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SCREENING OF SORGHUM GENOTYPES AGAINST SPOTTED STEM BORER, *CHILO PARTELLUS* (Swinhoe) (LEPIDOPTERA: CRAMBIDAE)

By

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In the partial fulfillment of the requirement for the attainment of the degree of Master of Science in Biology (Insect Sciences)

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Abstract

Sorghum (*Sorghum bicolor* (L) Monech) is among the leading cereal grains produced in Africa and it is a staple food for millions of people in the continent. In Ethiopia, sorghum stands third in terms of area coverage after teff and maize, and second in terms of yield per hectare after maize. The spotted stem borer, *Chilo partellus* (Swinhoe) (Lepidoptera: Crambidae) is a major constraint limiting production of sorghum in Ethiopia. The present study was conducted at Melkassa Agricultural Research Center experimental field with the main objective of screening sorghum genotypes which are resistant against *Chilo partellus*. Two hundred one sorghum genotypes were planted at Melkassa Agricultural Research Center in two replications in Randomized Complete Block Design. Twelve of these genotypes were selected for artificial infestation study in screen house pot experiment depending on stem borer percent infestation. The twelve genotypes were four from resistance, four from intermediate and four from susceptible groups and they were planted in pot in screen house in completely randomized design in three replications. Forty mated *C. Partellus* adults were released in to the set up for artificial infestation of the genotypes. Population growth of *C. partellus* was also studied on the most resistant and the most susceptible genotypes. The results obtained indicate that there were high level of variability among the genotypes tested both under natural infestation of field condition and artificial infestation of pot-screen house experiment. Significantly ($P < 0.05$) lower number of egg masses, lower percent hatchability, lower percent pupation and lower percent survival of *C. partellus* were recorded on A3 X 76 T1 # 23 suggesting that there is a possibility of developing *C. partellus* resistant varieties. However, further evaluation of the sorghum genotypes, which are found in different adaptation areas are important and there is also a great need to develop varieties by breeders that can resist stem borer attack.

Key words: *Sorghum bicolor*, spotted stem borer, genotypes, artificial infestation, screen

house.

in the country (Emana *et al*., 2003). The major insect pests causing damage to sorghum crop are lepidopterous stem borers (*Chilo partellus* (Swinhoe) and *Buseola fusca* (Fuller)), sorghum Midge (*Contarinia sorghicola*) (Coquillet) and Shoot fly (*Atherigona soccata*) (Ronadani) (Diptera: Muscidae) (Taneja, 1989).

Lepidopterous stem borers account for 20-50% crop losses (Emana and Tsedeke, 1999). Sorghum is grown by the resource poor farmers who cannot afford to use insecticides for the control of insect pests (Assefa, 1985; Kishore, 1986; Overholt *et al*., 1997). The cryptic feeding nature of *C. partellus* and other stem borers is also another factor, which limit the use of insecticides. However, the damage by *C. partellus* to sorghum is increasing from time to time in previously infested areas and it is also been expanding to the high land areas (Emana *et al*., 2003; Emana, 2004; Amanuel, 2005).

Currently, attempts are geared towards the development of sound integrated management of *C. partellus*, which include biological control, botanical control, habitat management, intercropping and varietal resistance. From the attempts made so far for the management of *C. partellus,* biological control using *Cotesia flavipes* (Cameron) (Hymenoptera: Braconidae) and the use of resistant varieties are the most promising methods in Ethiopia (Emana, 2005).

Cotesia flavipes, an Asian origin larval endo parasitoid of *C. partellus* and other African stem borer species for the first time reported in Ethiopia by Emana *et al*. (2001,2002,2003). Different conservation efforts and Augmentation releases of *C. flavipes* are already operational at *C. partellus* prune areas of northeastern, central and eastern parts of Ethiopia (Emana *et al*., 2003).

This effective biological control program should be supplemented with compatible IPM components like use of resistant varieties. Use of resistant varieties is one of the most recommended methods of controlling stem borers. Integrated pest management (IPM) approach emphasizes the importance of using host plant resistance in the management of *C. partellus* and other lepidopterous stem borers on cereal crops including sorghum. Host plant resistance is ecologically sound, economically feasible, socially acceptable and environmentally friendly technology (Robert *et al*., 2003). Resistance can be grouped into genetic resistance and induced resistance. Induced resistance is defined as an enhancement of the defensive capacity of the plant against a wide range of pests. It is acquired after appropriate stimulation. Genetic resistance on the other hand is the development of plant varieties with bound bases of resistance, which may reduce the development of insect populations.

Information gathered on a few sorghum genotypes indicates that there is variability among sorghum genotypes with respect to *C. partellus* infestation (Emana *et al*., 2003). However, all available genotypes were not evaluated for their reaction against *C. partellus*. Thus, this study was initiated to investigate the reaction of sorghum genotypes which are available in Ethiopia against *C. partellus* and to contribute to integrated management of *C. Partellus*.

2. Literature Review

2.1 Status of sorghum production in Ethiopia

Sorghum is one of the most drought tolerant cereal crops grown in Ethiopia. It is a common name for corn - like grasses native to Africa and Asia, where they have been cultivated since ancient times.

Sorghum is an important food crop in Ethiopia ranking third in terms of acreage of cultivated land, and second in terms of yield per hectare (CSA, 2003). It is grown in all regions of the country at elevations ranging below1500 meters above sea level (Benti and Ransom, 1993). Sorghum is one of the important cereal crops in the world (ICRISAT, 1989). The most important sorghum producers of Africa are Nigeria, Sudan and Ethiopia (Van Rensburg and Van Hamburg, 1975). It is drought resistant and out yields maize in drier areas. Sorghum is cultivated worldwide for fodder, grain, and syrup production. Grassy sorghums, including Sudan grass, are widely grown for fodder and pasture. Sorghum cultivation for grain began in Egypt thousands of years ago. Today grain sorghums are the staple food for millions of people in China, India, and Africa. The stalks are used for animal feed, fuel, mulching and fence construction. Sorghum grain is also used for brewing.

2.2 Production constraints of Sorghum

In Ethiopia, the national average yield for sorghum is nearly 1 t/ha (Benti and Ransom, 1993), which is far less than its potential yield. The reduction in yield is due to a wide range of production constraints, among which poor soil fertility, moisture stress, striga, lack of pure seed, improper cultural practices, diseases and insect pests are the major ones.

One of the constraints to sorghum production is herbivory by lepidopteran stem borers. So far six stem borer species are reported on sorghum in Ethiopia (Emana *et al*., 2001, 2002, 2003). These are the noctiuds *Busseola fusca* (Fuller), *Sesamia calamisitis* Hampson (Lepidoptera: Noctuidae), and *S. nonagrioides botanephaga* Tams and Bowden (Lepidoptera: Noctuidae); the crambid, *Chilo partellus* (Swinhoe) and *Rhynchaenus niger* (Horn) (Coleoptera: Rhynchophoridae) and *Pissodes dubious* (Storm) (Coleoptera: Rhynchophoridae) (Emana *et al*., 2001). All stem borers recorded are indigenous to Africa with the exception of *C. partellus*, which is of Asian origin and invaded Africa some time before 1930, when it was first recorded in Malawi (Tams, 1932). Stem borer accounts for 20-50% sorghum crop losses in Ethiopia (Emana and Tsedeke, 1999).

2.3 Geographic distribution of *C. partellus*

The geographical distributions of cereal stem borers are generally dependent on altitude and environmental factors (Tessema, 1982; Seshu Reddy, 1983; Harris and Nwanze, 1992;

Overholt *et al*., 1997).

In Ethiopia, Assefa (1985), Emana (1997) and Emana and Tsedeke (1999) reported three species of stem borers, namely *Busseola fusca*, *C. partellus* and *Sesamia calamistis* on maize and sorghum. In later surveys, Emana *et al*. (2001, 2002, 2003) reported three more species of stem borers in Ethiopia. *B. fusca* is indigenous to Africa occurring throughout sub Saharan Africa and its pest status varies from country to country (Overholt, 1998). In East and South Africa, it is a pest at higher altitudes (>600 m. a. s. l.) (Nye, 1960; Overholt, 1998), but in West Africa, it is a pest from sea level to 2000m (Tams and Bowden, 1983). Assefa (1985) recorded *B. fusca* in Ethiopia at elevations ranging from 1160 to 2500m in cooler areas of the country.

