RELATIVE RESISTANCE OF STORED SORGHUM *(SORGHUM BICOLOR* (L) MOENCH) VARIETIES TO THE RICE WEEVIL, *SITOPHILUS ORYZAE* (L) (COLEOPTERA.CURCULDAE)

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CERTIFICATION

This thesis entitled "RELATIVE RESISTANCE OF STORED SORGHUM (*SORGHUM BLOCLOR* (L.) MOENCH) VARIETIES TO THE RICE WEEVIL, *SITOPHILUS ORYZAE* (L)" by Bamaiyi, Lucius Joseph satisfy the regulations governing the degree of Master of Science of Ahmadu Bello University, Zaria, and is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

To my late Father, Joseph Bamaiyi, and my Mother, Baita to whom I owe all that I am today and whatever I aspire and hope to be in future.

ABSTRACT

Laboratory studies were carried out to evaluation 36 sorghum varieties maintained at the Institute for Agricultural Research (I.A.R.) Samaru and ICRISAT Kano, for their relative res, istance to the rice weevil, *Sitoplilus oryzae* (Linnaeus) (Coleoptera: Curculionidae). The criteria used for the evaluation of the sorghum varieties to postharvest infestation and damage included Fl progeny emergence, median developmental period (in days), index of susceptibility, percentage damage to grains and poercentage weight loss. The effect of physical characters like grain and biochemical compositions of the grains on the relative resistance of the sorghum varieties to *S.oryzae* were also investigated. The grains of the sorghum varieties BES, ICSH89009NG, ICSV247, - ICSVII, and ICSV1079BF supported fewer Fl progeny emergence, had longer median developmental periods, lower index of susceptibility, suffered less damage and weight loss than grains of varieties Singe-2, SK5912, ICSV902NG, KSV8, 18495 and ICSV210. The former group of sorghum varieties showed a higher degree of resistance than the latter group. Singnificant positive correlations were obtained between Fl progeny emergence and index of susceptibility as well as with percentage damage and weight loss, but all these parameters showed a negative correlation with median developmental period of *S.oryzae.*

Biochemical analysis showed that carbohydrate, protein,

lipid, ash, fibre, tanning and phytic acid content of the sorghum grains had a non-significant negative correlation with the index of susceptibility.

Physical charateristics of the different sorghum grains were investigated for their effect on the behavour including seed-coat colour, seed-coat texture, and seed size. The grain hardness of the various sorghum grains was also determined. The results showed that even though there was preference for certain grain characters (white and red seed coats, warty and rough textured seeds and large-seeded grains) under choice conditoons, no such preference show significant preference for the various grain characteristics.

Grain hardness had significant negative correlation with Fl progeny emergence, index of susceptibility, percentage damage and percentage weight loss, but significant positive correlation with median developmental period. There was negative and non-significant correlations between grain hard less and biochemical composition.

Grain hardness appeared to be the major factor responsible for resistance of sorghum grains to *S.oryzae.* This is evident by the fact that those sorghum varieties that supported fewer *S.oryzae* emerging from them were simply fragamented on grinding while those with more *S.oryzae* emerging form them were finely crushed on grinding.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Nomenclature and Taxonomy of Sorghum

Sorghum, (*Sorghum bicolor* (L) Moench) (Gramineae) is known by different common names in various parts of the world. For example, it is called Guinea corn or great millet in West Africa, Kafir corn in South Africa; Milo or Sorgo in the United States of America, Kaoliang in China, Durra in Sudan; Mtama in East Africa, and jowa or Cholam in India.

Doggett (1970) considered that cultivated sorghum and its attendant weed, sorghum arundinaceum (Desv) Stapf., were taken at an early date from Ethiopia across the Sudan to West Africa. It was taken from West Africa to the New world by the Slave trade.

Sorghum accounts for about 50% of the total cereal production (including rice, maize millet and wheat) and occupies 46% of the total land area devoted to cereal production in Nigeria (Egharevba, 1979). It is grown largely in northern Nigeria which lies approximately between latitudes 70N and 14oN, and is characterized by different grades of savanna which range from Southern Guinea through Northern Guinea and Sudan Savannas with Sahel vegetation at the northern-most tip of the country. This zone has a single rainy season of three to six months from April to October leaving most parts of the region hot and dry for the rest of the year (Ayertey and Ohiagu, 1982). Land devoted to sorghum

has increased over the last decade from 3.1 million hectares in 1981 to 4.8 million hectares in 1991 and production has equally increased from 3.3 million metric tons in 1981 to 4.8 million metric tons in 1991. This is about 45% of the world production which stand at 12.5 million metric tons from 11.1 million hectares in 1991 (F.A.O. 1992).

Usual yields on peasant farms are 500kg/ha whereas yields of 1,025 to 2,500kg/ha are obtainable under improved technology (F.A.O. 1992).

Sorghum is a staple food in most parts of the tropical world, particularly Nigeria. It is used widely for brewing beer in Africa and most parts of the world. It is used for the manufacture of syrup in the united states of America. The grain and straw are valuable stock food. The crop is grown for forage and silage. cultivars with a waxy endosperm are used for starch production, which is used in adhessives. Sorghum oil is extracted from the embryos removed during the starch manufacture. The oil is used as cooking and salad oils. Dried sorghum straws are used as fuel, for thatching, for reed walls in houses and for fencing. thin stems are used for making baskets and fish traps. A red dye is obtained from sorghum in West Africa which is used for dying leather (Purseglove, 1976).

Sorghum is adapted to a wide range of ecological conditions and produces useful yields under conditions which are quite unfavourable for most other cereals. It can

tolerate hot and dry weather conditions, but can also be grown in areas with high rainfall in which water logging may occur. It may be grown under irrigation.

The optimum temperature for growth is about 30oC. Its great merit is its drought resistance ability. Its Xerophytic character permits it to survive physiological drought produced by water-logging when root functions are temporarily impaired. Where condition are borderline, maize may fail with disastrous results, but sorghum thrives very well.

Sorghum can tolerate a wide range of soil conditions. It can be grown with a wide range of soil pH and tolerates salinity better than maize. It resists serious attack by the parasitic Striga spp. better than maize.

Sorghum is affected by many diseases in the field right from the time of germination to harvesting including anthracnose, leaf blight, charcoal rot, milo disease, rust, smut, sooty stripe, downy mildew, etc. Most important among its weeds is the parasitic Striga spp.

Over 120 insect pest species are known to infest sorghum in many parts of Africa (Reddy, 1981). The key pests of Sorghum include the sorghum midge, *Contarinia sorghicola* Coquillet (Diptera: Cecidomyidae) shootfly. *Atherigona soccata* Rondani (Diptera: Muscidae), Maize stalk borer, *Busseola fusca* Fuller (Lepidoptera: Noctuidae) etc.

The soil pests of sorghum include white grubs, *Phyllophaga crinita* (Burmeister) (Coleoptera: Scarabaeidae)

wireworms, *Agriotes lineatus* (Lin.) (Coleoptera Elateridae), and cutworms, *Euxoa tessellata* (Harris) (Lepidoptera: Noctuidae). Termites are *Microtermes thoracalis* Sjost. (Isoptera: Termitidae), and harvester ants, *Messor barbarus* L. (Hymenoptera: Formicidae). They damage the germinating sorghum seeds and roots, and also young seedlings, resulting in withering and lodging (ICRISAT, 1983). Seedling and foliage pests include grass hoppers, *Oedaleus senegalensis* (Krauss) (Orthoptera: Acrididae) Ailopus simulatrix Walker (Orthoptera: Acrididae), Locusta migratoria migratoriodes R&F (Orthoptera: Acrididae), Zonocerus variegatus (L) (Orthoptera: Acrididae), aphids and *Busseola fusca* Fuller (Lepidoptera: Noctuidae). Earhead or panicle pests include the midges, *Contarinia sorghicola* Coquilet (Diptera: Cecidomyidae), head caterpillars of the corn earwom *Helicoverpa zea* (Boddie) (Lepidoptera: Noctuidae), shootfly, *Atherigona soccata* Rondani (Diptera: Muscidae), and sucking bugs e.g. *Dysdercus superstitiosus* (F) (Hemiptera: Pyrrhocoridae) and *Nezara viridula* (L.) (Hemiptera: pentatomidae).

Storage pests include the rice weevil *Sitophilus oryzae* (L.) (Coleoptera: Curculionidae), the maize weevil, *Sitophilus zeamais* (Motsch) (Coleoptera: Curculionidae), the Angumois grain moth, *Sitotroga cerealella* (Olivier) Lepidoptera: Gelechiidae), the confused flour beetle, *Tribolium confusum* (du val) (coleoptera: Tenebrionidae), the red flour beetle, *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae), the

lesser grain borer, *Rhizopertha dominica* Fab. (Coleoptera: Bostrichidae), *Oryzaephilus surinamensis* (L.) (Coleoptera: Silvanidae), *Trogoderma granarium* (Everts) (Coleoptera: Dermestidae), etc. The most important storage insect pests are the rice and maize weevils, *Sitophilus* spp.

This work is intended to look not only at the physical characteristics of the grains but also the effect of biochemical composition of the sourghum grains and their relationship to susceptibility/resistance.

The objectives of this research are as follows:

1. To screen the available sorghum grains at the Institute for Agricultural Research (I.A.R). Samaru and ICRISAT Kano, for resistance to *Sitophilus oryzae (L.)*.
2. To determine the index of susceptibility for the 36 sorghum grains screened.
3. To examine the effect of physical characteristics e.g. seed coat colour, seed coat texture, seed size and grain hardness on infestation by *S. oryzae* and their relationship to resistance parameters.
4. To examine the biochemical characteristics of the sorghum grains and their relationship to susceptibility or resistance.
5. To assess the percentage of grains damaged and loss in seed weight for the 36 sorghum varieties by the pest (*S.oryzae*).

6. To possibly make suggestions to farmers on the sorghum grains that store well because they are resistant or tolerant to *S. oryzae*.

CHAPTER TWO

2.0 LITERATURE REVIEW: *SITOPHILUS ORYZAE*

2.1 Nomenclature, Taxonomy and Geographical Distribution.

Sitophilus spp. was first described by Linnaeus in 1763 as *Curculio oryza*, the first named species of the group. It was later revised by de Clairville and Scheltenberg in 1798 as *Calandra oryzae*, which is the commonest generic synonym for *Sitophilus*.

The rice weevil, *Sitophilus oryzae (L.)* belongs to the order *coleoptera*, family *Curculionidae*, genus *Sitophilus* and species *Sitophilus oryzae* (Linnaeus).

The pest is cosmopolitan, being found in both tropical and temperate regions of the world. It has a wide range of hosts with wheat, rice, barley, maize and sorghum as its major hosts (Kundu and Gupta, 1969).

2.2 Ecology and Pest Status

Sitophilus oryzae (L.) needs high relative humidities and a good temperature to survive. The development of the various stages of instars depends on the temperature and relative humidity which range from 18-30oC and 50-80%,respectively (Richards, 1947) *S. oryzae* oviposits within the seeds, the adult female bores or drills a hole into the seed and lays an egg in it. The egg hatches into a larva within the seed. Damage is caused principally by the larva feeding and developing within the seeds. In warm tropical climates where

sorghum is grown, *Sitophilus spp.* completes a life cycle in less than one month, which means large populations can develop and severe losses may occur in four to six months of storage (Young and Teetes, 1977). Ohiagu (1983) found losses to be as high as 76.86% when sorghum was stored on the head in rumbus or granaries without insecticidal treatment. Giles (1964) reported that in 1962, damage to sorghum world wide was equivalent to a weight loss of 115,000 tons which is sufficient to meet the cereal needs of some 1,258,000 people. Caswell (1978) estimated that 1.4% of sorghum produced in northern Nigeria was lost annually to insect pests, particularly *Sitophilus spp.*

The feeding activity of *S.oryzae* on sorghum during storage results in direct loss of protein and other nutrients. Khare et. al. (1972) found out that the loss in protein content in damaged maize grains by *S.oryzae* varied from 8.76-50.85 mg/g. Average loss was 30.35mg/g. It is evident that the insect feeds on the protein content along with carbohydrate and other nutrients during the period of their development on food grains.

Howe (1952) estimated that the amount of stored foodstuff eaten, and therefore, the amount of the weight loss caused by a population of an insect species is roughly proportional to the size of the population. The amount of damage caused depends on how rapidly the population increases. This in turn depends mainly on the temperature and humidity of the

environment as well as the nutritional value and moisture content of the food.

The period of the year for optimum damage by pests varies from one place to another. Caswell (1980) reported that the period of maximum damage in Samaru is May-October with a peak of about 40% in August. January and February is the period of minimum damage, about 20%.

In temperate regions, adults of *S.oryzae* die out during the winter without leaving the stored rice, and the winter is passed by the larval stage within the grain. It follows therefore, that the infestation by *S.oryzae* in the following year largely depends on the amount of infested grain carried over through the winter (white,1953).

2.3 Biology of the Rice weevil, *S.oryzae*

2.3.1. Identification of S.oryzae

The adult of S.oryzae is about 3-4mm long. It has two light-coloured areas on each elytron, and pits on the pronotum are nearly round and closer together than in *S.zeamais* The adults are characterized by a rostrum, which is a forward snout-like extension of the head which carries the mouthparts in a position that is ideal for penetrating plant tissues like roots, stem and seeds. The antennae elbowed in shape while at rest and when walking, they are carried in an extended position. Antennae have eight segments. The adult has metathoracic flight wings with circular punctures on the

prothorax. Elytra are very slightly shorter than the abdomen whose tip is therefore visible from above. The curve of the aedeagus in *S.oryzae* is more less uniform to the tip unlike in *S.zeamais* where the tip of the aedeagus is distinctly hooked (Proctor, 1971).

There are morphological characters that can be used to separate male and female S.oryzae. These include the length and width of the rostrum, the curvature and deflectioon of the abdominal sternites and the depressions and markings in the sternal segments of the insect (Reddy, 1951). In the male the basal groove is broader and the median area narrower than in the female. When the abdomen is seen in profile, the basal groove is deeper and the median area much more convex in the male than in the female (Lum and Baker, 1975). The male has a shorter and thicker snout which is straighter than that of the female. The lateral and dorsal surface of the male snout is covered by coarse irregular pits producing a rough appearance, the finer pits on the female snout are ovoid and regularly spaced, and the surface between the pits is smooth with a shiny appearance (Halstead, 1964).

When the genitalia are examined, the surface of the aedeagus in the male, is completely smooth and convex. In the females the 'prongs' of the Y-shaped sclerite are round and the gap between them is narrower than their combined width (Howe,1952). The larvae are apodous in all species of *Sitophilus*.

