STUDIES ON SORGHUM (Sorghum bicolor (L.) Moench) HEADBUGS AT SAMARU, ZARIA.

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This thesis entitled "STUDIES ON SORGHUM HEADBUGS AT SAMARU-ZARIA" by Anna M Malgwi, meets the regulations governing the award of 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

This Thesis is dedicated to my Lord JESUS CHRIST, late parents Mr and Mrs E.D. Amos, husband (Dr. M.M. Malgwi), Children, (Jemima, Esther and Yadzarma) and to my brothers and sisters.

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ABSTRACT

Seven mirid headbugs were identified in this study on six sorghum varieties (ICSV 111, ICSV 247, NR 71168, NR 71182, KSV 8 and SK 5912) . They are in order of their abundance, Campvlomma spp. Odhiambo, Psallus spp., Adelphocoris apicalis Reuter, Taylorilycpas vosseleri Poppius, Creontiades pallidus Ramber and Sternotus affinis Poppius. Peak population of headbugs occurred at the middle of October and towards end of November, at the soft to medium dough stages of sorghum development. At soft dough stage, E. oldi had the highest population of 53 9.0 per 5 panicles, while C. Pallidus had the lowest population of 6.75 per 5 panicles. Campvlomma spp and Psallus spp occurred earlier in the season than the rest of the seven headbugs. Orius spp (which could be a predator on headbugs) was recorded in high numbers.

Three planting dates were also observed for avoiding severe headbugs infestation. Sorghum sown on 15 July showed less infestation of mirid headbugs (52.0 and 56.0 for 1993 and 1994, respectively) and this gave the highest grain yield of 73 0 kg/ha. More headbug numbers occurred in 24 June sown sorghum (57.0 in 1993) and on 5 August sown sorghum (76.0 in 1994) . Lower grain yields were obtained on 24 June sown sorghum (615.0 kg/ha) and 5 August sown sorghum (583.0 kg/ha), respectively.

Artificial infestation of sorghum with 15 pairs of adult E. oldi caused grain yield loss of 44.0% and 34.0% at complete anthesis and milk stage of sorghum development, respectively; while infestation with 5, 10 and 20 pairs caused lower grain yield loss. The lowest grain yield loss of 32.0% and 26.0% at the two stages, respectively, was obtained with bugs infested with 5 pairs.

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CHAPTER ONE

INTRODUCTION.

Sorghum, Sorghum bicolor (L.) Moench, originated in Africa and is the fifth most important cereal crop in the world after wheat, rice, maize and barley. It is also the staple diet of the peoples of the semi-arid tropics, especially in Africa and India (ICRISAT, 1991). It is the second most important cereal in Africa and next in importance after rice and wheat in India. It is a hardy and reliable crop that grows well under adverse conditions and in areas where maize fails to establish. The full-grown plant is 1-5m tall and like millet, the seed-bearing panicle is at the apex of the stem (Hill and Waller, 1988).

Sorghum is grown on over 40 million hectares in the world and grain yields on peasant farms are generally low (500-800kg/ha). The white grain sorghum are locally consumed in various forms, while the red grain types are used in brewing beverages; the stalks provide shelter, fuel, fodder, sugar and syrup (ICRISAT, 1991, 1992).

Insects, diseases and weeds, especially Striga spp., constitute important factors limiting grain sorghum yield and storability (Uvah and Alabi, 1989). The losses of food crops such as sorghum to pests in the developing world are enormous; estimates generally run between 25 and 50% of the expected output. A large proportion of these losses could be prevented through improved plant protection methods (Teetes, 1984).

Although there are a number of reports on different aspects of sorghum insect pests, progress has been slow because of the percieved low market value of sorghum in developing countries (Leuschner (1985). Researchers have so far paid little attention to this crop in spite of its potentials. In India, researchers found that the colour of its grain flour and quality of sugar compared to wheat maize, rice and sugar-cane or sugar beet have slowed down industrial utilization of sorghum and hence its production. Conseqently, in relation to other cereal crops like wheat, maize and rice a low priority has been given to sorghum research by the Indian government (personal communication with B.U. Singh at ICRISAT Centre India and others from National Agricultural Research Institute (NARI) Hyderabad in 1995). In Nigeria, other, reasons identified by Ayoola and Idachaba, (1990) and Aribisala, (1990) include lack of immediate grain market and industrial utilization, and sorghum being traditionally a non-traded commodity, which will now require sucessful programs in backward integration and productivity improvements.

There are over 150 insect species which damage the sorghum plant from sowing to crop harvest (Seshu Reddy and Davies, 1979). More than 100 insect pest species have been recorded in Africa, of which more than 40 are panicle-feeding pests (Nwanze, 1985; Seshu Reddy, 1991). In most of the sorghum growing areas, especially in Nigeria, the most important insect pests of sorghum, in order of their time of

infestation are the shootfly, stemborers, the sorghum midge, headworms and headbugs (Ishaku, 1987). The economic importance of each of these groups has lonh been a subject of much debate (Haris, 1961; Bowden, 1965; Young and Testes, 1977); but there is no doubt that these insects cause considerable losses in yield of the sorghum grain and in deterioration of the grain quality.

In Africa, very little is known about headbugs; there are a few isolated reports, but no detailed report on the species complex, their abundance and damage (Odhiambo, 1958; MacFarlane, 1984; Nwanze, 1985; Steck et al., 1989; Ratnadass and Ajayi, 1995). This lack of interest may have resulted from the minor economic importance that was ascribed to headbugs since most farmers grow long season and loose panicle varieties which appear to support lower populations of head insects especiatlly headbugs. In recent years, there has been increased emphasis on short season, compact - panicle and high yielding varieties to overcome major food deficits which could in a very short time make headbugs a major sorghum pest in this region (Bowden, 1965; MacFarlane, 1984; 1989). Young and Teetes (1977) stated that little research has been conducted on the nature and intensity of damage caused by panicle - feeding bugs. Bugs damage sorghum grains by injecting digestive enzymes into developing seeds and sucking the partially digested material from the grains, thereby reducing both yield and quality. Of recent, some work has

been done on African species of headbugs (Steck et al, 1989; Seshu Reddy, 1991; Sharma, 1993). In Nigeria and Mali, several workers have reported on the biology of sorghum headbugs (Doumbia, 1992; Ajayi, 1993; Ratnadass et al, 1995), chemical control and management practices (Ajayi, 1993; Ratnadass, 1993; Ratnadass and Ajayi 1995; Ratnadass et al., 1995), and their ability to utilize and develop resistant varieties of sorghum (Sharma et al., 1992; Doumbia et al, 1995; Ratnadass et al, 1995). However, most of the research efforts have concentrated on headbugs, but mostly on the predominant species, Eurystylus oldi Poppius (E. immaculatus Odhiambo).

OBJECTIVES

The objectives of this study were:

i) To determine the intra-seasonal variation in populations of sorghum headbugs, their species complex, abundance and the damage caused on panicles of six varieties of sorghum under natural infestation.

ii) To determine the effect of sowing date on headbug incidence/abundance on sorghum.

iii To determine the damage potential of the most prominent headbug, Eurystylus oldi Poppius on sorghum using the headcage technique.

iv) To elucidate the over seasoning strategy of the important headbugs on sorghum (alternate hosts).

v) To correlate sorghum plant characteristics (for example, maturity period, vitrosity, type of panicle, plant height etc.) with incidence, abundance and damage by headbugs with a view to identifying components of resistance, if any.

Niger river. Sorghum was also taken from Ethiopia to East Africa by Bushmanoid hunters and food gatherers. Sorghum was taken from East Africa to India probably during the first millennium B.C (1000 B.C) and reached China along the silk route from India early in the Christian era (about 1300 A.D). Finally, sorghum was taken from West Africa to the New World by the slave trade shortly after 1800 A.D. (Miller, 1987) and was first cultivated in the United States of America in the middle of the 19th century.

2:1.2 Geographical Distribution and Production.

In terms of production, sorghum ranks fifth on earth among cereal grains after wheat, rice, maize and barley (ICRISAT, 1991; Leuschner, 1985). Consequently, only marginal progress has been made in the developing countries in increasing yield. This is attributable to its low market value in these countries. Therefore, researchers have so far paid little attention to this crop, until of recent. It is extensively cultivated in most parts of Africa, Asia, China, Australia and North, Central and South America. It is also grown in some parts of Europe and the Soviet Union (Ishaku, 1987). It is the most important cereal in Nigeria, accounting for about 46% of the total land area devoted to the growing of cereals and about 50% of the total cereal production in the country (Egharevba, 1979). It is cultivated in all the savannah zones of the country covering between latitude 6°N

and 12 °6N. Nigeria produces more sorghum than any other country in the West African sub-region: over 6 million hectares and about 9 million metric tonnes produced annually, mostly by peasant farmers. Usual yields on peasant farms are 500kg/ha, whereas yields of 1800 to 3,000kg/ha are obtainable under improved technology (Uvah and Alabi, 1989 and NAERLS, 1996).

In Nigeria, sorghum is produced both in the dry and rainy seasons. Rainfed sorghum is the most important and consists of two types: long season types (farafara) and short season types. The former mature in about 120 - 150 days and The later mature in about 90 - 110 days. In both types, seeds are directly sown into the field early in the rainy season. The dry season sorghum, often called masakwa or firgi is first sown in nurseries in July/August. The seedlings are transplanted in September/October and harvested as from late December to early January. It is drought and cold tolerant and is grown on residual moisture within the Chad Basin in North Eastern Nigeria (Ogunlela and Obilana, 1983).

Although sorghum is tropical in origin and best suited to the tropics, it has since been adapted by breeders for growing in the temperate regions where temperatures are sufficiently high and the growing season long. It is usually grown in the temperate regions during summer and in the tropics throughout the year, when the minimum temperature ranges from 7-10 °C (for germination) and 15°C (for growth). The optimum

temperature for growth is 27-30°C (Quinby and Martins, 1954). Sorghum is a short day plant, (Hill and Waller, 1988). Its main importance as a crop has been in areas that are too dry and hot for production of other cereals, particularly maize (Ishaku, 1987). The ability of sorghum to produce good yields under conditions of low soil fertility and high temperatures that are unfavourable for other crops, like maize and rice, makes it a favourable crop under semi-arid conditions with an average annual precipitation of 600-1000mm. The drought resistance of sorghum has been attributed to its extensive root system and the profusion of rootlets as well as morphological characters of the leaves which effectively reduce the rate of transpiration (Martin, 1941).

Sorghum grows on a wide variety of soil types, but does best on heavy soils, provided they are sufficiently fertile, well aerated well drained and of good tilth (Egharevba, 1979).

2:1.3 Nigerian Races

The term 'race' is used in the broadest sense to define a group of populations in which there appears to be a constant association of characters (Curtis, 1968). This definition is similar to that of Anderson and Curtler (1942) who regarded a race as being 'a group of related individuals with enough characteristics in common to permit their recognition as a group' Curtis (1968) identified the following Nigerian races of sorghum: guinea, Kaura, farafara, Chad, Sokoto, umbellate

and tunicate races.

2:1.4 Types and Uses

Lonis and Henry (1974) classified sorghum into four types:

i The grain sorghum

ii The sorghos or sweet sorghums.

iii The grass sorghum

iv) The broom corn sorghum.

Sorghum is a staple food in the drier parts of tropical Africa, India and China. The threshed grain is ground into whole meal flour, but grinding must be done frequently as the flour tends to become rancid because the embryos are not removed. In Africa, the flour is made into porridges or a thick paste/dough by boilling in water (Purseglove, 1972). In parts of northern Nigerian, the thick dough is known as "*Tuwo*" (Hausa) with a variety of soups; the flour could be made into '*Kunu*' (Hausa) by stiring into hot water and adding either sour milk, tamarind, groundnut - paste (milky part), liquid sorghum flour paste or a combination of the above, and sugar. The grains are also soaked in water, milled into a paste and then filtered through a fine mesh sieve. The solids are then allowed to settle and the paste used to prepare poridges like '*koko*' and Kunun zaki (Hausa), "*ecomumu*" or *orgi* (Yoruba), '*modubu*' (Bura) and also into '*kafa*' (Yoruba). Other preparations in Hausaland include '*masa*', '*pinkaso*' and

'*tsatsaffa*' by mixing the milled paste with sugar and salt and fring into pancakes in groundnut or vegetable oil. In the industries, sorghum grains are milled into flour and used as composite flour for baking bread, biscuits, wafers, cakes, chinchin and other confectioneries (Aluko and Olugbemi, 1990; Olatunji et al, 1990; Idowu, 1990; Orewa and Iloh, 1990; Priyolkar, 1990; Ogundipe and Omasevwerha, 1990).

Sorghums are also popped while the sweeter grains are boiled or roasted like maize in many parts of India and Africa (personal experience).

Sorghum is widely used for brewing local beer, particularly in Africa. The dark coloured or red grain sorghums are suitable for this purpose and also valuable as dietary supplements because of their high vitamin B content (Purseglove, 1972). Asien (1990) reported that the ban in importation of barley into Nigeria in 1988 forced the breweries to use sorghum and maize as a raw material for lager beer production, as well as stout, malt-based non-alcoholic drinks, and weaning foods (Baidu-Forson and Ajayi, 1995).

The type of sorghum, often called sorghos, with large juicy sweet stems containing up to 10% sucrose is used for chewing and the manufacture of syrup (Purseglove, 1972).

The broom sorghum or corn supplies brushes, used for the manufacture of brooms (Lonis & Henry, 1974).

In developed countries like the U.S.A., the grains as well as the fresh leaves and heads are used for livestock feed

(Pasture, bay stage). Sorghum grains are used as components of animal feeds, although high tannin sorghum grains are not efficiently utilised by monogastric animals (Umunna & Alewa, 1990). The dry leaves, threshed panicles and stalks are used locally for livestock feeds in Nigeria. Also, in many developing countries, including Nigeria, the dried stalks are used as fuel, for hatching houses (shelter), fencing and making toys. Also, the thin stems are used for making baskets and fish traps. A red dye is obtained from sorghum in West Africa for dying leather (Purseglove, 1972).

2:1.5 Major Diseases.

Sorghum is attacked by a variety of diseases including the smuts, foliar diseases, root-rots, seed moulds, downy mildew and ergot. The foliar and head diseases include anthracnose caused by Colletotrichum graminicola, downy mildew (Sclerospora sorghi), blight (Helminthosporium turcicum), grey leaf spot (Cercospora sorghi) sooty stripe (Ramulispora sorghi), zonate leaf spot (Ascophyta sorghina),oval leaf spot (Ramulispora sorghicola) amd rust (Puccinia purpurea). Seed moulds, whose associated fungi include Phoma sorghina, Fusarium moniliforme, Curvalaria lunata and Helminthosporium halodes) are important only in short season non-photo-sensitive sorghum varieties because their grain matures before the end of the rains (Uvah and Alabi, 1989). The most important panicle diseases of

sorghum are the smuts. These are long smut (Tolyposporium eherenbergii), covered smut (Sphacelotheca sorghi), loose smut (Sphacelotheca cruenta) and headsmut (Sporisorium reiliana) (Uvah and Alabi, 1989; Hill and Waller, 1988).

2:1.6 Major Insect Pests.

Insect pests constitute one of the most important limiting factors to sorghum production, both in the field and store. The most important insect pests of sorghum, in order of their time of infestation on the field, are:

i) Sorghum shootfly - Atherigona soccata Rondani (Diptera: Muscidae)

ii) Stem-borers - Maize stalk borer, Busseola fuscaFuller (Lepidoptera: Noctuidae)

- Pink stalk borer, Sesamia calamistis Hampson (Lepidoptera: Noctuidae)
- Sugar-cane borer, Eldana saccharina (Walker) (Lepidoptera: Pyralidae)
- Spotted stem borer, Chilo spp. (Lepidoptera: Pyralidae)

iii) Sorghum midge, Stenodiplosis sorghicola Coquillet (Diptera. Cecidomyiidae)

iv) Sorghum head caterpillars, Helicoverpa armigera Hubner (Lepidoptera: Noctuidae)

- Eublemma spp., Cryptoblames spp. and Pyroderces simplex Wsm. can be regarded as occasional pests

(Sharma, 1985a).

v) Flower feeders - blister beetles, Mylabris sp. (Coleoptera: Meloidae)

vi) Foliar feeders (sucking bugs) include:

- Red cuckoo spit, Locris rubens (Homoptera: (Cercopidae)
- Spittle bug, Poophilus costalis Walker (Homoptera: Aphrophoridae)
- Various aphids, such as Rhopalosiphum maidis Fitch. (Homoptera: Aphididae).
- Other foliar feeders include the locust (Schistocerca gregaria Forsk and Locusta migratoria migratoriodes Linn.)
- The army worms (Mythimna separata Walker, Spodoptera exempta Walker, S. fruqiperda J.E. Smith)

also cause sporadic defoliation of crops (Sharma, 1985a)

vii) Headbugs or panicle feeders include:

- Eurystylus oldi Poppius (Heteroptera: Miridae)
- Creontiades pallidus Ramb.
- Campylomma spp. Odh. (Heteroptera: Miridae)
- Diploxys floweri Dist " "
- Taylorilygus vosseleri Poppius " "
- Calocoris angustatus Leth. " "
- Leaf footed bug, Leptoglossus spp. (Heteroptera: Coreidae)
- Green stink bug, Nezara viridula (L.) (Heteroptera:

Pentatomidae)

viii) Storage insect pests include:

- The angoumois grain moth, Sitotroga cereallela (Oliv.) (Lepidoptera: Gelechiidae).

Maize and rice weevils, Sitophihus spp. (Coleoptera: Curculionidae)

- The lesser grain weevil, Rhizopertha dominica Fab. (Coleoptera: Bostrichidae).

- The flour beetles, Tribolium spp.(Coleoptera: Tenebrionidae) (Hill & Waller, 1988; Uvah and Alabi, 1989; Sharma and Lopez, 1992)

2:20 HEADBUGS

The present study is concerned with headbugs and would be considered in a greater detail.

2:2.1 Headbugs found in Nigeria.

MacFarlane (1984) and Uvah and Alabi (1989) listed the headbugs found in the savannah zones of Nigeria as follows:

Eurystylus (immaculatus) oldi Poppius (Heteroptera: Miridae)
Campylomma angustior Poppius " "
Campylomma subflava Odhiambo " "
Taylorilygus vosseleri Poppius " "
Creontiades pallidus Rambur " "
Paramixia saturalis Reuter " "
Orius spp (Heteroptera: Anthocoridae)

Diploxys floweri Lister (Heteroptera: Pentatomidae)

Nezera viridula (L.) " "

Leptoglossus spp. " Coreidae

Stonedhal (1995) confirmed that Eurystylus oldi Poppius is the predominant sorghum headbug in West Africa and has been variously known as E. rufocunealis odh (Macfarlane, 1984), and E. immaculatus odh. (Steck et al., 1989; Sharma 1989; Ratnadass et al 1991; Sharma et al., 1992; Doumbia, 1992; Ajayi, 1993).

2:2.2 Nomenclature/Taxonomy.

Kingdom	-	Animalia
Sub-kingdom	-	Metazoa
Sub-grade	-	Encoelomata
Division	-	Schizocoela
Sub-division	-	Annulata
Phylum	-	Arthropoda
Sub-Phylum	-	Euarthropoda
Super-class	-	Mandibulata
Class	-	Insecta
Sub-class	-	Pterygota
Infra-class	-	Paraneoptera
Super-order	-	Hemipteroidea
Order	-	Hemiptera
Sub-order	-	Heteroptera

Family - Miridae

Sub-family - Mirinae

Tribe - Mirini

(Webb and Elgood, 1955; Odhiambo, 1958).

There are a number of genera in the sub-order, and species some of which have been stated earlier in the literature review.

Heteropterans have piercing and sucking mouthparts, and hence cause qualitative damage to their host plants which often results in quantitative damage. The Heteroptera differ from the Homoptera (the second sub-order) in having two pairs of unequal wings (1 pair hemelytron + 1 pair thin or membraneous); the wings, when at rest, are flat with a well defined scutellum and the mouthparts are prostrate and directed forward (prognathus) (Webb and Elgood, 1955).

2:2.3 Morghology and diagnostic characters of the most important headbugs - Eurystylus Stal. species.

Odhiambo (1958) gave a detailed description of the different species of Eurystylus Stal. found in Uganda, Ethiopia and Senegal. Details of their distribution have been discussed (2:2.5). Although the species differ from one another, the genus Eurystylus Stal. has the following characteristics (as described by Odhiambo, 1958).

The body is distinctly thick set. Head transverse considerably declivous, from in front appears broader than high. Antechypeus convex or inflated, sometimes strongly so,

and with a slight longitudinal furrow at base. Vertex without a carina. Eyes large and convex, contiguous with pronotal collar; anterior margin broadly sinuate. Antennae inserted below middle of anterior margin of eyes, a little above the apex of the same with a shallow depression on each side immediately above the insertion of antennae. Antennal segment I large, more or less compressed. Segment II, gradually increases distally. Pronotum declivous and convex, collar broad; scutellum flat or moderately convex. Hemelytron longer than abdomen; cuneus usually strongly declivous; branchial vein of the membrane broadly rounded throughout its length. Segment I of hind tarsus about as long as II, the last about as long as the first two together; the claws simple (without a basal tooth). Pubescence - dorsum covered, sometimes densely, with flattened silky white hairs, inter mixed with semi erect pale hairs, hemelytron (especially on carium) with also with semi-erect hairs; antennae densely clothed with pale hairs, segment I covered with semi-erect black hairs interspersed with some flattened silky white hairs especially so on abdomen; basiternum almost glabrous; legs with pale pubescence, hind femora sometimes with semi-erect black hairs on apical half. Tibia spiny, the spines arranged in three or four more or less distinct rows; also with numerous black tubercles. Odhiambo (1958) further described the differences morphologically to distinguish between species and between males and females.

Doumbia (1992) also described E. (immaculatus) oldi Poppius as an insect which shows polymorphism. The colour of its integument varies with the colour of the panicles upon which it develops. The adults and nymphs have yellow/reddish colours on panicles with red grains, while yellow/greenish populations were found on panicles with white grains. He further stressed that the morphology of the females differ notably from that of the male by their large abdomen, this has been discussed by other workers (Sharma et al., 1992). The females have a wedge shaped abdomen and a ventrally placed dark ovipositor, while males are smaller and very active. The triangular head of E. oldi is characterised by a sclerotized ventral side lying behind the rostrum which is ventrally folded during resting times. The antennae usually long bearing four segments, the second of which is longer than all the other segments. The pronotum laterally bears circular spots. The scutellum is a bit large and triangular. The wings cover the abdomen entirely.

2.2.4 Description and biology of the most important Headbugs

The biology and seasonal activity of headbugs attacking sorghum have not been adequately investigated (Sharma, 1985).

Ballard (1916) and Charian and Kylam (1941) published notes on the biology of Calocoris angustatus Leth. Hiremath and Virak tamath (1992) also published a detailed biology of

C. angustatus which does not differ from the former reports. Studies carried out on C. angustatus at the ICRISAT Center have shown that the female, after pre-oviposition period of 2 - 4 days, lays cigar-shaped eggs inside the glumes before anthesis. According to Hiremath and Viraktamath (1992), the freshly laid eggs measured 1.11 x 0.25mm and were cigar-shaped, tapering towards the posterior end with an operculum at the anterior end. The freshly laid eggs were light blue to hyaline and changed to orange red before hatching. Egg incubation took from 5.6 - 9.7 days and 6.3 - 11.0 days under laboratory and field conditions respectively, while nymphal development period ranged from 10-15 days and 10-17 days under laboratory and field conditions respectively. The duration of the first upto the fifth nymphal instars was recorded as 2.2 - 3.4, 2.3 - 3.0, 2.0 - 2.8, 2.0 - 3.0 and 2.0 - 2.7 days, respectively. The males lived for 8.9 - 17.6 days and females for 12.2 - 21.3 days. Pre-oviposition, oviposition and post-oviposition periods varied from 1.2 - 2.1, from 7.2 - 14.0 and from 5.0 - 15.8 days respectively. According to Sharma and Lopez (1990) the sex ratio of male to female is 1:1.2.

The biology of Eurystylus (immaculatus) oldi has been described by Doumbia (1992). The eggs are shiny creamy in colour, sword shape and operculate. The eggs are usually laid singly in grains and in varying numbers, sometimes more than ten per grain. The first instar nymph, greenish eyes, lifts the operculum and comes out of the egg; it is greenish on

white grains reddish on grains with red panicles and life-cycle last about 18 to 20 days. Ajayi (1993) and Ratnadass et al., (1995) studied the biology under laboratory conditions. The pre-oviposition period was 5.32 ± 0.42 days for males and females, nymphal period (5 instars) lasted 7.29 ± 0.31 days for females; the total developmental period from egg to adult was 12.62 ± 6.90 for females. Maximum adult longevity was 46 for males and 33 for females. The mean number of eggs laid per female was 248 and the maximum was 517; 95% of eggs laid hatched. Peak egg laying occurred between 4 and 12 days after egg laying started. The sex ratio was 1:1.

According to Sharma and Lopez (1990), Eurystylus bellvoyei also lays its eggs in milk grain of sorghum and the tip projects outside the pericarp. The egg's incubation period takes 7 days and nymphal development (5 instar stages) is usually completed within 7-8 days. The entire life-cycle takes 14-16 days and sex ratio of male to female is 1:1.4. The sex ratio of most Eurystylus spp. is 1:1 according to Sharma and Lopez (1992) and adult males are usually smaller and have a dark colour on their back, and the females have wedge - shaped abdomen with a ventrally located with dark ovipositor.

