POST-HARVEST STUDIES ON STORED SUDANSEZ ONIONS

By

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Onion (Allium cepa L.) is very popular and widely grown vegetable crop in the Sudan. Onion is either used as a fresh, cooked or recently as a dehydrated product.

In the 1970/71 season approximately 13,546 feddans were put to onions. The average yield per feddan, according to the latest information supplied by the Department of Horticulture, is 8.75 tons.

Onions are stored by farmers in well ventilated, thatched-roof huts, for a period of approximately five months (July - December). Under such storage conditions, there are considerable losses due to shrinkage, diseases and sprouting. In January the winter crop is harvested. Therefore there is great fluctuation in the prices of onions during the year.

The Table below shows the prices of onions during the 1969/70 season, as reported by Sudan Ind. Coop. Ins. (1971).

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<th>Month</th>
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No attempts were made to find if these fluctuations of prices are justifiable.

*Feddan = 1.036 acres
Kassala dehydration factory was erected in 1967. Up to now the factory has not been working on a profitable basis. Jackson (1969) reported that the main reasons were the lack of a suitable variety for dehydration, both quality and quantity-wise, and the short operation period (90-120 days). Therefore he suggested the extension of operation to 180 days. This requires 60 days storage of 3,000 tons of onions, since the factory intake per day is 50 tons. Material soft rot caused heavy wastage in onions waiting to be processed for periods longer than three days in field bags.

In Kassala dehydration factory, the onions are stored under the shade of corrugated asbestos sheets supported on reinforced concrete pillars 4.5 meters high. The floor is covered with a cement layer. There is no protection from the sides. Thus the onions are not protected from sun or rains. However, the ventilation is good.

A trial was made in Kassala dehydration factory to store onions in two layers to minimize losses due to rotting. These losses amounted to 17% of the 1970/71 crop during storage period of 90 days. The results of the trial indicated that storage in two layers was impractical during loading and unloading.
Kassala dehydration factory is suffering from onion losses caused by soft rot, yeast and mostly *Aspergillus niger*.

The present study was designed to investigate the basic problems in losses during storage of onions such as weight loss due to moisture loss, pests and diseases and sprouting. Dormancy and respiration rate during storage were studied. Dry matter and soluble solids changes were recorded. It is hoped that this study will serve as a basis for future work to solve the different problems of onion storage in the Sudan.
Jones and Hann (1963) stated that the factors which were critical for successful onion storage were choice of cultivar; methods of culture, harvesting and curing, control of temperature and humidity in storage, design of storage structures, and use of sprout inhibiting substances.

1. Onion Varieties

Kagrudor (1941) classified the principal American varieties of onions according to their keeping quality as poor, fair, good and very good. Tromšková (1969) in Czechoslovakia working with thirty-nine different varieties found that there were varietal differences in keeping quality. Yonkett and Petersen (1950), Hanamoto and Ito (1957), Isol et al. (1966) and Radic (1968) reported that wild varieties were bad storers and sprouted early. Varieties with high dry matter content, on the other hand, were good storers. Hann et al. (1945) found that dry matter content increased from outer to inner scales. Also Keller (1939) and Hanamoto and Ito (1957) found that dry matter content increased from the top to the base of the bulb.
2. Onion Quality

Bulbs to be stored should be nature, healthy, single and with firm necks. Gaylord (1927) reported that good selection of bulbs before storage decreased loss due to drying to 4.3 percent, while in unsellected bulbs loss due to drying was 22.4 percent. Similarly, Boyle (1946) stated that onions for storage should be free from bruises, cuts and green material. Hanaoka and Ito (1957) indicated that round bulbs with firm flesh and neck sprouted least.

Jones and Mann (1963) indicated that onion quality depended chiefly upon cultural practices in the field and harvesting. For example excessive application of nitrates late in the growing season, or growing long day cultivars in short day conditions resulted in thick neck bulbs that did not keep well in storage. Brinkwater and Jones (1955) found that non-irrigated onions matured before irrigated onions. Also in storage, non-irrigated onions lost more weight than irrigated onions.

Croxall (1945) and Wallace and Rickman (1945) found that early lifting of bulbs before the tops had died down reduced losses in storage. Itagaki (1959) reported that early
harvest improved storage quality. Cussew (1923) reported that early maturing individuals sprouted and decayed less than late maturing individuals. On the other hand, Aoba (1965) found that bulbs harvested earlier, resulted in breaking dormancy faster than those harvested late in the season. Similarly Bagrued (1941) found that immature bulbs sprouted earlier than mature ones and were more susceptible to decay. Kamel (1962) found that in nature stored onions, stored for 3–6 months, 1-2 percent infection with neck rot occurred, whereas 11.4 per cent of the immature bulbs were infected. Harwood and Joshi (1941) found that immature bulbs lost more weight than mature bulbs.

Jones and Hann (1965) stated that onions for storage should be mature i.e. when necks become soft and tops fell over, indicating cessation of production of new leaves. The dried old leaves would seal the bulb neck. On the other hand, de Avila (1963) found that harvesting onions as soon as maturity was reached, while tops were still green, prolonged the storage life of onions.

Hoyle (1947) found an interaction between length of topping and maturity when harvesting and subsequent storage behaviour.
He found that short neck was superior among bulbs harvested with tops up and green, whereas for bulbs harvested with tops down and dry the topping length had little influence on subsequent storage behaviour. Results for bulbs harvested with tops down and green were not consistent.

Jones and Hann (1963) reported that, in most countries, onions were harvested when the necks softened but before they were fully mature and the tops were still green. They also stated that in many parts of the world onions were topped and the roots were removed immediately after harvest e.g. in Egypt and parts of the United States of America, while in other parts, such as the Cape Province of South Africa, onions were stored with their tops intact.

3. Curing

Walker (1937) pointed out that high humidity and rainy weather during harvest, almost invariably, resulted in heavy losses; since moisture is favourable to bacteria and fungi. Wallace and Hickman (1945) found that well dried necks were not easily infected with neck rot. Nokes (1963) pointed out that shoot emergence was delayed by curing.
In statements Forsälvikenskab (1959), it was advised that
that curing might take place within two weeks from lifting,
unless the keeping quality appeared to be poor, when they
should be dried without delay.

Jones and Hans (1963) reported that curing might be
in the field or away from it. Curing might be in the field
where relative humidity was low and rains were rare during
harvest as in Egypt and southwest United States of America.
The harvested bulbs were covered by their tops to prevent
sun scald and were left in the field after harvesting. The
bulbs might be placed in windrows, baskets or crates. Colby
et al. (1945) found that field curing in piled crates was
better than field curing in burlap bags or windrows.

There are contradicting results about field curing.
De avila (1965) stated that under conditions of Angola
careful drying away from direct sunlight was preferable.
Linsen (1959) on the other hand, found that for Rio Grande
onions sun curing was preferable.

Curing may be practiced away from the field under
shade as in the barn or artificially by hot air, depending
on locality, environmental conditions and facilities.
Hoyle (1948) found that curing by warm air at 105\(^\circ\) to 118\(^\circ\)F (40\(^\circ\) - 47\(^\circ\)C) for 16 hours was better than field curing. Krotova (1959) reported that heat treatment at 35\(^\circ\) to 40\(^\circ\)C (95\(^\circ\) - 104\(^\circ\)F) for 6 to 10 hours controlled neck rot and prevented sprouting in storage. In states Poroshenko and Foll (1959), it was reported that artificial drying of onions at 40\(^\circ\)C (104\(^\circ\)F) proved to be superior to field curing. Similarly Gull (1960) found that heated air blast at 110\(^\circ\)F (43\(^\circ\)C) for 20 hours kept onions better than non-cured bulbs. On the other hand Gabelman (1951) found that onions cured at 100\(^\circ\)F and 130\(^\circ\)F (38\(^\circ\)C and 54\(^\circ\)C respectively) exhibited great losses in weight and also exhibited internal breakdown.

Lorenz and Hoyle (1946) compared curing of topped and untopped bulbs. The necks of harvested bulbs were soft but the tops were still green and some were down. The bulbs without tops lost less weight than the bulbs with tops, indicating that moisture had been removed through the tops. There was gain in dry weight of untopped bulbs after curing, indicating that there was a movement of soluble solids from the top to the bulbs during curing. Franklin (1966) found that onions cured with green tops retained their scales better than machine topped onions, but they were attacked more by
neck rot during storage.

4. **Storage Temperature**

This is one of the most important factors controlling onion behaviour during storage and the growth of the bulbs afterwards in the field. It influences seed production, sprouting and disease development. Pratt and Harris (1956) reported that long storage might be achieved at either high or low temperatures. This appeared to be related to internal dormancy or rest period characteristic of fresh onions which had not been exposed to low temperatures. At high temperature the bulbs remained dormant and resistant to decay while at low temperatures, even though the rest period was broken, the temperature was too low for sprouting and decay to take place. At the intermediate temperatures, the temperature was low enough to break the rest period but not low enough to prevent losses due to sprouting and decay. Losses of dry or fresh weight due to higher respiration rate during high temperature storage were not so great as expected, doubtless because of the internal dormancy factor.
work carried by different scientists confirmed the findings of Pratt and Horrobin. Kamarakar and Joshi (1941) reported that bulbs remained dormant at 32°F (0°C) up to six months. Practically no sprouting occurred at the high temperature range of 79°F to 89°F and 95°F to 95°F (26°C to 30°C and 35°F to 35°C). Prolonged storage at high temperatures resulted in infection with black mould and attack by small insects and thrips. A few bulbs showed soft rot. Losses in weight at 90°F to 95°F (32°F to 35°C) was double that at 32°F (0°C). Temperature range between 45°F and 60°F (9°C and 13°C) was conducive to sprouting, 60°F (15°C) being the optimum temperature.

