COMBINING ABILITY AMONG MULTIPLE BORER RESISTANT, MAIZE (*ZEA MAIS*, L.) INBRED LINES, RESISTANT TO *CHILO PARTELLUS* AND *BUSSEOLA FUSCA* STEM BORERS

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DECLARATION

I declare that this thesis is my own original work. It is being submitted for the degree of Master of Science in Genetics and Plant Breeding in the University of Nairobi. It has not been submitted before for any degree in any other university.

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In memory of my late sister:

Rosemary Wanja

1972-2002

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LIST OF ACRONYMS

AD - 50% Days to anthesis

ASI - Anthesis silking interval

CIMMYT - International Maize and Wheat Improvement Center

EA - Ear aspect

EH - Ear height

EPP- Ears per plant

ER - Ear rot

EXH- Exit holes for the stem borers

GCA - General combining ability

NE - Number of ears harvested

NP - Number of plants harvested

NRRC - National Range Research Center

PH - Plant height

RL - Root lodge

RRC - Regional Research Center

SBD - Stem borer damage

SCA - Specific combining ability

SD -50% days to silking

SL - Shoot lodge

TNL- Tunnel length

TLPH- Tunnel length plant height ratio

YLD- Yield (tones per hectare)

YLOSS- Yield loss (tones per hectare)

ABSTRACT

Maize (Zea *mays* L.) is an important cereal crop of the world. It has worldwide significance as human food, animal feed and raw material for the manufacture of many industrial products. The most important insect pests of maize in Kenya are *Chilo partellus* and *Busseola fusca* stem borers. These two stem borers causes loss in maize worth Kshs. 7.2 billion. The objective of this work was to determine the combining ability of twenty insect resistant inbred lines. A partial Diallel mating design was used. One hundred and ten single crosses were made to give one hundred and ten F1 hybrids. The F1 hybrids were evaluated for insect resistance in two different sites i.e. in Lowland and Mid altitude areas for two seasons. The F1 hybrids and two local checks (PH3253 and H513) were artificially infested with black head eggs of *Chilo partellus* and *Busseola fusca* stem borers for Kiboko and Embu respectively. The F1 hybrids and two local checks were planted in a five meter row plot which was later divided into two. Half of the plot was infested with respective stem borer while the other half was protected against stem borer using a systemic insecticide. Thirteen traits were recorded to determine the combining ability of the inbred lines. The traits that were recorded to determine resistance included: stem borer damage, exit holes, tunnel length plant height ratio, tunnel length and yield loss. In both Kiboko and Embu inbred lines; 5, 6, 8, 10, 11, 14, and 16 showed negative general combining ability (GCA) effects for the insect damage. The GCA: Specific combining ability (SCA) ratio was higher in both Embu and Kiboko, an indication of higher GCA variances; the range was from 0.35 to 0.90 at Embu and 0.46 to 1.32 at Kiboko. Inbred lines 18, 19 and 20 were found to be good combiners for yield in both Embu and Kiboko. The F1 hybrids which were made with inbred line 3 as the male performed well in terms of insect resistance and yield and this proved it was a desirable good combiner. These good crosses included; 3x18, 3x9, 3x13, 3x10 and 3x14. Single crosses 3x18 and 3x14 were the best combiners for yield with 6.71 and 5.15 tons per hectare respectively. These crosses can be used to form synthetics

CHAPTER ONE

1.0 INTRODUCTION

Maize (*Zea mays* L) is the third most important cereal after wheat and rice in the world and it is also the most widely distributed (Purseglove, 1981). Maize is used for three main purposes: as a staple human food, particularly in the tropics, as feed for livestock in the temperate economically advanced countries, and finally as raw material for many industrial products (Onwueme *et. al*. 1991). In 1989 the total area under maize production in the world was 129.6 million hectares with a yield of 470.3 million tonnes respectively (Onwueme and Sinha 1991). This has increased over time due to the importance of maize as a food crop, and currently about 140 million hectares of maize is grown worldwide (CIMMYT, 2001) with approximately 96 million hectares grown in the developing world. The average maize productivity is 2.4 tonnes per hectare in developing countries compared to 5.9 tonnes per hectare in the developed world (Chopra, 2001). In Kenya, 1.4 million hectares were estimated to be under maize cultivation in the period between 1994 to 1998, with an average total grain production of 2.5 million tonnes per year (FAO, 1999). By 1981 approximately 70% of area under maize in Kenya was planted with F1 hybrids or composites and the remaining 30% was planted with either local or some advanced generation of commercial cultivars (Omolo, 1981). Growing of F1 hybrid has changed over the years due to the current market liberalization in Kenya. The cost of getting maize to the markets can sometimes outweigh the benefits of growing improved hybrid varieties (Songa *et al*. 2002).

Maize was first grown in East Africa on the islands of Zanzibar and Pemba in the sixteenth Century (Miracle, 1966). The Arab traders introduced the cereal from these islands to Kenya's coastal areas. Later, through the movement of the European settlers, the crop spread further into the mainland, where it remained a minor food crop until the turn of the 20th Century. In 1903, maize occupied only 20 % of Kenya's food crop area but by 1960 this area had risen to 44% (Meinertz L., 1957; Kenya, 1966). Maize was used to offset food shortages resulting from disease epidemics, drought and locust invasions that decimated the traditional food crops, sorghum and millet (Derek B. and Carl K. E., 1997).

Maize was popular because it was resistant to pests and diseases and it was also easier to store and process than the traditional food crops. As export markets for maize continued to expand, the colonial government imported maize seed, promised higher prices for maize and subsidized transport costs (Njoroge *et al.* 1992; Taylor, 1969; Gerhart, 1975).

Grain yield in maize depends on the genotype of the plant and its interaction with environmental factors such as soil, climate, pests, pathogens and cultural practices (Chumo, 1986). Field pests such as stem borers are known to play a considerable role in reducing the yield of an otherwise high yielding variety. This occurs through damaging the stalk, leaves and ears. Often the main breeding objectives are yield, resistance to pests and diseases, lodging, cold tolerance and improvement in grain quality as well as nutritive value (Bajaj, 1994). Among the pests, which have proved to be more damaging to maize crop in the field, are the stem borers. Lepidopteran stem borers are among the most damaging insect pest of maize in the semi-arid areas of eastern Kenya (Songa *et al.* 1999). The semi-arid and arid areas represent over 80% of Kenya's landmass and 50% of the country's arable land (Jaetzold and Schmidt, 1983). Kenya has an estimated annual population growth rate of 2.9% (De Groote *et al.* 2002) which has increased pressure on the available arable land, resulting in increased migration into semi-arid areas.

In maize production farmers face several constraints which includes, drought, cold, water logging, low nitrogen(N), acidity, diseases and insect pest (Chopra, 2001). The stem borers that infest maize in this region include *C. partellus* (Swinhoe). *B. fusca* (Fuller), *Sesamia calamistis* (Hampson), *Cryptophlebia leucotreta* (Meyrick) and *Eldana saccharina*, with *C. partellus* being the dominant and most widespread species (Songa *et al,* 1999).There is therefore a need to develop maize varieties resistant to stem borers.

1.1 PROBLEM STATEMENT

Stem borers are the most damaging group of insect pests in maize cultivation worldwide, including Kenya. The most damaging, widely distributed stem borer species include the spotted stem borer (*Chilo partellus*), the African stem borer (*Sesamia calamistis*), the African maize stalk borer (*Busseola fusca*), the pink stem borer (*Sesamia cretica*) and the sugarcane borer (*Eldana saccharina*) (CIMMYT, 2001). Throughout the maize and sorghum growing areas of Africa, *B. fusca* is a major pest requiring the application of expensive chemical control measures in order to avoid severe crop losses (Seshu Reddy 1985; Revington *et al.* 1984; Kaufmann, 1983a; Mlambo 1983; Egwuatu and Ita 1982; Walker 1981; Ogunwolu *et al.* 1981). Various attempts have been made to develop resistant maize cultivars as an alternative or a supplement to chemical application, but with little success (Kuhn 1978; Waltors 1974; du Plessis and Lea 1943). In Kenya, the most important species of stem borers are the spotted stem borer *Chilo partellus* (Swinhoe), which is essentially a pest of hot lowland areas and is seldom found above an altitude of 1500m above sea level (a.s.l). *Busseola fusca* (Fuller) is found in the cooler and higher altitude areas (Mulaa, 1995).

Stem borers are reported to be of particular importance in Kenya especially in lower altitude zones (Songa *et al*, 2002), because low altitudes have high temperatures and humidity that favor insect growth and development (Haines, 1991), and hence increase stem borer infestation levels to crops.

Total maize loss in Kenya due to stem borers is estimated at 13.5% valued at Kshs 7.2 billions (De Groote *et al*. 2002) which is enough to offset the balance that is imported. Chemical control method is the most widely used in control of stem borers, but this method exposes the farmer to health risks and can result in pesticide loading of the environment through continuous use. Biological control method can also be used to control stem borers, but it requires trained personnel for identification and deployment of control agents and commitment of the farming community to enhance the establishment of this method. Development of host plant resistance, to stem borers would increase the efficiency of farming by reducing or eliminating the expense of insecticides and reduce yield losses from stem borer damage.

Crop losses result from death of the growing point, early senescence, reduced translocation, lodging and direct damage to ears (Mutinda, 1996).

There is therefore, need to develop borer resistant maize varieties to curb these losses from stem borer damage. This is one of the most cost-effective and user friendly methods of pest control for resource poor farmers and is also environmentally sustainable.

This study therefore, was designed to determine the combining ability of twenty maize inbred lines resistant to *C. patellus* and *B. fusca* stem borers. This is important as opposed to other approaches because it would enable the breeder only to use the lines which are good combiners for both yield and resistance to stem borers.

1.2 BROAD OBJECTIVE

To determine the combining ability of known insect resistant maize inbred lines in order to identify lines that can be used to develop insect resistant maize synthetics and hybrid combinations.

1.2.1 Specific objectives

1. To determine the general combining ability (GCA) of the twenty insect resistant inbred lines.
2. To determine the specific combining ability (SCA) of the twenty insect resistant inbred lines.
3. To identify important agronomic traits that maize breeders could use to combine insect resistance and grain yield during selection.
4. To identify possible potential cultivars for further evaluation.

1.3 HYPOTHESES

This study was being carried out on the basis that:

1. Lines which exhibit higher heterotic effect regarding insect resistance will produce progenies with good general GCA and SCA for insect resistance.
2. Inbred lines which exhibit higher heterotic effect regarding grain yield and other traits related to grain yield will produce progenies with good grain yield for use directly as finished F1 variety combinations or as source material to improve other maize populations and further evaluation.

CHAPTER TWO

2.0 REVIEW OF LITERATURE

2.1 BOTANY OF MAIZE

Taxonomically maize is a coarse, annual grass and belongs to the family *Gramineae*, tribe *Maydeae* , genus *Zea* and species *mays* (Onwueme and Sinha, 1991).

2.1.1 Root system

The root system is fibrous and spreads out in all directions mainly in the topsoil. The maize plant has four seminal roots, which may persist throughout the life of the plant. The main adventitious fibrous system develops from the lower nodes of the stem below ground level and spreads out in a lateral direction in the upper layers of the soil. The roots then assume vertical downward trend to tap the lower levels of the soil. The extent to which the roots penetrate to the deeper layers depends largely upon the supply of nutrients and on the drainage of the topsoil and subsoil. In well drained soils rich in nutrients, the roots are comparatively strong and branch out in all directions, while in dry and infertile soils they grow longer and are weaker in damp soil as found in waterlogged areas. An individual maize root can penetrate to of 2.5 meters depth (Berger, 1962).

2.1.2 Stem and leaves

The maize stem is normally 2 to 3 meters high. Some early maturing varieties attain a height of only 90 centimeters and certain varieties of popcorn (*Zea mays everta*) reach a height of only

30 to 50cm. In tropical and sub-tropical regions, maize plants can reach a height of 6 - 7 meters (Berger, 1962). The stems are filled with pith and have from 8 to 21 internodes. The number of leaves ranges between 6 and 48 with an average of 15 leaves. Early maturing varieties have few leaves whereas late maturing varieties have more leaves (Anon, 1972).

2.1.3 Flowering and pollination

Maize plant bears its flowers in spikelets, the characteristic units of the inflorescence of all grasses. The spikelets are of two types, male and female; hence maize is a monoecious plant. The male inflorescence is the tassel carried terminally in the main axis. The female spikelets are seldom seen as such because the husks of the younger ear cover them. The female inflorescence is known as the "cob" or "ear". It consists of modified lateral branch deriving from an axillary bud of the main stem (Berger, 1962).

Pollination is by means of wind and gravity. Any movement of the plant helps to shake out the pollen, and pollen is usually all discharged within a few hours. Pollen is produced in large quantities from the opening flowers of the tassel. Counts and computations made on maize plants indicate that an individual plant produces probably 50,000 pollen grains for each one that become effective in producing a grain of maize. In some tropical varieties the ratio is probably much higher (Weather, 1955). The tip of the tassel is usually seen several days before the silk emerges. The silks are receptive as soon as they emerge, and remain receptive for sometime. Pollen shedding continues for about 5-8 days, with peak production occurring on the third day. The duration of viability of pollen ranges between 18 to 24 hours. Peak shedding on a typical sunny day is between 9.00 and 11.00am (Samuel, *et. al*, 1975) in many varieties.