Creontiades pallidus Ramb. lays cigar-shaped eggs in the milk grains of sorghum after a pre-oviposition period of 2 - 5 days (Schmutterer, 1969). Eggs hatch in 6 - 8 days and there are five nymphal instars. Complete development takes 8

- 18 days. On cotton, the eggs are laid in the tender tips of the shoot, and the development is completed in 17 - 20 days (Schmutterer, 1969; Doumbia, 1992). Adults survive for 10-15 days. The adults of C. pallidus are about 8mm long. The insect has a light green colouration with dark spots on the thorax. The hemi-elytra are transparent. The nymphs are greenish coloured, slender, and bear long antennae (Doumbia, 1992). According to Sharma and Lopez (1992), who gave a similar account of the life-cycle of C. pallidus, the eggs are inserted inside the grain and the tip or operculum of the egg can be seen from outside. The grain pericarp develops a red-brown or black ring around the egg. Females were observed to lay 4 - 251 eggs. Incubation period is 12-13 days and the male to female sex ratio is 1:1.7. They also recorded that the adult longevity was 11 days for males and 13 days for females.

Sharma and Lopez (1992) observed that Campylomma spp. lay their eggs inside the milk grain of sorghum and the eggs hatch within five days. Five nymphal instars were recorded and the development was completed in 11 days. The sex ratio of males and females was 1:1.2.

The green stink bug, Nezara viridula L.(Hemiptera: Pentatomidae) is very important on sorghum compact with panicles (Meksongsee and Chawanapong, 1985). The adults are green in colour. The female is about 14mm long and 8.5mm wide. The males is smaller than the female and is 12.5mm long

by 6.5mm wide. The eggs are cylindrical in shape and usually found deposited in clusters. Newly deposited eggs are whitish and become orange when nearing larval oclusion. The incubation period takes 4.3 days. The nymphs moult five times and reach the adult stage in about 21 days. Meksongsee and Chawanapong (1985) reported that when the bugs were reared on sorghum, the males lived for about 21 days, while the females lived for 18 days. About 50 eggs were laid by a female. Its life-span was longer when reared on a soybean based diet. On this crop, the adult lived for about 1-3 months and females laid about 200-300 eggs.

2:2.5 Distribution, Pest Status and Crop Loss

Mirid headbugs are important pests of sorghum in Asia and Africa. Teetes (1985) stated that species belonging to four genera (Calocoris, Campylomma, Creontiades and Eurystylus) are known to attack sorghum in all areas where it is a major crop. However, authentic species identification and economic importance in different sorghum growing areas are largely unknown. Headbugs have gained importance in recent years with the introduction of early flowering cultivars with compact panicles.

Of the various mirid species damaging sorghum panicles, Calocoris angustatus Lethiery is the most important in India while Eurystylus spp. are damaging both in India and Africa (Macfarlane, 1984; Doumbia and Bonzi, 1985; Nwanze, 1985;

Teetes, 1985; Seshu Reddy & Omolo, 1985; Sharma, 1985b; 1986).

In India, Srivastava (1984) reported C. angustatus as a key pest in the Southern States of Andhra Pradesh, Karnataka and Tamil Nadu. Kishore and Srivastava (1975) also reported a heavy incidence of Nezara viridula L. and Dysdercus spp. (Pyrrhocoridae).

In South East Asia, Meksongsee and Chawanapong (1985) reported N. viridula as the most important headbug.

In Africa, Campylomma angustior Poppius, C. subflava Odh., C. nicolasi Put. & Rent., Creontiades pallidus Ramb., Lygus spp., Paramixia sutralis Reut., Adelphocoris apicalis Reut and Taylorilygus vosseleri Popp. are other important headbugs of sorghum next to Eurystylus spp (Schmutterer, 1969; Macfarlane, 1984; Nwanze, 1985; Seshu Reddy and Omolo, 1985; Teetes, 1985; Steck et al., 1989; Sharma and Lopez, 1990; 1992; Ajayi, 1993).

In East Africa, A. apicalis are found in Kenya, Rwanda and Tanzania; C. angustatus in Kenya and Rwanda; T. vosseleri in Kenya, Tanzania and Uganda (Seshu Reddy and Omolo, 1985). Odhiambo (1958) gave a detailed description and listed different species of Eurystylus found in Uganda which included, E. risbeci (Sehouteden, 1942); E. fuscatus Odh., E. rubroseutellatus Odh., E. antennatus Odh., E. argenticeps Odh., E. phaiopterus Odh., E. varipennis Odh., E. immaculatus Odh. and E. marginatus Odh. In Ethiopia, Odhiambo (1958)

recorded the following additional species of Eurystylus: E. schoutedeni (Reuter) 1910, E. rufocunealis Popp. 1990, E. parvulus (Reut.) 1903, E. annulipes Popp. 1910, E. bellevoyei (Reut.) 1937, E. lineatocollis Popp. 1910, E. kivuensi (Schouteden, 1937), E. oldi Popp. 1912, E. pallidiventris Popp. 1914, and E. capensis (Distant) 1904 which are all found on sorghum. He also found E. bellevoyei in Sudan (Sharma, 1985).

In West Africa, E. capensi (Dist.) has been reported by Carvalho (1953) in Senegal. E. bellevoyei, is an important pest in Mali, Burkina faso, Niger and Nigeria (Nwanze, 1985). E. rufocunealis has been reported as the major headbug in Nigeria (MacFarlane, 1984). Sharma et al., (1992) reported that the earlier papers on E. marginatus Odh. and E. rufocunealis Odh. are based on E. immaculatus Odh., which by damaging sorghum grain quality and quantity, has become one of the major limiting factors to sorghum production in West Africa. Recently, however, Stonedhal (1995) confirmed the head bug in West Africa is Eurystylus oldi Poppius. Below is a table listing headbugs recorded in six West African countries.

Table 1. Main genera and species of sorghum head bugs (Heteroptera: Miridae) reported from six West African countries.

Headbug	Burkina Faso	Mali	Niger	Nigeria	Senegal	Togo
Eurystylus	+	+	+	+	+	+
Campylomma spp.	+	+	+	+	+	+
Creontiades pallidus Ramb.	+	+	+	+	+	+
Megaceolum apicale Reuter	+	+			+	
Paramixia sp.		+	+	+		
Taylorilygus sp.		+	+	+		
Adelphocoris apicale Poppius			+	+		
Tythus parviceps Reuter			+			
Stenotus transvaalensis Dist.			+			

1.+ = Presence of insect reported on sorghum
Sources: Nwanze (1985), Sharma (1985), Sharma (1986), Doumbia and Bonzi (1989), MacFarlane (1989), Steck et al, (1989), Ratnadass (1991), Ratnadass (1992a), Ratnadass (1992b), Ratnadass and Ajayi (1995).

In Australia, U.S.A., Central America, Mexico and Brazil, however, none of the headbugs listed above are significant pests of sorghum (Passlow et al 1985; Pitre, 1985; Rayes 1985; Castro, 1985 and Viana 1985. However, Oebalus mexicana (Feb.) and N. viridula have been reported as the major headbugs of sorghum and some other crops in Mexico and Brazil, respectively.

Research on damage caused by feeding bugs to sorghum is limited, but reports indicate that some species cause severe damage to sorghum seeds (Anonymous, 1979). Total avoidable losses from insects, including headbug feeding on panicles, have been valued at nearly 100 million dollars annualy in India (Leuschner and Sharma, 1983). This is due to the

introduction of the medium-maturity, high-yielding compact-head varieties and hybrids which has made headbugs key pests. Grains attacked during the milk stage shrivel and remain very small, causing substantial yield loss (Cherian et al., 1941; Rao et al, 1981). According to Sharma (1985), the mirid bugs feed mainly on the developing grains and occasionally on other tender parts of the plant. The nymphs and adults suck sap from the developing grains, which remain unfilled, shrivel and in severe infestations, become completely chaffy. Damage during the early stages of grain development results in heavy yield loss; later infestations result largely in quality loss. The damaged grains show distinct red-brown feeding punctures, and in cases of severe feeding, become completely tanned. In addition, such grains are more prone to disease attack and show poor germination (Sharma, 1985). There is hardly any scope for the plant to compensate for the damage due to the feeding punctures of the bugs.

Although Steck et al., (1989) and Sharma et al., (1992) had reported earlier that bug-damaged grains showed greater severity of mold incidence, data obtained at Sotuba, Mali are the first to clearly demonstrate the strong relationship between headbugs and grain mold (Ratnadass et al., 1995).

At Bagauda Nigeria, chemical control of headbugs improved grain yield by 86%, 1000-seed mass by 65%, and reduced the proportion of low density grains by 45% in 1989 (Ratnadass et al, 1995). In 1990, a 20% decrease in grain yield, 6%

Sharma and Lopez, 1989 and 1993). The green stink bug, Nezara viridula L. also damages sorghum grains. It sucks sap from the soft dough stage to ripening of grain. The seeds become spotted due to the feeding activity of the bugs impairing the grain quality. Heavy infestation may result in chaffy heads. The bugs are usually found more abundantly on compact-head than on open-head sorghum. Probably the compact head offers better shelter from attack by natural enemies (Meksongsee and Chawanapong, 1985). During August 1978, in Luna County of New Mexico, U.S.A., damage to grains due to stink bugs was severe and approximately 12,000ha of sorghum were treated 2-3 times for control (Anonymous, 1979). Dahms (1942) determined that five rice stink bugs (Oebalus pugnax (F.) per panicle caused some injury to sorghum seed, while 25 or more prevented production of normal seed. The false chinch bug, Nysius raphanus (Howard) reduced seed weight, number and germination (Wood and Starks, 1972). Teetes et al, (1974) further showed that the green stink and false chinch bugs significantly reduced yield of grain when present in large numbers, and suggested 140 bugs per panicle as an economic threshold level.

During 1970, several species of panicle-feeding bugs primarily N. viridula and Leptoglossus spp., seriously damaged late planted sorghum in Georgia (Forbes, 1920; Wiseman and Mcmillan, 1971). Damaged seeds weighed only one sixth as much as undamaged seeds. According to Young and

Teetes (1977), both adults of sorghum earhead bugs and nymphs cause damage to sorghum grains. Seeds infested are often exposed to infection with a fungus (Alternaria sp.) giving a black appearance to the grain and further lowering the seed quality.

2:2.6 Alternate/Carry-over hosts

Alternate host plants play an important role in infestations of panicle-feeding bugs in sorghum (Teetes, 1985). Teetes (1985) explained that bugs, principally the adults, move from alternative hosts to sorghum during grain development. The number of bugs moving into sorghum may depend upon availability of alternative hosts during grain development, densities of bugs present on these alternative hosts and specific preferences.

In India, Sharma and Lopez (1990) reported that besides sorghum, C. angustatus feeds on pearl millet (Pennisetum glaucum (L.) R.Br.) and maize (Zea mays L.) foliage and inflorescence, both during the rainy and post-rainy seasons. However, no nymphs have been recorded on the vegetative stage of these crops. This has also been reported by Ballard (1916) and Cherian et al (1941). During the summer (April - June), these insects were recorded on summer sorghum in farmers fields (Sharma and Lopez, 1990). No headbug have been recorded on sorghum stalks or on grasses, growing in and along water channels the ICRISAT Centre, India which could serve as alternative or carryover hosts during the off-season or dry

season.

In the Sudan, C Pallidus population migrates from sorghum to cotton. During the off-season, this insect occurs on Cynodon sp. in the Congo. It also feeds on beans, cucurbits, egg-plant and lucerne (Schmutterer, 1969). Sharma and Lopez (1990) also observed that C. pallidus feeds on pearl millet and pigeonpea at the ICRISAT Centre in India.

Campylomma spp. feeds on the flowering stage of many crops (Schmutterer, 1969). The natural enemies, alternate hosts and off-season carryover of E. oldi have not yet been elucidated (Sharma and Lopez, 1990).

In Nigeria, no work has been published concerning the off-season carryover of head bugs. However, headbugs have been observed to transfer from drying grains of sorghum to feed on flowers of mango and cashew trees at Samaru, Zaria (Apeji, 1992). Ajayi, (1996) reported that in Chad and Cameroun and Nigeria, headbugs have been found on Crotalaria sp and pigeon pea ICRISAT (1997) also found E. oldi adults on mango flowers at Bagauda, Nigeria.

N. viridula(L.), being a potential pest of sorghum in many countries as mentioned earlier, has been found to attack several crops such as rice, soybean, castor bean and cotton (Meksonsee and Chuwanapong, 1985).

2.2.7 Natural Enemies

In the absence of food, all the mirid bugs are known to be cannibalistic and also predacious on members of the other species (Sharma and Lopez, 1990). Headbugs are also predatory on sorghum maidge, Stenodiplosis sorghicola Coq. The anthocorid, Orius maxidentex Ghauri is known as a common predator of all headbug species.

2.2.8 Pest Management

The major conponents of pest management in agro-ecosystems are cultural practices, use of natural enemies, insecticides and host-plant-resistance (Sharma et al, 1992). The economic injury level defines the pest population below which damage is tolerable and above which pest control elements must be invoked to avoid economic damage from an outbreak of the pest (U.S. National Academy of Science, 1969). Establishing economic injury levels is essential to integrated pest management and crucial to the efficient use of pesticides (Stern, 1966; Stone and Peddigo 1972; Ogunlana and Pedigo, 1974; Stewart and Khattat, 1980). The determination of economic injury levels is usually based on density relationships between crop and pests (Teetes, 1985). However, determining economic injury levels; especially when the pest causes indirect damage such as the head bugs do is difficult (Chant; 1966; Stone and Pedigo, 1972). Ratnadass et al, (1995), determined economic threshold land of E. oldi as 2.52 bugs per panicle in 1989 and 0.97 in 1990.

Cultural practices are effective against certain pests, some having become an integral component of crop husbandry and farming systems. However, some of the cultural practices are only partially effective and are difficult to implement under rain-fed conditions. It is difficult to persuade all farmers to plant at a time when pest incidence can be avoided so that population build up of insects can be minimized (Sharma et al, 1992).

As part of the development of an integrated pest control strategy, the effect of sorghum management practices on the incidence of Eurystylus spp. was investigated at Baguada, Nigeria from 1989 - 92 (Ajayi, 1993). These practices included date of planting, intercropping, nitrogen fertilizer levels and plant density.

He also reported that date of planting significantly affected the population of E. oldi with peak infestation occuring in the mid-July planting in 1991 and in the 3rd June planting in 1992. Of the dates tested in 1989, he suggested that the best date for sowing in order to have low headbug damage for high yield was 15 June. This is also in agreement with Steck et al. (1989) and Sharma et al (1992). Ajayi (1993) concluded that dates of sowing can be manipulated to avoid severe damage to sorghum by Eurystylus spp. Ratnadass (1993) in Mali, examined the effect of planting date on headbugs population on sorghum and recorded the highest population on sorghum sown on 22 June. According to Steck et

al (1989), the earliest planted sorghum had a low population of Eurysylus spp in panicles of sorghum variety Mota Galmi and Tarna CNRA planted on 12 June 1986; they had 54 bugs per 10 panicles compared to sorghum sown on 4 July, 1986 that had 842 bugs per 10 panicles. The early planted sorghum had less than one-tenth the level of headbug infestation which undoubtedly would correspond to lower damage potential, greater yield and better quality.

Ajayi and Tabo (1993) suggested that depending on the sorghum cultivar used, intercropping sorghum with soybean decreased headbug incidence on sorghum by up to 22% in 1989 and 8 - 49% in 1991. 1 sorghum: 1 soybean and 1 sorghum: 2 soybean alternate row arrangement had fewer headbugs than sole sorghum. Intercropping with pigeon pea reduced headbug infestation by 3% averaged over three sorghum and two pigeon pea cultivars. Intercropping sorghum with pearl millet and cowpea had no effect on headbug numbers on ICSV 247, but increased them by 2-3 times on the taller and later maturing Gaya Early (Ajayi and Tabo, 1993). Also, headbugs were significantly more on the compact head hybrid ICSH 507 than on ICSV 247: but Samsorg 14, a late maturing variety had more headbugs than ICSH 507 and ICSV 247. Ratnadass (1993) reported that intercropping sorghum with legumes (soybean, cowpea, groundnuts) did not significantly affect the incidence of headbugs at Bamako and Longorola in Mali.

Ajayi and Tabo (1993) observed that neither variation in

planting density between 2.7 and 17.8 plant m^{-2} nor level of nitrogen fertilizer between 0 and 90kg/ha of N significantly affected headbug population on sorghum.

Chemical control is expensive and numerous applications may be required. This is often beyond the reach of most farmers in the semi-arid tropics. In many areas, insecticides and spraying equipment are either not available or farmers lack the proper knowledge of their use (Painter, 1951; Sharma et al, 1992). Ajayi (1991) tried the use of cypermethrin to control Eurystylus spp on sorghum variety ICSV 247 (one of the susceptible cultivars) and found that concentrations from 0.001% - 0.02% a.i had no significant effect on the yield (2.66 kg/ha and 2.47kg/ha respectively); even though the population was brought down to zero after three sprays. However, there were significantly fewer floaters from 40.6% - 17.4% for the treated compared to the non-treated sorghum which had 78.1% floaters. In situations of moderate to heavy infestation, two insecticidal sprays are necessary to minimize the qualitative losses from headbug (Sharma and Leuschner, 1987). In view of the high cost of chemicals and lack of properly trained personnel to handle them in the semi-arid tropics the use of resistant or less susceptible cultivars is one of the most important methods of keeping insect populations below economic threshold levels. Most plant resistance does not involve the farmer in any extra cost or application skills in pest control techniques. However, host-

plant resistance is not a panacea for all pest problems. It is most useful when carefully utilized with other components of pest management (Painter, 1951, Sharma et al, 1992). For this reason, a lot of research is now going on in India and Africa on screening sorghum for headbug resistance by the use of the head-cage technique, infester-row technique, field screening, hot spots and sowing date (Sharma, 1985c; Sharma and Lopez, 1992 and Sharma et al, 1992).

If combinations of other measures such as date of planting, early maturity, hard grain, resistant cultivars of sorghum and inter-cropping are put together it could give effective control measures against headbugs. An understanding of the biology and ecology (especially the life-cycle, alternate/carryover/off-season hosts of headbugs) of an insect can be useful in the development of ecologically sound pest management strategies against it.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1.0 CULTURAL PRACTICES

3.1.1 Experimental site.

The experiments were conducted at the Research farm of the Institute for Agricultural Research (I.A.R) and the Department of Crop Protection experiment plots at Samaru (11°, 07° 38'E, 686m above sea level) in the Northern Guinea Savannah zone of Nigeria during the 1993 and 1994 cropping seasons.

3:1.2 Land Preparation

At the establishment of rainfall in June/July, the fields were ploughed using a tractor-mounted disc plough to destroy the weeds and break the earth's crust for proper drainage. They were harrowed in order to pulverize the soil, level the land, and break large soil clods for a fine tilth. The fields were then ridged (0.75m apart) to create suitable seed beds for germination and deep extension of roots. This has the advantage of facilitating proper drainage channels to reduce water logging.

3:1.3 Planting materials (seeds)/varieties and seeding.

There were six sorghum varieties of which two were obtained from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Bagauda, Kano; and four were

supplied by the Department of Plant Scince, Ahmadu Bello University (A.B.U.) Samaru Zaria. The varieties (plate 1) were:-

(i) ICSV 111 - This is a medium height variety about 1.5m tall, with a compact panicle which matures within 100 days after planting.

ii ICSV 247 - This is a medium height variety, about 1.5m tall with a semi-compact panicle which matures within 100 days after planting.

iii NR 71168 - This is a short variety, about 1.2m tall, with a compact panicle which matures in about 100-110 days after planting.

iv NR 71182 - This is a short variety, about 1.2m tall, with a semi-compact panicle which matures in about 100-110 days after planting.

v KSV8 (farafara) - This is a tall improved local variety, about 3-4m tall, with a loose panicle which matures in about 120-130 days after planting.

vi SK 5912 (short kaura) - This is an improved local variety, about 1.7m tall with a compact panicle which matures within 130-150 days after planting.

The seeds were planted towards the end of June to early August (first week) depending on the type of experiment.



Plate 1: The panicles of the six sorghum varieties

1.	ICSV 111	4.	NG 71182
2.	ICSV 247	5.	KSV 8
3.	NG 71168	6.	SK 5912



Plate 1: The panicles of the six sorghum varieties

1.	ICSV 111	4.	NG 71182
2.	ICSV 247	5.	KSV 8
3.	NG 71168	6.	SK 5912

The seed rate was 7-10 per hole in order to ensure 100% establishment. The spacing between plants was 0.75m apart. Plants were thinned at 2 weeks after germination to 2-3 plants per stand. At maturity, the average plant height was taken on 10 plants per plot. Also days to 50% flowering was recorded.

3.1.4 Weeding

Hoe weeding was done at two weeks after germination together with thinning, and three weeks later as the second weeding. Moulding-up was done three weeks after the second weeding. Usually, weeding operation was carried out two days after a heavy rainfall in order to ease the process and expose the weeds to sunshine. This ensures good weed control.

3.1.5 Fertilizer Application

The compound fertilizers (NPK) 15:15:15: and 25:10:10 were applied at four and eight weeks after planting respectively, at the rate of 64kgN/ha in two split doses using the spot application method.

3.1.6 Seed dressing

Apron plus 50 DS at the rate of 2g/kg of seed to dress the seeds before planting in order was used, to dress the seeds before planting in order to ensure good germination and protection against soil-borne and seed-borne pests and birds damage at germination and seedling stages.

3.2.0 EXPERIMENTS

3.2.1 EXPERIMENT 1

3.2.1.1 Title: Incidence of and damage by headbugs on six sorghum varieties

3.2.1.2 Sorghum Varieties and Experiment Design

The following six varieties were used: ICSV 111, ICSV 247, NG 71168, NG 71182, KSV 8 and SK 5912. Each variety was replicated four times in a randomized block design. Each plot size of 8m by 4m. The varieties were planted on the 5th of July in both 1993 and 1994.

3.2.1.3 Sampling and Data Analysis

Sampling was done at weekly intervals on sorghum panicles from the anthesis to the hard dough stages. The dates of sampling varied with the varieties depending on the date of flowering. The following were the observations made:

i) Species Composition and Headbug Counts

The species composition and headbug counts were done by using polythene bags of size 54cm length by 36cm. Five panicles per plot were chosen at random. Each panicle was covered with a bag and shaken vigorously to dislodge all the headbugs on it. The same bag was used to sample the five panicles. This method has been previously adopted by Steck et al., (1989) and ICRISAT, Bagauda Kano (O. Ajayi, personal communication). Five plants were sampled weekly per plot for a period of six to seven weeks. The insects were immobilized

by using chloroform on a piece of cotton swab and later taken to the laboratory and the contentss emptied, sorted out, counted and recorded. The insects were identified at the Institute for Agricultural Research (I.A.R.) Samaru Entomology Museum, by comparing them with the available specimens pre-identified at the International Institute for Entomology, London.

ii) **Headbug damage in relation to the phenology of the crop**

At maturity, the panicles were harvested according to replicates, hand threshed and analysed as follows:

a) Grain damage ratings

Discolouration due to headbug feeding and oviposition - fifty (50) grains per replicate were examined under a compound microscope and rated on a scale of 1-5 as follows:

1. = no discolouration
2. = seeds with few feeding punctures
3. = seeds slightly discoloured with <25% feeding punctures of grain surface and slightly shrivelled.
4. = > 25%, but < 50% of grain discoloured, moderately shrivelled and few feeding punctures.
5. = > 50% of grain discoloured, severely shrivelled and a lot of feeding punctures.

This method has similarly been adopted by (Steck et al., 1989).

b. Grain mouldiness

Fifty (50) grains from each replicate were examined under

a compound microscope and rated on a scale of 1 - 5, where:

1. = No mould
2. = 1/4 (25%) of the surface with mould
3. = 1/2 (50%) of the surface covered with mould
4. = 3/4 (75%) of the surface with mould
5. = The entire surface with mould

This method was previously used by Steck et al. (1989).

c. Vitrosity

Fifty (50) grains per replicate were examined under the microscope and rated on a scale of 1 - 5, where:

1. = Thick corneous layer comprising 25% or more seed volume.
2. = Thin corneous layer adjacent to pericarp.
3. = No corneous layer, but interior with white crystalline appearance.
4. = Endosperm somewhat floury and discoloured.
5. = Endosperm thoroughly floury and discoloured.

This method was also previously been used by Steck et al., (1989); and Sharma and Lopez, (1992).

d. Grain Mass and Floaters

A sample of 1000 grains from each replicate was taken at random. The grains from each replicate and variety were weighed in order to provide a measure of pest damage and susceptibility. A solution of sodium nitrate (Na NO_3) of specific gravity 1.24 was prepared. The 1000 grain sample was submerged in a beaker containing the $NaNO_3$ solution. The number of grains floating on the surface was counted and

expressed as a percentage of the total number of grains (Steck et al. 1989; Sharma and Lopez, 1992).

e. Germination Test

A sample of 100 grains chosen at random from each replicate placed on a water soaked filter paper in a Petri-dish and covered. These were kept at the laboratory at room temperature (35°C) for about 72 hours. The percentage of the grains with radicle and plumule emergence has recorded (Sharma and Lopez, 1992).

