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Resistance in maize genotypes to the spotted stem borer, *Chilo partellus* (Swinhoe) (Lepidoptera: Crambidae)

By

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Abstract

In the current study, 134 maize genotypes were screened against *C. partellus* at Melkasa Agricultural Research Center (MARC) under field and laboratory conditions.

Initially, 134 maize lines against *Chilo partellus* were screened based on the number of leaf infestation and dead heart. From 134 lines tested in the field, 34 lines ($\leq$10% infestation) showed promising in terms of *C. partellus* resistance, 74 (11-25% infestation) lines were intermediate and the rest 20 lines (>25% infestation) were susceptible. From each category four lines were randomly selected and planted in three replication using completely randomized design (CRD) to verify the plantsresult obtained under field screening. Number of egg masses and leaf infestation per plant were recorded and then dissected to check for number of borer density, larvae exist holes and tunnel length. There were significant differences for all parameters were observed among the three categories. Furthered more, the results confirmed the presence of similar trends with field screening result in leaf infestation with screen house outcome.

Finally, the growth and development of the borer were measured on the most susceptible and resistant maize lines which were determined under natural, and artificial infestations. These maizelines were examined for their relative resistance to the *C. partellus* (Swinhoe) in relation to feeding. Freshly hatched larvae of *C. partellus* were allowed to grow on the leaf sheath and stem cuts of the two lines separately. The rate of growth, egg lying, egg hatchability, pupation, and adult emergence were studied. The insects showed better growth when reared on susceptible maize line than on the resistant line.

The majority of Ethiopian farmers have small land holdings. For these reasons, and the hazards associated with insecticide applications, there is a great need to develop varieties that can resist pest attack with out requiring any traditional expenditure by the farmers.

1. INTRODUCTION

Maize (*Zea mays L.*) is one of the most important crops used primarily as a staple food for millions of people in Africa. Besides this, it is used as a cash crop and animal feed (Minja, 1990). Maize originated in America and is now the principal cereal crop in the tropics and sub-tropics. The main production areas are South America, parts of USA, Eastern and South Africa (Dennis, 1983). Maize is an important food crop in Ethiopia ranking second in terms of area coverage and first in terms of yield per hectare (Emana *et al.*, 2002).

Although maize is the most important food crop in eastern and southern Africa, its potential yield cannot be realized mainly due to the foraging of insect pests particularly lepidoptrous stem borers (Ampofo and Saxena, 1987). Lepidopterous stem borers are regarded as a major limiting factor to the production of maize and sorghum (*Sorghum bicolor* Moench) in tropical Africa (Kfir *et al.*, 2002). The *Chilo* group, of which 41 are pestiferous of particular importance in Africa and Asia, where they attack a wide range of wild and cultivated plants. The spotted stemborer, *Chilo partellus* (Swinhoe) (Lepidoptera: Crambidae), is by far the most dominant and important species in the lowland tropics and mid-altitudes of East Africa (Overholt, 1998). The distribution of *C. partellus* is rainfall and temperature dependent i.e. *C. partellus* is abundant and causing more damage under low rainfall and hot environment (Emana *et al.*, 2002).

Chilo partellus introduced to Africa from Asia some time before 1930 (Tams, 1932) and now occurs in most countries of Eastern and Southern Africa (Overholt, 1998). Currently, it is a serious threat to the production of maize and sorghum in Eastern and Southern African countries (Harris, 1990) where in combination with other stem borers species such as *Busseola fusca* (Fuller) *Sesamia calamistis* and other *Sesamia* species (Lepidoptera: Noctuidae), which causes yield losses ranging from 10% to 100% (Emana and Tsedeke, 1999; Kfir *et al.*, 2002).

Chilo partellus causes damage to maize plants in two main ways; foliar damage and stem tunneling (Schmutter, 1969). Foliar damage, usually caused by the young larvae (first and second instars), results in the reduction of the total leaf area and a depression in the photosynthetic capacity of the plant (Ampofo and Saxena, 1987). Stem tunneling is generally caused by older larvae (third to fifth instars). These bore into the stem and chew their way through it, destroying the central pith and conductive tissues, hence causing a reduction in nutrient uptake (Ampofo and Saxena, 1987).

The four general approaches to stem borer control are chemical, biological, cultural, and host plant resistance. The chemical control method is the most widely used, but this method exposes the farmer to health risks and can result in pesticide load in the environment (Jotwani, 1983). In Africa, a large proportion of the total land area under maize cultivation (70 to 80%) is held by small-scale subsistence farmers. For such farmers, it is not economically feasible to use chemical pesticides (Ampofo and Saxena, 1987).

Cultural control methods, such as intercropping with non-cereals and early planting, have been practiced for centuries by farmers (Minja, 1990). But their impact on stem borer populations is limited (Oloo, 1989; Skovogard and Pats, 1996). Besides, crop residue destruction, tillage, and water and fertilizer management have been recommended. However, these methods are often not applicable due to conflicts with traditional uses of crop residues, high labor requirements and lack of financial resources. Biological control agents often require trained personnel for identification and deployment and the commitment of the farming community to enhance the establishment of biological control agents. Therefore, they must depend on a more fundamental approach to pest management.

Cultivars with high levels of resistance to the pest attack can serve as effective and economical means of pest control (Stilling, 1985). Host plant resistance offers the most promising means of insect control in crop plants. In certain cases, host plant resistance is almost the only effective means for controlling insects, whereas in others, resistant cultivars are used as a component of an integrated pest management (Ampofo and Saxena, 1987). A resistant plant variety that reduces the insect population by 50% each generation is sufficient to reduce the pest population below the economic injury level in a short period (Stilling, 1985).

It has long been identified that some varieties of plants are more resistant to pest attack than others (Painter, 1951). Scientists as well found variability among maize genotypes to insect pests. International Maize and Wheat Improvement Center (CIMMYT) already developed resistant genotypes for some insects like stem borers and maize weevil. These verities are under evaluation in different countries where CIMMYT is operating. Emana tested eight stem borer resistant maize genotypes at Melkassa in 2000 and found tremendous variability among the genotypes (Emana unpublished data). These findings with a few genotypes are good indication for the possible presence of resistance gene (s) in maize against *C. partellus* and warrant for the inclusion of more genotypes in the screening programs to get highly resistance genotypes.

2- LITERATURE REVIEW

2.1 Economic importance of maize

Maize (*Zea mays* L.) is originated in Central America and was introduced to Africa in the early 1500s by Portuguese traders (Dowswell *et al*., 1996). It was introduced to Ethiopia during the 1600s to 1700s (Benti and Ranson, 1993). Maize is worldwide cultivated on about 3.9% of the arable land (FAO, 2002). In Ethiopia, maize is one of the most important cereal crops and in terms of area; it is the second most important commodity covering 1.33 million ha. of land and accounting for 20.86% of the total arable land. It ranks first in production and productivity (CSA, 2004).

Maize is increasingly an important component of diets across the country. It is mainly used directly for human food and indirectly used for animal feed. In the highland areas, maize is the first crop grown, and is a popular "hunger breaking" crop when harvested and consumed green. Maize production, processing and utilization serve as very important employment and income generation activities for a large cross-section of the population including men, women and children. The relatively high productivity, favorable growing conditions and the technological advances over the last decade have contributed to its increased area of production in the country (Kassa *et al*., 2003).

2.2 Maize Production constraint

Despite the large proportion of arable land allotted to maize grain, yield tend to be very low and in 2001 the average grain yield for the sub-Saharan Africa was 1600 kg/ha, while the world average was 4420 kg/ha (FAO, 2002). The poor performance of maize in Africa in general and Ethiopia in particular, could be attributed to unfavorable agro-climatic conditions, poor soil fertility, and the prevalence of numerous insect pests and diseases (CIMMYT and EARO, 1999). Among the insect pests attacking maize Lepedopteran stem borers are considered to be the most important insect pests on maize and sorghum in tropical Africa. In Ethiopia, six stem borer species were reported to attack these crops (Emana *et al.,* 2001). Among these two borer species cause significant yield loss (*Buseola fusca* and the *Chilo partellus*) (Emana and Tsedeke, 1999).

