ex Gayanawa	1780	758	1022	57.4
6.	Ex Kano	2841	2024	814	28.6
7.	Bama Improved	573	489	93	16.7
Total		10084	6610	2872	32.3

Foot Note: Early Texas Grano Variety had 100% losses within 2 months of storage and therefore was not included. Survivals above were used for seed production.

Table A.3: Average weight of 100 bulbs of the different varieties (kgs)(1981)

S/No.	Variety	Total weight of 100 bulbs (kg)
1.	Maiduguri Improved	145
2.	Ex Mubi I	146
3.	Ex Mubi II	158
4.	DS/79/B2	153
5.	Ex Gayanawa	156
6.	Ex Kano	90
7.	Bama Improved	164
8.	Early Texas Grano	243

Table A.1: Weight of dried seeds obtained from harvested umbels (1982)

S/No.	Variety	No. of bulbs planted	Seeds by weight (kgs)
1.	Maiduguri Improved	1019	6.73
2.	Ex Mubi I	228	0.95
3.	Ex Mubi II	80	0.33
4.	DS/79/B2	188	2.91
5.	Ex Gayanawa	1022	7.19
6.	Ex Kano	814	0.98
7.	Bama Improved	93	0.72

Table A.5: Evaluation of seedling emergence in the Nursery: Experimental layout

RI	$V_1S_1M_1$	$V_1S_1M_4$	$V_1S_2M_4$	$V_1S_1M_2$	$V_1S_2M_1$	$V_1S_1M_3$	$V_1S_2M_3$	$V_1S_2M_2$
RII	$V_1S_2M_2$	$V_1S_2M_1$	$V_1S_1M_3$	$V_1S_2M_3$	$V_1S_1M_4$	$V_1S_1M_1$	$V_1S_1M_2$	$V_1S_2M_4$
RIII	$V_1S_1M_4$	$V_1S_2M_3$	$V_1S_2M_2$	$V_1S_1M_1$	$V_1S_1M_3$	$V_1S_2M_3$	$V_1S_2M_1$	$V_1S_1M_2$
RIV	$V_1S_1M_3$	$V_1S_2M_2$	$V_1S_2M_4$	$V_1S_1M_2$	$V_1S_1M_1$	$V_1S_2M_1$	$V_1S_2M_3$	$V_1S_1M_4$

Key Note:

V_1 = Variety: Composite

S_1 = Size one: Less than 2.0mm

S_2 = Size two: 2.0 to 2.5 mm

M_1 = Storage condition one: Baft bags in room temperature

M_2 = Storage condition two: Polythene bags in refrigerator

M_3 = Storage condition three: Polythene bags in freezer

M_4 = Storage condition four: Paper envelopes in the desiccator

Plot size: $1m^2$

100 seeds sown/row; 4 rows/plot.

Total number of plots = 32

Replicates 4

20 cm pathway between replicates.

20 cm pathway between plots.

Table A.6: Experimental layout for the Nursery on transplant evaluation

RI	RII	RIII	RIV
$V_1S_1M_1$	$V_1S_2M_2$	$V_1S_1M_4$	$V_1S_1M_3$
$V_1S_1M_4$	$V_1S_2M_1$	$V_1S_2M_4$	$V_1S_2M_2$
$V_1S_2M_4$	$V_1S_1M_3$	$V_1S_2M_2$	$V_1S_2M_4$
$V_1S_1M_2$	$V_1S_2M_3$	$V_1S_1M_1$	$V_1S_1M_2$
$V_1S_2M_1$	$V_1S_1M_4$	$V_1S_1M_3$	$V_1S_1M_1$
$V_1S_1M_3$	$V_1S_1M_1$	$V_1S_2M_3$	$V_1S_2M_1$
$V_1S_2M_3$	$V_1S_1M_2$	$V_1S_2M_1$	$V_1S_2M_3$
$V_1S_2M_2$	$V_1S_2M_4$	$V_1S_1M_2$	$V_1S_1M_4$

Key Note:

V_1 = Variety: Composite

S_1 = Size 1: less than 2.0 mm

S_2 = Size 2: 2.0 to 2.5 mm

M_1 = Storage condition 1: Baft bags in room temperature

M_2 = Storage condition 2: Polythene bags in the refrigerator.

M_3 = Storage condition 3: Polythene bags in the freezer

M_4 = Storage condition 4: Paper envelopes in desiccator

Plot size : 0.8 m x 0.6 m

4 grams seeds planted 4 rows/plot

Total number of plots = 32

Replicates: 4.

Table A.7: Experimental Plan for the Field Trials of the Effect of Seed size and storage conditions on the germination and subsequent yield of onion bulbs (Randomized Block Design).