The data were analysed by analysis of variance (Anova)

3.2.2 Experiment II

3.2.2.1 Title: Effect of planting date on incidence/abundance of sorghum headbugs.

3.2.2.2 Treatment and Experimental Design

Sorghum variety, NR 71168 was planted on three dates at three weeks intervals (24th June, 15th July and 5th August) in 1993 and 1994 cropping seasons. Each plot size was $40m^2$ (4m by 10m) and inter-plot spacing was 1.5m while intra-row spacing was 0.75m. The experiment was arranged in a randomized block design with three replications.

3.2.2.3 Sampling and Data analysis

Sampling was done as described in experiment I with polythene bags as described in experiment 1 at three stages of panicle development (anthesis, milk and medium dough stages) on five randomly selected panicles per plot. Analysis of

variance was used to analyse the data.

3.2.3.0 Experiment III

3.2.3.1 **Title: Damage potential of the most important headbug, (Eurystylus oldi Poppius) on sorghum variety ICSV.**

3.2.3.2 **Treatment, Experimental Design and Procedure.**

Sorghum variety ICSV 111 was planted on 29th July in 1993 and 1994 cropping seasons in a plot measuring 500m^2 (25m x 20m). Infester rows were planted three weeks earlier than the test material in order to ensure sufficient bug numbers for infestation. Sorghum varieity ICSV 247 was used as the infester row. Three ridges were planted and a ridge (unplanted) in between the infester row and test material on both sides of the field (Plate 2).

Muslin bags (180cm by 42cm) with two openings and a rope for tying each end were used (Plate 3). The bags were slipped over wire frames or cages similar to those described by Sharma et al. (1992). Thirty-two plants with about the same size of stem thickness were selected at random and caged at the boot stage in order to prevent natural infestation by pests. Each plant represented a replicate. Five infestation levels(0, 5, 10, 15 and 20 pairs of bugs) representing five treatments, and replicated four times were used in the experiment. The bugs were collected as described in experiment I. The males and females were sorted out (Plate 4). The males are smaller (5.4)mmlong) and dark markings on the back and towards the

apex on antenna, while the females are bigger (5.9cm long)with a wedge - shaped abdomen and long chitinized ovipositor as long as the abdomen. The antenna and pronotum are yellow. The female are paler in colour than male. (Odhiambo, 1958). The following number, 0, 5, 10, 15 and 20 pairs of bugs were introduced into each the cage at the completre anthesis and milk stages of sorghum development following the method described by previous workers (Steck et al., 1989; Sharma and Lopez, 1992 and Sharma et al., 1992).

A week later, the cages were examined to remove any predatory spiders and head caterpillars. Twenty days after infestation, a polythene bag and a swab of cotton wool with chloroform was gently slipped over each cage and a rubber band or rope was used to fasten the polythene bag round the peduncle to make it air tight and left for about 5 - 10 minutes to immobilize the bugs. The insects were dislodged by vigorous shaking of the peduncle and collected into a container. The bugs were counted and recorded. The twenty days was necessary because it takes about twenty one days for the headbug to complete its life - cycle (Doumbia, 1992; Ajayi, 1993 and Ratnadass et al, 1995).



Plate 2: Infester row (right) planted three weeks before the test material (left).



Plate 3: The headcage used for artificial infestation.



Plate 4: Eurystylus oldi Poppius. (Hemiptera: Miridae) showing adult male (m) and female (f) dorsal view on extreem (left) and ventral view extreem (right) for each sex.

3.2.3.3 Data Analysis

The data collected was analysed by Anova.

Yield loss was also quantified by expressing the loss in grain yield of infested panicles as a percentage of the grain yield of non-infested panicles with the formula:

$$\text{Yield loss (\%)} = \frac{A - a}{A} \times 100$$

where,

A = Weight of uninfested pancile (control with 0 pairs) and

a = Weight of infested panicle (5, 10, 15 or 20 pairs).

CHAPTER FOUR

4.0 RESULTS

4.1.0 RESULTS OF EXPERIMENT 1

The different species of headbugs identified on sorghum in this study are presented in Table 2:

Table 2: Species of sorghum headbugs identified

Species	Family	Stage	Plate Number
Eurystylus oldi Poppius	Miridae	Adults and nymphs	5.1
Campylomma spp. odhiambo	Miridae	Adults	5.2
Psallus sp.	Miridae	Adults	5.3
Creontiades pallidus Rambur	Miridae	Adults	6.4
Taylorilygus vosseleri Poppius	Miridae	Adults	6.5
Adelphocoris apicalis Reuter	Miridae	Adults	6.6
Sternotus affinis Poppius	Miridae	Adults and nymphs	7.7
Liorhyssus hyalinus fab.	Rhopidae	Adults	7.8
Orius sp. (a predator)	Anthocoridae	Adults	7.9

The population trend of E. oldi on six sorghum varieties in 1993 and 1994 is presented in figures 1 and 2 respectively. In 1993, ICSV 247 had the highest population of 539 per 5 panicles; while KSV 8 had the lowest population of 92.8 per 5 panicles (figure 1). In 1994, SK 5912 had the highest population of 477.8 per 5 panicles, while ICSV 111 had the lowest population of 58.3 per 5 panicles (figure 2).



Plate 5: Hemiptera Miridae collected on sorghum panicles
1, Eurystylus oldi Poppius (adult (left) and nymphs (right)
2, Campylomma spp. odhiambo (adults)
3, Psallus sp. Adults

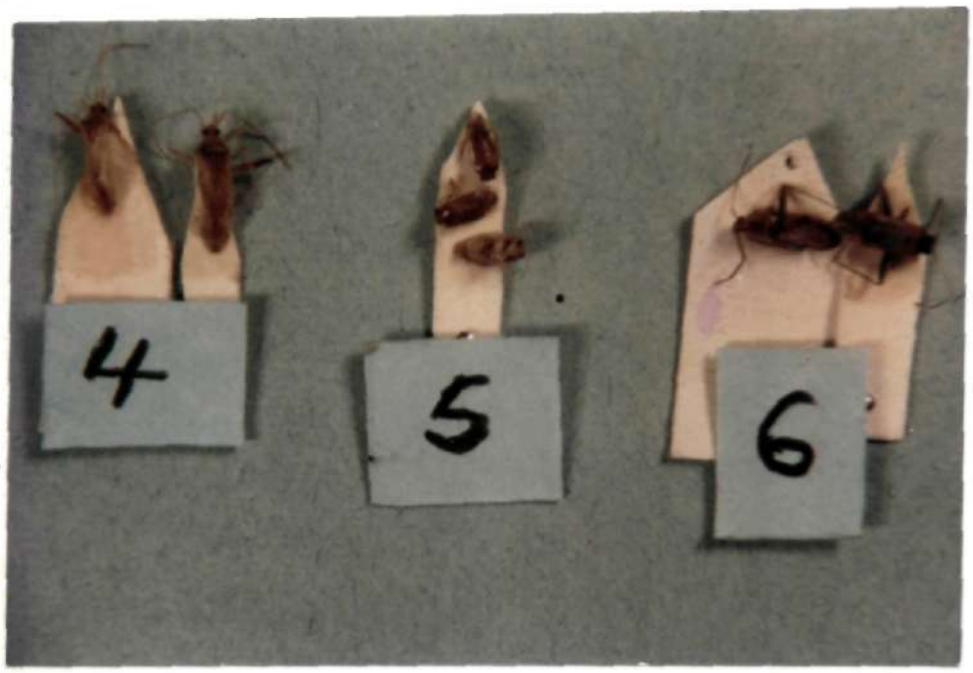


Plate 6: Hemiptera: Miridae collected on sorghum panicles
4, Crenotiades pallidus Rambur (Adults)
5, Taylorilygus vosseleri Poppius (Adults)
6, Adelphocoris apicalis Reuter (Adults)

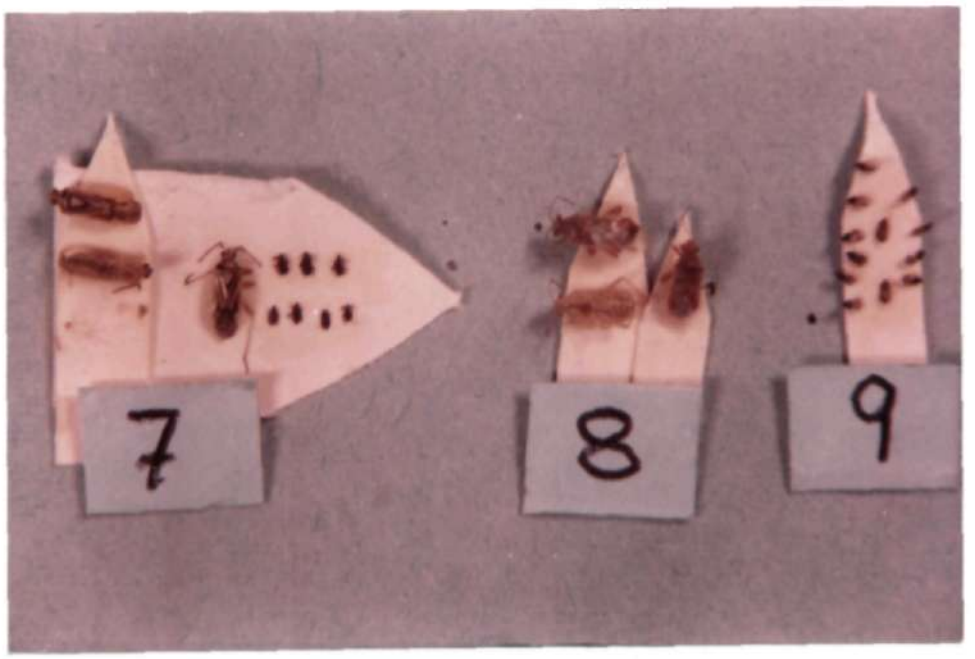


Plate 7: Hemiptera collected on sorghum panicle.
7:7 Sternotus affinis Poppius (Miridae) Adults (left) and numph (right)
7:8 Liorhyssus hyalinus Fabricius (Adults) [Rhopidae]
7:9 Orius sp. (Adults) [Anthocoridae]

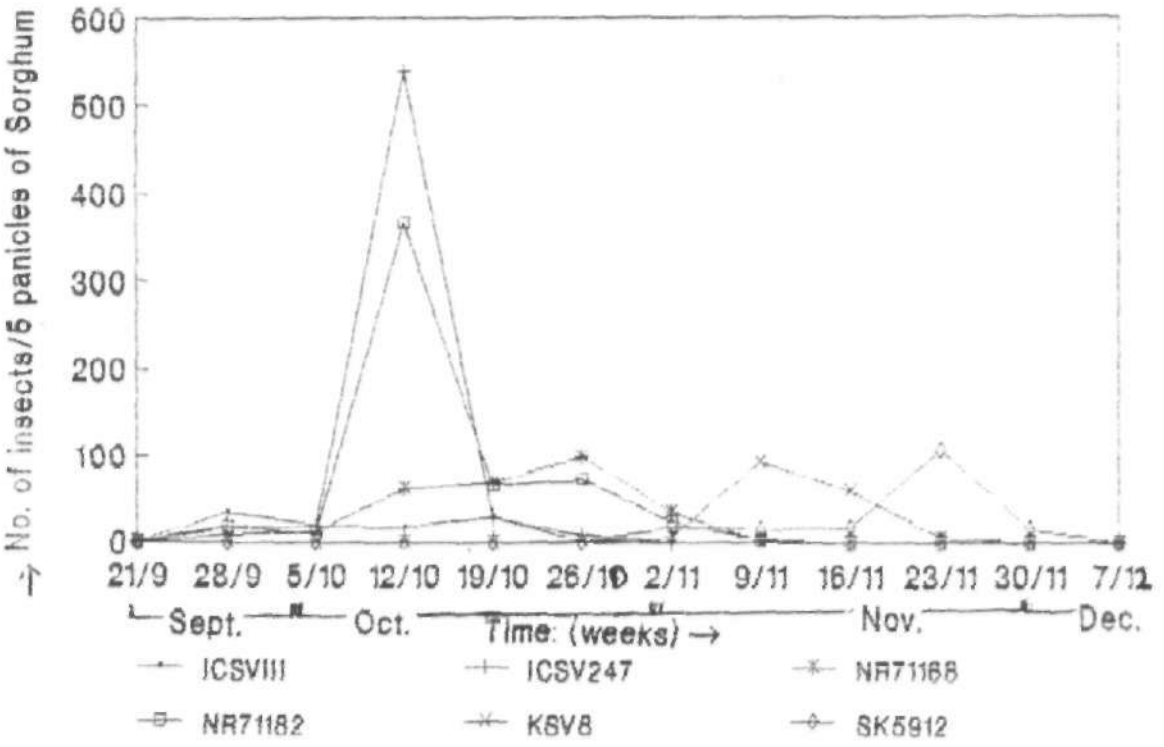


Fig. 1: Mean Weekly Population of Eurystylus oldi Poppius on Six Sorghum Varieties at Samaru in 1993.

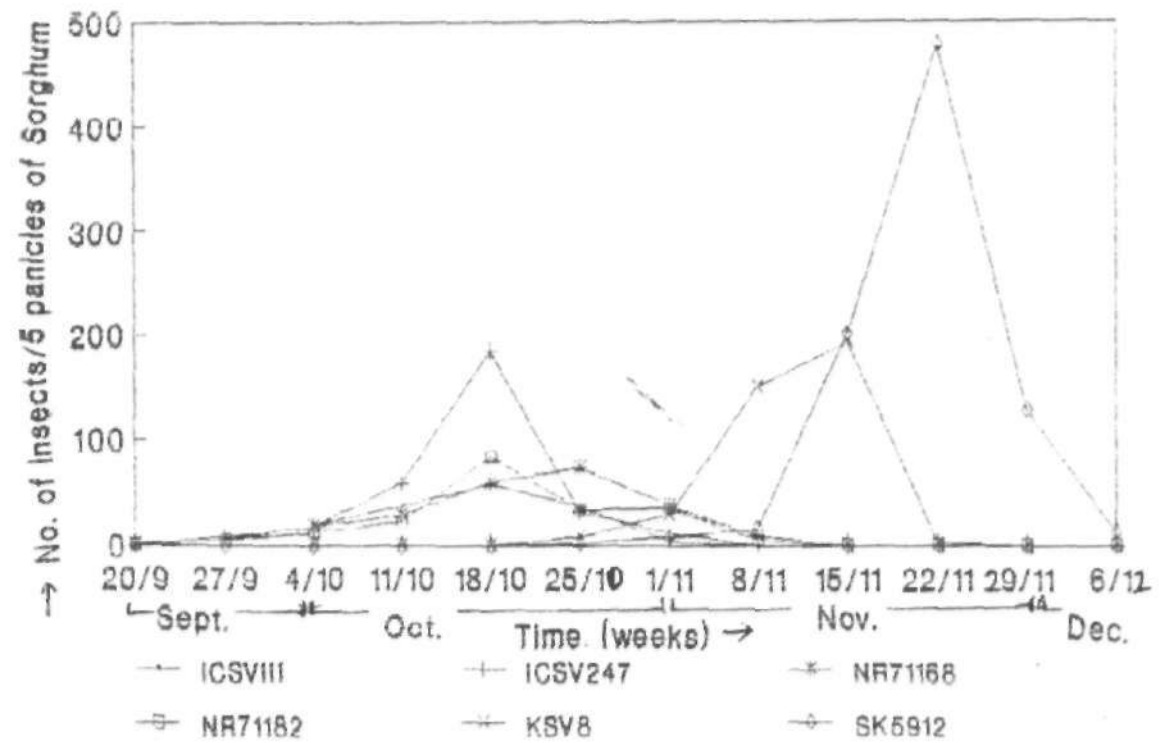


Fig. 2: Mean Weekly Population of Eurystylus oldi Poppius on Six Sorghum Varieties at Samaru in 1994.

In figure 1, the peak population occured on 12 October (for ICSV 111, ICSV 247 and NR 71182) 26 October (NR 71168), 9 November (KSV 8) and 23 November for (SK 5912) in 1993. In 1994, peak populations occured on 18 October, 25 October, 15 November and 22 November (ICSV 111, 247 and NR 71182), NR 71168, KSV 8 and SK 5913, respectively. The seasonal fluctuation of E.oldi is represented in figure 3. The main peak occurred on 12 October for early maturing varieties and 11 and 23 November for late maturing varieties in 1993. The peaks were recorded on a low rainy day as shown in figure 3. In 1994, peaks were recorded on 18 October and 12 November. In both years, E.oldi population was recorded when rainfall was less than 10mm.

The weekly population of Campylomma spp. for 1993 and 1994 on six sorghum varieties from complete anthesis to dough stage is shown in figure 4 and 5. In 1993, ICSV 111 had the highest peak population of 296.5 per 5 panicles, while KSV 8 supported the lowest population of 16.50 per 5 panicles. This is reversed in 1994 when KSV 8 supported the highest population of 16.3 per 5 panicles, while NR 71168 had the lowest population of 11.0 per 5 panicles. However, the differences between the highest and the lowest populations in 1994 (11.0 to 16.3 per 5 panicles) was not significant. Campylomma spp. appears earlier in the season than E. oldi.

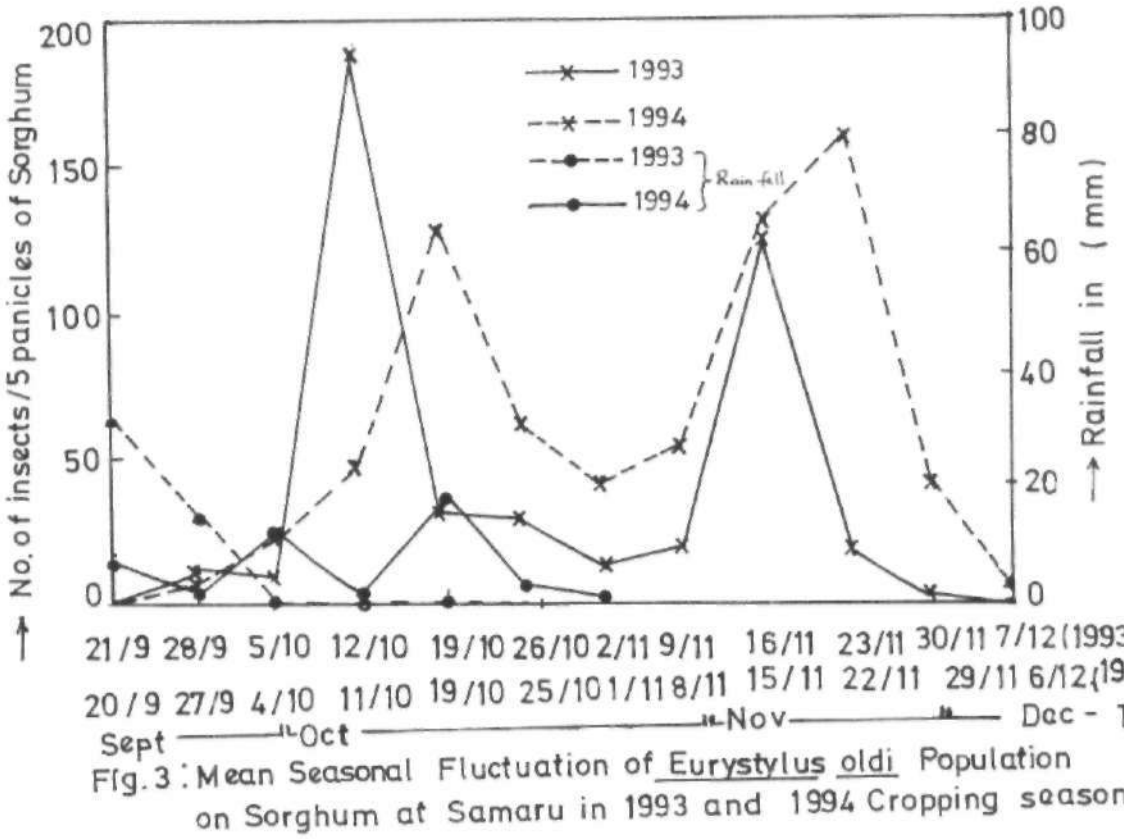


Fig. 3 : Mean Seasonal Fluctuation of Eurystylus oldi Population on Sorghum at Samaru in 1993 and 1994 Cropping seasons

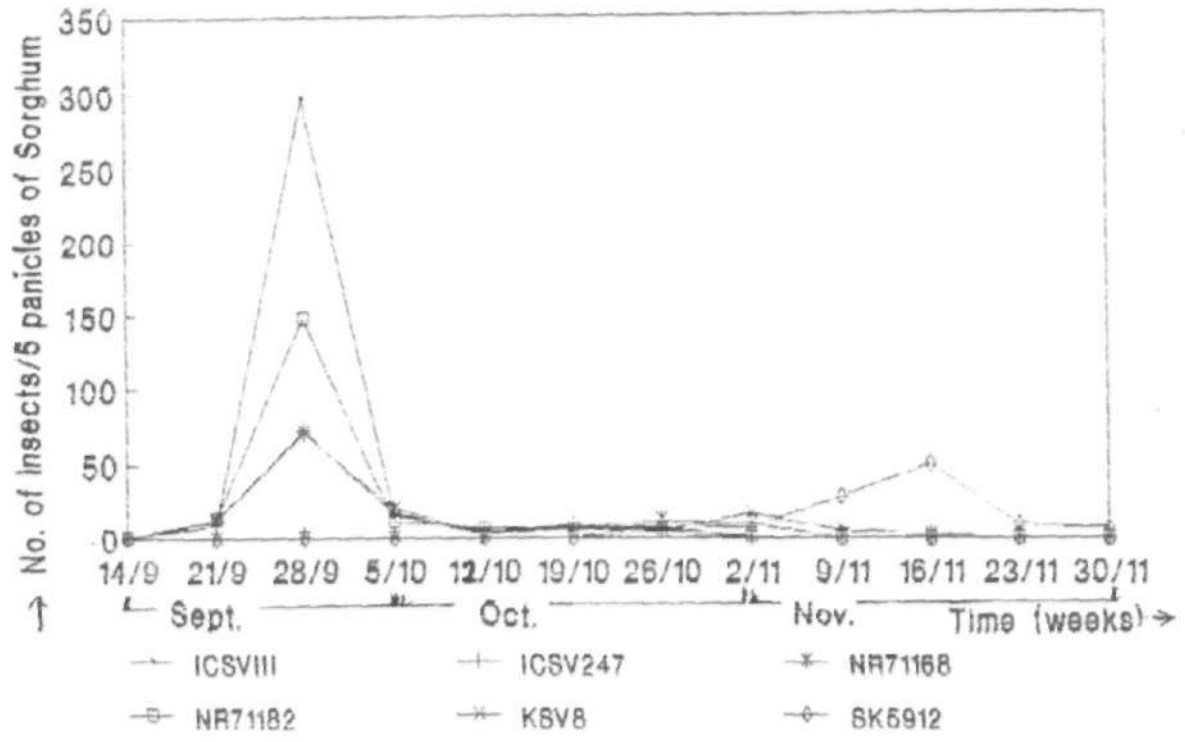


Fig. 4: Mean Weekly Population of Campylomma spp Odh. on Six Sorghum Varieties at Samaru in 1993.

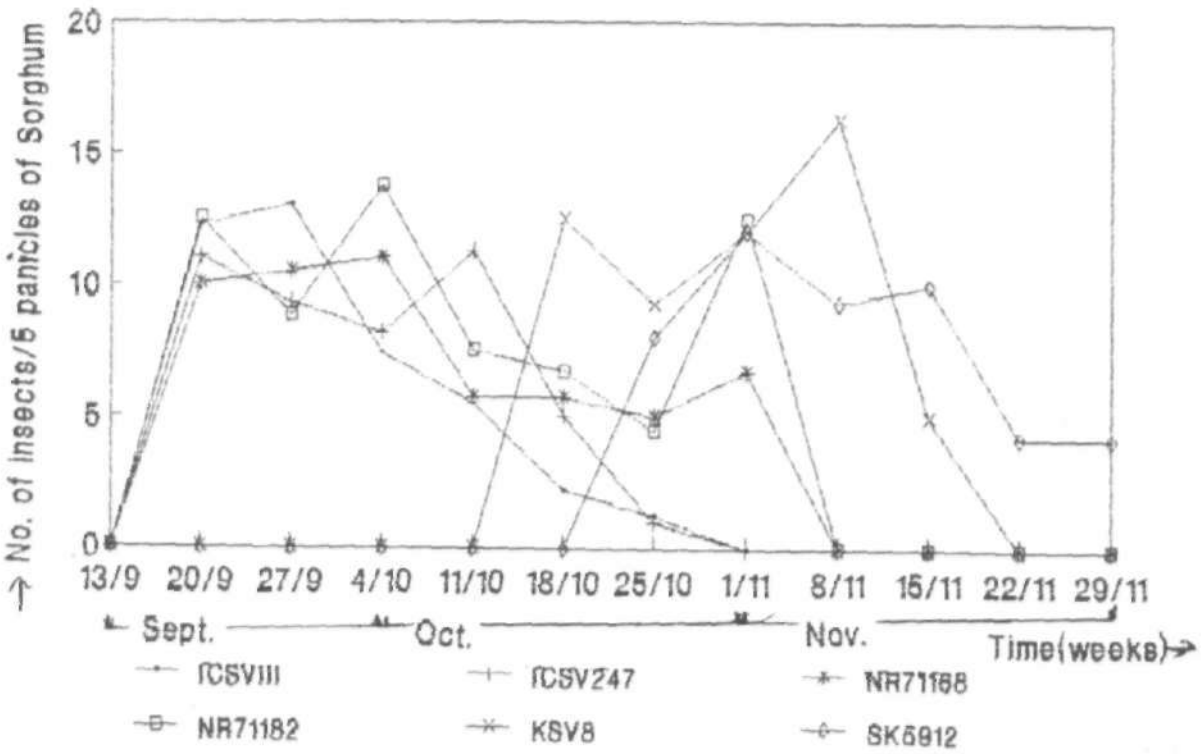


Fig. 5: Mean Weekly Population of Campylomma spp. Odh. on Six Sorghum Varieties at Samaru in 1994.