Aobe (1955) reached similar conclusions. Also, Yanaguchi at al. (1957) storing Southport White Globe onions at a temperature range of 0°C to 46°C (32°F to 110°F) found that temperatures 0°C, 2.5°C and 30°C (32°F, 35.5°F and 86°F) gave highest yield of sound bulbs and 5°C, 7.5°C and 25°C (41°F, 45.5°F and 77°F) proved to be next highest while intermediate temperatures of 10°C, 15°C and 20°C (50°F, 59°F and 68°F) gave the lowest yield of sound bulbs. The temperature range of 9°C to 15°C (46°F to 59°F) was found to be conducive to both sprouting and inflorescence initiation and bulbing;
(Hartema 1947; Moys 1960; Aura 1963). No sprouting was reported at low temperatures of -2°C to 4°C (29°F - 39°F) (Van Sickle 1949; Nible 1952; Asa 1966 and Arsen and Suvakot 1969). The best temperature range for storage of onions was found to be around -1°C (30°F) (Kaguder et al. 1941; Karmarkar and Joshi 1941; Golby et al. 1945; Yanagushi 1957 and Aura 1963).

Lower temperatures might cause injury. Asa (1964) reported that -3°C (26.6°F) caused injury to onion bulbs. On the other hand Wächter (1968) found that onion cultivar Mittlauer Kissen kept very well during a 10 days treatment at -9°C (16.2°F); in only a few of the onions had some of the outer scales frozen. There might be varietal differences in this respect. However, Hanussen (1957) recommended cooling in stages for long period storage to allow a process of acclimatization to take place.

Second best temperature range for storage was 23° to 30°C (73.4° to 86°F) since at this range sprouting was controlled and high percentage of sound bulbs were obtained. (Karmarkar and Joshi 1941; Blaauw 1944; Heath 1947; Slawinsky 1948; Yanagushi et al. 1957; Abdulla 1963 and Aura 1963).
5. Relative Humidity

Jones and Mann (1963) stated that, "With the choice of cultivar, relative humidity probably has more influence on keeping quality of onion bulbs than any other factor". At low relative humidity and high temperature bulbs lose weight at a relatively constant rate (Bright et al. 1952; Jones and Mann 1963; Ang 1963). Schippers (1968) stated that loss in weight was not directly related to temperature but directly related to the moisture deficit of the surroundings which depends upon both temperature and relative humidity of the surroundings.

Low relative humidity is needed during curing. During storage moisture loss should be held to a minimum to avoid excessive loss in weight. A relative humidity of 74 to 85% was recommended at storage temperature of 0°C (32°F).

(Habel 1952; Simos 1959; Dunkel 1965; Briten and Novakot 1969).

According to Blatensius et al. (1974), the humidity of the storage chamber had an appreciable effect on the keeping quality of onions when the temperature was above 0°C (32°F) but at temperature below the freezing point the moisture content was of little importance. High relative humidity resulted in rooting and did not affect the sprouting rate.
(Wright et al. 1932, Karmarkar and Joshi 1941 and Aura 1963). Aura (1963) found differences in root formation between various strains. Hagerdor (1941) found that those cultivars which formed roots early sprouted readily.

High humidity encouraged the development of rotting organisms (Walker 1937; Karmarkar and Joshi 1941; Ang 1953; Aura 1963 and Schipper 1968).

6. Storage Atmosphere

For best results onions should be well ventilated to remove moisture and heat of respiration (Kobel 1956 and Ogata 1957). Long (1969) recommended an air velocity of 250 cu.ft/min/ton for drying and 100 cu.ft/min/ton for the remaining storage period.BUTTON (1970) reported that hot air at 30°C (60°F) controlled rotting and improved external quality.

Heiss (1937) reported that nitrogen gas storage is superior to ordinary cold storage. Storage at 1 per cent oxygen and a relative humidity of 45 to 50 per cent prolonged storage life (Ogata 1937, 1961). Chawan and Pflug (1960) reported that onions stored at 4°C (40°F) in either 10 per cent carbon dioxide and 3 per cent oxygen or in 5 per cent carbon dioxide and 5 per cent oxygen were superior to onions stored
in air at 40°C (40°F) for Downing Yellow Globe or Shandana cultivar.

7. Onion dormancy

Jones (1961) pointed out the fact that onions when freshly harvested were in a state of rest. The rest-period is a cultivar characteristic (Jones and Mann, 1962). Abdalla and Mann (1963) confirmed these findings and indicated that the longer the bulbs stayed in storage, the quicker they sprouted when planted out. Aara (1963) found that the resting phase gradually changed to a state of dormancy and that no sudden changes occurred during the gradual disappearance of the rest state. During the time of deepest rest the activity of the apical meristem was minimal.

Abdalla and Mann (1963) showed that there was a definite brief rest in onions, where leaf initiation did not take place. Twenty days before maturity leaf initiation ceased and resumed back in seven days time after harvest. Even then the apical meristem showed mitotic division indicating that the shoot apex was morphologically active.

Kato (1966a) reported that onions have a rest period of 56 days, followed by a dormancy period of 60 days, just before sprouting and roots start to elongate.
Jones and Kamm (1963) concluded that bulbs held for long time in storage were capable of rooting and sprouting, and were then held dormant by conditions of moisture or temperature which were unfavourable to growth.

The rest period in stored onions disappeared most rapidly at a temperature range round 3° to 21°C (37.4° - 69.8°F), especially the range 13° to 15°C (55.4° - 59°F). At -1°C (30.2°F) and at 31°C (87.8°F) the bulbs exhibited a weak state of rest after seven months of storage. Rooting dormancy was not affected by temperature, during a period of eight months storage but was appreciably influenced by the humidity during storage.

Kato (1966b) investigated the relationship between bulb dormancy and components of onion juice. He found that onion juice from a dormant bulb inhibited germination of onion seeds and growth of onion seedlings. Allyl sulfide, an inhibiting substance to seed germination, was found in large amounts in dormant bulbs and in lesser amounts in sprouting bulbs. Kato (1967) concluded that sugar accumulation during bulbing depressed respiration and induced dormancy, and then gradual decline in sugar concentration resulting from respiration during storage facilitated the breaking of dormancy.
Thomas (1969) reported that there was conclusive evidence that dormancy could be broken by gibberelllic acid or 1-naphthalene acetic acid.

5. Onion Respiration During Storage

Jones and Mann (1963) reported that in stored onions respiration resulted in continuous loss of stored food (dry matter) and heat production. Heat should be removed by cooling or ventilation. Dry matter losses were 0.5 per cent and 4.3 per cent of the total dry weight of Southport White Globe onions stored at 0°C (32°F) and Yellow Bermuda onions stored at 23°C (73°F) for 180 days respectively. Heat production for the two above mentioned varieties were 660 and 5,900 British thermal units per ton of bulbs per 24 hours respectively. Jones and Mann (1963) indicated that the respiration rate increased over the entire temperature range of 0°C to 40°C (32°F-104°F). At the temperature range 0°C to 35°C (32°F-95°F) respiration increased slightly over four times, while between 35°C to 40°C (95°F-104°F) it doubled. The slow increase in respiration rate with rise in temperature might favour storage under relatively high temperatures. The high respiration rate at 45°C (113°F) might be due to the fact that storage under this temperature was injurious to the bulbs.
Ogata and Kurata (1960) and Ogata (1961) reported that respiration rate decreased during the final stage of bulb development. It reached a minimum before harvest, which persisted for some time after harvest and then rose gradually towards sprouting time in storage. Karmarkar and Joshi (1941) reported an increase in the respiration rate during storage. Aoka (1960) found that respiration rate in onions was high immediately after harvest, then decreased during storage and increased towards sprouting date. Hather (1956), Iseemberg et al. (1954) and Date (1960) indicated that the application of naphthalic hydrazide at high concentrations reduced the rate of respiration.

9. Sprouting Inhibitors

Many chemicals were used as sprout inhibitors such as naphthalene acetic acid, 2-naphthoxy acetic acid, 6-phenyl-1-naphthalene acetyl and naphthalene hydrazide (Sittower et al. 1950; Dallyn and Smith 1952; and Kaneshaw and Ranapuri 1966). Differd (1955a) reported that equal amounts of 2-(4-chloro-2-propoxyphenyl) carbonate and methyl-naphthalene acetyl controlled sprouting. Jones and Khan (1963) stated that of all these chemicals naphthalic hydrazide was considered the most effective sprout inhibitor and it
did not produce any undesirable flavour or off-colour in the bulbs.

Jones and Hans (1983) reported that in order that maleic hydrazide became effective in controlling sprouting the chemical should reach the onion's growing points. There were strong interactions between dosage, time of application, stage of plant growth and relative humidity.

Coslin (1959) recommended the use of 4 pounds of maleic hydrazide per acre two weeks before harvest i.e. while the tops were still green so that the chemical could be transported to the growing points. Early application resulted in soft bulbs. Rain within 24 hours after application might reduce its effectiveness. Bendixen (1966) and Sheehy (1966) found that time of application had little effect. Other workers found that maleic hydrazide an effective sprout inhibitor at different concentrations and applied at different dates prior to harvest e.g. Wittwer and Sharma 1956, Wittwer and Paterson 1951; Ciferrì 1953b, Meeks 1954; Isaacberg 1956 and Fenderson and Isaacberg 1963. Isaacberg (1956) reported that post-harvest treatment with maleic hydrazide was effective when the tops were still green.