2.3.2. Life cycle of *Sitophilus oryzae* (L.)

The adults are long-lived (several months to one year). Eggs are laid throughout most of the adult life, although 50% may be laid in the first four to five weeks, up to 150 eggs may be laid per female. The eggs are laid individually in small cavities chewed into cereal grains by the female. Each cavity is sealed, and the egg is thus protected, by a waxy secretion (an egg-plug) produced by the female. The incubation period of the egg is about six days at 25°C (Howe, 1952). Eggs are laid at temperatures between 15°C and 35°C (with an optimum around 25°C) and at grain moisture contents of over 10%. Rates of oviposition, however are very low below 20°C or above 32°C, and below about 12% moisture content (Birch, 1944). Upon hatching, the resulting larva begins to feed inside the grain, excavating a tunnel as it develops. The whole developmental life is spent inside the one grain. The larva leaves the grain only in exceptional conditions which sometimes occur in culture. When this happens the larva does not enter another grain but it can subsist on flour, frass or grain detritus. S.oryzae can not complete its life cycle or development in flour. This is because the grain serves as a stimulus for oviposition and the first stage larva needs a firm medium to be able to feed. Because of this, it is not possible to follow individual insects through from egg to adult as with free-living store-product pests. Even dissecting young larvae from grains and growing them on flour

is unsatisfactory (Howe, 1952).

The life cycle of weevils under any set of conditions must therefore be examined by taking regular samples of grains containing eggs laid over a known short period. As a rule, only one *S.oryzae* completes its development in a grain, the rest being eliminated by cannibalism as egg, larva or pupa. this competition within a grain slow the development of the survivor (Birch, 1945).

The life cycle of *S.oryzae* starts from eggs and passes through four larval instars and a pupa before developing into the adult. The egg hatches into the first instar larva which starts feeding on the grain immediately and such feeding continues for all the successive or remaining three larval instars. At 25°C and 70% r.h., pupation takes place in English wheat after about 25 days, although development periods are extremely protracted at low temperatures. Pupation takes place within the grain, and the newly develop adult chews its way out leaving a large characteristic emergence hole. Total development periods range from about 35 days under optimal conditions to over 110 days in unfavourable conditions. The actual length of the life-cycle depends also on the type and quality of grain being infested (Howe, 1952).

2.4 Control of *Sitophilus oryzae*

S.oryzae may be controlled by physical, cultural, legislative, chemical and biological methods.

2.4.1. Physical Methods

By the physical method, the pest may be eliminated or the environment may be altered to make it inimical or inaccessible to the pest. In small quantities of stored grains and at low infestation levels *S.oryzae* can be removed physically by hand *picking. Removal of foci of infestation in store-houses* greatly reduces and sometimes totally eliminates the insect population from the stored commodities. With a thorough knowledge of the ecology of *S.oryzae*, it may be possible to develop effective novel physical control measures.

Relative humidity helps in controlling insect populations in stored products. The death of insects under a carbondioxide-rich atmosphere is largely due to excessive loss of water from their bodies caused by prolonged opening of their spiracles (Kumar, 1982). Howe (1965) noted that many storage pests, particularly *S.oryzae*, could not reproduce at ambient relative humidities of 50%.

High temperature (45°C), normally used in artificially drying grains for storage, are lethal to insects. On the other hands lowering of temperature retards the development of insects in stored grains (Kumar, 1982).

2.4.2 Cultural Methods

Abdel-Gawaad and Khatab (1985) reported that Egyptian farmers use to mix stored grain with fine ashes obtained from the Kitchen oven fire by placing this material at the base of

the silo and, after filling, also directly above the stored grains. The fine burned material absorbed the moisture of the grains and also from the waxy layer of the cuticle of the insects and caused cuticle abration leading to loss of moisture.

Sharaby (1988) working on guava, *Psidium guajava L. and Eucalyptus globulus L.*, found guava leaf powder to be more toxic to both *S.oryzae* and *S.granarius* adults. The toxicity of both materials may be attributed to one or more of the following factors. Fumigation effect, contact poisoning effect, or stomach poisoning effect (in the cases where the insects fed on admixed grains). The guava and *Eucalyptus spp.* leaf powders mixed with grains deterred the adults of *Sitophilus spp.* from the treated grains. The repellency effect of plant leaf powders was sustained all through the seven days of observations, showing a stronger repellent effect of Eucalyptus on both *S.oryzae* and *S.granarius* than on guava leaf powder. The repellent effect from admixed grain may be largely dependent on olfactory and gustatory sensation of the test insects. Guava and Eucalyptus leaf powders may be used to reduce infestation of *S.oryzae* and *S.granarius* and protect relatively small quantities of rice and sorghum grains.

Ivbijaro (1984) found that 5-20ml/kg of maize of groundnut oil is very toxic to adult *S.oryzae*. In less than two days after oil treatment, 100% of the weevils had died at

10 and 20 ml/kg and 63% at 5ml/kg. There is a progressive decline in oil toxicity and weevil mortality at every dose of groundnut oil with increase in storage period up to 21 weeks. He observed that eggs were laid only in the control and in the 1ml/kg oil-treated grains. Groundnut oil still had a remarkable effect on reduction of egg laying and development of progeny in the fresh rice weevils that were introduced on treated maize 19 weeks after oil application. No significant difference in viability was seen between oil-treated grains and untreated grains.

Powdered neem seed kernel mixed with sorghum grains at rates of 1.5-2.5% (m/m) protected sorghum grains against S.oryzae for up to six months (Deshpande, 1967). The seed protection was attributed to inhibition of oviposition by *S.oryzae*.

Ground hot pepper, *Capsicum frutescens* has been used to control the population of weevils in small quantities of stored grains. (Mba and Dike, 1988) When mixed with grains, the pepper is thought to exert a suffocating and contact effect on the weevils, thus resulting in their death.

2.4.3 Legislative Methods

Most storage pests have moved from one country to another along with infected food materials. The larger grain borer, *Prostephanus truncatus* (Horn) (Coleoptera: Bostrichidae) has spread to more than five African countries in less than five

years since it was first reported in Tanzania in 1980 (Makundi, 1987).

The presence of any new pest in any country should be reported promptly so that neighbouring countries are alerted to protect their borders against the invasion of such pests. Well trained personnels should be stationed at borders to prevent the importation of storage pests.

2.4.4. Chemical Methods

Common insecticides used against storage pests are Lindane, Carbon disulphide, Phostoxin, Pyrethrins, Permethrin, Malathion, Diazinon, Sumithion, Actellic dust, Actellic E.C., Ethylene dibromide, etc. (Evans, 1985).

In several trials with different insecticides, at the Intitute for Agricultural Research, Samaru, Actellic E.C., Sumithion 1.5% dust, and Reldan 2% at 10 ppm gave significantly better protection of stored sorghum against insect pests than did Actellic 2% dust at both 2-and 4-month storage periods (Annonymous, 1987).

Aman et.al. (1946) used ethylene dibromide as a fumigant for protecting sorghum. Insects exposed to ethylene dibromide, even if they seemed normal during the time of exposure, often died 48 hours later in a normal atmosphere. There was no recovery, among those that appeared dead when removed from the toxic atmosphere of ethylene dibromide. Other fumigants such as carbon disulphide and hydrocyanic acid

have a stupefying effect and insects seemingly dead may recover after sometime if put into a normal atmosphere. Ethylene dibromide has no effect on mammals when consumed from treated grains or flour, but is toxic when inhaled. It does not affect the viability of seeds. It is highly toxic to *S.oryzae*. Owing to its high toxicity and high specific gravity only a small volume is needed per ton of sorghum to be fumigated. It is strongly absorbed but does not penetrate very far into the material being fumigated. Its high retention by commodities may prove to be an advantage by preventing reinfestation. Experiments by Aman at.al (1946) have shown that in a storeroom of 60m3, a concentration of 15g ethylene dibromide per m3 and an exposure of 24 hours were sufficient for a 100% kill of *S.oryzae* compared with a concentration of 150g/m3 required when an ethylene dichloride carbon tetrachloride mixture is used. It is especially suitable for the fumigation of airtight storerooms filled with sacks, where a layer of only about 20CM has to be penetrated, and for fumigation under suitable tents. It is also suitable for the fumigation of grains in large mechanized silos.

Hewleth (1947) compared the toxicities of three petroleum oils to *S.oryzae* namely: Solutions of pyrethrins in shell oil (P31), odourless distillate (O.D) and pool burning oil (PBO). P31 by direct spray had a knock-down effect about 4-6minutes on *S.oryzae* which increased with time. Knock-down by a direct spray of O.D. or P.B.O. took place less than 4 minutes after

spraying, and its onset was even more rapid than that due to a direct spray of P31. Complete recovery from poisoning through knock-down by O.D. was more frequent than by P31. Hewleth(1947) concluded that P31 shows more promise than O.D. or P.B.O. because it is more toxic, and non-inflamable.

Shepard (1942) considered that the toxic action of petroleum oils on insects was due to blockage of the spiracles, and consequent suffocation, penetration of the tissues and breakdown of the tissue structure by the oils, and fumigant action by the volatile components of the oils.

Mkhize and Gupta (1985) found Insect Growth Regulators (IGRs) to be very lethal to S.oryzae if formulated with surfactants and detergents which increased the penetration of the IGRs into the sorghum Kernels.

Matsumura (1975) found surfactants to function as detergents where they form bridges between lipophilic and water-soluble substances. When these surfactants come in contact with the insect cuticle, they not only penetrate the cement layer of the epicuticle but also bind to and disrupt the lipid layer of the endocuticle presumably by emulsifying the epicuticular wax layer (Richards and Korde, 1948). It may be assumed that these materials disrupted the cuticular layer of the weevils, and thus enhanced penetration of the IGRs into the weevils bodies. Thus weevil mortality is due to the action of the IGRs and surfactants.

2.4.5. Biological Control Methods

The manipulation of natural enemies of pests to reduce pest populations to a level where economic losses are not possible is a promising alternative method of controlling storage pest. There may also be the use of genetically impaired pests to limit reproduction and survival of their own species in natural populations.

Major parasites of *S. oryzae* are the *Pteromalids* and the *Bethylid*. The pteromalids include *Aplastomorpha calandrae* How., *Cereocephalla cornigera* Westw., *Chaetospilla elegans* Westw., *Lariophagus distinguendus* Foerst, and *Zatropis incertus* Ashm, while the Bethylidae include *Cephalonomia formiciformis Westw.* The predaceous mite is *Pyemotes ventricosus* (Newp.) (Schmutterer, 1969).

The female of *Aplastomorpha calandrae* is able to detect within a rice grain the presence of larval *S.oryzae* and lays an egg nearby. Development of the parasitic larva within the weevil larva takes 10-12 days. This insect has been described as the most important parasite of S.oryzae (Grist and Lever, 1967). Reptiles like lizards eat up most storage pests including S.oryzae during drying process.

Russell (1962) reported that a large culture of S.oryzae was wiped out by Cereocephalla cornigera (Hymenoptera: Pteromalidae). Although no records of the wide use of these parasites in the control of S.oryzae was seen, it is believed that they can effectively control this pest.

2.5 Resistance to Grain Insects in Sorghum.

2.5.1 Introduction

Synthetic pesticides have been used for many years to control agricultural insect pest. However, continued application of these insecticides has resulted in the development of resistance by insects, pollution of the environment and hazards from handling toxic compounds. Resistance to seed protectants has become a limiting factor in long storage of cereal seeds in most parts of the world. The major pest species of sorghum, S.oryzae has developed resistance to DDT which was used extensively for grain and seed protection in post-war years, and subsequently, to lindane which replaced DDT in 1952 (Champ and Cribb, 1965. Georghiou, 1990 of Moberg 1990). The occurrence of insecticide resistance has resulted in many control failures.

Local plant materials used for controlling *S.oryzae* only give limited protection to the grains for a short time and lose their potency. (Golob & Webley, 1980) Some of these plant materials stain the grains and leave an unpleasant odour on treated grains decreasing their palatability e.g neem products.

This calls for the need to develope other safe and effective control measures against this and other storage pests. The use of host plant resistance has no environmental hazards, does not require the use of chemicals. It is most cost-effective compared to chemical control measures. It does

not require sophisticated skill or training for the farmer before use, but only the cultivation of the resistant cultivars.

2.5.2 Effects of physical properties of sorghum grains on resistance to insects.

The degree of resistance of sorghum to S.oryzae in the store depends on a combination of many grain factors e.g. hardness, texture, moisture content and the ability to retain husk. Doggett (1957) found a positive correlation between the low rate of loss from weevil infestation and a thick corneous outer endosperm shell in the grain. Small grains were seen to suffer less damage than large ones. Russell (1966) showed that the life span of weevils could be correlated with Kernel hardness and was significantly shorter when bred on relatively hard grains. Davey (1965) working on grains of 10 varieties of sorghum with endosperms ranging from mealy to vitreous, found adult weevils consuming more of the mealy varieties per day than the vitreous ones. Higher oviposition and adult emergence were observed from mealy than from vitreous grains. Since the vitreous grain was seen to be harder than that which was mealy, it was inferred that grain hardness was the principal factor responsible for resistance to weevil infestation.

Rooney and Miller (1981) described the kernel structure of sorghum and reported that the endosperm texture of sorghum

was related to its storage potential, insects more readidly attacking soft, floury endosperms than corneous sorghum.

The damage to sorghum in storage by *S.oryzae* often depends on the thickness of the corneous endosperm layer of the seed. When a given variety changed in relative hardness when grown in different geographical locations, the insects responded to the difference.

The mortality of immature stages of *S.oryzae* was increased by lower humidities (57-59%). When *S.oryzae* is maintained at two relative humidities (60 and 70%), the reactions to the hardness are accentuated in that the differences in life span are proportionally greater when the hard and soft varieties are compared. The effect of the lowered relative humididty is greater in itself, however, causing a drastic reduction in survival time. *S.oryzae* showed an additional reaction to grain hardness in that the average life span of small cultures is significantly shorter than when maintained on relatively hard grains. It was established that grain hardness and size influenced oviposition. (Russell, 1962).

2.5.3 **Effect of Biochemical composition of sorghum grains on resistance to insects.**

The sorghum grain colour ranges from off-white to yellow, brown, red, variegated, etc. In the coloured or pigmented forms, the polyphenolic and other related compounds like

tannins are located primarily in the pericarp and testa. The presence of these compounds make the grains immune or resistant to attack by birds, locusts, storage pests e.g *S.oryzae*, as well as pathogens. The tannins in sorghum render the grain astringent and unpalatable especially in the green stage. In some varieties, the astringency diminishes on ripening, until it almost disappears; but in some, it persists even in storage. High tannin levels result in low digestibility and reduced protein efficiency ratio levels (Doggett,1981; Kochlar,1986).

The dried grains contain about 68-74 % carbohydrate, 3% fat, and 9-12% protein, although some protein-rich cultivars (up to 20%) have been reported (Kochlar, 1986). Singh and McCain (1963) working on weevil infestation in sorghum and maize, reported positive correlations between higher sugar and starch levels with weevil numbers and weights particularly Sitophilus spp.