The exotic species, *C. partellus* spread to most countries in eastern and southern Africa, including Ethiopia, Kenya, Malawi, Mozambique, Somalia, South Africa, Sudan, Tanzania, Uganda (CAB, 1977), Botswana, Swaziland, Zimbabwe (Sithole, 1990), Comoros Islands, Madagascar (Bleszynski , 1970), Lesotho (Ebenbe *et al*., 1998). Additionally, recent surveys conducted by the International Center of Insect Physiology and Ecology (ICIPE) and/or national programs have found *C. partellus* in Eritrea, Zambia, Zanzibar and Somalia (Overholt and Maes, 2000).

C. partellus is predominant in the warm and low altitude areas (510-1700) (Taneja, 1989). *C. partellus* reportedly occurs below 1500m (Overholt *et al*., 1997). However, Emana *et al*.

(2001) and Goufa *et al*. (2001) reported changes in the distribution of maize and sorghum in East Africa, and as a result of this, *C. partellus* was found to occur at higher elevations of up to 2300 m.a.s.l and the first author also pointed out that distribution in Ethiopia is highly influenced by precipitation, maximum and minimum temperatures. Currently, *C. partellus* is recorded and becomes an economically important pest at 2080 m (Emana, 2002; 2006; Emana *et al*., 2001, 2002, 2003, 2004; Abyi, 2005; Amanauel, 2005) in Ethiopia.

2.4 Economic importance of *Chilo partellus*

More than 18 species of stem borers from the order lepidoptera cause damage to maize and sorghum in Africa (Maes, 1997). They belong to three families: Crambidae, Noctuidae and Pyralidae (Maes, 1997). The indigenous noctuids, *B. fusca* and *S. calamisitis* across Africa, and the exotic crambid, *C. partellus* in eastern and southern Africa, are by far economically the most important pests on maize and sorghum (Ingram, 1958; Harris and Nwanze, 1992; Overholt *et al*., 1997; Van Den Berg *et al*., 1997). Most cereal stem borers indigenous to Africa are generally polyphagous and attack several graminous wild and cultivated plants. Hosts are found in three main families: Cyperaceae, Gramineae (Poaceae) and Typhaceae. Grain yield losses in maize and sorghum due to stem borers vary greatly and are influenced by cultivars, age of the crop at the time of infestation and density of the borer population (Warui and Kuria, 1983; Seshu Reddy and Walker, 1990). In Zimbabwe, Sithole (1994) reported that the loss in sorghum yield could range from 50-60% due to *C. partellus.*

In Ethiopia, Assefa (1985) and Emana and Tsedeke (1999) have reported yield losses ranging from 10 to 100%. If plants are attacked at mature stage, the damage is less devastating. However, the loss can range from 21-60% of the potential yield (Warui and Kuria, 1983; Ampofo, 1986; Seshu Reddy, 1988; Seshu Reddy and Sam, 1992). *C. partellus* has proved to be a highly competitive colonizer in many areas it has invaded, often becoming the predominant and most important stem borer species in maize and sorghum (Seshu Reddy and Walker, 1990). There are evidences of partial displacement of native stem borers by *C. partellus*. In costal areas of Kenya, *C. partellus* has displaced *C. orichalcociliellus* cited in (Emana, 2002). A similar study in South Africa by Kfir (1992) indicated the displacement of *B. fusca* over a period of 5-7 years where the proportion of *C. partellus* increased from 3% in 1986 to 91% in 1992.

2.5 Biology of *C. partellus*

Chilo partellus is a medium sized moth, straw or light brown in color, with numerous shiny brown spots on the fore wing margins. The hind wings are papery thin and white. The moth is nocturnal in habit and usually lives approximately one week (Pats, 1992). Although adults are present throughout the year, the numbers are low between cropping seasons (Unnithan and Sexana, 1990). Mating generally takes place during the early hours of the day soon after emergence and on the two to three subsequent nights (Bonhof, 2000) and egg laying during the evening hours. Once the females have made their choice for ovipostion, they lay their eggs in mass (Leuschner, 1990). The female lays up to 500 eggs in batches of 10-80 near the midrib on the under surface of the leaves (Bonhof, *et al*., 1997).

Eggs can be found in the field from one week to three weeks after plant emergence (Seshu Reddy, 1983). Eggs hatch in 5-11 days early in the morning (Pats, 1992) and many larvae are carried away by the wind on silken threads and infest the neighboring plants (Berger, 1992). *C. partellus* usually passes 5-6 instars with head capsule measurements of 0.31, 0.43, 0.68, 1.38, and 1.78 mm for 1^{st}, 2^{nd}, 3^{rd}, 4^{th} and 5^{th} instars, respectively. Rarely an additional instar (6^{th} instar) is present with a head capsule measuring 2.09 mm and a few larvae pupate in the fifth instar.

After feeding in the leaf whorls for 10-15 days, the grown up larvae (third and fourth instars) leave the whorls and come to the base of a plant. Here they feed between the leaf sheath and the stem for a short time before boring into the stem. During the rest of its developmental period the larva feeds in the stem causing a characteristic dead heart symptom (if the infestation occurs in the early crop growth stage), or stem tunneling in the latter growth stages. The larva molts 4 times (5 instars) within a period of 15-18 days under normal environmental conditions, and the larvae pupate within the stem/peduncle or even in the panicle after making a window hole for moth emergence. Before pupation, the majority of the larvae move towards the low humidity zones within a plant (Neupane *et al*., 1985).

The pupal period lasts for 7-8 days, and thus one generation (from egg to adult) is completed within 27-31 days under favorable environmental conditions. The moth emerges from pupa in the late afternoon and early evening and is active at night. Under unfavorable conditions (low or high temperature, low humidity, and dry stems), the larvae enter into diapauses within stalks and stubbles, where it can survive from six month to one year (Bonhof, 2000).

2.6 Management of *Chilo partellus*

2.6.1 Cultural control

Simple modifications of a pest's environment or habitat can be effective methods of pest control. As a group, these tactics are usually known as cultural control practices.

Cultural management of pests involves changes to the way a crop is grown in order to make the crop less suitable for the pest, to make it more suitable for natural enemies, or to enhance the ability of the crop to withstand pest attack. The ultimate goal is to change the agro ecosystem in such a way that the pest populations remain below the economic injury level (Robert *et al*., 2003).

Cultural control is defined as regular farm operations, which are specifically designed to destroy the pest or group of pests, or to prevent them from causing damage to the crops (Omolo and Seshu Reddy, 1983). Cultural practices that may affect sorghum stem borers include tillage and mulching, time of planting, fertilizer application, sanitation, crop rotation, and intercropping (Seshu Reddy, 1985).

During the off-season, tillage will destroy stubble and volunteer hosts that may harbor the stem borers (Seshu Reddy, 1985). Mohyuddin and Greathead (1970) in Uganda observed high levels of stem borer infestation when untreated crop residues were used to mulch the next crop. In Ethiopia, the infestation of *C. partellus* was 100% in areas where farmers had used old stalks as mulch for soil conservation (Emana, 1997; Emana and Tsedeke, 1999).

Adjustment of planting dates could be an effective method for the control of stem borers in maize and sorghum (Seshu Reddy, 1985). In northern Indian states, *C. partellus* caused more damage in early sown than in late sown sorghum (Seshu Reddy, 1985).

The use of nitrogen fertilizers to enhance plant nutrition often influences the longevity and fecundity of insects and the damage they cause (U.S National Academy of Sciences, 1969). In Uganda, Starks *et al*. (1971) found more *C. partellus* in a sorghum plot fertilized with nitrogen and phosphorus fertilizers than the unfertilized plot.

Ingram (1958) and Nye (1960) in east Africa reported that the destruction of all crop residues and wild species of sorghum around cultivated areas would considerably reduce stem borer attack at the beginning of the growing season. Mohyuddin and Greathead (1970) stated that ratooning of sorghum is a dangerous source of stem borer infestation for other crops. Taley and Thakare (1980) in India found that the storage of sorghum stalks for fodder was conducive to the carry over of *C. partellus* and recommended the practice of chopping stalks to help control the pest. In Ethiopia, horizontal placement of the stalks in thin layers on the ground was recommended (Assefa, 1988).

Crop rotation is a classical cultural practice, which denies access of the pest to its host. A sequence of closely related crops such as maize and sorghum should be avoided (Seshu Reddy, 1985).