BLOCK I		BLOCK II		BLOCK III
$S_1V_2M_4$ 1.1		$S_1V_1M_2$ 2.1		$S_2V_2M_3$ 3.1
$S_2V_1M_2$ 1.2	Y	$S_1V_2M_4$ 2.2	Y	$S_1V_1M_4$ 3.2
$S_2V_1M_1$ 1.3	A	$S_1V_1M_1$ 2.3	A	$S_1V_2M_2$ 3.3
$S_2V_1M_3$ 1.4	M	$S_2V_2M_2$ 2.4	W	$S_2V_2M_2$ 3.4
$S_1V_1M_1$ 1.5		$S_1V_2M_3$ 2.5		$S_1V_2M_1$ 3.5
$S_1V_1M_2$ 1.6	Y	$S_2V_2M_1$ 2.6	Y	$S_2V_1M_3$ 3.6
$S_1V_1M_3$ 1.7	E	$S_1V_2M_2$ 2.7	E	$S_1V_1M_3$ 3.7
$S_1V_2M_2$ 1.8	L	$S_2V_2M_4$ 2.8	L	S $S_2V_1M_2$ 3.8
$S_2V_2M_4$ 1.9	L	$S_1V_1M_3$ 2.9	L	$S_2V_2M_4$ 3.9
$S_1V_2M_3$ 1.10	Y	$S_2V_2M_3$ 2.10		$S_2V_1M_1$ 3.10
$S_2V_2M_1$ 1.11		$S_1V_1M_4$ 2.11		$S_2V_2M_1$ 3.11
$S_2V_2M_2$ 1.12		$S_2V_1M_4$ 2.12		$S_2V_1M_4$ 3.12

(CONTINUED ON PAGE136)

Table A.7: (Continue!)

BLOCK I	BLOCK II	BLOCK III
$S_1V_2M_1$ 1.13	$S_1V_2M_1$ 2.13	$S_1V_1M_2$ 3.13
$S_2V_1M_1$ 1.14	$S_2V_1M_2$ 2.14	$S_1V_2M_3$ 3.14
$S_2V_2M_3$ 1.15	$S_2V_1M_3$ 2.15	$S_1V_2M_4$ 3.15
$S_1V_1M_1$ 1.16	$S_2V_1M_1$ 2.16	$S_1V_1M_1$ 3.16

Key Note:

S_1 - Size 1 = Less than 2.0 mm seed size

S_2 - Size 2 = 2.0 mm - 2.5 mm seed size

V_1 - Variety 1 = Maiduguri Improved

V_2 - Variety 2 = Ex Gayanawa

M_1 - Storage 1 = Baft bags in room temperature

M_2 - Storage 2 = Polythene bags in the Refrigerator

M_3 - Storage 3 = Polythene bags in the freezer

M_4 - Storage 4 = Paper envelopes in the desiccator

Plot size 2.8m x 3.4m.

Total Number of plots = 48

1 m alleyway between each block

0.5 m alleyway between each plot.

BIOGRAPHY

NAME: Rachael Kehinde A. Cole-Egharevba

DATE OF BIRTH: June 25th, 1943

PLACE OF BIRTH: Lagos, NIGERIA

STATE OF ORIGIN: Lagos

MARITAL STATUS: Married with Children

BUSINESS ADDRESS: College of Agriculture,
Ahmadu Bello University,
Zaria.

HOME ADDRESS: 12, Bazuaye Lane, Benin City.

PREVIOUS QUALIFICATIONS:

INSTITUTIONS ATTENDED	FROM	TO	CERT/DIPLOMA/DEGREE
1. Baptist Girls High School, Agbor	1956	1961	WASC II
2. School of Agric., Akure	1962	1964	Diploma in Gen.Agric.
3. Western Illinois University Macomb, Illinois, U.S.A.	1964	1967	B.Sc. Hort.
	1967	1969	M.Sc. Agric.

POST HELD SINCE THE AWARD OF FIRST DEGREE

Organization	From	To	Position
Western Illinois University Macomb, Illinois.	1967	1969	Graduate Teachnig Assistant
Ministry of Agric. & Natural Resources, W/State	1970	1972	Agric. Officer i/c Devpt.of Horticulture
Ministry of Agric. & Natural Resources, W/State	1972	1974	Agric. Officer i/c State Hort. Training
Ministry of Agric. & Natural Resources, W/State	1974	1975	Senr. Agric.Officer i/c State Hort. Progs.
Ahmadu Bello University, Zaria.	1975	1979	Lecturer in Hort.
Ahmadu Bello University, Zaria	1979	-Date	Snr. Lecturer in Hort.
Ahmadu Bello University, Zaria	1978	1983	Vice Principal College of Agric.
Ahmadu Bello University, Zaria	1977	1981	College Exam. Officer
Ahmadu Bello University, Zaria.	1977	- Date	Head, Horticulture Section, College of Agric.,