

**INVESTIGATION INTO MAIZE GRAIN
DAMAGE AND DETERIORATION IN CRIB
STORAGE**

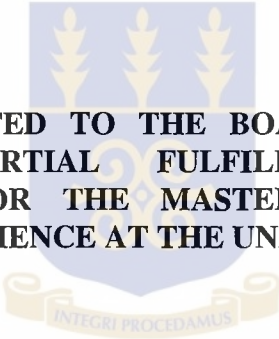


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INVESTIGATION INTO MAIZE GRAIN DAMAGE AND DETERIORATION IN CRIB STORAGE

BY

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DECLARATION

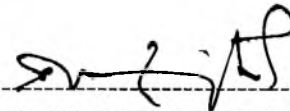
I, William Anthony Jonfia-Essien, do hereby declare that the work presented in this dissertation

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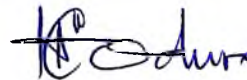
was done entirely by me in the Department of Crop Science, Faculty of Agriculture, University of Ghana, Legon. I further affirm that this work has never been submitted to this University or elsewhere either in part or wholly for any degree.



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ABSTRACT

A study was conducted into the traditional method of storing maize in Ghana to determine the best form of storing maize to minimise losses in storage and to evaluate the effectiveness of using insecticides in crib storage.

Two separate experiments were conducted, one with maize variety Abrotia and the other with maize variety La Posta. In each experiment, a split-plot design was used with the main plot factor being insecticide application and the subplot factor being husking. Actellic 2D was the insecticidal dust used.

Insect infestation increased with increase in storage period throughout the ten (10) months storage period. Insects identified on the stored maize were Sitophilus zeamais, Tribolium castaneum, Oryzaephilus mercator, Stegobium penicium, Rhizopertha dominica, Prostephanus truncatus and Sitotroga cerealella. S. zeamais was the most prevalent whereas P. truncatus made the least appearance. With maize stored with insecticides, insect infestation on dehusked cobs differed significantly from that of undehusked cobs ($P = 0.05$). There was no significant difference ($P = 0.05$) between insect infestation on dehusked and undehusked cobs stored without insecticides. The fungi identified on the stored maize were Aspergillus ochraceus, Aspergillus flavus, Chaetonium globosum, Rhizopus oryzae, Curvularia lunata and Nigrospora sp. Fungal infection was higher on maize stored undehusked compared to those stored

dehusked. A. flavus infested mostly undehusked maize and A. ochraceus infested only undehusked maize.

Weight loss of maize increased with increase in storage period. Damage caused to maize stored dehusked was not significantly different from those stored undehusked. The germinability of maize declined with increase in storage period. For Abrotia variety it declined from 91% to 0% for both dehusked and undehusked maize stored with insecticide application, from 94% to 1% for dehusked maize stored without insecticide application and from 96% to 0% for undehusked maize stored without insecticide application. The germinability of La Posta variety declined from 95.33% to 0% for dehusked maize and from 94% to 0% for undehusked both with insecticide application. It declined from 95.33% to 0% for maize stored dehusked and from 92.67% to 0% for maize stored undehusked both without insecticide application.

From the results of the investigation, dehusked maize could be sorted and the undamaged cobs selected for storage before the application of insecticides. The sheaths of undehusked maize prevent such sorting and selection. For crib storage therefore, maize could best be dehusked and the storage should not exceed four months.

DEDICATION

This work is dedicated to my dear wife

Ophelia Fanny Jonfia-Essien.

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I am indebted to my supervisors, Prof. J. N. Ayertey, Head of Department and Dr. K. A. Oduro, both of Crop Science Department, University of Ghana, Legon, through whose tireless supervision and encouragement, this thesis has been completed. Prof. Ayertey was responsible for the entomological aspect while Dr. Oduro was responsible for the mycological aspect of the thesis.

I am grateful to Sasakawa Global 2000, a non-governmental international organization, for sponsoring the construction of my cribs at the University of Ghana farm. My thanks also go to Prof. G. C. Clerk of Botany Department, Dr. K. Ofori of Crop Science Department, Mr. S. T. Nartey, farm Manager, Mr. Nicholas Adu-Adjekum, technical assistant grade II, all of the University farm and Mr. Emmanuel Otu Ankrah, Senior technician, Crop Science Department, tractor drivers and the farm hands for their assistance.

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CHAPTER ONE

INTRODUCTION

Maize (*Zea mays* L) is the world's third leading cereal after wheat and rice (FAO, 1974). It is the most widely distributed cereal which generates 8.9% of the world's food production (FAO, 1974). The cereal maize crop is a very important staple food crop in Africa. It is stored for varying periods as buffer stock for human consumption and as an ingredient for poultry and livestock feed. Maize production in Ghana is primarily for human consumption and a large proportion of the population (> 70%) depend on it as a principal source of food (Fischer and Palmer, 1984).

Being a seasonal crop, especially in West Africa, maize is stored as dry grains and forms an enormous reserve of food. However, a substantial amount of the crop in storage is subject to attack by a variety of insects, fungi, rodent and other biological agents of deterioration. Losses in storage due to insects and fungi are estimated to be between 30%-50% of annual harvest (Rawnsley, 1970; Adams, 1977). From information obtained from the Statistics Division of the Policy Planning Ministry and Evaluation (PPMED) of the Ministry of Agriculture, Ghana is reported to have lost 1,555 metric tonnes of maize to insects and fungi in 1983.

In Ghana, loss estimates are now fixed at 30% by the Post Harvest Development Unit of the Crop Services, Ministry of Agriculture. It is expected that as production increases import supplements would be low, in reality this is not the case; because

30% of what has been produced is destroyed in storage and the 70% left is not able to meet the increasing demand for maize. The government of Ghana is therefore compelled to import maize to compensate for the shortfall. Information obtained from both the Central Bureau of Statistics and the Statistics Division of PPMED of the Ministry of Agriculture in 1982 indicates that, 264,300 metric tonnes of maize were produced in 1982 and 81,709.5 metric tonnes were imported. In 1992, 71,233.1 metric tonnes of maize were imported in spite of the increased production of maize (730,600 metric tonnes).

With an increase in human population and subsequent increase in the demand for food, attempts have been made by various governments, without success to increase production and to reduce demand for food through population control such as family planning. Another approach has been the protection of what had been produced so as to reduce losses experienced after harvest. This option was given a boost by the United Nations General Assembly Resolution passed at the Seventh Special Session of the United Nations (UN) assembly in September 1975 in which member nations were to reduce within ten years, their post-harvest losses by 50% (FAO, 1984). Following the UN resolution, research in post-harvest production intensified, and the interest of various governments in the area of grain conservation were stimulated so that post-harvest losses in developing countries have been undertaken as a matter of priority.

Traditionally in Ghana, maize is stored with the husks on (undehusked) because of the extra protection provided by the husk from insect attack, but in the more humid areas, deterioration due to fungi is greater in maize stored undehusked than when stored without the husks (dehusked). In highly infested areas however, dehusking pre-disposes the cobs to greater insect attacks.

In humid environments, structures used for grain storage are designed to aid drying (Anon, 1976). Properly designed open-sided cribs promote rapid drying of dehusked maize and minimises losses due to fungi (Anon, 1978). But long term storage of maize in open-sided cribs exposes dehusked maize to moisture up-take during the rainy season; and this renders the produce susceptible to insect and fungal attack and deterioration (Ayertey, 1984). In a series of trials conducted in Ghana, Benin and Nigeria the scope for natural drying of dehusked maize cobs in freely ventilated structures was considered by FAO/Danida (1978). To reduce the total damage and deterioration to maize grain in storage in Ghana, the Ministry of Agriculture in conjunction with Sasakawa Global 2000 (SG2000) (a non-governmental international organisation), has initiated an extensive country wide programme which seeks to encourage farmers to adapt the FAO/Danida (1978) improved 'narrow' crib. Without any comparative investigation, farmers are encouraged to store their maize dehusked. In spite of that, most farmers in Ghana, for reasons best known to them, still store their maize unhusked. It became necessary therefore to investigate the scientific basis of both storage practices under Ghanaian conditions. Much work has been done in the area of grain conservation, and the losses caused by insects are probably the most widely reported among post-harvest loss estimates (Morris, 1978; Hindmarsh and MacDonald, 1980; Adesuyi, 1982). Most of the work is reported on the type of insect pests encountered in the storage environment and the damage they cause. The knowledge on this subject has become available through informative documents published on pests of stored grain and their control (Khare, 1972; Pederson *et al.*, 1971, 1974), food losses, their estimation and evaluations (De Padua, 1974; Schulten, 1975; Adams, 1976a, 1976b; Araullo *et al.* 1976; Adams and Harman, 1977; FAO, 1977; Harris and Lindblad, 1978, TPI, 1978), post-harvest wastage prevention (Asian Productivity Organisation, 1974), handling and storage of food grains (TPI, 1970) and the effect of long term storage of dehusked maize in open-sided cribs (Ayertey,

1984). So far, none of these researchers considered a comparison of maize storage in the dehusked or undehusked forms under prevailing conditions in Ghana.

The role of fungi in deterioration of grains is well documented in developed countries(Bothast et al., 1975; Tuite, 1978) but there is paucity of information regarding these fungi on maize grains in West Africa and the role such fungi play. There has been sporadic reports of acute food poisoning (and sometimes death) arising from ingestion of maize contaminated by mixtures of growing fungi(Odamtten, 1986). The situation is such that any grain lot with an objectionable aesthetic look attributable to fungal discoloration is inadvertently passed on for use as ingredients in poultry and livestock feed. It is thought that mycotoxin contamination of meat, egg and milk at the farm level is imminent after feeding animals with contaminated rations. Transmission of Aflatoxins and Ochratoxin A from contaminated rations have been demonstrated in dairy cattle (Rodricks and Stoloff, 1977), pigs (Krogh, 1977) and poultry (Elling et al., 1975). According to Calderon(1975), about two percent of the total world production of grain is damaged by microflora. It is therefore necessary to examine maize stored in the narrow crib to determine the extent to which it is contaminated by fungi and the consequence of this contamination on grain quality.

To extend the storage life of grain, pesticides are increasingly used by man to control insects (FAO, 1984) although it has its own associated problems. In developing countries the problem of pesticide usage in stored maize is more acute than in developed countries since the chemicals are used indiscriminately and without any supervision. It is known that, the high demand for pesticides has increased the production of these chemicals. As to whether the use of chemicals in crib storage of maize(stored dehusked or undehusked) has yielded the required results, is not yet known.

The Investigation shall therefore consider, the following as its main objectives:

- (i) To compare the level of insect and fungal infestation on maize stored dehusked or undehusked in the 'narrow' crib.

- (ii) To evaluate insecticide application on maize stored dehusked or undehusked in the 'narrow' crib.

CHAPTER TWO

REVIEW OF LITERATURE

One vital step toward producing more maize for society is to reduce the losses that occur between harvest and consumption. It is difficult to estimate present post harvest losses accurately. Studies however, indicate that post harvest losses of maize and other major food commodities in developing countries are enormous, in the range, conservatively, of tens of millions of metric tons per year (F A O, 1979). Pests contribute significantly to this by feeding on and contaminating the harvested products (FAO, 1975; Lindblad and Druben, 1976; Hopf et al., 1976; NAS, 1978).

2.1 Maize production in Ghana

Information obtained from both the Central Bureau of Statistics and the Statistic Division of PPMED of the Ministry of Agriculture shows that maize production has been stepped up over the past decade, the government of Ghana depends on importation of the crop as supplement (Table 1) since a substantial amount of the maize is destroyed in storage. According to PPMED, out of 13,628,179 hectares of Agriculture Land Area (ALA) which is 57.1% of Total Land Area (TLA), only 4,320,000 hectares (18.1% of TLA) were under cultivation as at 1990. The area under maize cultivation in 1990 was 464,800 hectares. It is clear from calculations that the yield per hectare of maize cultivation was 1.19 ton/ha. Also the net domestic supply of the maize is often lower than the total demand of the crop, resulting in a deficit of thousands of metric tonnes of maize (Table 2).

Table 1**Production and Import Supplement Of Maize In Ghana****For the Period 1980 - 1992**

Year	Area Estimates(a) (ha)	Production Figures(a) (mt)	Import Supplement(b) (mt)
1980	319900	354000	12,610.4
1981	315500	334200	26,977.7
1982	276300	264300	81,709.5
1983	279800	140800	18,177.9
1984	723600	574000	2,416.3
1985	405000	395000	12.8
1986	472100	559100	12.0
1987	548300	597700	82.7
1988	500000	600000	3.9
1989	595800	715000	
1990	464800	553000	
1991	610400	931500	62.0
1992	606800	730600	71,233.1

NOTE:(a) i. *Total Land Area (TLA)* =23,853,900 (100%)
 ii. *Agriculture Land Area (ALA)* =13,628,179 (57.1%)
 iii. *Area under cultivation (1990)* = 4,320,000 (18.1%)

Source: (a) *PPMED (Statistics Division), Ministry of Agriculture, Accra.*
 (b) *Central Bureau of Statistics, Accra.*

Table 2

**Domestic Supply of Maize Relative to Demand in Ghana
for the Period 1980 -1992.**

Year	Total Demand (^{'000}mt)	Net Domestic Supply* (^{'000}mt)	Deficit(-) Surplus(+) (^{'000}mt)
1980	369	248	-121
1981	379	234	-145
1982	388	185	-203
1983	399	99	-300
1984	409	402	-7
1985	445	277	-168
1986	457	391	-66
1987	469	419	-50
1988	481	420	-61
1989	494	500	+6
1990	506	387	-119
1991	520	652	+132
1992	533	512	-21

**Net Domestic production is 70% of Biological Production.*

NOTE:

- i Biological Production is what our farmers really harvested from their farms which is actually the total out put or production.*
- ii. For maize, 30% of biological production covers post-harvest losses, feed and seed production.*
- iii. The resultant 70% when (ii) is deducted from (I) above is referred to as Net Domestic Supply*
- iv. The Total Demand is the product of the per capital consumption and the population of the country at that time.*
- v. The Dfcit or Surplus is the difference between the Net Domestic Supply and the Total Demend.*

2.2 Principal storage pests of maize

Most of the investigations conducted into grain damage in storage have focused on the principal insect pests and fungal pathogens. Among the principal pests in storage are Sitophilus zeamais (Motsch) and Sitotroga cerealella (Oliv.) (FAO, 1985); and at times the rice weevil Sitophilus oryzae (L) (Purseglove, 1972); Prostephanus truncatus (Horn) (FAO/GTZ, 1990) and fungi belonging to the genera Aspergillus and Penicillium (Oyeniran, 1973a; 1973b). Parkin (1958), Yoshida(1959, 1982a, 1982b.), Solomon (1964), Halstead (1975), Freeman (1977), Bezant (1979) and Buckland (1981) have reviewed and discussed the origin and evolution or domestication of these stored product insect pests and changes in their status.

2.3 Insect infestation of stored maize in Ghana

Rawnsley (1969) reported that Sitophilus oryzae (now known to be Sitophilus zeamais) is the most important pest on stored maize. The extent of insect attack on maize depends on a number of factors which includes the variety of maize. According to Rawnsley (1969) losses in maize stored with the sheath is lower than maize stored without the sheath. Report by FAO(1969) indicated that "In various experiments in Ghana in which farmers stored maize on the cob with the sheath, losses ranged from 8% to 16% over average periods varying from 53 to 161 days. When maize was stored on the cob without the sheath however, weight losses after 162 days of storage was 26%. Shelled maize stored for similar periods showed losses in weight as high as 34%."