The sorghum grain may possess some biological characteristics that confer on it some resistance to storage insects including S.oryzae. Adetunji (1984) found higher mortality of immature stages in resistant sorghum grains than in susceptible ones. He attributed this increased mortality to antibiosis or antixenosis.

2.5.4 Index of susceptibility

Dobie (1977) reported that the index of susceptibility of

a material to a pest is proportional to the intrinsic rate of increase of population of the pest breeding upon the material. He found that for each parent insect *(Sitophilus spp.)* infesting a variety of maize, the logarithm of the number of adult insects developing from the original insect will be proportional to the index of susceptibility of the variety. The index of susceptibility can thus be used as a means of classifying materials into groups of similar susceptibility. In sourghum storage, the number of *S. oryzae* present at any time depends upon the initial population of the insect at the start of the experiment and the rate of multiplication of the insect depends upon the ambient temperature, the moisture content of the sorghum and upon the suitability of the sorghum grain for the reproduction of the insect. The number of eggs laid and the time taken to complete development may all differ on samples of different varieties of sorghum (Dobie, 1974).

Howe (1971) introduced a parameter for comparing the susceptibility of experimental laboratory environments for insect development. When a fixed number of eggs are added to food in an environment, the index is given by

$$\frac{\text{LogeS}}{\text{T}}$$

Where S is the percentage (%) of insects reaching the adult stage and T is the average duration of development.

In the proposed work, to compare varieties, the adult insects lay an unknown number of eggs, some of which may die

during development and there may be some adult mortality during the test period. The yield (y) of the experiment (total number of F1 adults) can therefore properly replace S in the above function to give (LogeY)/T as an index of susceptibility.

Dobie (1977) modified this formular as follows

$$\frac{\text{LogeF}}{\text{D}} \times 100$$

Where F is the total number of F1 progeny emerged and D is the median developmental period (days), estimated as the time from the middle of the oviposition period to the emergence of 50% of the F1 pregeny.

2.5.5. Use of Resistant Sorghum Grains

From the foregoing, it is clear that resistance of sorghum grains to storage pests depends on hardness, texture, moisture content and the ability to retain husk. Sorghum varieties that retain the husk after normal threshing are more resistant to storage pests than those not retaining the husk (Samuel and Chatergi, 1953). It is well known that consumers and industrialists do not like sorghum grains retaining the husk after threshing. Thus, there is the need for further search for good characters. Doggett (1957) breeding sorghum for resistance to weevil attack found some of the hybrids although resistant to weevils attack because of their thick corneous outer endosperm shell, were highly susceptible to

moulds and other diseases. Sorghum grains with vitreous endosperms suffer less damage by S.oryzae than those with mealy endosperms (Davey, 1965).

This work is intended to look at the sorghum varieties in common use in Nigeria as various workers concentrated on the varieties within their locations. Some of the sorghum varieties being evaluated in this work may be the same as the ones already worked on by these workers but resistance or susceptibility of sorghum is known to be affected by a change in geographical location (Russell, 1962). Russell (1962) concentrated on the effect of relative humidity on the oviposition and longevity of S.oryzae. Davey (1965) used fewer and probably different sorghum varieties, under temperate conditions. Doggett (1957) was concerned with breeding for weevil resistance and early maturity. Although he worked under tropical conditions, used different sorghum varieties. This work is intended to look beyond just the physical characteristics of the grains but also the effect of biochemical composition of the sorghum grains and their relationship to susceptibility/ resistance.

CHAPTER THREE

3.0. MATERIALS AND METHODS

3.1 Introduction

The grains of 36 sorghum varieties maintained at the Institute for Agricultural Research (IAR) Samaru and ICRISAT Kano were evaluated for relative resistance to *Sitophilus oryzae*. These Sorghum grains were fumigated in airtight drums with phostoxin tablets to disinfest them of all contained insects, if any. The varieties were KSV8, ICSV1007BF, ICSH89009NG, BES, ICSH89002NG, ICSV400, Framida, Mori (a local variety) White mutant, ICSV1079BF, L 533, SK.5912, 16-5BF, ICSV1049,18495, ICSV1002, BOPEN-R-5, ICSV554 ICSV424, ICSV111, singe-2 firkan, singe-1, 3443, Kam[illegible], 84-5-130, ICSV655, 85-4BF, IS9928, IS21658-Y, 1023BF, 84-W-830, ICSV905NG and ICSV902NG.

3.2 The Insect Culture

S. oryzae adults were obtained from the stock culture at the storage laboratory of the Department of Crop Protection, I.A.R. at Samaru. *S. oryzae* was carefully selected on examination of the rostrum characters. The rostrum of *S. oryzae* is straight, not constricted basally in profile. It is swollen sub-basally, more coarsely punctured and sculptured in males. Scrobe has a posterior extension running ventrally,

anterior to eyes. The pronotum is coarsely and densely punctured. Scutellum is visible, and usually with lateral elevations closer together than their length and evidently more than half as long as Scutellum (Halstead, 1964, Dike, 1994). Post-humously, the genitalia were also examined in order not to confuse *S. oryzae* with *S.zeamais*. A large culture of adult *S. oryzae* was maintained in a large stock (about 1kg) of Sorghum. After 10 days, the parent insects were sieved out and discarded while the Sorghum sample was left in the laboratory. On the thirty fifth day of initial infestation, the emerged F1 progeny were removed for Sub-culturing. This was done for a few generations to obtain a large stock of insects of known ages. These insects were used to infest the different sorghum grains.

3.3 Determination of Moisture Content

The moisture content of the grains of each sorghum variety used was determined before and after the experiment using the oven-dry method (Pixton, 1967). A specimen tube-full of sorghum grain (about 1) were ground using a mechanical blender/grinder (Regent Maskiner Mill). The resultant powder was placed in small aluminium tins of known weights in three replicates. The initial weight of each tin and contained sample were recorded. These were placed in an oven already maintained at 120oC and fitted with a celsius thermometer. The samples were left in the oven for four hours after which the oven was switched off and allowed to cool for

sometime. The samples and tins were removed and their final weights were taken.

Percentage loss in moisture content (% MC) in each replicate was calculated using the following formula:

$$\% \text{ MC} = \frac{\text{initial sample weight} - \text{final sample weight}}{\text{initial sample weight}} \times 100$$

The mean percentage moisture content for the three replicates were calculated for each sorghum sample and recorded.

3.4 Screening For Resistance

The Screening was carried out from July to September in (1993, from December 1993 to February 1994 and from August to October 1994). These three trials were carried out at different periods of the year to obtain an indication of the climatic effects on the activity of *S.oryzae* on the different sorghum grains. The insect is known to be at its peak period of activity between the month of July and October in Zaria (Caswell, 1980). It was therefore thought that any cultivar that shows some resistance to the pest during this period is indeed resistant.

For each sorghum cultivar, three replicates of 200g each were placed in 1 litre capacity kilner jars and labelled according to the varieties. Each replicate was infested with 20 adult insects between 0-3 days old made up of 7 males and

13 females. The jars were arranged in a completely randomized design in a uniformly lighted laboratory at room temperature. The temperature and relative humidity was recorded on a daily basis using a thermohydrograph.

After 10 days of infesting the grain, the parent S.oryzae were sieved out from the various sorghum grains, when they wou d have laid their eggs The whole set-up was left on a laboratory bench. The insect count commenced 40 days post-infestation when the F1 progenies started emerging; the mean development period from egg to adult is 35 days (Howe, 1952). Counts of emergent adults were taken daily using a tally counter and the number recorded for each sample. Sampling for adult emergence continued up to the 50th day when most F1 progenies would have emerged but no F2 progenies would yet have emerged.

At the end of each trial the weight of each replicate was recorded to determine any loss of w[illegible]ht as a result of the ~~in~~sect feeding.

3.5 Determination of Susceptibility Index.

Susceptibility index is a measure of the suitability of a particular food source for development of a given insect pest species Measuring susceptibility index involves a determination of the number of F1 progenies developing from a set number of parent insects of a known age as well as the length of the development period of the insects. The

determination was carried out as follows: fifty grams of sorghum grains weighed from each sample were replicated three times. Adult *S.oryzae* between 0 and 3 days old were infested into each replicate. The insects were sieved out after 10 days and discarded. The samples were left until the F1 progenies started emerging. The F1 progenies were counted daily until all F1 adults emerged. The data obtained was used to determine the total number of F1 progenies and the median developmental period for each replicate of the varieties.

The index of susceptibility was then calculated using the formula first introduced by Howe (1971) and later modified by Dobie (1977) as shown in section 2.5.4:

$$\text{Index of susceptibility} = \frac{\text{LogeF}}{\text{D}} \times 100$$

The index of susceptibility obtained was used as a means of classifying the various sorghum varieties according to similar susceptibility. The difference between highest and lowest index of susceptibility was used to calculate for the lower 20%, the next 30% the other 30% and the upper 20% on a normal distribution curve.

3.6. Influence of Physical Characteristics

The aim of this experiment was to find out the effect of the various physical characteristics of the sorghum grains on the behaviour of *S.oryzae*. Sorghum grains of various physical

characteristics including seed-coat colour, seed coat texture and seed size were used for this assessment. For seed coat colour, five sorghum varieties were selected on the basis of their seedcoat colour. Three replicates each measuring 10g were taken from each of the five varieties and were each sealed in a transparent polythene bag. The various colours selected were white, red, variegated, dark brown and yellow. For seed-coat texture, five sorghum varieties were selected on the basis of seed texture including smooth, rough, moderately-smooth, moderately-rough and warty. Some 10g each of the selected varieties were sealed in bags. For seed size, varieties selected were very large seeded, large seeded, medium seeded, small seeded and very small seeded The selected varieties were sealed as usual to exclude the effect of smell on the behaviour of the insects. For each physical character, the sealed samples were placed at equal spacing against the sides in a wide trough. Some 50 adult insects were placed at the centre of the trough for each replicate and the trough was covered with a transparent muslin cloth to allow the insects to respire. The set-up was left for 24 hours after which the cloth was removed and the number of *S.oryzae* in the close vicinity of each sample was counted and recorded in each case for all the physical characters examined.

3.7 Grain Hardness Assessment.

Grain hardness is known to be a factor of sorghum grains resistance to *S.oryzae* attack (Russell 1962, Doggett, 1957 Davey, 1965). The measurement of grain hardness has always been problematic. Francisco et al (1982) determined grain hardness by characterizing particles sizes after milling the grains in attrition and roller mills. By milling, the softer sorghum grains were found to have produced more finer or smaller particle sizes on milling. Obuchoswski and Bushuk (1980) measured hardness by Penetrometers which is defined as the force required to crack the kernel grain. In bulk samples, they suggested measuring either the grinding or pearling resistance or the nature of the ground product. Resistance to crushing, breaking, shearing or penetration could be used as val.d measures of hardness. Dobie (1977) reported that a favourable measure of hardness is the average power used by an electric mortor to grind a sample og grain in a "Brabender Farinograph" fitted with grinding head .

The materials used int he above methods of determining grain hardness were not readily available in the course of this work, thus, the method siggested by Dobie (1974) was used here. Three replicates each of 10g for each of the 36 varieties of sorghum were placed in specimen tubes. The content of each tube was ground at a constant setting in a manually operated Regent Maskiner mi[illegible] The resultant flour was sieved using a 50u aperture sieve for a period of 15

seconds in each case. The fractions of the sorghum passing through and retained by the sieve were weighed to the nearest milligram and recorded as "filtrate" and "residue" respectively (Dobie, 1974). The data obtained was used to determine grain hardness by observing that the finely crushed varieties produced more flour and were thus considered as soft. Those that were simply fragmented produced less flour (filtrate) and more fragments (residue) and were thus considered hard.

3.8 Biochemical Analysis.

Biochemical analyses was carried out to determine the carbohydrate, protein, lipid, ash, tannin, phytic acid and fibre contents of all the sorghum samples screened. The analysis was also aimed to determine correlation between these biochemical components and the index of susceptibility. These analyses were carried out at the Food Science and Technology Programme, Institute for Agricultural Research, Samaru, and the Department of Biochemistry, Ahmadu Bello University (ABU) Zaria. The Analysis was carried out to determine whether there was any association between the biochemical composition of the sorghum grains and their resistance to *S.oryzae* through correlation analysis. The analyses were carried out as follows:

3.8.1 Sample preparation.

For each sorghum variety 5g of the sample was milled using both electric operated and hand-operated milling machine. The hand-operated milling machine was used when there was power failure. In each case (during the milling), the milling machine was thoroughly cleaned after milling a particular sorghum variety, with cotton wool. This was done so as to avoid contamination of one variety with another. Each sample was kept separately in clean specimen tubes and labelled appropriately.

3.8.2 Carbohydrate Determination

When the total protein and lipid contents are subtracted from organic matter, the remainder accounts for carbohydrate and nucleic acid i.e % organic matter - % protein + % lipid = carbohydrate + Nucleic acid.

The shorghum flour was digested with perchloric acid and hydrolysed starches together with soluble sugars are determined colorimetrically by the Anthrone method. This method is referred to as estimation by difference (Oyeleke, 1984).

% carbohydrate = 100 - (% protein + % Lipid + % Ash + % Fibre)

3.8.3 Protein Determination

Protein content of each sorghum sample was determined using Micro-Kjeldahl Method (Oyeleke, 1984). The method entails the estimation of total nitrogen content after conversion of the protein nitrogen to Ammonium salt by digestion with sulphuric acid.

From a finely ground sample 0.2g was weighed into a clean 50 ml micro-kjeldahl flask including half tablet of selenium catalyst. Some antibombing granules were added. Some 3-5ml nitrogen free concentrated H_2SO_4. Was added and then followed by the addition of 5ml hydrogen peroxide to speed up the reaction.

3.8.4 Determination of Crude Lipid Content

Lipid content of each sorghum sample was determined using petroleum ether in soxhlet extractor (Oyeleke, 1984).
The procedure was as follows:

Exactly 2g sample was accurately weighed into a clean dry previously weighed cellulose thimble and weighed again with de-greased cotton wool as cover. 200ml petroleum ether (b.p 40o - 60oC) was poured into a clean dry 250ml round bottom flask. Some antibombing granules were then added.

The content of the flask was filtered to the soxhlet extractor and placed on heating mantle. The flask was subjected to moderate heat (50oC). Just before the solvent

started boiling, the water source (the tap) was turn on to ensure a proper cooling of the apparatus. The extraction process was continued for 6 hours after which the process was stopped and the apparatus left to cool. The thimble with its contents was removed and air dried for 10 minutes or dried in a desiccator for 2-3 hours. The loss in weight of thimble with content represent the ether extract (crude fat) content.

$$\% \text{ Lipid} = \frac{\text{wt.loss(g) of sample (extracted fat)}}{\text{initial weight of sample (g)}} \times 100$$

3.8.5 Determination of Ash Content

This was carried out at 550oC with the aid of a muffle furnace (AOAC, 1984).