The weekly population trend of Adelphocoris apicalis are shown in Tables 3 and 4 for 1993 and 1994, respectively. There was no significant difference between the six sorghumvarieties in 1993. The highest population were 1.63 per 5 panicles. In 1994, the highest population was recorded on variety NR 71168 (70.8 per 5 panicles followed by NR 71182 50.0 per 5 panicles). The least population was recorded on SK 5912 (8.25 per 5 panicles) (Table 4). These trends are shown in figure 6. In 1994, there were three peaks on 11 October, 1 November and 8 November. ICSV 111 and 247; NR 71162 and 71182; KSV 8 and SK 5912, respectively.

The weekly population trends of Taylorilygus vosseleri are presented in tables 5 and 6 for 1993 and 1994, respectively. The population of T. vosseleri in 1993 was negligible compared to 1994. In 1993, the mean population was 2.42 per 5 panicles while in 1994, it was 4.21 per 5 panicles. The highest peak population for 1994 was recorded on variety NR 71182 (9.0 per 5 panicles) followed by SK 5912 (8.25 per 5 panicles), NR 71168 (8.0 per 5 panicles), and the least was on ICSV 111 (3.75 per 5 panicles). Population peaks occured on 1 November and 22 November and least on 4 October. The results for 1994 are shown in figure 7.

Table 3: Weekly Population of Adelphocoris apicalis per 5 panicles on six sorghum varieties at **Samaru** in 1993 Dates (Weekly) collection from September to December

Variety	21/9	28/9	5/10	12/0	19/10	26/10	2/11	9/11	16/11	23/1	30/11	7/12
ICSV 247	5.0	0.0	1.7	0.0	0.0	0.0	0.0	-	-	-	=	-
ICSV 247	0.0	0.0	1.0	0.0	0,0	0.0	0.0	0.0	-	-	-	-
NR 71168	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0,0	-	-	-	-
NR 71182	00	0.0	2.0	0.0	0.0	0.0	0.0	0.0	-	-	-	-
KSV 8	-	-	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SR5912	-	-	-	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	5.0	0.0	6.5	O.O	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mean	1.25	0.0	1.63	0.0	0.0	0.0	0.0	0.0	0.0	00	0.0	0.0

Table 4: Weekly Population of Adelphocoris apicalis per 5 Panicles on six sorghum varieties at Samaru in 1994 Weekly (dates) collection from September to December

Variety	20/9	27/9	4/10	11/10	18/10	25/10	1/11	8/11	15/11	22/11	29/11	6/12
ICSV 111	3.25	3.75	4.50	23.25	23.3	9.0	0.0	-	-	-	-	-
ICSV 247	1.25	4.0	5.75	30.25	19.0	14.0	0.0	-	-	-	-	-
NR 71168	0.50	1.25	6.0	10.25	11.0	26.0	70.8	0.0	-	-	-	-
NR 71182	0.05	.3.50	5.25	13.0	13.0	24.0	50.0	0.0	-	-	-	-
KSV 8	-	-	-	0.0	1.3	4.0	8.2	27.25	17.25	0.0	-	-
SK 5912	-	-	-	-	0.0	2.0	3.2	8.0	8.25	8.0	2.50	0.0
TOTAL	5.5	12.5	21.5	76.75	67.6	79.0	132.2	36.25	25.5	8.0	2.5	0.0
MEAN	0.92	2.08	3.58	12.79	11.27	13.17	22.03	5.88	4.25	1.33	0.42	0.0

Table 5: Weekly Population of Taylorilygus vosseleri per 5 panicles on six sorghum varieties at Samaru in 1993

Variety	21/9	28/9	5/10	12/10	19/10	26/10	2/11	9/11	16/11	23/11	30/11	7/12
ICSV 111	6.0	3.25	0.0	0.0	1.5	0.0	0.0	-	-	-	-	-
ICSV 247	3.75	2.5	0.0	0.0	0.0	0.0	0.0	-	-	-	-	-
NR 71168	0.0	3.75	0.0	0.0	1.5	0.0	0.0		-	-	-	-
NR 71182	0.05	3.50	5.25	13.0	13.0	24.0	50.0	0.0	-	-	-	-
KSV 8	-	-	-	0.0	1.3	4.0	0.0	0.0	0.0	0.0	-	-
SK 5912	-	-	-	-	0.0	0.0	0.0	0.0	0.0	1.25	3.50	0.0
TOTAL	14.5	9.5	0.0	0.0	5.5	0.0	0.0	0.0	0.0	1.25	3.50	0.0
MEAN	2.42	1.58	0.0	0.0	0.92	0.0	0.0	0.0	0.0	0.21	0.58	0.0

Table 6: Weekly Population of Taylorilygus vosseleri per 5 Panicles on six sorghum varieties at Samaru in 1994

Weekly (dates) collection from September to December												
Variety	20/9	27/9	4/10	11/10	18/10	25/10	1/11	8/11	15/11	22/11	29/11	6/12
ICSV 111	0.0	0.0	3.75	2.5	2.25	0.5	0.0	-	-	-	-	-
ICSV 247	5.25	3.25	2.05	2.75	2.5	0.75	0.0	-	-	-	-	-
NR 71168	6.0	2.5	2.5	2.5	2.0	2.75	8.8	0.0	-	-	-	-
NR 71182	5.5	3.75	2.75	4.75	2.25	3.25	9.00	0.0	-	-	-	-
KSV 8	-	-	-	0.0	0.75	4.25	5.50	5.75	2.5	0.0	-	-
SK 5912	-	-	-	-	0.0	2.75	2.75	3.50	3.75	8.25	3.50	0.0
TOTAL	16.75	9.5	11.0	12.5	9.75	14.25	25.25	9.25	6.25	8.5	3.50	0.0
MEAN	2.79	1.58	1.83	2.08	1.63	2.38	4.21	1.54	1.04	1.42	0.58	0.0

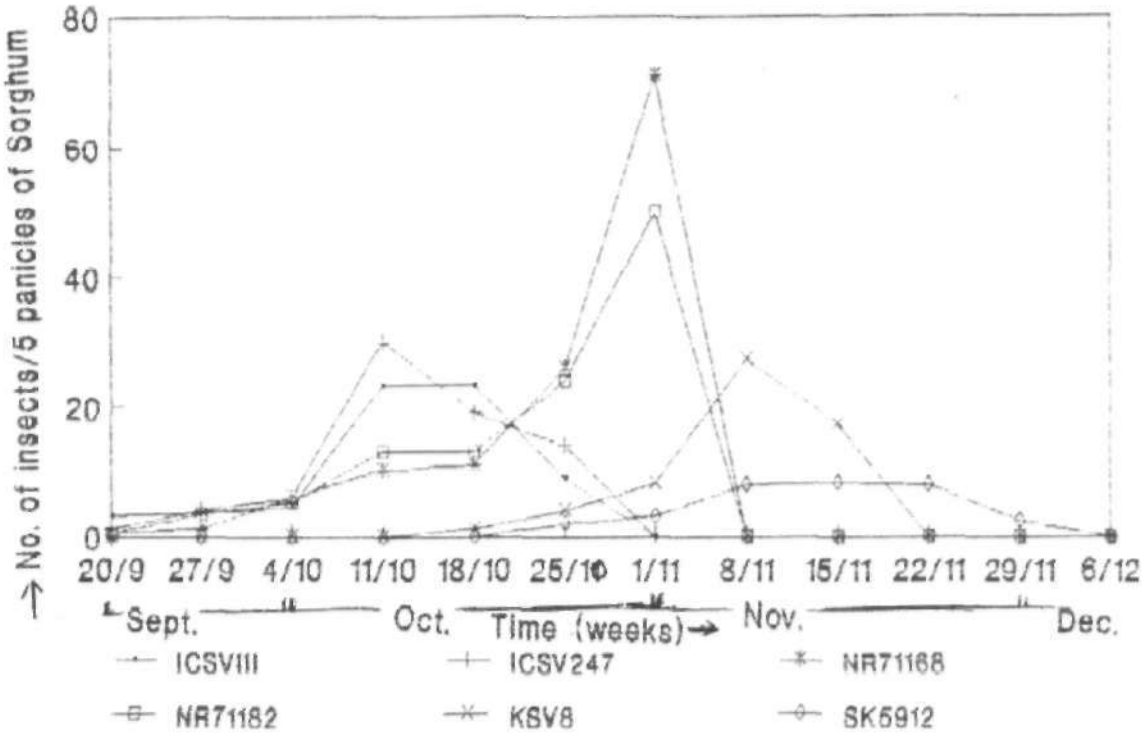


Fig. 6: Mean Weekly Population of Adelphocoris apicalis Reuter on Six Sorghum Varieties at Samaru in 1994.

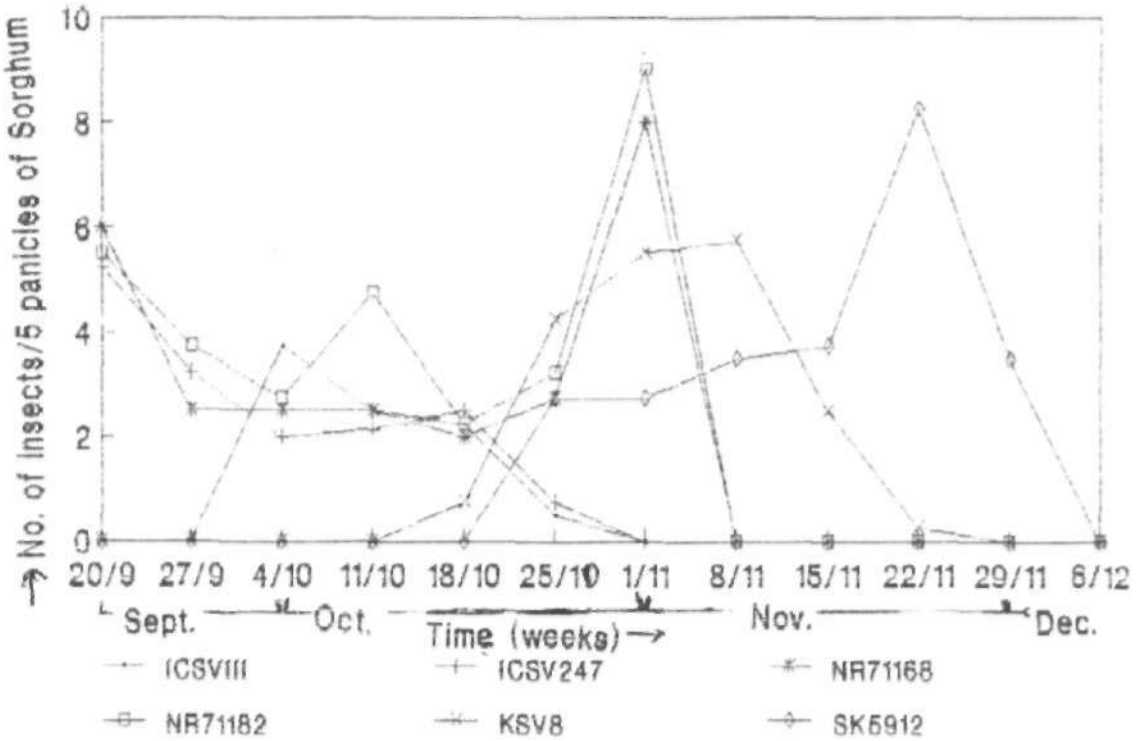


Fig. 7: Mean Weekly Population of Taylorilygus vosseleri Poppius on Six Sorghum Varieties at Samaru in 1994.

The weekly trends in the population of Creontiades pallidus for 1993 and 1994 are shown in Tables 7 and 8, respectively. In 1993, the highest population was recorded on variety NR 71168 (6.75 per 5 panicles) while KSV 8 had (0 per 5 panicles). In 1994,the highest peak was recorded on variety SK 5912 (5.25 per 5 panicles) and the least on variety ICSV 111 (2.25 per 5 panicles) The results for 1994 are shown in figure 8. There were three main peaks: for ICSV 111 and ISCV 247, on 11 October; for NR 71168 and NR 71182 peaked 1 November; and for KSV 8 1 November and for SK 5912 8 November.

The populations of the different heading species varied according to the growth stage of sorghum. E. oldi was most abundant at the soft dough stage, followed by hard dough stage (figure 9). Lower populations occurred at complete anthesis and at maturity.

The highest population of Campylomma spp occurred at the milk and soft dough stage. While lower populations occurred at complete anthesis and at maturity stages in both 1993 and 1994 (figure 10).

Table 7: Weekly Population of Creontiades pallidus per 5 Panicles on six sorghum varieties at Samaru in 1993

	Weekly (dates) collection from September to November									
Variety	28/9	5/10	12/10	19/10	26/10	2/11	9/11	16/11	23/11	30/11
ICSV 111	0.0	0.0	0.0	0.0	0.0	-	-	-	-	-
ICSV 247	0.0	0.0	0.0	0.0	0.0	-	-	-	-	-
NR 71168	0.0	6.75	1.0	0.0	0.0	0.0	-	-	-	-
NR 71182	0.0	3.0	0.0	0.0	0.5	0.0	-	-	-	-
KSV 8	-	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-
SK 5912	-	-	-	1.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	0.0	9.75	1.0	1.0	0.5	0.0	0.0	0.0	0.0	0.0
MEAN	0.0	1.63	0.17	0.17	0.08	0.0	0.0	0.0	0.0	0.0

Table 8: Weekly Population of Creontiades pallidus per 5 Panicles on six sorghum varieties at Samaru in 1994

	Weekly (dates) collection from September to November									
Variety	27/9	4/10	11/10	18/10	25/10	1/11	8/11	15/11	22/11	29/11
ICSV 111	0.0	1.50	2.25	1.0	1.0	0.0	-	-	-	-
ICSV 247	0.0	0.75	3.25	2.0	1.0	0.0	-	-	-	-
NR 71168	0.0	1.75	2.75	1.5	1.25	2.5	0.0	-	-	-
NR 71182	0.0	2.5	3.0	1.75	1.5	3.0	0.0	-	-	-
ksv 8	-	-	0.0	0.5	1.25	3.0	2.25	0.25	0.0	-
SK5912	-	-	-	0.0	2.0	0.25	5.25	4.25	1.0	0.0
TOTAL	0.0	6.5	11.25	6.5	8.0	6.75	7.50	4.5	1.0	0.0
MEAN	0.0	1.08	1.88	1.08	1.33	1.13	1.25	0.75	0.17	0.0

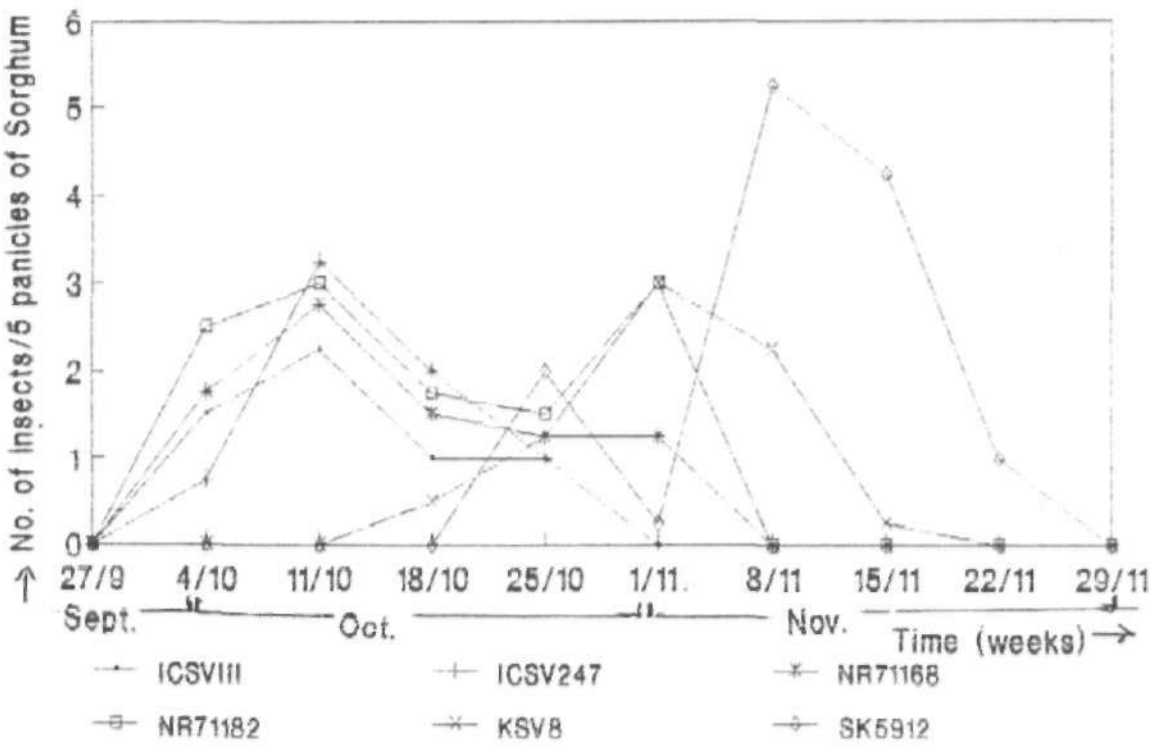


Fig. 8: Mean Weekly Population of Creontiades pallidus Ramb. on Six Sorghum Varieties at Samaru in 1994.

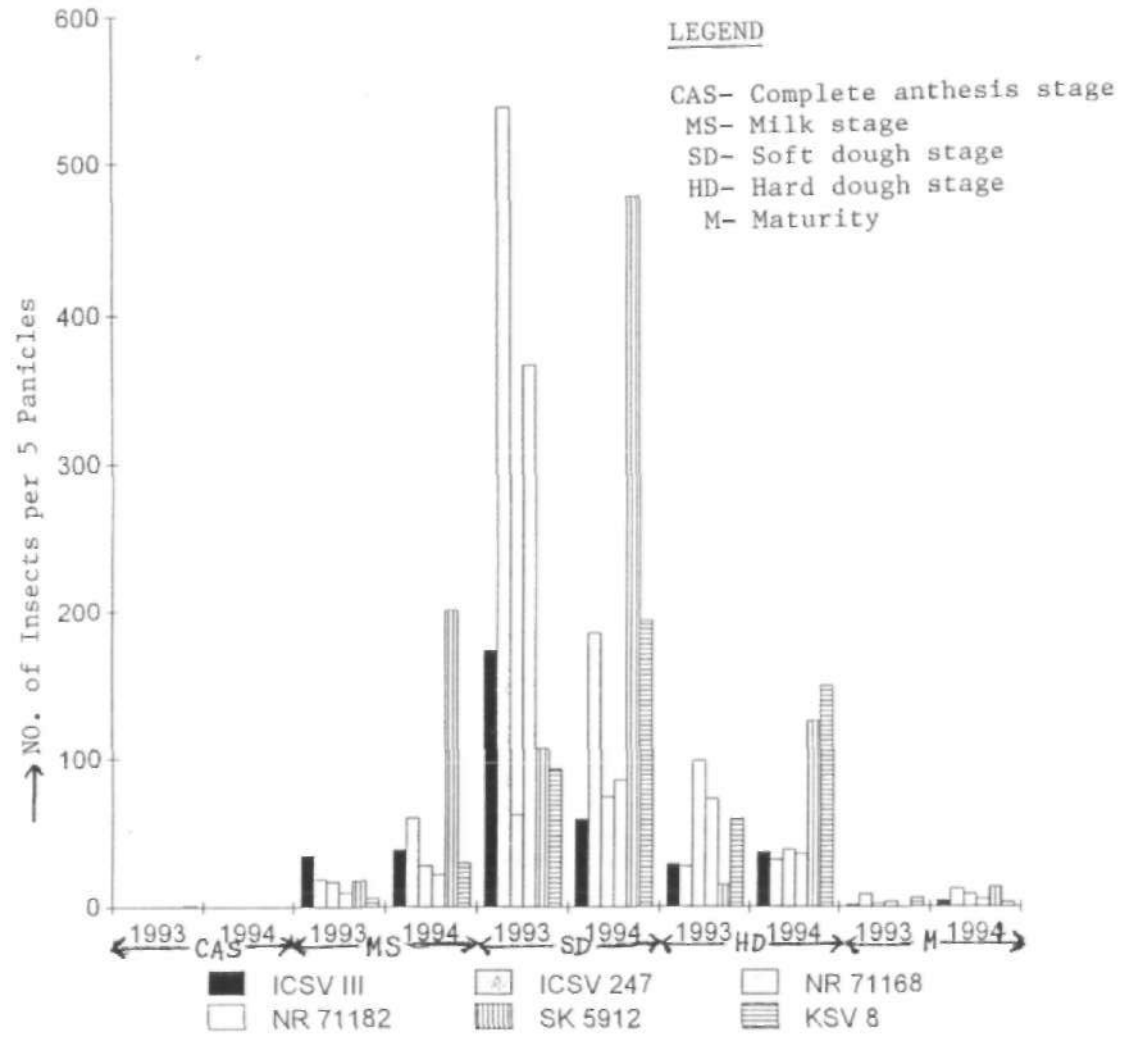


FIG. 9. NO. of Eurystylus oldi (poppius) per 5 panicles at different growth stages of six sorghum varieties in 1993 and 1994

The highest population of A. apicalis occurred at soft dough and hard dough stages (figure 11) in 1994. 1993 results is not significant (Table 3 and Figure 11). The least population was also occurred at maturity.

The highest populations of T. vosseleri occurred at hard dough stage, while lower populations occurred at soft dough and complete anthesis stages. ICSV 111 and 247 recorded their highest population at complete anthesis stage, KSV 8 and SK 5912 recorded their highest population at soft dough stage while NR 71168 and 71182 recorded their highest population at hard dough stage (figure 12). The least population occurred at maturity.

C. pallidus highest population occurred at soft dough stage on five of the varieties; however, on NR 71168, it occurred at the milk stage (figure 13). The least population was recorded at maturity and complete anthesis.

The relative abundance of the different species of headbugs are presented in Tables 9 and 10 for 1993 and 1994, respectively.