2.3 Geographic distribution of *Chilo partellus*

Chilo partellus, is a major pest of maize, sorghum, finger millet, sugar cane, and rice in the hot and humid lowland areas of Eastern Africa and South Asia. Its distribution covers the area from Ethiopia to South Africa and extends as Far East as Australia (CIMMYT, 1989). *C. Partellus* is indigenous to Asia (Bleszynski, 1970) and occurs up to 2080 m.a.s.l (Emana , 2002). It was first recorded in Africa from Malawi in 1930 (Tams, 1932), but was not reported again until some 20 years later in Tanzania (Duerdon, 1953). Since that time, the geographic distribution of *C. partellus* has continued to expand with reports from Kenya, Rwanda, South

Africa, Ethiopia, Sudan, Somalia, Botswana, Malawi, Mozambique, Swaziland, Zimbabwe and Zaire (Nyee, 1960; Overholt *et al.*, 1997). There is evidence that in some locations, the exotic stem borer may be displacing indigenous species (Overholt *et al.*, 1994).

Currently, The spotted stemborer, *C. partellus* is by far the most dominant and important species in the lowland tropics and mid-altitudes of East Africa (Sétamou et al., 2005). In Ethiopia, Assefa (1985) recorded *C. partellus* at an elevation range of 510 to 1700 m and in warmer areas of the country. Emana *et al.* (2002) developed a model on the distribution of *C. partellus* indicating that the distribution of *C. partellus* depends on temperature and rainfall, i.e., high temperature and low rainfall favors *C. partellus.* There is a status change to *C. partellus*, which was only reported below 1700 m before 1999. Currently, *C. partellus* was recorded and become economic pest at 2080 m (Emana *et al.*, 2001).

2.4 Biology and Behaviour of *Chilo partellus*

Chilo partellus survives the dry season as diapausing larvae. As soon as sufficient moisture is available at the beginning of the rainy season, the diapauses is terminated and the first generation of adults start to appear. After mating, host finding and ovipostion are the first two activities by the female moths. Once the females have made their choice for ovipostion, they lay their eggs in mass (Leuschner, 1990).

Chilo partellus moths are nocturnal in their habits. Depending on prevailing environmental conditions, adults have an average life span of two to five days. The female in her lifetime oviposits masses of 200-600 eggs in 15-20 batches or clusters. They hatch with in 12-18 hours. Thus, under normal conditions incubation period is 5 days. However, the incubation period can be prolonged at low temperatures provided high humidity is maintained (Harris, 1990).

The first instar larvae crawl up to the leaf whorl and start feeding within the whorl. The damaged leaves show papery epidermis within the feeding site and give a characteristic 'window' appearance. However, feeding by later instars cause irregular shaped holes in the leaves. Very often the larva bores the central leaf horizontally, which results in 4-6 similar shaped 'shot holes' in a horizontal line as the leaf unfurls (Leuschner, 1990).

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 with in 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 (Bonholf, 2000).

2.5 Crop Damage and yield loss to Maize plants

Chilo partellus make damage to maize plants in two main ways. Foliar damage occurs when the whorl stage plants are attacked. This type of damage is expressed characteristically as lesions, formed by the scraping of the epidermis and parenchyma on one side of the leaf, often leaving the other epidermis intact and transparent. When the leaves unfold, the lesions are seen as small holes of windows on the leaves (Ampofo and Saxena, 1987). Damaged leaves show, in the fully developed stage, characteristic transverse rows of holes resembling each other in size and appearance (Schmutterer, 1969).

Foliar damage, usually caused by the young (first and second instars) larvae, results in the reduction of the total leaf area and a depression in the photosynthetic capacity of the plant (Ampofo and Saxena, 1987). When larvae attack the growing tip of the plant, the characteristic "dead heart" condition occurs. Such damage usually results in total plant loss. Severe foliar damage may also result in the death of the plant (Schmutterers, 1969). The second type of damage, stem tunneling is generally caused by older (third to fifth instars) larvae. These bore into the stem and chew their way through it, destroying the central pith and conductive tissues, causing a reduction nutrient uptake (Ampofo and Saxena, 1987).

The yield of maize was seriously reduced (up to 60%) when the insect infestation is heavy. In Ethiopia, Assefa (1985) and Emana and Tsedeke (1999) have reported yield losses ranging from 10 to 100%.

2.6 Control measures of *Chilo partellus*

2.6.1 Cultural control

Manipulation of crop residues: Ingram (1958) found that *Chilo zonellus* bred continuously in the dry season on trash, stubble and volunteer tillers of sorghum. He concluded that the destruction of all crop residues and wild species of sorghum around cultivated areas would considerably reduce borer attack at the beginning of the growing season.

Mohyuddin and Greathead (1970) conducted surveys of parasitoids of Graminous stem borers in east Africa and reported that high level of stem borer infestation usually resulted directly from wrong farming methods. Old infested stems from a previous crop were often the main source of infestation on a young crop and the degree of crop hygiene practiced. They stated categorically that ratooned sorghum is a dangerous source of stem borer. In India, Taley and Thakare (1980) found that the storage of sorghum stalks for fodder was conducive to the carry over of *Chilo partellus* and recommended the practice of chopping stalks to control the pest.

The effect of horizontal placement of stalks to sun for various length of time on mortality of diapausing larvae was evaluated in Ethiopia at Sirenka. It was found that sorghum stalks exposed horizontally for 6 to 8 weeks had 86 to 88% mortality of diapausing larvae. On the per plant (0.6 borers per plant per week) and the number increased with late sowing to nearly 1.6 borers per plant per weck. Thus, early planted maize will have passed the susceptible growth stages by the time *Chilo partellus* and *Chilo orichalociliellus* reach high population in the field. However, adjusting the sowing date to escape damaging populations of stem borers is of limited value, because rainfall is unreable in most areas and therefore farmers tend to stagger sowing dates, thus making it impossible to effect area wide synchronization of sowing dates.

Intercropping: The resource concentration and natural enemy hypothesis explain the mechanism involved in intercropping in the control of insect pest (Emana, 2002). Amoako-Atta *et al.* (1983) reported a significant delay in *C. partellus* colonization and establishment until 42 days after germination (DAG) on cereals in different cow pea, maize and sorghum intercropping combinations, compared with maize and sorghum monocrop or maize and sorghum dicrop where borer infestation was recorded from 14 DAG. Skovgard and Pats (1996) showed that fewer larvae and pupae of *C. partellus* occurred in maize/cow pea intercrop plots than maize mono cropping in Kenya.

In Ethiopia, 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. Similarly, Pats *et al.* (1997) reported that intercropping maize with cowpea was an efficient way of reducing damage caused by *C. partellus* larvae migrating from neighboring plants.

Habitat management: Recent studies have shown that the high grass diversity surrounding farmers' fields in tropical Africa is important in stem borer Management (Emana, 2002). Most African stem borers are generally polyphagous and have several graminacious and other wild hosts in addition to more than one cultivated crop (Ingram, 1958; Seshu Reddy, 1985). On the other hand, *Chilo partellus*, an indeigenous species to Asia which turned out to be the most important pest of maize and sorghum in Eastern, Southern and Central Africa nowadays is also polyphagous and attacks several wild host plants (Harris, 1990). In Kenya, *Busseola fusca, C. partellus* and *Sesamia calamistis* have been recorded on 24 wild plant species (Poalascek and Khan, 1998), gravid female moths prefer most of these grasses over cultivated crops for oviposition, yet with subsequent poor survival of the immature stages, an indication of their potential use as trap plants.

The International Center of Insect Physiology and Ecology (ICIPE) and its partners have exploited this in a 'push–pull' system where gravid female moths are repelled from the main crop (maize) by an intercrop that provides the 'push' and are attracted to a trap crop (the 'pull') (Khan *et al.*, 2001). The candidate 'push' crops currently in use in the system are desmodium (*Desmodium uncinatum* Jacq.) (Fabaceae) and molasses grass (*Melinis minutiflora* Beauv) while the 'pull' crops used are Napier grass (*Pennisetum purpureum* Schumach) and Sudan grass (*Sorghum vulgare sudanense* Pers.). Khan *et al.* (2006) demonstrated the potential of Napier grass varieties as trap plants and indicates that the four proposed varieties (Ex-machakes,Bana, Goldcost , and EcoNyanza-z) would provide an acceptable level of protection against *C.partellus* in the various regions where they occur and where they are popular with farmers.

parasitoids have already been identified, but critical ecological studies are required to indicate more precisely the areas where the addition of further parasitoids are most likely to be effective (Minja, 1990).