The procedure was as follows:

Exactly 2g of the finely ground sample were weighed into a previously weighed clean crucible which has been ignited in the muffle furnace at 550oC for 10 minutes and the crucible and content weighed. It was then transferred into the muffle furnace. The temperature of the furnace gradually increased until it reached 550oC. The samples were left for 5 hours at this temperature so as to ensure proper ashing of the samples. Thereafter the samples were removed from the furnace into a desiccator where they were cooled. Each cooled crucible with its ash content was weighed. The weight of the residue in the crucible corresponded to the ash content of the sample while the loss in weight corresponded to the organic matter content.

Calculation:

$$\text{Percentage Ash} = \frac{\text{weight of Ash(g)}}{\text{weight of samples(g)}} \times 100$$

$$\text{Percentage Organic Matter} = \frac{\text{weight loss(g)}}{\text{weight of samples(g)}} \times 100$$

3.8.6 Determination of Crude Fibre Content

This was carried out by the AOAC method for each crude fibre (AOAC, 1984). This method involves sequential digestion of the sample with dilute acid and alkali solutions. The residue obtained was ignited to obtain crude fibre. The procedure is as follows:

About 1g of the finely ground sorghum sample was put in a flask and 1.25% of H_2SO_4 was added and boiled for 30 minutes. The resulting residue was dried to a constant furnace at 550oC for 2hrs, cooled and reweighed (Cz). The calculations were:

The loss in wt on incineration = C1 - Cz

$$\text{Percentage fibre} = \frac{C2 - C3}{W} \times 100$$

Where C2 = wt. of insoluble residue

C3 = wt. of incinerated residue

W = wt. of original sample.

3.8.7 Determination of Tannin content

Tannin was determined by the Vanillin HCl procedure which was based on an acid catalysed addition of vanillin to flavonols and their polymers as well as addition to other polyphenolic compounds such as dihydro chalcone and flavones. The reactions are determined colorimetrically at 500nm (Earp et al., 1981). The concentration of catechin in the samples were determined on the standard curve by extrapolation in which catechin equivalent (C.E.) was determined according to the following equation:

$$\% \text{ (C.E)} = \frac{\text{Mg Catechin/M x volume made up}}{\text{Vol. of extract taken x wet. of sample (mg).}} \text{ X } 100$$

3.8.8 Determination of Phytic Acid Content.

Phytate phosphorus was determined by the colorimetric method of Stewart (1974). The acidified extract was used to dissolve the phytin present in the sample. Phytic acid was then isolated as Iron (III) phytate. It was recovered, digested and estimated as phytate phosphorus.

$$C_{unknown} = \frac{A_{unknown} \times C_{standard}}{A_{standard}}$$

Where C = concentration of phytate phosphorus in the sample which is determined on the standard curve by extrapolation.

Concentration of standard phosphorus = 1.2ppm

Absorbance of the standard = 0.97.

$$\% \text{ Phytate phosphorus} = \frac{\text{Cmg} \times 3.75 \times \text{Df} \ (10)}{\text{Sample weight} \ (2.5\text{g})}$$

% Phytate phosphorus is then expressed in mg/100g samples.

3.9 Assessment of Grain Damage

The aim of this assessment was to determine the extend of damage to the various sorghum samples. For the assessment of grain damage, 1000 grains were taken randonuly from each sorghum sample in three replicates. The selected grains were separated into whole (undamaged) and holed (damaged) seeds. The number of seeds in each category was recorded and the data used to compute the percentage damage for each grain sample, using the following formula:

$$\text{Percentage damage} = \frac{\text{Damaged Grains}}{\text{Total Grains}} \times 100$$

3.10 Assessment of Weight Loss

This was carried out to determine the effect of the insects feeding and development on the weight loss. To assess the weight loss in the sorghum samples after 50 days post infestation, the 1000 grains used for the damage assessment were again used. The damaged and undamaged grains separated out were weighed and recorded appropriately. The result obtained were used to compute the percentage weight loss using the formula given by Golob et al. (1982) as follows:

$$\text{Percentage weight loss} = \frac{(UNd) - (DNu)}{U \times (Nd + Nu).} \times 100$$

Where U = weight of undamaged grains

D = weight of damaged grains

Nd= number of damaged grains

Nu= number of undamaged grains.

3.11 Analysis of Data

The data for F' progeny emergence, median developmental period, index of susceptibility, percentage damage and weight loss, grain hardness and other physical characteristics of the grains were subjected to analysis of variance. Where the F values were found to be significant, the means were compared using the Duncan Multiple Range Test (DMRT). The F' progeny emergence, median developmental periods, percentage damage and weight loss, biochemical composition of grains and grain hardness were all correlated with index of susceptibility.

CHAPTER FOUR

4.0 RESULTS

4.1 *Introduction*

Analysed data from the experiments on the evaluation of 36 sorghum grain samples for resistance to post harvest infestation with *S.oryzae* is presented in Table 1. Using Duncan's Multiple Range Test (DMRT), the means from the 36 sorghum grains screened showed that in each of the parameters shown in Table 1 th re were significant (P=0.05 and 0.01) differences among most cultivars.

4.2 F1 Adult Emergence

At 50 days post-infestation with *S.oryzae*, the mean numbers of F1 progenies that emerged from the 36 different sorghum cutivars ranged from 27.70 in BES to 697.70 in SINGE-2. Using DMRT, it was determined that there was no significant difference (P>0.55) in the number of emergent F1 progenies from the varieties SINGE-2 and SK5912. However, the varieties SINGE-2 and SK5912 had significantly higher numbers of emerged F1 adults than ICSV902NG, KSV8, 18495 and ICSV 210 (P<0.05) although they all had generally high numbers of emergent F1 adults. There was no significant difference (P>0.05) between varieties 84-5-130 and ICSV905NG, but both had significantly higher emergence than varieties ICSV1002, MORI, KAMPTI, SINGE-1 and ICSV424. Similarly, varieties

ICSV1049, ICSV554 and 3443 had similar emergence which was significantly higher ($P<0.05$) than varieties L.533, FIRKAN and 1023BF. Among the varieties with low emergence, White mutant, ICSH89002NG and 16-5BF supported similar emergence which was significantly higher than varieties FRAMIDA, IS9928, ICSV400, ICSV655 and IS21658-Y. With lower emergence still were the varieties ICSV 1079BF and ICSV247 which nevertheless sustained higher *S.oryzae* emergence ($P<0.05$) than varieties ICSH89009NG, ICSV III and BES which recorded the least progeny emergence.

4.3 Median Developmental Period

The median developmental period from egg to adult for *S.oryzae* ranged from 32.97 on SK5912 to 42.97 on the variety BES. The general trend appeared to be similar to that for the F1 adult emergence. Varieties with high F1 adult emergence tended to have short median developmental periods and their individual median developmental periods were less than the general mean for all the varieties (Table 1). The reverse was the case with those that had low F1 adult emergence.

Comparison of the means using DMRT showed that the median developmental periods of *S.oryzae* bred on varieties BES, FRAMIDA, ICSV1007, ICSV1079BF and IS21658-Y were significantly longer than that on other cultivars ($P<0.05$). Among these, varieties ICSV1079BF and IS21658-Y were similar in this respect but progeny development took longer than in the varieties White Mutant, KSV8, ICSH89002NG, 16-5BF, ICSV III,

ICSV655, IS9928 and 1023BF. Development to adult took a similar length of time in the varieties ICSV902NG, ICSV 247 and ICSV400 which was longer ($P<0.05$) than in the varieties ICSV554, ICSH89009NG, 84-5-130 and ICSV905NG. The varieties Kampti, 3443, SINGE-1 and BOPEN-R5 generally allowed short developmental periods for *S.oryzae* which nevertheless were longer than in the varieties SK5912 and ICSV1002.

4.4 Index of Susceptibility

The index of susceptibility (described in section 3.5) is shown in Table 1 and ranged from 7.72 in BES to 19.80 in SK5912. A greater number of the varieties had their index of susceptibilities higher than the general mean. By DMRT, the means showed that varieties SK5912 and SINGE-2 with the highest indices were significantly different from each other and also higher than ICSV1002 and ICSV902NG. The varieties 18495, ICSV210, MORI, KSV8, SINGE-1, KAMPTI, 84-5-130, and ICSV905NG had similar susceptibility index which was higher than those for the varieties, BOPEN-R5, L.533, ICSV1049, FIRKAN, 85-4BF and 84-W-830. The varieties White Mutant, ICSH89002NG and 16-5BF has similar susceptibility indices which were higher than those for varieties IS 21658-Y, FRAMIDA and ICSV1007. Furthermore, the latter (ICSV1007) had higher susceptibility indices than those for variety ICSVIII and BES which had the lowest indices and yet the latter ICSV1007 was significantly lower than the latter BES ($P<0.05$).

Table 1: Effect of sorghum varieties on emergence of Adult S. oryzae, median developmental period, index susceptibility, percentage damage to grains and weight loss at Samaru, 1994.

Variety	FI adult emergence	Median dev. period(days)	% damage	% weight loss	Index of suscept.
SK5912	684.00[a]	32.97[l]	16.78[b]	8.41[b]	19.80[d]
SINGE-2	697.70[a]	36.23[ijk]	17.74[a]	9.08[a]	18.07[f]
ICSV902NG	620.70[b]	36.63[hi]	14.38[c]	7.23[c]	17.55[h]
ICSV1002	324.70[gh]	33.20[o]	8.56[f]	4.09[gh]	17.42[i]
18495	444.30[d]	36.07[ikl]	10.84[d]	4.72[e]	16.90[d]
KAMPTI	319.70[hi]	34.20[s]	8.19[fg]	4.01[gh]	16.87[d]
KSV87	517.30[c]	37.10[efg]	13.96[c]	6.45[d]	16.84[d]
SINGE-1	316.70[hi]	34.40[rs]	8.22[fg]	4.03[gh]	16.74[de]
84-5-130	358.00[f]	35.30[nop]	9.88[e]	4.21[g]	16.66[fg]
ICSV210	419.00[e]	36.37[ij]	10.48[d]	4.46[f]	16.60[fg]
AMORI	323.00[ghi]	34.87[pq]	8.53[f]	4.04[gh]	16.57[def]
ICSV905NG	342.30[fg]	35.47[mno]	9.38[e]	4.11[gh]	16.45[def]
34433	267.30[kl]	34.20[s]	7.47[hi]	3.17[l]	16.34[efg]
ICSV424	302.30[ij]	35.70[lmn]	8.16[fg]	3.91[h]	16.00[fgh]
ICSV554	273.70[kl]	35.20[opq]	7.50[hi]	3.20[l]	15.94[gh]
BOPEN-R5	230.00[no]	34.40[rs]	7.04[i]	2.87[l]	15.80[hi]
FIRKAN	242.70[mn]	34.97[pq]	7.22[i]	3.01[ij]	15.70[hi]
85-4BF	229.70[no]	34.90[pq]	7.10[i]	2.93[l]	15.57[hi]
ICSV1049	281.70[jk]	36.30[ij]	7.91[gh]	3.19[l]	15.54[hi]
L.533	255.00[lm]	35.83[klm]	7.40[hi]	3.06[ij]	15.47[i]
84-W-830	212.00[o]	34.83[qr]	6.95[i]	2.61[k]	15.38[i]
1023BF	241.70[mn]	37.30[ef]	7.14[i]	2.92[l]	14.71[j]
WHITE MUTANT	166.30[p]	37.40[e]	5.47[j]	2.20[l]	13.65[k]
ICSH89002NG	152.30[pq]	37.20[ef]	5.42[j]	2.20[l]	13.49[k]
16-5BF	147.00[pqr]	37.20[ef]	5.45[j]	1.80[m]	13.41[k]
IS9928	127.70[rst]	37.07[efgh]	4.93[j]	1.76[m]	13.08[lm]
ICSV400	125.00[st]	36.93[fgh]	5.01[j]	1.77[m]	13.07[lm]
ICSV655	117.70[st]	37.10[efg]	3.09[k]	1.75[m]	12.85[m]
IS21658-Y	113.70[st]	38.40[d]	3.56[k]	1.43[n]	12.32[n]
FRAMIDA	134.30[qrs]	39.80[c]	5.38[j]	1.76[m]	12.31[n]
ICSV1007	110.70[t]	38.90[b]	3.31[k]	1.18[o]	12.09[n]
ICSV247	59.67[u]	36.67[ghi]	1.32[l]	0.44[p]	11.14[o]
ICSV1079BF	70.70[u]	38.47[c]	1.41[l]	0.60[p]	11.09[o]
ICSH89009NG	48.70[v]	35.20[opq]	1.21[l]	0.25[q]	11.01[o]
ICSV111	43.00[v]	37.13[ef]	1.63[l]	0.57[p]	10.05[p]
BES	27.70[v]	42.97[a]	0.30[m]	0.13[q]	7.72[q]

Values followed by the same letter(s) are not significantly different at P = 0.05 and 0.01 levels.