Arthur (1950) reported that maleic hydrazide reduced wastage due to *Monocilina nigra* and *Abitosoma nigricans*. 
Sundaresan (1969) found that maleic hydrazide controlled both rooting and rotting, whereas Celestino (1961) found that although it controlled sprouting it slightly increased rotting and shrinkage.

10. Irradiation As a Rooting Inhibitor

Sparrow (1955) found that sprouting could be controlled using X-ray, gamma rays and fast electrons. Similarly Campus et al. (1969) reported that the percentage of sprouting was inversely proportional to X-ray dosage. Dallyn and Sawyer (1959a) found that fast electrons could control sprouting when applied only at the base of bulbs which was impractical when applied commercially.

Sawyer and Dallyn (1956) reported that 3000 r for 48 hours completely inhibited sprouting, while 4000 r prevented sprouting at 65°F but was not entirely effective at 55°F. Fast electron irradiation failed to check sprouting. Dosages of 3000, 6000, 7000, 8000, and 12000 r of gamma rays were found to be very effective in controlling sprouting and no detrimental effect in flavour, sugar content, volatile content, growth promoting substances or inhibitory substances were noticed (Dallyn and Sawyer 1959b).
Ogata et al. (1959); Ogata 1961; Abdel-El 1967; MacRae and Oates 1969 and Guha and Revelli 1970). Nuttal et al. (1961) reported that irradiated onions have a milder flavour and that irradiation time with regard to length of period after harvest, seemed very critical for control of sprouting. Pullins and Murr (1961) reported that 2 weeks, 2 weeks after harvest inhibited sprouting but not 250 K rad or 17 weeks after harvest, while Abdel-El (1967) working with Egyptian onions found that irradiation within 5 months after harvest controlled sprouting since Egyptian onions usually sprout 5 months after harvest.

Abdel-El (1967) also confirmed the findings of Ogata et al. (1959), Dallyn and Sawyer (1959a), Dallyn and Sawyer (1959b) and Nuttal et al. (1961), that discoloration observed at the growing points depended upon the length of internal sprout at time of irradiation.

Dallyn and Sawyer (1959a) found that irradiation did not affect the amount of decay developed in storage. Ali (1970) found that irradiation reduced decay while Hall (1965) found that decay increased as a result of irradiation. Rashid (1965) found that decay increased in the doses above 3000 r.
Ogata et al. (1959) found that irradiation caused suppression to the increase of respiration at pre-sprouting time and non-reducing sugar did not decline as in the control when sprouting started.

Korshleva and Ketlickij (1953) found that nucleic acid synthesis was retarded and that damages that inhibited sprouting also affected dry matter content and distribution of nucleic acid in the various tissues. Kawakami (1971) found that 7-15 Krad gamma rays' doses, used for sprouting inhibition decreased the activity of cysteine sulphoxide lyase and the formation of di-n-propyl disulphide, one of the odour compounds, was reduced. However, after 3 months in storage, their level was restored.

A joint committee from I.C.A. and I.S.B. (1970) found that the data related to the wholesomeness of onion irradiated with doses up to 15,000 rad of radiation was shown to be unsatisfactory. Although the studies did not indicate any harmful effect due to irradiation, the results were complicated by the fact that the high level onion feed caused toxic symptoms in the control animals as well as those fed on the irradiated diet.
11. **Storage structures and methods of storage**

Jones and Hans (1963) stated that storage structures vary from simple shelters that protect onions from rain and sun to well insulated houses with heaters to prevent freezing and cold-storage rooms that provide low temperatures.

In the Bombay region of India, grass-thatched roof houses with bamboo sides are used for storage of onions. These houses ensure good ventilation and protection from rains. In Japan onions are tied in bundles and hung from bamboo poles in well ventilated shelters.

In the Valencia district of Spain onions are piled 5 to 6 feet deep in sheds. In the United States of America and Canada onions are stored in crates stacked on slatted floors or piled in bulk 6 to 14 feet deep, through which air is circulated from below upwards through the crates.

Franklin (1966) stated that at depths greater than 8 feet excessive pressure damaged the onions. radio (1966) found that for periods of more than four months, losses of onions stored in crates were greater than those exposed to air.
Varid (1960) described different methods of storage of onions in Egypt as follows:

a) Onions are piled over maize stalks in well aerated places.
b) Onions are piled in the field and covered from the sides.
c) Onions are stored in palm frond boxes.
d) Onions are stored in layers separated by wheat stalks.
e) Onions are stored in sacks arranged in rows on sand or wood under well ventilated shelters.
f) Onions for seed production are hung from the roofs of store houses.

12. Onion Diseases and Pests during Storage

Jones and Mann (1953) reviewed the types and control of the organisms attacking onions in the field and during storage. They also mentioned the damages caused by chemical or physical injuries and sunscald during storage.
Fungal Diseases

Black mould is caused by *Aspergillus niger* Tiegh. Hatfield (1940) described *A. niger* as a mild pathogen. Owen (1950) found that coloured varieties were more susceptible than white varieties under moist conditions. He concluded that pungency was not important in determining the incidence of black mould. Karmarkar and Joshi (1941) reported that infection with *A. niger* was more severe at high temperatures 75° - 85°F and 90° - 95°F (i.e. 24° - 35°C and 32° - 35°C) during the rainy season. Beerli (1954) indicated that dryness reduced the activity of *A. niger*. Bauza De Segura (1959) found no infection at 10°C (50°F) under dry conditions, while at 20° to 25°C (60° to 76°F) infection took place.

*Aspergillus alliatus* was reported by Ahlstrand (1949) to cause rot in onions in Sweden.

*Penicillium sp.* was reported by Beerli (1954) in stored onions and Warid (1964) found *P. cyclopium Westling* in certain varieties of onions.

Neck rot of onions is caused by *Botrytis alliacea*. *B. hypoxilis* J. C. Walker, *B. sambucina* J. C. Walker and
A. *septospora* (Jones and Mann, 1963; Al Salehi 1962). The disease is destructive and the mild varieties are more easily infected than the pungent varieties. White varieties in the pungent class were infected more than coloured varieties in the same class (Hatfield 1948, Owen 1950).

Onion smudge is caused by *Colletotrichum circinale* (Berk) Vogl. It affected white varieties chiefly, since coloured varieties were resistant to it (Jones and Mann 1963). Tonkins (1951) found that the presence of catechol and protocatechuic acid in scales of certain onion varieties rendered them resistant to smudge. Hatfield (1948) and Owen (1950) found that pungent varieties were more resistant to smudge and that this organism was more pathogenic than *Asperillus niger*.

Bottom or basal rot is caused by *Asperillus oxyasperus* Schlecht. *F. solani* and *A. nodosum*. The development was reported to be most at 30°C and 20°C. At temperatures of 15°C and 8°C decay was inhibited (Jones and Mann 1963).

White rot is caused by *Sclerotium cepivorum* Berk. It develops most rapidly at 10°C to 25°C (50°F - 68°F). At 24°C or above its development was inhibited (Jones and Mann 1963).
B. lodiola natalensis was observed to attack the dead outer scales and dying parts of fleshy scales of white onions, but not the coloured varieties (Nasey et al. 1946).

Downy mildew is caused by *Peronospora destructor* (Berk.) Camp.

Purple blotch is caused by *Alternaria porri* (Ell.) Olf.

*Macosporum* caused discolouration in the outer scales of onions although it did not penetrate inside the bulb (Nasey 1930).

**Bacterial diseases**

Bacterial soft rot of onions is caused by *Arvinia carotovora* (L. R. Jones) Holland. (Varid 1960 and Jones and Hann 1963).

Sour skin or slippery skin is caused by *Pseudomonas cepacia* Burk (Jones and Hann 1963). Kawamoto and Lorbeer (1967) isolated soft rot bacteria from decaying onions and from organic soil cropped with onions and the isolates were identified as *P. alicicola* and *P. cepacia*. Some of these were similar to *P. marginalis* and a group similar to *Aerobacter*, Varid (1960), and Vitanov (1966) also reported *Pseudomonas alicicola* Burkholder in rotted onions.
Evtjunkin (1968) found *Pectobacterium carotovorum* and
and *E. amylovora* in stored onions.

**Virus diseases**

Aster yellow was reported by Jones and Mann (1963)
to attack stored onions.

**Onions pests**

Onion thrips (*Thrips tabaci* Lind.) attacked onions in
the field and during storage. The degree of attack was a
variable characteristic. Thrips fed on the foliage of
sprouted bulbs (Jones and Mann 1963, Humo 1965).

Onion maggot (*Hyledrya antiqua* Wals) is a widely spread
organism that fed upon plants from seed to mature bulb.
Maggots eat through the mature bulbs and forming channels
that permit rotting organisms to invade the bulbs (Jones
and Mann 1963).

Wire worm (*Limonius sp.*) is in the larval stage of the
click beetle. The worms attack seedlings and channelise
mature bulbs (Jones and Mann 1963).

Stem and bulb nematode (*Ditylenchus dipaeci*
(Kühn) Filipjev) is a tiny worm-like organism that
infests both the plants and the bulbs in the field.
During storage its activity continues and the bulbs become lighter in weight and puffy (Newhall and Ghitwood 1940, Wallace and Hickman 1945 and Hune 1963).
The onion used in this trial was the local red cultivar grown in the Ed Samli area, about 30 miles north of Abderous.

This onion cultivar is commercially grown in different parts of the Sudan. It is characterized by its marked pungency, high dry matter content, and ability to store for a long period.