Insect parasitoids have been the most common type of natural enemies introduced for biological control of insects (Hall and Ethler, 1979). Parasitoids kill their host and they complete their development in a single host, unlike predators, which generally must consume several preys to complete their development (Doutt, 1959). Most parasitoids that have been used in biological control are from the order Hymenoptera and to a lesser degree, Diptera. Parasitoids are also found in the order Strepsiptera and Coleoptera (some members of families of Staphylinidae, Meloidaeand Rhipiphoridae). Polaszek (1997) listed 121 species of parasitoids in 56 Genera associated with the African stem borers.

Indigenous parasitoids of African stem borers have expanded their host ranges to include the exotic stemborer (*C. partellus*). but do not appear to effectively regulate densities at acceptable levels (Oloo and Ogedah 1990; kfir, 1992). Studies at the Kenyan coast and other parts of eastern Africa have shown that although stem borer larvae including that of *C. partellus* are attacked by wide range of indigenous parasitoids, but parasitism is often less than 10% (Mohyuddin and Greathead, 1970). Because of the aforementioned reasons, and the economic importance of *C. partellus*, and its status as an introduced pest the former common Wealth Institute of Biological control (CIBC) imported nine species of parasitoids of *C. partellus*, of which *Cotesia flavipes* was one and introduced from India and subsequently released in Uganda, Tanzania and Kenya from 1968-1972 (CIBC, 1968-72). However, no successful the first time in Ethiopia in 1999, *C. flavipes* tremendously spread and its parasitism increased from 7.5% to 58% in 2005 (Emana, unpublished data).

Predators, such as ants, spiders, ladybird beetles and earwigs can cause high mortality of eggs and young larvae of *C. partellus, B. fusca* and *S. calamistis* in some areas in Africa (Bonhof *et al.,* 1997). For example, Bonhof (2000) in Kenya reported *Diaperasticus erythrocephala* on eggs and larvae of *C. partellus* and *B. fusca*. In Ethiopia, Emana *et al.* (2001) reported 14 species of predators feeding on larvae and eggs of *C. partellus, B. fusca* and *S. calamistis. Forficula senagalensis* (Sorv.) and *Pheidole megacephala* (Forel) were the abundantly found predators on stemborers in Ethiopia.

The use of *Bacillus thurigiensis* Berliner in the control of stemborer was reported by Abraham *et al.* (1993). Biological control studies were conducted with isolates of entomopathogenic fungi *Beauveria bassiana* and *Metarrhizium anisopliae* from Ethiopia against spotted stem borer *Chilo partellus* (Tadele 2004). Four isolates of *B. bassiana* and six isolates of *M. anioplìae* were tested against second instar larvae. Of these isolates, *B. bassiana* (BB-01) and *M. anisopliae* (PPRC-4, PPRC-19, PPRC-61 and EE-01) were found to be highly pathogenic inducing 90 to 100% mortality seven days after treatment.

2.6.3 Chemical control

Chemical control is the most powerful tool available for controlling stem borers and usually recommended by national agricultural extension agencies, especially in treating outbreaks (Warui and Kuria, 1983) However, Chemical control of stem borers is unusually laborious, because of the necessity for precise placement except when systematic insecticides are used. In addition, the prices of insecticides have been escalating, making it impossible for most farmers to afford the required quantities of pesticides to meet their needs. Furthermore, the chemicals are hazardous to man and other non target organisms as well as promoting resistance in target pest to insecticides if used for a long period or in sub-lethal quantities (Kfir, 1988).

There has been conflicting reports on the effects of applying insecticides on the incidence and severity of stem borers on maize and on yield performance. Some workers have obtained reduced damage levels with significant yield increases (Swaine, 1957; Warui and Kuria, 1983), while others have not recorded similar responses (Ingram, 1958). A possible reason for this variation is the critical time of maize infestation and its relationship to time of insecticide application.

Based on trials in Uganda (Coaker, 1956) and Kenya (Warui and Kuria, 1983), effective control of stem borers has been reported. Warui and Kuria (1983) reported that Furadan (carbofuran) granules when applied during planting and Dipterex (trichlorphon) granules applied at 2-3 weeks after plant emergence (WAE) are effective against stem borers.

Warui and Karia (1983) demonstrated that selected chemical treatment at the appropriate time reduced losses due to stem borer in maize by about 20%. They concluded that there was a need to monitor fluctuations of borer populations from season to season and adjust sowing dates based on the seasonal borer infestation records.

In Ethiopia, Assefa (1982) and Emana (1997) recommended the application of carbaryl WP, endsulfan EC, cypermethrin G and cymbush EC for the control of *Busseoea fusca*. On the other hand, chemical screening of thirteen insecticides was carried out at Awassa and Areka. Compared with the untreated check, the lowest cob infestation at both locations was observed on Ethiosulfan 35%, Diazinon 60%, Ethiosulfan 5%, Thionex 25%, Actellic E.C., Decitab and Cypermethrin G sprayed plots. At Awassa, the highest yield (98.4 q/ha) was obtained from plots treated with Cypermethrin G (EARO, 1998).

Neem berries (*A. indica*), pyrethrum flowers (Chrysanthemum spp.), garlic bulbs and abasoyo-hot-pepper pods were tested against 2nd and 3rd instar of maize stemborer larvae under laboratory conditions. Applications of extracts of neem berries (seed) and pyrethrum flowers at 8% concentration resulted in 90 and 100% mortality to I and II instar of *B. fusca* within three days, respectively (EARO, 1998/99). Habte (1999) studied the effect of seed powder and aqueous suspension of neem against *C. partellus*. In this study he demonstrated that neem seed powder and extract markedly reduced primarly crop damage [ncluding foliar damage, dead heart and stem tunneling.

2.6.4 Host plant resistance

It is generally accepted that host plant resistance (HPR) is the most farmer-friendly pest control option (Newanze, 1997; singh *et al.,* 1983). Resistance is the inherent ability of the host plant to prevent, restrict, retard or over come pest infestations (Pathak, and Olela, 1983). Resistance to pest is a relative trait and not an absolute quality. Genetic resistance is heritable and suppresses pest population or reduces pest damage. The degree of resistance ranges from very small to very large and plant reaction ranges from high susceptibility to immunity. These reflect the phenotypic expression of damage by pests and dictate levels of management required for effective use of resistance in pest control. Resistance levels are measured qualitatively and quantitatively with reference to cultivars and strains (Davis, 1985).

The susceptibility or resistance of different plant species or varieties to an insect species varies with their suitability or unsuitability, respectively, for the establishment of insect population. The greater the suitability in this respect of a plant, the greater would be the damage it sustains greater would be its susceptibility to the insect species (Saxena, 1985). Plant resistance to pests is based on the plant genetics and the consequential molecular interactions that occur between the host and pest organism (Gebhardt and Valkonen, 2001; Pedley and Martin, 2003).

Many morphological characters contribute to the resistance of plants to insect pests. These include trichomes, surface waxes, and hardness of plant tissues, thickening of cell walls and cuticle, rapid proliferation of tissues, anatomical modifications of plant organs, colour and shape of plant parts (Davis,1985). Insect resistance in plants is also due to the chemical constituents, which may be either qualitative or quantitative. These chemicals occur within certain parts of the plant or in specific stages of plant growth. The herbivores' behavior and adaptation to the host plant are influenced by the chemical composition of the host plant (Pedley and Martin, 2003).

There are three general types of mechanisms of resistance: non-preference, antibiosis and tolerance. 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 (Painter, 1951). 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 oviposition. 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 (Kogan and Ortman , 1978)

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. Biochemical 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 are causes of most antibiosis. Tolerance refers to the ability of the host plant to withstand an insect population sufficient to cause damage severely to the susceptible plants. Tolerant varieties do not depress insect populations nor do they provide any selection pressure on the insects (Painter, 1951).