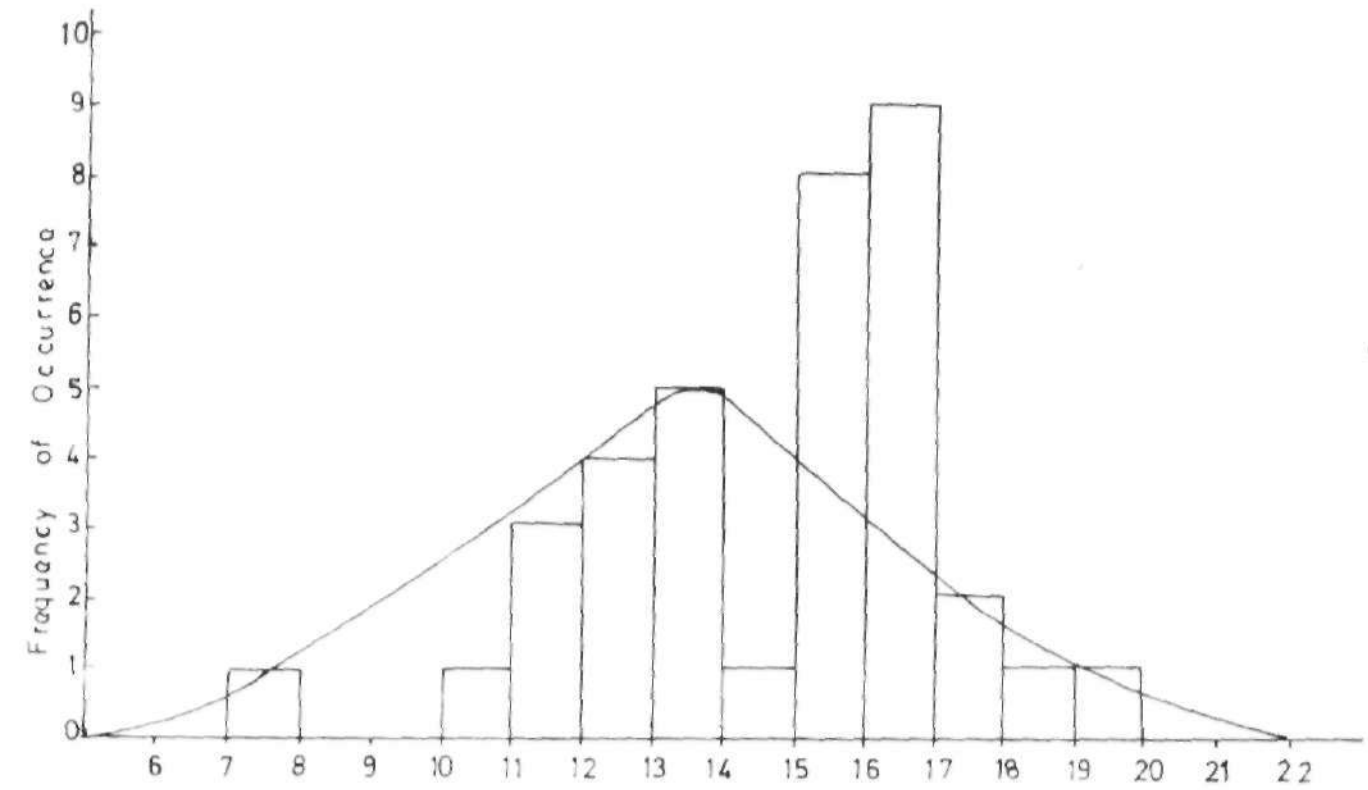


Fig.1 : Frequency distribution of relative susceptibility of 36 sorghum varieties to S oryzae

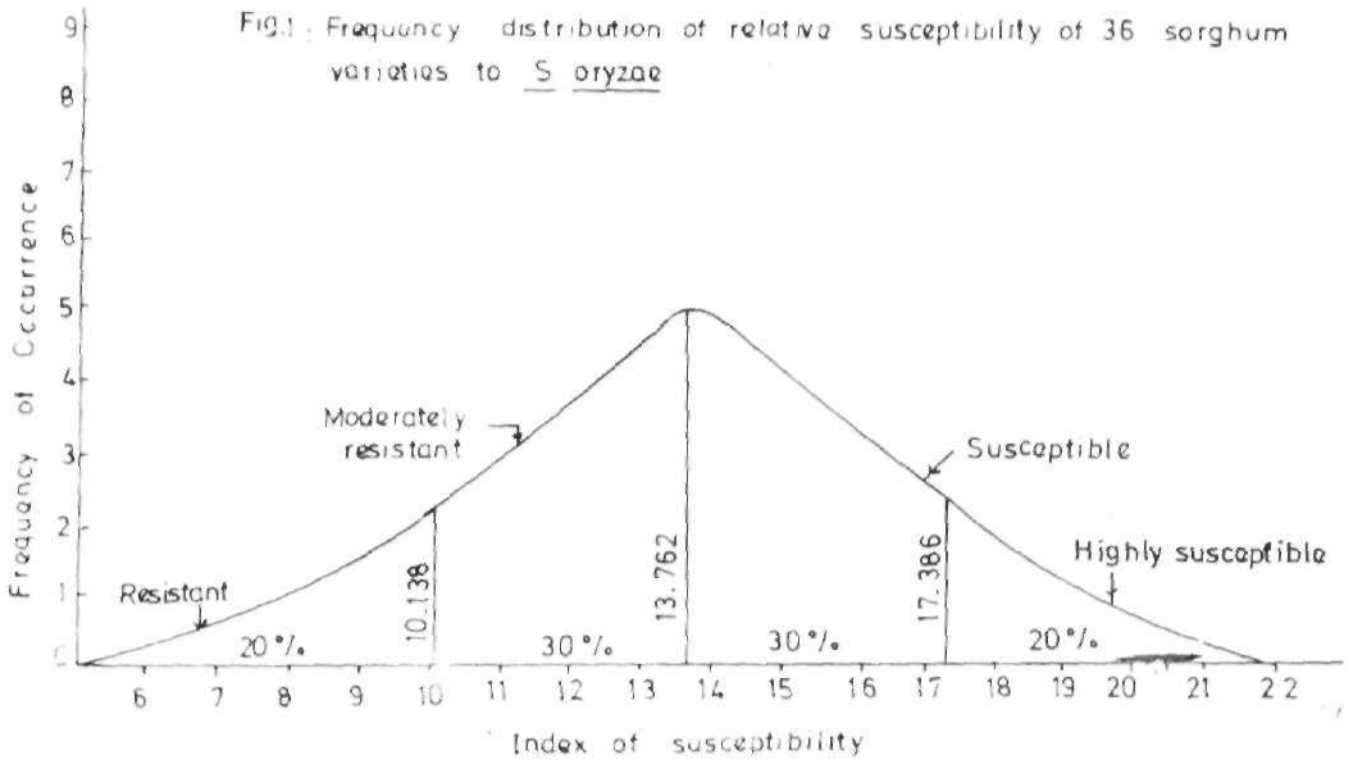


Fig 2 Resistance scale developed on a normal distribution curve

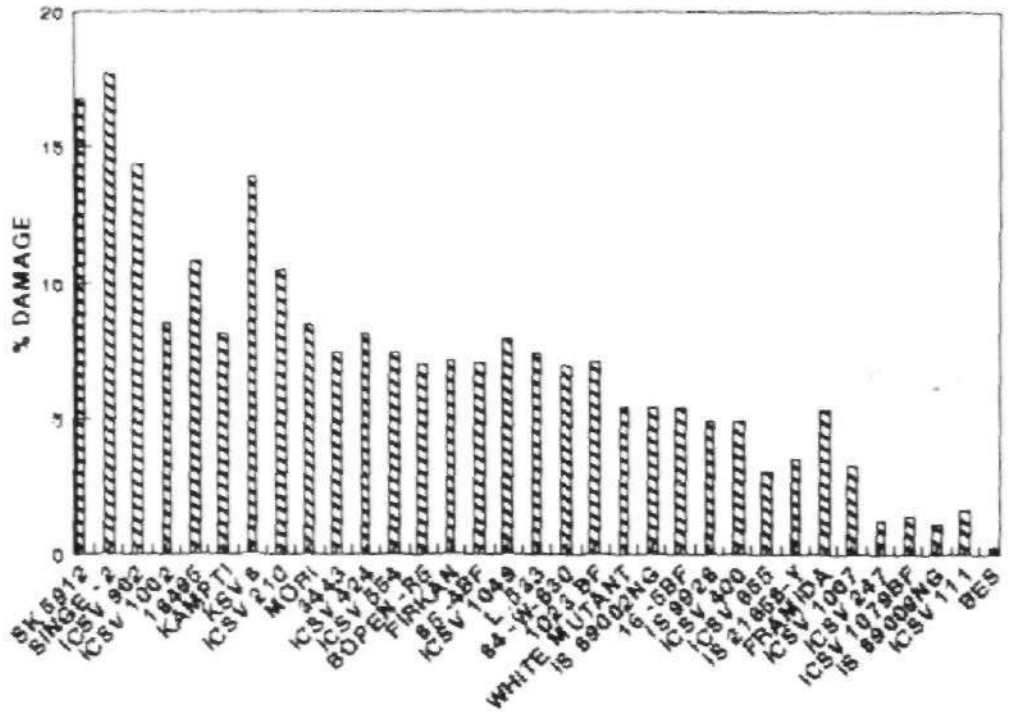
Fig. 1 is a frequency histogram based on the index of susceptibility determined for the 36 sorghum varieties. Generally, the data is almost normally distributed with a mean of 13.76 and a standard deviation of 2.52 but slightly skewed towards the higher indices. For convenience, however, a normal distribution curve was superimposed on the histogram which was then used to classify the varieties into four groups ranging from resistant to highly susceptible (Fig.2), according to Dobie (1977). Those varieties of sorghum with an index of susceptibility less than 10.14, representing the lower 20% of the observations were regarded as resistant. Those with index of susceptibility between 10.15 and 13.76, representing the next 30% of the observations (i.e. 20> 50%) were regarded as moderately resistant. The varieties with index of susceptibility between 13.77 and 17.39, representing the next 30% of the observations (i.e. 50>80%) were regarded as susceptible. Those with index of susceptibility over 17.40, representing the upper 20% of the observation (i.e. 80> 100%) were regarded as highly susceptible (Dobie, 1977)

4.5 Percentage Damage

The percentage of seeds that sustained damage as shown in Table 1 ranged from 0.3 for variety BES to 17.74 for variety singe-2 S.oryzae caused greatest damage to the varieties singe-2 and SK5912, the former sustaining greater damage ($P<0.05$). Following these were the varieties ICSV902NG and

KSV8 which sustained similar damage among themselves but which was higher than that in the varieties 18495 and ICSV210. Next were the varieties 84-5-130 and ICSV905NG which had higher damage than the varieties ICSV1002, Mori, Singe-1, Kampti, and ICSV424. After that, were the varieties ICSV1049, ICSV554, 3443, and L.533 with similar damage which in turn was higher ($P<0.05$) than that in the varieties Firkan, 1023BF, 85-4BF, Bopen-R5 and 84-W-830. Similarly the varieties White Mutant, 16-5BF, ICSH89002NG, Framida, ICSV400 and IS9928 with similar damage among them were more affected ($P<0.05$) than the varieties IS21658-Y, ICSV1007BF, and ICSV655. The varieties ICSVIII, ICSV1079BF, ICSV247 and ICSH89009NG were among the least damaged and yet sustained higher damage ($P<0.05$) than BES.

Fig. 3 is a frequency histogram of the percentage damage of the 36 sorghum varieties evaluated. Most sorghum varieties had a percentage damage between 7.00 and 7.99%.



VARIETIES

Fig: 3 Frequency Distribution of 36 Sorghum varieties in respect of damage by S. oryzae

4.6 Percentage Weight Loss

The percentage weight loss shown in Table 1 ranged from 0.13 for variety BES to 9.08 for variety singe-2. The varieties singe-2 SK5912, ICSV902NG, KSV 8, 18495 and ICSV210 generally lost the most weight but each lost more weight ($P<0.05$) than the others in a descending order. The varieties 84-5-130, ICSV905NG, ICSV1002, Mori, Singe-1, and Kampti sustained similar weight loss but which was more than the varieties ICSV554, ICSV1094, 3443, L.533 and Firkan ($P<0.05$). The varieties 16-5BF, ICSV400, Framida, and ICSV655 had similar weight loss among them as did the varieties ICSV1079BF, ICSVIII, and ICSV247. The latter group, however, had a greater loss of seed weight than ICSH 89009NG and BES.

Figure 4 is a frequency histogram of the 36 sorghum cultivars evaluated in respect of loss of seed weight through insect feeding. It shows that eight varieties suffered a weight loss of 4.00 to 4.99% and seven others suffered a weight loss of between 1.00 and 1.99% Only five varieties suffered a weight loss of less than 1%.

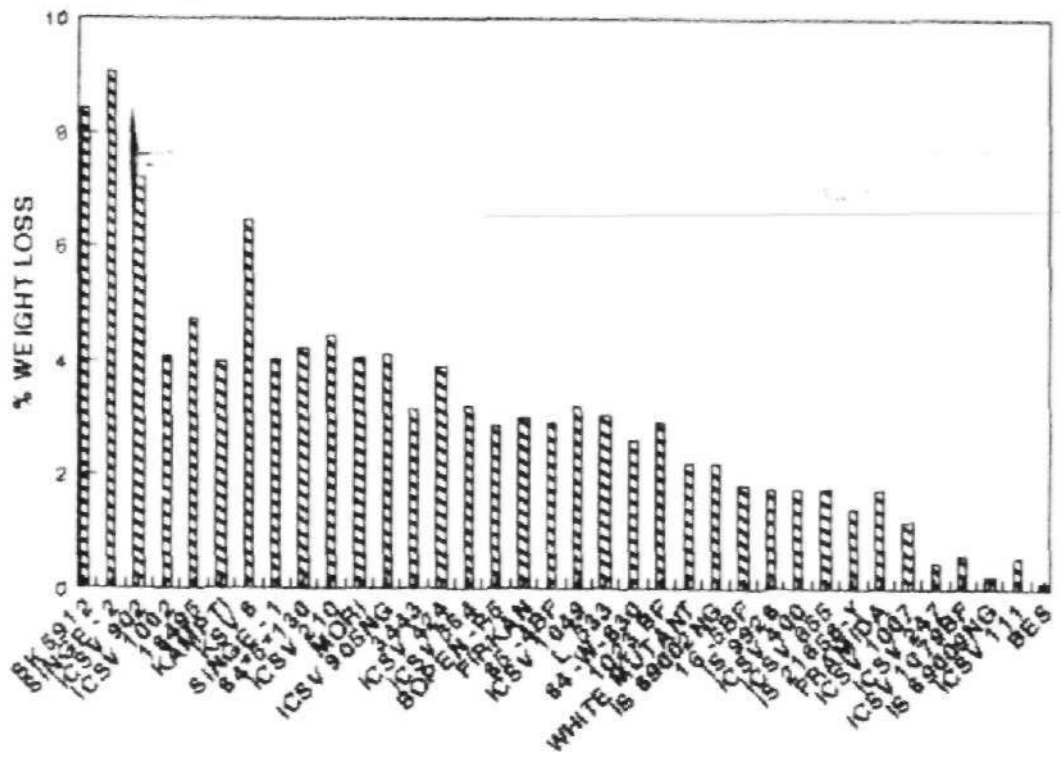


Fig. 4 Frequency distribution of 36 Sorghum varieties in respect of weight loss by S. oryzae

TABLE 2: BIOCHEMICAL COMPOSITION OF SORGHUM VARIETIES (in %)