E. oldi was more abundant in both years, 2069.0 (1993) and 2139.0 (1994). The second in abundance was Campylomaa spp. with a total of 91.99 in 1993, while it was the third in 1994 with a total number of 322.4. However, in 1994, A. apicalis was the second in abundance with a total of 490.2, and in 1993 it was the least with a total number of 11.75. The third in abundance in 1993 was Psallus spp with a total of 58.5 while it was the fourth in abundance in 1994 with a total number of 279.0. The fourth in

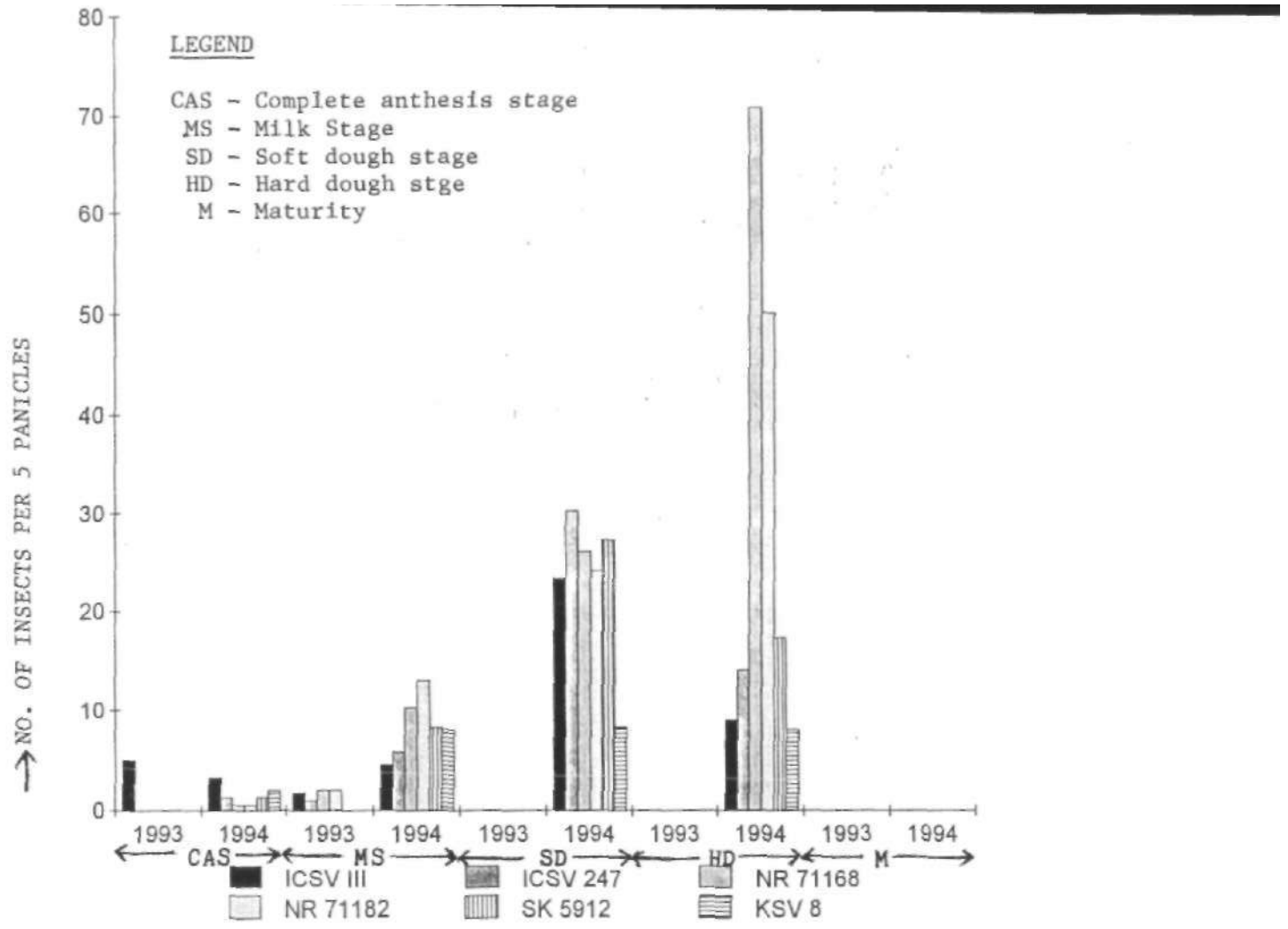


FIG. 11. No. of Adelphocoris apicalis (Reuter) per 5 panicles at different growth stages of six sorghum varieties in 1993 and 1994

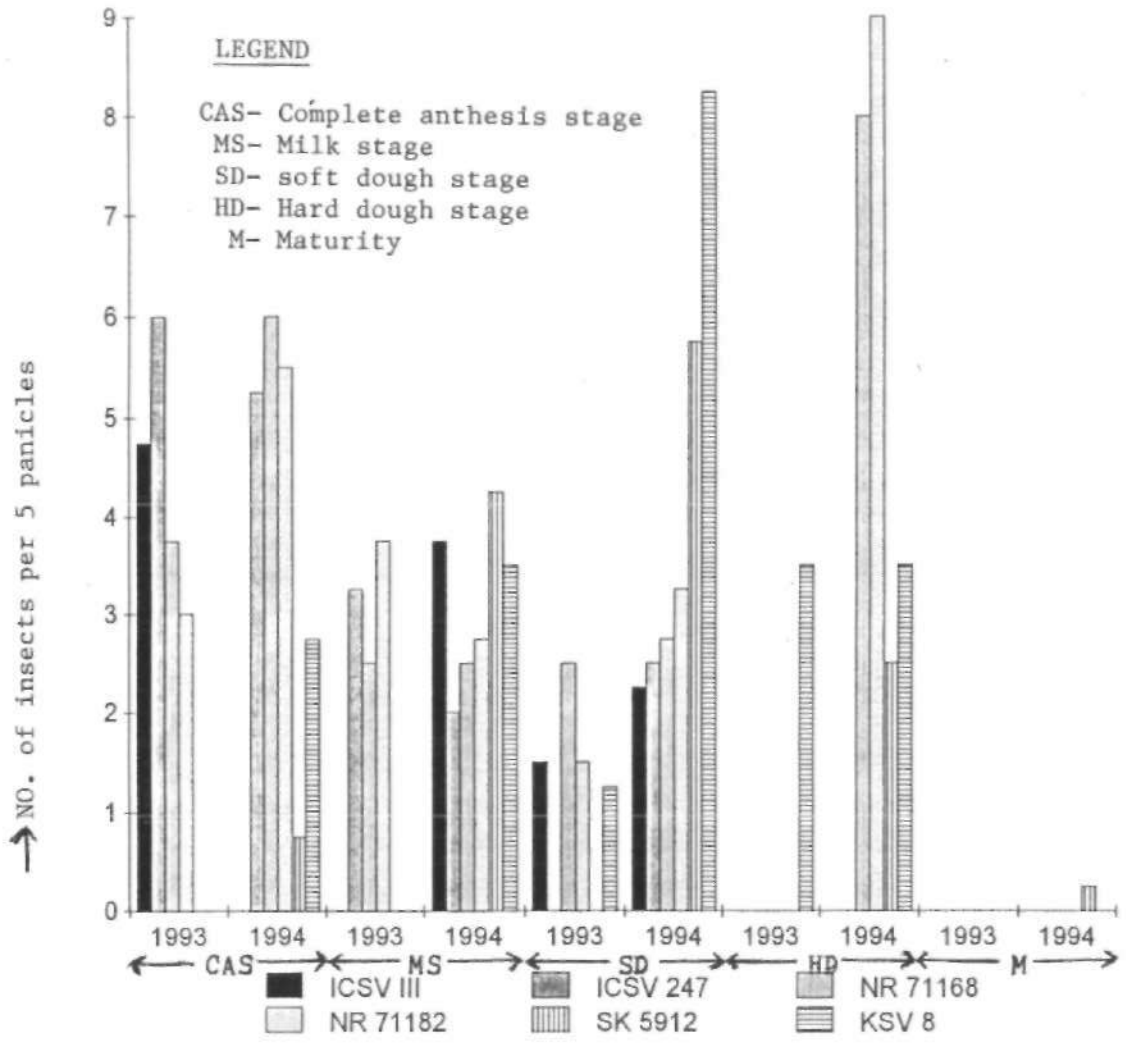


FIG. 12 NO. of Taylorilygus vosseleri (poppius) per 5 Panicles at different growth stages of six sorghum varieties in 1993 and 1994.

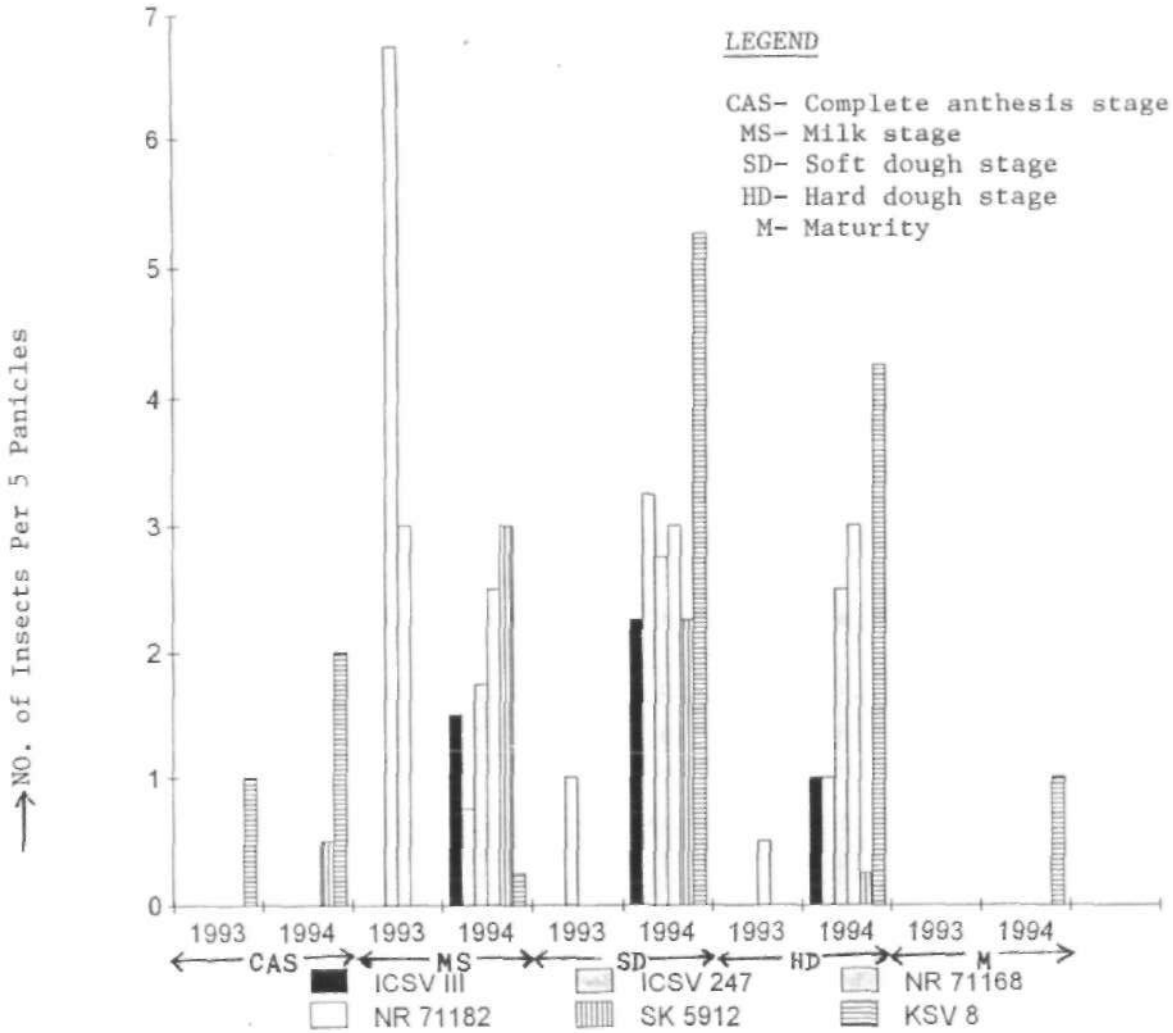


FIG. 13. NO. of Creontiades pallidus (Ramb.) per 5 panicles at different growth stages of six sorghum varieties in 1993 and 1994.

abundance in 1993 was I. voseleri with a total of 34.25, while it was the fifth in abundance in 1994 with a total number of 118.75. The fifth in abundance in 1993 was S. affinis with a total number of 17.25 while it was the least in abundance in 1994 with a total number of 31.75. The sixth in abundance in both years was C. pallidus with a total number of 12.25 and 60.25 in 1993 and 1994, respectively. The results showed that there were more mirid headbugs in 1994 than 1993 (Tables 9 and 10).

Among the varieties, NR 71182 had the highest number of mirid headbugs in 1993 with a total number of 763.25 while the highest population was recorded with SK 5912 in 1994 with a total of 1051.25, while SK 5912 had the least poulation in 1993 with a total of 81.55. Based on the two years results none of the varieties could be pointed to support the highest bug number.

Other non-mirid headbugs found was L hyalinus (Table 9 and 10). This bvug closely resemble E. oldi in appearance (Plate 7.8). Not large numbers were found in 1993 (.70) compared to 1994 (46.25). Another Hemiptera found in large number was Orisu spp (Plate 7.9 and Tables 9 and 10). This was found to be a comon predator on all the heabugs (Sharma and Lopez, 1990). No specific study was carred out to a certain its predatory habit, but large numbers were recorded weekly in both years, Appendix I and II. The population however, was recorded more in 1993 (618.4) than 1994 (403.2), Tables 9 and 10.

The damage inflicted by headbugs due to their feeding and oviposition, and the labortory analysis on vitrosity, germination,

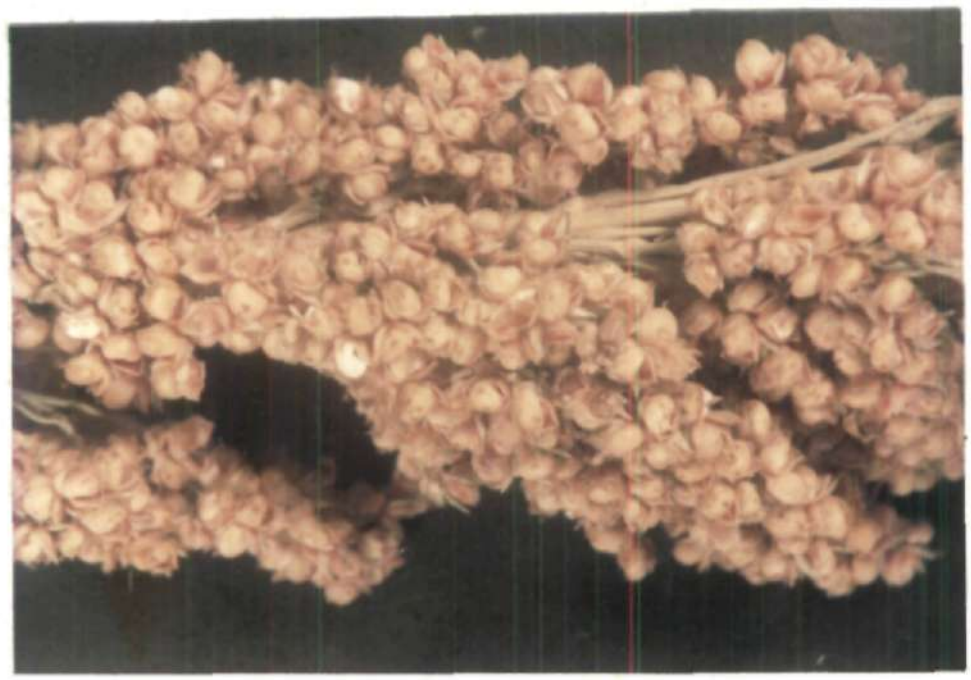


Plate 8: A typical damage inflicted by Eurystylus oldi on variety ICSV 247 with a damage rating of 4 on a scale of 1-5 where 1 = No discolouration, 2 = seeds with few feeding punctures, 3 = seeds slightly discoloured with <25% feeding punctures of grain surface and slightly shrivelled, 4 = >25% but <50% of grain discoloured, moderately shrivelled and few feeding punctures, 5 = >50% of grain discoloured, severely shrivelled and a lot of feeding punctures.

1000 grain weight and percentage floaters for each of the six sorghum varieties in 1993 and 1994 are presented in Plate 8. Plant height, maturity period, grain colour,. days to 50% flowering and yield for each variety are also presented in Tables 11 and 12.

In both years, although ICSV 247 (4.50 and 4.00 for 1993 and 1994, respectively) had the highest level of discolouration, differences between the varieties were not statistically significant in 1993. There was significant difference between varieties in 1994. KSV 8 had the lowest discolouration (2.50) while the other varieties showed no significant difference between them. The most discolored variety (ICSV 247) also had the highest rate of mouldiness and vitrosity, KSV 8 had the lowest discolouration, mouldiness and vitrosity Plate 8. There was no significant differences in both years with mouldiness and vitrosity, while less significant difference was shown between the remaining four varieties (ICSV 111, NR 71168, NR 71182 and SK 5912). In 1993, the germination percentage was high in all the varieties, but KSV 8 had the highest in both years (1993 - 95.75% 1994-86.5%). NR 71168 (88.0%) had the lowest germination in 1993 while the least in 1994 was SK 5912 (54.8%). In 1993, there were more floaters in NR 71168 and NR 71182 (25.77% and 22.98%, respectively) than the other entries, with the least occuring in SK 5912 (9.38%). However, differences were not significantly different. More floaters were recorded in 1994 than in 1993 (Table 12). KSV 8 (41.45%) and SK 5912 (37.7%) had significantly more

Table 9: Cumulative number of different species of Headbugs per 5 panicles collected in 1993 from complete anthesis to dough stage of sorghum development.

Insect species	Varieties of sorghum/headbug population						TOTAL	Ranking	LSD
	ICSV 111	ICSV 247	NR 71168	NR 71182	KSV 8	SK 5912			
Eurystylus. oldi	257^{a}	611^{a}	287^{b,c}	555.0^{a,b}	188.0^{c}	171.0^{c}	2069.0	1	285.3*
Campylomma spp	341.8^{a}	118.8^{a}	132.0^{c}	193.5^{c}	29.0^{d}	104.8^{c}	919.9	2	53.2**
Adelphocoris apicalis	6.75^{a}	1.0^{b}	2.0^{c}	2.0^{c}	0.0^{c}	0.0^{c}	11.75	7	2.7**
Taylorilygus voseleri.	6.25^{a,b}	9.25^{a}	8.72^{a,b}	5.25^{a,b}	0.0^{e}	4.75^{c}	34.25	4	4.45**
Creontiades Pallidus	0.0^{c}	0.0^{c}	7.75^{a}	3.50^{c}	0.0^{b}	1.0^{b,c}	12.25	6	3.22**
Psallus sp	0.0^{c}	2.0^{b}	56.5^{a}	0.0^{b}	0.0^{b}	0.0^{b}	58.5	3	21.13**
Sternotus affinis	2.75^{b}	10.5^{a}	0.0^{c}	4.0^{b}	0.0^{c}	0.0^{c}	17.25	5	1.55**
Total mirid headbugs	614.55	725.55	494.0	763.25	217.0	81.55	3122.9		-
Ranking	3	2	4	1	5	6			
orius sp	125.55^{b,c}	184.8^{a}	908^{a,c}	130.0^{c}	28.8^{c}	58.2^{d,c}	618.4		36.7**
Liorhyssus.hyalinus	0.0^{c}	1.0^{b,c}	3.5^{a}	.5^{a,b}	0.0^{c}	0.0^{c}	7.0		1.73**

Figures followed by the same alphabets in the same row are not significantly at P = 0.05
** significant at both P = 0.05 and 0.01

Table 10: Cummulative number of different species of Headbugs per 5 panicles collected in 1994 from complete anthesis to dough stage of sorghum development.

Insect species	Varieties of sorghum/headbugs population						TOTAL	Ranking	LSD
	ICSV 111	ICSV 247	NR 71168	NR 71182	KSV 8	SK 5912			
Eurystylus. oldi	157.0^{c}	$327.0^{b,c}$	$232.0^{b,c}$	$197.0^{b,c}$	383.0^{a}	843.0^{a}	2139.0	1	190.5^{**}
Campylomma spp	44.3	45.8	54.8	66.5	55.0	56.0	322.4	3	15.24NS
Adelphocoris apicalis	67.0^{b}	74.3^{b}	125.8^{a}	109.3^{a}	61.3^{c}	52.5^{b}	490.2	2	24.4^{**}
Taylorilygus vosseleri	9.0^{d}	$13.75^{c,d}$	24.50^{a}	28.5^{a}	$19.0^{b,c}$	$24.0^{a,b}$	118.75	5	5.44^{**}
Creontiades Pallidus	5.75^{c}	7.0^{c}	$9.75^{b,c}$	$11.5^{a,b}$	$11.75^{a,b}$	14.5^{a}	60.25	6	4.29^{**}
Psallus sp	$42.0^{b,c}$	27.5^{c}	$45.25^{a,b,c}$	63.25^{a}	$40.5^{b,c}$	$60.5^{a,b}$	279.0	4	21.27^{**}
Sternotus affinis	10.25^{a}	5.25^{b}	9.75^{a}	5.25^{b}	0.50^{c}	0.75^{c}	31.75	7	2.57^{**}
Total mirid headbugs	335.3	500.6	501.85	481.3	571.05	1051.25	3441.35		-
Ranking	6	4	3	5	2	1			
orius sp	$56.0^{c,c}$	$54.5^{b,c}$	67.8^{b}	122.3^{a}	43.0^{c}	$59.8^{b,c}$	403.2		20.1^{**}
Liorhyssus. hyalinus	$7.5^{a,b,c}$	$4.75^{b,c}$	12.25^{a}	11.0^{a}	$8.25^{a,b}$	2.5^{c}	46.25		5.13^{**}

Figure followed by the same alphabets in the same row are not significantly different at P = 0.05
** significant at both P = 0.05 and 0.01

TABLE 11: HEADBUG DAMAGE PARAMETERS ON SIX SORGHUM VARIETIES AT SAMARU IN 1993

Varieties yield	Average plant height	Maturity period (days)	Days to 50% flowering	Physical colours of Sorghum	Discolouration[1]	Mouldiness[2]	Vitrosity[3]	Germination %	1000 Grain wt (g)	Floaters %	Grain (kg/ha)
ICSV 111	1.5	90-100	68	Dirty white	4.25^{a,b}	3.00^{b}	3.00^{a}	88.50^{c,d}	25.30^{b}	13.03^{c}	566.8^{c}
ICSV 247	1.5	90-100	68	"	4.50^{a}	3.75^{a}	3.25^{a}	93.00^{b}	22.48^{b}	14.08^{b}	567.0^{c}
NR 71168	1.2	100-110	72	Milky	4.25^{a,b}	3.5^{a,b}	3.50^{a}	89.50^{c,d}	21.88^{c}	25.77^{a}	462.0^{c}
NR 71182	1.2	100-110	72	"	3.50^{b,c}	2.00^{d}	3.50^{a}	88.00^{c,d}	16.56^{c}	22.98^{a}	466.0^{c}
KSV 8	3.5	120-130	81	White	2.50^{d}	1.00^{e}	2.00^{c}	98.75^{a}	32.83^{a}	14.05^{b}	1122.0^{a}
SK 5912	1.7	130-150	95	Dirty white	3.25^{c,d}	2.25^{b}	2.25^{c}	90.25^{c}	33.92^{a}	9.38^{c}	859.0^{b}
				LSD	0.791**	0.594**	0.635**	2.14**	4.02**	3.47**	226.95**
				S.E±	0.524	0.394	0.422	1.418	2.67	2.67	105.7
				CV (%)	14.1	15.3	14.5	1.6	10.5	13.9	22.4

Note:

** Highly significant at P = 0.01

Figures followed by the same alphabets are not significant different at P = 0.05

1 Discolouration was rated on a scale 1-5, where 1 = no discolouration, 2 = seeds with few feeding punctures, 3 = seeds slightly discoloured with <25% feeding punctures of grain surface and slightly shrievelled, 4 = >25%, but <30% of grain discoloured, moderately shrievelled and feeding punctures, 5 = 50% of grain discoloured, severely shrievelled and a lot of feeding puncutures.

2. Mouldiness was rated on a scale 1 -5, where 1 = no mould, 2 = 25% of the surface with mould, 3 = 50% of the surface covered with mould, 4 = 75% of the surface with mould, 5 = the entire surface mouldy.

3. Vitrosity Was rated on a scale 1 - 5, where 1 = thick corneous layer comprising 25% or more seed volume, 2 = thin corneous layere adjacent to pericarp, 3 = no corneous layer, but interior with white crystalline appearance, 5 = endosperm thoroughly floury and discoloured.

TABLE 12: HEADBUG DAMAGE PARAMETERS ON SIX SORGHUM VARIETIES AT SAMARU IN 1994

Varieties	Average plant height (m)	Maturity period (days)	Days to 50% flowering	Grain colour of Sorghum	Discolouration[1]	Mouldiness[2]	Vitrosity[3]	Germination %	1000 Grain wt (g)	Floaters %	Grain (kg/ha)
ICSV 111	1.5	90-100	66	Grain	2.25	$2.25^{c,d}$	3.00^{b}	$78.8^{a,b}$	$22.17^{c,d}$	$23.08^{b,c}$	609^{c}
ICSV 247	1.5	90-100	66	Grain	4.00	4.25^{a}	3.25^{b}	$73.8^{b,c}$	$25.95^{a,b}$	18.50^{c}	$617^{b,c}$
NR 71168	1.2	100-110	71	Milky	3.25	$2.50^{b,c}$	3.50^{a}	$72.0^{c,d}$	16.46^{d}	25.48^{b}	$694^{b,c}$
NR 71182	3.5	120-130	71	Milky	3.25	3.00^{b}	3.50^{a}	63.0^{d}	$19.22^{c,d}$	27.40^{b}	934^{b}
KSV 8	1.7	130-150	80	White	2.50	1.75^{d}	2.00^{c}	86.5^{a}	30.76^{a}	41.45^{a}	1531^{a}
SK 5912	1.7	130-150	95	Yellow	3.25	3.00^{b}	3.25^{b}	54.8^{d}	29.74^{b}	35.70^{a}	1500^{a}
				LSD	NS	0.822**	0.469**	11.08**	5.29**	6.71**	232.06**
				S.E±	0.738	0.545	0.312	7.35	3.51	4.451	214.4
				CV (%)	23.9	19.5	12.3	10.3	14.5	15.6	21.9

Note
** - Highly significant at P = 0.01
NS - Not significant at P = 0.01
Figures followed by the same alphabets are not different at P = 0.05 significantly

1 Discolouring was rated on a scale of 1-5, where 1 = no discolouration, 2 = seeds with few feeding punctures, 3 = seeds slightly discoloured with <25% feeding punctures of grain surface and slightly shrievelled, 4 = >25%, but <30% of grain discoloured, moderately shrievelled and feeding punctures, 5 = 50% of grain discoloured, severely shrievelled and a lot of feeding puncutures.

2. Mouldiness was rated on a scale 1 -5, where 1 = no mould, 2 = 25% of the surface with mould, 3 = 50% of the surface covered with mould, 4 = 75% of the surface with mould, 5 = the entire surface mouldy.

3. Vitrosity Was rated on a scale of 1 - 5, where 1 = thick corneous layer comprising 25% or more seed volume, 2 = thin corneous layere adjacent to pericarp, 3 = no corneous layer, but interior with white crystalline appearance, 5 = endosperm thoroughly floury and discoloured.

12). KSV 8 (41.45%) and SK 5912 (37.7%) had significantly more than thte other varieties; NR 71168 (25.48%) and NR 71182 (27.40%) had significantly more floaters than ICSV 111 (23.08%) and ICSV 247 (18.50%). KSV 8 in both years, had the highest 1000 grain weight (32.83 g in 1993 30.76 g in 1994) and grain yield (1122.0 kg/ha in 1993 and 1531.0 kg/ha in 1994). However, in 1993, SK 5912 had slightly higher 1000 grain weight (33.92 g) than KSV 8, but are not significantly different, (Tables 11 and 12). The lowest grain yield was obtained in variety NR 71168 (466.0 kg/ha) in 1993, but results wer enot significantly different with ICSV 111, ICSV 247 and NR 71182. This was not so in 1994. ICSV 111 had the lowest grain yield of 609.0 kg/ha. Not withstanding, yields of 1994 were more than 1993 (Tables 11 and 12).

4.20 RESULTS OF EXPERIMENT II

The effect of three planting dates on different species of headbugs on an early maturing variety (NR 71168) of sorghum was examined in 1993 and 1994 cropping seasons. The results are presented in Tables 13 - 18.