In intercropping, modification of the microenvironment and differences in nutrient uptake by the intercrops may influence plant infestation, and the development and movement of insect pests (Omolo *et al*., 1993). Crop combinations range from maize/legume to maize/ cereal or sorghum/legume to sorghum/cereal and a range of several food and non-food crops. Amoako-atta *et al*. (1983) reported that the incidence of *C. partellus*, *B. fusca*, *E. sacchorina*, and *S. calamistis* on maize/sorghum dicrop was earlier and increased over time, whereas intercropping these two cereals with cowpea caused a significant delay in borer colonization and establishment. Skovgard and Pats (1996) in Kenya found that fewer larvae and pupae of *C. partellus* occurred in maize-cowpea intercrop plots than maize monocroping. However, Pats *et al*. (1997) in coastal Kenya found that intercropping did not affect *C. partellus* nor *C. orichalcocilienus* oviposition behavior. Hadush (2003) reported that stem borer abundance and damage on sorghum were usually lower in the sorghum-cowpea intercropping than in the sorghum monocropping in Tigray. Number of predators (ants, spiders & ladybird beetles) was relatively high in the intercrop than in the monocrop. Sweet sorghums are readily attacked by C. *partellus* (Swinhoe) (Lepidoptera: Crambidae) and *Busseola fusca* (Fuller) (Lepidoptera: Noctuidae) and have potential for use as trap crops for these species (Rebe *et al*., 2004).

2.6.2 Biological control

Biological control does not cause immediate reduction in target pest population. It only achieves partial suppression of the target pest, as a residual pest population is necessary to maintain natural enemies.

After the arrival or inoculation of a biological control agent in a field or area, its population gradually increases (Robert *et al*., 2003). Eventually the natural enemy population increases to the point at which it starts to reduce the population growth rate of the target pest, causing it to decline (Robert *et al*., 2003). There are three strategies of biological control: importation (classical), augmentation, and conservation of beneficial organisms such as parasitoids, predators and pathogens for density regulation of other organisms (Van Driesche and Bellows, 1996). According to the authors, classical biological control is the importation and establishment of exotic natural enemies in to a new environment. Augmentation of natural enemies is the action taken to increase the populations or beneficial effects of natural enemies; whereas conservation of natural enemies refers to actions purposely taken to promote the activities of natural enemies (Van Driesche and Bellows, 1996). Several studies have been published on the species composition and distribution of natural enemies of *C. partellus, B. fusca, Sesamia calamistis* and other stem borers in maize and sorghum (Waage and Greathead, 1985; Oloo, 1989).

Insect–parasitoids kill their hosts and be able to complete their development on a single host, unlike predators, which generally consume several preys to complete their development (Doutt, 1959). Parasitoids have been the most common type of natural enemies introduced for biological control of insects (Hall and Ethler, 1979; Greathead, 1986). Most parasitoids that have been used in biological control are in the order Hymenoptera and to a lesser degree, Diptera. Parasitoids are also found in the order Strepsiptera and Coleoptera (some members of the families are Staphylinidae, Meloidae, Rhipiphoidae). *C. flavipes* is suppressing stem borer populations in some areas of Kenya where it has been established (Zhou *et al*., 2001).

Polaszek (1997) listed 121 species of parasitoids in 56 genera associated with the African stem borers. According to Pinoto and Stouthamer (1994), there are about 80 genera and over 60 species of insect egg parasitoids in the family Trichogrammatidae of the order Hymenoptera. Toay, there are about 200 species of Trichogramma and 25 species of Tricogrammatoidea worldwide (Pinto, 1999). Among the Scelionids, *Telenomus buseeolae* Gahan were common in many countries in Africa (Polaszek and Khan, 1998).

The diversity, efficiency and type of natural enemies vary from region to region and from country to country within Africa (Seshu Reddy, 1983; Adugna, 2000). In Kenya, Seshu Reddy (1983) recorded *C. sesamiae* and *Dentichamias busseolae* Heinrich (Hymenoptera: Eulophidae), *Telenomus busseolae* Gahan (Scelionidae), *Trichogrammatoidea luea* (Trichogrammatidae) and *Bracon sesamiae* Cameron (Braconidae) in South Africa. In Eritrea, Adugna (2000), reported *C. sesamiae, D. busseolae* and *Podiobius furvus* Gahan (Hymenoptera: Eulophidae) as parasitoids. A number of parasitoid species have been recovered from cereal stem borers in east Africa. The parasitoid species can attack the most important stem borers including *Chilo spp, S. calamistis, B. fusca* and *E. saccharina*. Egg parasitoids of stem borers in east Africa belong to the genera *Tricogramma*, Tricogrammatoidea and *Telenomus*. According to Bonhof *et al*., (1997), the most abundant and widespread parasitoids in East African region are the egg parasitoids *Telenomus spp*. and *Trichogramma spp*., the larval parasitoids of *Cotesia sesamiae* and *Sturmiopsis parasitica* Curren (Diptera: Tachinidae) and the pupal parasitoids *P. furvus* and *D. busseolae.*

Egg parasitism fluctuates greatly between seasons and locations, presumably because of differences in climatic conditions (Mathez, 1972).At the Kenyan coast, Mathez (1972) recorded 92% egg parasitism of *Chilo partellus* and 97% of *S. calamistis*, while in a more recent study, levels of parasitism ranged between 19 and 76 % (Skovgard and Pats, 1996). Egg parasitism in western Kenya and Uganda seems to be equally variable, with parasitism ranging from <5% to over 50 % (Mohyuddin and Greathead, 1970). The larval stages of stem borers are attacked by a great variety of parasitoids. *C. sesamiae* and *S. parasitica* are the most widely spread and abundant indigenous larval parasitoids in eastern Africa (Ingram, 1958; Milner, 1967). *S. parasitica* is primarily found in the drier areas of Africa and high levels of parasitism have been reported from Zimbabwe and Tanzania (Milner, 1967). *C. Sesamiae* is more common in the wetter parts of Africa and parasitism was 0.20% at the Kenyan coast and in Uganda (Milner, 1967). The exotic parasitoid, *Cotesia flavipes* was introduced to Kenyan coast in 1993 as part of biological control programme (Overholt *et al*., 1994). Seasonal parasitism of stem borers by *C. flavipes* currently ranges between 0 and 7% at the coast while in Western Kenya and Tanzania up to 62.5% parasitism has been found (Omwega *et al*., 1997). Pupal parasitoids such as *P. furvus*, *D. busseolae* and *Psilochalcis soudanensis* Steffan (Hymenoptera: Chalcididae) are widespread in East Africa, but they are generally not able to keep the stem borer populations at a low level (Oloo and Ogeda, 1990).

Species composition of parasitoids and their distribution in Ethiopia was reported by Emana *et al*. (2001). Twenty one parasitoids from the orders Hymenoptera and Diptera were recorded on eggs, larvae and pupae of *B. fusca*, *C. partellus* and *S. calamistis*. Percent parasitism ranged between 0.01 and 7.47. Larval parasitism was highest, followed by pupal and egg parasitism. *C. flavipes* was the most abundant natural enemy of stem borers and was distributed in eastern, northern, southern and western Ethiopia.

Assefa (1981) recorded *C. sesamiae* (Hymenoptera: Braconidae) and *P. nigromoculaus* (Hymenoptera: Icheunomonidae) on *B. fusca* and indicated that *C. sasamiae* was the most widespread internal parasite of larvae of *B. fusca* and *S. calamistis*. Assefa (1985) and

Mulugeta (2001) recorded *Bracon sesamiae* Cameron (Hymenoptera: Braconidae), *C. sesamiae*, *Bracon hebetor*, *P. furvus* and *P. nigromaculatus* in Ethiopia.

Surveys on stem borer species in Ethiopia has so far revealed the occurrence of species of egg parasitoids in two families: Scelionidae and Tricogrammatidae. Emana (2001) recorded *Telonomus busseolae* Gahan attacking *B. fusca* eggs and *Trichgramma lutea* Girault attacking *C. partellus* and *B. fusca*, whereas, *Chelonus curvimalulatus* Cameron was observed as egg/larval parasitoid. The natural enemies recorded in India includes three larval parasitoids, viz. *Cotesia ruficrus* (Haliday) and *C. flavipes*, and *Sturmiopsis inferens* Townsend and one pupal parasitoid *Xanthopimpla stemmator* Thunberg (Duale, 1999).