In the barns, Rawnsley(1969) noted that insect infestation on maize stored with the sheath is confined mainly to a certain percentage of the cobs, probably that portion attacked before harvest. According to him " It seems probable that the sheath restricts the movement of insects within the barn and also limits the entry of insects from outside."

2.4 The economic impact of storage insect pests of maize

In a survey conducted in East Africa in 1981, samples of maize cobs which had been stored for up to 6.5 months exhibited as much as 80% damaged grain and frequently, all the cobs in samples collected from farmers were damaged (Hodges, et al., 1983). Losses due to small scale storage may be as high as 35% in 5 - 6 months of storage, and losses of up to 60% or more may occur over a 9-month storage period(Golob and Hodges, 1982; Hodges et al., 1983; Keil, 1988). The potential loss of maize has been estimated at five hundred and forty three thousand tonnes(543,000t) per annum in Tanzania, which has a value of nearly 87 million US dollars (Autrey and Cutcomb, 1982). In 1987-1988, 18,000 tonnes of surplus maize could not be exported to Malawi and Mozambique due to concern about possible larger grain borer (LGB) infestation. As a consequence, a loss of 1.5 million US dollars as missed export opportunity was suffered (FAO/GTZ,1990).

2.5 Storage fungal pests associated with maize

The principal storage fungi that invade the stored grains belong to the genera Aspergillus and Penicillium of the family Moniliaceae. Raper and Fennel (1965) listed 80 species of Aspergillus of which 26 occur on stored grains. Aspergillus glaucus has been noted to grow on high sugar or high salt substrates. Their spores can germinate and grow under conditions of high osmotic pressure. Some important fungi

of the genus Aspergillus that invade the stored grains are A . amstelodami, A . repens, A . restrictus, A . ruber, A . candidus, A . ochraceus, A flavus, A . versicolor, and A . tamari.

Raper and Thom (1949) listed 137 species of which 66 have been recorded from stored grains. They are frequently referred to as blue or green moulds. The species that invade the stored grains are P. notatum, P. oxalicum, P. palitans and P. viridicatum . Other common fungi associated with maize as retorted by Webster (1980) are Chaetomium, Curvularia, Fusarium, Nigrospora and Rhizopus .

2.6 Major characteristics of storage fungal pests of maize

The principal features of identification in the fungi imperfecti are the characters of the conidia and conidiophores. The sporangia and sporangiophores are characters restricted to phycomycetes and the most familiar example of the group is Rhizopus.

Conidia are the predominant asexual spores formed by fungi. They are borne on special branches called Conidiophores. The form of a conidiophore may be a special shape by which a group can be identified. Thus the conidiophore of Aspergillus terminates in a bulbous head, that of Penicillium branches repeatedly at the tip to look like a brush.

In Aspergillus, asci are completely enclosed by a well-defined envelope of sterile hyphae or peridium. The general features are : ascocarps lacking ostioles and paraphyses; asci irregularly distributed throughout the ascocarp and not arranged in a bundle, produced from fertile hyphae which ramify throughout the centrum of the ascocarp, quickly evanescent; ascospores unicellular, lacking germ pores or germ slit. The conidial states are generally phialidi, and include such genera as Aspergillus and

Penicillium. Here the conidia are developed within a specialized cell termed the phialide. (Fennell, 1973; Kendrick, 1971) Conidia produced from phialides (Phialidic Conidia) may be termed phialoconidia.

The fine structure of phialides and phialoconidium ontogeny has been studied in Aspergillus by Trinci *et al.* (1968), Oliver (1972), Fletcher (1976), Hanlin (1976) and in Penicillium by Fletcher (1971). In Penicillium, Fletcher has described an "apical plug" of material lining the neck of the phialide but distinct from the phialide wall itself. The apical plug forms the primary wall of the conidium and as each conidium is extruded, a septum formed by centripetal ingrowth of wall material pinches off the conidial protoplast from the protoplast of the phialide. Mature spores are often pigmented; green in Penicillium; Yellow, green, brown or black in Aspergillus. A large number of non-ascocarpic species of Aspergillus are known (Raper & Fennel, 1965). Barnett and Hunter (1972) reported that in Aspergillus the conidiophores are upright, simple and terminating in a globose or clavate swelling, bearing phialides at the apex or radiating from the entire surface, but the conidia are 1-celled and globose. The conidia are often variously colored in mass and in dry basipetal chains. Penicillium is a form genus based on conidial morphology. The different kinds of ascocarp represented by these generic names appear to be correlated with the type of conidiophore, especially with the complexity of conidiophore branching. However, most species of Penicillium have no known ascocarps.

In Chaetomium, the perithecia are superficial and barrel-shaped, and they are clothed with dark, stiff hairs. In some species, the hairs are dichotomously branched. In others the body of the perithecium bears straight or slightly wavy, unbranched hairs, whilst the apex bears a group of spirally coiled hairs. The hairs are roughened or ornamented, and the type of ornamentation is an aid to identification (Hawsworth & Wells, 1973). When the perithecia are ripe, a column-line mass of black ascospores

arises from the apex. In most species, the spores are lemon-shaped, with a single germ pore. The spore column results from the breakdown of the asci within the body of the perithecium, that is the asci do not discharge their spores violently. The young asci are cylindrical to club-shaped, but this stage is very evanescent, and is only found in young perithecia. The development of perithecia in Chaetomium shows some variation between species (Whiteside, 1957; 1961; Corlett, 1966; Berkson, 1966; J. C. Cooke, 1969 a,b,1970). The ascogonia are coiled and lack antheridia. Investing hyphae arising from the ascogonial stalk or from adjacent vegetative cells surround the ascogonium at the base of the centrum. Conidial state are rare in Chaetomium, but simple phialides and phialospores occur in C. elatum and C. globosum, whilst C. piluliferum forms both phialospores and globose thalloconidia of the Botryotridium type (Daniels, 1961).

Members of the family Hypocereaceae to which Fusarium belong have brightly colored (white, yellow, orange, red, violet) perithecia which may be single or seated on a stroma. The perithecial ostiole is lined by periphyses. The asci are unitunicate, and contain ascospores which are often two or more celled, and may break up inside the ascus to form part-spores. The ascogonia, which are formed within a stroma, become surrounded by concentric layers of vegetative hyphae which form a true perithecial wall. The conidia states of this family are phialidic and belong to form genera such as Fusarium. Barnett and Hunter (1972) reported that in Fusarium, the mycelium are extensive and cottony in culture. They are often with some tinge of pink, purple or yellow. The conidiophores are variable, slender and simple, or stout, short and branched irregularly or bearing a whorl of phialides, single or grouped into sporodochia. The conidia hyaline are variable and principally of two kinds. They are often held in small moist heads. These are macroconidia which are several-celled and slightly curved or bent at the pointed ends are typically canoe-shaped; and

microconidia which are 1-celled, ovoid or oblong and are borne singly or in chains. Some conidia intermediate are 2-celled or 3-celled and oblong or slightly curved.

The characteristic features of the form-genus Curvularia are the formation of Macronematous, mononematous, erect conidiophores (and occasionally stromata), bearing spores spirally or in whorls. The spores are usually curved; the third cell from the base of the spore is larger than the rest, and the end cells are paler. In some species, the base of the conidium bears a protruberant hilum. The first conidium bears a protruberant hilum. The first conidium develops tetrically, that is as a poroconidium at the apex of the elongating conidiophore. A tiny apical pore forms at the tip of the conidiophore by dissolution of the outer wall, and a spherical, cytoplasmic bubble is blown out through the pore. The first conidium assumes an ovoid shape and, after it has matured, the conidiophore develops a new sub terminal growing point, from which a second conidium initial arises. The process is repeated so that a succession of new apices, each terminated by a conidium, is formed. The term sympodula has been applied to this type of conidiophore apex. In brief Barnett and Hunter (1972) reported that the conidiophores of Curvularia are brown, mostly simple and bearing spores apically or on new sympodial growing point. Their conidia are dark but the end cells are lighter . They are 3-celled to 5-celled, more or less fusiform and typically bent, with one of the central cells enlarged.

In Nigrospora the conidiophores are short and mostly simple. Their conidia are black, 1-celled and globose. They are situated on a hyaline vesicle at the end of the conidiophore.

In Rhizopus sporangia are globose or pear-shaped and may be borne singly at the tip of a sporangiophore or may occur on a branched sporangiophore. In some genera example Absidia, the sporangia may be arranged in whorls on actual branches, and in

many species of Rhizopus the sporangiophore arise in groups from a clump of rhizoids

2.7 Factors influencing mouldiness of stored maize

In storage, fungal attack generally occurs under several conditions: such as when drying has been inadequate, when large numbers of insects are present causing a temperature rise in the grain, when the stored crop is exposed to high humidity or actual wetting etc. (FOA,1979). Temperature and water availability do not operate in isolation but interact to determine the range of conditions allowing growth of individual organisms, the range of species able to colonise a substrate and also to determines their interactions with other species and their ability to produce mycotoxins (Lacey et al, 1986). Temperature determine the rate of spore germination and mycelial growth.

Fungi differ greatly in their responses to temperature, not only between genera but also between species of a genus and sometimes, between isolates of a species. However, species usually have characteristic temperature minima, optima and maxima for germination, growth and sporulation (Lacey, 1980). Fungi also differ in their tolerance of low water availability and for each species there is a minimum which it can tolerate. Storage fungi are mostly tolerant of lower water activity. Some spore germination may occur outside these limits but sporulation usually increases with increasing water activity (Lacey, 1986).

Evolutionary development has allowed some fungi to grow at moisture levels much lower than any other life form (King, 1990). This ability to grow at low moisture

concentrations (low water activity) creates concern for the stored products industry. Water is the single most important factor in fungal growth and in the ability of stored products to resist spoilage (Magan and Lacey, 1988; CAST, 1989).

2.8 Effects of storage fungi on maize

Christensen and Kaufmann (1968) reported that storage fungi are the major cause of damage of stored grains. According to them, there are six major types of losses caused by fungi growing in stored grains. These are decrease in germinability, discolouration of part (usually the germ or embryo) or all of the seed or kernel, heating and mustiness. Also various biochemical changes, loss in weight (Christensen and Kaufmann, 1969) and production of toxins that if consumed may be injurious to man and to domestic animals have also been recorded.

In recent years, attention has been given to the toxic products of certain fungi, such as aflatoxin and zearalenone out of the over two hundred mycotoxins, which are metabolites of Aspergillus flavus and Fusarium moniliforme (FAO, 1979; King, 1990). In 1960, the famous "Turkey X" killed some hundred thousand turkey poult in Great Britain and aflatoxin was found to be responsible (King, 1990). The aflatoxins produced by Aspergillus flavus and A. parasiticus have received the most attention (Hesseltine *et al.*, 1966; Hesseltine, 1972). These two moulds produce aflatoxins B1, B2, G1, G2 and other mycotoxins (King, 1990). Aflatoxin B1, which is the most toxic of the aflatoxins, is acutely toxic to young animals (Wogan, 1972), especially poultry and causes hepatic lesions in pigs (King, 1990).

Trichothecenes which are produced by Fusarium, Trichoderma, Myrothecium and Stachybotrys (Ueno, 1987) are a major group of at least 148 mycotoxins (Scott, 1990). Fusarium mycotoxins (for example deoxynivalenol (DON), nivalenol,

zearalenone and T-2 toxin) have been detected in a number of grain products (Blaney *et al.*, 1987; Blaney and Dodman, 1988; Jelinek *et al.*, 1989; Scott, 1990), corn and animal feeds (Abbas *et al.*, 1988). In addition they cause economic loss because animals eating infected grains exhibit poor feed performance (Gilbert, 1989).

Ochratoxin is produced by several moulds. It was first isolated from *Aspergillus ochraceus* and has subsequently been isolated from other aspergilli of the ochraceus group such as *A. sulphureus*, *A. sclerotiorum*, *A. alliaceus*, *A. melleus*, *A. ostianus* and *A. petrakii* (Shotwell *et al.*, 1969; Hesseltine, 1972; Hesseltine *et al.*, 1972; Martin, 1972; Krogh, 1987). Ochratoxin is also produced by *Penicillium purpurescens*, *P. commune*, *P. viridicatum*, *P. palataus*, *P. cyclopium*, and *P. variable* (van Walbeek, 1969; Krogh, 1987). Ochratoxin causes a kidney disease in pigs now known as mycotoxic porcine nephropathy (Krogh, 1987).

It has been established that storage fungi do not invade grain before harvest (Christensen and Kaufmann, 1969; Christensen, 1971) but they may be found on seed in very low percentages, often below one percent, nevertheless providing for the presence of inoculum of storage fungi (Qasem and Christensen, 1958; Tuite, 1959, 1961). They may be present not only as contamination but as dormant mycelium within the tissues of pericarp or seed coat (Warnock and Preece, 1971).

2.9 The economic impact of storage fungal pests of maize

The economic impact of fungal spoilage to food and feed is less easily recognized. In some areas of the world where the climate is warm and damp the spoilage can cause staggering economic loss (King, 1990). It is estimated that one quarter of the world's food crops are affected by mycotoxins annually (CAST, 1989). The economic impact of mycotoxins can be from lower yields, from losses to livestock and poultry, from

death or from less dramatic effects such as reduced growth rates, less feed efficiency and immune suppression (CAST,1989).

Mycotoxins have been suspected for hundreds of years to be related to human diseases. A hazard to human health can result when food contaminated with these substances are eaten by man. It is important to note that mycotoxins remain in food long after the fungus that produced them has died. Many kinds of mycotoxins are relatively stable substances that survive normal cooking or processing (Wogan, 1972).

Clear evidence for causal association of mycotoxins and human disease has been recorded only for aflatoxin, for Alimentary Toxic Aleukia (ATA) caused by Fusarium toxins, for ergotism caused by fungal alkaloids and possibly for human nephropathy by ochratoxin A (CAST, 1989; Krogh, 1989).Aflatoxin B1 is acutely toxic to humans and laboratory animals (CAST, 1989) and is highly carcinogenic for selected species of laboratory animals causing hepatocellular carcinoma (Wogan, 1972; King, 1990). Several epidemiological studies have been carried out in Africa and South East Asia to determine the risk of aflatoxin in human liver cancer (Autrup et al., 1987; Krogh, 1989).

2.10 Traditional methods of drying and storing maize

Traditional structures for the storage of cereals in Ghana include granaries, barns, baskets, clay pots, gourds, ordinary rooms and roofs of living houses, especially the part over the kitchen. The most popular and widely distributed are the barns which take various forms such as circular, rectangular, simple platform or a circular platform with radiating sticks(Nyanteng, 1972).

According to a report by FAO (1983), the common practice among farmers in other parts of Africa is to store the cobs initially in open, round or rectangular covered and elevated structures. From the report, maize grain is stored in inverted baskets in Angola and in Ethiopia; uninverted baskets are also used. The "ngoko" store is used in Tanzania, though farmers of southern Tanzania construct stores attached to the dwelling quarters located over the domestic cooking area. The typical maize barn of the "Ewe" tribe in southern Ghana in which whole cobs are laid with their butts outwards to form a wall that also tapers outwards is common in Benin. In Kenya, a large solid-built maize store is constructed for the storage of maize while a mud-brick storage hut for the cob maize is constructed in Chivuna area in Zambia.

Traditionally, cereal grains are stored in the dry form after allowing matured cobs in the field to dry in the sun before harvesting. The maize cereal is harvested with high moisture content ranging between 21% and 30% (Forsyth, 1962). To avoid heating and fungal growth, further drying may be done after harvesting. In certain parts of Ghana especially in Ashanti and Brong-Ahafo, the sheath of maize may be removed and the maize cobs sorted into two lots: damaged and undamaged (Nyanteng, 1972). According to Nyanteng (1972), the undamaged cobs are stored and the damaged ones given to livestock and poultry as feed or, where the extent of damage is not severe, used for immediate human consumption; while in other regions in the south, the maize sheath is not removed before storing and therefore selection is not done.