In 1993, there was no significant difference between planting dates in the populations of Eurystylus oldi, Adelphocoris apicalis, Taylorilygus vosseleri, Creontiades pallidus and Liorhyssus hyalinus. However, in 1994, there was a significat difference between planting dates in the population of E. oldi and A. apicalis (Tables 13 and 14).

There were more E. oldi population in 1993 than 1994, even though 1993 results was not significant between planting dates, but the results showed that more population of E. oldi was recorded on the 5th August sowing than 24th June and 15th July sowings. The 5th August sowing in 1994 (38.9) was higher than 1993 (19.7) -

Tables 13 and 14. In 1993, Campylomma spp showed a significant difference only at P = 0.05, while there was no significant difference on the 24th June (13.75) and 15th July (14.67) sowing, but compared to E. oldi, Campylomma spp are more on the two dates than on the 5th August sowing (6.92). This means Campylomma spp appears early in the season, which is similar to the results of experiment 1. This also applies to the results of 1994 even though there was no significant difference between the three planting dates. The population of Psallus sp was also significant only at P = 0.05 in 1993 (Table 13) but not significant in 1994 (Table 14). The population in 1993 was higher on the 5th June sowing (16.42) and lower on the 15th July (7.50) and 5th August (5.17) sowing which are not significantly different. This results showed that Psallus sp appears early in the season as compared to E. oldi which agrees with the results of experiment 1. In 1994, A. apicalis had the highest population on the 15th July sowing (16.5) than on the 24th June (6.3) and 5th August (8.4) sowings. However, looking at the total number of the 6 mirid headbugs on the three planting dates, there was more mirid headbugs on the 24th June (56.9) than on the 5th August (40.54) sowings in 1993. This was the reverse in 1994. There were more mirid headbugs in 1994 on the 5th August (76.47) than on the 24th June (36.38) sowings. The differences could be due to weather as more prolonged rainfall was recorded in 1994 than in 1993 (Appendix IV). Orius sp which from literature is known as a predator, (Sharma and Lopez, 1990) showed a high significant difference between planting dates in both 1993 and 1994 (Tables 13 and 14).

Table 13: Effect of Planting dates on different headbugs populations on sorghum variety NR71168 at Samaru in 1993

No. of headbugs/5 panicles at medium dough stage

(SOWING DATE)	24th June	15th July	5th August	S.E±	LSD
1. Eurystylus old Poppius	17.4	18.1	19.7	6.95	NS
2. Campylomma epp. Odhiambo	13.75[a]	14.67[a]	6.92[b]	4.75	3.995*
3. Adelphocoris apicalis Reuter	4.92	5.17	5.33	3.08	NS
4. Talylorilygus vosseleri Poppius	3.33	4.58	2.50	2.92	NS
5. Creontiades pallidus Rambur	1.08	2.17	0.92	1.64	NS
6. Psallus sp.	16.42[a]	7.50[b]	5.17[b]	5.29	4.45*
7. Liorhyssus hyalinus fabricius	1.17	1.42	2.17	1.35	NS
8. Orius sp. (a predator)	17.8[ab]	16.1[a]	7.12[b]	7.26	6.10**
TOTAL no. of mirid headbugs (1-6)	56.9	52.19	40.54		

NS - Not significant at both P = 0.01 and 0.05
** - Highly significant at both P = 0.01 and 0.05
* - Significant at P = 0.05.

Figures followed with the same alphabets are not significantly different at P = 0.05.

Table 14: Effect of Planting dates on different headbugs populations on sorghum variety NR 71168 at Samaru in 1994

No of headbugs/5 panicles at medium dough stage

(SOWING DATE)	24th June	15th July	5th August	S.E±	LSD
1. Eurystylus oldi: Poppius	2.7[b]	11.5[b]	38.9[a]	17.35	14.61*
2. Campylomma spp. Odh.	12.3	10.2	9.0	6.48	NS
3. Adelphocoris apicalis Reuter	6.3[b]	16.5[a]	8.4[b]	7.12	6.01**
4. Talylorilygus vosseleri Poppius	3.25	5.67	5.25	2.70	NS
5. Creontiades pallidus Rambur	1.33	1.85	1.92	1.91	NS
6. Psallus sp.	10.50	10.67	13.00	4.59	NS
7. Liorhyssus hyalinus Fabricius	1.25	2.87	1.75	1.44	NS
8. Orius sp. (a predator)	10.33	7.67[b]	16.25[a]	4.11	3.47**
TOTAL no. of mirid headbugs (1-6)	36.38	56.39	76.47		

NS - Not significant at both P = 0.01 and 0.05
** - Highly significant at both P = 0.01 and 0.05.
Figures followed by the same alphabets are not significantly different at P = 0.05

The effect of planting dates with respect to stage of sorghum development are shown in tables 15 and 16. In 1993 and 1994, E. oldi Psallus sp and Orius sp showed a high significant difference at each of the growth stages with respect to the planting dates at both P = 0.01 and 0.05. Though A. apicalis exhibited significant difference in 1993, these differences were absent in 1994. The third planting date had the highest headbug number at the medium dough stage for E. oldi and A. apicalis. E. oldi had 52.0 (1993) and 89.5 (1994) for the August sown sorghum. A. apicalis had 10.5 (1993) for June and July sown sorghum. It however had 25.5 (1994) for July sown sorghum. Psallus sp was highest at complete anthesis stage in June sown sorghum 34.5(1993) and 33.5 (1994) in August sown sorghum. In both the years, population was least at the medium dough stage (Tables 15 and 16). Even though Campylomma spp. was not significant with the three growth stages, the populations was highest at milk stage, 20.0 (1993) and 13.5 (1994) in the July sown sorghum (Tables 15 and 16).

The damage caused by mirid headbugs is shown in Tables 17 and 18. The effect of planting date on grain discolouration was significant in 1994 but not so in 1993. In 1994, discolouration was highest in June sown sorghum (3.50) and least in August sown sorghum (2.75), while in 1994, discolouration in June sown sorghum was (3.25) and in August sown sorghum (2.0). A similar trend was observed for grain mouldiness and vitrosity. Even though virosity was not significant in 1993 between the three planting dates. Germination percentage was not significant in both the years between planting dates, but the highest germination was recorded in

Table 15 **Effect of planting dates on different species of headbugs at three stages of sorghum development at Samaru in 1993**

		No of Headbugs per 5 parnicles at 3 stages of Sorghum development			
Headbug species	Date of planting (pd)	CAS	MS	MDS	LSD
1. *Eurystylus oldi* Poppius	Pd. 1	0.0d	18.C	34.3b	
	Pd. 2	0.0d	17.5[c]	36.8b	10.13**
	Pd. 3	2.3[d]	4.8[d]	52.0[a]	
2. *Campylomma* Spp. Odh.	Pd.1	14.75	17.75	8.75	NS
	Pd.2	19.50	20.00	4.50	
	Pd.3	9.25	9.00	2.50	
3. *Adelphocoris apicalis* Reuter	Pd.1	1.75[b]	2.50[b]	10.50[a]	4.49**
	Pd.2	1.75[b]	3.25[b]	10.50[a]	
	Pd.3	1.75[b]	11.50[a]	2.75[b]	
4. *Taylorilygus vosseleri* Poppius	Pd.1	4.00	5.00	1.00	NS
	Pd.2	3.75	3.25	6.75	
	Pd.3	1.00	4.50	2.00	
5. *Creontiades Pallidus* Ramber	Pd.1	0.50	2.25	0.50	NS
	Pd.2	1.00	4.25	1.25	
	Pd.3	1.50	0.75	0.05	
6. *Psallus* sp	Pd.1	34.50[a]	14.25[b]	0.50[d]	
	Pd.2	12.50[b]	9.75[bc]	0.25[d]	7.72
	Pd.3.	10.50[bc]	4.75[c,d]	0.05[d]	
7. *Liorhyssus hyalinus* Fab.	Pd.1	0.50	1.00	2.00	NS
	Pd.2	1.00	2.25	1.00	
	Pd.3	0.50	2.00	4.00	
8. *Orius* sp. (a predator)	Pd.1	25.0[a]	10.0[b,c]	0.5[c]	10.6**
	Pd.2	32.5[a]	15.8[b]	0.0[c]	
	Pd.3	16.0[b]	5.3[c]	0.3[c]	

NS - Not Significant at both P = 0.01 and 0.05
** - Highly significant at both P = 0.01 and 0.05
Figures followed by the same alphabets are not significantly different at P = 0.01 and 0.05.
CAS = Complete anthesis stage, MS = Milk stage and MDS = Medium dough stage

Pd 1. - 24 June; Pd.2 - 15 July and Pd. 3-5 August.

Table 16: Effect of planting dates on different species of headbugs at three stages of sorghum development at Samaru in 1994

Headbug species	Date of planting (pd)	No of Headbugs per 5 panicles at 3 stages of Sorghum development CAS	MS	MDS	LSD
1. Eurystaylus oldi Poppius	Pd. 1	0.0d	4.5[c]	37.7[a]	25.33**
	Pd. 2	0.0d	2.5[c]	32.0[b,c]	
	Pd. 3	8.7[c,d]	18.5[b,c]	89.5[a]	
2. Campylomma spp. Odh.	Pd.1	13.5	13.7	9.8	NS
	Pd.2	11.8	13.5	5.3	
	Pd.3	14.5	6.8	5.8	
3. Adelphocoris apicalis Reuter	Pd.1	4.3	4.3	10.5	NS
	Pd.2	6.0	18.0	25.5	
	Pd.3	4.3	10.3	10.8	
4. Taylorilygus vosseleri Poppius	Pd.1	2.00	4.00	3.75	NS
	Pd.2	4.75	4.00	8.25	
	Pd.3	5.50	5.75	4.50	
5. Creontiades Pallidus Pamb	Pd.1	1.75	1.75	0.50	NS
	Pd.2	2.00	1.75	1.75	
	Pd.3	1.50	2.50	1.75	
6. Psallus sp	Pd.1	13.00[b]	14.50[b]	4.00[c]	6.70**
	Pd.2	17.75[b]	14.25[b]	0.00[c]	
	Pd.3	33.50[a]	5.50[c]	0.00[c]	
7. Liorhyssus hyalinus Fab	Pd.1	-0.00	0.00	3.75	NS
	Pd.2	1.75	4.50	1.75	
	Pd.3	1.25	4.00	0.00	
8. Orius sp. (a predator)	Pd.1	20.75[b]	10.25[c,d]	0.00[e]	10.6**
	Pd.2	14.75[b,c]	8.25[d]	0.00[e]	
	Pd.3	41.00[a]	7.75[d]	0.00[e]	

NS - Not Significant at both P = 0.01 and 0.05
** - Highly significant at both P = 0.01 and 0.05

Figures followed by the same alphabets are not significantly different at P = 0.01 and 0.05.

CAS - Complete anthesis stage, MS - Milk stage and MDS - Medium dough state.

Pd 1. - 24 June; Pd.2 - 15 July and Pd. 3-5 August.

Table 17: Effect of Planting dates on headbug Damage and Grain yield on Sorghum Variety NR 71168 at Samaru in 1993

Variables	24th June	15th July	5th Aug.	SE ±	LSD
Discolouration[1]	3.50	3.00	2.75	3.08	NS
Mouldiness[2]	3.75[a]	2.50[b]	2.25[b]	0.601	1.04*
Vitrosity[3]	3.25	2.25	2.25	0.577	NS
Germination (%)	91.0	92.0	85.8	4.23	NS
1000 grain wt. (g)	17.83	21.49	16.48	3.16	NS
Floaters %	19.68[a]	12.00[b]	21.73[a]	1.55	2.68**
Grain Yield (kg/ha	538.0[b]	727.0[b]	500[b]	74.3	128.7*

NS - Not significant at both P = 0.01 and 0.05
** - Highly significant at both P = 0.01 and 0.05
* - Significant at P = 0.05 only
Figures followed with the same alphabets are not significantly different at P = 0.01 and or 0.05.

1. Discolouration - was rated on a scale 1-5, where 1 - no discolouration 2 = seeds with few feeding puncutes, 3 = seeds slightly discoloured, moderately sheivelled and feeding of grain discoloured, moderately shrievelled and feeding punctures, 5 = 75% of grain discoloured severely shrievelled and alot of feeding punctures.

2. Mouldiness was rated on scale 1-5, where 1 = no mould, 2 = 25% of the surface with mould, 3 = 50% of the surface covered with mould, 4 = 75% of the surface with mould, 5 = the entire surface mouldy.

3. Vitrosity was rated on scale 1-5, where 1 = thick corneors layer comprising 25% or more seed volumes, 2 = thin corneous layer adjacent to pericarp; 3 = no corneous layer, but interior with white crystalline appearance, 4 = endosperm somewhat floury and discoloured, 5 = endosperm thoroughly floury and discoloured.

Table 18: Effect of Planting dates on headbug Damage and Grain yield on Sorghum Variety NR 71168 at Samaru in 1994

Variables	24th June	15th July	5th Aug.	SE ±	LSD
Discolouration[1]	3.25[a]	2.50[b]	2.00[b]	0.50	0.866**
Mouldiness[2]	3.25a[a]	2.25[b]	2.00[b]	0.289	0.499**
Vitrosity[3]	3.25[a]	2.00[b]	2.00[b]	0.289	0.499**
Germination (%)	82.3	83.3	75.5	10.44	NS
1000 grain wt. (g)	21.39[a]	18.30[a,b]	16.01[b]	2.302	3.98*
Floaters %	721.2	23.4	17.9	8.61	NS
Grain Yield (kg/ha	615.0	730.0	538.0	242.8	NS

NS - Not significant at both P = 0.01 and 0.05
** - Highly significant at both P = 0.01 and 0.05
* - Significant at P = 0.05 only
Figures followed with the same alphabets are not significantly different at P = 0.01 and or 0.05.

1. Discolouration - was rated on a scale 1-5, where 1 - no discolouration 2 = seeds with few feeding puncutes, 3 = seeds slightly discoloured, moderately sheivelled and feeding of grain discoloured, moderately shrievelled and feeding punctures, 5 = 75% of grain discoloured severely shrievelled and alot of feeding punctures.

2. Mouldiness was rated on scale 1-5, where 1 = no mould, 2 = 25% of the surface with mould, 3 = 50% of the surface covered with mould, 4 = 75% of the surface with mould, 5 = the entire surface mouldy.

3. Vitrosity was rated on scale 1-5, where 1 = thick corneors layer comprising 25% or more seed volumes, 2 = thin corneous layer adjacent to pericárp; 3 = no corneous layer, but interior with white crystalline appearance, 4 = endosperm somewhat floury and discoloured, 5 = endosperm thoroughly floury and discoloured.

July sown sorghum (92% in 1993 and 83.3% in 1994) and least in August sown sorghum (85.8% in 1993 and 75.5% in 1994). One thousand grain weight was not significant in 1993 between the three sowing date, but was significant in 1994, while the highest weight was shown in June sown sorghum (21.39g) and least in August sown sorghum (16.01g). Floaters percentage was significant in 1993, but not so in 1994. But the result also showed that there were more floaters in August sown sorghum (21.73) than in June sown sorghum (19.68). Grain yield was highest in July sown sorghum (727kg/ha in 1993, 730 kg/ha in 1994). While the August sowing had the lowest yield (500kg/ha in 1993 and 538 kg/ha in 1994).

4.3.0 RESULT OF EXPERIMENT III

The results of experiment III are presented in Tables 19, 20 and 21. The results showed a significant difference within the infestation levels at complete anthesis stage of panicle development (in terms of population build-up) in 1993 and 1994.

Bugs infested with 15 pairs had highest population build-up (210.5 in 1993 at CAS, 211.9 1994 at CAS; 131.8 in 1993 at MS and 177.6 in 1994 at MS). This was followed by 20 pairs of bugs, 10 pairs and the least was with bugs infested with 5 pairs (67.8 in 1993 at CAS; 77.4 in 1994 at CAS; 73.8 in 1993 at MS and 71.5 in 1994 at MS - Tables 19 and 20). There was no significant difference within the infestation levels with respect to discolouration, mouldiness and vitrosity only in 1993 (Table 19). Germination percentage was least with panicles infested with 15 and

20 pairs of bugs (85.25 and 84.25 in 1993 at CAS; 89.13 and 85.38 in 1994 at CAS; 86.0 and 85.50 in 1993 at MS and 86.75 and 85.63 in 1994 at MS) Tables 19 and 20. Five pairs of bugs showed the highest germination percentage. The results on germination showed a similar trend with 1000 grain weight and floaters (Table 19 and 20). The only difference was observed in 1993, where there was no significant differeces in panicles infested with 15 and 20 pairs of bugs both at CAS and MS.

Grains infested with 15 pair of bugs showed the highest yield loss at complete anthesis stage (40.13% in 1993 and 39.66% in 1994), while at milk stage, yield loss values of 35.20% in 1993 and 34.34% in 1994 (Tables 19 and 20) was obtained. Yield loss was lowest in panicles infested with 5 pairs of bugs, 32.96% in 1993 and 33.27% in 1994 at CAS; 18.83% in 1993 and 22.58% in 1994 at MS. The population build-up for the two years in a combined analysis is shown in Table 21 with its damage evaluation parameter. The results still showed the population build-up was highest with bugs infested with 15 and 20 pairs both at CAS and MS (213.3 and 159.5 at CAS and 223.5 and 157.0 at MS), respectively, Table 21.

However, the results still standout clearly with the control which is without bugs (0 pairs), damage is minimized and therefore higher yield of sorghum grains.

TABLE 19: Damage Caused by Eurystylus oldi (Popp). introduced at two growth stages and five infestation levels on sorghum variety ICSV 111 at Samaru in 1993.

Infestion levels	Complete anthesis stage (CAS)									Milk Stage (MS)								
	No. of Eurystylus per panicle	Discolou-ration[1]	Mouldi-ness[2]	Vitro-sity[3]	Germi-nation (%)	1000 grain wt. (g)	Float-ers (%)	Weight of grain panicle (g)	Yield loss per panicle (%)	No. of Eurystylus per panicle	Discolo-uration[1]	Mouldi-ness[2]	Vitro-sity[3]	Germi-nation (%)	1000 grain wt. (g)	Float-ers (%)	Weight of grain per panicle (g)	Yield loss (%)
0 pairs (control)	0.00[e]	1.00[c]	1.00[c]	1.00[c]	98.50[a]	19.22[a]	10.02[e]	44.6[a]	0.00[d]	0.00[d]	1.00[c]	[illegible]	1.00[d]	98.50[a]	19.21[a]	10.02[a]	44.6[a]	0.00[c]
5 pairs	67.8[d]	2.25[b]	2.50[a]	2.25[b]	93.25[b]	13.82[d]	13.82[d]	29.9[b]	32.96[a]	73.8[c]	2.50[b]	2.50[a]	2.00[c]	94.00[c]	15.32[b]	11.40[c]	36.2[b]	18.82[b]
10 pairs	121.5[c]	3.25[a]	3.00[a]	3.00[a]	90.00[b]	11.24[c,d]	19.42[c]	28.9[b]	35.20[a]	103.8[b]	3.00[a]	2.50[a]	3.00[b]	91.75[b]	13.85[b,c]	17.97[b]	35.5[b,c]	20.40[b]
15 pairs	210.5[a]	3.50[a]	3.50[a]	3.50[a]	85.25[c]	10.47[d]	27.93[b]	26.7[b]	40.13a	131.8[a]	3.50[a]	3.00[a]	3.25[a,b]	86.00[c]	12.95[c]	21.86[a]	31.1[b,c]	30.27[a]
20 pairs	164.8[a]	3.00[a]	3.25[a]	3.25[a]	84.25[c]	12.70[b,c]	24.34[b]	28.7[b]	35.65[a]	129.0[a]	2.50[a]	2.75[a]	3.50[a]	85.50[a]	15.14[b]	21.86[a]	31.1[b,c]	30.27[a]
Grand mean	112.9	2.60	2.35	2.60	90.25	13.49	19.11	1.8	28.78	87.7	2.50	2.35	2.55	91.30	15.29	16.48	35.3	20.94
S.E.	23.46	0.418	0.587	0.418	2.638	1.186	2.236	7.98	17.03	16.08	0.408	0.592	0.316	2.41	1.163	3.072	4.96	10.24
C.V (%)	20.8	16.1	16.5	16.1	2.9	8.8	11.7	25.1	61.7	18.3	16.3	25.2	12.4	2.6	7.6	18.6	14.1	51.4
L.S.D.	34.24**	0.611**	0.565**	0.611**	3.489**	1.732**	3.263*	11.64**	24.85**	23.47**	0.596**	0.863**	0.462**	3.517**	1.69**	4.483*	7.27*	14.94*

NS - Not significant at both P = 0.01 and 0.05 ** Highly significant at both P = 0.01 and 0.05 Figures followed by the same alphabets are not significantly different at P = 0.01 and 0.05.

1. Discolouration - was rated on a scale 1-5, where 1 = no discolouration, 3 = seeds slightly discoloured with <25% feeding puntures of grain surfaces and slightly shrievelled, 5 = > 50% of grain discoloured severely shrivelled and alot of feeding puntures.

2. Mouldiness - was rated on a scale 1-5, where 1 = no mould, 3 = (50%) of the surface covered with mould, 5 = the entire surface mouldy.

3. Vitrosity - was rated on a scale 1-5, where 1 = thick corneous layer comprising 25% or more seed volume, 3 = no corneous layer, but exterior with white crystalline appearance, 5 = endosperm thoroughly floury and discoloured.

TABLE 20: Damage Caused by Eurystylus oldi (Popp). introduced at two growth stages and five infestation levels on sorghum variety ICSV 111 at Samaru in 1994.

Infestion levels	Complete anthesis stage (CAS)									Milk Stage (MS)								
	No. of Eurystylus per panicle	Discolouration[1]	Mouldiness[2]	Vitrosity[3]	Germination (%)	1000 grain wt. (g)	Floaters (%)	Weight of grain panicle (g)	Yield loss per panicle (%)	No. of Eurystylus per panicle	Discoloration[1]	Mouldiness[2]	Vitrosity[3]	Germination (%)	1000 grain wt. (g)	floaters (%)	Weight of grain per panicle (g)	Yield loss (%)
0 pairs (control)	0.00^{a}	1.00^{c}	1.00^{b}	1.00^{b}	98.38^{a}	19.66^{a}	7.58^{d}	44.55^{a}	0.00^{b}	0.00^{a}	1.00^{c}	1.00^{b}	1.00^{a}	98.38^{a}	19.66^{a}	7.58^{c}	44.55^{a}	0.00^{c}
5 pairs	77.4^{d}	2.25^{b}	2.50^{a}	2.50^{a}	88.00^{b}	14.74^{b}	16.05^{c}	29.73^{b}	33.27^{a}	71.5^{d}	2.375^{b}	2.375^{b}	2.00^{a}	91.50^{b}	15.61^{b}	15.13^{b}	34.49^{b}	22.58^{b}
10 pairs	122.5^{a}	3.00^{a}	2.875^{a}	2.70^{a}	83.13^{b}	$12.64^{c,d}$	22.48^{b}	29.58^{b}	33.65^{a}	111.1^{c}	2.875^{a}	2.625^{a}	2.625^{a}	88.25^{b}	13.99^{c}	20.80^{a}	$32.69^{b,c}$	$26.62^{a,b}$
15 pairs	211.9^{a}	3.125^{a}	2.625^{a}	3.00^{a}	89.13^{b}	11.50^{d}	30.64^{a}	26.83^{b}	39.66^{a}	177.6^{a}	3.00^{a}	2.50^{a}	2.75^{b}	86.75^{b}	13.40^{c}	19.93^{a}	29.25^{c}	34.34^{a}
20 pairs	162.1^{b}	2.875^{a}	2.625^{a}	3.00^{a}	85.38^{b}	13.09^{c}	$25.01^{a,b}$	27.15^{b}	39.06^{a}	143.0^{b}	2.375^{b}	2.625^{a}	2.875^{a}	85.63^{b}	15.14^{b}	22.04^{a}	$30.68^{b,c}$	31.13^{a}
Grand mean	114.8	2.45	2.325	2.45	88.80	14.33	20.35	31.58	29.13	100.7	2.325	2.225	2.25	90.1	15.56	17.09	34.33	22.93
S.E.	21.65	0.520	0.461	0.555	5.33	1.283	5.63	5.813	12.38	21.96	0.443	0.504	0.371	5.83	1.016	3.58	3.774	7.81
C.V (%)	18.9	21.2	19.8	22.7	6.0	9.0	27.7	17.4	43.4	21.8	19.0	22.7	16.5	6.5	6.5	20.9	11.00	34.8
L.S.D.	22.35^{**}	0.537^{**}	0.476^{**}	0.573^{**}	5.50^{**}	1.32^{**}	5.79^{**}	5.99^{**}	12.78^{**}	22.68^{**}	0.457^{**}	0.520^{**}	0.383^{**}	6.02^{**}	1.05^{**}	3.69^{**}	3.89^{**}	8.05^{**}

NS - Not significant at both P = 0.01 and 0.05 ** Highly significant at both P = 0.01 and 0.05 Figures followed by the same alphabets are not significantly different at P = 0.01 and 0.05.

1. Discolouration - was rated on a scale 1-5, where 1 = no discolouration, 3 = seeds slightly discoloured with <25% feeding puntures of grain surfaces and slightly shrievelled, 5 = > 50% of grain discoloured severely shrivelled and alot of feeding puntures.