Pathogenic microorganisms generally invade and multiply in an insect and spread to infect other insects. Infectious microorganisms can be separated broadly in to potential, facultative and obligate pathogens (Yoshinori and Harry 1992). Potential pathogens are those microorganisms that are incapable of invading the host, either through the body wall or through the digestive tract, without assistance of external factors that lower the insect's resistance or enhance the ability of the microorganism to invade the insect (Yoshinori and Harry 1992).

Facultative pathogens are those microorganisms that do not require an insect weakened by external factors to cause infection (Yoshinori and Harry 1992). Moreover, the survival of both potential and facultative pathogens is not dependent entirely on the insect host, and they can live and multiply independently of the insect. These pathogens are readily cultured on non-living media in the laboratory(Yoshinori and Harry 1992). Most of them are bacteria and fungi. Obligate pathogens require living insect hosts for survival and reproduction/replication. Viruses, most nematodes, certain fungi and bacteria are obligate pathogens(Yoshinori and Harry 1992).

2.6.3 Host plant resistance

Painter (1951) described plant resistance as the relative amount of heritable qualities that influence the ultimate degree of damage done by the insect. In practical agriculture, resistance represents the ability of a certain variety to produce a larger crop of good quality than do ordinary varieties at the same level of insect population. The existence of resistance in sorghum to *C. partellus* was first reported by Trehan and Bustani (1949). Later, Kalode and Pant (1967) and Jotwani *et al*. (1978) showed evidence of antibiosis in sorghum to stem borer larvae. Girdharilal and Pant (1980) screened two varieties of sorghum and attributed that low larval survival on resistant cultivars was possibly due to presence of some antibiotic factor(s) either in the leaf or in the stem of resistant cultivars. Since stem borers feed on the leaves as well as on the stems of sorghum plants, either of these parts may influence the life cycle of the borer. Singh *et al*. (1983) have earlier examined the varietal resistance of 70 selected sorghum varieties and hybrids to the stem borer in the field and identified 13 improved varieties having high level of resistance compared to known resistant cultivars.

Host plant resistance is the most important component of integrated pest management (IPM) in sorghum. It does not involve any extra costs or require application skills in pest control techniques, and is compatible with other methods of pest control. Host plant resistance is most useful when carefully combined with other components of integrated pest management (Robert *et al*., 2003)

IPM has historically placed great hopes on host plant resistance. Host plant resistance is ecologically sound, economically practical, socially acceptable and environmentally sustainable technology (Robert *et al*., 2003). Host plant resistance is classified in to genetic resistance and induced resistance. Genetic resistance to insects contributes to the development of insect biotypes. Induced resistance is the qualitative or quantitative enhancement of plants defense mechanism, which may induce changes in protein, lipid and phenol metabolism, which are detrimental to insects.

There are three types of mechanism of resistance: non-preference, antibiosis and tolerance (Painter 1951).

Non-preference is the response of the insect to the characteristics of host-plant, which made it unattractive to the insect for feeding, ovipostion or shelter. Since the term non-preference pertains to the insect and not to the host plant, Kogan and Ortman (1978) proposed the term 'antixenosis' to describe the plant properties responsible for non-preference. Antixenosis signifies that the plant is considered unsuitable or a bad host. Antixenosis may result from certain morphological characters or presence of allelochemicals in the host plant. Morphological, physical or structural resistance traits interfere with the mechanisms of host selection, feeding, colonization, ingestion, digestion, mating or ovipostion. Plant colour, shape, anatomical adaptations of plant parts such as frego bract and okra leaf in cotton, trichomes on leaves, petioles, stems, leaf surface waxes, sclerotization of tissues and a combination of these traits act as deterrents or barriers to pests.

Antibiosis refers to the adverse effect of the host plant on the biology of the pests and their progenies. It is the most frequently exploited mode of resistance to pests. It causes a reduction in pest population by death or a decrease in the rate of development or reproductive potential. Bio-chemical factors are more important than differences in morphology in determining the level of antibiosis to an insect pest. Secondary metabolites/allelochemicals in the host plant in most cases cause for antibiosis.

Tolerance refers to the ability of the host plant to withstand an insect population sufficient to damage severely the susceptible plants. Tolerant varieties do not depress insect populations nor do they provide any selection pressure on the insects.

Host plant resistance is one of the important components in pest management in sorghum. The importance of resistant varieties is to increase sorghum production through the development of sorghum varieties which are resistant to *C. partellus.* Growing of resistant varieties play an important role in reducing the insect-pest populations. Particularly in the case of stem borers, which are, carried over from one season to another as a diapausing larva in stalks and stubbles of sorghum, resistant varieties have a significant role in reducing the insect-pest population to the next season. In a study on the effect of sorghum genotypes on stem borer biology, the most significant parameters affected by resistant genotypes were: first-instar larval establishment, time interval between hatching of larvae and boring into the stem, larval density, and larval survival rate (Taneja and Woodhead, 1989).

It is generally accepted that host plant resistance (HPR) is the most farmer friendly pest control option (Singh *et al*., 1983; Newanze, 1997). There is much more success with regard to varietal resistance to stem borers in sorghum. Jotwani (1978) and Jotwani and Agrawal (1982) screened 6243 sorghum lines available in the world germplasm collection and finally selected 26 lines as promising source of resistance. Singh *et al*. (1983) screened 70 sorghum varieties and found significant differences among the varieties in terms of leaf-feeding injury, percent dead hearts, number of holes, and percent of tunneling. In India, 14000 sorghum germplasm were screened under natural and artificial infestations and lines with low percentages of dead heart and stem tunneling were identified (Sirvastara, 1985). Two resistance mechanisms were identified in all of these varieties: non-preference and antibiosis.

Lal and Pant (1980) reported that gravid female moths of *C. partellus* laid more egg masses on susceptible varieties of sorghum than on resistant ones. Dabrowski and Kidiavai (1985) tested 100 sorghum lines under field conditions and found that 11 were non-preferred for ovipostion. Jotwani (1978) reported prolongation of larval period, higher larval mortality and low percentage pupation on resistant lines of sorghum as compared with the susceptible ones. Sharma (1993) provided detailed information on the use of resistant sorghum cultivars in IPM, in different ecosystems, worldwide. Over 190 genotypes of sorghum with varying degrees of resistance to *C. patellus* and *Busseola fusca* were reported between 1974 and 1989. But, most of the cultivars were rejected by farmers because of their long maturity period, Panicle compactness, reduced crop height and poor vigor (Sharma, 1993; Newanze, 1997).

2.6.4 Botanical control

Field experiments (Habte *et al*., 2006) in Ethiopia, demonstrated that primary crop damage by *C. partellus* had been markedly reduced by applying 3 gm/plant neem seed powder and 500 l/ha of 10% aqueous extract of leaf and such application did not hinder larval and pupal parasitoids from ovipositing and developing on larvae and pupae on *C. partellus*.

2.6.5 Chemical control

Chemical control is the most powerful tool and suitable control options of stem borers out breaks (Pal and Das, 1997). It requires application methods based on specific insect habitats, peak period of activity, and vulnerable stages of the life cycles (Kishore, 1989). Economic thresholds are also important considerations of chemical control, both for cost effective application and for minimum impact on the environment (Pal and Das, 1997).

Stem borers of maize and sorghum can be effectively controlled by leaf whorl placement of granular or dust of endosulfan, phenthoate, quninalphos, carbaryl, malathion, and fenvalerate (Pal and Das, 1997). Whorl application of insecticides targets the vulnerable stage of the pests, less environmental pollution and minimum effects on non-target organisms (Kishore, 1989; Pal and Das, 1997). In Ethiopia, Assefa (1982) and Emana (1997) recommended the application of carbaryl WP, endosulfan EC, cypermethrin G and cymbush EC for the control of *B. fusca.*

2.6.6 Genetic control

A few species of bacteria are highly effective at killing insects. The most important of these is *Bacillus thuringiensis* (Bt). It occurs naturally in insect-rich locations, including soil, plant surfaces and grain stores. It kills a range of insect orders and is the most widely used microbial biopesticide. It is also used in transgenic crops. Genetic improvement of sorghum for resistance against the spotted stem borer has been a very important component in integrated management approaches against insect pests. *B. thuringiensi*s is a species of bacteria found throughout the world (Mwangi and Ely, 2001). *Bacillus thuringiensis*, or *Bt* for short, is a naturally occurring organism that produces a toxin that kills insects (Girijashankar *et al*., 2005). Reduction in leaf damage 5 days after infestation was up to 60%; larval mortality was 40%, with the surviving larvae showing a 36% reduction in weight over those fed on control plants and the transgenic plants showed partial tolerance against first instar larvae of the spotted stem borer (Girijashankar *et al*., 2005).