2.1.4 Grain

The seeds are surrounded on the cob by the chaffy remains of the glooms and lemmas and paleas of the two flowers and are supported on very short, spongy pedicels. The length of the cob varies between 8 and 42 cm, in extreme cases between 2.5 and 50cm. In large cobs diameter can be 7.5 cm but it normally lies between 3 and 5 cm. The normal ear of maize contains 8-30 rows of grains while each row bears 20-70 grains (Onwueme and Sinha, 1991).

Usually, a maize cob contains between 300 and 1000 seeds. The seeds are rounded or dented according to variety hence maize grain is classified as either flint or dent texture. The color of the grain also varies greatly with variety ranging from white through yellow, red and purple to almost black (Berger, 1962).

2.2 COMBINING ABILITY

Combining ability is the capacity of a parent to produce superior progenies when combined with another parent. It should always be examined when the objective is the development of superior progenies, when heterosis is practically exploited (Borojevic, 1990). Combining ability of maize inbred lines is the ultimate factor determining future usefulness of the lines for hybrids (Hallauer and Miranda, 1987).

Combining ability involves crossing each line with several others and the variance in performance among crosses is then partitioned to better understand the use of cross-breeding for improvement. Large numbers of lines, crosses and individuals are used, so that all means are estimated with minimum experimental error. Crossing a line to several others provides an additional measure of the worth of the line, i.e. the mean performance of the line in all its crosses.

General combining ability (GCA) of a line is the mean performance, when expressed as a deviation from the mean of all crosses. It is the average value of all F1's having this line as one parent, the value being expressed as a deviation from the overall mean of crosses. Any particular cross, then has an 'expected' value which is the sum of the GCA abilities of its two parentals. The cross may, however, deviate from this expected value to greater or lesser extent.

Specific combining ability (SCA) is the deviation of the two parental lines in combination (Falconer, 1996). In statistical terms, the general combining abilities are main effects and specific combining ability is an interaction. According to Falconer (1991) the true mean X of a cross between lines P and Q can thus be expressed as:

$$x - \bar{x} = GCAP + GCAQ + SCA_{PQ}$$

Where $\bar{x}$ = mean of all crosses.

X= True mean

$GCAP$= General combining ability for line P

$GCAQ$= General combining ability for line Q

$SCAPQ$= Specific combining ability of the cross between line P and Q.

2.2.1 Estimation of combining ability

The method that is convenient for use with plants is known as the polycross method. A number of plants for all the lines to be tested are grown together and allowed to pollinate naturally, self pollination being prevented by the natural mechanism for cross pollination, or by the arrangement of the plants in the plot. The seeds from the plant of one line are therefore a mixture of random crosses with other lines, (i.e. 'polycross') and their performance when grown tests the GCA of that line. The GCA measured is those of lines used as female parents. The GCA of a line can be estimated by crossing it with individuals from the best population instead of with other inbred lines. This method is known as top crossing (Falconer, 1996). In maize the diallel method of crossing is used.

2.2.2 Diallel crosses

A Diallel cross is a method whereby, single crosses are made in all possible combinations of lines or clones. Any single cross will measure SCA, while the average combining ability of several different single crosses of one line or clone will reflect its GCA (Briggs, 1967). Diallel crosses are sometimes used to pinpoint parents capable of rendering a large number of superior lines or those capable of producing heterotic F1 hybrids as it is impossible to know beforehand the combining ability of an inbred line (Borojevi, 1990).

2.2.2.1 Partial diallel

A partial diallel cross may comprise progenies obtained by crossing according to a scheme for a balanced incomplete block design.

Partial diallel is much preferred because it does not require too many crosses as in the case of complete diallel. There are many types of diallel but the most popular is the *circulant partial diallel*.

Circulant partial diallel: Description of mating design: The number of crosses is given by ***PS/2*,** where:

P= number of parents, and S= number of plants that each parent is crossed with.

$S \geq 2$ and it's a whole number, i.e. the sample size.

P and S cannot both be odd numbers, so that $PS/2$ is an integer crossing.

In partial diallel instead of crossing each parent with all other parents, each parent is crossed with only a few others. Each parent is used in the same number of crosses, but not necessarily with the same parents.

In the assignment of crosses for circulant partial diallel: The numbers are allocated randomly to crosses as follows:

Assigned no.		Parents to cross onto:
Parent 1	X	$k+1$, $k+2$, ...$k+s$
Parent 2	X	$k+2$, $k+3$,.............$k+s+1$
Parent 3	X	$k+3$, $k+4$,.............$k+s+2$
Parent I	X	$k+I$, $k+I+1$,.........$k+s+I-1$

Where; $k= (P+1-S)/2$

For k to be a whole number either P is even and S is odd, or vice versa. For example if we have 5 parents and $S= 2$, our k would be $k= (5+1-2)/2=2$. The crosses would be assigned as shown below:

Assigned number.		Parents to cross onto.
Parent 1	X	$2+1=3$, $2+2=4$, $2+3=5$
Parent 2	X	$2+2=4$, $2+3=5$
Parent 3	X	$2+3=5$

2.3 POPULATION IMPROVEMENT IN MAIZE

Work at North Carolina State University in the late 1940s and early 1950, showed that considerable additive genetic variance for grain yield existed in the F2 populations and in open pollinated varieties of corn (Robinson, *et al*, 1941; Robinson and Cornstock, 1955). Variance is a measure of variation, which is simply the mean of the squared values of a variate. Total variance is the sum of all the components of variance, which can be broken down as follows:

$$VP = VG + VE$$

$$= VA + VD + VI + VE$$

Where;

VP= Phenotypic variance

VG= Genotypic variance

VA= Additive genetic variance

VD= Dominance variance

VI= Interaction variance

VE= Environmental variance

Additive variance is the variance of the breeding value. It is the important component since it is the chief cause of resemblance between relatives (Falconer, 1996).

The population, which has been improved by recurrent selection procedures, is a promising source of new germplasm. Recurrent selection is a method of selection where genotypes at the positive end of frequency distribution are selected and intercrossed for several cycles as long as genetic variability exists in the population (Frey, 1983). Recurrent selection provides an excellent way of utilizing exotic germplasm in maize-breeding program to further broaden the

With a continuation of the inbreeding, there is a marked decrease in vigor and an increase in the uniformity of the plants within any progeny row. After five or six generations of self pollination, every plant is practically like every other plant within any line, but differences among the lines are large. At this point selfing is often discontinued, and the lines are thereafter continued by sib pollination (Hallauer and Miranda, 1988). Regardless of the value of selection in improving hybrids performance, it is accepted that selection during inbreeding does serve a useful purpose in the development of inbreds lines (Allard, 1960).In the first stages of development of hybrid maize, inbreds of necessity had to be isolated directly from a heterozygous source. Later on the emphasis shifted from the isolation of new inbreds to improvement of existing inbreds (Chopra, 2001).

The improvement of established inbreds has usually had one of the following three objectives;
(1) to increase the productivity of the inbreds themselves to facilitate the production of hybrid seed, (2) to fix inbreds so that they will produce hybrids improved in disease and insect resistance and standing ability or other specific characters and (3) to enhance the combining ability of specific inbreds so as to increase the yield potential of their hybrids.

Historically two methods of improving inbreds were tried. The ‘pedigree’ was the first. This consists of crossing two inbred lines that complement each other in desirable attributes and selecting for desired recombinations in the segregating generations. Back crossing was the second method. The method has been widely used to improve inbreds in standing ability, resistance to diseases and insects such as smut, *Exserohilum turcicum* leaf blight and stem borer (Allard, 1960).

2.4 INSECT RESISTANCE IN MAIZE

2.4.1 Types and classification of Resistance

The characteristics that enable a plant to avoid, tolerate or recover from attacks by insects under conditions that would more severely injure other plants of the same species are termed as plant resistance. Plant resistance to an insect is the collective heritable characteristics by which a plant species, race, clone or individual may reduce the probability that an insect species, race, biotype or individual successfully uses the plant as a host. Classifications of resistance phenomena may express the relative success or failure of an insect species to survive, develop, and reproduce on a plant species; or the classification may describe the relative damage to the host plants in qualitative or quantitative terms. Tolerance represents the ability of a certain variety to produce a larger crop of good quality than would other varieties under the same insect population.

2.4.2 Intensities of resistance

The interaction varies from plants being completely adequate to completely inadequate hosts. The intensity of resistance was described by Painter, (1951) as being of four types:

(i) Escape - The plants are not infested or injured; this can occur due to transitory circumstances as incomplete infestation.

(ii) Susceptible - Shows average or more than average damage by an insect.

(iii) Resistance - This is a cultivar that has qualities that result in small damage by a specific insect under a given set of conditions.

(iv) Tolerance- these are plant responses that result in the ability to withstand

infestation and to support insect populations that would severely damage susceptible plants.

2.4.2.1 Non preference

This is the insects' response to plants that lacks the characteristics to serve as a good host. It results from negative reactions or total avoidance during search for food, oviposition sites, or shelter. The non-preference by insect is a property of the plant. It is basically antixenosis, which is a condition whereby the insect do not prefer certain plants as source of food or shelter. The insect avoids the plant as a bad host. In certain situations, even though the insects may come in contact with the plant, the antixenotic characteristics of the plant do not allow the insect to colonize. Sometimes, the antixenosis mechanism is so effective that the insects starve and die. The antixenotic mechanism may be due to biophysical or biochemical factors or a combination of both. Plants that exhibit antixenotic resistance should have a reduced initial number of colonizers early in the season; the size of the insect population should be reduced after each generation as compared with susceptible plants (Panda and Khush, 1995).

Antixenosis in maize for oviposition-Oviposition refers to the laying of eggs by a female insect. The eggs may be deposited on leaves or for the insects with ovipositors, the eggs can be laid in the soil (Barton and Brown, 1974).

There is differential preference for oviposition by *C. partellus* in maize (Sharma and Chatterji, 1971a, Lal and Pant 1980, Sekhon and Sajjan 1987). According to Sekhon and Sajjan (1987) young plants e.g. 5 days old were not preferred at all but plants which were about 15 days old were the most preferred for oviposition by *C. partellus*. As the plant age, increased from 15 days onwards, the number of eggs laid by *C. partellus* thus went on decreasing so much that it was reduced to one fourth.

2.4.2.2 Antibiosis

In antibiosis, the biology of the insect is adversely affected e.g. survival, development and reproduction. This is the resistance mechanism that operates after the insects have started utilizing the plant. Panda and Khush (1995) found out that antibiotic plants affects growth, development, reproduction, and survival of the insects. This effect may result in a decline in insect size or weight, reduced metabolic processes, increased restlessness, and greater larval or pre adult mortality. Plants that exhibit antibiosis reduce the rate of population increase by reducing the reproduction rate and survival of the insects (Panda and Khush, 1995). The antibiotic properties of the host plant may be expressed as constitutive or induced resistance against herbivores.

Antibiosis in Maize germplasm-Antibiosis is the adverse effect of a temporary or a permanent nature, on the insect biology resulting from the ingestion of a plant by an insect. Antibiosis has been evaluated on the basis of larval survival (Pant *et al,* 1961, Kalonde and Pant, 1966, Mathur and Jain, 1972 and Lal and Pant, 1980) and development period (Panwar and Sarup, 1980). Sharma and Chatterji (1971), Sekhon and Sajjan (1987) and Durbey and Sarup (1984) evaluated different populations and hybrids. They studied larval survival and also the antibiotic effect of these germplasm on parameters such as larval and pupal weight larval and pupal period, pupal survival, fecundity, and egg viability, sex ratio and multiplication rate. These workers reported that the resistant varieties had reduced larval survival, larval weight and pupal weight, prolonged larval and pupal period as compared to the susceptible local variety.

Durbey and Sarup (1985, 1988) observed an antibiotic effect on *C. partellus* when the pest was reared on a diet that contained powdered dry material and the ether extract of resistant populations.

Antibiosis in different plant parts-The antibiotic effect of four plant parts, stem whorl, ear and tassel on the biological parameters of C. partellus, has been investigated by Sharma and Chatterji (1971). The percentage survival of the larvae, larval weight, pupal weight, sex ratio (female/male), fecundity and egg viability were found to be relatively higher in the case of the larvae reared on ears than those on other parts of plant. Also larval and pupal period and incubation period were relatively less when reared on tassels. This suggested that the tassel and the ear had the maximum and minimum antibiotic effect, respectively.

Antibiosis in relation to plant age- Plant age has been reported to influence antibiosis (Kalonde and Pant 1967). Sekhon and Sajjan (1990) evaluated larval survival of C.partellus on the plants of different ages (5,10,15,20 and 25 days old) in Antigua Gr.1, Ganga 5 and Basi local. It was found out that there were very small differences among the lines for larval survival on 5 and 10 day old plants. The borer survival however, sharply declined on 15-day old plants of resistant populations (Antigua Gr.1 and Ganga 5) and the decline was confined up to 25 days, but at a lower rate. This showed that the most critical time for the development of antibiosis may be when the plants are 10 to 15 days old. Lack of expression of antibiosis in resistant germplasm during their early growth period has also been observed by Mathur and Jain (1972).