Each of these two major forms of storing maize has its merits and demerits. Insect infestation starts in the field (Rawnsley, 1969), so removal of the sheath makes it possible to select and store the cobs which have not been infested (Nyanteng, 1972). However, infestation can occur in the barns, which is higher in cobs stored without the sheath (FAO, 1969; Rawnsley, 1969; Nyanteng, 1972). According to the FAO

(1969), the rate of infestation of maize stored unhusked in barns is lower but the storage of unhusked maize does not allow for selection and hence both damaged and undamaged cobs are stored together. This implies that the husks offer a degree of protection from insects (FAO, 1980) but hinders selection of damaged and undamaged maize.

In order to assist African countries in the humid tropics to reduce pre- and post-harvest crop losses at the farm level, the Africa Rural Storage Centre Project was established in 1972 at the International Institute of Tropical Agriculture at Ibadan, Nigeria, and sub-stations were established in Benin, Ghana, and Zambia (FAO, 1980). The scope for natural drying of dehusked maize cobs in freely ventilated structures was considered in detail by FAO/Danida(1978) in a comprehensive series of investigations conducted in Ghana, Benin and Nigeria. FAO (1980) reported that the use of improved narrow cribs which fully exploit the drying capabilities of natural air appear to offer at present the most practical and economical method of drying and storing maize in the cob, together with dehusking and treatment with suitable insecticides.

2.11 The storage environment

One major problem of maize in storage is the initial high moisture content. Forsyth (1962) estimated the moisture content level of maize at the time of harvest to be between 21% and 30%. Rawnsley (1969), however put the estimates at the time of harvest at between 15% and 18%. It is noted by Forsyth (1962) that after a few days of storage in the local barns the moisture content decreases to a level of between 15 % and 17%. This is confirmed by the findings of an experiment conducted at Pokoase by the Crop Research Institute Unit (Nyanteng, 1972). The level of moisture content of maize in storage is largely a function of the relative humidity as well as conditions

within the storage structures. In southern Ghana, the average relative humidity is very high, averaging over 80% throughout the year, but the humidity fluctuates in the course of the day ranging from about 63% to 96% (Nyanteng, 1972).

According to the FAO (1979), high temperature and humidity encourage mould formation and provide conditions favourable for rapid growth of insect populations. Seasonal and diurnal temperature differences between stored grains and the surrounding environment can result in moisture translocation or migration among quantities of bulk grains or in condensation of moisture on the grain (FAO, 1979). Concentration of moisture in grain can lead to conditions favourable to the development of fungi.

2.12 Chemical control of storage pests

The use of chemicals as a means of pest control has been with man; since after the second world war, with the discovery of DDT which earned Paul Muller a Nobel prize (Kumar, 1984). Chemicals are man's chief weapon against pests although, they have brought a lot of problems. These problems include chemical residues in food (Hickey *et al.*, 1966; Lincer *et al.* 1981); environmental effects (Tahori, 1971a, 1971b); health problems (Bressan, 1975) and the development of chemical resistance (Dyte, 1970; Georghion and Taylor, 1977; Champ, 1979).

The threat that insecticide resistance in pests of stored grain might limit the effectiveness of chemicals in maintaining grain at the standards required in international trade and domestic consumption, led to the FAO Global Survey of Pesticide Susceptibility of stored grain pests (Champ and Dyte, 1976). The current general world situation, in terms of species and countries in which resistance has been detected, has recently been well covered by Champ (1986). The rise and spread of

malathion resistance in Australia has been well documented and correlated with an upsurge in insect infestation of grain (Greening, 1979; Murray, 1979). Pesticide resistance and related control failures in South East Asia have been described by Sample (1986). Attempts to solve these problems have ushered in high cost of production of chemicals. It is therefore necessary to evaluate the cost effectiveness of using chemicals in crib storage.

CHAPTER 3

MATERIALS AND METHODS

3.1 Experimental site

The study was conducted at the University of Ghana farm, Legon and the Crop Science Department from April 1992 to September 1993. The farm had previously been cropped with various varieties of maize.

The climate of the University of Ghana farm, near Accra, falls within the dry equatorial tropical climatic region. The rainfall has a characteristic bimodal distribution pattern with peaks in June and in September and a period of low precipitation in August. December through February constitute the major dry season. The rainfall pattern results in two distinct growing seasons, one from April to July and the second from Mid-August/September to November/December. From information obtained from the Meteorological Services Department, Legon the annual rainfall is variable ranging from 74cm to 89cm (Anon . 1993).

The temperature regime is characterised as equatorial, with no great variation throughout the year. Annual temperatures range from an average of 26.7°C to 36.1°C over a decade. During the dry season, the cool North-East trade winds blowing southwards across the Sahara desert help keep the weather cool for most of the dry periods, especially during December and January. The mean monthly duration of sunshine over the storage period was 6.7 hours.

3.2 Storage crib and experimental set up

Four improved narrow cribs with rodent guards were constructed at the University farm where on-farm storage was undertaken over a period of ten months. The construction was done in a way to ensure good aeration. The width of the cribs were narrow and this makes the cribs improved. The investigation involved the examination of maize stored dehusked or undehusked. Both dehusked and undehusked maize were stored with or without actellic dust. Split-plot design was used as described by Snedecor and Cochran (1967), Steel and Torrie (1980), and Hicks (1982).

Two separate experiments were conducted. One with maize variety, Abrotia and the other with maize variety, La Posta. La Posta variety have harder kernel and more sheets compared to Abrotia variety. The maize seeds of both varieties were collected from Crop Science Department (University of Ghana), Legon. They were cultivated on a six acre land at the University farm.

There were two main treatments. One consisted of maize with insecticide applied while the other consisted of maize with no insecticide applied. Within each main treatment were two sub-treatments. One consisted of maize stored undehusked while the other consisted of maize stored dehusked (Figure 1). To ensure that good cobs of maize were used in the investigation, the maize cobs were sorted out before loading them into the cribs.

In the experiment involving the Abrotia variety, each sub-plot was loaded with 250kg of maize cobs. In this case there were two replicates for samples treated with insecticide and three replicates for samples without insecticide application. In the experiment involving La Posta variety, each sub-plot was loaded with 175kg of maize

cobs. In this case there were three replicates for all samples (both with and without insecticide application). In all the experiments, Actellic dust insecticide was applied layer by layer at the rate of 500g of dust per 1000kg of maize. Samples were taken randomly from all parts of the compartments every three months beginning from the month of storage.

dt	Dt	dt
DT	dT	DT

Dt	dt	Dt
dT	DT	dT

T.....Insecticide treatment

t.....No insecticide treatment

D.....Dehusked maize

Td.....Undehusked maize

Figure 1. Illustration of arrangement of treatments.

3.3 Assessment of infestation of stored maize by insect pests

Samples were taken from the cribs a day after loading the cribs with maize and this was repeated every three months. Four samples were taken throughout the storage period. Each sample was made up of twenty two sub-samples and each sub-sample contained thirty cobs of maize. The sub-samples were each sealed airtight in clean labelled polythene bag. Undehusked maize cobs were dehusked. This was followed by shelling of the maize grains on the cobs. The maize grains were sieved to get rid of

dirts and maize frass after which each sample was examined for insect pests. Insects in the maize grains were collected into air-tight, clean labelled sample bottles and killed by heating them in the oven. These insects were identified with the aid of a binocular microscope and NRI(1991) manual. The population of each species of insects were recorded. The results obtained were converted to number of insects per cob basis.

At the beginning of the storage period, the number of adult insects per cob were recorded. On the average, 15.35 per dehusked cob and 10.0 per undehusked cob adult insects were counted on Abrotia variety. In the case of La Posta variety, the adult insects counted were 9.91 per dehusked cob and 6.81 per undehusked cob.

3.4 Assessment of damage of stored maize

3.4.1 Count and weigh method

To enable damage and losses to be assessed, samples were taken at random from all parts of the compartments of the cribs, placed into polythene bags and labelled. Each sample was made up of twenty two sub-samples and each sub-sample contained thirty cobs of maize. The maize was shelled and sieved. A sample of one thousand(1000) maize grains was taken using a tally counter from each sub-sample and this was replicated three times. Each triplicate was separated into two, Damaged and Undamaged grain, with the aid of a hand lens. Both the damaged and the undamaged maize grains were separately counted using the tally counter and weighed using an electronic balance. Separation of damaged and undamaged, and a comparison of their weights were calculated as a percentage of the whole sample. The simple loss assessment method was employed by substituting the figures obtained in the formula of Adams and Schulten(1978).

$$\text{Weight loss} = \frac{(\text{UNd}) - (\text{DNU})}{\text{U}(\text{Nd} + \text{Nu})} \times 100\%$$

Where **Nd = Number of damaged grains**
 Nu = Number of Undamaged grains
 D = Weight of damaged grains
 U = Weight of Undamaged grains

3.4.2 Standard volume/weight method

The standard volume-weight method is based on the use of a hopper, a modified test weight apparatus designed by Boerner (1916), for the determination of bulk density of grain. The underlining basic principles used were (a) causing a sample of maize grain to fall from a standard container through a standard height into a standard (one litre) weighing bucket, (b) leveling the surface of the maize in the weighing bucket in such a way as to influence its packing, and (c) weighing the maize loaded in the bucket (Boxall, 1986). The procedure employed in this loss assessment was based on the work by Adams and Schulten (1978).

Maize samples were sieved to remove foreign matter and then sub-divided into five. The moisture content of each sub-sample were determined. Also a range of moisture content which might be expected in the field over the storage period was determined. The range of moisture content selected was 12% to 24% at 3% interval. The moisture content of the sub-samples were changed either by drying in the oven at a temperature of 35% or wetting in order to cover the range. The weight of water to be added or

removed from the sub-samples to achieve the required moisture content was computed using the formula of Adams and Schulten(1978).

$$X = \frac{MC_2 - MC_1}{100 - MC_2} \times Wt$$

Where

- X** - Water to be added or removed
- MC₁** - Initial moisture Content
- MC₂** - Expected Moisture Content
- Wt** - Wet Weight of grains

Samples which were wetted with water were sealed in polythene bags and shaken vigorously every day for two weeks. During this period the samples were kept at the cold store to discourage mould growth. The mean weights of the five sub-samples were taken and converted to dry weights according to the formula of Adams and Schulten(1978).

$$\text{Dry Weight} = \text{Wet Weight} \times (100 - MC / 100)$$

moisture contents and the dry weights constituted a baseline data which was used in plotting a baseline The graph of dry weight of maize against the percentage moisture content of the maize (Figures 2 and 3). This graph was used throughout the study to represent the dry weight of the samples at any moisture content. Using the dry weight

FIGURE 2 A SAMPLE OF A STANDARD BASELINE GRAPH FOR DRY WEIGHT OF A FIXED VOLUME OF GRAIN AS MOISTURE CONTENT CHANGES. (ABROTIA VARIETY)

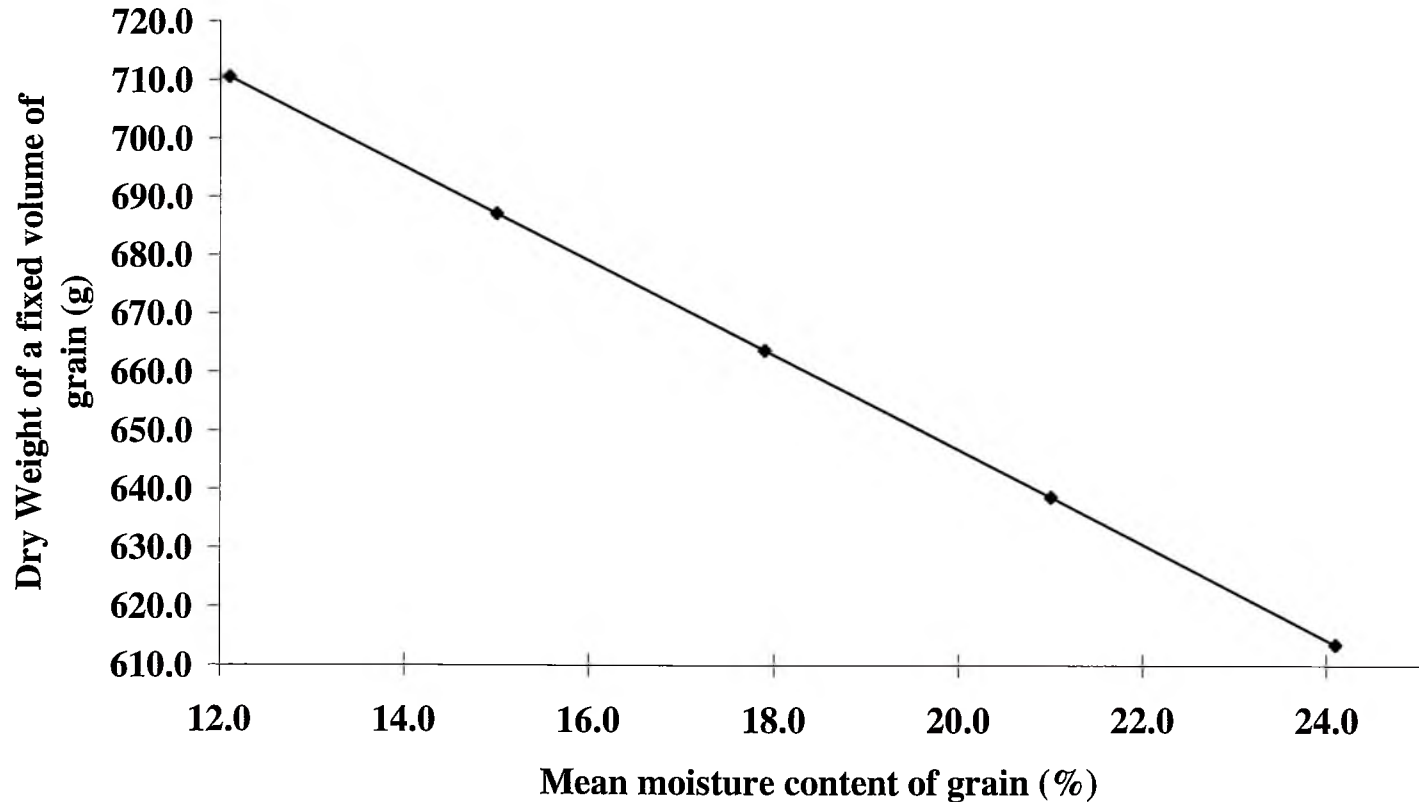
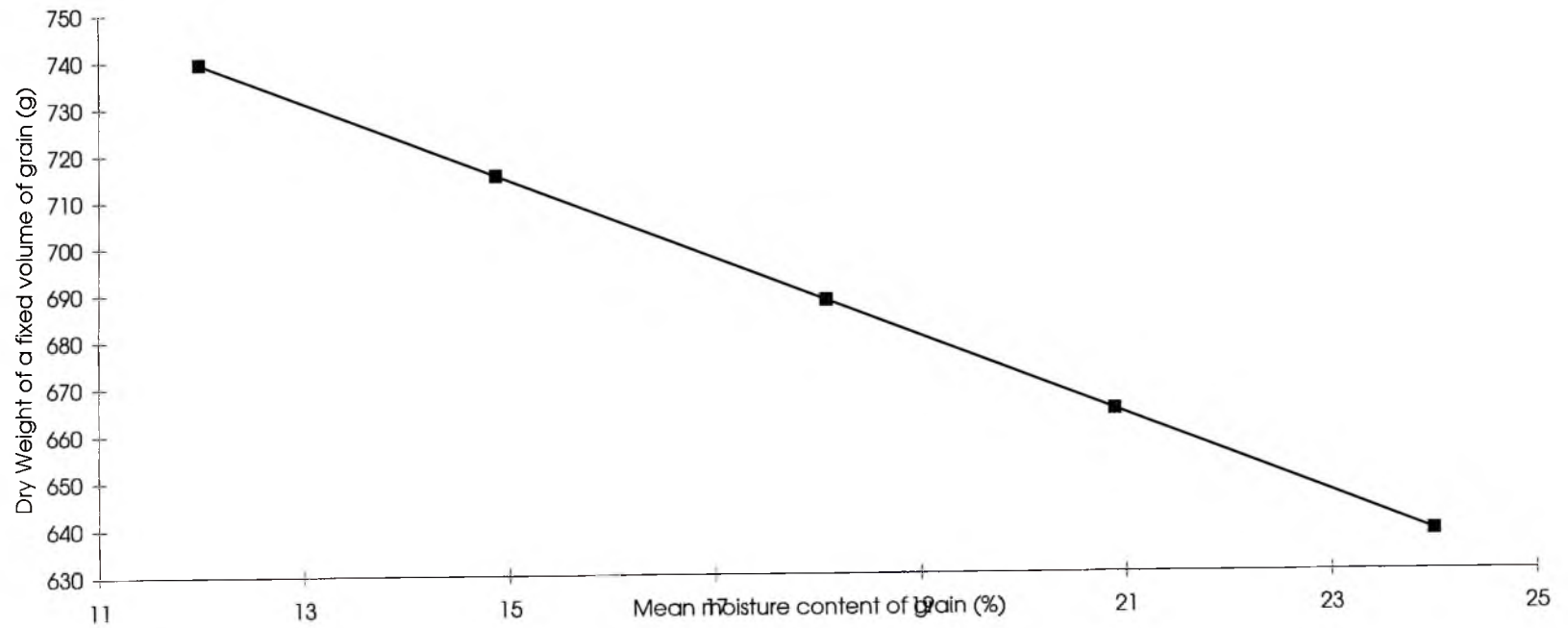