Use of host resistance as the key component of IPM system has greater potential than any other tactic for pest suppression. It is compatible with other insect control methods. Host plant resistance enhances the efficacy of insecticides. Generally, a lower concentration of insecticides is needed to control insects feeding on resistant varieties than the susceptible one. Pest resistant varieties are usually compatible with biological control and enhance the predatory activity (Maxwell, 1985).

The techniques used for screening plant genotypes for resistance vary with crop, insect, resistance mechanisms and site of screening experiments (laboratory, growth chamber, green house field or field cage). To effectively screen plant genotypes for resistance, the entomologist with the assistance of plant breeder must develop techniques to provide a uniform insect infestation of sufficient level at the desired plant growth stage and must develop measurement techniques for evaluating the responses of the plant to insect populations. Success in identifying resistant sources is often proportional to the number of plant genotypes that can be evaluated. Therefore, large number of insects in the desired life stages are needed (Davis, 1985).

The strategy for evaluating maize germplasm for resistance to *C. partellus* requires a basic knowledge of the population biology of the pest in relation to the phenology of the crop. For an effective comparison among the screening materials it is important to create the conditions necessary for normal growth. Plants that are adapting or not growing properly because of stress are likely to be abnormally susceptible to damage by the borer. This results in unreliable evaluation (Leuschner, 1990).

Screening under natural infestation: Natural pest populations can be used effectively to achieve an infestation by adjusting planting dates (Mohyddin and Attique, 1978). For a good plant resistance screening programme, it is essential to develop an efficient and reliable screening technique that ensures a uniform level of insect pressure, at the most susceptible stages of the crop. Theses requirements can be met by selecting a hot spot area of the pest (CIMMYT, 1989).

Screening under artificial infestation: The major bottleneck of screening for *C. partellus* resistance under natural infestation is that *Chilo* population may fluctuate over years leading to low and different levels of infestations in certain cropping seasons. In addition, breeders require uniform infestation to be able to select in segregating generations. Only artificial infestation can meet this requirement (Leuschner, 1990). Screening under artificial infestation involves rearing of *C. partellus* on natural or artificial diets. The main advantage of screening under artificial infestation is that the time of infestation is known, each plant is infested more or less with a uniform number of *Chilo* and early and late generation infestation can be simulated separately or together (Davis, 1985).

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 tunneling. Lal and Pant (1980) reported that gravid female moths of *C. partelus* laid more egg masses on susceptible varieties of sorghum than on resistant ones. Dabrowski and Nyangiri (1983) tested 100 sorghum lines under field conditions and found that 11 were non-preferred for ovipostion. Many efforts also have been made by many scientists affiliated to various organizations world wide in developing resistant varieties of maize against stem borers. Parvez *et al.* (1990) evaluated twenty maize cultivars for relative resistance to *C. partellus* and observed that the cultivars Antigua, Gauher and Manawar were resistant where as Azam was the most susceptible. Various other workers identified a large number of maize genotypes with varying levels of resistance to *C. partellus* (Kumar and Mihm, 1997; Kumar, 1994; Kumar and Asino, 1994). Omolo (1983) identified new source of stem-borer resistance from local and exotic maize lines, which offered a wide scope in multiple resistance or multilines approach towards stem borer management.

3. OBJECTIVES

3.1 General Objective

- To identify maize genotypes resistant to the spotted stem borer of *Chilo partellus*

3.2 Specific Objectives

- To investigate on the possibility of the variability in maize genotypes in their reaction to *Chilo partellus* attack.

-To determine the effects of resistant and susceptible maize genotypes on some life table parameters of *C. partellus.*

- To determine the ovipositional preferences of *C. partellus* on different maize genotypes with different level of resistance.

4. MATERIALS AND METHODS

4.1 Description of the Study site

The study was carried out at Melkassa Agricultural Research Center (MARC) near Nazereth which is located at about 120 km from Addis Ababa. The study area is characterized by erratic rainfall, and receives an average annual rainfall of about 550 mm and locate an elevation of 1500 to 1550 m a.s.l. It has average annual minimum and maximum temperatures of 14^{O}C and 28^{O}C, respectively. The relative humidity in the area ranges between 40% and 60%.

The study was conducted in three phases. These include Screening and evaluation of maize lines for level of resistance against *C. partellus* under field condition (phase I), Evaluation of selected maize lines for their level of resistance under artificial infestation in green house (phase II) and e valuation of the effect of resistant and susceptible maize lines on growth and development of *Chilo partellus* in the laboratory (phase III).

4.2 0pen field evaluation of maize genotypes for their level of resistance to C. *partellus* attack

A total of 134 maize lines acquired from Melkasa Agricultural Research Center Maize Breeding section were evaluated for the level of resistance to *C. partellus* in the field from August to October 2005. Maize lines considered for evaluation of their resistance to *C. partellus* are presented in Appendix 1. Each line was planted in a single row of 7 meter length with 75cm spacing between rows and 30 cm between plants. The plots were furrow irrigated and recommende cultural practices were followed. The maize plants were left unprotected to allow for natural infestation to take place. The level of resistance in the test lines was determined by counting infested plants at weekly interval starting from three weeks after crop emergence up to harvesting. Leaf damage symptoms, dead heart or holes and frass on the stem of maize plants 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 plants in each maize line were recorded and used to compute percent infestation using the following formula

$$\% \text{ Infestation} = \frac{\text{no. of plants with stem borer damage} \quad \times 100}{\text{Total no. of plants in row}}$$

Then after, Maize lines evaluated under field conditions were categorized into resistant (≤10%infestation), moderately resistant (11-25%infestation) and susceptible (>25% infestation) (Emana, 2002).

4.3 Evaluation of selected maize lines for their level of resistance under artificial infestation

After categorizing maize lines into resistant, moderately resistant and susceptible based on their performance under natural pressure of the pests, four maize lines from each category were promoted to screen house pot experiment. Five seeds of each test line were sown on soil in plastic pots and thinned to three after seedling establishment. Maize plants of the selected 12 lines in pots maintained in the screen house arranged in completely randomized design (CRD) in three replications.

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

Larvae and pupae of *C. partellus* collected from the field were reared in the Melkassa Agricultural Research Center entomology laboratory. The maize plants were sown in the field in two rows of 3 meter length to serve as a food for *C. partellus* larvae to be considered for artificial infestation in screen house pot experiments.

The larvae were provided with the leaf sheath as food until the third instars larvae and then were provided with maize stems. Stem cuts for larval feeding were changed every three-day after dipping in 0.05% sodium hypochlorite to avoid fungal contamination. Larvae were checked for pupation every day. After pupation, the pupae were put in rearing cages where emerging moths were allowed to mate for 12 hrs.

4.3.2 Artificial infestation and data collection

Forty female *Chilo partellus* moths were then sorted and released into the screen house when test maize plants in pots attain 3-4 leaf stage in the screen house from rearing cage hanged in the center at an elevated position well above the plants in the pot. The maize plants in pots were covered with mothproof cloth mesh (10x3x3m) to avoid escape of the moths outside of the experimental prior to ovipositon (Fig. 3).

Examination of maize plants and data collection was conducted starting twelve hours after the release of *C. partellus* moths and continued for 40 days. Each plant was checked for the presence of egg batch, leaf infestation by *C. partellus* larvae and then dissected to check for presence of larvae, pupae and pupal case. Moreover, the number of exit holes and tunnel length were recorded.

4.4 Evaluation of the effect of resistant and susceptible maize lines on growth and development of *Chilo partellus* in the laboratory

The most resistant and the most susceptible lines of maize (based on the data both from field and screen house pot experiments) were planted in the field in two rows of 3 meter length to serve as a food for *C. partellus* larvae to be considered for growth and development study. The spacing used was 30 cm between plants and 75 cm between rows.

About 100 larvae and pupae were collected from MARC experimental field and put in six rearing cages. These were maintained in the laboratory both by feeding the susceptible and resistance maize lines separately until adult emergence. For growth and development study of *C. partellus* , the emerging five moths from each category were selected. The selected adults from each category were allowed to mate and oviposit independently in ten rearing cages being provided with the leaf sheath for egg laying until her death. Eggs masses laid in leaves by each moth were counted with the help of microscope and egg laying and their hatchability were compared.