3. Objectives of the study

3.1 General objective

To screen sorghum genotypes to identify resistant ones against *Chilo partellus*

Specific objectives

1. To identify the level of resistance/susceptibility in sorghum genotypes to *C. partellus* under field conditions depending on pressure of the pest.

2. To determine the mechanisms of resistance on selected resistant and susceptible sorghum genotypes using artificial infestation with *C. partellus*.

3. To determine the effect of resistant and susceptible sorghum genotypes on growth and development of *C. partellus* under laboratory conditions.

4. Materials and Methods

4.1 Description of the study site

The experiments were carried out in Melkassa Agricultural Research Center (MARC) experimental field at Melkassa. MARC is characterized by receiving erratic rainfall, which amounts to 550 mm per year. It is found at an elevation range of 1500 to 1550 meters above sea level (m.a.s.l.). The average minimum and maximum temperature are $14^{O}C$ and $28^{O}C$, respectively and the relative humidity ranges between 40% and 60%.

4.2. Experiments carried out

4.2.1 Open field evaluation of sorghum genotypes for their level of resistance to *C. partellus* attack

Field experiment was super imposed on MARC breeding program experiments. Weekly evaluation of leaf infestation was carried out on 201sorghum genotypes starting from the vegetative stage up to crop maturity growth stages from July to October 2005 main cropping season.

Sorghum genotypes considered for field evaluation are presented in Appendix Table 1. Sorghum genotypes were planted in two rows of 5 m length. The spacing used was 75 cm between rows and 30 cm between plants. There were more than 20 plants per genotype. The experiment was designed in completely randomized block design with two replications. The plots were furrow irrigated and recommended agronomic practices were followed. The sorghum genotypes were left unprotected to allow for natural infestation to take place. The level of resistance in the test sorghum genotypes were determined by counting infested plants at weekly interval starting from three weeks after crop emergence (vegetative stage) up to harvesting. Leaf damage symptoms, holes and frass on the stem of sorghum genotypes due to the feeding activities of *C. partellus* larvae were used as criteria to determine infested and healthy plants. During each observation, the number of infested genotypes were recorded and used to compute percent infestation using the following formula:

$$\% \text{ infestation} = \frac{\text{No. of plants with stem borer damage}}{\text{total no. of plants}} \times 100$$

Then genotypes with less than 10% infestation, between 11 and 20% infestation and > 21% infestation were grouped as resistant, intermediate and susceptible, respectively (Emana, 2002).

4.2.2 Evaluation of selected sorghum genotypes for their level of resistance under artificial infestation in screen house pot experiments

Laboratory rearing of *Chilo partellus* for artificial infestation in pot experiments

Chilo partellus larvae were reared in MARC Entomology Laboratory by feeding them with sorghum stem cuts. To start the culture 100 *C. partellus* larvae of 3-5th instars were collected from MARC experimental field and put in Petri dishes beside sorghum stem cuts. Every three days, food (sorghum stem) was changed after dipping in 0.05% sodium hypochlorite to avoid fungal infection. After adult emergence, the moths were left for 24 hrs for mating in the rearing cages.

Artificial infestation and data collection

After categorizing sorghum genotypes into resistant, intermediate and susceptible, based on their performance under natural field infestation, four sorghum genotypes from each category were promoted to the screen house pot experiment depending on percent infestation. Resistant (A3 X 76 T1 # 23, A3 X IESV PGRC/E # 69420, ICSA-22 X Gobye, and ICSA-15 X IESV 92018 D), Intermediate (P 9501 X Seredo, ICSA-15 X P- 89008, A3 X P 9406 and ICSA-22 X IESV 92087 DL) and Susceptible (A1 X Gambella 1107, A1 X P 89001, ICSA-22 X P

89006 and A1 X IESV 92011 DL). Five seeds of each test genotypes were sown in a soil filled plastic pot and thinned to three after seedling establishment. The pot-screen house experiment was designed in completely randomized design (CRD) in three replications. Sorghum plants in pots were exposed to artificial infestation by releasing laboratory reared mated females under screen house condition at three weeks after crop emergence.

Forty 24 hours old laboratory reared female *C. partellus* moths were released in to the experimental set up from a centrally located rearing cage placed well above the pots at elevated position, at 12: 00 pm. The release was made at three weeks after crop emergence. Escape of *C. partellus* moths was prevented by covering the whole set up with muslin cloth (10mx3mx3m) (Fig. 1). Data were collected on number of egg batches laid per plant per pot, number of plants infested per pot, number of larvae per plant per pot, number of pupae and pupal case per plant per pot, number of exit holes per plant per pot and tunnel length per plant per pot starting from 12 hrs from the release of the moths.

4.2.3 Evaluating the effect of resistant and susceptible sorghum genotypes on the growth and development of *C. partellus* under laboratory conditions

The most resistant (A3 X 76 T1 # 23) and the most susceptible (A1 X IESV 92011 DL) sorghum genotypes were planted in the field in two rows of five-meter length each in two replications to serve as food for *C. partellus* larvae and for oviposition by and mass rearing of

C. partellus was done both on the resistant and susceptible genotypes using field-collected *C. partellus* larvae in the rearing cages.

To start *C. partellus* rearing, sorghum stems from Melkassa experimental field were dissected and about 40 larvae which are 3-5th larval stages were collected and each larva put in a Petri dish along with the stem cut. Stem cuts of larval feeding were changed every three days by being dipping in Sodium Hypochlorite (0.05%) to avoid fungal infection. Larva was checked for pupation every day and after pupation, each pupa was collected and put in a rearing cage, and the emerging moths were allowed for mating for 24 hours. Twenty four hours old mated females were randomly selected and put into two rearing cages. One rearing cage for susceptible genotype and the other one for resistant genotype and each moth provided with leaf sheath in the rearing cage twice a day on the treatment for egg lying activity and there was also placed sugar solution as food source for the moths.

After the eggs were hatched and the larvae developed, each larva was put in a petri dish and given sorghum stem cuts of susceptible or resistant genotype depending on the treatment. The stem cuts were changed every three days after dipped in Sodium Hypo chlorite (0.05%) to avoid fungal infection. The larvae were checked for pupation every day. Up on pupation, each pupa was collected and put in the respective rearing cage. The emerging five moths from each respective treatment were allowed to mate for 24 hours for mating with 1:1 ratio of *C. partellus* in ten rearing cages, five for resistant and five for susceptible and given sugar solution and sorghum leaf sheath, twice a day, from the susceptible or resistant genotype depending on the treatment in each cage until their death.

After the larvae were developed from the leaf sheath of susceptible or resistant genotype, depending on the treatment, each larva was put in a Petri dish and provided with stem cut in a petri dish with respective of mother moth depending on the treatment. The stem cuts were changed every three days after dipped in Sodium Hypochlorite (0.05%) to avoid fungal infection. For evaluation of the effect of resistant and susceptible sorghum genotypes on growth and development of *C. partellus* under laboratory condition, the following data were collected on each female of *C. partellus*: number of egg masses laid per female, number of eggs laid per female, number of larvae hatched per female, number of pupa per female, number of adults (male/ female) and developmental time stages (egg-larva, larva-pupa and pupa-adult). The development and mortality was recorded every day in all stages of the insect until adult emergence. Growth index was calculated by dividing percent adult emergence by the average number of days taken to emerge.

4.3 Data analysis

Analysis of the data on the number of egg masses, leaf infestation, number of borer per plant, number of exit holes and stem tunnel length was done by using SPSS 11.0, a computer based statistical package for windows. Tukeys Studentized Range Test (HSD) was used for mean separation. T- test also used for mean separation between the number of eggs, larvae, pupae, number of adults and development time in days.

Figure 1. Screen house set up for sorghum genotypes screening against *C. partellus*.

5. Results

5.1 Screening of sorghum genotypes for resistance to *C. partellus* under natural field conditions

The response of sorghum genotypes to *C. Partellus* under natural field condition is summarized in Table 1. Accordingly 55% and 6.46% of the tested genotypes were rated as resistant and susceptible, respectively.