2.4.2.3 Host plant resistance

Plant resistance represents the inherent ability of a crop variety, to retard or overcome insect pest infestations. According to Beck (1965), plant resistance is the collective heritable characteristics by which a plant species, race, clone or individual may reduce the probability of successful utilization of that plant as a host by an insect species, race, biotype or individual.

These are varieties with tight or extensive leaf sheath, they are not favored for oviposition; other varieties have an increased Silica content in their tissues and feeding larvae usually die.

2.4.2.4 Tolerance

This is the ability of the plant to repair injury or grow to produce an adequate yield despite supporting an insect population at a level capable of damaging a more susceptible crop. The cultivars exhibiting a moderate level of antibiosis and high level of tolerance are considered ideal, as they allow the survival of an adequate pest population, large enough to maintain the parasites and predators, but prevent the build up of new biotypes (Horber, 1972).

2.5 MULTIPLE BORER RESISTANCE (MBR) POPULATIONS

Multiple borer resistant maize populations are the maize capable of resisting stem borer damage not only from one species but from a number of them e.g. two or three different stem borer species (Chopra, 2001).

In development of maize varieties resistant to stem borers, resistance may be controlled by different allelochemicals that kill or impair the growth of stem borers. Morphological factors, including increased leaf fiber and silica content as a defense against the European Corn Borer

(ECB) surface wax and high hemicellulose against South Western Corn Borer (SWCB) or a thickened cuticle against Sugar Cane Borer have been identified as resistance mechanisms. Considerable work on both resistance and tolerance mechanisms to stem borers have been pursued by CIMMYT (Mihm, 1997).

2.6 DEVELOPMENT OF INSECT RESISTANT MAIZE

Insect resistant germplasm can be developed through conventional breeding methods or through using biotechnology-mediated approaches. These include molecular genetics technology and transformation technologies. Quantitative trait loci (QTL) can be used to transfer stem borer resistance from donors to recipient elite inbred lines. Marker assisted selection using the resistance factor(s) derived from genes that encode delta - endotoxins; i.e. proteins derived from the soil bacterium *Bacillus thuringiensis* (Bt) has been developed. The protein binds to the brush border membrane vesicles of the peritrophic membrane resulting in pore formation and larval mortality of susceptible insects.

2.6.1 Conventional Breeding

Mihm (1997) developed a multiple borer resistance population by recombination and recurrent selection under infestation with Southwestern corn borer (SWCB), sugarcane borer (SCB), (*Diatrae sacharalis*), European corn borer (ECB), *Ostrinia nubilalis* and fall armyworm (FAW), (*Spodoptora)*. This MBR was developed after noticing that a new germplasm with resistance to a single species of insect pest is not as useful as one resistant to the complex problems in a given area (Mugo *et al*, 2000).

Success in developing MBR through recurrent selection was due to two factors. First, tropical maize resistant to lepidopteran pests appears to be controlled by polygenic genes and involves primarily additive variation. Then the inbred lines from MBR have shown GCA as the most important source of variation among F1s for leaf feeding resistance and grain yield.

2.6.2 Maize improvement using Biotechnology

2.6.2.1 Marker assisted selection for resistance to stem borers

The concept of marker-assisted selection (MAS) came early in the 20th century (Sax, 1923). This refers to the use of molecular markers in mapping the chromosomal location of the gene(s) controlling the trait of interest (Mihm, 1997) and using these to enhance the pace of breeding. The basic premise is that genes for difficult-to- measure traits can be accumulated by selection on the basis of linked genes with easily detectable phenotype. Integration of molecular marker technology has an immediate benefit in marker-aided improvement of selection efficiency. Statistical association between alleles at the molecular marker loci and desirable agronomic traits can be used for indirect selection of qualitative as well as quantitative traits. If a large number of marker differences between parental lines are worked out, they could be condensed to a molecular score and included in the selection index as one more character (Lande, 1991).

MAS can especially be useful for traits that are difficult to measure e.g. cooking quality and aroma of rice, and those traits for which selection conditions are uncertain e.g., drought and pest resistance. In maize restriction fragment length polymorphism (RFLP) markers has been used and seven genomic regions were identified to account for 38% of the phenotypic variance for resistance to corn borer (Schon *et al*, 1993).

MAS is particularly suitable for pyramiding disease or pest resistance genes, where many genes controlling diseases or pests are put in a particular variety.

Through use of MAS, quantitative trait loci (QTL) involved in resistance to SWCB and SCB have been identified in two mapping populations. Most of the QTLs showed additive and dominance effects and most of the QTLs common to both insects were identified from MBR populations. MAS may help to improve the efficiency of selection for resistant germplasm.

2.6.2.2 *Bt* Maize Resistance to Stem Borer

Transgenic plants expressing *Bacillus thuringiensis* δ-endotoxins are now being used commercially in several crop species such as tobacco and tomato, in control of tobacco hornworm and tomato pinworm respectively (Mihm, 1997). The toxins have demonstrated good control of temperate (*Ostrimia nubilaris*) and tropical (*Diatrae grandiosella* and *D. Saccharalis*) stem borers in maize. After being activated by mid-gut proteases, *Bt* toxins bind to the stomach wall of the insect, creating pores that result in cell lyses (Mugo *et al.* 2000).

The resistance being developed from the MBR populations will be used to pyramid genes for resistance as an insect resistance management strategy in development and deployment of *Bt* maize in Kenya.

2.7 TARGET STEM BORER SPECIES IN KENYA

2.7.1 Spotted stem borer, *Chilo partellus* (Swin hoe)

Chilo partellus belongs to the family Pyralidae and their main hosts are maize, sorghum, bulrush millet, sugarcane, and rice (Hill, 1983). *C. Partellus* is distributed widely in India, Pakistan, Indonesia, Sri Lanka, Thailand, Ethiopia, Kenya, Somalia, Tanzania and South Africa. (Seshu Reddy, 1983). *C. Partellus* remains active in Africa throughout the year (Ampofo, 1986). *C. partellus* life cycle begins with the laying of its eggs on maize leaves. The female deposits a total of 200-300 eggs in masses with a variable number of eggs on any green part, such as the stem, sheath, and leaf blades. Incubation period is about six days (Matibet, 1990). The eggs hatch into neonate first instar larvae, which move into the leaf whorls where they feed and develop on the bases of the leaves, i.e. underside of the leaves near the midrib causing lesions that reduce photosynthetic area of the plant. The larvae then develop to the late third or early fourth instar, bore into the stem, feeding on the tissues and making tunnels. As a result of the larvae feeding within the leaf whorl or stem, the meristematic tissues may be cut through and the central leaves dry up to produce the "dead heart" symptom and the plant dies. Three damage parameters, namely, leaf feeding, dead heart, and stem tunneling, lead to grain yield loss (Mutinda, 1996). In late attacks, larvae may complete development by feeding on maize heads. Larval development takes 28-35 days. The mature caterpillar is 25mm long, buff-colored and thoracic shield pupation takes place in the stem in a small chamber and takes 7-10 days. In the adult moth, male is smaller and darker than the female. The male has forewings which are pale brown, with dark brown scales forming streaks along the costa, the hind wings are a pale straw color. The female has much paler forewings and hind wings almost white. The control of the pest includes destruction of crop residues as well as volunteer plants.

Chemicals are also used and are generally very successful (Hill, 1983). A number of studies have been reported which give information on some genotypes that are resistant to *C. partellus* and that can be used in the management of the pest (Omolo, 1983; Ampofo and Saxena, 1984; Ampofo *et al*, 1986; ICIPE, 1991; Ajala and Saxena, 1994).

2.7.2 Maize Stem Borer, *Busseola fusca* (Fuller)

B. fusca belongs to the family Noctuidae. Their main hosts are maize and sorghum. The attack of *B.fusca* on the plants begins by laying of its eggs under a leaf sheath in a long column stretching up the stem. The eggs are white when first laid but darken with age. As a result of the larvae feeding, young plants have holes and 'windows' (semi-transparent hole-like sections) in the leaves and small dark caterpillars may be seen in the funnel. When there is a severe attack, the central leaves die. In older plants the first generation caterpillars bore in the main stem and later some of the second-generation caterpillars may be found boring in the cobs. Hatching takes place after about 10 days. The larva is a buff or pinkish caterpillar with more or less distinct black spots along the body; the full-grown size is about 40mm long. The total larval period is usually 35 days or more. There are usually two generations of stalk borer before the crop matures. In the second generation some eggs may be laid on the cobs, they feed on cobs but later move into the stem when fully grown. The mature caterpillar of the second generation often goes into a diapause which will be broken at the onset of the next rainy season when it will prepare a pupal chamber in the stem and pupate (Hill, 1983). The adult is a brown night-flying moth. It emerges through the hole in the stem prepared by the mature caterpillar. *Busseola fusca* is a widespread pest in the maize-growing areas of tropical and sub-tropical Africa south of Sahara.

2.8 CONTROL OF *C. partellus* AND *B. fusca*

2.8.1 Cultural control

This is a method of pest control which is achieved by manipulating crops and land through management and husbandry practices. The main objective is to make the environment unfavorable for the pest and thereby either avert damage or at least limit the severity of the pest. The following practices can be employed:

(i) Destruction of crop residue - Important for killing pupae left in old stems and tall stubble.

(ii) Destruction of thick-stemmed grass weed, which would act as alternate hosts.

(iii)Close season of at least two months to prevent population continuity.

2.8.2 Biological control

This involves the management of natural enemies of the pests to reduce their populations to a level where economic losses due to them are tolerable. The natural enemies prevent a species from reaching pest proportions especially in long established communities such as forests. Natural enemies are usually parasites, predators or pathogens of insect pests. For example we have:

(i) *Trichogramma spp* (Chalcidoidea) - These are egg parasites of the stem borers.

(ii) *Apanteles spp* (Bracomidae) - They can be used as larval parasites of the stem borers.

2.8.3 Insecticidal control

This involves use of chemicals that affect the biological processes of the stem borer and may thus act as poison. These chemicals are used to combat pests (Kumar, 1984). The chemicals are used in form of:

(i) **Dusts and sprays** - These are contact insecticides applied down the funnel of young plants to kill the emerging and feeding first instar larvae.

(ii) **Granules** - They are applied either on foliage or in the soil at the base of the plant and are usually systemic in action.

(iii) **Systemics applied as sprays** - includes diazinon, endosulfan, fenthion, monocrotophos, among others (Hill, 1983).

2.8.4 Control through Breeding

Barrow (1985) reported that different amount of leaf damages were caused to several maize genotypes by *B.fusca* larvae feeding on whorl tissue and the extent of damage was correlated with the mean larval biomass/plant. The variation in mean larval biomass present in the different maize cultivars was ascribed in this study to two resistance factors present in the leaves:

(i) A short-lived but effective resistance factor which either kills or repels early instar larvae, resulting in fewer larvae surviving.

(ii) Operative for most of the larval feeding period in the whorl, retards larval development and growth.

The interaction between *B. fusca* and the maize occurs in different generations and the first generation infestation develops from moths emerging in spring from a diapausing larval over-wintering in maize stalks. The moths are attracted over great distances to young maize plants where they oviposit within the leaf sheaths.

2.9 PHENOTYPIC CORRELATIONS

The Genetic cause of correlation is chiefly pleiotropy though linkage is a case of transient correlation, particularly in a population derived from crosses between divergent strains. Pleiotropy is the property of a gene whereby it affects two or more characters so that if the gene is segregating it causes simultaneous variation in characters it affects. Some genes may increase both characters (Positive correlation) while others increase one and reduce the other (negative correlation). The association between two characters that can be observed directly is the phenotypic correlation. It is determined from measurements of the two characters in a number of individuals of the population (Falconer 1989).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 MATERIALS

Twenty insect resistant maize inbred lines from CIMMYT were used. These inbred lines, were received from Mexico when they were at S3 generation. The inbred lines were advanced up to S6 generation. The 20 inbred lines were grown at Kiboko site for crossing in order to develop F1 hybrids. These inbred lines were selected after several evaluations under artificial infestation with stem borers. They are all MBR lines i.e. they are resistant to not only *C. partellus* and *B. fusca* but also resistant to other stem borers. Some of the inbred lines were also screened for diseases; these are the Multiple Disease resistance (MDR) lines. These inbred lines were from eight different families. These families are: F1, F8, F14, F13, F43, F44, F113 and F114. Most of these inbred lines were in cycle 5 (C5) and three were in cycle 3 (C3). The inbred lines that were used are shown in table 3.1:

Table 3.1. Inbred lines used in making F1 hybrids.