After hatchability, the larvae were placed individually in petri-dish. The larvae were provided with the leaf sheath of each line until the third instars larvae. Thereafter, fed to the stem pieces of each line individually in separate rearing cage. Stem cuts for larval feeding were changed every three day by being dipped in sodium hypochlorite (0.05%) to avoid fungal contamination. 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. 5 Data analysis

Analysis of the data on the number of egg masses, leaf infestation, number of borer per plant, number of exist hole and stem tunnel length was done by comparison of means with one way ANOVA using SPSS 11.0, a computer based statistical package for windows. Duncan Multiple range Test was used for mean separation.

Table 1. Percent infestation of maize lines by *C. partellus* under field Condition and rank of lines into different categories

Infestation level	Number of line	Category of the line
0 – 10%	39	Resistant
11 – 25	74	Moderately resistant
>25 %	21	Susceptible

5.2 Response of *Chilo partellus* to susceptible and resistance maize lines in pot expereiment under screen house condition.

5.2.1 Ovipostional responses of *C. partellus* and level of infestation on selected 12 maize lines in pot experment

Analysis of variance of the data on mean number of egg masses and leaf infestation per plant indicated that significant differences were observed among the lines tested ($P<0.001$) (Appendix 2). Mean number of egg masses recorded per plant varied from 0 to 5 (Table 2). The highest mean egg masses were recorded in line J (5). No egg masses were recorded in lines A, B, C and D (Table 2). The highest mean leaf infestation was recorded in line E and no infestation was recorded on line A (Table 2)

Table-2 Mean number of *C. partellus* egg masses and leaf infestation on different maize lines under screen house-pot experiment.

Mean number of egg masses and leaf infestation per plant

Tested Line	Mean no. of Egg masse ± SE	Mean no. of leaf infest ± SE
A	0.00± 0.00a	0.00 ± 0.00a
J	5.00± 0 .94c	0.67 ± 0.17bc
E	0.22± 0 .14a	0.78 ± 0.15c
K	3.77± 0.61bc	0.67 ± 0.17bc
G	0.22± 0 .22a	0.44 ± 0.18abc
F	0.33± 0.23a	0.33 ± 0.17abc
D	0.00± 0 .00a	0.33 ± 0.17abc
B	0.00 ± 0 .00a	0.22 ± 0.15ab
L	3.88 ± 0 .904bc	0.67 ± 0.17bc
I	2.70 ± 0 .32b	0.67 ± 0.17bc
H	0.22 ± 0 .146a	0.56 ± 0.18bc
C	0.00 ± 0 .00a	0.22 ± 0.15ab

Means within a column followed by the same letter(s) are not significantly different at $p<0.05$, Duncan's multiple range test.

A= A-511 MS 293-1-1-1-2-1
J=(((NAW5867/P30-SR)- 40-1(NAW5867/P30-SR)- 114-2)-16-2-2-b-2-CMl394)-B-2-5-1-1-2
E= [CML 202/CML395-5]-B-1-1-1-1-1
K= [CML 395/CML395-5]-B-3-3-1-1-1
G= [CML 206/CML312)-B-3-3-1-1-1
F=(CML197/CML390)-B-3-2-1-1-1
D= (CML197/CML390)-B-3-2-1-1-2
B= [CML 206/CML312)-B-3-2-1-1-1
L= [CML 312/CML395-1]-B-2-1-1-1-1

I= [CML 312/CML395-5]-B-3-2-1-1-1
H= (CML197/CML206)-B-3-1-1-1-2
C=[90323(B)-1-X-1-B/CML202]-B-2-3-1-1-2

5.2.2 *Chilo partellus* density per plant on selected 12 maize lines under screen house- pot experiment.

Appendix 3 shows the results of ANOVA for *C. partellus* density per plant on different maize lines under screen house-pot experiment. Data on the mean *C. partellus* density per plant recorded on the 12 maize lines are presented in Table 3. Analysis of variance of the data on mean borer density per plant indicated that significant differences were observed among the lines tested (P<0.001). Mean borer density recorded per plant varied from 0.11 to 7. The highest mean borer density was recorded on line K and the lowest density was on line A and C (Table 3).

Table-3 Mean *C. partellus* density per plant on different maize lines under screen house-pot experiment

Mean number of borer per plant

Tested Line	Mean no. of Borer ±SE
A	0.11 ± 0.11a
J	6.33 ± 0 .88ef
E	3.55 ± 0.83cd
K	7.00 ± 0.52f
G	2.77 ± 1.11bc
F	1.11 ± 0 .56ab
D	0.66 ± 0.44ab
B	0.33 ± 0.16a
L	5.11 ± 0.82def
I	4.55 ± 0.94cde
H	2.66 ± 0.97bc
C	0.11 ± 0.11a

Means within a column followed by the same letter(s) are not significantly different at $p<0.05$, Duncan's multiple range test

5.2.3 Number of exit holes and stem tunneling length due to *C. partellus* on selected 12 maize lines in pot experiment.

Data on the mean number of exit hole and stem tunnel length per plant of 12 maize lines screened for their resistance/susceptibility attributes are presented in Table 4. Analysis of variance of the data on mean number of exit holes and stem tunnel length per plant indicated that significant differences were observed among the lines tested (P<0.001). the mean value varied from 0 to 7.22 and 0 to 9.77, respectively. The highest mean number of exit holes and stem tunnel length were recorded on line I and K respectively. There was no exist hole and stem tunnel recorded on lines A (Table 4).

Table 4- Mean number of exit holes and stem tunneling due to *C. partellus* on different lines of maize under screen house-pot experiment.

Maize Line	Mean no. of hole per plant ±SEM	Mean no. of tunnel length per plant ±SEM
A	0.00 ± 0 .00a	0.00 ± 0.00a
J	6.66 ± 0.50e	8.56 ± 0.69e
E	2.66 ± 0 .45bcd	4.33 ± 0.78bcd
K	6.33 ± 0.94e	9.78 ± 1.51e
G	1.77 ± 0.46abc	3.44 ± 0.76abc
F	1.22 ± 0.36ab	2.44 ± 0.65ab
D	0.66 ± 0 .44a	1.89 ± 0.65a
B	0.44 ± 0.24a	1.11 ± 0.56a
L	4.00 ± 0.66d	5.89 ±1.1d
I	7.22 ± 0.75e	9.44 ± 1.30e
H	3.33 ± 0.04c	5.11 ± 1.69cd
C	0.22 ± 0.14a	0.67 ± 0.44a

Means within a column followed by the same letter(s) are not significantly different at $p<0.05$, Duncan's multiple range test

5.3 Growth and Development of *C. partellus* on different maize lines in the laboratory at room temperature

Table 5 shows that the percentage of larvae pupating was greater when fed on the line H as compared to line A. Pupal mortality was almost negligible in case of line H, where as it is higher in case of A . Percent mortality of the insect till adult stage is highest, about 90% in line A while it was about 47% in the cases of larvae fed on line H (Table 5).

The developmental period of *C. partellus* larvae from first instars to adult is much shorter on H as compared to line A (Table 6). Growth index for C. *partellus* on H is 1.399, while on line A this value decreases to 0.239. The sex ratio (Male: female) is more in favor of females in case of larvae fed on line H, where as the reverse is true for the line A (Table 5). The egg laying potential of adults that emerged from larvae fed on the susceptible (H) and the resistant (A) line was significantly different and was highest in line H. The hatchability of the eggs laid is also higher for line H than line A (Table 7). A more obvious difference is seen in the percent hatchability of the eggs laid which is reduced to almost 46% in case of leaves of line A (Table 5).

Table-5 Percentage of hatchability, pupation and adult emergence of *C. partellus* reared in two different maize line.

Maize line	%Hatched	%Pupation	% Adult emergence	Sex ratio Male: female	Growth index
H	69.67	68.59	46.88	0.79:1	1.4
A	46.07	29.74	10.43	1.26:1	0.24

Table- 6 Mean number of days taken in developmental stage of *Chilo partellus* reared in two susceptible and resistance maize lines.

Maize line	Egg (days ± SE)	Larva (days ± SE)	Pupa (days ± SE)	Total (days ± SE)
H	5.80 ± .20	20.60 ± .51	7.20 ± .12	33.50 ± .45
A	6.80 ± .37	25.90 ± .24	10.80 ± .66	43.60 ± .73

Table- 7 Mean number of eggs, larvae, pupae and adult of *Chilo partellus* reared in two maize lines.