Figure 3 A sample of a standard baseline graph for dry weight of a fixed volume of grain as moisture content changes.
(LA POSTA VARIETY)



obtained from both calculations and the graph of each sample taken from the crib, weight loss during storage was computed for every sample using the formula of Adams and Schulten(1978).

$$\text{Weight Loss} = \frac{\text{Dry weight(graph)} - \text{Dry Weight(calc)}}{\text{Dry Weight(graph)}} \times 100$$

3.5 Determination of germination of stored maize

Germination tests were conducted to determine the germinative capacity of the maize at each sample period. Hundred grains of maize were collected from each sub-sample taken from each compartment. These grains were sowed in four big rectangular trays with sand in rows, each row representing a particular sub-sample. Watering was done at two days intervals. One week after the commencement of the experiment, the germinated seeds of each sub-sample were counted and recorded.

3.6 Assessment of fungal infection on stored maize

Random samplings of maize cobs was done from the cribs, placed in polythene bags and labelled. The maize cobs of each sample were examined thoroughly for mouldiness so as to determine incidence of fungal pathogens. Suspected fungal infested maize grains of each sample were shelled out separately and cultured to ascertain whether or not the samples contain fungal pathogens.

The bench and the inoculating chamber were sterilised with detol and 70% ethanol respectively. Surface sterilisation of the maize grains was done using full strength sodium hypochloride. Full strength was selected after a trial experiment was

conducted using 1%, 10%, 20% and full strength each of sodium hypochloride and 70% ethanol for the surface sterilisation.

Water agar media were prepared by weighing 20g of agar powder, dissolved in one litre distilled water and the solution autoclaved in two one-litre sterilised conical flasks. This was poured into labelled, oven sterilized petri dishes already packed in the inoculating chamber. After the water agar media had set, the surface sterilized maize grains were placed on the media and incubated at room temperature for three to five days. For each sample, three cultures were prepared and the number of cultures infested with fungi were recorded.

Cultural examination was conducted and slides were made out of each culture showing fungal growth. With the aid of microscope and assistance from Prof. G. C. Clark of the Botany department, University of Ghana, Legon and reference made from Barnett and Hunter (1972), Raper and Thom (1945) and Smith (1960), all the fungi were identified.

3.7 Analysis of data

The data collected were statistically assessed separately using analysis of variance techniques as described by Snedecor and Cochran (1967); Steel and Torrie (1980); Hicks (1982) on the split-plot design. Data on germination test were transformed using the arcsin transformation (steel and Torrie, 1980) before subjecting it to the analysis of variance.

Mean comparison was done after the analysis of variance using Least significance Difference (LSD) procedures (Steel and Torrie, 1980; Gomez and Gomez, 1984).

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 The Storage Environment

The storage period of the maize grain experienced both dry and wet conditions. Figure 4 illustrates the environmental mean temperatures and relative humidity over the storage period. The environment was generally humid in the mornings. With the exception of January 1993 and March 1993, all the relative humidities taken at 0600 hours were above 90%. At each period the loss of moisture to the environment by the maize grain was generally low or negligible.

At 1500 hours, low relative humidities were registered even during the major raining season between April 1993 and July 1993 (Figure 4). The lowest relative humidity was 50% which occurred in January 1993. The loss of moisture to the environment by the maize grain was generally high in the afternoons. There was a gradual increase in mean environmental temperatures from September 1992 to May 1993 after which the environment registered a steep drop in temperature (Figure 4).

Dry conditions generally prevailed during the day due to the high mean temperatures and low relative humidities in the afternoons. This accounted for high loss of moisture by the maize grain in the afternoons and the subsequent general reduction in the moisture content of the maize grain over the storage period (Tables 3 and 4).

Figure 4 Mean Monthly Temperatures and Relative Humidities of the Environment over the Storage Period

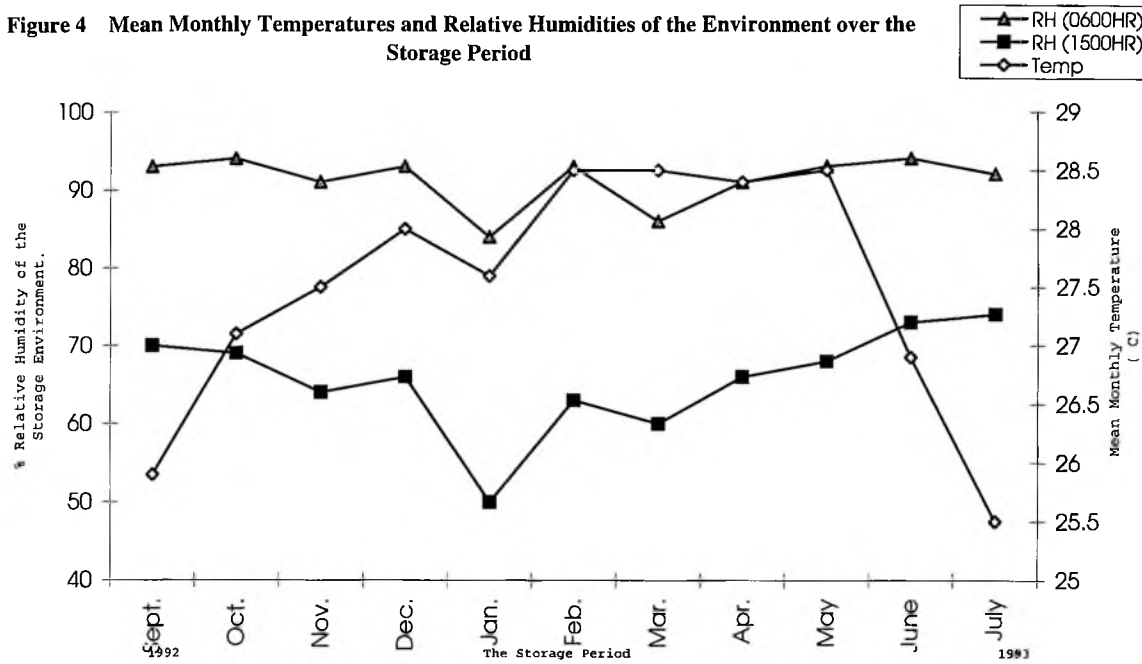


Table 3 THE MEAN MOISTURE CONTENT (%) OF MAIZE GRAIN OVER THE STORAGE PERIOD AT THREE MONTH INTERVALS (ABROTIA VARIETY)

HUSKING	MONTHS OF STORAGE								LSD
	0*		4		7		10		
	T	t	T	t	T	t	T	t	
DEHUSKED	20.1	19.8	15.7	15.3	13.6	13.6	14.0	14.9	NS
	20.4	19.9	15.7	15.3	13.7	13.7	13.7	14.7	
	-	19.4	-	15.3		13.4	-	14.8	
UNDEHUSKED	19.8	19.7	16.5	17.0	13.7	13.8	14.3	14.6	
	20.1	19.6	16.7	16.6	13.5	13.4	14.3	14.3	
	-	19.4		16.6	-	13.6	-	14.6	
LSD	0.45								

NS not significant

* Initial data taken at the day of stage

Where,

T ---- Insecticide treatment

t ---- No insecticide treatment

Table 4 THE MEAN MOISTURE CONTENT (%) OF MAIZE GRAIN OVER THE STORAGE PERIOD AT THREE MONTH INTERVALS (LA POSTA VARIETY)

HUSKING	MONTHS OF STORAGE								LSD
	0*		4		7		10		
	T	t	T	t	T	t	T	t	
DEHUSKED	19.1	18.6	15.7	15.1	12.5	13.3	14.8	14.7	NS
	19.3	19.0	15.2	15.3	13.3	13.7	13.0	14.3	
	20.8	18.8	15.8	15.1	14.0	13.8	14.5	14.1	
UNDEHUSKED	19.1	19.6	16.4	16.5	13.4	13.4	14.2	12.9	
	19.1	18.6	16.6	16.5	13.5	13.4	14.0	14.4	
	19.2	18.6	16.4	16.6	13.8	13.2	14.7	13.9	
LSD	NS								

NS not significant

* Initial data taken at the day of stage

Where,

T ---- Insecticide treatment

t ---- No insecticide treatment

The rate of drying of maize was gradual for both Abrotia and La Posta varieties of maize stored unhusked at least for the first seventh months of storage . For maize stored husked, the rate of drying was also gradual throughout to the seventh month in both Abrotia and La Posta varieties (Tables 3 and 4).The difference in the rate of drying from the beginning of storage to the end of it was significant ($P=0.01$) for Abrotia variety only in both maize cobs stored husked and unhusked. There was however, no significant difference ($P=0.05$) between maize cobs stored husked and those stored unhusked for both Abrotia and La Posta varieties. The slight difference in the rate of drying between maize cobs stored husked and those stored unhusked for both Abrotia and La Posta varieties could be accounted for by the fact that, maize cobs stored husked were exposed to the environment directly which resulted in a lost of water to the environment easily. Maize cobs stored unhusked were not directly exposed to the environment. The husk provided a barrier between the maize grains and the environment. This reduced the rate of movement of water from the maize to the environment. At the tenth month of storage of both husked and unhusked cobs of both varieties of maize, the moisture content of the maize grain registered a slight increase probably due to insect activities which caused mustiness in the maize grain (Tables 3 and 4).

4.2 Infestation of stored maize by insect pests.

There was a general increase in the population of insects in the stored maize grain with time. The number of species of insects identified showed an increase with storage. In all, seven different species of insects were identified (Table 5). These were Sitophilus zeamais (Motsch), Tribolium castaneum (Herbst), Oryzaephilus mercator (Fauvel), Stegobium peniceum (L.), Rhizopertha dominica (F.), Prostephanus truncatus (Horn) and Sitotroga cerealella (Oliv.).

The infestation of each cob of maize by insects increased with the length of storage period (Tables 6 and 7). Insect infestation per maize cob with regard to treatments were significantly different ($P=0.05$). More insects were found on dehusked maize

Table 5 INSECT SPECIES OBSERVED ON TWO VARIETIES OF MAIZE (ABROTIA AND LA POSTA) COBS UNDER DIFFERENT TREATMENTS DURING STORGE (FROM OCTOBER 1992 TO JULY 1993).

SAMPLE	INSECTS																											
	Sitophilus zeamais				Tribolium castaneum				Oryzaephilus mercator(Fauvel)				Stegobium raniceum				Rhizopertha dominica				Prostephanus truncatus				Sitotroga cerealella			
	Oct.	Jan.	April	July	Oct.	Jan.	April	July	Oct.	Jan.	April	July	Oct.	Jan.	April	July	Oct.	April	JAN	July	Oct.	Jan.	April	July	Oct.	Jan.	April	July
ATD	947	2318	3477	5642	84	201	303	502	41	116	156	417	-	18	29	59	-	12	7	20	-	-	-	12	15	11	16	72
AID	952	2253	3727	8697	296	292	457	679	40	111	278	647	-	27	89	102	-	8	6	29	-	-	-	23	17	12	20	117
Atd	680	1770	3240	7117	87	227	402	746	55	149	250	654	5	33	44	195	11	24	12	55	10	8	14	40	11	14	22	69
ATd	466	1191	2127	4535	100	174	366	490	52	125	199	407	-	16	28	124	6	9	4	21	5	4	7	18	8	14	16	43
LTD	646	1595	2488	6634	155	384	556	718	70	183	273	604	-	25	40	88	3	12	8	26		3	3	21	11	18	26	115
LHD	646	1679	2855	7207	165	386	554	711	70	185	205	640	2	24	45	99	2	20	10	38	3	6	12	30	41	13	18	117
Ltd	520	1383	2395	7207	85	216	360	752	40	112	130	444	2	22	42	214	2	24	16	47	2	9	15	38	6	18	28	73
Ltd	379	910	1662	7047	104	267	416	730	52	143	184	655	8	26	45	192	9	18	12	39	3	7	10	29	10	39	41	57

Where.

A — Abrotia variety

L — La Posta variety

T — Insecticide applied

f — No Insecticide applied

D — Dehusked maize

d — Undehusked maize

example ATD — Dehusked Abrotia variety with Insecticide applied

TABLE 6

**NUMBER OF INSECTS ON MAIZE COBS (ABROTIA
VARIETY) UNDER VARIOUS TREATMENTS**

MONTHS AFTER STORAGE	NUMBER OF INSECTS PER COB				
	INSECTICIDE		NO INSECTICIDE		LSD
	DEHUSKED	UNDEHUSKED	DEHUSKED	UNDEHUSKED	
0'	18.1	10.6	12.6	9.4	6.74
4	44.5	26.6	28.8	24.1	15.39
7	66.6	45.9	50.0	44.8	0.99
10	108.4	94.0	114.8	98.4	16.25

* Initial data taken at the day of storage

TABLE 7

NUMBER OF INSECTS ON MAIZE COBS (LA POSTA VARIETY) UNDER VARIOUS TREATMENTS

MONTHS AFTER STORAGE	NUMBER OF INSECTS PER COB				
	INSECTICIDE		NO INSECTICIDE		LSD
	DEHUSKED	UNDEHUSKED	DEHUSKED	UNDEHUSKED	
0'	9.83	6.28	9.99	7.33	3.39
4	24.62	15.60	25.59	19.18	8.60
7	37.78	27.01	42.41	33.87	10.80
10	91.18	97.21	97.95	99.97	4.23

* Initial data taken at the day of storage

than undehusked maize in both varieties. The infestation was lower in maize stored with insecticide applied irrespective of the form of storage.