Table 1. Summary of sorghum genotypes reaction to *C. partellus* at Melkasa under field conditions

Resistance category	% infestation used for rating	Number of genotypes in each resistance category	Genotype proportion
Immune	0	0	0%
Resistant	1-10	111	55.2%
Medium	11-20	77	38.3%
Susceptible	≥ 21	13	6.46%

5.2 Response of *C. partellus* to selected sorghum genotypes in pot experiments using artificial infestation under screen house conditions

Significant differences (P<0.05) among the sorghum genotypes tested for their reaction against *C. partellus* were observed with respect to ovipositional preferences, mean percent infestation, mean number of holes per plant, mean tunnel length and mean borer density per plant (Table 2).

Mean number of egg masses counted on each genotype ranges between 0.11 and 4.11. The lowest mean egg mass was recorded on a genotype, A3 X 76 T1 # 23, while the highest was recorded on a genotype A1 X IESV 92011 DL. Mean percent infestation of the different sorghum genotypes ranged between 11 and 89 %. The genotype A3 76 T1 # 23 had the lowest mean percent infestation, while the highest was recorded on the genotype A1 X IESV 92011 DL.

Mean number of *C. partellus* exit holes, mean tunnel length and borer density were significantly (P< 0.05) lower in genotype A3 X 76 T1 # 23, while significantly higher in a genotype A1 X IESV 92011 DL.

Table 2. Mean number of ***C. partellus*** **egg masses, percent infestation, number of holes , tunnel length and number of borers per plant recorded on different sorghum genotypes under screen house artificial infestation condition**

Sorghum genotypes	mean number of egg masses per plant	Mean percent infestation per plant	Mean number of holes per plant	Mean tunnel length per plant	Mean number of borers per plant
A3 X 76 T1 # 23	0.11 ± 0.11a	0.11 ± 0.11a	0.11 ± 0.11a	0.33 ± 0.33a	0.11 ± 0 .11a
A3 X IESV PGRC/E # 69420	0.11 ± 0.11a	0.22 ± 0.15b	0.33 ± 0.23a	1.67 ± 1.10a	0.44 ± 0.29a
ICSA-22 X Gobye	0.22 ± 0.15a	0.22 ± 0.15b	0.22 ± 0.14a	0.78 ± 0.52a	0.22 ± 0.15a
ICSA-15 X IESV 92018 DL	0.22 ± 0.15a	0.33 ± 0.17b	0.44 ± 0.24a	2.11 ± 1.20b	0.67 ± 0.37a
P 9501 X seredo	0.33 ± 0.17b	0.44 ± 0.18b	1.00 ± 0.40b	3.11 ± 1.26c	1.33 ± 0.55b
ICSA-15 X P- 89008	0.44 ± 0.18b	0.67 ± 0.17b	1.67 ± 0.44d	4.33 ± 1.14d	1.78 ± 0.46b
A3 X P 9406	0.44 ± 0.24b	0.44 ± 0.17b	1.33 ± 0.55c	3.77 ± 1.58c	1.56 ± 0.62c
ICSA-22 X IESV 92087 DL	0.56 ± 0.24b	0.56 ± 0.17b	1.67 ± 0.65d	5.00 ± 2.00d	2.00 ± 0.76c
A1 X Gambella 1107	2.44 ± 0.88c	0.67 ± 0.17b	5.33 ± 1.57e	12.00 ± 3.65d	5.44 ± 1.61d
A1 X P 89001	2.67 ± 0.76c	0.78 ± 0.15b	4.89 ± 1.25e	10.56 ± 2.36d	5.22 ± 1.25d
ICSA-22 X P 89006	3.33 ± 0.75c	0.78 ± 0.15b	5.67 ± 1.50e	12.44 ± 3.31d	6.11 ± 1.63d
A1 X IESV 92011 DL	4.11 ± .93c	0.89 ± 0.11b	7.11 ± 1.4e	13.67 ± 2.88d	7.22 ± 1.45d

Means followed by the same letter(s) within a column are not significantly different at $P < 0.05$, Tukey's Studentized Range Test (HSD).

5.3 Effect of resistant and susceptible sorghum genotypes on the growth and development of *C. partellus* under laboratory conditions

The resistant genotype, A3 X 76 T1 # 23 has allowed lowest percent hatchability of eggs, % pupation, % adult emergence and growth index as opposed to the susceptible genotype, A1 X IESV 92011 DL. The sex ratio is more or less the same on both resistant and susceptible genotype (Table 3). *C. partellus* took longer time to complete its life cycle when fed on a resistant variety, A3 X 76 T1 # 23 (Table 4).

The density of different stages of *C. partellus* was significantly ($P<0.05$) lower when fed on a resistant genotype, A3 X 76 T1 # 23 as compared to the susceptible genotype, A1 X IESV 92011DL (Table 5).

Table 3. **Percent hatchability, pupation, adult emergence, sex ratio and adult growth indices of *C. partellus* reared on resistant and susceptible sorghum genotypes under laboratory conditions**

Genotype	Genotype reaction	% hatchability	% pupation	%adult emergence	Sex ratio male: female	Growth index
A3 X 76 T1#23	R	48.1*	37.4*	17.08*	1:1	0.427*
A1 X IESV 92011 DL	S	68.92	81.46	53.19	1:1	1.009

*= Significant at P< 0.05

Table 4. Mean developmental time in days of different life stages of *C. partellus* reared on resistant and susceptible sorghum genotypes under laboratory conditions

		Development time in days		
Genotype	Genotype reaction	Egg-larva	Larva-pupa	Pupa-adult
A3X76 T1#23	R	7.00 ± 0.00*	26.40 ± 0.24*	9.60 ± 0.24*
A1 X IESV 92011 DL	S	5.80 ± 0.20	22.8 ± 0.2	8.50 ± 0.04

*= Significant at P< 0.05

Table 5. **Effect of on the density of mean number of different developmental stages of *C. partellus* reared on resistant and susceptible sorghum genotypes under laboratory conditions**

Genotypes	Genotype reaction	No. of eggs	No. of larva	No. of pupae	Number of adults
A3X76 T1#23	R	128.8±4.93*	62.00±4.69*	23.4±1.43*	19.8±1.49*
A1 X IESV 92011 DL	S	209.8±12.78	144.6±8.88	117.8±19.32	111.6±18.93

*= Significant at $P < 0.05$

6. DISCUSSION

The results in the present study clearly indicated the existence of variability among sorghum genotypes with respect to the level of resistance they have to *C. partellus.*

Out of 201 sorghum genotypes which are screened under natural field conditions, four varieties *viz.,* A3 X 76 T1 # 23, A3 X IESV PGRC/E # 69420, ICSA-22 X Gobye, and ICSA-15 X IESV 92018 DL were exhibited low number of leaf infestation under natural field condition and also they exhibited the lowest number of egg masses, holes, percent infestation and density of *C. partellus* under artificial pot experiments. Under the laboratory conditions A3 X 76 T1 # 23 showed less number of eggs, number of larvae, number of pupa and less number of adults (male/ female) but it showed high developmental time stages (egg-larva, larva-pupa and pupa-adult). The incidence of leaf infestation by *C. partellus* was reduced on resistant sorghum genotypes. All the resistant sorghum genotypes were significantly different from the susceptible ones.

Dabrowski and Kidiavi (1985) tested 100 sorghum lines under field conditions and found that 11 were non-preferred for oviposition. Sorghum germplasm of national collections and introductions from International Research Centers for various purposes including varieties reported as stem borers resistant have been evaluated at different times to identify sources of resistance against stem borers in sorghum. Out of the 90 genotypes evaluated for 4 years

(1986-1989), IS-1054, IS-2146, IS-4664, and PS 18822-4 were reported to show better resistance to stem borers (IAR, 1989).

Twenty-five genotypes obtained from ICRISAT for multi-location test for stem borers resistance were evaluated for 3 years (1991-1993) under natural pressure of the pest at Ziway and Melkassa. Of the tested genotypes ICSV-708, PB-14376-1, PB-15469-2-1-3 and PB-12747 were reported as good sources of resistance (IAR, 1993). From the large number of sorghum germplasm tested against stem borers SODF 103, 90 MW 5353, ICSV 680 and ICSV 708 were found to be resistant (Adane and Abraham, 1996). Emana (2005) reported high variability among sorghum genotypes with respect to stem borers particularly to *C. partellus.* According to the author some of the released varieties such as Gobeye and 76 T1#23 were found to be resistant against *C. partellus* (Emana, 2005). Out of 17 genotypes tested at Meiso T3-307, Is 127-3-4 and Ps-1882-4 exhibited low number of holes and number of larvae and/or pupae (Ferede, 1988).