	CHO	ASH	PROT	FAT	FIB	TAN	MOIST	PHY
KSV8	77.52	1.75	15.88	4.17	0.68	0.05	9.81	5.06
ICSV1007	80.05	0.39	13.13	6.23	[illegible]0	0.01	9.79	4.96
IS[illegible]009NG	83.19	1.07	10.25	5.02	0.47	0.05	9.52	4.96
[illegible]	81.23	1.61	10.81	5.48	0.87	0.01	10.11	5.79
IS89002NG	82.20	0.70	11.50	5.02	0.36	0.01	9.21	6.21
ICSV400	82.20	0.31	11.50	5.74	0.25	0.05	9.55	4.76
FRAMIDA	81.85	0.23	12.31	5.49	0.12	0.07	9.88	6.21
MORI	84.13	0.89	11.19	3.48	0.31	0.08	9.92	6.21
W/MUTANT	81.36	0.15	14.06	4.33	0.10	0.01	9.58	6.00
ICSV210	85.61	0.25	10.94	3.02	0.18	0.01	9.78	5.38
ICSV247	80.48	0.33	13.50	5.46	0.23	0.05	9.51	4.96
ICV1079BF	85.14	0.67	10.63	3.34	0.22	0.05	9.46	6.00
L.533	85.60	0.17	10.56	3.51	0.16	0.05	11.43	6.62
SK5912	85.91	0.79	8.63	4.27	0.40	0.01	11.16	6.00
16-5BF	83.87	0.87	9.38	5.29	0.59	0.01	9.70	5.79
ICSV1049	81.77	1.15	11.38	4.80	0.90	0.05	9.86	5.06
18495	81.39	1.45	10.88	5.62	0.66	0.01	9.40	5.06
ICSV1002	82.15	0 25	10.63	6.82	0.15	0.01	9.90	4 34
BOPEN-R5	81.08	1.08	9.69	7.56	0.59	0.19	9.33	5.38
ICSV554	82.98	0.73	11.19	4.72	0.38	0.01	9.37	4.55
ICSV424	84.71	1.20	10.50	3.01	0.58	0.23	9.22	5.06
ICSVIII	85.12	0.33	11.13	3.27	0.15	0.01	9.80	5.06
SINGE-2	79.59	0.[illegible]4	10.56	8.11	0.80	0.01	9.51	4.76
FIRKAN	84.12	0. 6	9.69	5.02	0.41	0.01	9.30	5.59
SINGE-1	85.94	0.75	8.31	4.80	0.20	0.01	9.41	5.06
3443	86.59	0.43	7.76	4.92	0.30	0.05	10.94	6.21
KAMPTI	79.25	0.98	13.31	5.92	0.54	0.01	10.17	5.59
84-5-130	81.83	1.10	11.06	5.60	0.41	0.01	10.61	2.07
ICSV655	83.11	0.86	10.19	5.26	0.58	0.01	9.60	5.06
85-4BF	83.08	1.01	10.31	4.87	0.73	0.01	10.06	5.06
IS9928	81.44	1.04	12.75	4.00	0.77	0.01	10.97	5.79
IS21658-Y	85.15	0.36	10.75	3.45	0.29	0.01	10.69	5.79
1023BF	82.45	0.51	12.38	4.37	0.29	0.05	10.86	6.83
84-W-830	84.62	0.31	9.19	5.75	0.13	0.01	10.40	4.55
ICSV905NG	81.90	0.27	12.75	4.93	0.15	0.05	9.87	5.79
ICSV902NG	82.32	0.45	13.69	3.17	0.34	0.01	10.16	5.38

CHO = Carbohydrate, PROT = Protein, FIB = Fibre,

TAN = Tannin, PHY = Phytic Acid and MOIST = Moisture Content

4.7 Biochemical Composition of Grains of the Sorghum Varieties.

The biochemical composition of the grains of 36 sorghum varieties is given in Table 2.

4.7.1 Percentage Carbohydrate Content

The percentage carbohydrate contents for the 36 sorghum varieties analysed ranged from 77.52-86.59%. Variety KSV8 had the least carbohydrate content while variety 3443 had the highest carbohydrate content.

4.7.2 Percentage Ash Content

The percentage ash for all the sorghum varieties analysed ranged from 0.15-1.75%. Variety White Mutant had the least ash content while variety KSV8 had the highest ash content.

4.7.3 Percentage Protein Content

For all the 36 sorghum varieties analysed for their biochemical composition, the percentage protein ranged from 7.76-15.88%. The variety with the least percentage protein was 3443 while variety KSV8 had the highest protein content.

4.7.4 Percentage Lipid (Fat) Content

The range for the percentage lipid in the 36 sorghum varieties was from 3.01-8.11%. Variety ICSV424 had the least lipid content.

4.7.5 Percentage Fibre Content

The percentage fibre content for all the 36 sorghum varieties analysed ranged from 0.01-0.90%. The least fibre content was found in variety White Mutant while the highest was found in variety ICSV1049.

4.7.6 Percentage Tannins Content

For the 36 sorghum grain varieties analysed the range of the percentage Tannins was from 0.01-0.23%. The percentage Tannins was generally low, with 22 varieties having 0.01% Tannins, while variety ICSV424 (a red-coated seeds) had the highest Tannins content.

4.7.7 Percentage Phytic Acid Content

The percentage phytic acid content ranged from 2.07-6.83%. Variety 84-5-130 had the least phytic acid content while variety 1023BF had the highest percentage phytic acid.

4.7.8 Percentage Moisture Content

The percentage moisture content before infestation ranged from 9.21-11.43%. The least percentage moisture content was found in variety ICSH89002NG while the highest was found in variety L.533. After infestation, the range of the moisture content was from 9.33-11.62%. The lowest percentage moisture content was recorded in variety ICSH89009NG while the highest was found in variety SINGE-2.

TABLE 3: ASSESSMENT OF SORGHUM GRAIN HARDNESS

S/No.	Varieties	Flour(filtrate)	Fragments (residue)
1	KSV8	10.31ijklm	8.46pqrs
2	ICSV 1007BF	9.80pq	8.23t
3	ICSH89009NG	8.14wx	10.55d
4	BES	9.09st	10.73d
5	ICSH89002NG	10.09mnop	9.21fgh
6	ICSV400	9.36rs	8.95jk
7	FRAMIDA	9.19st	8.73lmn
8	MORI	10.52efghij	8.93jkl
9	WHITE MUTANT	9.94nopq	9.18fghi
10	ICSV210	11.82a	8.43qrst
11	ICSV247	8.90tu	11.54b
12	ICSV1079BF	8.03x	11.99a
13	L.533	9.13st	8.63mnop
14	SK5912	11.23bc	9.00ijk
15	16-5BF	9.33s	8.81klm
16	ICSV 1049	10.68defg	8.71mno
17	18495	10.62defghi	8.71mno
18	ICSV1002	10.67defg	8.55nopq
19	BOPEN-R5	10.48fghijk	9.63e
20	ICSV 554	10.77def	9.31fg
21	ICSV424	10.40ghijklm	8.29st
22	ICSV111	8.46vm	11.14c
23	SINGE-2	11.30B	8.42qrst
24	FIRKAN	10.83de	9.16ghi
25	SINGE-1	10.33hijklm	9.36fg
26	3443	10.26jklmn	9.61e
27	KAMPTI	10.43fghijkl	8.52opqr
28	84-5-130	10.15klmno	8.93jk
29	ICSV655	9.70qr	9.38f
30	85-4BF	9.75q	9.10hij
31	IS 9928	9.83opq	9.33fg
32	IS 21658-Y	8.68uv	8.32rst
33	1023BF	10.65defgh	9.08hij
34	84-W-830	10.41ghijklm	8.73lmn
35	ICSV905NG	10.11lmnop	9.03hij
36	ICSV902NG	11.26b	8.32rst

Values followed by the same letter(s) are not significantly different at P<0.05.

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4.8 Grain Hardness of Sorghum Varieties.

The results on the determination of grain hardness (Table 3) showed that sorghum varieties ICSVIII, BES, ICSV1079BF and ICSH89009NG appeared to be harder than all the other grains. These sorghum varieties with harder endosperms (corneous endosperm) fragmented on grinding suggesting that they are harder. Varieties singe-2, SK 5912, Mori, ICSV902NG ICSV1002, KSV8, 84-W-830, 18495 and ICSV210 were relatively softer (floury endosperm). These varieties became finely crushed during grinding suggesting that they are softer than the former group.

4.9 *Effect of Colour and Texture of the Seed Coat and Seed* Size on Preference Behaviour of *Sitophilus oryzae*.

The effect of seed-coat colour, seed-coat texture and seed size on the preference behaviour of *S.oryzae* were examined and given in Tables 4, 5, and 6. For seed-coat colour, a white (KSV8) variety was found with more *S.oryzae* followed by a red (Framida) variety. The other three colours (variegated, dark brown and yellow) had almost the same number of insects. For seed-coat texture, a warty coated texture variety had more insects, followed by a rough texture seed. The moderately smooth (Firkan) and moderately rough-seeded varieties had the same number of insects. A smooth-seeded varieties (Singe-2) had the least number of insects. For seed size varieties with very large, large and medium sized seeds

had decreasing number of *S.oryzae* in that order while a variety with very small seeds had the least number of insects.

The result (Tables 4, 5,and 6) showed that there was no significant difference between the treatments in each of the three parameters i.e colour, texture and seed size. Except for seed-size, where insects preferred large seeded grains, the insects seemed to move to the various sorghum colours and texture, indiscriminately without preference to colour or texture.

TABLE 4: EFFECT OF COLOUR OF SEED COAT ON THE BEHAVIOUR OF *S. ORYZAE*

S.NO	CHARACTER/VARIETY	NO OF INSECTS ATTRACTED
1	VARIEGATED (WHITE MUTANT)	4.00c
2	RED (FRAMIDA)	8.67ab
3	DARK BROWN (ICSV1007BF)	5.67bc
4	WHITE (KSV8)	10.00a
5	YELLOW (SK5912)	5.00c

TABLE 5 EFFECT OF GRAIN SIZE ON THE BEHAVIOUR OF *S.ORYZAE*

1	VERY LARGE ICSV905NG)	6.67a
2	LARGE (16-5BF)	9.33a
3	MEDIUM (ICSV 210)	9.00ab
4	SMALL (L.533)	3.00b
5	VERY SMALL (ICSV247)	2.33b

TABLE 6 EFFECT OF SEED COAT TEXTURE ON THE BEHAVIOUR OF *S. ORYZAE*

1	ROUGH (ICSV1049)	9.00ab
2	SMOOTH (SINGE-2)	3.33c
3	MODERATELY SMOOTH (FIRKAN)	5.67bc
4	MODERATELY ROUGH (IS21658-Y)	5.33c
5	WARTY (ICSV 655)	11.00a

Values followed by the same letter are not significantly different at P=0.05.

4.10 Correlation Analysis of the Candidate Factors of Resistance of Sorghum Grains to *S.oryzae*.

Result of a correlation analysis of the parameters in Tables 1, 2, and 3 are shown in Table 7. The results show that there was a negative, significant correlation (r= - 0.251 p= 0.05) between carbohydrate and median developmental period (r= - 0.251,p=0.05). There was significant positive correlation between percentage protein and median developmental period (r=0.363,p=0.0.5). however, % protein correlated negatively with index of susceptibility (r=-0.131,P=0.05). There was significant negative correlation between moisture content and median developmental period (r=-0.319,P=0.05). There was significanly negative correlation between grain hardness and F1 adult emergence (r=-.759,p=0.05), index of susceptibility (r=-.809,p0.05), percentage damage (r=-.779,p=0.05), and percentage weight loss (r=-.717,p=0.05). There was however a significant positive correlation between grain hardness and median developmental period (r=.466,p=0.05). The F1 adult emergence was significantly and negatively correlated with median developmental period (r=-.470,p=0.05). This is represented by a regression graph (Figure 5). There was, however, a positive and significant correlation between F1 adult emergence and index of susceptibility (r=.876,P=0.05), percentage damage (r=.973,P=0.05), and percentage weight loss (r=.967,P=0.05).(see regression graphs in Figures 6,7 and 8).

A significant negative correlation existed between median developmental period and index of susceptibility (r=-.756,P=0.05), percentage damage (r=-.501,P=0.05), and percentage weight loss (r=-.427,P=0.05). There was a positive significant correlation between index of susceptibility and percentage damage (r=.901,P=0.05) and percentage weight loss (r=.846,P=0.05). A positive significant correlation existed between percentage damage and percentage weight loss (r=.948,P=0.05). All the biochemical components of the 36 sorghum grain varieties analysed were non-significantly correlated with index of susceptibility (r=.037,064,.....P=0.05), percentage damage, percentage weight loss and F1 adult emergence at the 5% and 1% levels.

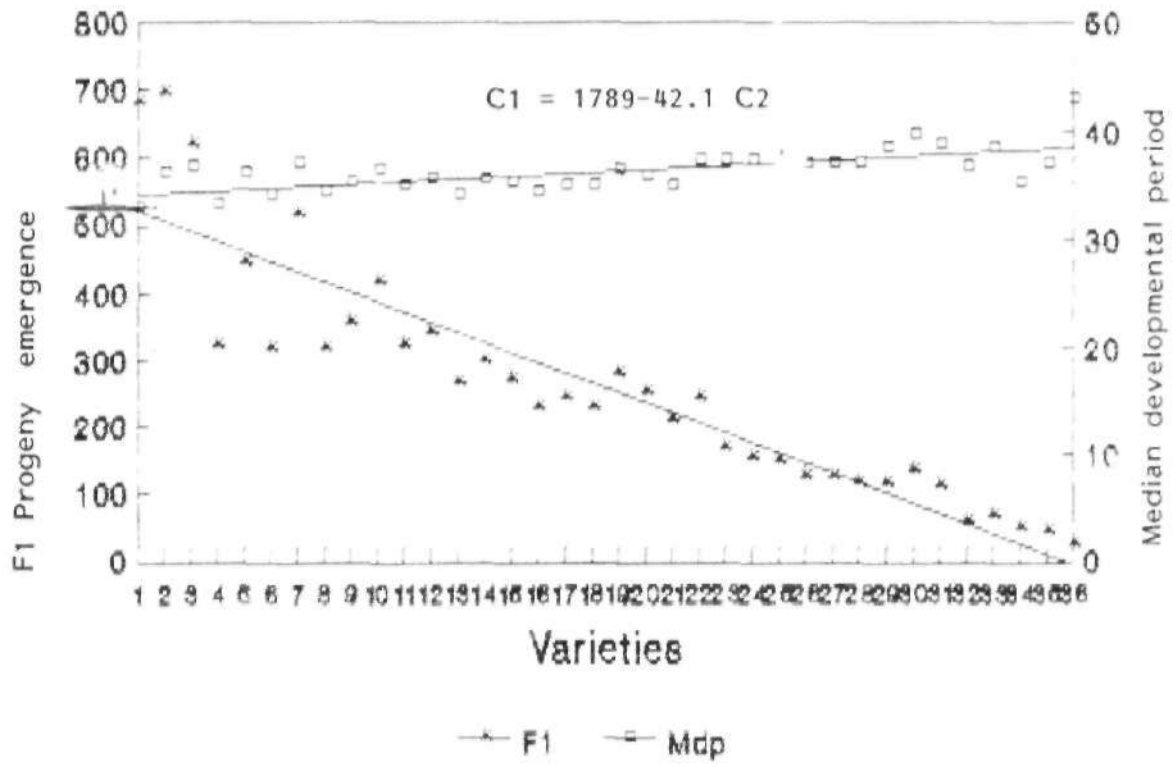


Fig 5 Regression graph between F1 adult emergence and median developmental period of S.oryzae