Onion seeds were sown in the nursery on the first week of November, 1969. Two months later the seedlings were transplanted to the field in plots of 2 x 5 meters each. Plants were spaced 18 to 15 cm apart. The land was fertilized before transplanting with manure at the rate of 200 kilograms per feddan. The crop received a total of seventeen waterings. Bulbs were harvested 135 days after transplanting. Harvested bulbs were removed immediately to sheds, where they were packed in sacks and transported in trucks to the Faculty of Agriculture at Khartoum two days after harvest. All damaged or diseased bulbs were removed and the sound bulbs were cured under shade for eleven days after which the first season onion storage trial was started.
Seeds for the second season's trial were sown on November 20th., 1970 and were transplanted on January 1st., 1971. Similarly, manure was applied at the rate of 200 kilogrammes per feddan before transplanting. One month after transplanting a dose of ammonium sulphate at the rate of 25 kilogrammes per feddan was applied. Three weeks later a similar dose was administered. The plots were sprayed twice with gammoxone at the rate of 10 litres per feddan. The first spray was two months after transplanting and the second spray one week later. The crop received sixteen waterings. Bulbs were harvested 160 days after transplanting, cured for seven days under shade and stored in a farmer's cottage for one and half months. On August 1st., 1971 the onions were packed in sacks and transported by trucks to the Faculty of Agriculture at Aswan. These onions were used for the bulk storage experiment only.

Onions used for the other experiment in the 1971 season were grown in the farm of the Faculty of Agriculture at Aswan. Two months old transplants obtained from one of the farmers of the Aswan area were used. Yield setting took place on February 20th., 1971. The seedlings were planted 7.5 cm. apart on ridges spaced 60 cm. apart.
Ammonium sulphate was applied two weeks after transplanting at the rate of 50 kilograms per feddan. Watering was applied twice a week and thus the total number of waterings was thirty-three.

**Experiment (1)**

**Determination of Bulb Sizes**

Onions were classified roughly into small, medium, and large bulbs according to their size. Ten bulbs from each class were weighed, the diameter and height of each bulb was measured.

**Experiment (2)**

**Determination of Dry Matter Content**

Twenty five medium size bulbs were chosen at random. The outer dry leaves were removed. Bulbs were cut in quarters using a sharp knife with a minimum loss of juice. One quarter from each bulb was weighed and dried in the oven at 65°C to 70°C for 144 hours until it attained a constant weight.

At the end of the storage period the dry matter content of the bulbs were determined by the same method.
**Determinant of Total Soluble solids**

Twenty-five medium-sized bulbs were selected at random. A cork borer was drawn horizontally through the centre of the bulb to collect the sample. The samples obtained were crushed gently in separate containers and drops of the juice were placed in a hand refractometer. The values obtained were corrected, since the refractometer used is calibrated at 25°C.

**Local Bulk Storage Method**

The purpose of this trial was to determine storage losses in bulbs stored in bulk by the local cottage method.

The cottages used in this trial were constructed in a similar manner to those cottages used by Hungarian farmers for onion storage.

The cottages are made of a wooden frame covered by a layer of straw. The main structure of the cottage is cylindrical while the roof is cone shaped. The diameter of the cottage is 3.5 meters and its height is 4.5 meters.
The full capacity of the cottage is 6 tons. At the bottom of the cottage a bamboo frame 40 cm high is placed. The onions are then piled on this frame. Plates 1, 2 and 3 show the different stages of a cottage under construction. Plate 4 shows onion piled on bamboo frame. Plate 5 shows a farmer's cottage at Had Samli and a curing shed. Plate 6 shows onions stored in a farmer's cottage. Plate 7 shows different types of cottages in which the bottom part is made of mud with holes in it for ventilation. This type is not very popular since it does not provide adequate ventilation. Accordingly greater losses occur during storage.

Onions selected for this experiment were similar to those selected by local farmers for storage, who usually discard diseased and injured bulbs.

The onions were weighed at the beginning of the experiment. They were then stored in two different cottages. An inspection was made every four weeks in one of the cottages to discard diseased and sprouted bulbs. The second cottage was inspected only at the end of the experiment (during December), which is the same as the farmers' practice.
Plates 1, 2 and 3 - Show the different stages of constructing an onion storage cottage in the Faculty of Agriculture, Shambat.
EXPERIMENT (5)
Storage Losses

(a) Shrinkage

Four lots of onions, 25 kilograms each, were stored in wooden crates placed in a cottage similar to those used in Experiment (3).

Bulbs were inspected every two weeks. At each inspection bulbs were weighted to determine loss in weight due to shrinkage.

(b) Disease

Diseased bulbs; those showing soft rot or badly shrivelled, were counted, weighed and then discarded.

(c) Sprouting

Four lots of 200 bulbs each were placed in ,base flats. Bulbs were inspected every two weeks and bulbs showing visible sprouts; approximately 2 cm long, were recorded.

EXPERIMENT (6)
Storage Diseases and Pest

Two hundred bulbs were placed in a crate and stored in the cottage. The bulbs were inspected for diseases and
plants at two weeks intervals. The rotted bulbs were recorded, removed and then categorized according to the type of the damage. Representative samples from rotted bulbs were chosen. Organisms causing the damage were isolated, purified and identified.

Fungi were isolated in a potato dextrose agar medium containing Mon Bongal and were identified with the help of Dr. M.M. Abdalla of the Faculty of Science, University of Khartoum.

Plants were identified with the help of Dr. A.I. A. Bechir and M. H. Younis H. of the Crop Protection Department, Faculty of Agriculture, University of Khartoum.

Bacteria were isolated in a nutrient agar medium. Biochemical characteristics of the bacteria were studied according to the Manual of Microbiological Methods (American Society for Bacteriology 1951) under the kind supervision of Mr. B. Habish of the Faculty of Agriculture, University of Khartoum. The isolates were identified as far as possible following the key in Sergey's Manual of Determinative Bacteriology (1957). The pathogenicity of the different isolates were tested on sterile discs of raw potatoes and raw onions.
EXPERIMENT (7)

Temperature effect on the development of *Aspergillus niger*

In the first season (1970), it was found that *Aspergillus niger* was a common contaminant of red onion bulbs. Some of the infections were confined to the outer scales, while in other cases the bulbs were rotted and the infection was deeply situated. This implied that there were special environmental conditions under which *Aspergillus niger* caused severe damage.

This experiment was designed to study the effect of temperature on the activity of *Aspergillus niger* on two different varieties.

In the 1971 season the red onion cultivar grown at the Faculty of Agriculture's farm and the yellow cultivar named Mongola White were used. Mongola White is a selection of red onions and is not yet released. Mongola White was grown at Kudela Research Station and had been stored for seventy five days before the beginning of this experiment.

Four temperatures were used: ambient, 5°C, 2°C and 4°C. The relative humidity was recorded.
The experiment was designed as a split plot design with four replications. The temperatures ambient, 5°C, 20°C, and 40°C were in the main plots. The two onion varieties were in the subplots. Each subplot consisted of ten bulbs. Inspection was carried out monthly and the discolored bulbs were recorded and discarded.

**Experimental (6)**

**Seed Period of Onion Bulbs**

Fifty bulbs were planted in flats filled with moist soil, the same day they were harvested. Then planting took place once every two weeks. Bulbs with visible sprouts were recorded daily. The number of days to 50 per cent germination was calculated by graphing the number of bulbs that germinated against the number of days from planting date to germination date according to the method of Abdalla and Mann (1963).

**Experimental (9)**

**Respiration of Shaded Onion**

The respiration rate of onion bulbs was measured by the carbon dioxide absorption method. Three respiration trains were used. The respiration rate was determined at 30°C once every two weeks in a dark room.
Air from the air pump was passed at the rate of 120 ml/min through calcium chloride to absorb moisture and 40 per cent sodium hydroxide to absorb any carbon dioxide in the air stream. The air was then passed through distilled water to wash any traces of sodium hydroxide. The carbon dioxide free air was passed through an air-tight jar containing 2 kilograms of onions. Air from the jar was passed through a bottle containing 200 ml of 1 N sodium hydroxide to absorb the carbon dioxide resulting from the respiring bulbs. The air was then passed through 1 N barium hydroxide to check if there were any non-absorbed carbon dioxide. At the end of the train a bottle containing 40 per cent sodium hydroxide was connected to absorb any carbon dioxide that might enter. The respiration trains were run for two hours.

The solution of sodium hydroxide and sodium carbonate was titrated against approximately 0.5 N hydrochloric acid using method No. 2 of titration of mixture of alkali hydroxide and carbonate (Cunning and Way 1956). The weight of sodium carbonate obtained was equivalent to the carbon dioxide produced by the two kilograms of respiring onion bulbs in two hours time. Hence the weight of carbon dioxide produced per kilogram of bulbs per hour was calculated.
EXPERIMENT (10)

Irradiation of Local Sudanese Onions

Onions were irradiated with gamma rays from a cobalt-60 source at the radiation unit of Khartoum Hospital under the kind supervision of Mr. Ibrahim Abdel Rahman.

In the 1970 season Wad Hamli cultivar was used. The onions were stored for three months prior to the experiment. The experiment was designed as randomized block design. The irradiation treatments were as follows: control, 4000 rads, 6000 rads, 8000 rads, 10000 rads and 12000 rads. Each treatment was replicated four times and each replicate consisted of ten bulbs.