2. Mouldiness - was rated on a scale 1-5, where 1 = no mould, 3 = (50%) of the surface covered with mould, 5 = the entire surface mouldy.

3. Vitrosity - was rated on a scale 1-5, where 1 = thick corneous layer comprising 25% or more seed volume, 3 = no corneous layer, but exterior with white crystalline appearance, 5 = endosperm thoroughly floury and discoloured.

TABLE 21: Damage Caused by Eurystylus oldi (Popp). introduced at two growth stages and five infestation levels on sorghum variety ICSV 111 at Samaru in 1993 and 1994

Infestion levels	Complete anthesis stage (CAS)									Milk Stage (MS)								
	No. of Eurystylus per panicle	Discolouration[1]	Mouldiness[2]	Vitrosity[3]	Germination (%)	1000 grain wt. (g)	Floaters (%)	Height of grain panicle (g)	Yield loss per panicle (%)	No. of Eurystylus per panicle	Discolouration[1]	Mouldiness[2]	Vitrosity[3]	Germination (%)	1000 grain wt. (g)	Floaters (%)	Height of grain per panicle (g)	Yield loss (%)
0 pairs (control)	0.00^{a}	1.00^{b}	1.00^{b}	1.00^{b}	98.3^{a}	20.11^{a}	5.1^{b}	44.57^{a}	0.00^{d}	0.00^{d}	1.00^{b}	1.00^{c}	1.00^{b}	98.3	20.11^{a}	5.13^{b}	44.51^{a}	0.00^{c}
5 pairs	67.0^{d}	2.25^{a}	2.50^{a}	2.75^{a}	82.8^{b}	15.65^{b}	18.3^{a}	38.38^{b}	31.74^{c}	69.3^{c}	2.25^{a}	$2.25^{a,b}$	2.00^{a}	88.3	15.90^{b}	18.85^{a}	32.77^{b}	26.38^{b}
10 pairs	122.5^{a}	3.00^{a}	2.875^{a}	2.70^{a}	83.13^{b}	$12.64^{c,d}$	22.48^{b}	29.56^{b}	$33.65^{b,c}$	111.1^{c}	2.875^{a}	2.625^{a}	2.625^{a}	88.25	13.99^{c}	20.60^{a}	$32.69^{b,c}$	$26.62^{a,b}$
15 pairs	213.3^{a}	2.75^{a}	2.50^{a}	2.50^{a}	93.0^{a}	12.52^{c}	33.3^{a}	24.86^{a}	44.15^{a}	223.5^{a}	2.50^{a}	2.00^{b}	2.25^{a}	87.5	13.84^{c}	18.70^{a}	29.57^{c}	33.57^{a}
20 pairs	159.5^{b}	2.75^{a}	2.75^{a}	2.75^{a}	86.5^{b}	13.48^{c}	25.7^{a}	$27.56^{b,c}$	38.68^{b}	157.0^{b}	2.25^{a}	$2.50^{a,b}$	2.25^{a}	85.8	15.14^{b}	22.23^{a}	$29.85^{b,c}$	$32.94^{a,b}$
Grand mean	116.7	2.30	2.30	2.30	87.3	15.16	21.6	31.38	29.51	113.7	2.15	2.10	1.95	88.9	15.63	17.70	33.40	24.96
S.E.	16.9	0.606	0.524	0.665	706	1.373	7.64	1.981	4.107	26.61	0.474	0.398	0.418	7.88	0.844	4.023	1.919	4.123
C.V (%)	16.9	26.3	22.8	28.9	8.1	9.1	35.4	6.3	13.9	23.4	22.1	18.9	21.5	8.9	5.3	22.7	5.7	16.6
L.S.D.	28.7^{ns}	0.884^{ns}	0.776^{ns}	0.97^{ns}	10.2^{ns}	2.004^{ns}	11.15^{ns}	2.89^{ns}	5.99^{ns}	38.82^{ns}	0.691^{ns}	0.581^{ns}	0.61^{ns}	NS	1.23^{ns}	5.87^{ns}	2.80	6.02^{ns}

NS - Not significant at both P = 0.01 and 0.05 ns Highly significant at both P = 0.01 and 0.05 Figures followed by the same alphabets are not significantly different at P = 0.01 and 0.05.

1. Discolouration - was rated on a scale 1-5, where 1 = no discolouration, 3 = seeds slightly discoloured with <25% feeding punctures of grain surfaces and slightly shrivelled, 5 = > 50% of grain discoloured severely shrivelled and alot of feeding punctures.

2. Mouldiness - was rated on a scale 1-5, where 1 = no mould, 3 = (50%) of the surface covered with mould, 5 = the entire surface mouldy.

3. Vitrosity - was rated on a scale 1-5, where 1 = thick corneous layer comprising 25% or more seed volume, 3 = no corneous layer, but exterior with white crystalline appearance, 5 = endosperm thoroughly floury and discoloured.

4.4.0 POSSIBLE ALTERNATE HOST OF HEADBUGS

General observation was carried out around the farms on weeds and other plants which could possibly habour headbugs towards the end of the rainy season. In 1995 and 1996, pigeon pea (Cajanus cajan) was planted close to a sorghum field and a number of E. oldi and A apicalis adults were seen on the pigeon pea plant feeding on the sap of flowers leaves and stems.

4.5.0 OTHER INSECT PESTS OF SORGHUM

Many other insect pests of sorghum were found during the course of this study; some of major economic importance as pests, while some were predators or of minor economic importance Table 22).

Table 22: *Other Instect pests of sorghum*

Common Name	Scientific Name	Pest Stage	Part of plant found and comments
1. Maize stalk borer	Busseola fusca Fuller (Lepidoptera: Noctuidae)	Larvae	Stems, leaves, causing holes on leaves, stem tunneling; deadhearts panicle breakage and may result to chaffy panicles at harvest
2. Spittle bugs	Locris rubens Erichison (Hemiptera: Cercopidae Poophilus costalis walker (Hemiptera: Aprophoidae)	Adults	Leaves, stem, panicles, sap suckers, produces foamy spittle on leaves and stem and cause chlorotic spots and blotches on leaves
3. Melyrid Beetle	Melyris abdominalis (Coleoptera: Melyridae)	Adults	Panicles, feed on developing grains
4. Lygaeus bug	Lygaeus rivularis Germ. (Hemipterta: Lygaedidae	Adults	Panicle feed on developing grains.
5. Black and red bug	Paramius Paraclypeatus Scudder (Hemipetra: *Lygaedidae*)	Adults	Panicles feed on developing grains.
6. Cluster Bug	Agonoselis versicolor F. (Hemiptera: Pentomidae)	Adults	Panicle feed on developing grains and nymphs
7. Spiny Brown Bugs	Clavigralla tomentisicollis	Adults	Panicle, feed on developing grains.
8. Pod-sucking bug	Mirperus jaculus (Thumberg) (Hemiptera: Alydidae)	Adults	Panicles, a sap sucker and feed on developing grains.
9. Flower or scarabaeid beetles	Pachnoda cordata (Coleoptera: Scarabaeidae)	Adults	Panicles, feed on flowers and milky grains.
10. Maize weevils	Sitophilus zeamais Motschalsky (Coleoptera: Curculionidae)	Adults and Larvae	Panicles, fed on developed grains (found right from dough stage to storage)

Other insects found in association which from literature are known as predators include: spiders, Monolepta sp (Coleoptera : Chrysomelidae), Scymnus spp (Coleoptera: Coccinelidae) and Forficula senegalensis Serville (Dermeptera: Forficulidae).

CHAPTER FIVE

5.0 DISCUSSION OF RESULTS

5.10 DISCUSSION OF EXPERIMENT 1.

The results on the population trends of sorghum headbugs is an important step in knowing its abundance, which time in the season or year they appear mostly and at what growth stage of sorghum they appear.

From the results, there are two peak population periods of Eurystylus oldi in a year. These are clearly shown in figures 1 and 2 for 1993 and 1994. The mean seasonal fluctuation is represented in figure 3 with respect to rainfall which is an important factor in determining its population and abundance at a particular time of the year and at what growth stage of crop. The two peak periods from this study are middle of October (12th Oct.) and towards the end of November (23rd Nov,). In 1993, the peak periods occurred a week early than 1994, because rainfall was earlier in 1993 than 1994 (fig.3 appendix IV). However, Ratnadass et al (1995) reported that peak population of E. oldi occured in late September and late October in Mali which a similar results was obtained in India (Rana and Singh, 1995). The difference of course could be due to the weather conditions of the two regions, notably rainfall pattern (Doumbia and Teetes, 1991). This observation is similar to results obtained in India with Calocoris angustatus Leth (Sharma and Lopez, 1990). The peak period of infestation by E. oldi also depends on the stage of crop development, usually it occurs at the soft dough stage to hard dough stage of sorghum

(figure 9). This explains the occurance of a second peak period in late November for late maturing sorghums. From the results, it is best to attempt control measures before the peak population is reached. This validates the results found by Ratnadass et al. (1995) and Sharma et al. (1992). So the best time to start control measures for early maturing sorghum (ICSV 111, ICSV 247, NR 271168 and NR 71182) is before milk stage as from fourth week of September (21-28) and for late maturing sorghum (KSV 8 and SK 5912) as from 25 October to November).

The population of Campylomma spp peaked at the end of September (28 Sept.) in 1993 especially and declined sharply thereafter (fig.4), with a smaller peak on 16 November for the late maturing sorghum. The population fluctuated throughout the cropping season in 1994 (fig.5) and there was no significant difference amongst the varieties. This observation was similar with results obtained by Sharma and Lopez (1990). The differences in varieties was highly significant in 1993. ICSV 111 had the highest population of 296.5, which has a compact panicle, followed by NR71182 with 148.8 which has a semi-compact panicle and the least was recorded in KSV8 which had 16.5 a loose panicle sorghum. This result supported the earlier findings of Leuschner (1995) that late traditional loose heads cultivars habours fewer headbugs compared to early maturing cultivars with compact panicles. The differences in the results of 1993 and 1994 could be due to the weather conditions, especially rainfall. Based on the stage of sorghum development, the highest population of Campylomma spp. was

recorded at the milk stage (fig.10). This signifies that Campylomma spp occurs earlier in the season than E. oldi. Therefore, population counts for resistance screening should commence earlier for Campylomma spp than for E. oldi, possibly at half anthesis since, at complete anthesis there was already a measurable population in both 1993 and 1994 (fig.10). Because Campylomma spp. is a much smaller insect than E. oldi working on it will be more difficult than for E. oldi and its damage potential and economic importance is yet to be determined. Nevertheless, this study has provided some of the information needed, including its abundance, the time of the year when it occurs, and the growth stage of sorghum preferred by it.

Next to E.oldi in size and agility is Adelphocoris apicalis. In 1993, the population of A. apicalis (Table 3) was low compared to 1994 (Table 4 and Fig. 6). Its high population in 1994 suggests that this insect could be as important as E. oldi in the future. NR 71168 followed by NR 71182 had the highest population of A. apicalis in 1994 (71 and 50 per 5 panicles) respectively, with a peak on 1 November at the end of the rainy season, while the crop was at the soft dough and hard dough stages (fig.11). For early maturing sorghum ICSV 111 and 247, the peak population was recorded on 11 October while for the late maturing sorghum peak period was recorded on 8 November. Therefore, when screening for resistance, it is best to screen to coincide with the highest bug population and at soft to hard dough stage of sorghum. This concludes that, early maturing sorghum should be screened together and late

maturing together.

The populations of T.vosseleri and C.pallidus were also very low (almost negligible) in 1993, but the populations were more in 1994. They are therefore not as important as E. oldi. It should also be noted that T. vosseleri appears earlier in the season than most of the other headbugs discussed earlier. In 1994, this insect first appeared on 20 September and its population reached a peak on 1 November on both NR 71168 and 71182 (fig.7). For the late maturing sorghum, the peak occurred on 8 and 22 November at the soft dough and hard dough stages. This means that the populations are important towards the end of the season and at the late crop developmental stages (fig. 12).

The relative abundance of mirid head bugs populations on five sorghum panicles averaged over the six varieties in 1993 and 1994 are presented in Tables 9 and 10, respectively. In both the years, Eurystyslus oldi is the most abundant as shown in the results followed by Campylomma spp., despite the fact the population was lower in 1994 than 1993. The third in abundance neglecting the 1993 results were Adelphocoris apicalis, Psallus sp, Taylorilygus vosseleri, Creontiades pallidus and the least, Sternotus affinis. This corroborates previous reports by MacFarlane (1984), Nwanze (1985) Steck et al. (1991), Sharma and Lopez (1990), (1992), Sharma et al. (1992), Doumbia (1992), Ajayi (1993), Sharma and Nwanze (1995), Ratnadass and Ajayi (1995), that E. oldi is the most important headbug in Nigeria and the whole of West Africa. E. oldi has been identified in Cote d'lvoire (Ratnadass and Cisse, 1990), Togo (Ratnadass, 1991), and Senegal (Ratnadass, 1992), but infestation levels were much lower than those observed in Mali,

Burkina Faso, Niger and Nigeria. The results obtained showed that the late maturing varieties (KSV 8 and SK 5912) supported high populations but less damage compared to the early maturing varieties (ICSV 111, ICSV 247, NR 71168 and NR 71182) (tables 11 and 12). Sternotus affinis (plate 7.7) was the least abundant but, since it closely resembles the most notorious headbug in India, Calocoris angustatus Leth., (Sharma, 1985; Sharma and Lopez, 1989; 1990; and 1992), it could be an important headbug in the future. More detailed work should therefore be done on it. The damage evaluation (Tables 11 and 12) showed that, the more the discolouration, the more the mouldiness, more vitrosity, less germination, more mass of floaters and consequently lower the yield is shown on the most damaged variety (ICSV 247, Plate 8). The early maturing varieties (ICSV III, 247, NR 71168 and 71182) were more discolored than the late maturing varieties (KSV 8 and SK 5912); but SK 5912 (compact panicle) showed more damage than KSV 8 (loose panicle). Despite the fact that, the early maturing varieties, matures and the headbugs migrates or are transfered to the late maturing varieties, damage caused by headbugs is minimal on the late maturing sorghum. The possible reasons why KSV 8 had the least damage in both years could be due to its loose nature of panicle, plant height which could discourage headbug infestation due to the winds which swings the plants and the prevailing weather conditions as stated by Leuschner (1995), that it does discourage headbug infestation in the loose panicle sorghum as it matures late when rainfall has almost finished.

KSV 8 still gave the highest yield in 1993 and 1994 with 1122.0 and 1513.0 kg/ha, respectively, followed by SK 5912 (859.0

and 1500 kg/ha in 1993 and 1994, respectively). The 1000 grain weight were higher in this late maturing varieties than the early maturing varieties. The early maturing varieties on the average fall within 16-25 compared to the late maturing varieties which fall within 30-33 g. These differences among the varieties could be due to the physical characteristics of the grain preference by headbugs in size of grains, moisture or sap flow at the time of feeding, size and opening of glumes. This is similar to the work by Ratnadass et al. (1995), Ajayi (1997) and ICRISAT (1997) that under natural conditions, headbug numbers and grain damage is greatly influenced by variety preference which could be due to the physical characteristics of the panicles with regards to size, compactness, length and type of glumes, opening time, grain vitrosity or hardness, which have not been carried out in these study to validate their findings. Also, Steck et al. (1989), Sharma and lopez (1992) and Sharma et al. (1995), further emphasized that the extent of damage by headbugs is mostly affected by maturity period, population density of bugs and prevailing weather conditions. These factors, again could change over time and space, hence it takes a longer time to identify stable sources of resistance under natural conditions in different sorghum varieties.

However, conclusions about the level of resistance of these varieties to each insect pest await further studies in which artificial infestation will be used to evaluate them against standard resistant checks.

5.20 DISCUSSION OF EXPERIMENT 11 RESULTS

The results clearly indicate that planting date affects head bug population and hence damage. However, the trend differed according to the headbug species. Eurystylus oldi seems to be more prominent in number than any other head bug, and therefore the most important. This result agrees with the earlier finding in experiment 1, MacFarlane (1984), Sharma et al (1992), Ajayi and Tabo (1993; 1995). The results also showed that E. oldi appeared late in the season which are more in number, together with Adelphocoris apicalis, Taylorilygus vosseleri, Creontiades pallidus and Liorhyssus hyalinus (Tables 13, 14, 15 and 16). While Campylomma spp and Psallus spp appears early in the season (Tables 15 and 16).

The results obtained in this study showed that among the three planting dates (24th June, 15th July and 5th August) 15th July seems to be the best date to plant early maturing variety, even though it supported more headbug population, it gave a moderate yield, less discoloration, mouldiness, vitrosity, floaters and germination percentage (Tables 17 and 18). These results agrees with the earlier findings of Steck et al (1969) and Ajayi and Tabo (1993; 1995).

The stage of development of sorghum also had effect on planting date, especially in terms of their number. As indicated earlier and in the results (Tables 15 and 16), the medium dough stage supported the highest bug number, especially E. oldi. Based on the life-cycle in literature, Ajayi (1993), under field

condition, few numbers which are adults, appears at complete anthesis stage and they multiply reaching adult stage within twenty-one days, which coincides with the medium dough stage and hence they become more in number than at complete anthesis stage. In view of this, control measures should start at complete anthesis inorder to prevent the first rainyseason generation from multiplying.

The differences, in result obtained in 1993 and 1994, could be due to weather effects. In 1993 there was less rainfall prolongation, the rains stopped in September, though it was very much established earlier than in 1994, while in 1994, the rains extended to October, and it did establish very much earlier in the season (Appendix IV). In this view, observation showed that there were more headbugs in 1994 than 1993 which weather could be a contributing factor, and also headbugs with time could be a major pest of sorghum, and long duration of rainfall could increase their numbers. There should be a detail study to correlate rainfall or weather with headbug population and regression analysis.

In conclusion, one can see that planting date could be manipulated to escape high incidence of headbugs on short season sorghum and could also serve as an important tool in screening for resistance against headbugs and hence an important component in integrated pest management.

5.30 DISCUSSION OF EXPERIMENT 111

The results obtained for the two years (1993 and 1994) does

not differ much, therefore a combined analysis for the two years (Table 21) showed that E. oldi caused up to 44% yield loss when caged. This agrees with Steck et at. (1989) and Sharma and Teetes (1995) who recorded a 42% yield loss when panicles were infested at complete anthesis stage of sorghum development at Niger. Panicles infested with 15 pairs of E. oldi (Table 20) at the milk stage had a yield loss of 33.57%. Based on the results obtained, it is best to infest sorghum with 15 pairs of bugs inorder to minimize the amount of labour involved in infestation process, since with 20 pairs of bugs a yield loss of 38.08% at CAS and 32.94% at MS was obtained, compared to 15 pairs as mentioned earlier. The possible reasons for yield loss infested with 20 bugs pairs to be lower than bugs infested with 15 pairs could be due to competition for food, space and shelter, and some of the bugs must have died since population was also lower at 20 pair (162.1 at CAS and 143.0 at MS) than with bugs infested with 15 pairs (213.3 at CAS and 223.5 at MS) table 20. Steck et al (1989); Sharma and Lopez (1992) and Sharma et al. (1992) also reported that infestation trial should be carried out at complete anthesis stage, since eggs could be laid in the glumes even before grain filling starts. In addition, Rana and Singh (1995), also confirmed that infestation during early grain development results in more severe damage than at the hard dough stage.

Headbug damage decreased grain vitrosity, 1000 grain weight, seed germination and increased mouldiness (Tables 19, 20 and 21). Headbugs damaged grain may be unfit for human consumption, due to

reduction in grain quality Plate 8. This also agrees with Sharma et al. (1992) and (1995). Sharma and Teetes (1995) further reported that bug damaged grain is of poor nutritional quality, poor seedling establishment and vigor. Recent studies (Ratnadass et al (1995) showed that grain-mouldiness is enhanced by headbug damaged. This work is presently undergoing a regional trial and the types of grain moulds involved and the mechanism of infestation will soon be determined (P.S. Marley and A.M. Malgwi paper in press).

However, this particular experiment is a step in determining the economic injury level and economic threshold level. The lesson learnt from this experiment, is that E. oldi is a potential threat to sorghum production since it could couse upto 44% grain yield loss.

5.40 POSSIBLE ALTERNATE HOST OF HEADBUGS

In search of alternate host plants of headbugs, only pigeon pea (C. cajan) was found to be habouring headbugs which wer feeding on the sap of the flowers, leaves and stems. This result is in agreement with Ajayi et al (1996) and Jacques (1996), who in addition found other alternate hosts.

However, more work need to be done on the over seasoning strategy of headbugs.

5.50 SUMMARY

i) The different species of headbugs found in order of their population and importance were Eurystylus oldi Poppius, Campylomma spp odh., Adelphocoris apicalis Reuter, Psallus sp., Taylorilygus vosseleri Poppius, Creontiades pallidus Ramb and Sternotus affinis Poppius.

ii) There are two peak population period of E.oldi in the year, towards middle October and towards end of November. The peak period of Campylomma spp is ending September, while that of A. apicalis is towards the end of Novermber.

iii Campylomma spp and Psallus sp appears much earlier in the season, T. vosseleri middle way, while E.oldi, A. apicalis and S. affinis appears towards the end of the season.

iv The highest head bugs population was recorded at soft dough stage to medium dough stage of sorghum development (both nymphs and adults).

v) The type of sorghum panicle influences headbug numbers. Semi-compact and compact panicles, early maturing varieties are mostly favoured.

vi) Sowing or planting date influences incidence of all headbugs. However, the trend differs according to the type of insect species. E. oldi (the most important) escapes damage in late-June sown sorghum. More mouldiness and poorer grain quality of sorghum will be obtained in June sown sorghum, while low yield, small grains and head bug damage grain will be obtained in June sown sorghum. The best time to plant early maturing

sorghum is middle of July which gives moderate yield and better grain quality sorghum.

vii) Artificial infestation with 15 pairs of E. oldi per panicle at complete anthesis stage of sorghum development caused 44% yield loss on ICSV III (early maturing sorghum).

viii) Artificial infestation with 15 pairs of E. oldi at complete anthesis was the best combination for screening sorghum for resistance to E. oldi. This will reduce cost of labour for infestation.

ix) Grain vitrosity or hardness, mouldiness, germination percentage, 1000 grain weight are important factors in evaluating the damage potential of headbugs in addition to its population and discolouration (damage rating).

x) Pigeon pea, could be a possible alternate host of headbugs.

xi) Orius spp could be an important predator on headbugs which could be used as a biological control.

5.60 CONCLUSION

In conclusion, the studies confirmed that E.oldi is the most important headbug at Samaru, Nigeria, and Samaru is a "hot spot" for screening headbug resistance . Early maturing variaties of sorghum were more susceptible to headbugs than late maturing varieties. Time of planting could be manipulated to escape headbug damage and possibly give better yields. This study is very

important as it provides a good base for screening resistance to headbugs on sorghum and could be used in integrated pest management. Some of the headbugs like A. apicalis could be important pests of sorghum in the future. Grains damaged by headbugs may be unfit for human consumption due to reduction in grain quality, mouldiness and poor seed germination. Headbug damaged grain could also create entry points for pathogens, such as grain mould fungi.

5.70 SUGGESTIONS

The following areas of further research which could not be covered during the study are suggested;

i) Determination of the biology and damage potential of headbugs other than E.oldi since they may become important pests of sorghum in the future.

ii) Screening for multiple resistance to panicle pests, stem and leaf feeders and storage insects of sorghum needs to be studied.

iii) Screening for resistance under natural condition (field) is better and more practical to farmers benefit, than the headcage technique designed by Sharma et al (1992) and is more labourious and time consuming.

iv) The dry season survival strategy of headbug is yet to be determined.

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APPENDICES

APPENDIX I

Weekly Population of orius sp. on six sorghum varities per 5 panicles in 1993 at Samaru.

Variety	14/9	21/9	28/7	5/10	12/10	19/10	26/10	2/11	9/11
ICSV 111	0.00	99.0	21.00	0.00	0.0	5.75	0.00	-	-
ICSV 270	0.00	118.8	46.25	0.00	1.75	4.50	0.00		
NR71168	0.00	60.8	23.75	0.00	1.75	4.50	0.00		
NR71182	0.00	94.3	31.75	0.00	4.00	0.00	0.00		
KSV8		-	-	-	0.00	4.25	23.50	1.00	0.00
SK5912	-	-	-	-	-	0.00	5.75	0.0	0.00
TOTAL	0.00	372.9	122.75	0.00	7.5	14.75	29.5	1.00	0.00
MEAN	0.00	93.2	30.68	0.00	1.75	2.46	14.75	0.5	0.00

APPENDIX II

Weekly Population of orius sp. on six sorghum varities per 5 panicles in 1993 at Samaru.