Observations show that, S. zeamais, T. castaneum, O. mercator and S. cereallela appeared in every maize sample unlike S. penicium, R. dominica and P. truncatus which were found in some samples. It is evident from Table 5 that S. zeamais is the most important pest on stored maize as was reported by Rawnsley (1969). It occurred in greater numbers (379 - 8,697) in all the samples whereas P. truncatus occurred in small numbers (2 - 40) whenever they made their appearance.

The extent of insect attack on maize depends on the variety of maize irrespective of the treatment. The higher insect infestation on Abrotia variety compared to that of La Posta variety supports the findings by Adams (1977) who attributed this to the fact that, Abrotia was an improved variety compared to La Posta. Also, the kernels of La Posta being harder than that of Abrotia rendered the variety less attractive to insects (Dobie 1974 and 1977) than Abrotia. The fact that there were more sheath covering on La Posta compared to Abrotia also gave the variety more protection against insect infestation than Abrotia. This is in agreement with the work of Giles (1969); Giles and Ashman (1971). It is also possible that, the differences in levels of infestation during sampling may be due to differences in levels of initial insect infestation.

Rawnsley (1969) noted that the sheath on maize restricts the movement of insects from outside. The general observation that insect infestation was higher on maize stored dehusked compared to those stored undehusked supports the findings of Rawnsley (1969). For both varieties, insect infestation on dehusked maize with insecticide application differed significantly from that of undehusked maize with insecticide application ($P=0.05$). Giles (1969); Giles and Ashman (1971) explained that the sheath offered a degree of protection to maize stored undehusked against

insect infestation but this degree of protection was enhanced by the use of insecticide to control insect infestation.

Contrary, insect infestation on dehusked maize with no insecticide treatment showed no significant difference to that of undehusked maize with no insecticide treatment. This shows the importance of insecticide in controlling insect infestation and how insecticide offer some degree of protection to maize in storage. Most experts agreed that, removal of insecticides from crop protection would result in an immediate drop in food supplies (NAS, 1975). The combined effect of sheath or husk and insecticides in curbing insect infestation support the idea of integrated pest control expressed by Smith and Van den Bosch (1967).

4.3 Damage of stored maize

Weight loss of grains increased with the length of storage period (Tables 8 and 9). In both Abrotia and La Posta varieties, the weight loss increased gradually up to January 1993 and there after, it increased sharply throughout the sampling period. With the exception of April 1993 results of Methods 1a (Table 8), weight loss of maize grains with regard to treatments showed no significant difference ($P=0.05$) in all the varieties used.

An increased in weight loss of grain with length of storage period is in supported by FAO (1969). The sudden and sharp increase in weight loss may be due to lack of re-application of insecticides as recommended by FAO (1980).

TABLE 8

WEIGHT LOSS OF MAIZE GRAINS (ABROTIA VARIETY) UNDER VARIOUS TREATMENTS

MONTHS AFTER STORAGE	WEIGHT LOSS OF GRAINS / gm									
	METHOD 1 ^a				LSD	METHOD 2 ^a				LSD
	INSECTICIDE		NO INSECTICIDE			INSECTICIDE		NO INSECTICIDE		
	DEHUSKED	UNDEHUSKED	DEHUSKED	UNDEHUSKED	DEHUSKED	UNDEHUSKED	DEHUSKED	UNDEHUSKED		
0'	2.49	1.87	2.04	1.83	NS	-	-	-	-	
4	7.44	8.29	7.08	8.72	NS	3.35	9.90	5.37	6.18	NS
7	32.89	28.38	30.87	25.65	5.24	20.87	20.12	23.81	18.10	NS
10	62.29	70.26	63.38	67.15	NS	38.50	39.18	39.84	39.10	NS

1^a Count and Weigh Method

2^a Standard Volume / Weight Method

NS Not significant

* Initial data taken at the day of storage

TABLE 9

WEIGHT LOSS OF MAIZE GRAINS (LA POSTA VARIETY) UNDER VARIOUS TREATMENTS

MONTHS AFTER STORAGE	WEIGHT LOSS OF GRAINS / gm									
	METHOD 1 ^a				LSD	METHOD 2 ^a				LSD
	INSECTICIDE		NO INSECTICIDE			INSECTICIDE		NO INSECTICIDE		
	DEHUSKED	UNDEHUSKED	DEHUSKED	UNDEHUSKED	DEHUSKED	UNDEHUSKED	DEHUSKED	UNDEHUSKED		
0'	0.65	1.33	0.31	1.14	NS	-	-	-	-	-
4	5.57	5.32	5.57	5.75	NS	6.35	7.28	8.18	8.05	NS
7	21.32	19.70	14.38	32.94	NS	17.24	12.73	16.80	13.05	NS
10	56.70	66.31	60.04	62.01	NS	42.69	40.96	40.56	40.53	NS

1^a Count and Weigh Method

2^a Standard Volume / Weight Method

NS Not Significant

* Initial data taken at the day of storage

Weight loss of maize grains stored dehusked did not differ significantly from maize stored unhusked irrespective of chemical control of insect infestation. This is opposed to the report by Rawnsley (1969) which stated that losses in maize stored with the sheath is lower than that of maize stored without the sheath. The sheath or husk provided some degree of protection to maize against insect infestation by restricting their entry (Rawnsley, 1969) but did not protect the maize grains against damage by micro-organisms. According to Calderon (1975), damage of grains could be attributed to micro flora. Christensen and Kaufmann (1968) noted that storage fungi are the major cause of damage of stored grains.

The insignificant difference in weight loss between maize stored dehusked and unhusked could also be attributed to lack of proper sorting out of maize stored unhusked. With dehusked maize only undamaged cobs were stored which is in support of the work by Nyanteng (1972) since the maize cobs were sorted into damaged and undamaged. Such sorting out was not done with unhusked maize before storage and therefore selection was not done. This implies that the sheaths or husks offered only a degree of protection against insect infestation but hindered selection of damaged and undamaged maize as reported by FAO (1980).

4.4 Germination of stored maize

Germination of maize grains decreased generally with the length of storage period (Tables 10 and 11). The percentage germination differ significantly with regard to treatment of samples of Abrotia variety drawn at the beginning and seventh months of storage (Table 10). With La Posta variety (Table 11), the percentage germination showed no significant difference with regard to treatment. In both varieties, there was virtually no germination in samples drawn after ten months of storage.

TABLE 10

**PERCENTAGE GERMINATION OF MAIZE GRAINS
(ABROTIA VARIETY)**

MONTHS AFTER STORAGE	% GERMINATION				
	INSECTICIDE		NO INSECTICIDE		LSD
	DEHUSKED	UNDEHUSKED	DEHUSKED	UNDEHUSKED	
0'	91	91	94	96	5.03
4	78	79	81	83	NS
7	27	31	28	36	3.65
10	0	0	1	0	NS

NS Not Significant

* Initial data taken at the day of storage

TABLE 11

**PERCENTAGE GERMINATION OF MAIZE GRAINS
(LA POSTA VARIETY)**

MONTHS AFTER STORAGE	% GERMINATION				
	INSECTICIDE		NO INSECTICIDE		LSD
	DEHUSKED	UNDEHUSKED	DEHUSKED	UNDEHUSKED	
0'	95.33	94.00	95.33	92.67	NS
4	82.00	82.00	81.33	80.00	NS
7	51.33	49.33	55.33	40.67	NS
10	0.00	0.00	0.00	0.00	NS

NS Not Significant

* Initial data taken at the day of storage

Reduction in the germinative capacity of maize grain with length of storage could be attributed to activities of insects as reported by FAO (1983). The insects by their activities completely hollowed out the kernels, leaving the pericarp alone. With the germ scooped out, the maize grains lost the ability to germinate.

Reduction in the germinability of the maize grains could also be accounted for by the activities of micro-organisms such as fungi which is in conformity with the report by Christensen and Kaufmann (1968). Neergaard (1977) attributed the decrease to the invasion of the embryo by storage fungi. Fields and King (1962) noted that uninfected grains maintained 95% germination within six month period of storage at 30°C temperature and 85% relative humidity. Fungi can cause a lot of biochemical changes in storage such as Lipolytic, proteolytic, saccharolytic, changes in mineral matter and vitamin, and this affects germination (Doharey, 1989).

Percentage germination of maize grains differed significantly ($P \leq 0.05$) in samples drawn at the beginning and seventh months of storage (Tables 10) because of protection offered by the insecticide applied. The insignificant difference in samples drawn at the fourth month of storage (Table 10) may be due to chance.

4.5 Fungal infection on stored maize.

Six different fungi belonging to five genera were isolated during the storage period (Figures. 5 - 9 and Table 12). The fungi were identified with assistance from Prof. G. C. Clerk, Dr. K. A. Oduro and reference made from Barnett and Hunter (1972), Raper and Thom (1945) and Smith (1960). These were Aspergillus sp. with upright conidiophores which terminate in a globose swelling with phalides radiating from the entire surface. The globose were yellowish in Aspergillus ochraceus (Figure 5), but

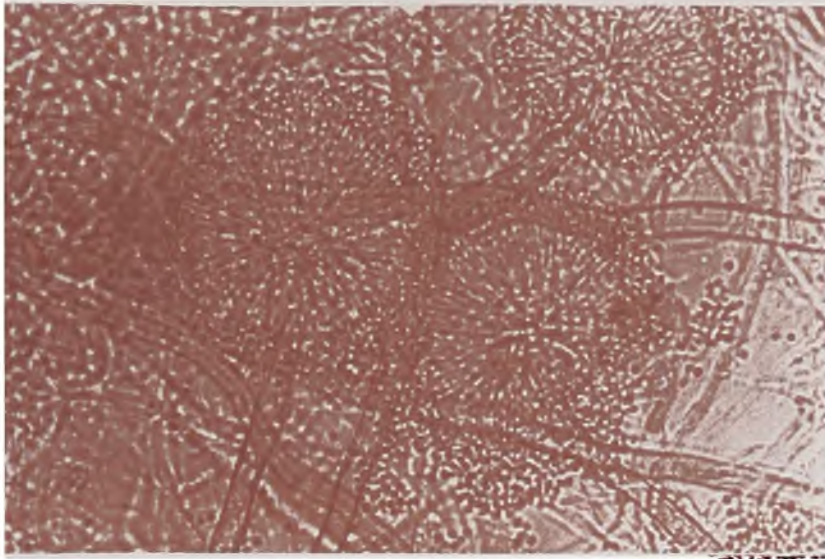


Figure 5 Conidiophores, globose swelling head bearing phialides and spores of Aspergillus ochraceus.

Note: Figure 5 resembles Figure 6 but in culture, conidia of Figure 5 were yellowish while in Figure 6 the conidia were greenish in colour.

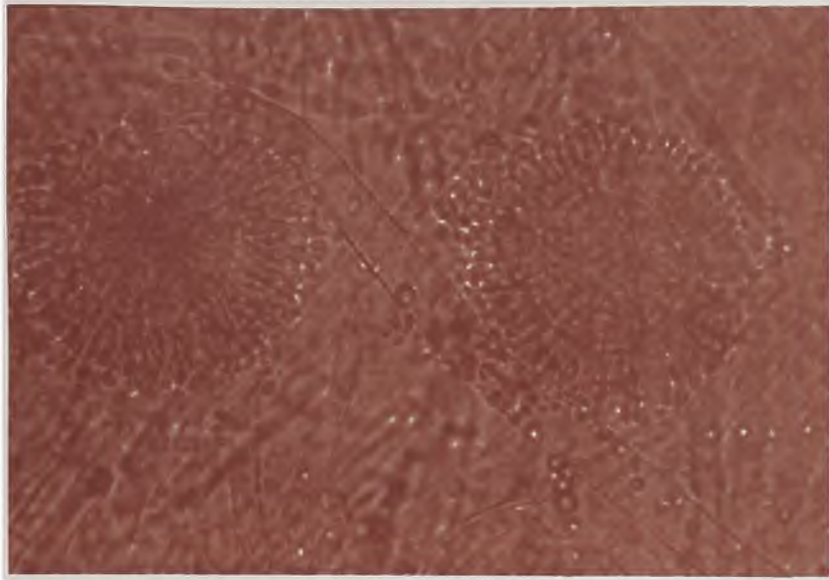


Figure 6 Conidiophores, globose swelling head bearing phialides and spores of Aspergillus flavus.

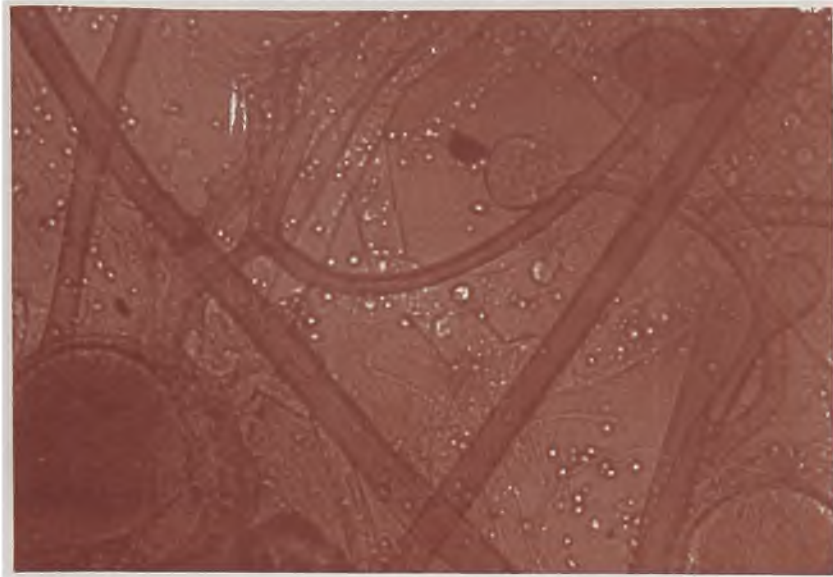


Figure 7 Sporangiphores, sporangia, stolon and rhzoids of Rhizopuc oryzae.

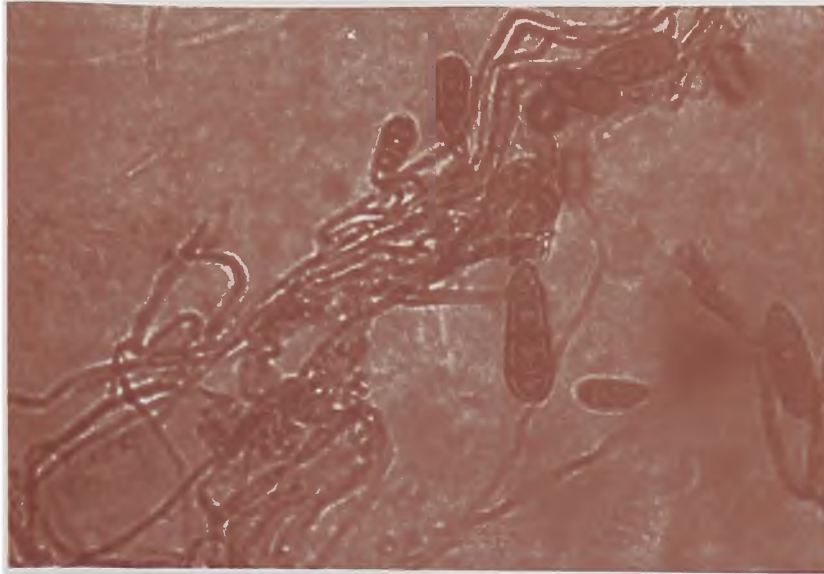


Figure 8 Conidiophores and 3 - celled to 5 - celled spores of Curvularia lunata.