Name of Line	no. of eggs per female	no. of larvae per female	no. of pupa per female	no. of adult per female
H	237.60 ± 9.11	165.60 ± 4.99	113.60± 3.74	111.40 ± 3.91
A	201.40 ± 9.98	112.80 ± 7.9712	27.60 ± 3.89	21.20±3.94

H= CML312ICML206]-B-3-1-1-1-2

A= A-511 MS 293-1-1-1-2

6. DISCUSSION

The current study clearly pinpointed the existence of variability among the maize lines in their reaction against C. partellus attacks.. There was also a wide gap (between 0 and 47). Earlier studies, Dabrowski and Nyangiri (1983) also found great variability and wide range of difference among tested lines. The criteria used in the current study for Screening of maize lines against *C. partellus* in the field were based on percent plant infestation. Kumar (1994), and Kumar and Asino (1994) who studied the difference between susceptible and resistant lines in terms of percent plant infestation and found that susceptible lines were distinctly more infested than the resistance ones.

Infestation of a considerable number of plants within a line with *Chilo partellus* larvae and low number of plants on other line may suggest that the plants with low number of plants infested might be resulted from plants that failed to provide positive gustatory stimuli required by *C. partellus* larvae or by the possession of characteristics having adverse effects on larval feeding activities such as the presence of dense trichomes and/or plant secondary metabolites the acting feeding suppressant or deterrents (Beck, 1965).

Several maize genotypes have been screened by various workers for their susceptibility or resistance to stem borer infestation. Among the factors determining susceptibility or resistance of maize plants to *Chilo partellus* in oviposition preference response of different genotypes and the characters involved in the initial selection of plants by the oviposting females (Kumar and Saxena, 1985).

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 current experiment, as shown in Table 2, differences in the ovipostional responses of *C. partellus* to the susceptible and resistant maize lines are observed. The experimental techniques have clearly established that *C. partellus* lays no eggs on the resistant line and lays less egg on the moderate resistance line, but relatively large number of egg masses establish on all susceptible lines. Like wise, field tests by Ampofo (1985) revealed differences in *C. Partellar* oviposition on certain susceptible and resistant maize lines. Thus, using the terminology initiated by painter (1951), the insect's non- preference for the resistant and relatively to the moderate resistant genotypes evidently one of the mechanisms of these lines resistance to *C. partellus.*

This is possibly the variation in maize lines with morphological, biochemical and physiological characteristics, which make these traits influencing the adult to select a suitable host plant for oviposition. 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 has been given by Saxena (1984, 1985). After contact with the plant, surface waxes (chemicals) and the physical structure of the leaf surface become the next selection criteria. There is evidence from work done by saxena (1985) that contact perceivable characters also play a role in selection of plant for oviposition. 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, *C. partellus* (swinhoe). Moreover, with regard to ovipostional response, the results of the current study agreed with the previous studies by Kumar and Saxena (1985) that they reported *C. Partellus* lays less egg on the resistant line than on the susceptible one.

In the present study, there is also variability in leaf infestation by *C. partellus* on resistance, moderate resistance and susceptible lines under screen house pot experiment. The screen house pot experiment complemented the result obtained under field experiment condition such that percent leaf infestation by *C. partellus* for the 12 maize lines growing under screen house and field conditions showed comparable trend. This result is in agreement with Omolo (1983) who found similar trends in plant damage and infestation by *C. partellus* larvae for three maize lines growing under screen house and natural field conditions. In both experiments he found, the rating from the resistant to the susceptible line is similar.

The incidence of leaf infestation by *C. partellus was* reduced on resistance lines. All the resistant maize lines significantly differed from the susceptible lines and also from two moderate resistant lines. However, no significant differences were observed among the resistant and moderlately resistant lines with respect to leaf infestation. 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. They further revealed that the number of larvae developed on the susceptible line higher than on resistant lines and the larval feeding activity in the stains was twice as high on the susceptible line than on moderate resistance. The finding of the previous authors also agree with current findings, in terms of the difference in suitability of resistance and susceptible maize line (i.e. the number of larvae developed on the susceptible line higher than on the resistance line)

In the present study, there were marked differences among maize lines in the density of *C. partellus,* in the numbers of holes and stem tunnel length. There were also similar trends on leaf damage score with the density of *C. partellus*, number of holes and stem tunnel length for resistant and susceptible maize line but some variation in the moderately resistant ones. In both result (density of *C. partellus*, numbers holes and tunnel length) there was no significant difference among the resistant line and the susceptible lines (I, J, K and L), respectively.

The susceptible lines had the highest number of *C. partellus* density, highest number of hole number and extended stem tunnel length per plant. These may be owing to the high number of larvae that survived on the leaves of susceptible than resistant line. Further more, as a result of mechanical and biochemical characteristics the susceptible lines were more chosen by *C. partellus* for feeding and continued existence. Earlier studies, Omolo (1983) also revealed that there were differences in larval survival on the resistant and susceptible maize lines. He further indicated that the most significant differences were observed in the extent of the destructive effect of larval feeding in the stem of resistant lines is less as compared to susceptible ones and a lower number of larvae penetrated the stems. In good turn of the present result, recently Awan and khaliq (2003) had evaluated 34 maize varieties against *C. paretellhs* attack based on plant infestation, number of holes made by larvae for entrance and tunnel length and they found great variability among the varieties, finally they conceived that a variety having less infestation, less number of holes and tunnel length selected as resistant against *C. partellus*.

The present study on number of exist hole and tunnel length on different maize line showed a similar trend. In agreement with the present results, kumar (1997) have found a highly significant correlation between number of holes and stem tunneling (expressed as the absolute tunnel length or the percentage of stem length tunneled) by *C. partellus* on four maize lines. These results indicate that number of holes can be used in place of the laborious method of splitting stalks for determining resistance in maize against *C. partellus*.

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. When the insect's response in each of these cultivars to a cultivar is lowered the plant's resistance will be greater. Observation in the current study showed higher mortality, longer development period, lesser pupation and adult emergence and a lower growth index for *C. partellus* larvae reared on A-511 as compared to H maize line. Earlier studies, Hough and Pimentel (1978) and Das and Agrawel (1993) also indicated that the criteria for optimal growth are short larval duration , high larval and pupal weights, and high survival food on which insects gain greater body weight is classified as a better source of energy. This clearly suggests that the maize line H is a better growth supporter and hence susceptible to *C. partellus,* while line A is a poor supporter and is almost completely resistant to this insect.

According to Das and Agrawel (1993), in nature a slightly higher percentage of females is preferred as compared to the males, because less number of females may lead to lesser production of eggs and more pressure on females. A diet can thus be categorized as poor if the males outnumber the females. On this basis line A can be categorized as poor diets for *C. partellus*. The persistent high mortality of the larvae feeding on line A may be due to the presence of either an anti feedant which prevents the insects from feeding, resulting in reduced growth or due to some inhibitory / toxic factor in the plant. The data shows lesser egg laying and hatchability of the eggs oviposited by females reared on A maize line. This highlights the effect of nutrition on oviposition, not only in the egg laying capacity of the female affected by these grown on a favorable variety, but the percentage of sterile eggs laid also increase in case of insects grown on unsuitable variety so much so that more than half of the eggs laid by the adults reared on line A were unable to hatch.

The difference in the number of eggs laid could also have been caused by the lower quantity of food ingested by *C. partellus* larvae feeding on line A. Chapman, (1973) also reported that in *Ephestia* the amount of flour ingested during the larval stage decides the number of eggs laid and in Cimex the number of eggs laid increases with the size of blood meal. Like wise Bailey (1976) reported the same result for *Mamestra configurata*. As shown in Table 7, in which Females of *C. partellus* were observed to lay less number of eggs on leaves of resistant line (A) as compared to susceptible line (H). Similarly, Das and Agarwals (1990) observed that less number of eggs were laid by *C. partellus* which were provided resistance maize line. Moreover, Kumar (1988) also reported that the number of eggs laid by *C. partellus* reared in susceptible line was much higher than C. *partellus* reared on resistance maize line. Thus, it can be said that the line H is nutritionally acceptable to the pest of C. *partellus*, while line A is nutritionally in adequate for its proper growth.