Entry	Pedigree	Entry	Pedigree
1	MBR/MDR C3 Bc F8-1-2-1-B-2-2-B	11	MBR C5 Bc F14-3-2-8-B-4-2-B
2	MBR C5 Bc F43-3-1-1-B-3-2-B	12	MBR/MDR C3 Bc F1-1-1-1-B-3-2-B
3	MBR C5 Bc F14-3-2-8-7-2-B	13	MBR C5 Bc F114-1-2-3-B-2-2-B
4	MBR C5 Bc F8 –1-1-1-B-2-2-B	14	. MBR C5 Bc F13-1-2-2-B-1-2-B
5	MBR C5 Bc F13-2-1-3-B-4-2-B	15	MBR C5 Bc F14-3-2-9-B-2-2-B
6	MBR C5 Bc F13-1-2-2-B-2-2-B	16	MBR C5 Bc F113-1-2-2-B-3-2-B
7	MBR C5 Bc F113-3-2-1-B-3-2-B	17	MBR C5 Bc F114-3-2-5-B-1-2-B
8	MBR C5 Bc F14-3-2-5-B-2-2-B	18	MBR C5 Bc F14 –3-2-8-B-8-2-B
9	MBR C5 Bc F14-3-2-9-B-1-2-B	19	MBR C5 Bc F114-1-1-3-B-5-2-B
10	MBR C5 Bc F114-1-2-3-B-6-2-B	20	MBR/MDR C3 Bc F44-2-1-2-B-1-2-

In this thesis, these materials will be referred to by their entry numbers.

3.2 METHOD

Single cross hybrids were made from the 20 inbred lines using partial diallel mating design. This was done between April and August, 2002 at the NRRC Kiboko. Fifteen randomly selected inbred lines were used as male parents to pollinate the others including themselves. The crossing was done in such a way to ensure that each of the twenty inbred lines was involved in the crosses but not necessarily the same number of crosses nor with the same inbred lines. With **P** number of parents, and S number of parents crossed with, 110 number of crosses were made as follows:

No. Of Crosses $=PS/2=20(11)/2=110$

Where, P = Total number of parents and,

S = Number of plants that each parent is crossed with.

In order to get the parent to cross with, ***K*** is used which is a constant

$K= (P+1-S)/2=5$

Where, ***K*** is a constant, which is used in the design and,

S is the sample size.

In this case the ***S*** is 11 and ***P*** is 20.

Figure 1. The 110 crosses made through use of partial diallel.

Males planting **Females**

1st 2n 3rd

1	1	1	6	7	8	9	10	11	12	13	14	15	16
2	2	2	7	8	9	10	11	12	13	14	15	16	17
3	3	3	8	9	10	11	12	13	14	15	16	17	18
4	4	4	9	10	11	12	13	14	15	16	17	18	19
5	5	5	10	11	12	13	14	15	16	17	18	19	20
6	6	6	11	12	13	14	15	16	17	18	19	20	
7	7	7	12	13	14	15	16	17	18	19	20		
8	8	8	13	14	15	16	17	18	19	20			
9	9	9	14	15	16	17	18	19	20				
10	10	10	15	16	17	18	19	20					
11	11	11	16	17	18	19	20						
12	12	12	17	18	19	20							
13	13	13	18	19	20								
14	14	14	19	20									
15	15	15	20										

hree sets of males were planted in three different periods during the year to ensure that females of ifferent maturity were pollinated. The first male planting was done five days before the female arents in order to ensure earlier germination while the 2nd male planting was done at the same time ith females (i.e. 0 days after planting females).

Table 3.2 Three different planting periods

Planting	Date
1st Male planting	17/08/2002
2nd Male and female planting	22/08/2002
3rd Male planting	27/08/2002

The third planting was done five days after the females were planted (i.e. +5 days after planting females). Crossing was done with great care in order to ensure that no contamination occurred; this was done by immediately covering the silk as it emerges using silk bags and the same was done on the tassel before shedding pollen.

3.3. FIELD EVALUATION

The experiments were planted at two sites: KARI RRC Embu and NRRC Kiboko. The approximate location of Kiboko is about 200 Kilometers from Nairobi and it receives 600mm of rainfall per annum and that of Embu is about 150 kilometers from Nairobi and receives a bimodal type of rainfall.

An alpha lattice design with three replicates was used. Plants were spaced 25 cm within rows and 75 cm between rows. An alley of 150 cm separated the three replications in each site and two guard rows surrounded the trial.

At planting, diammonium phosphate (DAP) was applied at the rate of 448kg per hectare. The seeds were treated with murtano dust to reduce pest damage during germination and early growth. Murtano acts both as an insecticide as well as a fungicide. It was applied at the rate of 30 grammes per 10 kilogrammes of seeds. One hand weeding 3 weeks after planting and one spot weeding in Kiboko adequately controlled weed while in Embu two-hand weeding controlled weed. After two weeks from planting, the trials were side dressed with calcium ammonium nitrate (CAN) at the rate of 448kg per hectare. In total the nitrogenous fertilizer which was applied was 50kg N per hectare.

Each plot had one row with twenty one hills whereby ten plants were infested with stem borers while the rest were protected using Bulldock® 0.05GR granules which is a synthetic pyrethroid insecticide (S.Mugo, personal communication) which was applied into the whorl of the young maize plants.

To evaluate for insect resistance 10 plants per plot were infested with 20 black head eggs of *C. partellus* and *B. fusca* at the three leaf stage per plant at both NRRC Kiboko and KARI RRC Embu sites respectively (Songa, personal communication).This was done by placing the eggs into the whorl of the plant (Niranjan and Gurdev, 1995) while the rest were protected. The adaptability was determined by comparing grain yield and responses to foliar diseases.

3.4 DATA COLLECTION

Data was recorded from the whole plot for most of the variables apart from yield, lodging, ears harvested and ear aspect which were recorded from the net plot, this was after removing the end most hills from both sides of the plot i.e. the border plants in each plot.

Data was recorded on the following traits:

3.4.1 Stem borer damage

This was recorded by scoring on a scale of 1-9 where 1= no damage and 9= 100% damage. The scale can be divided into three: 1-3, resistant; 4-6, moderately resistant; and 7-9, susceptible (Niranjan and Gurdev, 1995). For the ease of scoring the foliar damage the table below can be used;

Table 3.3. Scale for scoring stem borer damage to whorl-stage maize plants

Visual rating of damage	Numerical score	Resistance reaction
No damage	0	(Likely escape)
Few pin holes	1	Highly resistant
Few shot holes on a few leaves	2	Resistant
Several shot holes or small holes on A few (<50%) leaves	3	Resistant
Several (>50%) leaves with shot holes or small lesions (<2cm long)	4	Moderately resistant
Elongated lesions (>2cm long) on a few leaves	5	Moderately resistant
Elongated lesions on several leave	6	Susceptible
Several leaves with long lesions or tattering	7	Susceptible
Most of the leaves with long lesions or Severe tattering	8	Highly susceptible
Plant dying as a result of foliar damage	9	Extremely sensitive to Damage

Adopted from CIMMYT, (1989)

Cumulative tunnel length was recorded by measuring the length of the tunnel made by the stem borer in centimeters while the number of exit holes was recorded by counting the holes on the maize stalk. The tunnel length: plant height ratio was computed as follows;

$$(tl/ph)*100,$$

where; tl= Tunnel length and ph = Plant height.

3.4.2 Days to flowering

This was recorded as the number of days from planting to the date when 50% of the plants in a plot had flowered. This was done for both male and female. Days to flowering for male was recorded when 50% of the plants in a plot had shed pollen while days to flowering for female was recorded when 50% of the plants had produced silk.

3.4.3 Anthesis silking interval (ASI)

This was computed from the difference between the days to pollen shed and days to silking.

3.4.4 Plant height (cm)

This was measured from the base of the plant at the soil surface to the second last leaf near the tassel at maturity. Height per plant was calculated as the average of the ten plants per plot.

3.4.5 Ear height (cm)

This was measured from the base of the plant at the soil surface to the point where the first ear was placed. Ear height per plant was calculated as the average of the ten plants per plot. These was from the ten plants which were picked randomly per plot.

3.4.6 Number of ears per plant

This was recorded as the total number of ears harvested per plot divided by the number of the plants harvested. Rotten ears were also recorded per plot and calculated as a percentage of the total ears harvested.

3.4.7 Root lodge and shoot lodge

This was recorded by counting the number of plants lodged per plot. Root lodge was recorded by counting the number of plants fallen at the base of the plant while shoot lodge was recorded by counting the number of plant fallen through stem breakage above the soil surface. Both root lodge and shoot lodge were calculated as a percentage of the total plants per plot.

3.4.8. Ear aspect

This was recorded through visual evaluation; a scale of 1-9 was employed. This was done after harvesting all plants per plot. The ears were arranged alongside the plot for scoring; a score of 1 represented the worst ears while a score of 9 represented the best ears. When awarding the scores, features such as grain filling, uniformity of the ears, size of the ears and resistance to rotting was considered.

3.4.9 Grain yield (tons/ha)

This was based on the harvested plants per plot. The ears were shelled, weighed and the weight adjusted to the moisture content recorded for each plot. Grain yield (tons/ha) was calculated as;

$$((y/a)*(10000/1000))-(((y/a)*(10000/1000))*(mc/100)$$

Where; y = weight in grammes

a = plot area (m^2)

mc = moisture content determined after shelling by use of a moisture meter.

3.4.10 Yield loss (tons/ha)

This was computed by subtracting the yield of the infested area in each plot from the protected area. It was calculated as;

$$Yp - Yi$$

Where; Yp = yield of the protected area in a plot.

Yi = yield of the infested area in a plot.

3.5 STATISTICAL ANALYSIS

General combining ability (GCA) and specific combining ability (SCA) effects of the parental genotypes were estimated in the F1 hybrids using Griffing's (1956) model method 4. This method involves use of F1s only to study the combining ability. A computer programme SAS menu Partial diallel was used to estimate combining abilities. The experimental material consists of F1's generation only without reciprocals i.e. $\frac{1}{2} P (P-1)$ combinations, where P= number of parents which were used. In our case we used $PS/2$ which gave us 110 combinations, where P=total number of parents =20, and S=selected sample =11.

The combining ability analysis can be determined using the following linear model according to (Borojevic, 1990);

$$Xij=\mu+gi+gj+Sij+1/bc\Sigma k\Sigma l eijkl$$

Where,

Xij=the mean value between crosses of i and j parents

U = population mean effect

gi = the GCA effect for the i th parent

gj = the GCA effect for the jth parent

Sij = the SCA effect for the cross between *i*th and *j* th parents

Eijkl = the environmental effect associated with the *ijkl*th individual observation

The analysis of variance for general and specific combining ability can be prepared as shown below:

				Expectation of mean
Source	d.f	s.s	m.s	squares model 1
GCA	p-1	Sg	Mg	$\delta^2{}_{+(p+2)\ 1/p-1\Sigma gi2}$
SCA	p (p-1)/2	Ss	Ms	$\delta^2{}_{+2/p(p-1)}{}^{\Sigma\ \Sigma}{}_{1}{}^{sij}$
Error	m	Se	Me	δ^2

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Variability among the F1's

A combined analysis for the two seasons was done in Kiboko and Embu. Differences were observed among the hybrids for all traits at Embu and Kiboko (Tables 4.1a,b,c and d,).In general, the F1's took longer time to mature in Embu than at Kiboko, this was attributed to the altitude because Kiboko is in the lowland region while Embu is a Mid-altitude region. The plants performed better in Kiboko in terms of yield and maturity than at Embu. The F1's at Embu were taller than at Kiboko (Appendix I and II). Compared to the local checks H513 and PH3253, the materials performed better in all aspects apart from plant height. Both local checks took more days to pollination in both sites, PH3253 took an average of 58.7 days in Kiboko and 66 days to pollination in Embu while H513 took an average of 59.2 days to pollination in Kiboko and 65.5 days to pollination in Embu. With regard to insect damage the F1 hybrids exhibited low scores where most of them ranged between two and three while the two local checks gave higher scores, above 5 (Tables 4.1a, and C). However under protection from the insect damage the local checks performed extremely well than the F1 hybrids.

4.1.1 Stem borer damage

Significant differences were observed at 0.1% probability level at Kiboko. The mean value was 2.7 and the range was 2.2 to 5.3 (Table 4.1a). In exit holes significant differences (P=0.001) were observed and the mean value was 1.2. Significant differences were also observed in tunnel length and tunnel length: plant height ratio at 0.01 probability level. Significance difference was observed between the checks and the crosses at 0.1% probability level in insect damage, 0.1% probability level for exit holes and 1% for tunnel length and tunnel length: plant height ratio.

The yield for the two local checks was affected by the insect damage and it is clearly shown in figure 2, the higher the insect damage score the lower is the yield and vice versa. Some entries could also be classified as tolerant especially entry 43 and 108, the tunnel length was high but they still gave higher yield. There were also some entries which performed poorly in terms of other agronomic traits e.g. they gave low yield but they had very low stem borer damage scores e.g. entries 10 and 11; these materials can be used in breeding programs to incorporate resistance into more adapted but susceptible materials. A Similar observation was made by CIMMYT 1989.

Table 4.1 (a) Mean performance of the top 18 F1 hybrids and two local checks (PH3253 and H513) infested with *Chilo partellus* at Kiboko.