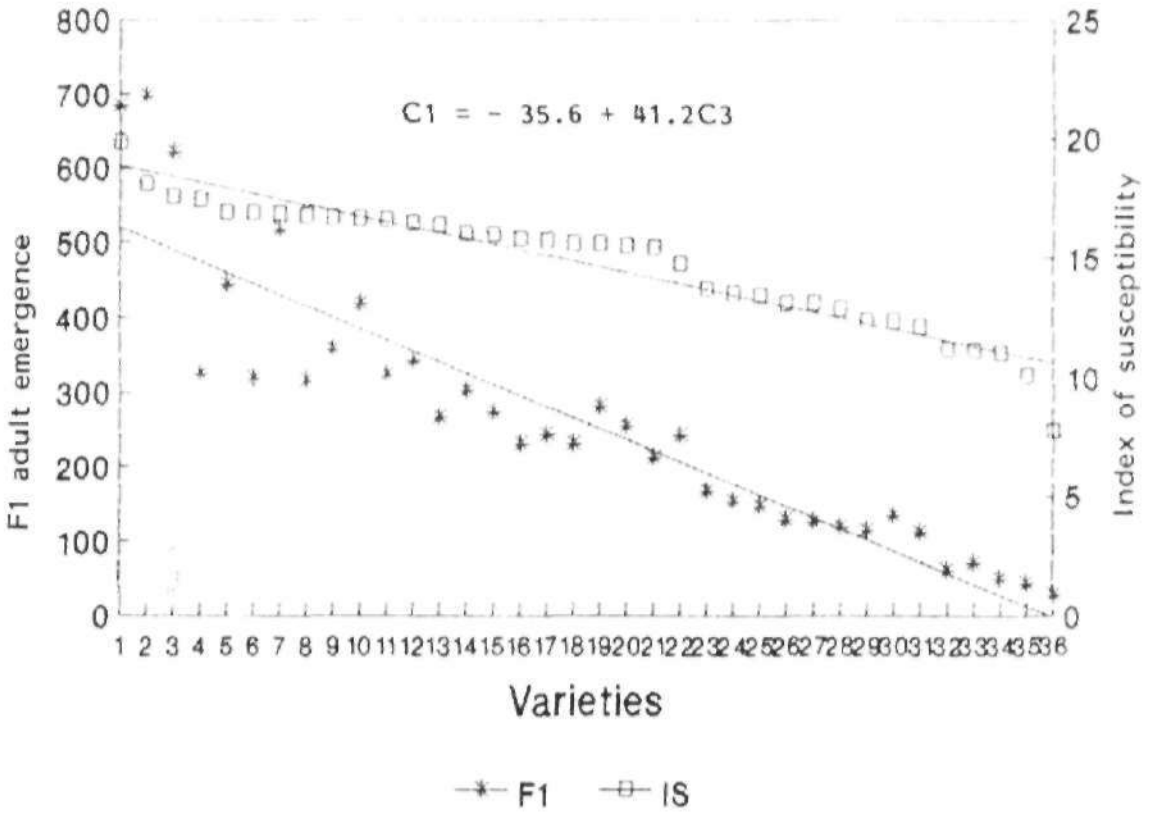


Fig 6 Regression graph between F1 adult emergence of S. oryzae and index of susceptibility of the sorghum varieities.

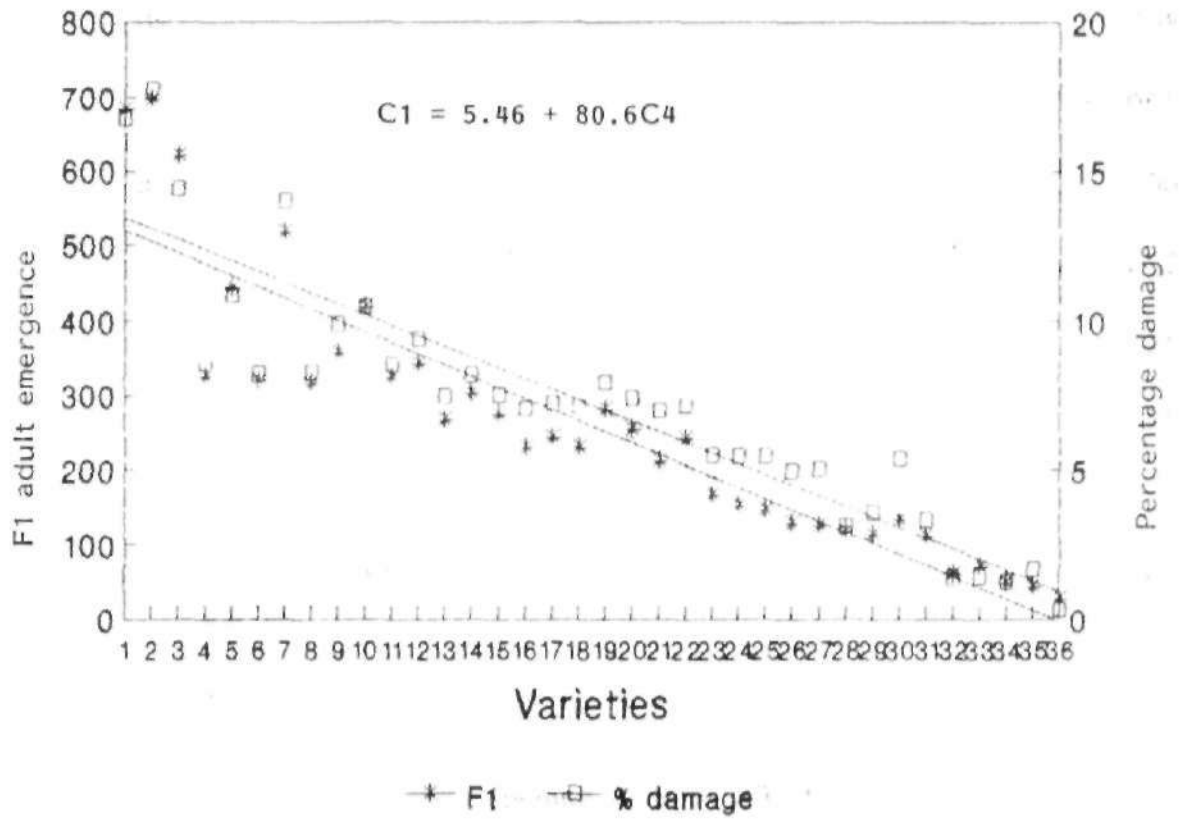


Fig 7 Regression graph between F1 adult emergence of S. oryzae and percentage damage of sorghum varieties.

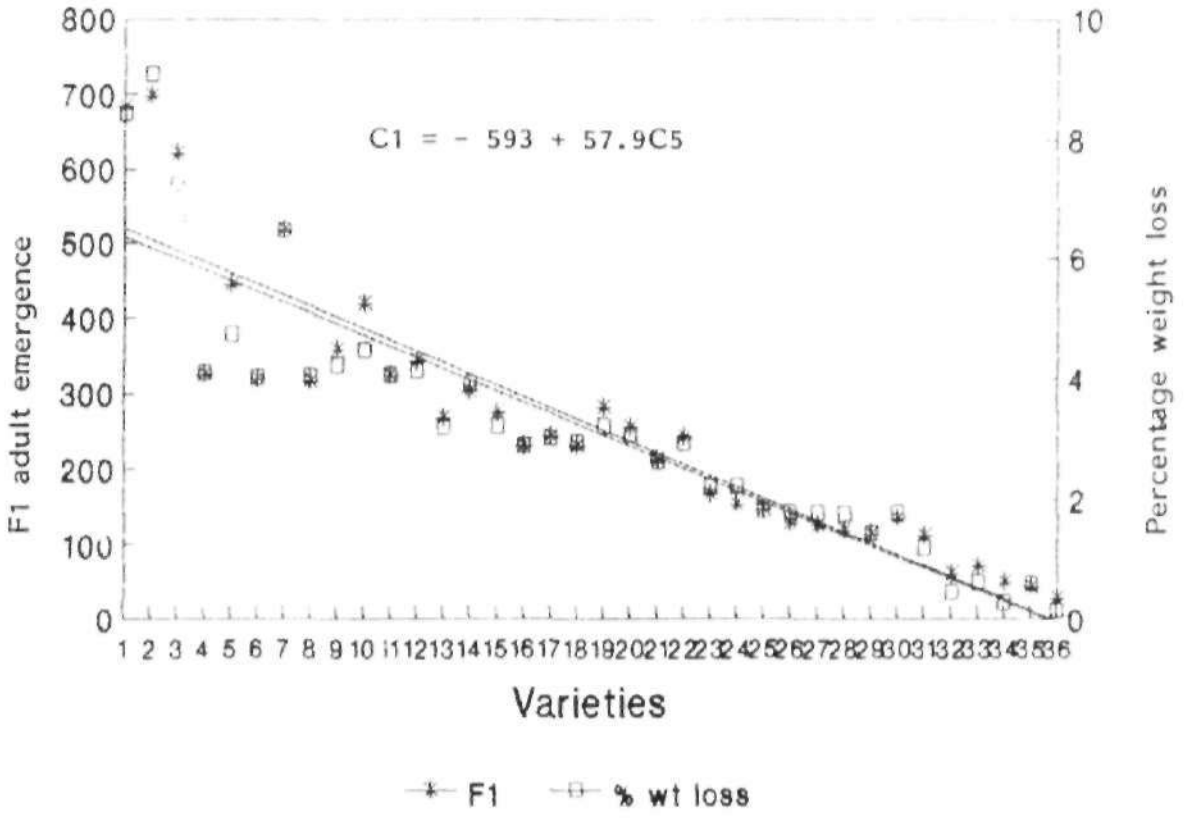


Fig 8 Regression graph between F1 adult emergence of S. oryzae and percentage weight loss of sorghum varieties.

TABLE 7

CORRELATION ANALYSIS RESULT FOR BIOCHEMICAL COMPOSITION, GRAIN HARDNESS AND PARAMETERS ON TABLE 1.

	CHO	ASH	PROT	LIPID	FIB	TAN	MOIST	PHYA	F_1AE	MDP	IS	%D	%WL
ASH	-0.376												
PRO	-0.731	0.011											
LIPID	-0.521	0.131	-0.124										
FIBRE	-0.398	0.857	-0.018	0.233									
TANNIN	0.025	0.177	-0.054	-0.047	0.087								
MOIST	0.163	0.120	-0.136	-0.169	0.160	-0.192							
PHY A	0.235	-0.213	0.025	-0.349	-0.124	0.111	-0.082						
F1 AE	-0.103	0.187	0.019	0.055	0.175	-0.050	0.169	-0.133					
MDP	-0.251	0.069	0.363	-0.116	0.114	-0.108	-0.319	0.230	-0.470				
IS	0.037	0.064	-0.131	0.087	0.043	0.053	0.206	-0.149	0.876	-0.756			
%D	-0.101	0.144	-0.005	0.104	0.146	-0.040	0.137	-0.145	0.973	-0.501	0.901		
%WL	-0.171	0.151	0.061	0.132	0.151	-0.059	0.160	-0.143	0.967	-0.427	0.846	0.948	
GH	-0.092	0.105	-0.046	0.159	0.154	-0.016	0.150	-0.111	-0.759	+0.466	-0.809	-0.779	-0.711

KEY:

CHO	=	Carbohydrate Content,
PRO	=	Protein Content,
MOIST	=	Moisture Content
PHY A	=	Phytic Acid
F1 AE	=	F1 Adult Emergence
MDP	=	Median Developmental Period
IS	=	Index of Susceptibility
%D	=	Percentage Damage
%WL	=	Percentage Weight Loss

CHAPTER FIVE

5.0 DISCUSSION

5.1 Introduction

The results of the present work showed a wide variability between the cultivars with respect to the numbers of F1 adults emerging, median developmental period, index of susceptibility, seed damage, weight loss of seeds, biochemical composition, and grain hardness.

These taken together, reflect the inherent ability of a particular cultivar to resist pest attack. These may be largely attributed to the differences in the physical characters and biochemical composition among the grains of the different sorghum cultivars.

That the sorghum varieties BES ICSH89009NG, ICSV247, ICSV1079BF and ICSVIII had few adult insects developing from them may be said to be a reflection of their resistance to *S.oryzae*. In contrast, varieties Singe-2,SK5912, ICSV902NG, KSV8,18495 and ICSV210 which supported more *S.oryzae* populations may therefore be regarded as susceptible. These results show some correlation (though not significant) with some of the biochemical components of the different sorghum cultivars in the present work.

It is clear from the results of the median developmental period that varieties with high F1 adult emergence like Singe-2, SK5912, and others had short median developmental

periods. The grains of such varieties are softer, thus the developing larvae has a comfortable environment for development. The larvae find it easier eating softer grains, thus, they consume a lot and develop faster (Dobie, 1977). Adetunji (1988) found that in sorghum seeds oviposition is related to susceptibility. This may be the possible explanation for SK5912 having the shortest median developmental period of 32.97 days because it had softer grains (Table 3).

Varieties like BES had the least number of F1 progenies and also had the longest median developmental period of 42.97 days. It appears that the resistant varieties like BES, ICSV1079BF, ICSV247, ICSVIII, and ICSH89009NG will not allow the female S.oryzae easy penetration of the grains. The insect will require more time to bore or drill the hole before laying the egg in the resistant varieties than in the susceptible varieties. Thus, the ease with which the adult weevil can feed may determine the rate of oviposition. Dobie (1984) and Saxena (1987) reported that resistant sorghum cultivars cause reduction in the rate of oviposition and/or cause a high mortality of the developing insect pests. Resistant sorghum varieties are nutritionally poorer than susceptible varieties and developmental period takes longer in them (Adetunji, 1988 & 1990). It does appear that the mechanisms of resistance most act upon the larvae developing in the sorghum endosperm. That fewer insects emerge may be as

a result of greater mortality of the developing larvae. This manifests itself as an increase in the length of the development period of the larvae (Dobie, 1977). The condition within the grain is perhaps not comfortable, thus the developing larvae feed less, requiring more time to complete its development. This is the probable explanation for the long median developmental period in the resistant varieties.

Dobie (1977) reported that the index of susceptibility of a meterial to a pest is proportional to the intrinsic rate of increase of population of the pest breeding upon the material. He found that for each parent insect(*Sitophilus spp*) infesting a variety of maize, the logarithm of the number of adult insects developing from the original insect will be proportional to the index of susceptibility of the variety. The index of susceptibility can thus be used as a means of classifying materials into group of similar susceptibility.

In sorghum storage, the number of *S.oryzae* present at any time will depend upon the initial population of the insect at the start of the experiment and the rate of multiplication of the insect within the stored crop. The rate of multiplication of the insect depends upon the ambient temperature, the moisture content of the sorghum and upon the suitability of the sorghum grain for the reproduction of the insect. The number of eggs laid and the time taken to complete development may all differ on samples of different varieties of sorghum (Dobie, 1974).