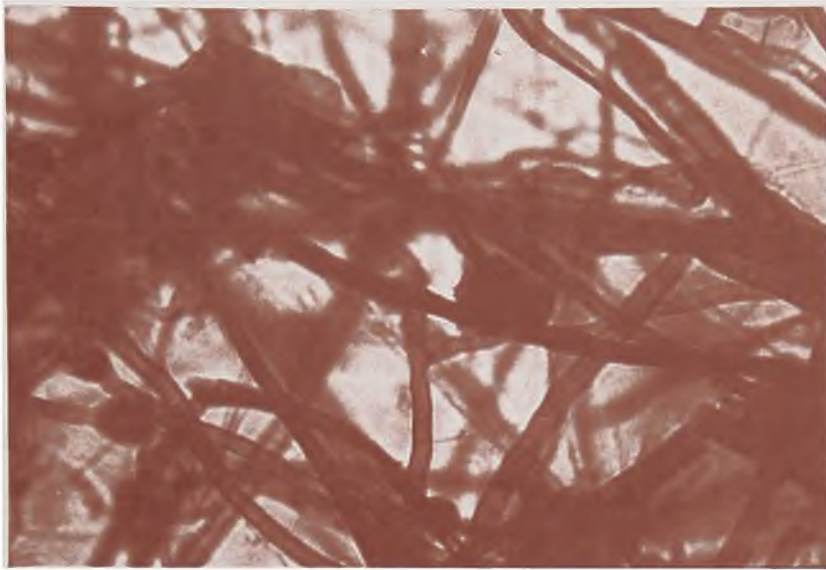


Figure 9 Conidiophores and 1 - celled globose conidia of Nigrospore sp.

Table 12 DIFFERENT SPECIES OF FUNGI IDENTIFIED ON TWO VARIETIES OF MAIZE (ABROTIA AND LA POSTA) COBS UNDER DIFFERENT TREATMENTS (OCTOBER 1992 TO JULY 1993).

SAMPLE	FUNGI																							
	Aspergillus flavus				Aspergillus ochraceus				Chaetomium globosum				Curvularia lunata				Nigrospora sp				Rhizopus oryzae			
	Oct.	Jan.	April	July	Oct.	Jan.	April	July	Oct.	Jan.	April	July	Oct.	Jan.	April	July	Oct.	Jan.	April	July	Oct.	Jan.	April	July
Atd			**	***								*								*				
Atd			**	***								*		**	*	*		*				**		*
AID														*	*			***	*	*				*
ATD												*			**	*		*	*	*			**	
Ltd			**	***								*			*				*					*
Ltd			*	***		**						*		**				**						*
LTD				*										*	*			*	*					*
LTD															*			*	***					

*** ----- Number of plates infected with fungi

Where,

- A ----- Abrotia variety
- L ----- La Posta variety
- T ----- Insecticide applied
- t ----- No Insecticide applied
- D ----- Dehusked maize
- d ----- Undehusked maize
- example ATD-----Dehusked Abrotia variety with Insecticide applied

greenish colour in Aspergillus flavus (Figure 6). Present also were Cheatomium globosum with short neck and dark, stiff hairs radiating from globose shaped head; and Rhizopus oryzae with long sporangiospores arising from a clump of rhizoids (Figure 7). The others were Curvularia lunata with brown conidiophores and dark conidia. The spore were 3-celled to 5- celled (Figure 8), some of which had their central cell enlarged; and Nigrospora sp. with dark conidia which is 1- celled and globose situated at the tip of the conidiophores (Figure 9). The growth of all these fungi resulted from actual infection and not surface contaminations because of the surface sterilization that was carried out.

The data obtained show a steady increase in fungal colonies in stored maize grain with time, especially maize grain stored undehusked compared to those stored dehusked. The genera and species of fungi isolated showed an initial increase and continued up to the tenth month of storage for maize grain stored undehusked. With maize grain stored dehusked, the genera and species of fungi isolated showed an initial increase up to the seventh month of storage but declined thereafter.

Distinct patterns of infestation were exhibited by the storage fungi during the ten months storage period. Aspergillus ochraceus was found on the fourth month in very few samples of maize grain stored undehusked. This was replaced by Aspergillus flavus on the seventh month. About half of the samples taken from maize stored undehusked were infested with Aspergillus flavus. Most of the samples taken from maize grain stored undehusked on the tenth month were infested with Aspergillus flavus. For maize grain stored dehusked, very few of the samples taken at the tenth month were infested with Aspergillus flavus. All other samples taken from the various months of storage were free from Aspergillus flavus.

Cheatonium globosum appeared only at the tenth month of storage. It was predominantly found on maize grain stored undehusked. A similar pattern was exhibited by Rhizopus oryzae except that very few samples of maize grain stored dehusked taken from the fourth month of storage contained the fungal growth.

Curvularia lunata exhibited an interesting pattern. It was found on the fourth month of storage and predominantly, the growth was found on maize grain stored dehusked. By the seventh month of storage the growth declined and continued to decline to the tenth month of storage on the maize grain stored dehusked. But the fungal growth on the maize grain stored undehusked increased sharply at the seventh month and reduced drastically at the tenth month of storage.

The growth of Nigrospora sp. increased with storage time up to the fourth month on undehusked maize grain and declined drastically by the tenth month. The fungal growth increased up to the fourth month on dehusked maize before declining steadily and finally disappeared completely by the tenth month.

The quality of maize grain consumed is dependent on its wholesomeness as well as the presence and dominance of certain micro-organisms which may be detrimental to its quality (Neergaard, 1972). The kinds of fungi present on any grain stock also depend on the geographical location, prevailing weather conditions in the locality and the post harvest storage conditions. This suggests that the microflora that would be present on any grain stock at a particular time would depend on the length of the storage period as observed. For example, Aspergillus flavus could not be isolated until at the seventh month of storage. The alteration in the biochemical quality of maize owing to the metabolic activities of the microflora probably becomes selective, favouring the growth of some and deleterious to others, explaining the observation that all the fungi were not found at the same time.

The growth of all the fungi at different periods could be accounted for by the moisture levels of the maize grains. For each of the common species of storage fungi, there is a minimum moisture content in maize grain below which the fungus cannot grow. These minimum moisture levels have been determined for most of the common storage fungi growing on starchy cereal grains (Christensen and Kaufmann, 1969). Davey and Elcoate (1965) put the safe moisture content for storage of maize at about 13%. This partly explains why the moisture content of maize grains rising above the stipulated safe level (Tables 3 and 4), permitted heavy invasion and growth of storage fungi (Table 12).

In the investigation, potential toxin-producing fungi namely Aspergillus flavus and Aspergillus ochraceus were encountered. Much pertinent literature exists on mycotoxicoses in animals, including man, caused chiefly by Aspergillus flavus (Brook and White, 1966; Tabor and Schroeder, 1967; Enomoto and Saito, 1972; Martin and Gilman, 1976) and Aspergillus ochraceus (Van der Merwe et al., 1965; Christensen et al., 1968; Van Walbeck et al., 1969; Udagawa et al., 1970). Ochratoxin A produced by Aspergillus ochraceus is a potent nephrotoxin in experimental chicks (Huff et al., 1974), rats (Purchase and Theron, 1968; Suzuki et al., 1975), dogs (Szezech et al., 1973 a) and Swine (Szezech et al., 1973 b). Based on 50% lethal dose determination and minimal growth inhibitory concentration, ochratoxin A is the most potent mycotoxin studied in chicken (Huff et al., 1974). An infection of maize grain by this fungus by the fourth month of storage therefore is sufficient to warrant concern.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

Insect attacks on maize may take place on the field prior to harvest and continue in the crib during storage. Farmers believe that the substantial husk cover protects the grain from insects so, they store cobs of maize under ventilated conditions with the husk on. The data obtained from the investigation confirmed the farmers claim.

The husk may protect maize grain against high levels of insect infestation but does not provide adequate protection against damage. Rather, it harbour the insects and serve as good breeding grounds for the insects, resulting in the high level of damage of the maize grain. Apart from the fact that insect infestation encourages fungal activities, the husk failed to protect the maize grains against fungal infection. Both the insect infestation and fungal infection affected the quality of maize grains, and seed production by decreasing its germinability. For seed production, preservation and maintenance of viability and germinability, it is better to store maize dehusked.

The control of insects by the application of insecticidal dust has generally been advocated. It become evident that the protection of maize grains in the crib by only one application of the insecticidal dust was only moderately effective and for a relatively short period. The data revealed that insect infestation and the subsequent damage of maize grains increased after three months of storage. Some form of re-application of the insecticidal dust was obviously necessary after the three months of storage. It would be a labour consuming task and expensive if the cobs were to be

removed from the cribs and an insecticidal dust applied. If the insecticidal dust were periodically applied to the outside of the cribs, the dust would presumably not reach the insects inside the cribs. Even when the dusts were applied directly on the cobs inside the cribs, it would be very difficult to control the insects since they would migrate deeper into the maize grain.

It was also observed that, the air current does blow away some of the insecticidal dust, indicating that the control of insect infestation of maize grains in cribs by the administer of insecticidal dust was not the best method. Apart from this, the cost of chemical alone would discourage local farmers from re-application of insecticides.

On the basis of the data obtained, from the investigation, it is recommended that, farmers should store their maize dehusked in the cribs. The dehusked maize should be sorted out into damaged and undamaged and only the undamaged dehusked maize should be stored. To minimise insect infestation, insecticide should be applied before storage. Also, the storage of maize in the cribs should not exceed four months but the maize cobs should be removed from the cribs and shelled just after the third month of storage. Insecticidal dust should then be applied to the maize grains and sealed in bags for storage.

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APPENDIX 1
BASE LINE DATA FOR ABROTIA

SAMPLE	MEAN STANDARD VOL.W T. (g)	MEAN MC1 (%)	EXPECTED MC1 (%)	X	MEAN MC2 (%)		DRY WT. (g)
					AFTER HEATING	BEFORE ADDNG H2O	
ATD1	849.05	20.1	21.0	9.67		20.9	633.39
		19.9	12.0	-76.22	12.0		734.36
		19.9	15.0	-48.95	15.0		710.16
		20.5	24.0	39.10		24.0	659.26
		20.1	18.0	-21.74	18.0	-	683.46
ATD2	808.31	20.1	12.0	-74.40	12.0		655.78
		20.2	15.0	-49.45	15.0		630.05
		20.6	21.0	4.09		21.0	730.49
		20.2	18.0	-21.69	17.9		705.59
A01	859.95	20.9	24.0	32.97	-	24.1	680.58
		19.5	12.0	-73.29	12.0		675.77
		20.0	21.0	10.89		21.0	729.09
		19.5	15.0	-45.52	15.0		701.43
A02	860.94	20.1	24.0	44.13		23.9	650.96
		19.9	18.0	-19.93	18.0		752.75
		20.2	24.0	43.05		23.9	699.98
		20.1	21.0	9.81		21.0	648.76
A03	870.63	20.0	18.0	-21.00	17.9		726.44
		19.5	12.0	-73.38	11.9		751.19
		19.5	15.0	-45.58	15.1	-	675.22
		19.6	21.0	15.43		21.0	643.28
A04	817.70	19.9	24.0	26.97		24.0	719.55
		19.3	18.0	-13.80	18.0		694.97
		19.1	12.0	-70.24	12.0		669.55
		19.3	15.0	-44.04	14.9	-	745.83
Atd1	817.70	19.9	24.0	44.11		23.9	755.22
		19.5	12.0	-69.69	12.0		677.98
		19.6	15.0	-46.18	15.0		729.47
		19.8	18.0	-17.95	17.9		703.72
Atd2	862.35	19.8	21.0	12.42	-	21.0	652.23
		19.5	15.0	-45.65	15.0		726.88
		19.7	21.0	14.19		20.9	701.22
		19.3	12.0	-71.54	12.0		650.77
Atd3	822.51	20.0	24.0	45.39		24.1	675.57
		19.5	18.0	-15.77	18.0	-	753.39
		19.8	24.0	45.45		24.0	645.10
		19.6	21.0	14.58		21.1	671.44
ATd1	834.50	19.5	18.0	-15.05	18.0		747.94
		19.3	15.0	-41.61	15.0		722.44
		19.0	12.0	-65.43	11.9	-	696.94
		20.6	24.0	37.33	-	24.1	633.39
ATd2	830.10	19.3	12.0	-69.23	12.0		734.36
		19.7	15.0	-46.14	14.9		710.16
		19.9	21.0	11.62		21.0	659.26
		19.7	18.0	-17.30	18.1	-	683.46
ATd2	830.10	20.3	21.0	7.36	-	21.0	655.78
		20.6	24.0	37.14		24.0	630.05
		19.6	12.0	-71.69	12.0		730.49
		20.3	15.0	-51.76	15.0		705.59
		19.6	18.0	-16.20	18.0	-	680.68

X ----- Water added to or subtracted from the maize grains

APPENDIX 2
BASE LINE DATA FOR LA POSTER

SAMPLE	MEAN STANDARD VOL. W T. (g)	MEAN MC1 (%)	EXPECTED MC1 (%)	X	MEAN MC2 (%)		DRY W T. (g)
					AFTER HEATING	BEFORE ADDING H2O	
LTD1	855.40	19.2	21.0	19.45	-	21.0	675.77
		19.0	15.0	-40.25	15.0		727.09
		19.0	18.0	-10.43	18.0		701.43
		19.3	24.0	52.90		23.9	650.96
		18.8	12.0	-66.10	12.0	-	752.75
LTD2	853.63	19.3	18.0	-13.53	18.0	-	699.98
		19.5	24.0	50.54		24.0	648.76
		19.2	15.0	-42.18	14.9		726.44
		19.1	12.0	-68.87	12.0		751.19
LTD3	847.53	19.3	21.0	18.37	-	20.9	675.22
		22.5	24.0	16.73	-	24.1	643.28
		19.5	15.0	-44.87	15.1		719.55
		20.2	18.0	-22.74	18.0		694.97
LTD1	858.20	22.5	21.0	-16.09	21.0		669.55
		19.3	12.0	-70.31	12.0	-	745.83
		18.4	12.0	-62.41	12.0	-	755.22
		18.7	21.0	24.99		21.0	677.98
		18.5	15.0	-35.34	15.0		729.47
LTD2	855.15	18.6	18.0	-6.28	18.0		703.72
		19.0	24.0	56.48	-	24.0	652.23
		18.6	15.0	-36.22	15.0	-	726.88
		18.8	18.0	-8.34	18.0		701.22
		19.7	24.0	48.38		23.9	650.77
LTD3	849.93	19.4	21.0	17.32		21.0	675.57
		18.7	12.0	-65.11	11.9		753.39
		18.9	24.0	57.03	-	24.1	645.10
		18.9	21.0	22.59		21.0	671.44
		18.7	12.0	-64.71	12.0		747.94
LTD1	847.27	18.8	15.0	-38.00	15.0		722.44
		18.8	18.0	-8.29	18.0		696.94
		20.1	21.0	9.65	-	21.0	669.34
		18.8	12.0	-65.47	12.0		745.60
		19.1	15.0	-40.87	14.9		721.03
LTD2	834.22	20.5	24.0	39.02		24.0	643.93
		19.7	18.0	-17.57	17.9		695.61
		18.5	15.0	-34.35	14.9	-	709.92
		18.8	24.0	57.08		23.9	634.84
		18.4	12.0	-60.67	11.9		734.95
LTD3	863.99	18.6	18.0	-6.10	18.0		684.06
		18.8	21.0	23.23		21.0	659.03
		18.7	21.0	25.15	-	21.0	682.55
		18.4	18.0	-4.21	18.0		708.47
		18.9	24.0	57.98		23.9	657.50
LTD1	840.03	18.4	15.0	-34.56	15.0		734.39
		18.4	12.0	-62.84	11.9		761.18
		19.5	24.0	49.74	-	24.0	638.42
		19.1	18.0	-11.27	18.1		687.98
		19.0	15.0	-39.53	14.9		714.87
LTD2	850.73	19.2	21.0	19.14		20.9	664.46
		18.8	12.0	-64.91	12.0		739.23
		19.2	21.0	19.38	-	21.1	671.23
		19.2	18.0	-12.45	18.0		697.60
		19.1	15.0	-41.04	15.1		722.27
LTD3	884.33	18.9	12.0	-66.70	12.0		748.64
		19.3	24.0	52.61	-	23.9	647.41
		19.4	24.0	53.53	-	24.0	672.09
		18.8	12.0	-68.33	11.9		779.09
		19.3	21.0	19.03		21.0	697.74
LTD1	855.40	19.2	15.0	-43.70	15.0		751.68
		19.2	18.0	-12.94	18.1	-	724.27