In the 1971 season three varieties were used for the experiment, namely, Wad Hamli, Dongola White and Nassi. Nassi is a white cultivar, a selection of a local cultivar called Sileim, which is not yet released. Both Nassi and Dongola White were stored for seventy-five days prior to the experiment while Wad Hamli was stored for forty-two days prior to the experiment.

The experiment was designed as a split plot design. The irradiation treatments were as follows: Control, 4,000 rads,
6,000 rads and 8,000 rads, an additional dose of 2,000 rads was used for Red Haari onions only. Each treatment was replicated three times and each replicate consisted of ten bulbs.

Loss in weight and number of sprouted bulbs were recorded monthly. At the beginning and the end of the experiment the length of internal sprouts was measured by cutting five bulbs longitudinally.

In the 1971 season samples from each treatment were dehydrated. Losses due to sprouting, peeling, and slicing in preparation for dehydration were recorded. Per cent weight, per cent moisture, flavour, neutral tint, optical density and overall appearance of dehydrated onions were determined.

The per cent moisture was determined by the vacuum oven drying method as described by Goslyn (1970). Flavour was determined by taking the average grades given by six different tasters. Neutral tint was determined by the use of a Lovibond tintometer. Optical density was determined by using a Klett-Summerson photometric colorimeter. A sample of 5 grams was taken from each treatment and was soaked in 50 ml. distilled water over night and then filtered through Whatman No. 2 filter paper. The absorption was determined using green filter (6654).
1 - Bulb Sizes

The measurements of different bulb sizes of the Nanli cultivar in both 1970 and 1971 seasons, are shown in Table (1). The data indicated that onion bulbs could be classified into small, medium and large bulbs. There is little difference in sizes between the two seasons.

2 - Dry Matter Content

Data shown in Table (2) indicated that the dry matter content of bulbs sampled six months after storage under ambient conditions was lower than the initial dry matter content in the 1970 season; but the difference failed to reach the level of significance. However, in the 1971 season the dry matter content of bulbs sampled six months after storage was significantly lower than the initial determination of dry matter content at the beginning of the storage period.

3 - Percentage Total Soluble Solids

Data shown in Table (3) indicated that the total soluble solids of bulbs sampled six months after storage under ambient conditions was lower than the initial total soluble solids content in both the 1970 and 1971 seasons, but the difference failed to reach the level of significance.
<table>
<thead>
<tr>
<th>Season</th>
<th>Size</th>
<th>Weight (gms)</th>
<th>Diameter (cm.)</th>
<th>Height (cms.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1970</td>
<td>Small</td>
<td>3.0-5.0</td>
<td>4.3-5.1</td>
<td>4.2-5.1</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>9.0-13.0</td>
<td>5.5-6.0</td>
<td>5.2-6.1</td>
</tr>
<tr>
<td></td>
<td>Large</td>
<td>15.0-23.0</td>
<td>7.3-8.0</td>
<td>7.2-8.0</td>
</tr>
<tr>
<td></td>
<td>Small</td>
<td>2.5-4.5</td>
<td>3.3-4.7</td>
<td>3.7-4.4</td>
</tr>
<tr>
<td>1971</td>
<td>Medium</td>
<td>7.5-10.5</td>
<td>5.6-6.5</td>
<td>4.5-5.1</td>
</tr>
<tr>
<td></td>
<td>Large</td>
<td>13.0-25.0</td>
<td>7.2-8.5</td>
<td>5.3-7.2</td>
</tr>
</tbody>
</table>
Table (2) Percentage dry matter content of bad multi onions determined at the beginning and the end of the storage periods.

<table>
<thead>
<tr>
<th>Sampling date</th>
<th>1970 season</th>
<th>1971 season</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial determination</td>
<td>15.6</td>
<td>16.4</td>
</tr>
<tr>
<td>After 6 months</td>
<td>14.2</td>
<td>15.4</td>
</tr>
</tbody>
</table>

L.S.D.  
9% : .83
Table (3) Percentage total soluble solids of red onion onions determined at the beginning and the end of the storage periods.

<table>
<thead>
<tr>
<th>Sampling date</th>
<th>1970</th>
<th>1971</th>
</tr>
</thead>
<tbody>
<tr>
<td>At the beginning</td>
<td>15.6</td>
<td>16.6</td>
</tr>
<tr>
<td>After 6 months</td>
<td>12.8</td>
<td>15.8</td>
</tr>
</tbody>
</table>

L.S.D. 5% H.S. B.S.
4. Percentage of Healthy and Diseased Bulbs by Local Cold Storage Method

Data shown in Table (4) indicated that the end results of both stores 1 and 2 were approximately similar.

The percentage of healthy bulbs decreased gradually with the increase in storage period. It is worth noting that 92.9 to 64.9 per cent of the total stored onions were found to be healthy at the end of the storage period (20 and 18 weeks in 1970 and 1971 seasons, respectively).

The weight of the diseased bulbs was higher at store 1, in both the 1970 and 1971 seasons, than in store 2.

5. Storage Losses

A close study of losses during storage was carried out on two small onions.

(a) Loss due to Shrinkage

Data in Table (5) showed no significant difference in shrinkage during the different inspection intervals in the 1970 season. On the other hand, in 1971 season there was a significant difference in shrinkage after twenty weeks of storage than any other storage interval. Nevertheless, there was no significant difference in shrinkage between twenty weeks and twenty-four weeks of storage. The data also showed
Table (4) Percentage weight of healthy and diseased bulbs stored by the local bulk method and inspected at four weeks intervals for store (1) and at the end of the storage period for store (2) during the 1970 and 1971 seasons.

<table>
<thead>
<tr>
<th>Storage period (weeks)</th>
<th>Healthy bulbs</th>
<th>Diseased bulbs</th>
<th>Healthy bulbs</th>
<th>Diseased bulbs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Store 1</td>
<td>Store 2</td>
<td>Store 3</td>
<td>Store 4</td>
<td>Store 5</td>
</tr>
<tr>
<td>0</td>
<td>100.0</td>
<td>100.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>4</td>
<td>38.4</td>
<td>4.0</td>
<td>98.3</td>
<td>0.8</td>
</tr>
<tr>
<td>8</td>
<td>36.2</td>
<td>1.5</td>
<td>81.5</td>
<td>1.3</td>
</tr>
<tr>
<td>12</td>
<td>67.9</td>
<td>1.2</td>
<td>72.7</td>
<td>1.0</td>
</tr>
<tr>
<td>16</td>
<td>61.1</td>
<td>1.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td></td>
<td></td>
<td>52.6</td>
<td>6.9</td>
</tr>
<tr>
<td>20</td>
<td>52.9</td>
<td>97.4</td>
<td>2.0</td>
<td>6.0</td>
</tr>
<tr>
<td></td>
<td>57.4</td>
<td>90.2</td>
<td>2.8</td>
<td>6.8</td>
</tr>
</tbody>
</table>
that in the 1971 season shrinkage was at a greater rate after four and eight weeks of storage than after twelve and sixteen weeks of storage.

Figure (1) shows the rate of shrinkage during storage in both the 1970 and 1971 seasons. The rate of shrinkage increased with length in storage.

Plate (6) shows the dry scales of an onion bulb one month after harvest due to excessive loss of moisture.

(b) Loss due to disease

Tables (6) and (7) show the percentage by number and weight of diseased bulbs respectively. The data indicated a significant difference between storage intervals in percentage of diseased bulbs in both the 1970 and 1971 seasons. The rate of infection was greatest after eight weeks of storage in both seasons. However, the rate of infection was greater in the 1970 season than in 1971 season.

Figures (2) and (3) illustrate the rate of infection by number and weight respectively in both the 1970 and 1971 seasons. An storage period increased the rate of infection increased.
Table (2) The percentage loss due to shrinkage of onion bulbs sampled at different storage intervals.

<table>
<thead>
<tr>
<th>Storage period (weeks)</th>
<th>Per cent shrinkage</th>
<th>1970 season</th>
<th>1971 season</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1970 season</td>
<td>1971 season</td>
</tr>
<tr>
<td>4</td>
<td>4.3</td>
<td>5.8</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>5.2</td>
<td>5.2</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>5.5</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>5.3</td>
<td>2.3</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>3.7</td>
<td>7.8</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>5.1</td>
<td>6.7</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>4.4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

L.S.D.  
|     | 1.6     | 2.00       |
| 2.5 | 1.8     | 2.77       |
Table 6. The percentage of diseased bulbs sampled at different storage intervals (number basis).

<table>
<thead>
<tr>
<th>Storage period (weeks)</th>
<th>1970 season</th>
<th>1971 season</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>1.6</td>
<td>2.4</td>
</tr>
<tr>
<td>8</td>
<td>3.4</td>
<td>4.7</td>
</tr>
<tr>
<td>12</td>
<td>4.3</td>
<td>3.3</td>
</tr>
<tr>
<td>16</td>
<td>8.4</td>
<td>4.7</td>
</tr>
<tr>
<td>20</td>
<td>3.4</td>
<td>3.4</td>
</tr>
<tr>
<td>24</td>
<td>4.2</td>
<td>3.3</td>
</tr>
</tbody>
</table>

L.S.D. 2
5%  4.75  2.28
1%  6.28  3.3
Table (7) Percentage of diseased bulbs sampled at different storage intervals (weight basis).