Rank	ENTRY	Anthesis Silking interval (days)	Plant height (cm)	Ear height (cm)	Ears per plant (no.)	Ear Aspect Scale(1-9)	Ear rot (no.)	Yield (t/ha)	Yield loss (t/ha)	Stem borer damage Scale(1-9)	Exit holes (no.)	Tunnel Length (cm)
1	68	0.7	177.6	91.1	1.1	7.5	0.2	7.0	1.1	2.1	0.6	2.2
2	108	1.0	178.1	103.6	1.0	6.8	0.2	6.8	0.8	2.7	1.4	5.6
3	78	-0.2	181.8	93.7	1.0	7.5	0.5	6.5	1.5	2.3	1.1	3.6
4	32	-0.3	178.9	96.0	1.1	7.3	0.2	6.5	1.3	2.4	1.8	4.8
5	18	1.8	175.3	96.4	1.2	6.2	0.5	6.4	1.3	2.8	0.8	1.8
6	95	0.7	162.7	82.2	1.0	7.0	0.2	6.3	1.5	2.7	1.0	2.3
7	45	-0.2	174.8	90.5	1.0	7.2	0.7	6.2	1.6	3.0	1.0	2.2
8	54	0.5	172.3	89.2	1.1	6.0	0.3	6.1	2.0	2.6	0.9	2.2
9	4	1.2	166.6	90.5	1.1	6.2	0.5	6.1	1.2	3.0	1.0	2.8
10	110	0.7	157.7	87.2	1.1	7.0	0.0	6.0	1.2	2.7	1.0	2.7
11	3	1.5	169.0	87.4	1.0	7.8	0.2	6.0	2.0	2.9	0.8	1.4
12	43	1.2	162.2	95.6	1.0	6.3	0.7	6.0	1.4	2.7	2.3	6.6
13	16	1.8	162.3	93.2	1.3	6.8	0.7	5.9	1.6	2.5	1.2	3.3
14	100	0.3	150.9	81.9	0.9	6.3	0.5	5.9	0.8	2.5	1.4	4.0
15	87	0.2	174.4	86.6	1.1	6.8	0.3	5.9	1.3	2.4	1.4	4.6
16	105	1.3	146.9	79.1	1.1	6.2	0.7	5.8	1.0	2.7	1.0	2.8
17	99	1.0	158.0	86.9	1.3	6.0	1.3	5.8	0.7	2.4	1.4	5.0
18	15	0.0	149.5	82.0	1.0	6.2	0.8	5.8	1.3	2.5	0.6	1.9
19	14	2.2	180.9	95.4	1.0	5.2	0.7	4.1	4.1	5.3	3.5	11.1
20	90	1.3	183.2	105.3	1.1	5.8	0.3	3.7	2.5	4.7	2.0	7.2
MEAN		**0.8**	**168.1**	**90.7**	**1.1**	**6.6**	**0.5**	**5.9**	**1.5**	**2.8**	**1.3**	**3.9**
CV		**77.11**	**7.52**	**10.36**	**20.03**	**19.12**	**139.64**	**21.29**	**67.75**	**22.86**	**89.52**	**98.93**
LSD		**1.00**	**18.70**	**14.00**	**0.40**	**2.10**	**1.80**	**1.10**	**1.20**	**0.90**	**1.20**	**2.80**
SIG		***	***	***	*	***	***	***	***	***	***	**

*, **, and *** significant at 0.05, 0.01 and 0.001 probability levels respectively.
Local checks: Entry 14-PH3253, entry 90-H513

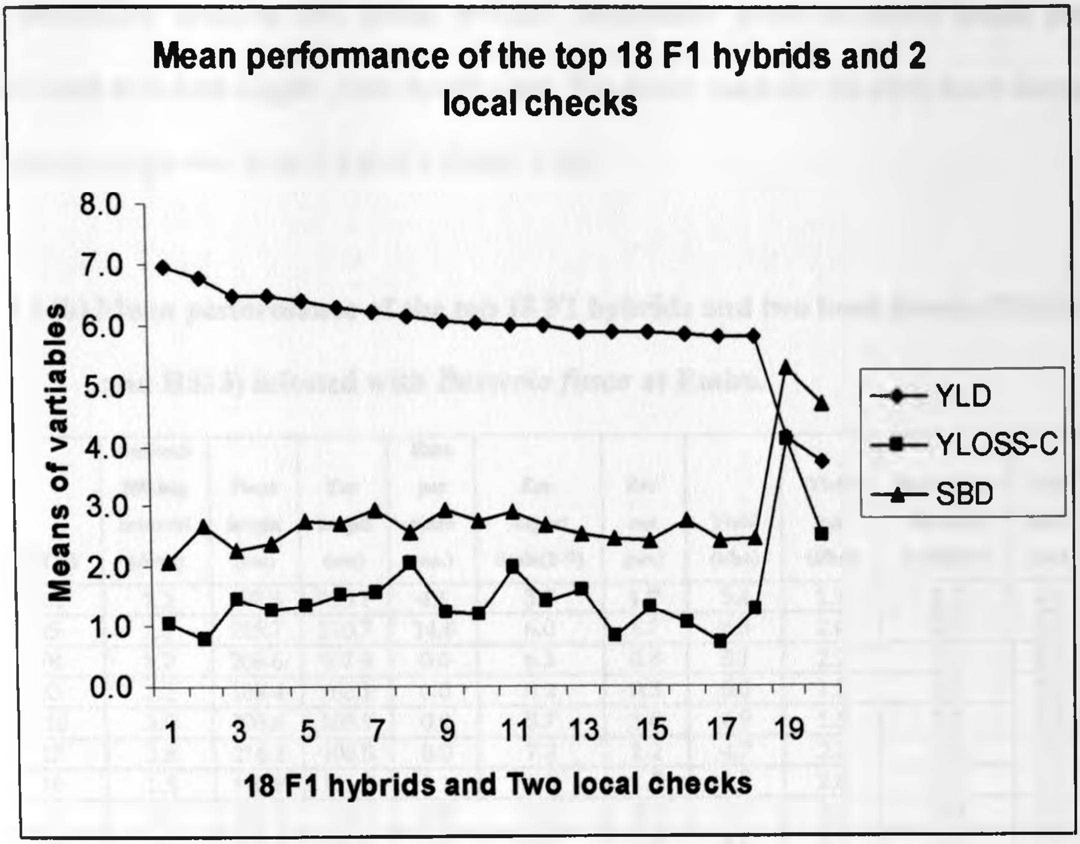

Fig. 2. Mean performance of the top 18 F1 hybrids and two checks (PH3253 and H513) under *Chilo partellus* infestation.

At Embu significant differences were observed at p= 0.001 probability level in stem borer damage, =0.001 probability level in exit holes, p=0.001 probability level in tunnel length and p=0.1 robability level in tunnel length: plant height ratio. The mean value for the stem borer damage score as 2.6 and the range was from 2.0 to 6.4 (Table 4.1b).

Table 4.1 (b) Mean performance of the top 18 F1 hybrids and two local checks (PH3253 and H513) infested with *Busseola fusca* at Embu.

Rank	ENTRY	Anthesis Silking interval (days)	Plant height (cm)	Ear height (cm)	Ears per plant (no.)	Ear Aspect Scale(1-9)	Ear rot (no.)	Yield (t/ha)	Yield loss (t/ha)	Stem borer damage Scale(1-9)	Exit holes (no.)	Tunnel Length (cm)
1	103	1.2	197.3	110.1	4.1	5.7	1.7	5.4	1.1	2.3	0.4	1.1
2	45	1.8	215.7	110.7	14.8	6.0	1.7	5.3	2.0	2.6	1.4	4.7
3	78	1.7	209.6	107.9	0.0	6.3	0.8	5.1	2.2	2.5	1.1	2.5
4	85	1.2	189.4	103.1	0.0	6.2	0.5	5.0	1.3	2.7	2.1	4.6
5	110	3.0	203.8	108.5	0.0	5.7	1.0	4.9	1.5	2.5	0.9	1.9
6	27	2.8	214.2	108.5	0.0	7.2	1.2	4.7	2.3	2.8	1.6	4.6
7	16	1.5	198.8	111.8	2.1	6.5	1.5	4.7	2.6	2.5	1.0	2.8
8	3	1.3	211.4	109.3	3.3	6.7	2.7	4.7	2.2	2.9	2.2	3.7
9	68	2.3	199.4	98.9	3.7	6.3	2.8	4.6	1.7	2.6	2.0	4.2
10	95	2.0	206.1	105.5	0.0	5.7	2.0	4.5	1.2	2.9	2.3	4.3
11	43	1.7	194.6	111.5	0.0	6.5	0.8	4.5	1.8	2.4	1.3	2.5
12	44	1.2	206.4	103.2	11.4	6.8	0.2	4.5	3.1	2.6	1.4	4.1
13	46	1.5	204.7	98.8	0.0	6.2	0.5	4.4	2.3	2.7	0.5	1.5
14	17	2.7	199.4	98.2	0.0	7.3	0.0	4.4	1.9	2.5	1.2	2.6
15	57	1.8	219.8	103.7	0.0	6.0	1.8	4.4	2.4	3.0	1.8	4.6
16	54	1.8	210.6	107.2	3.5	5.7	0.8	4.3	2.6	2.6	1.0	4.2
17	91	2.2	197.0	110.2	0.0	5.2	0.5	4.3	1.4	2.5	1.3	2.9
18	106	1.2	184.6	102.9	0.0	6.3	0.7	4.2	1.7	2.2	0.9	2.0
19	14	2.5	222.9	110.3	3.7	5.8	0.3	3.3	4.8	6.4	5.0	9.8
20	90	1.8	223.6	123.7	0.0	6.7	0.7	2.7	4.5	6.2	1.4	4.2
	Mean	1.9	205.5	107.2	2.3	6.2	1.1	4.5	2.2	3.0	1.5	3.6
	CV	61.83	7.75	10.51	19.94	16.91	92.51	26.08	52.19	17.53	102	100.7
	LSD	1.63	16.63	11.92	0.25	1.1	1.51	1.67	1.23	0.53	1.39	3.37
	SIG.	***	***	***	***	***	***	***	***	***	***	***

*, **, and *** significant at 0.05, 0.01 and 0.001 probability levels respectively.

Local checks: Entry 14-PH3253, entry 90-H513

The two local checks gave higher insect damage score and this resulted to low grain yield (Figure 3). The yield loss margin was also high for the two local checks compared to the F1 hybrids.

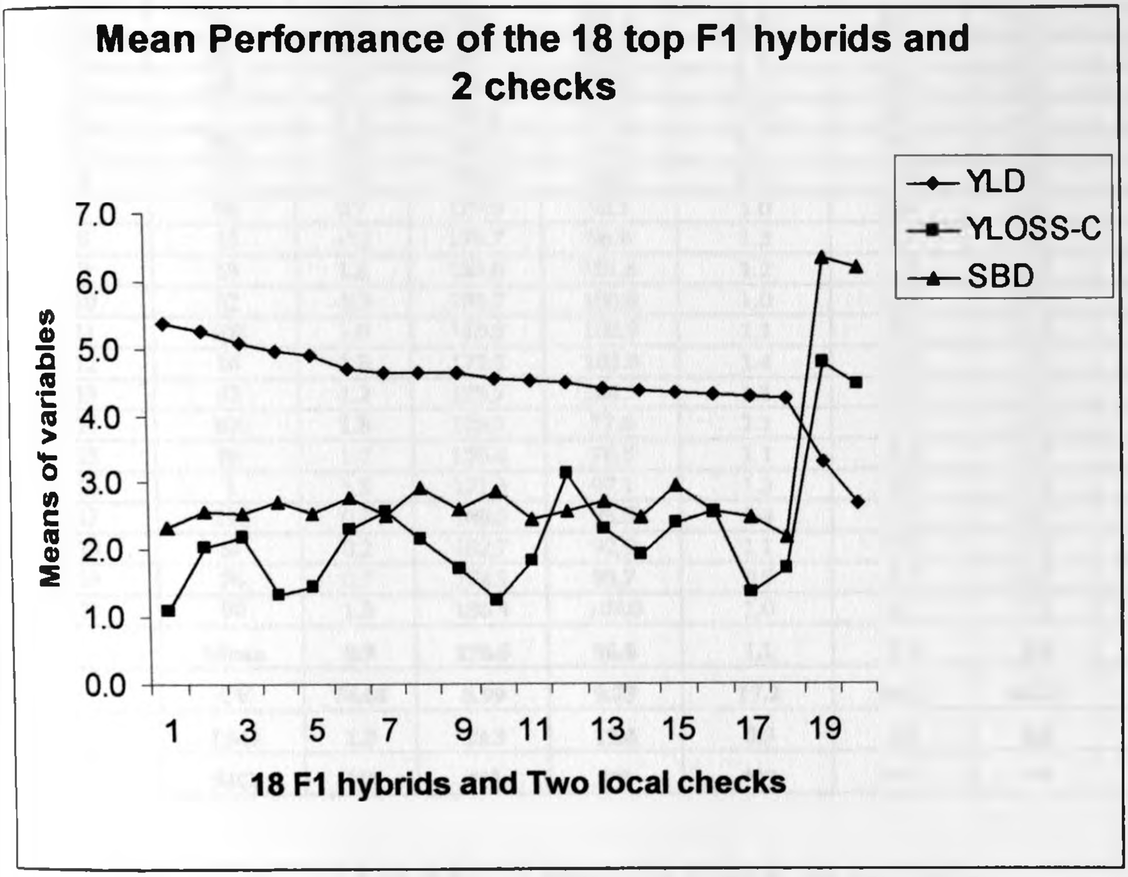

Fig. 3. Mean performance of the top 18 F1 hybrids and two checks (PH3253 and H513) under *Busseola fusca* infestation.