X ----- Water added to or subtracted from the maize grains

APPENDIX 3

DETERMINATION OF NUMBER AND WEIGHT OF DAMAGED AND UNDAMAGED MAIZE GRAIN FOR ABROTIA

SAMPLE	OCTOBER 1992				JANUARY 1993				APRIL 1993				JULY 1993			
	Damaged		Undamaged		Damaged		Undamaged		Damaged		Undamaged		Damaged		Undamaged	
	Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight
ATD1	147	29.05	853	202.12	165	23.40	835	210.40	765	131.23	235	87.60	893	115.54	107	45.31
	108	21.12	892	207.25	168	24.03	832	212.92	630	104.54	370	116.05	872	114.86	128	54.61
	128	26.02	872	205.33	177	22.50	823	202.41	657	123.31	343	115.09	861	114.07	139	56.87
ATD2	142	27.02	858	215.25	172	24.79	828	202.96	637	104.12	361	116.72	904	115.80	96	38.49
	134	24.87	866	217.02	162	23.52	837	209.28	684	114.60	316	103.59	901	115.47	99	40.95
	111	22.43	889	221.87	169	23.98	831	211.09	652	109.75	348	115.83	946	117.88	54	25.20
ATD1	90	21.18	910	240.68	158	22.98	842	205.81	661	121.92	339	113.85	939	117.14	61	29.32
	86	18.24	914	242.43	162	93.06	838	202.40	680	110.40	320	104.30	928	116.97	72	36.57
	81	15.16	909	237.51	172	23.94	828	199.86	636	115.13	364	117.10	937	117.48	63	30.24
ATd2	72	10.72	928	214.90	169	23.04	831	203.54	658	123.95	342	114.16	872	114.53	128	52.14
	62	9.13	938	217.04	171	23.25	829	200.19	643	110.20	357	109.13	876	114.94	124	50.42
	67	10.02	933	215.89	161	22.67	839	212.24	737	133.12	263	94.23	829	115.22	171	67.21
ATD3	112	25.90	888	235.52	166	24.04	834	207.51	605	100.64	395	120.35	890	115.41	110	49.60
	139	29.72	861	204.04	161	23.14	839	213.17	629	118.50	371	116.24	929	116.92	71	36.28
	123	27.17	877	227.38	157	21.33	843	217.50	615	101.28	385	119.38	902	115.66	98	39.22
ATd1	94	17.83	906	221.63	153	19.87	847	217.98	707	134.16	293	98.88	973	126.18	27	9.44
	96	18.20	904	219.50	245	32.83	755	194.29	565	90.72	435	128.82	982	127.18	18	6.86
	92	16.33	908	222.42	158	20.98	842	216.48	574	102.87	426	126.50	981	127.06	19	7.96
ATd2	114	24.19	886	219.35	241	34.33	759	195.94	586	105.70	414	124.48	985	117.31	15	6.41
	95	21.28	905	239.70	140	17.98	860	220.13	642	124.77	358	109.32	983	117.26	17	6.68
	103	22.17	897	224.63	159	21.43	841	216.72	605	102.76	395	123.08	971	116.41	29	11.50
ATd3	133	25.54	867	216.26	164	23.55	836	209.15	716	130.04	284	96.68	933	116.36	67	33.30
	102	19.36	898	205.12	165	23.75	835	208.89	671	122.29	318	104.67	989	117.73	11	4.68
	104	20.91	896	204.83	174	24.43	826	199.34	637	113.26	363	115.48	980	117.03	20	8.02
ATd1	106	20.92	894	217.94	237	27.59	763	196.62	632	114.17	368	116.80	926	116.81	74	37.80
	105	19.26	895	218.65	168	22.09	832	197.43	656	114.17	344	114.87	930	116.80	70	34.97
	98	18.41	902	223.13	177	24.89	823	195.02	663	123.47	337	112.92	971	117.82	29	12.98
ATd2	133	28.99	867	216.09	162	22.43	838	212.91	648	126.92	352	113.39	980	117.27	20	8.47
	124	25.01	876	218.84	161	22.35	839	219.98	698	128.00	302	101.26	980	117.52	20	8.86
	130	27.12	870	217.23	165	23.89	835	211.74	630	112.22	370	116.51	972	116.79	28	11.87

APPENDIX 4

DETERMINATION OF NUMBER AND WEIGHT OF DAMAGED AND UNDAMAGED MAIZE GRAIN FOR LA POSTER

SAMPLE	OCTOBER 1992				JANUARY 1993				APRIL 1993				JULY 1993			
	Damaged		Undamaged		Damaged		Undamaged		Damaged		Undamaged		Damaged		Undamaged	
	Number	Weight (g)	Number	Weight (g)	Number	Weight (g)	Number	Weight (g)	Number	Weight (g)	Number	Weight (g)	Number	Weight (g)	Number	Weight (g)
LTD1	69	12.51	931	198.38	137	18.67	863	196.05	559	70.49	441	127.77	820	106.23	180	67.58
	72	12.85	928	184.47	124	17.37	876	198.18	515	82.01	485	120.85	855	112.29	145	46.49
	70	12.64	930	197.76	141	19.55	859	194.50	585	64.85	415	134.17	830	107.03	170	52.96
LTD2	49	10.20	951	223.41	101	11.55	899	219.44	421	64.72	579	151.72	973	128.99	27	8.94
	54	11.53	946	220.90	109	12.42	891	219.98	586	83.98	414	124.20	989	130.01	11	4.13
	57	12.09	943	219.87	117	12.78	883	217.63	467	72.13	533	150.98	982	129.09	18	5.94
LTD3	59	12.14	941	219.02	139	19.25	861	199.71	431	69.21	569	132.20	828	130.18	172	53.04
	74	15.00	226	208.70	107	12.08	893	211.93	358	62.07	642	144.62	880	115.62	120	36.61
	63	14.28	937	214.35	136	18.78	864	199.97	344	55.54	654	166.60	965	117.66	35	10.26
LTD1	49	10.61	951	212.99	135	18.60	865	201.57	435	65.50	565	132.30	899	115.96	101	49.48
	68	13.66	932	203.23	101	11.67	899	219.84	458	68.08	542	128.32	930	116.22	70	26.78
	54	11.98	946	210.25	154	22.41	846	193.90	518	75.46	482	119.53	836	113.83	164	61.92
LTD2	38	7.42	962	204.92	104	12.05	896	219.72	343	55.80	657	148.20	944	116.46	56	22.60
	47	9.43	952	199.43	108	12.57	892	218.84	409	62.01	591	124.44	959	117.06	41	16.40
	51	11.22	949	198.01	109	12.98	891	218.23	389	60.20	611	134.93	982	120.25	18	5.96
LTD3	57	11.55	943	219.02	104	12.17	896	219.76	504	78.64	496	108.35	879	115.52	121	43.35
	50	10.38	950	218.24	114	12.75	886	201.67	432	65.30	568	125.37	878	115.50	122	43.49
	51	10.92	949	217.34	108	12.68	892	218.62	530	87.69	470	106.75	857	112.90	143	49.53
LTD1	64	12.88	936	203.14	166	23.12	834	190.52	612	97.45	388	128.15	903	115.24	97	39.80
	65	13.02	935	193.77	145	21.84	855	194.41	649	107.60	351	125.28	929	116.09	71	27.32
	68	14.27	932	190.94	153	22.40	847	193.76	435	62.81	565	148.99	964	117.42	36	14.57
LTD2	63	10.68	937	198.40	114	12.59	886	217.35	576	85.04	424	141.74	815	105.53	185	64.18
	140	24.69	860	180.10	153	22.74	847	193.80	572	83.07	428	146.46	928	116.54	72	29.95
	123	22.49	877	190.68	124	17.62	876	216.87	597	86.36	403	139.18	880	113.45	120	41.51
LTD3	94	18.15	906	199.25	125	18.40	875	216.41	634	90.64	366	140.00	959	117.51	41	16.38
	80	14.26	920	202.76	119	13.09	881	217.02	650	91.52	350	126.57	901	114.91	99	39.26
	86	15.34	914	200.45	116	13.02	884	217.81	562	82.48	448	149.50	983	117.73	17	6.44
LTD1	105	21.17	895	208.05	131	18.16	869	201.52	430	62.90	570	150.15	982	117.05	18	5.96
	101	19.54	899	213.88	125	17.98	875	216.41	317	59.14	683	166.05	985	117.22	15	4.99
	103	20.13	897	210.24	102	12.26	898	219.89	334	51.35	666	163.16	987	117.54	13	4.71
LTD2	93	18.94	907	218.46	144	21.98	856	195.69	369	62.78	631	147.59	988	118.02	12	4.65
	73	13.89	927	222.65	120	17.23	880	218.40	474	65.28	526	134.82	987	117.76	13	4.98
	87	15.67	913	220.11	129	18.05	871	217.86	495	69.30	505	133.15	988	118.05	12	4.57
LTD3	79	19.37	921	256.42	158	22.81	842	192.86	649	107.52	351	117.19	963	116.70	37	14.57
	91	12.95	909	247.33	135	18.98	862	201.76	609	106.18	391	129.17	981	117.71	19	7.23
	94	24.28	906	238.52	107	12.87	893	219.34	495	81.73	505	148.67	979	117.64	21	7.86

APPENDIX 5
STANDARD VOLUME-WEIGHT AND DRY WEIGHT OF MAIZE GRAINS FOR ABROTIA

SAMPLE	OCTOE 1992			JANUARY 1993			APRIL 1993			JULY 1993		
	Mean Standard Vol. Wt. (Wet Wt. (g))	DRY WEIGHT (g)		Mean Standard Vol. Wt. (Wet Wt. (g))	DRY WEIGHT (g)		Mean Standard Vol. Wt. (Wet Wt. (g))	DRY WEIGHT (g)		Mean Standard Vol. Wt. (Wet Wt. (g))	DRY WEIGHT (g)	
		from Calculation	from Graph		from Calculation	from Graph		from Calculation	from Graph		from Calculation	from Graph
ATD1	849.05	696.39	696.0	813.32	677.50	706.0	625.01	540.01	733.0	513.79	441.86	729.5
ATD2	808.31	662.65	662.5	786.45	655.11	673.0	684.35	590.59	697.5	504.67	435.53	697.5
AtD1	859.95	705.33	705.0	799.22	668.95	719.0	661.41	571.46	742.0	520.53	442.97	731.5
AtD2	860.94	706.32	705.5	824.87	682.17	711.0	647.90	559.14	742.0	514.25	438.66	734.0
AtD3	870.63	713.92	714.0	821.36	685.84	721.0	656.27	568.33	753.5	514.33	438.21	741.5
Atd1	817.70	670.84	670.0	781.46	648.61	678.0	714.64	616.02	704.5	513.23	438.30	698.0
Atd2	862.35	707.14	707.0	792.98	661.35	719.0	658.78	570.50	747.0	508.90	436.13	739.0
Atd3	822.51	674.46	674.0	778.78	649.50	685.5	714.23	617.09	710.0	512.86	437.98	702.0
ATd1	834.50	684.13	684.0	717.44	599.06	696.5	627.23	541.30	719.5	505.62	433.32	714.5
ATd2	830.10	680.52	680.5	782.00	651.41	691.5	696.84	602.77	713.0	506.32	433.92	711.5

APPENDIX 6
STANDARD VOLUME-WEIGHT AND DRY WEIGHT OF MAIZE GRAINS FOR LA POSTER

SAMPLE	OCTOBE 1992			JANUARY 1993			APRIL 1993			JULY 1993		
	Mean Standard Vol. Wt. (Wet Wt. (g))	DRY WEIGHT (g)		Mean Standard Vol. Wt. (Wet Wt. (g))	DRY WEIGHT (g)		Mean Standard Vol. Wt. (Wet Wt. (g))	DRY WEIGHT (g)		Mean Standard Vol. Wt. (Wet Wt. (g))	DRY WEIGHT (g)	
		from Calculation	from Graph		from Calculation	from Graph		from Calculation	from Graph		from Calculation	from Graph
LTD1	855.40	701.60	701.5	789.03	665.15	721.0	713.62	624.42	748.5	518.07	441.40	729.0
LTD2	853.63	700.32	699.5	805.45	674.97	715.0	694.00	601.71	740.0	445.06	387.20	742.5
LTD3	847.53	694.64	695.0	798.99	664.76	705.0	708.27	609.11	729.0	501.77	429.01	724.5
Ltd1	853.20	703.72	703.0	780.74	655.04	719.5	709.08	614.77	743.5	503.27	429.29	733.5
Ltd2	855.15	701.57	701.0	787.32	658.99	715.5	682.93	589.37	738.0	511.76	438.58	732.5
Ltd3	849.93	696.77	696.5	784.08	657.84	712.5	740.13	638.00	733.0	509.33	437.51	730.0
Ltd1	847.27	695.10	694.0	796.81	665.34	706.5	725.74	628.49	733.5	510.29	444.46	738.0
Ltd2	834.22	684.55	684.0	783.61	654.31	696.5	769.53	665.63	721.5	500.51	428.44	714.0
Ltd3	863.99	708.80	708.0	757.45	631.71	720.0	715.95	621.44	749.5	502.27	432.45	743.5
Ltd1	840.03	688.99	690.5	786.85	657.81	700.0	730.94	633.00	726.0	507.55	435.48	719.5
Ltd2	850.73	697.43	676.5	798.59	666.02	709.0	741.95	641.79	735.5	507.78	436.69	731.0
LTD3	884.33	724.97	725.0	797.91	667.05	739.0	772.33	665.75	762.0	502.72	428.82	754.5

APPENDIX 7

ANOVA FOR INSECT INFESTATION (ABROTIA) OCTOBER 1992

Source	df	SS	Mean square	F OBS.	F TAB.
Main plot total	3	24.99	8.33		
Block , R	1	1.44	1.44		
Chem., factor A	1	23.09	23.09	49.58	161.4
Error (a)	1	0.47	0.47		
Husk, factor B	1	56.87	56.87	36.41 *	18.51
Interaction , AB	1	9.40	9.40	6.02	18.51
Error (b)	2	3.12	1.56		
Total	7	94.38			

* Significant at 5% level

ANOVA FOR INSECT INFESTATION (ABROTIA) APRIL 1993

Source	df	SS	Mean square	F OBS.	F TAB.
Main plot total	3	165.08	55.03		
Block , R	1	10.28	10.28		
Chem., factor A	1	154.79	154.79	15,479.20 **	4,052
Error (a)	1	0.01	0.01		
Husk, factor B	1	336.31	336.31	13.65	18.51
Interaction , AB	1	119.58	119.58	4.85	18.51
Error (b)	2	49.26	24.63		
Total	7	670.23			