Most studies on the relation ship between oviposition and plant susceptibility or resistance are based on recording egg-laying patterns on different plant genotypes in the field or screen house. In the present study, differences in the ovipostional responses of *C. partellus* between susceptible and resistant sorghum genotypes were observed. It was observed that *C. partellus* lays less number of egg masses on the resistant genotypes and on moderately resistant sorghum genotypes, but relatively large number of egg masses establish on the susceptible sorghum genotypes. Lal and Pant (1980) reported that gravid female moths of *C. partellus* laid more egg masses on susceptible varieties of sorghum than on resistant ones. The results of the current study agreed with the previous studies by Kumar and Saxena (1985) who reported *C. partellus* lay less egg on the resistant genotype than on the susceptible one.This might be due to the variation in sorghum genotypes with morphological, biochemical and physiological characteristics that influence the adult females to select a suitable host plant for egg laying. Various plant characters like volatiles, color, and water vapor may be responsible as short distance perceivable characters. Evidence that these characters are involved in selection of sorghum plants are given by Saxena (1985). After contact with the plant, surface waxes (chemicals) and the physical structure of the leaf surface become the next selection criteria. Ampofo (1985) also indicated that maize lines show differences in morphological, biochemical and physiological characteristics which make these traits suspects of influencing oviposition by the moths of the spotted stalk-borer.

In the present study, considerable variation was found in the level of leaf infestation by *C. partellus* on resistance, moderately resistance and susceptible sorghum genotypes under screen house pot experiment. The findings in the screen house pot experiments complemented the result obtained under field conditions such that percent leaf infestation by *C. partellus* on 12 sorghum genotypes grown under screen house and field conditions showed comparable trend. Out of twelve selected sorghum genotypes, four sorghum genotypes which have lower number of leaf infestation (ICSA-22 X Gobeye, A3X76 T1 # 23, ICSA-15 X IESV 92018 DL and A3 X IESV PGRC/E # 69420) also exhibited lower number of egg masses/oviposition, less number of infestation, lower number of holes, lower tunnel length and lower number of larvae and/or pupae under screen house experiment. This result is in agreement with that of Omolo (1983) who reported similar trends in plant damage and infestation by *C. partellus* larvae on three maize genotypes growing under screen house and field conditions. Under both natural and artificial infestations the author observed that the genotypes that were found resistant under field infestation were also resistant under artificial infestation.

Less percent of hatchability, less percent of pupation and adult emergence were recorded on resistant genotypes. Resistant plants also adversely affected the growth of *C. partellus*. The survival and development of the larvae on resistant plants was considerably lower than those reared on susceptible plants.

Dabrowski and Nyangiri (1983) also indicated that some contact chemo and /or mechanoreceptors on the oviposition tip or on the tarsus of front legs of *C. partellus* females may play an important role in the plant acceptance for oviposition. The authors further revealed that the number of larvae developed on the susceptible genotype were higher than on the resistant genotypes and the larval feeding activity was twice as high as on the susceptible genotype than on moderately resistant genotype. Their findings also agree with the current findings, in terms of the difference in suitability of resistance and susceptible sorghum genotypes (i.e. the number of larvae developed on the susceptible genotypes were higher than on the resistant genotypes). Earlier studies by Omolo (1983) also revealed that there were differences in larval survival on the resistant and susceptible maize genotypes. The author further indicated that the most significant differences were observed in the extent of the destructive effect of larval feeding in the stem of resistant genotype which is less as compared to susceptible ones and a lower number of larvae penetrated the stems of the resistant genotypes. Jotwani (1978) reported prolongation of larval period, higher larval mortality and low percentage pupation on resistant genotypes of sorghum as compared to the susceptible ones.

The factors governing resistance of different crop cultivars were categorized by Saxena (1969) in to two broad categories. 1. Colonization responses of insects leading to establishment of the population on the plant, and 2. Plant characters determining orientation, feeding, utilization of ingested food, development and egg production and oviposition.

Earlier studies by Hough and Pimentel (1978), and Das and Agrawal (1993) also indicated that the criteria for the optimal growth of the pest are short larval duration, high larval and pupal weights, and high survival on the susceptible. These conditions on the growth and development of the pest were also observed in the present study which reared on the susceptible genotype under laboratory conditions. Observation in the current study showed higher mortality, longer development period, lesser pupation and adult emergence and lower growth index for *C. partellus* larvae reared on the resistant than the susceptible genotypes.

7. Conclusion and Recommendations

7.1. Conclusion

√ Variations among sorghum genotypes to *C. partellus* infestations were observed.

√ Similar trends were observed both in the field and screen house pot experiments suggesting that there is the possibility of developing *C. partellus* resistant varieties.

√ The lower number of eggs laid in the free choice test was an indicator for the presence of ovipositional non-preference.

√ The resistant genotypes exerted adverse effects on the egg laying activity, hatchability, growth and development of larva .The larval duration was also prolonged in resistant variety.

√The larval and pupal stages are most affected implying that antibiosis may be one of the resistance mechanism.

√The susceptible genotype is nutritionally acceptable to *C. partellus*, while the resistant genotypes were nutritionally in adequate to allow significant growth and survival of *C. partellus*.

7.2. Recommendations

√ Further evaluation of the sorghum genotypes which are found in different adaptation areas are important and there is also a great need to develop varieties by breeders that can resist stem borer attack.

√ The majority of Ethiopian farmers are generally not well informed about stem borer problems, the hazards associated with insecticide applications and most might not afford costly chemical methods to control stem borers. Thus, awareness should be created among farmers on the use of resistant varieties as different options of stem borer control.

√ The possibility of integrating resistant verities with biological control practices should be investigated

√ Awareness should be created among the stakeholders on the existence of resistant gene in sorghum genotypes.

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9. Appendices

Appendix Table1. Percent infestation of sorghum genotypes by *C. partellus* under field mass screening condition

No	Name of sorghum genotypes	% infestation	No	Name of sorghum genotypes	% infestation
1	ICSA-15xSDSL 89426	6	21	ICSA-15xIESV92087DL	6
2	ISCA-15x ISV-15	12	22	ICSA-15xIESV92001 DL	8
3	ICSA-15xMR-812	6	23	ICSA-15xIESV92003 DL	7
4	ICSA-15xADIV-150	6	24	ICSA-15xIESV92018 DL	3
5	ICSA-15xP-89002	4	25	ICSA-15xIESV 92086 DL	6
6	ICSA-15xDR-14	4	26	ICSA-15xPGRC/E 69441	3
7	ICSA-15xWSV-384	11	27	ICSA-15xPGRC/E 69420	7
8	ICSA-15xSDSL2670-2	4	27	ICSA-15xPGRC/E 222878	6
9	ICSA-15xp-9404	5	29	ICSA-15xPGRC/E 222879	5
10	ICSA-15xp-89004	3	30	ICSA-15xPGRC/E 222880	4
11	ICSA-15xp-89006	4	31	ICSA-15xPGRC/E 222885	5
12	ICSA-15 x P-89008	11	32	ICSA-15xPGRC/E 69391	4
13	ICSA-15xp-89010	4	33	ICSA-15xPGRC/E 69442	4
14	ICSA-15xIESV 91081 DL	4	34	ICSA-15xPGRC/E 69475	5
15	ICSA-15xIESV 91090 DL	5	35	ICSA-15xPGRC/E 69447	9
16	ICSA-15xIESV 92011 DL	5	36	ICSA-15xPGRC/E 200791	7
17	ICSA-15xIESV 92031 DL	4	37	ICSA-15xseredo	5
18	ICSA-15xIESV 92122DL	4	38	ICSA-15xSRN-39	8
19	ICSA-15xIESV 921005 DL	4	39	ICSA-15xFramida	5
20	ICSA-15xIESV 92061DL	2	40	ICSA-15xp 9406	6