Table 4.1 (c) Mean performance of the top 18 F1 hybrids and two local checks (PH3253 and H513) protected from stem borer damage at Kiboko.

Rank	ENTRY	Anthesis Silking interval (days)	Plant height (cm)	Ear height (cm)	Ears per plant (no.)	Ear Aspect Scale(1-9)	Ear rot (no.)	Yield (t/ha)
1	14	2.2	192.1	101.7	1.0	6.7	0.3	8.9
2	54	0.5	180.5	94.4	1.1	7.2	0.7	8.2
3	68	0.7	178.6	91.6	1.0	8.2	0.3	8.0
4	3	1.3	182.1	97.1	1.0	8.0	0.2	8.0
5	78	-0.2	186.0	94.1	1.1	7.5	0.0	7.9
6	57	0.2	193.8	96.9	0.9	7.8	0.0	7.8
7	95	0.7	179.9	93.1	1.0	8.0	0.0	7.8
8	45	-0.2	178.7	96.8	1.3	7.7	0.5	7.8
9	18	1.8	183.6	101.8	1.2	7.3	0.5	7.7
10	32	-0.3	186.7	100.8	1.0	8.5	0.0	7.7
11	108	1.0	185.8	108.9	1.1	7.5	0.3	7.6
12	16	1.8	172.2	103.8	1.4	7.0	1.7	7.5
13	43	1.2	175.7	104.7	1.1	6.8	0.5	7.4
14	101	1.8	156.1	77.6	1.1	7.3	0.5	7.3
15	86	1.2	155.4	78.5	1.1	7.8	0.7	7.3
16	1	1.5	171.3	97.1	1.3	6.7	0.2	7.2
17	110	0.7	168.5	93.5	1.4	7.2	0.5	7.2
18	87	0.2	182.7	92.9	1.1	7.3	0.2	7.2
19	76	0.7	174.1	93.7	0.9	6.7	0.7	7.1
20	90	1.3	188.4	109.0	1.0	6.7	0.3	6.7
	Mean	**0.9**	**178.6**	**96.4**	**1.1**	**7.4**	**0.4**	**7.6**
	CV	**76.04**	**6.99**	**9.73**	**17.2**	**14.2**	**147.7**	**17.4**
	LSD	**1.3**	**13.3**	**12.4**	**0.3**	**1.7**	**1.8**	**1.0**
	SIG.	***	***	***	***	***	***	***

*, **, and *** significant at 0.05, 0.01 and 0.001 probability levels respectively.

Local checks: Entry 14-PH3253, entry 90-H513

Table 4.1 (d) Mean performance of the top 18 F1 hybrids and two local checks (PH3253 and H513) protected from stem borer damage at Embu.

Rank	ENTRY	Anthesis Silking interval (days)	Plant height (cm)	Ear height (cm)	Ears per plant (no.)	Ear Aspect Scale(1-9)	Ear rot (no.)	Yield (t/ha)
1	14	3.3	207.8	109.0	1.0	6.3	0.8	7.8
2	44	1.7	211.9	108.9	1.2	7.0	1.5	7.6
3	29	1.0	207.1	110.0	1.2	7.0	0.7	7.6
4	45	2.2	197.9	100.0	1.1	6.7	1.7	7.3
5	78	1.3	206.8	107.8	1.1	6.8	0.8	7.3
6	16	1.2	203.6	117.3	1.4	6.0	0.7	7.2
7	27	2.8	216.6	111.0	1.1	7.2	1.2	7.0
8	54	1.8	199.6	103.3	1.4	6.7	1.5	6.9
9	32	2.3	210.6	109.3	1.1	6.2	1.3	6.9
10	31	2.5	194.1	105.8	1.3	7.2	1.5	6.8
11	3	1.7	202.2	104.8	1.3	6.2	2.0	6.8
12	57	1.8	206.0	103.2	1.0	6.7	1.7	6.7
13	46	2.2	206.8	103.7	1.1	6.7	1.0	6.7
14	105	2.2	198.8	112.8	1.5	6.5	1.5	6.7
15	55	1.8	197.5	99.2	1.3	6.7	1.2	6.6
16	15	2.0	196.3	100.7	1.2	6.2	1.5	6.6
17	56	2.3	192.5	99.5	1.2	6.5	0.8	6.5
18	103	3.0	205.0	107.0	1.0	6.8	1.0	6.5
19	28	2.2	197.9	99.3	1.0	7.2	0.5	6.4
20	90	3.3	203.9	107.0	1.3	6.8	1.5	5.9
	Mean	2.1	203.1	106.0	1.2	6.7	1.2	6.9
	CV	65.6	9.56	11.83	19.95	15.57	108.5	25.03
	LSD	1.73	21	13.62	0.26	1.09	1.59	1.57
	SIG.	**	***	***	***	***	*	***

*, **, and *** significant at 0.05, 0.01 and 0.001 probability levels respectively.

Local checks: Entry 14-PH3253, entry 90-H513

4.1.2 Days to flowering

50% days to anthesis

Significant (p= 0.001) differences were observed for 50% days to anthesis at Kiboko and the mean value was 55.8 days and the range was from 54.0 t0 57.0 days (Appendix I). At Embu the mean value was 63 days and the range was 59.7 to 65.5 days (Appendix III).

Among the twenty best F1's it was found out that the insect resistant F1 hybrids gave higher yield generally compared to the two local checks. It was also noted that even with some insect damage they were able to give good yield, (Tables 4.1).

50% days to silking

Significant differences (p= 0.001) were observed among the genotypes. At Kiboko the earliest F1 silked within 54.3 days while the latest one took 60.8 days (Appendix I).The mean value was 56.7 days. At Embu the earliest F1 to reach 50% days to silking took 63 days while the latest one took 69 days and the mean of 50% days to silking was 65.3 days. The local checks exhibited late maturity as they both reached 50% days to silking very late in both Kiboko and Embu.

Anthesis silking interval

Significant (p=0.001) differences were observed among the genotypes for both Kiboko and Embu. The mean value for kiboko was 0.8 and the range was from -0.3 to 2.2 (Table 4.1a). At Embu the mean value for the ASI was 1.9 and the range was from 1.2 to 2.7(Table 4.1 b).

4.1.3 Plant height (cm)

The plant height of the F1's differed significantly (p=0.001) at Kiboko for both under infestation and under protection from stem borer damage (Tables 4.1 a, &c). Entry 105 was the shortest while entry 90 which was one of the checks was the tallest (146.9cm and 183.2 cm) respectively (Table 4.1a).

When protected from the insect damage the plant heights of the genotypes exhibited a significant difference (p=0.001) and the mean for the plant height was 178.6cm. Entry 86 was the shortest with 155.4cm while entry 90 was the tallest with 188.4cm (Table 4.1c).

At Embu the F1's plant height differed significantly (p=0.001) both under infestation and under protection from stem borer damage. Entry 106 was the shortest with 184.6cm while entry 90 was the tallest with 223.6cm (Table 4.1b). Under protection from the insect damage, the range was from 192.5cm to 216.6cm (Table 4.1d). The mean plant height was generally lower under infestation for both kiboko and Embu than in the area where the crop was protected from the insect damage.

4.1.4 Ear height

At Kiboko the ear height of the F1's differed significantly (P=0.001) probability level, and the mean was 90.7cm. The range was from81.9 to 105.3 for the area which was infested with *C. partellus* stem borer. The area under protection from the insect damage also differed significantly at 0.1% probability level, the mean ear height was 178.6cm and the range was from 168.5 to 193.8cm (Table 4.1c)

At Embu the ear placement among the genotypes was significantly different at 0.1 probability level, the mean was 107.2cm and the range was 98.2 to 123.7cm under infestation (Table 4.1b). Significant difference (p=0.001) was observed in the ear placement in the area which was under protection from the insect damage. The mean was 106cm and the range was 99.2 to 117.3cm. The local check H513 exhibited a higher ear placement compared to the other F1 hybrids at both Kiboko and Embu sites (Tables 4.1) this was observed in both under infestation and under protection.

4.1.5 Number of ears per plant

The number of ears per plant among the hybrids under infestation ranged from 0.9 to 1.4 ears per plant at Kiboko (Appendix I) and the mean value was 1.1. The area which was under protection from the insect damage exhibited a significant difference P=0.001 (Appendix II). The range for the ears per plant was from 0.9 to 1.4.

At Embu significant difference were observed (p=0.001) in both under infestation and under protection from insect damage. The range was from 0.9 to 1.3 with a mean of 1.1 ears per plant under infestation while in the area which was protected the range was 1.0 to 1.5 with a mean of 1.2 ears per plant (Table 4.1b and d).

4.1.6 Rotten ears

Significant differences were observed (P=0.001) among the genotypes. The mean value for Kiboko under infestation was 0.5 and the range was from 0.00 to 1.3. In the area which was not infested with *C. partellus* the mean value for the ear rot was 0.4 and the range was 0.00 to 1.7 (Table 4.1c).

At Embu significant differences were observed (P=0.001) in the area under *B. fusca* infestation and p=0.05 in the area under no infestation. The mean value under infestation was 1.1 and the range was 0.00 to 2.8 (Table 4.1b). In the area under protection from the insect damage the mean value was 1.2 and the range was 0.5 to 2.0 (Table 4.1d).

4.1.7 Root and shoot lodging

Significant difference were observed (P=0.001) at Embu under infestation. The mean values were 0.4 and 0.7 for root and shoot lodge respectively, the range was from 0.00 to 1.7 and 0.00 to 2.70 for both root lodge and shoot lodge respectively (Appendix III).

In the area which was protected from the insect damage a significant difference was observed P=0.001, the mean value was 0.3 and the range was 0.00 to 1.8.

4.1.8 Ear aspect

Ear aspect significantly differed among the F1's (P=0.001) in both under infestation and under insect damage protection. The mean values were 6.6 and 7.4; the range was from 5.2.00 to 7.8 and 6.7 to 8.5 at Kiboko under infestation and protection respectively (Tables 4.1a and c).

At Embu significant difference (P=0.001) were observed in both under insect infestation and under protection. The means were 6.2 and 6.7 while the range was from 5.7 to 7.3 and 6.0 to 7.2 for the infested and non-infested areas respectively (Tables 4.1b and d).

4.1.9 Grain yield (tons/ha)

Significant difference was observed (P=0.001) among the genotypes at Kiboko in both treatment one (infested) and two (non- infested). The means were 5.9 and 7.6 tons/ha, the range was from 3.7 to 7.0 and from 6.7 to 8.9 for treatment one and two respectively (Tables 4.1a&c). Compared to the local checks most of the hybrids were above the mean but H513 and PH3253 were below the mean with 4.10 and 3.7 tons/ha respectively.

At Embu significant differences were observed (P=0.001) in treatment one and two. The means were 4.5 and 6.9 tons/ha while the range was from 2.7 to 5.4 and 5.9 to 7.8 tons/ha for treatment one and two respectively (Tables 4.1b &d). The lowest yielder was entry 10 while the highest yielder was entry 68 in Kiboko (Appendix I), and in Embu the lowest yielder was entry 10 while the highest yielder was entry 103 (Appendix III).

Both local checks did well under protection from the insect damage and they even outdid most of the F1 hybrids in Kiboko and Embu for the two seasons (Tables 4.1).

4.1.10 Yield loss

The yield loss was calculated as the difference between the areas under protection and the area under infestation. At Kiboko the yield loss was highly significant (P=0.001) among the F1's. The mean yield loss was 1.5 tons/ha. Significant differences were observed between the local checks and the F1 hybrids, the yield loss margin was very high compared to the F1 hybrids with a loss of 4.1 and 2.5 tons/ha for PH3253 and H513 respectively (Table 4.1a). The losses ranged between 0-55.8% and 0-67.8% in Kiboko and Embu respectively, of the potential yield, Youdowei, *et al* 1990, recorded a loss of 20-40% of the potential yield. The local checks exhibited a yield loss of between 20-55% of the potential yield. De Groote, (2002) recorded a loss of between 11% to 21%.

At Embu the analysis of variance revealed a significant difference (P=0.001) among the F1's. The mean yield loss was 2.2 tones/ha. The worst hit was the local checks, which were far above the mean yield loss. Both local checks gave the highest difference in Kiboko and Embu for the two seasons.

4.2 COMBINING ABILITY

Mean squares for general (GCA) and specific (SCA) combining abilities of the twenty inbred lines are presented in tables 4.2 (a) and (b) for Kiboko and Embu respectively. The estimates of general combining ability effects are presented in Tables 4.3 and 4.4.