Variety	14/9	21/9	28/7	5/10	12/10	19/10	26/10	2/11
ICSV 111	0.00	23.0	18.75	12.3	2.00	0.00	-	-
ICSV 247	0.00	15.8	14.75	20.8	0.75	2.00	-	
NR71168	0.00	16.8	24.25	22.0	3.50	1.25	-	
NR71182	0.00	18.3	29.00	68.8	5.00	1.25	-	
KSV8	-	-	-	-	0.00	22.50	1.0	0.0
SK5912	-	-	-	-	0.00	19.25	0.75	0.0
TOTAL	0.00	73.9	86.75	123.9	11.25	46.25	1.75	0.0
MEAN	0.00	18.48	21.69	30.98	1.88	7.71	0.88	0.0

APPENDIX III

Density Rainfall in (mm) at Samaru in 1993 and 1994

Date (days)	1993		1994	
	September	October	September	October
1	14.9		0.0	0.0
2	0.0		0.0	14.2
3	0.0		1.8	7.3
4	53.2		0.4	2.1
5	2.2		0.8	0.0
6	12.7		2.2	0.0
7	0.0		2.6	0.0
8	1.9		10.8	0.0
9	-		3.0	2.1
10	16.8		0.0	0.5
11	33.2		1.2	0.0
12	0.0		7.5	2.5
13	0.0		21.8	0.0
14	0.0		5.0	0.0
15	0.0	NO RAINFALL IN OCT.	0.0	20.8
16	0.0		0.0	0.0
17	6.9		0.0	0.0
18	16.5		3.1	13.8
19	0.0		0.0	0.0
20	8.4		14.6	0.0
21	0.0		0.0	0.0
22	0.0		0.0	0.0
23	0.0		0.0	5.6
24	2.3		0.0	0.0
25	0.0		0.0	0.3
26	12.8		0.0	0.0
27	0.0		0.0	0.0
28	0.0		2.1	0.0
29	0.0		1.3	0.0
30	0.0		0.0	0.0
31	0.0		0.0	0.0
TOTAL	181.81	0.0	82.5	69.2
TOTAL FOR THE YEAR	1029.3		909.2	

APPENDIX IV

Weekly Temperature and Relative Humidity at Samaru in 1993 and 1994 (September - December)

1993				1994			
Week beginning	Max.	Min.	Relative Humidity RH %	Week beginning	Max.	Min.	RH %
Sept.7/9	30.0	19.0	87.0	Sept6/9	29.0	19.0	88.0
14/9	29.0	20.0	83.0	13/9	29.0	20.0	87.0
21/9	30.0	19.0	63.0	20/9	30.0	20.0	76.0
28/9	30.0	19.0	71.0	27/9		20.0	76.0
mean	30.0	19.0	77.0	Mean	30.0 29.1	19.5	82.8
Oct.5/10	33.0	19.0	62.0	Oct.4/10	28.0	18.0	91.0
12/10	32.0	19.0	64.0	11/10	31.0	17.0	77.0
19/0	33.0	16.0	55.0	18/10/	31.0	19.0	70.0
25/10	35.0	20.0	-	26/10	33.0	20.0	68.0
Mean	34.1	18.7	63.1	Mean	31.0	19.0	76.0
Nov.2/11	34.0	13.0	Logistic	Nov. 1/11	31.0	16.0	84.0
9/11	33.0	13.0	problems	8/11	31.0	13.0	74.0
16/11	32.0	12.0	so no RH	15/11	32.0	15.0	30.0
23/11	34.0	16.0	was	22/11	29.0	15.0	24.0
30/11	32.0	16.0	recorded	29/11	29.0	14.0	24.0
Mean	33.6	14.1	for the month.	Mean	30.0	13.0	26.0
Dec.7/12	28.0	15.0	26.0	Dec.6/12	23.0	11.0	31.0
14/12	26.0	14.0	32.0	13/12	27.0	10.0	43.0

APPENDIX V

Appendix V.1

ANOVA - Number of Eurystylus oldi collected on six Sorghum Varieties, from Complete anthesis state to Dough Stage of Sorghum Development in 1993 at Samaru

Source of Variation	DF	SS	SS%	MS	F-value
Reps.	3	1107033	8.49	39011	1.088
Varieties	5	724106	52.51	144821	4.039*
Residual	15	537806	39.00	35854	
Total	20	1261912	91.51	63096	
Grand total	23	1378945	100.00		

Appendix V.2

ANOVA - Number of E.oldi collected on six Sorghum Varieties, from complete anthesis Stage to Dough Stage of Sorghum Development in 1994 at Samaru

Source of Variation	DF	SS	SS%	MS	F-value
Reps	3	21528	1.40	7176	0.449
Varieties	5	1275454	83.01	255091	15.970**
Residual	15	239594	15.59	15973	
Total	20	1515048	98.60	75752	
Grand total	23	1536576	100.0		

Appendix V.3

ANOVA - Number of Campylomma spp collected on six sorghum Varieties from Complete anthesis to Dough stage of Sorghum development in 1993 at Samaru

Source of Variation	DF	SS	SS%	MS	F-value
Reps	3	13696	5.29	4565	3.657
Varieties	5	226338	87.47	45268	36.261**
Residual	15	18725	7.24	1248	
Total	20	245063	94.71	12253	
Grand total	23	258759	100.00		

Appendix V.4

ANOVA - Number of Campylomma spp Collected on Six Sorghum Varieties from complete anthesis to Dough Stage of Sorghum Development in 1994 at Samaru

Source of Varieties	DF	SS	SS%	MS	F-value
Reps	3	405.5	12.53	135.2	1.323
Varieties	5	1297.7	40.12	259.5	2.542^{NS}
Residual	15	1531.8	47.35	102.1	
Total	20	2829.5	87.47	141.5	
Grand total	23	3235.0	100.00		

Appendix V.5

ANOVA - Number of Adelphocrois apicalis collected on six Sorghum Varieties from Complete anthesis to dough Stage of Sorghum Development in 1993 at Samaru

Source of Varieties	DF	SS	SS%	MS	F-value
Reps	3	4.125	2.28	1.375	0.407
Varieties	5	126.208	69.74	25.42	7.479**
Residual	15	50.625	27.98	3.375	
Total	20	176.833	97.72	8.842	
Grand total	23	180.958	100.00		

Appendix V.6

ANOVA - Number of A. apicalis Collection six Sorghum Varieties from Complete anthesis to dough Stage of Sorghum Development in 1994 at Samaru.

Source of Variation	DF	SS	SS%	MS	F-value
Reps	3	238.7	1.12	79.6	0.290
Varieties	5	1697.3	79.57	3393.5	12.363**
Residual	15	4117.3	19.31	274.5	
Total	20	21084.7	98.88	1054.2	
Grand total	23	21323.3	100.0		

Appendix V.7

ANOVA - Number of Taylorilygus Vosseleri on Six Sorghum Varieties from Complete anthesis to dough STage of Sorghum Development in 1993 at Samaru

Sources of Variation	DF	SS	SS%	MS	F-value
Reps	3	21.792	6.39	7.264	1.135
Varieties	5	223.208	65.46	44.642	6.978**
Residual	15	95.958	28.14	6.397	
Total	20	319.167	93.61	15.958	
Grand total	23	340.958	100.0		

Appendix V.8

ANOVA - Number of T. Vosselsri on Six Sorghum Varieties from Complete anthesis to dough stage of Sorghum Development in 1994 at Samaru.

Source of Variation	DF	SS	SS%	MS	F-value
Reps	3	89.46	6.57	29.82	2.290
Varieties	5	1077.21	79.09	215.44	16.548
Residual	15	195.29	14.34	13.02	
Total	20	1272.50	93.43	63.63	
Grand total	23	1361.96	100.0		

Appendix V.9

ANOVA - Number of Creontiades pallidus collected on six Sorghum Varieties from Complete anthesis to Dough Stage of Sorghum Development in 1993 at Samaru.

Sources of Variation	DF	SS	SS%	MS	F-value
Reps	3	1.458	0.55	0.486	0.107
Varieties	5	193.208	73.47	38.642	8.487**
Residual	15	68.292	25.97	4.553	
Total	20	261.500	99.45	13.075	
Grand total	23	262.958	100.00		

Appendix V.10

ANOVA - Number of C. pallidus Collected on six Sorghum Varieties from Complete anthesis to dough Stage of Sorghum Development in 1994 at Samaru.

Source of Variation	DF	SS	SS%	MS	F-value
Reps	3	4.792	1.42	1.597	0.197
Varieties	5	210.708	62.53	42.142	5.204**
Residual	15	121.458	36.05	8.097	
Total	20	332.167	98.58	16.608	
Grand total	23	336.958	100.00		

Appendix V.11

ANOVA - Number of psallus Spp collected six Sorghum Varieties from Complete anthesis to Dough Stage of Sorghum Development in 1994 at Samaru.

Source of Variation	DF	SS	SS%	MS	F-value
Reps	3	54.3	0.82	18.1	0.09
Varieties	5	3581.5	54.05	716.3	3.59^{NS}
Residual	15	2990.2	45.13	199.3	
Total	20	6571.7	99.18	328.6	
Grand total	23	6626.0	100.0		

Appendix V.12

ANOVA - Number of Sternotus affinis Collected on six Sorghum Varieties from Complete anthesis to dough Stage of Sorghum Development in 1994 at Samaru.

Source of Variation	DF	SS	SS%	MS	F-value
Reps	3	17.500	4.33	5.833	2.01
Varieties	5	343.500	84.92	68.700	23.69**
Residual	15	43.500	10.75	2.900	
Total	20	387.000	95.67	19.350	
Grand total	23	404.50	100.00		

Appendix V.13

ANOVA - Damage rating (Discolouration) caused by mirid Headbugs in 1993 on six Sorghum Varieties at Samaru.

Source of Variation	DF	SS	SS%	MS	F-value
Reps	3	1.1250	6.63	0.3750	1.36
Varieties	5	11.7083	69.04	2.3417	8.51**
Residual	15	4.1250	24.32	0.2750	
Total	20	15.8333	93.37	0.7917	
Grand total	23	16.9583	100.00		

Appendix V.14

ANOVA - Damage rating (Discolouration) caused by Mirid Headbugs in 1994 on six Sorghum Varieities at Samaru

Source of Variation	DF	SS	SS%	MS	F-value
Reps	3	1.8333	10.28	0.6111	1.12
Varieties	5	2.8333	43.93	1.5667	2.87^{NS}
Residual	15	8.1667	45.79	0.5444	
Total	20	16.000	89.72	0.8000	
Grand total	23	17.8333	100.00		

Appendix V.15

ANOVA - Mouldiness evaluation of six Sorghum Varieties in 1994 at Samaru

Source of Variation	DF	SS	SS%	MS	F-value .
Reps	3	0.1667	0.70	0.0556	0.35
Varieties	5	21.333	89.51	4.2777	27,42**
Residual	15	2.333	9.79	0.1556	
Total	20	23.667	99.30	1.1833	
Grand total	23	23833	100.0		

Appendix V.16

ANOVA - Mouldiness Evaluation of six Sorghum Varieties in 1994 at Samaru.

Source of Variation	DF	SS	SS%	MS	F-value
Reps	3	0.7917	3.97	0.2639	0.88
Varieties	5	14.7083	73.70	2.9417	9.89
Residual	15	4.4583	22.34	0.2972	
Total	20	19.1667	96.03	0.9583	
Grand total	23	19.9583	100.0		

Appendix V.17

ANOVA - Vitrosity Evaluation on Six sorghum Varieties in 1993 at Samaru.

Source of Variation	DF	SS	SS%	MS	F-value
Reps	3	0.8333	7.04	0.2778	1.56
Varieties	5	8.333	70.42	1.6667	9.37**
Residual	15	2.6667	22.54	0.1778	
Total	20	11.000	92.96	0.5500	
Grand total	23	11.8333	100.00		

Appendix V.18

ANOVA - Vitrosity Evaluation on six Sorghum Varieties in 1994 at Samaru

Source of Variation	DF	SS	SS%	MS	F-value
Reps	3	1.7716	14.98	0.5972	6.14
Varieties	5	8.70833	72.82	1.7416	17.91**
Residual	15	1.4583	12.20	0.09722	
Total	20	10.1667	85.02	0.5083	
Grand total	23	11.9583	100.00		

Appendix V.19

ANOVA - Germination Evaluation on six Sorghum Varieties in 1993 at Samaru

Source of Variation	DF	SS	SS%	MS	F-value
Reps	3	9.333	4.29	3.111	1.54
Varieties	5	177.833	81.83	35.567	17.68**
Residual	15	30.167	13.88	2.011	
Total	20	208.00	95.71	10.400	
Grand total	23	217.333	100.00		

Appendix V.20

ANOVA - Germination Evaluation on six Sorghum Varieties in 1994 at Samaru

Source of Variation	DF	SS	SS%	MS	F-value
Reps	3	230.46	6.43	76.82	1.42
Varieties	5	2542.71	70.95	508.54	9.40**
Residual	15	810.79	22.62	54.05	
Total	20	3353.50	93.57	167.68	
Grand total	23	3583.96	100.00		

Appendix V.21

ANOVA - Floaters evaluation on six sorghum Varieties at Samaru in 1993.

Source of Variation	DF	SS	SS%	MS	F-value
Reps	3	3.118	0.35	1.039	0.19
Varieties	5	810.652	90.75	162.130	30.67**
Residual	15	79.550	8.90	5.303	
Total	20	890.202	99.65	44.510	
Grand total	23	893.320	100.0		

Appendix V.22

ANOVA - Floaters evaluation on six Sorghum Varieties at Samaru in 1994

Source of Variation	DF	SS	SS%	MS	F-value
Reps	3	33.54	1.90	11.18	0.56
Varieties	5	1437.09	81.29	287.42	14.51**
Residual	15	297.13	16.81	19.81	
Total	20	1734.22	98.10	86.71	
Grand total	23	1767.76	100.00		

Appendix V.23

ANOVA - Grain Yield in kg/ha on six sorghum Varieties at Samaru in 1993

Source of Variation	DF	SS	SS%	MS	F-value
Reps	3	90527	4.99	30176	1.32
Varieties	5	1384395	76.26	276879	12.19
Residual	15	340519	18.76	22701	
Total	20	1724914	95.01	86246	
Grand total	23	1815441	100.00		

Appendix V.24

ANOVA - Grain Yield in kg/ha on six sorghum Valieries at Samaru in 1994

Source of Variation	DF	SS	SS%	MS	F-value
Reps	3	24099	0.54	8033	0.17
Varieties	5	3709437	83.87	741887	16.14**
Residual	15	689497	15.59	45966	
Total	20	4398935	99.46	219947	
Grand total	23	4423033	100.00		

Appendix V.25

ANOVA - Effect of Planting dates on Number of *Eurystylus oldi* on Sorghum Variety NR 71168 in 1993 at Samaru.

Source of Variation	DF	SS	SS%	MS	F-value
Reps	3	9167	0.73	30.56	0.633
Date	2	32.06	0.25	16.03	0.352^{NS}
Trts	2	10165.39	80.56	5082.69	105.311**
Date x Trt.	4	1171.11	9.28	292.78	6.066**
Residual	24	1158.33	9.18	48.26	
Total	32	12526.89	99.27	391.47	
Grand total	35	12618.56	100.00		

Appendix V.26

ANOVA - Effect of Planting dates on the Number of *E.Oldi* on Sorghum Variety NR 71168 in 1994 at Samaru.

Source of Variation	DF	SS	SS%	MS	F-value
Reps	3	2437.9	6.71	812.6	2.701
Date	2	8545.1	23.52	4272.5	14.199**
Trts	2	10579.1	29.12	5289.5	17.579**
Date x Trt	4	7543.6	20.77	1885.9	6.268**
Residual	24	7221.6	19.88	300.9	
Total	32	33889.3	93.29	1059.0	
Grand total	35	36327.2	100.00		

Appendix V.27

ANOVA - Effect of Planting dates on the number of *Campylomma* spp on sorghum Variety NR 71168 in 1993 at Samaru.

Source of Variation	DF	SS	SS%	MS	F-value
Reps.	3	185.56	9.00	61.85	2.747
Date	2	430.39	20.87	215.19	9.556**
Trts.	2	774.06	37.54	387.03	17.187**
Date x Trts	4	131.78	6.39	32.94	1.463^{NS}
Residual	24	540.44	26.21	22.52	
Total	32	1876.67	91.00	58.65	
Grand total	35	2062.22	100.00		

Appendix V.28

ANOVA - Effect of Planting dates on the Number of Adelphocoris apicalis on Sorghum Variety NR 71168 in 1993 at Samaru.

Source of Variation	DF	SS	SS%	MS	F-value
Reps	3	30.528	3.58	10.176	1.075
Date	2	1.056	0.12	0.528	0.056^{NS}
Trts	2	234.889	27.56	117.444	12.405^{**}
Date x Trts	4	358.611	42.08	89.653	9.469^{**}
Residual	24	227.222	26.66	9.468	
Total	32	821.778	96.42	25.681	
Grand total	35	852.305	100.00		

Appendix V.29

ANOVA - Effect of Planting dates on the number of A.apicalis on Sorghum Variety NR 71168 in 1994 at Samaru

Source of Variation	DF	SS	SS%	MS	F-value
Reps	3	357.64	11.0	119.21	2.349
Date	2	692.17	21.29	346.08	6.819^{**}
Trts	2	696.50	21.43	348.25	6.861^{**}
Date x Trts	4	286.33	8.81	71.58	1.410^{**}
Residual	24	1218.11	37.47	50.75	
Total	32	2893.11	89.00	90.41	
Grand total	35	3250,75	100.00		

Appendix V.30

ANOVA - Effect of Planting dates on the number of Creontiades pallidus on sorghum Variety NR 71168 in 1993 at Samaru

Source of Variation	DF	SS	SS%	MS	F-value
Reps	3	2.333	2.04	0.778	0.289
Date	2	11.056	9.65	5.528	2.052^{NS}
Trts	2	19.389	16.93	9.694	2.052^{*}
Date x Trts	4	17.111	14.94	4.278	1.588^{NS}
Residual	24	64.667	56.45	2.694	
Total	32	112.22	92.96	3.507	
Grand total	35	114.556	100.00		

Appendix V.31

ANOVA - Effect of Planting dates on the number of Creontiades pallidus on sorghum Variety NR 71168 in 1993 at Samaru

Source of Variation	DF	SS	SS%	MS	F-value
Reps	3	155.19	3.41	51.73	1.852
Date	2	846.06	18.58	423.03	15.141^{**}
Trts	2	2128.39	46.74	1064.19	38.089^{**}
Date x Trts	4	753.44	16.55	188.36	6.742^{**}
Residual	24	670.56	14.73	27.94	
Total	32	4398.44	96.59	137.45	
Grand total	35	4553.64	100.00		

Appendix V.32

ANOVA - Effect of Planting dates on the number of C.pallidus on sorghum Variety NR 71168 in 1993 at Samaru

Source of Variation	DF	SS	SS%	MS	F-value
Reps	3	24.33	0.59	8.11	0.385
Date	2	46.89	1.148	23.03	1.112^{NS}
Trts	2	2120.06	58.67	1210.03	57.374^{**}
Date x Trts	4	1127.11	27.33	281.78	13.361^{**}
Residual	24	506.17	12.27	21.09	
Total	32	4100.22	99.41	128.13	
Grand total	35	4124.56	100.00		

Appendix V.33

ANOVA - Effect of Planting dates on discolouration caused by mirid head bugs of sorghum variety NR 71168 in 1994 at Samaru

Source of Variation	DF	SS	SS%	MS	F-value
Reps	3	0.2500	5.08	0.833	0.33
Date	2	3.1667	64.41	1.5833	6.33^{**}
Residual	6	1.500	30.51	0.2500	
Total	8	4.617	94.92	0.5833	
Grand total	11	4.9167	100.00		

Appendix V.34

ANOVA - Effect of Planting dates on discolouration caused by mirid head bugs of sorghum variety NR 71168 in 1994 at Samaru

Source of Variation	DF	SS	SS%	MS	F-value
Reps	3	0.333	4.35	0.111	0.30
Date	2	3.500	67.39	2.5833	7.15^{*}
Residual	6	0.5000	28.26	0.3611	
Total	8	4.000	95.65	0.9167	
Grand total	11	5.000	100.0		

Appendix V.35

ANOVA - Effect of Planting dates on mouldiness evaluation on sorghum variety NR 71168 in 1994 at Samaru

Source of Variation	DF	SS	SS%	MS	F-value
Reps	3	1.000	20.00	0.333	4.00
Date	2	3.500	70.00	1.7503	21.00^{**}
Residual	6	0.5000	10.00	0.083	
Total	8	4.000	80.00	0.500	
Grand total	11	5.000	100.0		

Appendix V.36

ANOVA - Effect of Planting dates in floaters evaluation on sorghum variety NR 71168 in 1993 at Samaru

Source of Variation	DF	SS	SS%	MS	F-value
Reps	3	45.614	16.86	15.205	6.33
Date	2	210.477	77.81	105.239	43.86**
Residual	6	14.395	5.32	2.399	
Total	8	224.873	83.14	28.109	
Grand total	11	270.486	100.0		

Appendix V.37

ANOVA - Effect of Planting dates on vitrosity evaluation on sorghum variety NR 71168 in 1994 at Samaru

Source of Variation	DF	SS	SS%	MS	F-value
Reps	3	0.2500	5.08	0.0833	1.00
Date	2	4.1667	84.75	2.0833	20.00**
Residual	6	0.500	10.17	0.0833	
Total	8	4.667	94.92	0.5833	
Grand total	11	4.9167	100.0		

Appendix V.38

ANOVA - Effect of Planting dates on grain yield on sorghum variety NR 71168 in 1993 at Samaru

Source of Variation	DF	SS	SS%	MS	F-value
Reps	3	58.056	27.78	19352	3.50
Date	2	117.769	56.36	58884	10.65**
Residual	6	33.150	15.86	5525	
Total	8	150.919	72.22	188.65	
Grand total	11	20.8974	100.0		

Appendix V.39

ANOVA - Effect of Planting dates on grain yield evaluation on Sorghum variety NR 71168 in 1994 at Samaru

Source of Variation	DF	SS	SS%	MS	F-value
Reps	3	40.6294	48.63	135425	2.29
Date	2	754.399	59.03	37.729	0.64^{NS}
Residual	6	35.3680	42.34	58.947	
Total	8	4291109	51.37	53640	
Grand total	11	835.393	100.0		

Appendix V.40

ANOVA - Population building of Eurystylus oldi infested at 5 levels (0,5,10,15,20) at complete anthesis stage on sorghum variety ICSV 111 in 1993 at Samaru.

Source of Variation	DF	SS	SS%	MS	F-value
Reps	3	2041.0	1.75	680.3	1.23
Level	4	208292.3	92.61	27073.1	49.19***
Residual	12	6604.5	5.65	550.1	
Total	16	114896.8	98.25	7181.1	
Grand total	19	116937.8	100.0		

Appendix V.41

ANOVA - Population building of E. oldi infested at 5 levels (0,5,10,15,20) at milk stage on sorghum variety ICSV 111 in 1993 at Samaru.

Source of Variation	DF	SS	SS%	MS	F-value
Reps	3	646.2	1.25	215.4	0.83
Level	4	471582.3	92.64	11789.6	45.60**
Residual	12	3102.1	6.09	258.5	
Total	16	50260.4	98.73	3141.3	
Grand total	19	50906.5	100.0		

Appendix V.42

ANOVA - Discolouration (Damage evaluation) caused byE. oldi infested at 5 levels (0,5,10,15,20) complete anthesis stage on sorghum variety ICSV 111 in 1993 at Samaru.

Source of Variation	DF	SS	SS%	MS	F-value
Reps	3	0.4000	2.13	0.1333	0.76
Level	4	16.300	86.70	4.0750	23.28**
Residual	12	2.100	11.17	0.1750	
Total	16	18.400	97.87	0.1500	
Grand total	19	50906.5	100.0		

Appendix V.43

ANOVA - Discolouration (Damage evaluation) caused by E. oldi infested at 5 levels (0,5,10,15,20) at Milkstage on sorghum variety ICSV 111 in 1993 at Samaru.

Source of Variation	DF	SS	SS%	MS	F-value
Reps	3	1.000	5.88	0.333	2.00
Level	4	14.000	82.35	3.500	21.00**
Residual	12	2.000	11.76	0.1667	
Total	16	16.000	94.12	1.000	
Grand total	19	17.000	100.00		

Appendix V.44

ANOVA - Mouldiness evaluation on sorghum variety ICSV 111 infested at 5 levels 0,5,10,20 at complete anthesis stage in 1993 at Samaru.

Source of Variation	DF	SS	SS%	MS	F-value
Reps	3	0.9500	7.57	0.3167	2.11
Level	4	9.800	78.09	2.4500	16.33**
Residual	12	1.800	14.34	0.1500	
Total	16	11.600	92.43	0.7250	
Grand total	19	12.550	100.00		

Appendix V.45

ANOVA - Mouldiness evaluation on sorghum variety ICSV 111 infested at 5 levels 0,5,10,20 at complete anthesis stage in 1993 at Samaru.

Source of Variation	DF	SS	SS%	MS	F-value
Reps	3	0.5500	3.78	01833	0.52
Level	4	9.800	67.35	2.4500	7.00**
Residual	12	4.200	28.87	0.3500	
Total	16	14.500	96.22	0.8750	
Grand total	19	14.500	100.00		

Appendix V.46

ANOVA - Yield loss assessment caused by E. oldi on sorghum variety ICSV 111 infested at 5 levels 0,5,10,20 at complete anthesis stage in 1993 at Samaru.

Source of Variation	DF	SS	SS%	MS	F-value
Reps	3	1609.0	28.48	536.3	5.11
Level	4	2781.8	49.24	695.40	6.63**
Residual	12	1258.7	22.28	104.90	
Total	16	4040.5	71.52	252.5	
Grand total	19	14.500	100.00		

Appendix V.47

ANOVA - Yield loss assessment caused by E. oldi on sorghum variety ICSV 111 infested at 5 levels 0,5,10,20 at complete anthesis stage in 1993 at Samaru.

Source of Variation	DF	SS	SS%	MS	F-value
Reps	3	1839.6	19.69	613.2	2.11
Level	4	4026.0	43.09	1006.5	3.47**
Residual	12	3478.5	37.23	289.9	
Total	16	7504.6	80.31	469.0	
Grand total	19	9344.1	100.00		