Appendix Table1. Cont'd

No	Name of sorghum genotypes	% infestation	No	Name of sorghum genotypes	% infestation
41	ICSA-15xp 9408	4	61	P 9501 A X IESV 92011 DL	7
42	ICSA-15x M 90411	7	62	P 9501 A X IESV 92031 DL	5
43	ICSA-15xYE-28	5	63	P 9501 A X IESV 92112 DL	3
44	ICSA-15xIS 158x(2113)4	11	64	P 9501 A X IESV 92005 DL	6
45	ICSA-15x Abeqa mollela	9	65	P 9501 A X IESV 92061 DL	14
46	P9501 A X SDSL 89426	5	66	P 9501 A X IESV 92087 DL	11
47	P 9501 A X ISV-5	8	67	P 9501 A X IESV 92001 DL	5
48	P 9501 A X MR-812	6	68	P 9501 A X IESV 92003 DL	5
49	P 9501 A X ADIV-150	5	69	P 9501 A X IESV 92018 DL	4
50	P 9501 A X P 89002	5	70	P 9501 A X IESV 92086 DL	6
51	P 9501 A X DR-14	6	71	P 9501 A X PGRC # 69420	3
52	P 9501 A X P 89001	8	72	P 9501 A X PGRC # 222878	4
53	P 9501 A X P 89009	11	73	P 9501 A X PGRC # 222879	6
54	P 9501 A X WSV-384	5	74	P 9501 A X PGRC # 222880	8
55	P 9501 A X SDSL2690-2	5	75	P 9501 A X PGRC # 222885	8
56	P 9501 A X P 9404	4	76	P 9501 A X PGRC # 69391	11
57	P 9501 A X p 89004	5	77	P 9501 A X PGRC # 69447	7
58	P 9501 A X P 89006	7	78	P 9501 A X PGRC # 200791	8
5	P 9501 A X P 89010	5	79	P 9501 A X Seredo	11
60	P 9501 A X IESV 91090 DL	3	80	P 9501 A X IS 158 X (Ets 213)4	9

Appendix Table1. Cont'd

No	Name of sorghum genotypes	% infestation	No	Name of sorghum genotypes	% infestation
81	P 9501 A X Tetron# 2	11	101	P 9532x Rufe	11
82	P 9501 A X Zengada # 2	8	102	P 9532x Keradebia	22
83	P 9501 A X Abeqa mollela	22	103	P 9532x YE-28	12
84	P 9532x SDSL 89426	14	104	P 9532x76 T4 # 1	17
85	P 9532x MR 812	22	105	ICSA-22x SDSL 89426	9
86	P 9532x p 89009	17	106	ICSA-22xISV-5	5
87	P 9532x SDSL 2690-2	12	107	ICSA-22x MR 812	9
88	P 9532xp 89004	11	108	ICSA-22x ADIV 150	21
89	P 9532xp89006	9	109	ICSA-22x P 89002	11
90	P 9532 x IESV 92011 DL	9	110	ICSA-22x DR 14	12
91	P 9532x IESV92087 DL	8	111	ICSA-22x P 89001	7
92	P 9532x IESV 92003 DL	11	112	ICSA-22xP 89009	11
93	P 9532x IESV92086 DL	15	113	ICSA-22x WSV 387	12
94	P 9532xPGRC/E# 222878	16	114	ICSA- 22 X PSDSL 2690-2	11
95	P 9532xPGRC/E#222879	12	115	ICSA-22x P9404	14
96	P 9532xPGRC/E# 222880	9	116	ICSA-22x P 89004	12
97	P 9532xPGRC/E# 69442	11	117	ICSA-22x P 89006	22
98	P 9532xPGRC/E# 200791	22	118	ICSA-22x IESV 92011 DL	16
99	P 9532x Abshir	8	119	ICSA-22x IESV 92112 DL	8
100	P 9532x P 9406	11	120	ICSA-22x IESV 92005 DL	8

Appendix Table1. Cont'd

No	Name of sorghum genotypes	% infestation	No	Name of sorghum genotypes	% infestation
121	ICSA-22x IESV 92061 DL	21	141	ICSA-22x Gubiye	3
122	ICSA-22x IESV92087 DL	11	142	ICSA-22xAbshir	12
123	ICSA-22xIESV 92001 DL	9	143	ICSA-22x SRN-39	21
124	ICSA-22xIESV 92003 DL	11	144	A1XSDSL 89426	11
125	ICSA-22xIESV 92018 DL	8	145	A1xICSV-5	12
126	ICSA-22xIESV 92086 DL	8	146	A1xMR 812	17
127	ICSA-22xPGRC/E# 69441	12	147	A1xADIV-150	16
128	ICSA-22xPGRC/E# 69420	16	148	A1xP 89002	11
129	ICSA-22xPGRC/E# 222878	18	149	A1xDR-14	15
130	ICSA-22xPGRC/E# 222879	15	150	A1xP 89001	22
131	ICSA-22xPGRC/E# 222880	7	151	A1x P 89009	14
132	ICSA-22xPGRC/E# 222885	13	152	A1x WSV 387	19
133	ICSA-22 X PGRC/ E # 69391	11	153	A1x SDSL 2690-2	11
134	ICSA-22xPGRC/E# 69442	8	154	A1x P 9404	16
135	ICSA-22xPGRC/E# 69475	9	155	A1xP 89004	12
136	ICSA-22xPGRC/E# 69447	9	156	A1xP 89006	11
137	ICSA-22xPGRC/E#200791	11	157	A1x IESV 92011 DL	25
138	ICSA-22xTeshale	21	158	A1x IESV 92031 DL	22
139	ICSA-22xGambella 1107	18	159	A1x IESV 92122 DL	14
140	ICSA-22x Seredo	14	160	A1x IESV 92005 DL	9

Appendix Table1. Cont'd

No	Name of sorghum genotypes	% infestation	No	Name of sorghum genotypes	% infestation
161	A1 X IESV 92087 DL	16	182	A1xMR 812	9
162	A1x IESV 92018DL	7	183	A1xDr-14	8
163	A1x IESV 92086DL	5	184	A3xP 89001	13
164	A1x PGRC/E#69441	16	185	A3xP 89009	6
165	A1x PGRC/E# 69420	8	186	A3 X SDSL 2690-2	13
166	A1x PGRC/E# 222878	13	187	A3xP 9404	17
167	A1x PGRC/E# 222879	15	188	A3xP 89004	4
168	A1x PGRC/E# 222880	18	189	A3x P 89008	8
169	A1x PGRC/E# 222885	3	190	A3xIESV 92087 DL	8
170	A1x PGRC/E# 69442	12	191	A3xIESV 92018 DL	7
171	A1x PGRC/E# 69447	14	192	A3xIESV PGRC/E # 69441	18
172	A1x PGRC/E# 200791	8	193	A3xIESV PGRC/E #69420	3
173	A1x Gambella 1107	23	194	A3xIESV PGRC/E #222878	11
174	A1xGobiye	6	195	A3xIESV PGRC/E # 222879	13
175	A1xP-9406	18	196	A3xIESV PGRC/E #222880	12
176	A1xRufe	18	197	A3xIESV PGRC/E #69442	12
177	A1xKeradebia	8	198	A3x76T1#23	2
178	A1xYE-28	14	199	A3 x P 9406	11
179	A1x76 T4 #1	16	200	A3xRufe	9
180	A1xSDSL 89426	7	201	A3xYE-28	15
181	A1xICSV-5	17			

Appendix Table2. Analysis of variance (ANOVA) for *C. partellus* egg masses and leaf infestation on different sorghum genotypes under screen house-pot experiments

	Sum of Squares	df	Mean Square	F	Sig.
Eggs/plant* Treatment					
Between Groups (Combined)	209.583	11	19.053	8.365	.000
Within Groups	218.667	96	2.278		
Leaf infestation* Treatment					
Between groups (combined)	6.324	11	0.575	2.671	.005
Within Groups	20.667	96	0.215		

Appendix Table 3. Analysis of variance (ANOVA) for the number of exit holes and tunnel length due to *C. partellus* on different sorghum genotypes under screen house-pot experiments

	Sum of Squares	df	Mean Square	F	Sig.
Hole number/plant* Treatment Between Groups (Combined)	628.519	11	57.138	8.109	0.000
Within Groups	676.444	96	7.046		
Tunnel length/plant* Treatment Between groups (combined)	2402.963	11	218.451	5.728	0.000
Within Groups	3661.333	96	38.139		

Appendix Table 4. Analysis of variance (ANOVA) for density of *C. partellus* on different sorghum genotypes under screen house-pot experiments

	Sum of Squares	df	Mean Square	F	Sig.	
Borer number/plant* Treatment	652.991	11	59.363	7.395	0.000	Between Groups (Combined)
Within Groups	770.669	96	8.028			

Declaration

I, the undersigned declare that this thesis is my work and that all sources of material used for the thesis have been correctly acknowledged.

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