4.2.1 Stem borer damage

At Kiboko the analysis of variance for combining ability showed that the mean squares due to general combining ability (GCA) and specific combining ability (SCA) were significant for insect damage to the F1's (Table 4.2a). The GCA: SCA ratio was 0.69, indicating that the general combining ability variances were higher in magnitude than the specific combining ability variances (Khaemba, 1992).

Table 4.2 (a) Mean squares for general and specific combining ability for various traits of 20 inbred lines at Kiboko.

Source	df	PH	EH	SLP	RLP	REP	Y-HA	EAH	EA
Season	1	112996.05***	47145.3***	0.01*	3.84*	23180.26***	47237202.80***	2.064*	14.79***
Treatment	2	5762.90***	2592.41***	33.52**	3.14*	341.05**	80138175.24***	209.84***	92.14***
Enumb	109	552.12***	272.54***	5.69**	1.44*	142.64***	5951068.99***	2.44**	1.41***
Crosses vs checks	1	5446.00***	1977.49***	12.66*	0.48*	19.56*	122132292.08***	2.89*	1.70**
GCA	19	289.20***	174.75***	6.46*	1.01*	64.88*	3233157.93***	2.53*	0.72**
SCA	90	607.62	293.18	5.53	1.53	159.06	6524850.22	2.42	1.56
Pooled error	109	16.64	9.38	3.78	1.32	38.80	1050219.9	1.56	0.32
GCA:SCA ratio		0.48	0.60	1.17	0.66	0.41	0.50	1.05	0.46

Table 4.2 (a) continued

Source	df	Y-LOSS	EXH	TL	TL-PH	AD	SD	ASI	INDS
Season	1	35090212.67	29.46***	414.42	0.01***	1323.1***	1546.8***	8.74*	10.66***
Treatment	2	-	-	-	-	14.66*	0.002*	15.03*	-
Enumb	109	1305194.97*	0.65**	5.49*	0.0002*	40.17*	7.40***	40.12*	0.12**
Crosses vs checks	1	6239022.23**	10.30***	128.77***	0.003***	115.46*	156.27***	3.08*	2.51***
GCA	19	1510971.11	0.53*	4.63*	0.0002*	35.84*	4.64***	50.15*	0.09*
SCA	90	1261753.34	0.67	5.68	2.04	41.09	7.98	38.00*	0.13
Pooled error	109	1180546.20	0.45	4.89	0.0002	30.54	0.0022	30.55	0.07
GCA:SCA ratio		1.20	0.79	0.82	9.80	0.87	0.58	1.32	0.69

*, **, and *** significant at 0.05, 0.01 and 0.001 probability levels respectively. Enumb-Entry number

Table 4.2 (b) Mean squares for general and specific combining ability for various traits of 20 inbred lines at Embu.

Source	df	ASI	AD	SD	EH	PH	Y/HA
Season	1	16.81***	3005.68***	2572.95***	17100.29***	174018.35***	222138656.41***
Treatment	1	0.00***	0.00***	0.00***	3.66*	2379.83***	442287052.43***
ENUMB	109	2.15***	2.07***	4.44***	461.32***	490.35***	2986567.81***
Crosses vs checks	1	6.21***	2.97***	17.77***	626.05*	2259.04***	30422425.54***
GCA	19	1.71***	1.54***	2.91***	423.67	335.12***	1166359.63***
SCA	90	2.24	2.18	6.21	469.28	523.12	3370833.98
Pooled error	109	0.00	0.00	0.00	227.82	18.98	382737.50
GCA:SCA ratio		0.76	0.71	0.47	0.90	0.64	0.35

Table 4.2 (b) continued

Source	df	EXH	INDS	TL-PH	TL	Y-LOSS	EA
Season	1	27.47***	30.84***	0.003***	20.40**	76351256.32***	62.63***
Treatment	1	.	.	.	.	.	21.24***
Enumb	109	0.61*	0.16*	0.0001*	3.54*	992168.90*	1.05***
Crosses vs checks	1	7.83**	5.17***	0.0005*	32.20**	15622564.07***	1.44**
GCA	19	0.47*	0.09*	0.0001*	2.44*	603628.86*	0.74***
SCA	90	0.64	0.17	0.0001	3.77	1074194.02	1.11
Pooled error	109	0.64	0.13	0.0001	3.50	872429.18	0.15
GCA:SCA ratio		0.73	0.53	1.00	0.65	0.56	0.67

*, **, and *** significant at 0.05, 0.01 and 0.001 probability levels respectively.

Enumb-Entry number

Inbred lines 8, 12, 14, 16, and 17 showed negative general combining ability effects (Table 4.3) fro stem borer damage. In season wise analysis the same trend of negative general combining ability was observed.

Table 4.3 Estimates of general combining ability effects of the 20 inbred lines grown at Kiboko under *Chilo partellus* stem borer infestation.

Inbred line	Anthesis Silking interval (d)	Ear height (Cm)	Plant Height (Cm)	Ear rot (no.)	Root lodge (%)	Shoot lodge (%)	Yield (t/ha)	Exit holes (no.)	Stem borer damage	Tunnel Length (Cm)	Yield loss (T/HA)
1	3.1	-2.8	-0.2	3.5	0.2	0.6	-345.2	-0.2	0.2	-0.6	0.5
2	0.7	-0.3	-0.1	-0.6	0.0	-0.1	62.3	0.0	0.1	-0.1	-125.9
3	0.4	2.0	1.5	-0.7	0.2	0.2	-0.5	-0.1	0.0	-0.2	-84.6
4	-0.6	-0.4	-1.4	-0.2	0.1	-0.5	-344.2	0.1	0.0	0.7	-600.3
5	0.2	-1.7	-2.4	0.8	0.0	0.1	-479.7	0.1	0.0	0.1	-128.5
6	-0.2	-0.7	0.7	0.9	-0.1	0.0	-226.4	-0.3	0.0	-0.9	4.8
7	0.6	-3.9	-4.6	0.4	-0.2	0.0	-154.3	0.1	0.0	0.4	59.8
8	2.7	0.3	1.5	-0.7	0.2	0.4	-5.0	-0.3	-0.1	-0.7	-231.8
9	-1.2	-3.5	-3.5	0.3	0.1	0.2	-295.9	0.0	0.0	0.1	-827.2
10	-0.5	-1.6	-1.2	-0.4	0.1	1.1	259.8	0.1	0.0	-0.1	120.6
11	-0.2	-0.7	0.9	-0.5	0.1	0.0	-52.6	0.2	0.0	0.5	67.8
12	-0.4	3.2	3.6	-0.9	-0.2	-0.3	427.8	0.1	-0.1	0.2	274.0
13	-1.4	-0.9	-0.4	-1.0	-0.3	0.0	77.1	0.4	0.0	1.0	-86.1
14	-0.4	1.2	0.8	-0.1	-0.1	0.1	-96.4	-0.1	-0.1	-0.4	159.7
15	-0.6	-1.1	-1.4	-1.8	0.0	-0.1	-213.9	0.0	0.0	0.1	111.6
16	-1.6	1.3	1.0	2.0	-0.1	-0.4	59.7	0.0	-0.1	0.0	240.6
17	-0.3	1.4	0.5	1.0	-0.1	0.1	-37.2	-0.1	-0.1	-0.3	294.0
18	-0.3	1.3	4.6	-1.4	-0.2	-0.1	577.5	-0.2	0.0	-0.1	218.1
19	-0.1	2.5	2.4	-1.1	0.2	-0.5	318.5	-0.1	0.0	-0.5	285.7
20	-0.1	4.7	4.1	0.1	0.1	-0.8	520.6	0.1	0.0	0.5	307.9

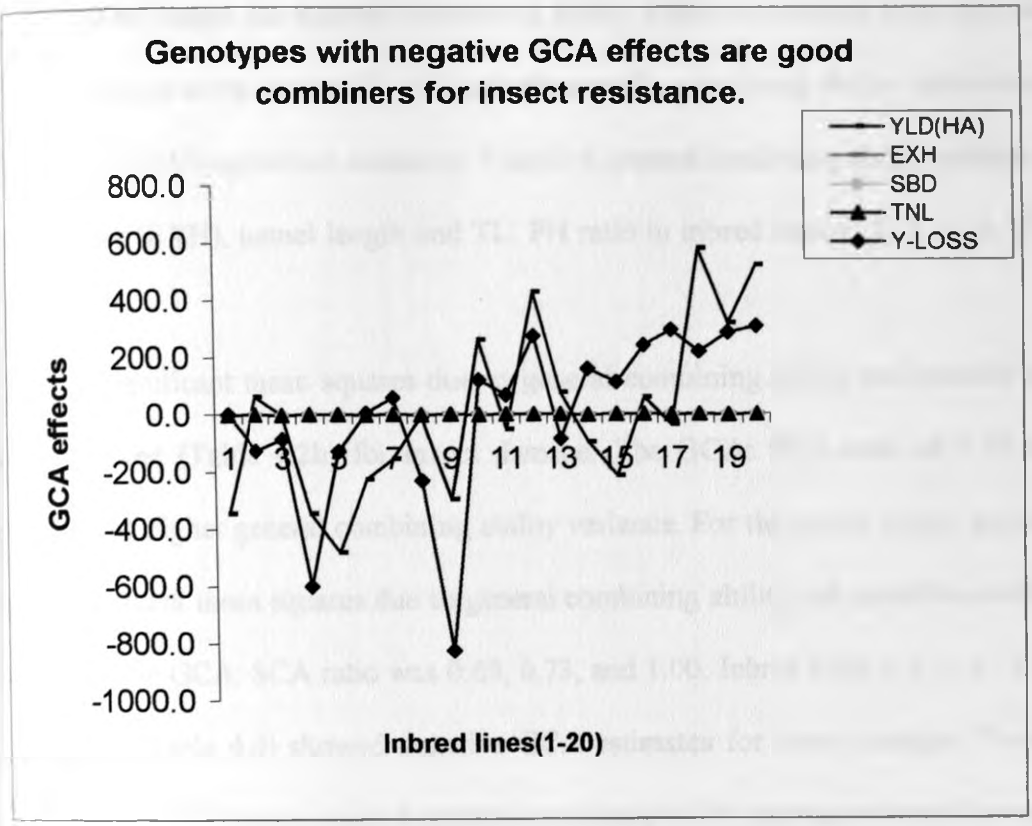

Fig. 4. GCA effects of maize genotypes (inbred lines) under *Chilo partellus* infestation in Kiboko.

A combined analysis for the two seasons revealed that inbred lines 8, 12, 16, and 17, were good general combiners for resistance to insect damage (Table 4.3). However not all of these entries were good general combiners for yield, among the four only entry 12 had appositive GCA for yield (Figure 4). This is an indication that general combining ability is not a reliable basis for the estimation of specific combining ability of a variety (Borojevic, 1990).

The mean squares for other insect infestation traits at Kiboko also showed significance due to general combining ability and specific combining ability. The GCA: SCA ratio for the number of exit holes was 0.79 (Table 4.2a), this was an indication that the general combining ability effect was higher than the specific combining ability effect. The ratio of GCA: SCA for Tunnel length (TL) was 0.82 and that of tunnel length: plant height ratio (TL: PH) was 9.80.

For the tunnel length the general combining ability effect was higher than the specific combining ability variances while for the TL: PH ratio the specific combining ability variances were higher than the general combining ability variances. Negative general combining ability estimates were observed in exit holes (EXH), tunnel length and TL: PH ratio in inbred lines 1, 2, 3, 6, 8, 14, 16, 17, 18, and 19.

At Embu significant mean squares due to general combining ability and specific combining ability were observed (Table 4.2b) for insect damage. The GCA: SCA ratio of 0.53 was observed, an indication of higher general combining ability variance. For the tunnel length, exit holes and TL: PH ratio, significant mean squares due to general combining ability and specific combining ability were observed. The GCA: SCA ratio was 0.65, 0.73, and 1.00. Inbred lines 1, 3, 5, 6, 7, 8, 10, 11, 14, 16, 18, and 19 (Table 4.4) showed negative GCA estimates for insect damage. For exit holes, tunnel length, and TL: PH ratio, negative general combining ability estimates were observed. Inbred lines 1, 3, 6, 11, and 20 exhibited a significant negative general combining ability estimates for exit holes. The general combining ability estimates in season one and two were negative in some inbred lines for insect infestation, exit holes, tunnel length and TL: PH ratio. Inbred lines 1, 3, 5, 6, 7, 8, 10, 16, 18, and 20, showed negative general combining abilities. For exit holes inbred lines 1, 3, 5, 6, 7, 8, 9, 10, 11, 16, and 20 showed negative general combining ability estimates. The same inbred lines exhibited negative general combining ability estimates in tunnel length and TL: PH ratio. Similarly as it was observed in Kiboko, the inbred lines which were good combiners for insect infestation were not good combiners for yield and other good agronomic characteristics (Figure 5).

Table 4.4 Estimates of general combining ability effects of the 20 inbred lines grown at Embu under *Busseola fusca* infestation.