7- CONCLUSION AND RECOMMENDATION

7.1 Conclusion

- Variation among maize genotypes to *C. parellus* attack is present

- The absence of eggs laid in the free choice test (green house) on line A is an indicator for the presence of ovipositional non-preference.

- Similar trends were observed both in the field experiment and screen house pot experiment suggesting the possibility of developing c. partellus resistant varieties.

- The susceptible line is nutritionally acceptable to the pest of *C. partellus*, while the resistant line nutritionally in adequate to allow significant growth and survival.

- The larval and pupal stages are most affected implying that antibiosis is one of the mechanism.

7.2 Recommendation

√ The majority of Ethiopian farmers have small land holdings. They are generally not well informed about pest problems and most might not afford costly chemical methods to control pests. For this reasons, and the hazards associated with insecticide applications, stalk borer resistant maize should be developed there is a great need to develop varieties that can resist pest attack with out requiring any traditional expenditure by the farmers.

√ the possibility of intgrity resistant verities with biological control practices should be investigated.

√ Awareness should be created among the stakeholders on the existence of resistant gene in maize lines.

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8. APPENDICES

Appendix 1. summary table of percent plant damage for screened maize lines under field condition.

Plot no.	Name of pedigree	% infestation
1	(((K64R/PL16-SR39-1/(K64R/PL16-SR)-20-2-)-5-1-2-B*4/CML393)-B-3-2-1-2-1	10
2	(((K64R/PL16-SR39-1/(K64R/PL16-SR)-20-2-)-5-1-2-B*4/CML395-6)-B-1-1-1-1-1	17.5
3	(((K64R/PL16-SR39-1/(K64R/PL16-SR)-20-2-)-5-1-2-B*4/CML395-6)-B-1-1-1-2	24
4	(((K64R/PL16-SR39-1/(K64R/PL16-SR)-20-2-)-5-1-2-B*4/CML395-6)-B-1-1-2-1	20
5	(((K64R/PL16-SR39-1/(K64R/PL16-SR)-20-2-)-5-1-2-B*4/CML395-6) -B-1-1-1-2-2	8.7
6	(((K64R/PL16-SR39-1/(K64R/PL16-SR)-20-2-)-5-1-2-B*4/CML395-6)-B-1-3-2-1-1	12.6
7	(((NAW5867/P30-SR)-111-2/(NAW5867/ P30-SR)-25-1)9-2-3-B-2-B/CML388)-B-1-1-1-1-1	12
8	(((NAW5867/P30-SR)-111-2/(NAW5867/ P30-SR)-25-1)9-2-3-B-2-B/CML388)-B-1-1-1-1-2	13
9	(((NAW5867/P30-SR)-111-2/(NAW5867/ P30-SR)-25-1)9-2-3-B-2-B/CML38)-B-1-1-2-1-2	13.3
10	(((NAW5867/P30-SR)-111-2/(NAW5867/ P30-SR)-25-1)9-2-3-B-2-B/CML388)-B-1-1-2-1-2	18.2
11	(((NAW5867/P30-SR)-111-2/(NAW5867/ P30-SR)-25-1)9-2-3-B-2-B/CML388)-B-1-1-2-2-1	29.5
12	(((NAW5867/P30-SR)-111-2/(NAW5867/ P30-SR)-25-1)9-2-3-B-2-B/CML388)-B-1-3-1-1-1	14.7
13	(((NAW5867/P30-SR)-40-1(NAW5867/P30-SR)-114-2)-16-2-2-b-2-CMl394)-B-2-5-1-1-1	2.1
14	(((NAW5867/P30-SR)- 40-1(NAW5867/P30-SR)- 114-2)-16-2-2-b-2-CMl394)-B-2-5-1-1-2	47
15	(((NAW5867/P30-SR)- 40-1(NAW5867/P30-SR)- 114-2)-16-2-2-b-2-CMl394) -B-3-5-1-1-1	20
16	(((NAW5867/P30-SR)- 40-1(NAW5867/P30-SR)- -114-2)-16-2-2-b-2-CMl395-6)-B-3-2-1-1-1	23
17	(925EW2)EARLYSEL-12-1-2-B/CML395-6)-B-3-1-2-1-1	26
18	(925EW2)EARLYSEL-12-1-2-B/CML395-6)-B-3-3-1-1-1	18.8
19	(925EW2)EARLYSEL-12-1-2-B/CML395-6)-B-3-3-1-1-2	26.3
20	(ENT43;92SEW2EALYSEL-444/(DMRESR-W)EARLYSEL#1-4-1-B/CML388)-B-1-1-1-1-1	19
21	(ENT43:92SEW2EALYSEL-444/(DMRESR-W)EARLYSEL#1-4-1-B/CML388)-B-1-1-1-1-2	24

22	(ENT43:92SEW2EALYSEL-444/(DMRESR-W)EARLYSEL#1-4-1-B/CML388)-B-1-2-1-1-1	5.9
23	(ENT43:92SEW2EALYSEL-444/(DMRESR-W)EARLYSEL#1-4-1-B/CML388)-B-1-3-1-1-1	14.7
24	(ENT43:92SEW2EALYSEL-444/(DMRESR-W)EARLYSEL#1-4-1-B/CML388)-B-3-1-1-1-1	20
25	(ENT43:92SEW2EALYSEL-444/(DMRESR-W)EARLYSEL#1-4-1-B/CML388)-B-3-2-1-1-1	8
26	(ENT341:92SEW2-99/(DMRESR)-B-3-3-1-1-1	11
27	(TEWD SRDROUGHT TOL SY. S1#-8X-X-1-B*4/CML386)-B-1-1-2-1-1	1
28	(NAW5867/P49-SR)F2-148-1-1-B(COMPE2/P43-SR//COMPE2)F2#-20-1-1)-B-3-1-1-1-1	14.7
29	(COMPE2/P43-SR//COMPE2)FS#-20-1-1-B/(NAW5867/P30-SR)F2-148-1-1)-B-1-2-1-1-1	14.7
30	((NAW5867/P49-SR)//NAW5867)FS#-48-2-2-B//89(32DRSTEW)#-107-2-3X-1)-B-1-1-1-1-1	16.2
31	((NAW5867/P49-SR)//NAW5867) FS#-48-2-2-B//89(32DRSTEW)#-107-2-3X-1)-B-1-2-1-1-1	34.7
32	((NAW5867/P49-SR)//NAW5867) FS#-48-2-2-B//89(32DRSTEW)#-107-2-3X-1)-B-2-2-1-2-1	18
33	((NAW5867/P49-SR)//NAW5867) FS#-48-2-2-B//89(32DRSTEW)#-107-2-3X-1)-B-2-2-2-1-1	12
34	((SW1SR/COMP1-W)-61PL27/TEWTSR POOL)#-51-1-X)-B-3-1-1-1-1	20
35	((SW1SR/COMP1-W)-61PL27/TEWTSRPOOL)#-51-1-X)-B-3-4-1-1-1	22.2
36	((SW1SR/COMP1-W)-61PL27/TEWTSRPOOL)#-51-1-X)-B-3-5-1-1-1	35
37	(CML197/CML390)-B-2-2-1-1-1	3.8
38	(CML197/CML390)-B-3-2-1-1-1	20
39	(CML197/CML390)-B-3-2-1-1-2	1
40	(CML197/CML206)-B-3-1-1-1-1	13
41	(CML197/CML206)-B-3-1-1-1-2	21.1
42	(CML197/CML206)-B-3-2-1-1-1	11
43	(CML197/CML206)-B-3-3-1-1-1	1.2
44	(CML197/CML206)-B-3-3-3-2-1	26
45	(CML197/CML206)-B-3-3-2-1-2	36
46	(CML197/CML206)- B-3-3-2-1-2	21
47	(CML197/CML206)-B-2-1-1-1-1	5
48	[CML 206/CML391]-B-3-1-1-1-1	0
49	[CML 206/CML391]-B-3-1-1-1-2	19
50	[CML 206/CML391)-B-3-2-1-1-1	2.2
51	[CML 206/CML391)- B-3-2-1-1-2	15
52	[CML 206/CML391)-B-3-2-1-2-1	27
53	[CML 206/CML391)-B-3-2-1-2-2	6.7