<table>
<thead>
<tr>
<th>Storage period (weeks)</th>
<th>1970 season</th>
<th>1971 season</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>2.6</td>
<td>2.5</td>
</tr>
<tr>
<td>8</td>
<td>10.5</td>
<td>4.3</td>
</tr>
<tr>
<td>12</td>
<td>2.9</td>
<td>1.9</td>
</tr>
<tr>
<td>16</td>
<td>6.2</td>
<td>1.6</td>
</tr>
<tr>
<td>20</td>
<td>5.6</td>
<td>1.2</td>
</tr>
<tr>
<td>24</td>
<td>2.0</td>
<td>0.2</td>
</tr>
<tr>
<td>30</td>
<td>1.7</td>
<td></td>
</tr>
</tbody>
</table>

L.S.D. 5%

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2.71</td>
<td>2.18</td>
<td></td>
</tr>
<tr>
<td>5.09</td>
<td></td>
<td>2.18</td>
</tr>
</tbody>
</table>
Table (8)  The percentage of sprouted bulbs sampled at different storage intervals (number basis).

<table>
<thead>
<tr>
<th>Storage period (weeks)</th>
<th>Per cent sprouted bulbs</th>
<th>1970 season</th>
<th>1971 season</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>0.0</td>
<td>0.0</td>
<td>0.1</td>
</tr>
<tr>
<td>8</td>
<td>0.0</td>
<td>0.0</td>
<td>0.1</td>
</tr>
<tr>
<td>12</td>
<td>0.0</td>
<td>0.0</td>
<td>0.6</td>
</tr>
<tr>
<td>16</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>20</td>
<td>0.3</td>
<td>3.7</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>1.6</td>
<td>41.3</td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>30.9</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

L.S.D.  
5%  2.02  2.02  
1%  2.29  2.30
Table (9) List of organisms isolated from rotted red onion bulbs stored under ambient conditions 1970 season.

**fungi**
1. Aspergillus niger
2. Aspergillus nidulans
3. Aspergillus fumigatus
4. Acremonium nidulans
5. Phialophora stolonifera
6. Penicillium decumbens

**arthropoda**
1. Ephelis cauta
2. An insect from the order Lepidoptera
3. An insect from the order Coleoptera
4. Acanthus nigra

**bacillaria**

<table>
<thead>
<tr>
<th>Isolate No.</th>
<th>Bacillus</th>
<th>Bacillus mesentericus</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 and 6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>Bacillus subtilis</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>Bacillus carotovora</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>Bacillus polymyxa</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>Bacillus coagulans</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>Bacillus firmus</td>
</tr>
<tr>
<td>Storage (weeks)</td>
<td>A. hiilera + A. niger</td>
<td>A. hiilera</td>
</tr>
<tr>
<td>---------------</td>
<td>------------------------</td>
<td>-----------</td>
</tr>
<tr>
<td>4</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>8</td>
<td>21.0</td>
<td>7.0</td>
</tr>
<tr>
<td>12</td>
<td>33.5</td>
<td>1.0</td>
</tr>
<tr>
<td>16</td>
<td>9.0</td>
<td>0.5</td>
</tr>
<tr>
<td>20</td>
<td>5.0</td>
<td>0.5</td>
</tr>
<tr>
<td>24</td>
<td>3.0</td>
<td>0.5</td>
</tr>
</tbody>
</table>
The percentage of infection by *M. nigropilatus* at the end of the storage period was 89.5, while the percentage of infection with all other pests and microorganisms was 3.5.

Tables (11), (12) and (13) (attached at the end) show the morphological, cultural, and biochemical characteristics of the bacterial isolates. The identity of the bacterial isolates based on the morphological and biochemical characteristics has already been reported in Table (1). In several attempts to test the ability of these isolates to produce soft rot in raw onion and raw potato discs inconsistent results were obtained. Only *Bacillus cereus* and *Alternaria porri* produced soft rot in most of the tests carried out.

7 - The effect of temperature on the development of *M. nigropilatus* in red Basili and Bengal white onion cultivars.

Data shown in Table (14) show that there were significant differences in the development of *M. nigropilatus* at different temperatures. The fungus developed best at 35°C and least at 5°C. However, there was no significant difference between the development of *M. nigropilatus* at 35°C and 20°C.
Table (14) The effect of different temperatures on the development of *A. niger* in different onion cultivars 1971 season.

<table>
<thead>
<tr>
<th>Temperature</th>
<th>K. N.</th>
<th>Percentage of bulbs infected with <em>A. niger</em> (number basis)</th>
</tr>
</thead>
<tbody>
<tr>
<td>35°C</td>
<td>3%</td>
<td>9.5</td>
</tr>
<tr>
<td>Ambient</td>
<td>34-53%</td>
<td>8.8</td>
</tr>
<tr>
<td>20°C</td>
<td>60-70%</td>
<td>4.0</td>
</tr>
<tr>
<td>5°C</td>
<td>85%</td>
<td>4.3</td>
</tr>
<tr>
<td>Variety mean</td>
<td></td>
<td>7.6</td>
</tr>
<tr>
<td>L.S. N.</td>
<td></td>
<td>9.1</td>
</tr>
<tr>
<td>Variety</td>
<td></td>
<td>1.0</td>
</tr>
<tr>
<td>Temperature</td>
<td></td>
<td>1.5</td>
</tr>
<tr>
<td>Variety x temperature</td>
<td>1.6</td>
<td>2.5</td>
</tr>
</tbody>
</table>
A. *niger* developed significantly better on *A. sativum* cultivar as compared with *Daucus carota* white cultivar.

Plate (10) shows different stages of development of *A. niger* on *Daucus carota* onions. The infection with *A. niger* started from the outer scales and spread to the inside where it caused softening of the tissues. The fungal invasion was sometimes followed by rapid evaporation of water resulting in shrivelling of the bulbs, which became fragile and hollow.

Moreover, the infection with *A. niger* caused the external red scales to turn pinkish white in colour. This might help in the future detection of *A. niger* without the removal of the external scales.

8 - Rest Period

Rest period was calculated as the number of days to fifty per cent germination of bulbs planted under shade. Figure (5) shows that as storage period increased the rest period decreased.

9 - Rate of Respiration

Figure (6) shows the rate of respiration during the 1971 season. The initial determination of the rate of
Plate 10 - Different developmental stages of black mould caused by *Aspergillus niger* on Mad Hanli onion bulbs. Top left is a healthy bulb. The rest of bulbs were arranged according to the degree of damage from left to right.
respiration was high, but there was a decline in respiration rate as the storage period increased. A sudden rise in respiration rate was recorded twenty two weeks after the date of harvest.

10 - Irradiation of Local Onion

a) Weight Loss

Table (15) shows the percentage loss in weight of irradiated and Kenli cultivar during the 1970 and 1971 seasons. Irradiation seemed to have little or no effect on the rate of weight loss during 1971 season, whereas in 1970 season irradiation seemed to decrease weight loss in and Kenli onions by approximately 16 per cent as compared with the control. Loss in weight seemed to be higher in 1970 season than in 1971 season both in the control and the irradiation bulbs.

Data in Table (16) shows that doses of 4, 6 and 8 krads had little or no effect on the rate of weight loss, in and Kenli, Longola white and Masi cultivars in the 1971 season.

b) Sprouting

Table (17) shows the percentage of sprouted bulbs (number basis) of irradiated and Kenli cultivar onions.
Table (15) Percentage loss in weight of irradiated
and baeli, cultivar after five months of
storage during the 1970 and 1971 seasons.

<table>
<thead>
<tr>
<th>Dose in Krads</th>
<th>Percentage loss in weight</th>
<th>1970 Season</th>
<th>1971 Season</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>48.3</td>
<td>21.4</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>-</td>
<td>22.4</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>31.9</td>
<td>16.4</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>34.4</td>
<td>25.6</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>30.6</td>
<td>19.9</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>36.6</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>32.8</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>
Table (16) Percentage loss in weight, of irradiated wad Hamli, Bengola white, and nassi cultivars, after five months of storage. 1971 season.

<table>
<thead>
<tr>
<th>Grade</th>
<th>Percentage loss in weight</th>
<th>Hamli</th>
<th>Bengola White</th>
<th>Nansi</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>21.4</td>
<td>28.7</td>
<td>29.7</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>16.8</td>
<td>23.1</td>
<td>27.3</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>25.6</td>
<td>25.8</td>
<td>29.7</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>19.9</td>
<td>26.5</td>
<td>23.7</td>
<td></td>
</tr>
</tbody>
</table>
during the 1970 and 1971 seasons. Doses of 4, 6, 8, 10 and 12 krad seemed to be very effective in inhibiting sprouting. On the other hand a dose of 2 krad seemed ineffective in inhibiting sprouting.

Data in Table (16) indicated that doses of 4, 6 and 8 krad inhibited sprouting in sad Bamli, Mongola White and Gassi cultivars. It also indicated that per cent sprouting in sad Bamli cultivar was considerably lower than the other cultivars.

c) Length of internal sprouts

Table (19) shows the average length of internal sprouts and the average height of the bulbs in the three cultivars. The data showed that the three cultivars responded similarly with respect to gamma irradiation. The length of internal sprouts of the controls in the three cultivars were as high as the bulbs. It seemed that the 2 krad dose used on sad Bamli onions did not inhibit further growth of internal sprouts.

It is worth mentioning that doses of 4, 6 and 8 krad caused browning near the stem end in Mongola White and Gassi cultivars.
Table (17) **Percentage sprouting (number bananas) of irradiated Wad kambal cultivar after five months of storage during the 1970 and 1971 seasons.**

<table>
<thead>
<tr>
<th>Dose in Krad</th>
<th>Percentage sprouting</th>
<th>1970 season</th>
<th>1971 season</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>75.0</td>
<td>33.3</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>-</td>
<td>20.0</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>0.0</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>2.0</td>
<td>1.3</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>0.0</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>3.3</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>0.0</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>
Table (18) Percentage sprouting (number basis) of irradiated and non-irradiated Zambian white and massi cultivars, after five months of storage. 1971 season.