Those varieties with lower index of susceptibility values, like BES, ICSVIII, ICSV1079BF, ICSH89009NG and ICSV247 may be considered to have a high level of resistance to *S.oryzae* infestation. These resistant varieties can be stored for longer periods without fear of insect infestation. The varieties with higher index of susceptibility like SK5912, SINGE-2, ICSV902NG, KSV8, ICSV1002,18495 were considered to be susceptible. These susceptible varieties can only be stored for longer period with the help of preserving materials.

That the varieties with high index of susceptibility had shorter periods for completion of the development of the insects whilst those with low index of susceptibility had longer periods within which development of insects was completed agrees with Dobie (1984) who reported that resistant maize cultivars extend the developmental period of insect pests. It can be concluded that if resistant sorghum varieties extend the developmental period and cause a high mortality of the developing insect pests, the post-harvest loss incured during storage of farm produce will be greatly minimized.

The result obtained in this work (Table 1) showed a significant difference in damage between the different sorghum varieties. Most sorghum varieties had a grain damage of between 7.0-7.9% within a storage period of 50 days. The highest percentage grain damage was recorded in variety SINGE-2 which had a grain damage of 17.74%. Those sorghum

varieties with high percentage grain damage like singe-2 SK5912, ICSV902NG, KSV8, Mori, ICSV1002 also had high numbers of F1 progenies. It is therefore not surprising that these same varieties had more grains with emergence holes (i.e. higher percentage of damage grains). Those varieties that suffered less grain damage like BES, ICSV247, ICSVIII, ICSH89009NG and ICSV1079BF had few F1 progenies and few emergence holes. This latter group of sorghum varieties which were considered as resistant may be stored unprotected for longer periods than the former group which are susceptible. The results also show that varieties with higher indices of susceptibility tended to also have higher levels of damage and vice versa.

Ibitoye (1981) reported that losses in weight are affected by such factors as the voraciousness of the insect attacking the grain, the stage of the insect, the general environmental conditions of the stored grain, the grain type and length of storage, among others. In this work the weight loss was only assessed at the end of the experiment i.e after 50 days of storage. The percentage weight loss was found to be positively correlated with the number of F1 adult emergence. Any sorghum variety that supported and allowed very many insects (*S.oryzae*) to develop in it would be expected to suffer more weight loss.

Those sorghum varieties that are considered to be resistant in this work include ICSVIII, ICSV247, BES,

ICSV1079BF and ICSH89009NG. They supported few insects (*S.oryzae*) developing from them and thus, suffered less weight loss as a result of *S.oryzae* feeding. This may be explained by the fact that resistant sorghum grains are said to contain some toxic alkaloids and insect feeding deterrents which may prevent the larvae from feeding, thus starving them to death (Adesuyi, 1979). This is probably the reason why these resistant sorghum grains had few emergence holes. The varieties identified through the susceptibility index as susceptible in this work including Singe-2, SK5912, ICSV902NG, Mori, ICSV210, KSV8 lso suspported more F1 adult emergence and suffered more weight loss.

Adesuyi (1979) reported that factors known to be responsible for the resistance of store products to attack by insects e.g *S.oryzae* included presence of toxic alkaloids or amino acids in some stored products, insect feeding deterrents, seed coat charactaristics that discourage oviposition, digestive enzyme inhibitors and kernel hardness.

The 36 sorghum grain samples screened in this work were analysed for their biochemical composition and grain hardness the effect of seed coat colour, seed coat texture and seed size on preference behaviour of *S.oryzae* was determined to identify the possible mechanism of resistance to *S.oryzae* damage in some sorghum grain cultivars.

The result indicated non-significant correlations between carbohydrates, protein, lipids, ash, fibre, tannin and phytic

acid contents and index of susceptibility. This result does agree with Singh and McCain (1963) who had earlier reported positive correlations between higher sugar and starch levels with weevil (*Sitophilus spp*) numbers. This means that high sugar and starch contents of the grains reduces weevils number and thus reduces the susceptibility of the sorghum grains. In this work, there was a correlation between % protein and index of susceptibility. This result agrees with Adesiyun (1990) who found that differences in essential amino acid content of sorghum seeds are related to susceptibility. Simmonds et al 1973) reported that in wheat, the factor responsible for grain hardness is the strength of the protein-starch bond. They also found the tightness of adhesion between protein matrix and starch granules to be implicated in determining grain hardness.

High tannin content in some sorghum varieties, especially the guinea race (red-coloured pericarp) have been reported to offer resistance to birds and probably moulds (Doggett, 1957;Rooney and Miller, 1981). The red-pericaped sorghum varieties particularly ICSV424, were found to be susceptible to *S.oryzae* (Table 1). However, another red-pericarped variety, framida, was found to be moderately resistant. It does appear from the present work that biochemical components of the sorghum grains play some role in the resistance of sorghum grains to *S.oryzae*.

The result showed that when *S.oryzae* had choice, there

was preference for white coloured grains, warty textured grains and large-seeded grains. This however does not explain the high indices of susceptibily recorded in those varieties that fall within the range of these groups of physical characteristic. This is because in the actual experiment for screening the grain samples for resistance, the insect (*S.oryzae*) never had a choice. Although the varieties identified through the susceptibility index as susceptible were all white coloured, except for SK5912. There was over-all preference for large seeded grains. This agrees with earlier workers who reported that grain size influenced oviposition, the larger the grains, the more the eggs deposited (Doggett, 1957, Russell, 1962).

All the sorghum varieties identified in the present work as having hard grains (corneous endosperm) were also found to be resistant to *S.oryzae*. Those varieties identified here as having soft grains (floury endosperm) were also found in the present study to be susceptible to *S.oryzae*. The results obtained from the determination of grain hardness of the sorghum grains in this work, agrees with the results of Dobie (1974) who found harder maze grains to be resistant to *S.zeamais*. The results also agrees with other workers who worked on other varieties of sorghum and in other parts of the temperate world who found harder and small seeded sorghum grains to suffer less damage than soft and large seeded sorghum grains (Doggett 1957;1958, Russell, 1962, Davey, 1965

Adetunji, 1990). It can be concluded from the foregoing reports that the most important factor responsible for resistance of sorghum grains to *S.oryzae* attack is over-all grain hardness.

5.2: Suggestions

If the agronomic qualities of sorghum varieties identified in this work as resistant, are acceptable to farmers, they should grow them as to reduce the post-harvest losses incurred. Breeders should select these good qualities fjrom the resistant varieties to be crossed with other good sorghum varieties to maintain good storage qualities.

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Appendix 1a: First Trial

S/No	CULTIVAR	Fladult emergence	Median developmental period	Index of susceptibility	% damage	% weight loss
1.	KSV 8	503.0	37.4	16.6	13.8	6.4
2.	ICSV1007BF	104.0	38.6	12.0	3.4	4.1
3.	ICSH89009NG	42.0	35.4	11.0	1.1	0.2
4.	BES	29.0	43.3	7.6	0.2	0.1
5.	ICSH89002NG	161	37.0	13.5	5.3	2.1
6.	ICSV400	133	37.1	13.0	5.0	1.6
7.	FRAMIDA	124	39.6	12.2	5.5	1.8
8.	MORI	325	35.2	16.6	8.6	4.0
9.	WHITE MUTANT	184	37.1	13.5	5.4	2.3
10.	ICSV 210	425	36.1	16.7	10.4	4.4
11.	ICSV 247	65	36.9	11.0	1.4	0.5
12.	ICSV 1079BF	73	38.2	11.0	1.3	0.5
13.	L.533	249	35.7	15.5	7.3	3.1
14.	SK 5912	679	33.1	19.7	16.7	8.3
15.	16-5BF	153	37.1	13.3	5.4	2.0
16.	ICSV 1049	277	35.5	15.6	7.8	3.1
17.	18495	448	36.2	16.7	10.5	4.4
18.	ICSV 1002	327	34.0	17.5	8.6	4.0
19.	BOPEN-R5	228	34.2	15.6	6.8	2.6
20.	ICSV 554	278	34.4	15.7	7.4	3.3
21.	ICSV 424	305	35.5	16.2	8.1	4.2
22.	ICSV 111	31	36.1	10.1	1.5	0.5
23.	SINGE-2	699	36.0	18.0	17.6	9.0
24.	FIRKAN	260	34.4	15.7	7.1	3.2
25.	SINGE-1	313	34.3	16.6	8.3	3.4
26.	3443	280	34.2	16.4	7.5	3.0
27.	KAMPTI	316	34.0	16.5	8.1	4.2
28.	84-5-130	352	35.4	16.6	10.2	4.0
29.	ICSV 655	120	37.2	12.4	3.1	1.2
30.	85-4BF	214	35.1	15.6	7.0	2.5
31.	IS 9928	130	37.0	13.0	4.5	1.4
32.	IS 21658-Y	118	38.2	12.2	3.5	1.2
33.	1023BF	245	37.4	14.8	7.0	2.0
34.	84-W-830	215	34.5	15.4	7.3	2.1
35.	ICSV 905NG	325	35.4	16.3	9.3	2.7
36.	ICSV 902NG	612	36.5	17.5	14.4	7.0

Appendix 1b: Second Trial

S/No	CULTIVAR	Fladult emergence	Median developmental period	Index of susceptibility	% damage	% weight loss
1.	KSV 8	532	36.8	17.1	14.1	6.5
2.	ICSV1007BF	117	39.2	12.1	3.2	4.2
3.	ICSH89009NG	55	35.0	11.0	1.3	0.3
4.	BES	26	42.6	7.8	0.4	0.1
5.	ICSH89002NG	144	37.4	13.4	5.5	2.3
6.	ICSV400	117	36.8	13.1	5.0	1.9
7.	FRAMIDA	144	40.1	12.4	5.3	1.7
8.	MORI	321	34.6	16.5	8.4	4.0
9.	WHITE MUTANT	148	37.7	13.8	5.6	2.1
10.	ICSV 210	413	36.6	16.5	10.5	4.5
11.	ICSV 247	54	36.5	11.2	1.2	0.3
12.	ICSV 1079BF	68	38.6	11.1	1.5	0.5
13.	L[illegible]3	261	35.9	15.4	7.5	3.0
14.	SK 5912	689	32.8	19.9	16.8	8.5
15.	16-5BF	141	37.3	13.5	5.5	1.6
16.	ICSV 1049	286	37.1	15.4	8.0	3.4
17.	18495	441	35.9	17.1	11.1	5.0
18.	ICSV 1002	322	32.4	17.3	8.5	4.1
19.	BOPEN-R5	232	34.6	16.0	7.2	3.1
20.	ICSV 554	269	36.0	16.1	7.6	3.1
21.	ICSV 424	300	35.9	15.7	8.2	3.6
22.	ICSV 111	55	38.1	10.0	1.7	0.7
23.	SINGE-2	696	36.4	18.1	17.8	9.1
24.	FIRKAN	225	35.5	15.6	7.3	2.8
25.	SINGE-1	321	34.5	16.8	8.1	4.6
26.	3443	255	34.2	16.2	7.4	3.3
27.	KAMPTI	323	34.4	16.4	8.3	3.8
28.	84-5-130	364	35.2	17.1	9.5	4.4
29.	ICSV 655	115	37.0	12.5	3.0	2.2
30.	85-4BF	245	34.7	15.5	7.2	3.3
31.	IS 9928	126	37.1	13.1	5.3	2.1
32.	IS 21658-Y	110	38.6	12.4	3.6	1.6
33.	1023BF	239	37.2	14.6	7.2	0.8
34.	84-W-830	209	35.1	15.3	6.6	3.7
35.	ICSV 905NG	360	35.5	16.6	9.4	2.5
36.	ICSV 902NG	630	36.7	17.6	14.3	7.4

Appendix 2a: Analysis of variance for the F1 progery emergence of S. oryzae on the grains of different sorghum (Sorghum bicolor) varieties.

Source of variation	DF	SS	MS	F
Between blocks	2	433.0	216.5	1.654
Between trts	35	310747[illegible].0	8867[illegible].9	67[illegible].[illegible]***
Residual	70	9162.[illegible]	130.9	
Total	105	3[illegible]5643.3	29682.2	

L.S.D = 18.68 (P=0.05)

Appendix 2b: Analysis of variance for the Median developmental period of S. oryzae on the grains of different sorghum varieties.

Source of variation	DF	SS	MS	F
Between blocks	2	0.11167	0.05583	0.983
Between trts	35	386.32004	11.03771	185.359***
Residual	70	4.16834	0.05955	
Total	105	390.48837	3.71894	

L.S.D = 0.3984 (P=0.05)

Appendix 2c: Analysis of variance for the index of susceptibility of the grains of different sorghum varieties infested with S. oryzae

Source of variation	DF	SS	MS	F
Between blocks	2	0.19797	0.09898	1.590
Between trts	35	709.86420	20.28183	325.773***
Residual	70	4.35803	0.06226	
Total	105	714.22223	6.80212	

L.S.D = 0.4074 (P=0.05)

Appendix 2d: Analysis of variance for the percentage damage of the grains of different sorghum varieties infested with S. oryzae

Source of variation	DF	SS	MS	F
Between blocks	2	0.05789	0.02895	3.108
Between trts	35	1781	50.90	5464.842***
Residual	70	0.6520	0.009314	
Total	105	1782	16.97	

L.S.D = 0.15760 (P=0.05)

Appendix 2e: Analysis of variance for the percentage weight loss of the grains of different sorghum varieties infested with *S. oryzae*

Source of variation	DF	SS	MS	F
Between blocks	2	1.3287	0.6643	0.903
Between trts	35	461.9876	13.1996	17.950***
Residual	70	51.4751	0.7354	
Total	105	513.4627	4.8901	

L.S.D = 1.4004 (P=0.05)

Appendix 3a: Analysis of variance for grain hardness of the grains of different sorghum varieties.

Source of variation	DF	SS	MS	F
Between blocks	2	0.20111	0.10056	3.189
Between trts	35	83.00457	2.37156	75.219***
Residual	70	2.20702	0.03153	
Total	105	85.21159		

L.S.D = 0.29 (P=0.05)

Appendix 3b: Analysis of variance for seed coat colour and its effect on the behaviour of S. oryzae

Source of variation	DF	SS	MS	F
Between blocks	2	0.533	0.267	0.05
Between trts	4	78.000	19.500	4.02
Residual	8	38.800	4.850	
Total	12	116.800	9.733	

L.S.D = 5.596 (P=0.05)

Appendix 3c: Analysis of variance for seed size and its effect on the behaviour of S. oryzae

Source of variation	DF	SS	MS	F
Between blocks	2	0.933	0.467	0.08
Between trts	4	161.333	40.333	5.86
Residual	8	55.067	6.883	
Total	12	216.400	18.033	

L.S.D = 4.284 (P=0.05)

Appendix 3d: Analysis of variance for seed coat texture and its effect on the behaviour of S. oryzae

Source of variation	DF	SS	MS	F
Between blocks	2	0.133	0.067	0.03
Between trts	4	113.733	28.433	14.33
Residual	8	15.733	1.983	
Total	12	129.600	10.800	

L.S.D = 2.300 (P=0.05)