54	[CML 206/CML391)-B-3-4-1-1-1	9
55	[CML 206/CML312)-B-1-2-1-1-1	17.8
56	[CML 206/CML312)-B-1-2-1-1-2	24.8
57	[CML 206/CML312)-B-1-3-1-1-1	9
58	[CML 206/CML312)-B-3-2-1-1-1	5.6
59	[CML 206/CML312)-B-3-2-1-1-2	16.9
60	[CML 206/CML312)-B-2-3-1-1-2	24
61	[CML 206/CML312)-B-2-4-1-1-2	23
62	[CML 206/CML312)-B-2-4-1-1-2	29.5
63	[CML 206/CML312)-B-2-4-2-1-1	26
64	[CML 206/CML312)-B-2-4-2-1-2	13
65	[CML 206/CML312)-B-2-5-1-1-2	17
66	[CML 206/CML312)-B-3-1-1-1-1	11
67	[CML 206/CML312)-B-3-3-1-1-1	13
68	[CML 312/CML395-5]-B-3-1-1-1-1	36
69	[CML 312/CML395-5]-B-3-1-1-1-2	26
70	[CML 312/CML395-5]-B-3-2-1-1-1	41.2
71	[CML 312/CML395-1]-B-2-1-1-1-1	40
72	[CML 202/CML395-1]-B-3-3-1-1-1	20
73	[CML 202/CML395-5]-B-1-1-1-1-1	18.8
74	[CML 395/CML202]-B-2-1-1-1-1	26
75	[CML 395/CML 202]-B-2-3-1-1-1	29
76	[CML 395/CML395-5]-B-3-1-1-1-1	28
77	[CML 395/CML395-5]-B-3-2-1-1-1	11
78	[CML 395/CML395-5]-B-3-2-1-1-2	23
79	[CML 395/CML395-5]-B-3-2-2-1-1	37
80	[CML 395/CML395-5]-B-3-3-1-1-1	39
81	[CML 395/CML395-5]-B-3-2-1-1-1	22.5
82	[CML 395/CML395-5]-B-3-2-1-1-2	11
83	[CML 395/CML395-5]-B-3-2-2-1-1	6
84	[CML 395/CML395-5]-B-3-2-2-1-2	7
85	[CML 395/CML395-5]-B-1-1-1-1-1	13
86	[CML 395/CML395-5]-B-1-1-1-1-2	12
87	[CML 395/CML395-5]-B-3-1-1-1-3	23.3
88	[CML 395/CML395-5]-B-1-1-2-1-1	13.3
89	[CML395-5/CML202]]-B-2-1-2-1-1	17.1
90	CML395-6/[COMPE2/P43SR//COMPE2]FS#-20-S6]-B-2-1-1-1-1	23.3
91	CML395-6/[COPE2/P43-SR//COMPE2]FS#-20-S6]-B-2-3-1-1-1	4.6
92	KILIMIMA(ST94)-S5:105-/(M37W//ZM607#BF37SR))-B-2-3-1-1-1	4.2
93	[[EV7992#/EV8449-SR]C1F-334-1(OSU9i)-8-2(1)-x-1-2-B/[CML206]-B-3-3-1-1-1	28.4
94	[90323(B)-1-X-1-B/CML202)-B-2-1-1-1-1	12.6
95	[90323(B)-1-X-1-B/CML202]-B-2-2-1-1-1	19
96	[90323(B)-1-X-1-B/CML202]-B-2-2-1-1-2	21
97	[90323(B)-1-X-1-B/CML202]-B-2-3-1-1-1	1.1

98	[90323(B)-1-X-1-B/CML202]-B-2-3-1-1-2	2.1
99	[SC/ZM605#b-19-2-x]-1-2-x-1-1-B/CML202]-B-1-1-2-1-1	12
100	[SC/ZM605#b-19-2-x]-1-2-x-1-1-B/CML202]-B-1-3-2-1-1	13
101	[SC/ZM605#b-19-2-x]-1-2-x-1-1-B/CML202]-B-1-3-2-1-1	13.7
102	[SC/ZM605#b-19-2-x]-1-2-x-1-1-B/CML202]-B-1-1-2-1-1	16.5
103	[SC/ZM605#b-19-2-x]-1-2-x-1-1-B/CML202]-B-1-1-2-1-1	20
104	CML212/[AC8342/)KEE{1}8149SR//PL9A]C1F1-500-4-S]-B-B-3-1-1-1-1	5
105	[CML212/[AC8342/KEE{1}8149SR//PL9A]C1F1-500-4-S]-B-B-3-3-1-1-1	19
106	[EV7992#/MEVPOP43-SRBC3]]#b-bsr-118-2-2-5-7-x-1/CML206]-B-B-2-2-1-1-1	9.5

108	A-511 MS 220-1-1-1-1-1	20
109	A-511 MS 293-1-1-1-2-1	4.2
110	A-511 MS 457-1-1-1-1-1	1
111	A-511 MS 556-1-1-1-1-1	17.9
112	A-511 MS 556-1-1-1-2-1-	18
113	A-511 MS 556-1-2-1-1-1	5.5
114	A-511 MS 556-1-2-1-1-2	8.9
115	A-511 MS 556-1-2-1-2-1	13
116	A-511 MS 557-1-1-1-1-1	13
117	A-511 MS 557-1-1-1-1-2	24
118	A-511 MS 653-1-1-1-1-1	8.4
119	A-511 MS 653-1-1-1-2-1	7.4
120	A-511 MS 653-1-1-1-2-2	15
121	A-511 MS 749-1-1-1-1-1	23
122	A-511 MS 749-1-1-1-2-1	7
123	A-511 MS 749-1-1-1-1-1	9
124	A-511 MS 749-1-1-1-1-2	4.8
125	A-511 MS 803-1-1-1-1-1	21
126	A-511 MS 803-1-1-1-2-1	21.9
127	A-511 MS 803-1-1-1-2-2	3.5
128	A-511 MS 803-1-1-2-1-1-	3.3
129	A-511 MS 803-1-1-2-2-1	20
130	A-511 MS 947-1-1-1-1-1	5.7
131	A-511 MS 990-1-1-1-1-1	7.4
132	A-511 MS 990-1-1-1-1-2	6
133	A-511 MS 990-1-1-2-1-1	20
134	A-511 MS 990-1-1-2-2-1	14.5
107	[FR810/TZMSRW-5-2-1-3-X-1/CML202]-B-B-1-2-1-1-1	6.5

Appendix 2. Summary table for analysis of variance (ANOVA) for number of *C. partellus* egg masses and leaf infestation on different maize genotypes under screen house-pot experiment.

	Sum of Squares	df	Mean Square	F	Sig.
Egg/plant * Tratment between Groups (Combined	358.519	11	32.593	18.551	.000
Within Groups	168.667	96	1.757		
	527.185	107			
Leaf infesta.* Treatment between Groups (combined)	5.741	11	.522	2.373	.012
With in Groups (Combined)	21.111	96	.220		
Total	26.852	107			

Appendix 3. Summary table for analysis of variance (ANOVA) for *C. partellus* density per plant on different maize genotypes under screen house-pot experiment

		Sum of Squares	df	Mean Square	F	Sig.
Borer No* Treatment	Between Groups (Combined)	603.361	11	54.851	12.034	.000
	Within Groups	437.556	96	4.558		
	Total	1040.917	107			

Appendix 4. Summary table for analysis of variance (ANOVA) for the number of exit holes and due to *C. partellus* on different maize genotypes under screen house-pot experiment

		Sum of Squares	df	Mean Square	F	Sig
Hole No* Treatment	Between Groups (combined	690.991	11	62.817	19.551	.000
	Within Groups	308.444	96	3.213		
	Total	99.435	107			

Appendix 5. Summary table for analysis of variance (ANOVA) for the stem tunneling length due to *C. partellus* on different maize genotypes under screen house-pot experiment

	Sum of Squares	df	Mean Square	F	Sig
Tunnel length* Treatment	1165.667	11	105.970	12.748	.000
	798.000	69	8.312		
	1963.667	107			