<table>
<thead>
<tr>
<th>Dose in Krad</th>
<th>Percent sprouting</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>33.3</td>
<td>76.7</td>
<td>63.4</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>0.0</td>
<td>3.3</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>3.3</td>
<td>0.0</td>
<td>3.3</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>0.0</td>
<td>6.6</td>
<td>6.6</td>
<td></td>
</tr>
</tbody>
</table>
Table (19) Length of internal sprouts and height of bulbs in one of the onion cultivars (Mad Rnali, Dongola White and Nashi) before and 5 months after irradiation treatment, 1971 season.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>At beginning</th>
<th>After 5 months doses in brads</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Mad Rnali</td>
<td>Length of</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>sprout</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Height of</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td>bulb</td>
<td></td>
</tr>
<tr>
<td>Dongola White</td>
<td>Length of</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>sprout</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Height of</td>
<td>5.4</td>
</tr>
<tr>
<td></td>
<td>bulb</td>
<td></td>
</tr>
<tr>
<td>Nashi</td>
<td>Length of</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td>sprout</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Height of</td>
<td>6.6</td>
</tr>
<tr>
<td></td>
<td>bulb</td>
<td></td>
</tr>
</tbody>
</table>
Plates (11), (12), and (13) show the clear difference between the control and the irradiated bulbs with respect to sprouting in Wad Nasli, Dongola white and Kassi respectively.

Plates (14), (15) and (16) show the cross sections of irradiated and non-irradiated bulbs of the three cultivars. Internal sprouting was clearly visible in the controls of the three cultivars and in the Wad Nasli cultivar that received the 2 krad dose.

Tables (20) and (21) show per cent losses in weight during preparation for dehydration and physical characteristics of dehydrated, irradiated onions respectively. The data were so inconsistent that no conclusions could be drawn from any of the two tables.
Plate 11 - Wad Rami bulbs irradiated with 2000, 4000, 6000 and 8000 rads and the control. External sprouts are clear in each of the controls.
<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Percent</th>
<th>Weight (mg)</th>
<th>Yield (g)</th>
<th>Daily yield (g)</th>
<th>Nitrogen (%)</th>
<th>Protein (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>8</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>8</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>8</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>8</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>8</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>8</td>
<td>0</td>
<td>4</td>
</tr>
</tbody>
</table>

Note: Physical characteristics of different rice cultivars under irrigated conditions.

Table (21): Physical characteristics of different rice cultivars under irrigated conditions.
The red onion cultivar is the most widely grown onion in the Sudan. In this trial, the red cultivar from Mad Arabi area was used. It is a mixed variety as indicated by the great variation in sizes and scales colour. The results of this study have shown that losses from red Arabi onions were great during storage, mainly due to shrinkage, diseases and sprouting according to their order of importance. Ward (1960) found that diseases resulted in greater loss in weight than shrinkage. This may be due to the high relative humidity in Egypt.

Losses due to shrinkage and diseases were about fifty percent in bulk storage experiments after five months. It seemed there was a harmful effect of regular inspection of bulk stored onions, since it increased the rate of diseases. This might be due to injuries caused by frequent handling, that facilitated the ingress of micro-organisms. On the other hand Ward (1960) found only 9% of bulbs healthy, when stored in sacks in a common store for 30 weeks and were not regularly inspected. This great loss was attributed to high humidity that encouraged diseases in storage.
Loss in weight due to shrinkage was at maximum under high temperature and low relative humidity. Schippers (1968) said that loss in weight was related to moisture deficit between bulbs and surrounding atmosphere. It is known that moisture deficit is controlled by temperature and relative humidity. Shrinkage rate seemed to be high whenever the temperature was high and relative humidity was low, confirming Schippers' findings. The increase in shrinkage rate observed in 1971 season could be explained, following Karwarker and Joshi (1961), as not only due to high temperature and low relative humidity prevailing at that time (35°C and 41% R.H.), but also possibly due to drying up of external leaves and consequently the internal leaves started to lose water.

Total loss due to shrinkage was about 30% after twenty-four weeks of storage at a temperature range of 21.9°C-37.6°C and relative humidity of 19-99%. Karwarker and Joshi (1961) reported 21% loss in weight after a similar period at 32°C - 35°C. Sarad (1960) reported 23% loss in weight after 30 weeks of storage at 22°C - 29°C and 30-72% R.H. The greater loss in weight in the Sudan might be due to lower
relative humidity. Magruder (1941) found that White Creole, which has similar dry matter content as red koni onions (Abdalla 1960), lost 31.6% of its original weight due to shrinkage after four months of storage at 25° - 28° C and low relative humidity. On the other hand red koni onions lost only about 17% of its original weight at a similar period.

The study also showed that the rate of disease increased with rise of temperature and relative humidity. The highest percentage of diseased bulbs was after eight weeks of storage which corresponded with temperatures of 37.5° C and 34.4° C, and 47% and 53% relative humidity for 1970 and 1971 seasons respectively. No other interval in both seasons showed this combination of high temperature and high relative humidity. These findings were in accordance with Walker (1937), Sekeri (1954), Jason De Segura (1959) and Varid (1960) who found that high temperature and high humidity increased bacterial and fungal rotting.

Only 13% by number of red koni onions remained healthy after six months of storage. On the other hand the total marketable bulbs were 83%. This is because onions externally infected with A. niger are sold in the local market. White Creole, which
had similar dry matter content as Had Hamli onions, and
Red Creole did not show rotting at 10°-25°C after four months
of storage (Krautler 1941).

Aspergillus niger is the most important causal agent
of diseases in onions under Sudan conditions. The other
Aspergillus species were found, which could be attributed
to the fact that Aspergillus favour hot dry conditions
generally. This is similar to the findings of Owen (1956)
and Nasun De Segura (1959).

The highest rate of infection with A. niger was observed
6 and 12 weeks after the beginning of storage. In both dates
the temperature and relative humidity were highest (30.4° -
31.2°C and 43%-53% R.H.). This indicated that A. niger
developed best under both high temperatures and high relative
humidities. This was in accordance with the work of Karnagar
and Joshi (1941) and Beberi (1954) who found that dryness
reduced A. niger activity and sterility to that of Owen (1956)
and Nasun De Segura (1959).

Temperature and relative humidity seemed to have a great
effect on the development of A. niger. At 35°C and 50% R.H.
the rate of infection with A. niger was more severe than at
20°C and 60%-70% R.H. Nevertheless, under ambient conditions (20.6°C - 31.2°C and 3%-53% R.H.) the degree of infection was lower than at 20°C, although the temperature was higher and relative humidity was lower.

These results might raise a third possibility that at a certain range of temperatures, somewhere around 20°C and 30°C, the higher the relative humidity, the greater the rate of infection with A. niger. At very high temperatures such as 35°C and very low temperatures such as 5°C the relative humidity seemed to have little effect on development of A. niger. The main effect might be due to temperature alone. This suggestion of the importance of relative humidity at only a certain range of temperatures needs further investigations. Mongolian white, a yellow cultivar, was less susceptible to A. niger infection than red Maui onions. Similarly Owen (1950) found that white cultivars were less susceptible to A. niger infection than coloured varieties.

Bacteria isolated from soft rotted material were mostly spore formers which were resistant to high temperatures prevailing under Sudan conditions. Most of the bacteria isolated were saprophytic with the exception of Enterio aerogva and Pseudomonas asplanchna. This does not eliminate the possibility
that pure cultures of the rest of the bacteria could become pathogenic, when occurring together under natural conditions.

Bakeri (1994) reported that high temperature was suitable for the growth of *A. niger*. This high temperature is prevailing under Sudan conditions. He also reported *A. niger* in stored Egyptian onion, but its incidence was very low. *Penicillium sp.* was also reported by Bakeri (1994) and Dard (1960) in Egypt. Hatvr (1958) reported *Mizogra nigricans*. The rest of the micro-organisms found in this study were not reported before in stored onions.

Pests seemed to infect rotten bulbs. Occasionally they attacked healthy bulbs causing channels that might facilitate ingress of micro-organisms. None of the pests found in this study were reported elsewhere in stored onions.

While diseases caused losses during the whole period, losses due to sprouting occurred only towards the end of the storage period. This makes diseases and pests more important factors in losses of storage than sprouting.

Jones and Ham (1963) considered bulbs that were dormant because of internal factors were in a state of rest. The length of this rest period seemed to be very difficult to define.
Some workers, such as Jones (1921), Beawell (1923) and Ward (1960) considered visible sprouting as the end of the resting period and resumption of active growth. Abdalla and Mann (1961), on the other hand, pointed out that rest period is not broken suddenly, but depleted gradually in storage. They also pointed out that sprouting was the result of elongation of leaves initiated well before harvest. The rest period was considered by them to end when leaf elongation started and not when sprouts were visible.