** Significant at 1% level

ANOVA FOR INSECT INFESTATION (ABROTIA)**JANUARY 1993**

Source	df	SS	Mean square	F OBS.	F TAB.
Main plot total	3	169.66	56.55		
Block , R	1	0.14	0.14		
Chem., factor A	1	166.32	166.32	51.90	161.4
Error (a)	1	3.20	3.20		
Husk, factor B	1	257.61	257.61	37.98 *	18.51
Interaction , AB	1	87.63	87.63	12.92	18.51
Error (b)	2	13.57	6.78		
Total	7	528.47			

* Significant at 5% level

ANOVA FOR INSECT INFESTATION (ABROTIA)**JULY 1993**

Source	df	SS	Mean square	F OBS.	F TAB.
Main plot total	3	69.65	23.22		
Block , R	1	10.42	10.42		
Chem., factor A	1	58.70	58.70	109.59	161.40
Error (a)	1	0.54	0.54		
Husk, factor B	1	473.55	473.55	35.84 *	18.51
Interaction , AB	1	1.93	1.93	0.15	18.51
Error (b)	2	26.43	13.21		
Total	7	571.56			

* Significant at 5% level

APPENDIX 8

ANOVA FOR INSECT INFESTATION (LA POSTA)

OCTOBER 1992

Source	df	SS	Mean square	F OBS.	F TAB.
Main plot total	5	7.03	1.41		
Block , R	2	4.05	2.03		
Chem., factor A	1	1.10	1.10	1.17	18.51
Error (a)	2	1.87	0.94		
Husk, factor B	1	28.92	28.92	14.43 *	7.71
Interaction , AB	1	0.61	0.61	0.31	7.71
Error (b)	4	8.02	2.00		
Total	11	44.58			

* Significant at 5% level

ANOVA FOR INSECT INFESTATION (LA POSTA)

JANUARY 1993

Source	df	SS	Mean square	F OBS	F TAB.
Main plot total	5	46.49	9.30		
Block , R	2	21.69	10.85		
Chem., factor A	1	15.46	15.46	3.31	18.51
Error (a)	2	9.34	4.67		
Husk, factor B	1	178.64	178.64	13.54 *	7.71
Interaction , AB	1	5.12	5.12	0.39	7.71
Error (b)	4	52.78	13.20		
Total	11	283.03			

* Significant at 5% level

ANOVA FOR INSECT INFESTATION (LA POSTA)

APRIL 1993

Source	df	SS	Mean square	F OBS	F TAB.
Main plot total	5	189.96	37.99		
Block , R	2	68.45	34.23		
Chem., factor A	1	99.07	99.07	8.83	18.51
Error (a)	2	22.44	11.22		
Husk, factor B	1	279.75	279.75	14.06 *	7.71
Interaction , AB	1	3.72	3.72	0.19	7.71
Error (b)	4	79.60	19.90		
Total	11	553.03			

* Significant at 5% level

ANOVA FOR INSECT INFESTATION (LA POSTA)

JULY 1994

Source	df	SS	Mean square	F OBS	F TAB.
Main plot total	5	119.32	23.86		
Block , R	2	5.56	2.78		
Chem., factor A	1	68.16	68.16	2.99	18.51
Error (a)	2	45.60	22.80		
Husk, factor B	1	48.56	48.56	28.17 **	21.20
Interaction , AB	1	12.12	12.12	7.03	7.71
Error (b)	4	6.90	1.72		
Total	11	186.90			

** Significant at 1% level

APPENDIX 9

APPENDIX 9

ANOVA FOR COUNT AND WEIGH METHOD (ABROTIA) OCTOBER 1992

Source	df	SS	Mean square	F OBS.	F TAB.
Main plot total	3	0.12	0.04		
Block , R	1	0.00	0.00		
Chem., factor A	1	0.11	0.11	8.38	161.4
Error (a)	1	0.01	0.01		
Husk, factor B	1	0.34	0.34	0.43	18.51
Interaction , AB	1	0.09	0.09	0.12	18.51
Error (b)	2	1.57	0.78		
Total	7	2.13			

ANOVA FOR COUNT AND WEIGH METHOD (ABROTIA) JANUARY 1993

Source	df	SS	Mean square	F OBS.	F TAB.
Main plot total	3	1.52	0.51		
Block , R	1	0.73	0.73		
Chem., factor A	1	0.00	0.00	0.00	161.4
Error (a)	1	0.79	0.79		
Husk, factor B	1	3.11	3.11	8.25	18.51
Interaction , AB	1	0.32	0.32	0.84	18.51
Error (b)	2	0.75	0.38		
Total	7	5.70			

ANOVA FOR COUNT AND WEIGH METHOD (ABROTIA) APRIL 1993

Source	df	SS	Mean square	F	F TAB.
Main plot total	3	13.64	4.55		
Block , R	1	1.99	1.99		
Chem., factor A	1	11.31	11.31	33.22	161.4
Error (a)	1	0.34	0.34		
Husk, factor B	1	47.39	47.39	56.34 *	18.51
Interaction , AB	1	0.26	0.26	0.30	18.51
Error (b)	2	1.68	0.84		
Total	7	62.96			

ANOVA FOR COUNT AND WEIGH METHOD (ABROTIA) JULY 1993

Source	df	SS	Mean square	F OBS.	F TAB.
Main plot total	3	24.48	8.16		
Block , R	1	1.67	1.67		
Chem., factor A	1	2.05	2.05	0.10	161.4
Error (a)	1	20.77	20.77		
Husk, factor B	1	68.97	68.97	2.05	18.51
Interaction , AB	1	8.80	8.80	0.26	18.51
Error (b)	2	67.42	33.71		
Total	7	169.67			

* Significant at 5% level

APPENDIX 10

APPENDIX 10

ANOVA FOR STANDARD VOLUME/WEIGHT (ABROTIA)				JANUARY 1993	
Source	df	SS	Mean square	F OBS	F TAB.
Main plot total	3	24.62	8.21		
Block , R	1	9.07	9.07		
Chem., factor A	1	1.45	1.45	0.10	161.4
Error (a)	1	14.10	14.10		
Husk, factor B	1	27.01	27.01	2.50	18.51
Interaction , AB	1	16.47	16.47	1.52	18.51
Error (b)	2	21.61	10.81		
Total	7	89.71			

ANOVA FOR STANDARD VOLUME/WEIGHT (ABROTIA)				APRIL 1993	
Source	df	SS	Mean square	F OBS	F TAB.
Main plot total	3	143.25	47.75		
Block , R	1	7.03	7.03		
Chem., factor A	1	0.42	0.42	0.0031	161.4
Error (a)	1	135.80	135.80		
Husk, factor B	1	20.93	20.93	1.84	18.51
Interaction , AB	1	12.30	12.30	1.08	18.51
Error (b)	2	22.79	11.39		
Total	7	199.27			

ANOVA FOR STANDARD VOLUME/WEIGHT (ABROTIA)				JULY 1993	
Source	df	SS	Mean square	F	F TAB.
Main plot total	3	7.24	2.41		
Block , R	1	0.70	0.70		
Chem., factor A	1	0.79	0.79	0.14	161.4
Error (a)	1	5.75	5.75		
Husk, factor B	1	0.0018	0.0018	0.0013	18.51
Interaction , AB	1	1.02	1.02	0.73	18.51
Error (b)	2	2.79	1.40		
Total	7	11.05			

APPENDIX 11

ANOVA FOR COUNT AND WEIGH METHOD (LA POSTA)

OCTOBER 1992

Source	df	SS	Mean square	F OBS	F TAB.
Main plot total	5	1.47	0.29		
Block , R	2	0.18	0.09		
Chem., factor A	1	0.21	0.21	0.38	18.51
Error (a)	2	1.09	0.54		
Husk, factor B	1	1.70	1.70	5.54	7.71
Interaction , AB	1	0.02	0.02	0.05	7.71
Error (b)	4	1.22	0.31		
Total	11	4.41			

ANOVA FOR COUNT AND WEIGH METHOD (LA POSTA)

JANUARY 1993

Source	df	SS	Mean square	F OBS	F TAB.
Main plot total	5	0.35	0.07		
Block , R	2	0.17	0.09		
Chem., factor A	1	0.14	0.14	7.34	18.51
Error (a)	2	0.04	0.02		
Husk, factor B	1	0.00	0.00	0.06	7.71
Interaction , AB	1	0.14	0.14	2.76	7.71
Error (b)	4	0.21	0.05		
Total	11	0.70			

ANOVA FOR COUNT AND WEIGH METHOD (LA POSTA)

APRIL 1993

Source	df	SS	Mean square	F OBS	F TAB.
Main plot total	5	44.44	8.89		
Block , R	2	2.61	1.30		
Chem., factor A	1	29.80	29.80	4.95	18.51
Error (a)	2	12.03	6.02		
Husk, factor B	1	215.48	215.48	2.66	7.71
Interaction , AB	1	305.32	305.32	3.77	7.71
Error (b)	4	323.73	80.93		
Total	11	888.97			

ANOVA FOR COUNT AND WEIGH METHOD (LA POSTA)

JULY 1993

Source	df	SS	Mean square	F OBS	F TAB.
Main plot total	5	58.18	11.64		
Block , R	2	12.35	6.18		
Chem., factor A	1	0.69	0.69	0.03	18.51
Error (a)	2	45.13	22.57		
Husk, factor B	1	100.46	100.46	4.27	7.71
Interaction , AB	1	43.70	43.70	1.86	7.71
Error (b)	4	94.11	23.53		
Total	11	296.44			

APPENDIX 12

ANOVA FOR STANDARD VOLUME/WEIGHT (LA POSTA) JANUARY 1993

Source	df	SS	Mean square	F OBS	F TAB.
Main plot total	5	19.12	3.82		
Block , R	2	12.53	6.26		
Chem., factor A	1	5.06	5.06	6.58	18.51
Error (a)	2	1.54	0.77		
Husk, factor B	1	0.48	0.48	0.07	7.71
Interaction , AB	1	0.83	0.83	0.13	7.71
Error (b)	4	25.53	6.38		
Total	11	45.95			

ANOVA FOR STANDARD VOLUME/WEIGHT (LA POSTA)

APRIL 1993

Source	df	SS	Mean square	F OBS	F TAB.
Main plot total	5	5.18	1.04		
Block , R	2	0.54	0.27		
Chem., factor A	1	0.01	0.01	0.0042	18.51
Error (a)	2	4.63	2.32		
Husk, factor B	1	51.25	51.25	2.92	7.71
Interaction , AB	1	0.43	0.43	0.02	7.71
Error (b)	4	70.30	17.57		
Total	11	127.17			

ANOVA FOR STANDARD VOLUME/WEIGHT (LA POSTA) JULY 1993

Source	df	SS	Mean square	F OBS	F TAB.
Main plot total	5	26.93	5.39		
Block , R	2	8.60	4.30		
Chem., factor A	1	4.94	4.94	0.74	18.51
Error (a)	2	13.40	6.70		
Husk, factor B	1	2.31	2.31	0.31	7.71
Interaction , AB	1	2.18	2.18	0.29	7.71
Error (b)	4	30.17	7.54		
Total	11	61.59			

APPENDIX 13

ANOVA FOR GERMINATED SEEDS (ABROTIA)				OCTOBER 1992	
Source	df	SS	Mean square	F OBS	F TAB.
Main plot total	3	81.30	27.10		
Block , R	1	27.98	27.98		
Chem., factor A	1	47.34	47.34	7.91	161.4
Error (a)	1	5.99	5.99		
Husk, factor B	1	4.00	4.00	23.81 *	18.51
Interaction , AB	1	4.00	4.00	23.81 *	18.51
Error (b)	2	0.34	0.17		
Total	7	89.64			

* Significant at 5% level

ANOVA FOR GERMINATED SEEDS (ABROTIA)				JANUARY 1993	
Source	df	SS	Mean square	F OBS	F TAB.
Main plot total	3	26.08	8.69		
Block , R	1	12.73	12.73		
Chem., factor A	1	12.98	12.98	34.69	161.4
Error (a)	1	0.37	0.37		
Husk, factor B	1	2.24	2.24	.177	18.51
Interaction , AB	1	0.29	0.29	0.23	18.51
Error (b)	2	2.52	1.26		
Total	7	31.12			

ANOVA FOR GERMINATED SEEDS (ABROTIA)				APRIL 1993	
Source	df	SS	Mean square	F OBS	F TAB.
Main plot total	3	9.80	3.27		
Block , R	1	3.03	3.03		
Chem., factor A	1	6.77	6.77	2.07	161.4
Error (a)	1	0.0024	0.0024		
Husk, factor B	1	27.68	27.68	38.75 *	18.51
Interaction , AB	1	2.86	2.86	4.00	18.51
Error (b)	2	1.43	0.71		
Total	7	41.76			

* Significant at 5% level

ANOVA FOR GERMINATED SEEDS (ABROTIA)				JULY 1993	
Source	df	SS	Mean square	F OBS	F TAB.
Main plot total	3	2.14	0.71		
Block , R	1	0.71	0.71		
Chem., factor A	1	0.71	0.71	1.00	161.4
Error (a)	1	0.71	0.71		
Husk, factor B	1	0.71	0.71	1.00	18.51
Interaction , AB	1	0.71	0.71	1.00	18.51
Error (b)	2	1.43	0.71		
Total	7	5.00			

APPENDIX 14

ANOVA FOR GERMINATED SEEDS (LA POSTA)

OCTOBER 1992

Source	df	SS	Mean square	F OBS	F TAB.
Main plot total	5	55.27	11.05		
Block , R	2	2.19	1.09		
Chem., factor A	1	1.69	1.69	0.07	18.51
Error (a)	2	51.39	25.70		
Husk, factor B	1	22.96	22.96	4.38	7.71
Interaction , AB	1	2.32	2.32	0.44	7.71
Error (b)	4	20.99	5.25		
Total	11	101.54			

ANOVA FOR GERMINATED SEEDS (LA POSTA)

JANUARY 1993

Source	df	SS	Mean square	F OBS	F TAB.
Main plot total	5	19.28	3.86		
Block , R	2	0.01	0.00		
Chem., factor A	1	6.26	6.26	0.96	18.51
Error (a)	2	13.01	6.51		
Husk, factor B	1	2.85	2.85	1.60	7.71
Interaction , AB	1	2.85	2.85	1.60	7.71
Error (b)	4	7.13	1.78		
Total	11	32.11			

ANOVA FOR GERMINATED SEEDS (LA POSTA)

APRIL 1993

Source	df	SS	Mean square	F OBS	F TAB.
Main plot total	5	28.98	5.80		
Block , R	2	6.35	3.17		
Chem., factor A	1	5.48	5.48	0.64	18.51
Error (a)	2	17.15	8.57		
Husk, factor B	1	69.55	69.55	2.86	7.71
Interaction , AB	1	40.15	40.15	1.65	7.71
Error (b)	4	97.35	24.34		
Total	11	236.03			

ANOVA FOR GERMINATED SEEDS (LA POSTA)

JULY 1993

Source	df	SS	Mean square	F OBS	F TAB.
Main plot total	5	2.38	0.48		
Block , R	2	0.95	0.48		
Chem., factor A	1	0.48	0.48	1.00	18.51
Error (a)	2	0.95	0.48		
Husk, factor B	1	0.48	0.48	1.00	7.71
Interaction , AB	1	0.48	0.48	1.00	7.71
Error (b)	4	1.90	0.48		
Total	11	5.24			