The study showed that percentage sprouting was greatest at the end of the storage period in both seasons. It also showed that the number of days needed for planted bulbs to reach 50% germination decreased with the length of storage time. This could be attributed to the fact that with storage the rest period was depleted gradually as Abdalla and Mann (1961) mentioned. The increase in sprouting rate at the end of the storage period could be attributed to the relatively low temperature prevailing at that time (22.3°C and 20.4°C in 1970 and 1971 respectively). Ward (1960) also found that sprouting rate increased after five months of storage, when temperature became about 21°C - 25°C.
Karzmarkar and Joshi (1941), Hartsema (1947), Koba (1955), Yamaguchi et al. (1937), Pratt and Morris (1958), Koba (1960), Abdalla (1965), and Auma (1965) found that a high temperature of about 30°C and a low temperature of 0°C were not conducive to sprouting, since leaf elongation was slow at 0°C and 30°C, and no leaf elongation was observed during a period of storage of ten weeks. It seemed that low and high temperatures depleted rest very slowly, while temperatures of 9°C-20°C seemed to deplete rest very rapidly. In fact leaf elongation was observed after two weeks in storage at 15°C. Nevertheless, no external sprouts were observed up to eight weeks of storage. A high temperature of 40°C seemed to be more effective in depleting rest than 30°C; as reported by Yamaguchi (1937) who believed that quick germination of the bulb was due to heat injury as a result of storage in 40°C for a long period. On the other hand, Abdalla and Ham. (1965) reported that bulbs stored at 40°C did not show any symptoms of heat injury, although they did not completely eliminate its possibility.

The Kenji cultivar planted on the harvesting day took sixty days to 50% germination, which is similar to Australian Brown cultivar which took sixty days to 50% germination at 15°C.
(Abdalla and Hann 1963). Warid (1956) reported that Elia 6 had a rest period of 8-9 weeks before elongation of sprouts took place. Eto (1966) reported that onions had a rest period of 30 days followed by a dormancy of 60 days. On the other hand Abdalla and Hann (1963) found that the only period when bulbs did not show any activity was 20 days before harvesting; even then the shoot apex showed mitotic figures. They found that leaf initiation was going on all the time during storage but at a slower rate than in the field.

The rest period depends upon the cultivar and storage temperature (Jones 1921 and Abdalla and Hann 1963). Cultivars with high dry matter content sprouted least as reported by Reeset and Peterson (1950), Kamoehn (1957), Aoba (1960) and Treskova (1969). Hardneck onions were reported by Abdalla (1963) to have a high dry matter content in comparison with 16 imported cultivars. This might be one of the reasons why it had a long dormant period, ranging between 5 to 6 months.

The study demonstrated that respiration rate was high at harvesting date and decreased during storage. Respiration rate again increased towards sprouting time. The same pattern
was observed by Aoba (1960), Ogata (1960) and (1961)
found that respiration rate decreased during the
final stages of bulb development till it reached
a minimum which persisted for some time after after
harvest then increased towards sprouting time.
Karmarkar and Joshi (1941) also reported an increase in
respiration rate during storage.

The respiration rate during storage fluctuated.
This could be attributed to physiological factors such
as rest period and to temperature and its effect on
rest period and respiration rate. The study showed
that up to 18 weeks of storage, whenever there was
an increase in respiration rate, there was an
increase in number of days to 50% germination of
planted bulbs. This phenomenon might be due to
high temperatures prevailing at that time (30.5°
31.6°C). Later the temperature became lower which
resulted in termination of rest period and
consequently the respiration rate increased and planted bulbs germinated very rapidly.

Dry matter content and total soluble solids decreased with storage, which might be attributed to respiration during storage. Similarly Karmarkar and Joshi (1941), Kasur (1953) and Kato (1967) reported a decline in sugar content which was attributed to respiration during storage. Total soluble solids and dry matter content were found to be related to sugar content by Foskett and Peterson (1950), Hanonoka and Ito (1957), and Trontzova (1969).

The data indicated that weight loss in irradiated Wad Hamli onions was reduced in 1970 season but not in 1971 season. Whereas in the other two cultivars irradiation seemed to have little or no effect in controlling weight loss. On the other hand, Patil (1965) found that irradiation reduced shrinkage compared to untreated
Control and Nandpuri (1969) found that weight loss was reduced above a dose of 9 Krad.

Irradiation doses of 4, 6 and 8 Krad controlled sprouting very effectively in Wad Ramli, Dongola White and Nassi cultivars, whereas a dose of 2 Krad did not control sprouting in the Wad Ramli cultivar. This might be attributed to the fact that the onions were stored for 42 days before irradiation, which possibly resulted in elongation of the internal sprouts. The 2 Krad dose was too low to stop any further growth of the internal sprouts. However, the length and number of external sprouts was less than in the control, indicating that irradiation did affect the growth of the internal sprouts. Nullins and Bui (1961) found that a dose of 2 Krad inhibited sprouting two weeks after harvest, but a dose of 250 Krad did not inhibit sprouting 11 and 17 weeks after harvest. This might be the case here.
Nuttal et al. (1961) reported that irradiation time with regard to length of period after harvest, seemed very critical for control of sprouting.

Irradiation of Wad Hamli onions with the doses of 4, 6 and 8 Krads three months after harvest, seemed to be very effective in controlling sprouting. In case of Dongola White and Nassi, irradiation with 4, 6 and 8 Krads doses, 75 days after storage controlled sprouting very effectively. Similarly workers such as Dallyn Sawyer (1959 b), Ogata et al. (1959), Ogata (1961), Abdel-Al (1967), Rouhanisadeh (1969) and Gunn and Aevetti (1970) found that doses of 3, 6, 7, 8 and 12 Krads controlled sprouting very effectively.

The browning observed near the stem end in Dongola White and Nassi cultivars might be due to the killing of internal sprouts. Other scientists mentioned that discolouration depended upon the length of internal sprouts at the time of irradiation (Ogata et al. 1959),
Dallyn and Sawyer (1959 a), Dallyn and Sawyer (1959 b), Nuttal et al. (1961) and Abdel-Al (1967).

Physical characteristics and losses of dehydrated products seemed to be inconsistent, but this suggested that there was no definite difference between irradiated bulbs and the control except that the control seemed to have the poorest overall appearance in the three cultivars. Wad Ramli onions that received a dose of 2 kRads also had poor overall appearance.

Further re-evaluation studies on the effects of irradiation of dehydrated onions are highly recommended.
Onion is widely grown in the Sudan. However, little attention had been paid to its storage problems. The red cultivar is the most used type. In this study red cultivar from wad Beali area was used. The onions were stored in grass cottages. The temperature ranged between 26.9°-37.6°C and relative humidity was between 19-93% during the storage seasons in 1970 and 1971.

Onions were stored in bulk in two cottages similar to the farmers’ practice. One of the cottages was inspected every four weeks and the other only at the end of the storage period. Another lot of onions was stored in wooden crates to study losses due to shrinkage, rotting and sprouting. Organisms that caused the rotting were identified.

Aspergillus niger is the most destructive disease in stored onions under Sudan conditions. Activity of A. niger under different temperatures and relative humidities and on different cultivars (yellow cultivar, Dongola White and the red cultivar Jad Hamm) were studied.

The rest period and respiration rate of red Beali onions were studied. Also the Sudanese cultivars Jad Hamm, Dongola White and Haisi were irradiated with gamma rays from a Cobalt-60 source at different doses.
The study revealed that:

1. Regular inspection of onions stored in bulk increased rotting incidence.

2. Loss due to shrinkage was about 30% after 6 months of storage. Monthly losses ranged between 2.3-7.8% depending on temperature and relative humidity.

3. Loss in weight of bulk stored onions was about 5% after 5 months in storage.

4. High humidity and high temperature encouraged rotting in stored onions.

5. *Aspergillus niger*, the major storage disease under Sudan conditions, survived best between 20°C and 35°C. It seemed that interaction between temperature and relative humidity had a great influence on its activity, especially between 20°C and 30°C.

6. Dangola White was less susceptible to *A. niger* infection than Red Danli. *A. niger* resulted in change in the colour of the red scales of Red Danli to pinkish white.

7. *Pseudomonas carotovora* and *Bacillus subtilis* were the only pathogenic bacteria that were isolated from stored onions.
(8) Sprouting started when relatively low temperature of about 20°C prevailed.

(9) Rest period was depleted gradually. Vad Hanli cultivar had a rest period of 60 days (assuming that rest period is the number of days to 50% germination of planted bulbs). Vad Hanli onions could remain dormant for 5-6 months under ambient conditions depending on the methods of cultivation.

(10) Respiration rate was high at harvesting time, then decreased during storage, and increased again towards sprouting date.

(11) Dry matter content and total soluble solids decreased with storage.

(12) Irradiation with gamma rays at 4, 6 and 8 Krad seemed to have little or no effect on the shrinkage rate of Vad Hanli, Dongola White and Hassi cultivars. It effectively controlled sprouting in them.

(13) Unirradiated control of Vad Hanli sprouted less than unirradiated controls of Dongola White and Hassi.

(14) Physical characteristics of dehydrated flakes of irradiated onions seemed to have no difference from unirradiated controls; except that the controls and the
Appendix (1) Mean monthly relative humidity and temperature during 1970 and 1971 seasons at Shambat.

<table>
<thead>
<tr>
<th>Month</th>
<th>Relative humidity</th>
<th>Maximum temperature</th>
<th>Minimum temperature</th>
<th>Mean temperature</th>
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<td>42.3</td>
<td>25.4</td>
<td>34.1</td>
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<td>June</td>
<td>20</td>
<td>41.6</td>
<td>25.4</td>
<td>33.8</td>
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<td>July</td>
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<td>37.9</td>
<td>25.3</td>
<td>37.6</td>
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<td>36.7</td>
<td>25.4</td>
<td>31.1</td>
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<td>30.9</td>
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<td>31.5</td>
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<td>30.5</td>
<td>18.8</td>
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<tr>
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<td>30.2</td>
<td>18.4</td>
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<tr>
<td>February</td>
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**Note:** References with Mark* original papers were
not seen