Entry	Anthesis Silking Interval (d)	Ear Height (Cm)	Ear aspect Score(1-5)	Plant height (Cm)	Yield (t/ha)	Exit holes (no.)	Stem borer damage Score (1-9)	Tunnel length (Cm)	Yield loss (t/ha)
1	0.1	-1.7	-0.3	-3.5	-60.5	-0.3	-0.1	-0.6	-70.8
2	0.3	-2.7	-0.1	-0.2	110.3	0.2	0.1	0.5	-141.2
3	0.0	-0.9	0.3	1.3	410.9	-0.1	0.0	-0.4	131.4
4	0.2	-2.8	0.0	-4.1	41.9	0.0	0.1	0.5	123.9
5	0.3	-3.9	0.0	-1.2	83.6	-0.1	0.0	0.1	-274.3
6	0.4	0.9	0.0	0.2	28.3	-0.2	0.0	-0.6	-57.9
7	0.1	-1.3	-0.1	0.9	-151.8	-0.2	-0.1	-0.3	-145.1
8	0.3	-0.9	0.2	1.4	19.7	0.0	-0.1	-0.2	-236.4
9	-0.3	-2.3	0.0	-0.8	-291.9	0.1	0.0	-0.1	-115.3
10	0.3	-0.3	0.0	-0.9	-144.4	-0.1	0.0	0.1	-463.8
11	0.2	-0.4	0.1	3.4	-218.4	-0.1	0.0	-0.1	-31.0
12	-0.2	8.2	0.1	3.9	19.1	0.0	0.1	0.0	200.0
13	-0.2	-4.3	-0.2	-3.5	-62.6	0.3	0.1	0.3	211.8
14	-0.2	-1.1	-0.1	-6.0	-372.6	0.3	0.0	0.8	29.6
15	-0.2	1.3	0.0	4.4	95.4	0.1	0.0	0.2	258.7
16	0.0	2.4	0.0	2.0	-29.0	0.0	0.0	0.1	55.2
17	-0.3	0.0	0.0	-3.2	62.4	0.1	0.0	0.1	158.5
18	-0.3	8.6	0.1	1.5	179.1	0.0	0.0	0.0	143.4
19	-0.3	2.4	0.0	1.7	-53.9	0.2	0.0	0.1	41.2
20	-0.1	-0.3	0.1	2.4	314.0	-0.1	-0.1	-0.3	196.1

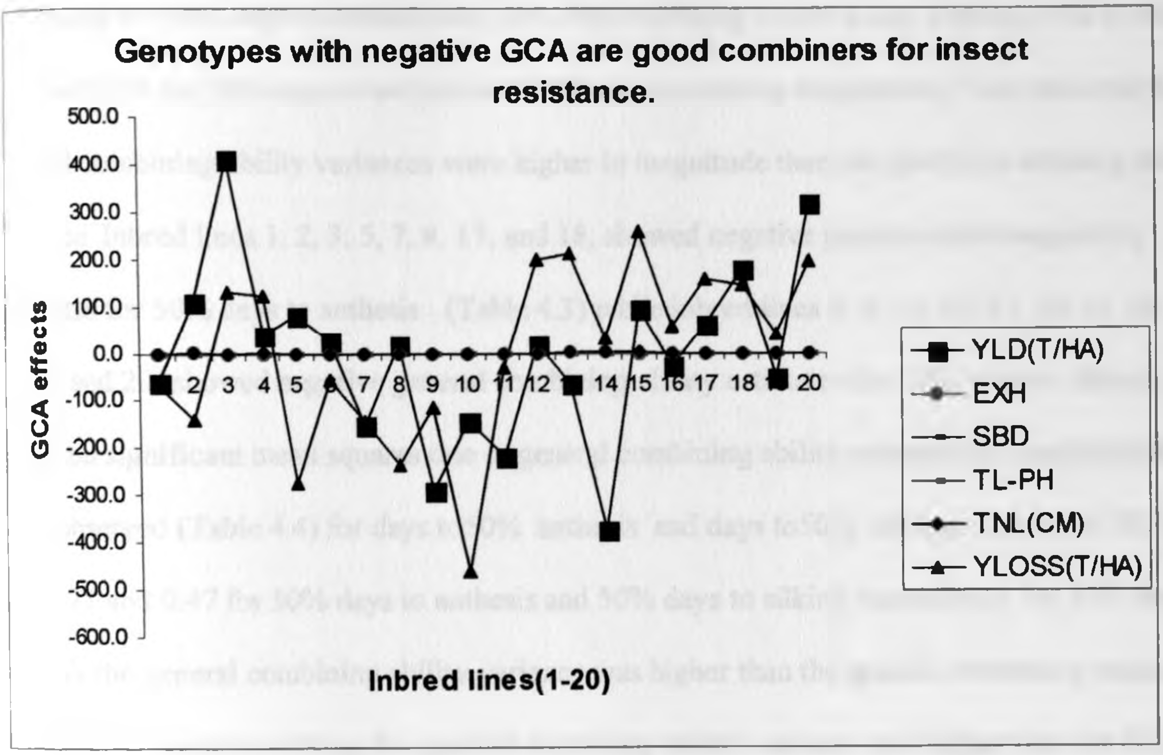

Fig. 5. GCA effects of maize genotypes (inbred lines) under *Busseola fusca* infestation in Embu

4.2.2 Days to flowering

The mean squares due to general combining ability and specific combining ability at Kiboko were significant for 50% days to anthesis and 50% days to silking (Table 4.2a). The GCA: SCA ratio was 0 87 and 0.58 for 50% days to anthesis and 50% days to silking respectively. This indicated that the general combining ability variances were higher in magnitude than the specific combining ability variance. Inbred lines 1, 2, 3, 5, 7, 8, 17, and 18, showed negative general combining ability estimates for 50% days to anthesis (Table 4.3) while inbred lines 4, 9, 10, 12, 13, 14, 15, 16, 17, 18,19, and 20, showed negative general combining ability estimates for 50% days to silking.

At Embu significant mean squares due to general combining ability and specific combining ability were observed (Table 4.4) for days to50% anthesis and days to50% silking. The GCA: SCA ratio was 0.71 and 0.47 for 50% days to anthesis and 50% days to silking respectively, for 50% days to anthesis the general combining ability variance was higher than the specific combining variance while for 50% days to silking the specific combining ability variance was higher than the GCA variance. Negative general combining ability estimates were observed in inbred lines 3, 5, 6, 7, 9, 12, 13, 17, 18, 19, and 20, (Table 4.4) for 50% days to silking entries 2, 3, 4, 5, 6, 7, 8, 9, 10, and 20, showed negative general combining ability estimates. Significant mean squares due to general combining ability and specific combining ability for Anthesis silking interval (ASI) was observed at both Kiboko and Embu. The GCA: SCA ratio was 1.32 at Kiboko and 0.76 at Embu (Tables 4.2). Sanghi *et al.*, (1983) stressed on the importance of GCA effects for day to tasseling, silking and maturity. At Kiboko inbred lines 4, 6, 9, 10-20, exhibited negative general combining ability estimates for ASI while at Embu inbred lines 9, 12, 13, 14, 15, 17, 18, 19, and 20, showed negative general combining ability estimates (Table 4.2 a, and b) respectively.

4.2.3 Plant height

Inbred lines which had positive and negative general combining abilities were observed, it was also observed that lines which had positive GCA had positive GCA for yield and vice versa (Table 4.2a). Kimani (1984) reported a highly significant GCA effects for plant height. Inbred lines with significant general combining ability effects were identified. The mean squares due to general combining ability and specific combining ability were significant for plant height in both Kiboko and Embu (Tables 4.3 and 4.4). Revilla *et al.* (1999) also reported significant GCA for plant height. The GCA: SCA ratio was 0.48 and 0.64 for Kiboko and Embu respectively (Tables 4.2a&b). At Kiboko inbred lines 1, 2, 4, 5, 9, 10, 13, 14, and 17 showed negative general combining ability estimates. At Embu inbred lines 1, 2, 4, 5, 9, 10, 13, 14, and 17, showed negative general combining ability estimates for plant height.

4.2.4 Ear height

Significant mean squares due to general combining ability and specific combining ability were observed at both Kiboko and Embu for ear height (Tables 4.2a and 4.2b). Qadri *et al* (1983) also reported significant GCA and SCA for ear height. The GCA: SCA ratio was 0.60 and 0.90 at Kiboko and Embu respectively. This is an indication that the general combining ability variances were higher in magnitude than the specific combining ability variances. Negative general combining ability estimates for ear height were observed at Kiboko and Embu. At Kiboko and Embu inbred lines 1, 2, 4, 5, 6, 7, 9, 10, 11, 13, and 15 had negative general combining ability while at Embu inbred lines 1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 13, 14,and20 had negative general combining ability (Tables 4.3 and 4.4).

4.2.5 Ear Aspect

The mean due to general combining ability and specific combining ability at Kiboko and Embu showed significance for the ear aspect. The GCA: SCA ratio was 0.46 and 0.67 at Kiboko and

Embu respectively (Tables 4.2a&b). This was a good indication that the SCA variances were higher than the general combining ability variances. Inbred lines 2, 3, 7, 8, 10, 11, 13, 14, 15, 17 and 18 were found to be good combiners for ear aspect at Kiboko (Table 4.3) while inbred lines 3, 8, 10, 11, 17, 18, 19 and 20 were the best combiners for the ear aspect at Embu (Table 4.4).

4.2.6 Grain yield

Combining ability analysis revealed significant mean squares due to general combining ability and specific combining ability. Ahmad and Saleem (2003) reported significant mean squares for grain yield in maize. The GCA: SCA ratio for Kiboko and Embu was 0.50 and 0.35 respectively (Table 4.2a & b). This was an indication that the specific combining ability variances were higher than the general combining ability variances. It also indicated that the specific combining ability variances were more important than the general combining ability variances. Significant GCA effects for yield was revealed, a similar observation was reported by Kimani (1984). Inbred lines 10, 12, 18, 19 and 20 were the best general combiners for yield at Kiboko (Table 4.3) while inbred lines 2, 3, 5, 15, 18 and 20 were found to have good general combining ability for yield at Embu (Table 4.4).

4.2.7 Yield loss

Significant mean squares due to general combining ability and specific combining ability were observed for yield loss at Kiboko and Embu (Tables 4.2a & b). The GCA: SCA ratio was 1.20 and 0.56 at Kiboko and Embu respectively. At Kiboko the general combining ability and specific combining ability variances were found out to be important. At Embu the specific combining ability variances were more important than the general combining ability variances.

Negative general combining ability estimates were observed at Kiboko and Embu (Tables 4.3 and 4.4). Inbred lines 2, 3, 4, 8, 9, and 13 showed negative general combining ability estimates at Kiboko while at Embu inbred lines 1, 2, 5, 7, 8, 9, and 11 showed negative general combining ability estimates.

Significant SCA effects were observed both at Embu and Kiboko. This was observed in single crosses: 1x16, 8x18, 7x14, 3x10, 3x13, and 1x7 in Embu (Table 4.6.). At Kiboko single crosses 7x16, 5x20, 3x10, 1x7, 1x13, and 10x17 gave significant negative SCA effects, which are desirable for insect resistance (Table 4.5.). Significant SCA effects were observed among the F1's in plant height, ear height and yield. A similar observation was made by Kimani (1984). Beck *et al.* (1990) also found significant SCA effects for ear height.

Table 4.5 Estimates of specific combining ability effects of the 20 best single crosses grown at Kiboko under *Chilo partellus* infestation.

Rank	Entry	Crosses	Anthesis Silking interval (days)	Plant height	Ear height	Yield (t/ha)	Yield Loss (t/ha)	Insect damage Score(1-9)	Exit Holes (no.)	Tunnel Length (cm)	Tunnel length plant height ratio
1	11	1x16	-0.74	-16.95	-18.84	-859.56	-976.39	-0.56	-0.05	-0.77	-0.006
2	81	8x20	1.32	21.88	17.22	268.41	-399.77	-0.47	-0.43	-1.37	-0.01
3	69	7x16	0.41	-4.4	-10.9	-1156.04	-976.35	-0.43	-0.65	-1.05	-0.004
4	55	5x20	0.25	5.89	0.74	91.74	-175.39	-0.41	-0.04	0.83	0.004
5	25	3x10	0.5	-12.76	-4.4	-1510.04	-1153.09	-0.39	-0.67	-1.78	-0.007
6	30	3x15	-0.21	-3.59	3.41	740.1	704.01	-0.37	-0.08	-1.43	-0.007
7	2	1x7	0.99	28.04	18.03	349.92	596.82	-0.36	0.42	-0.98	-0.007
8	86	9x18	0.24	11.47	10.37	410.54	69.45	-0.33	-0.25	-0.93	-0.007
9	59	6x14	0.03	0.23	1.7	-991.15	107.95	-0.32	-0.71	-1.31	-0.007
10	8	1x13	1.43	-9.14	-4.61	-1603.22	-609.57	-0.29	0.02	0.21	0.002
11	23	3x8	0.15	-9.74	-0.54	-1502.02	-660.48	-0.28	0.33	-1.08	-0.005
12	60	6x15	-0.02	-8.42	1.71	318.97	-432.37	-0.28	-0.26	-1.09	-0.005
13	64	6x20	-0.5	-2.03	1.28	567.35	1135.58	-0.28	-0.88	-1.09	-0.007
14	91	10x17	-0.39	4.05	4.81	1147.62	560	-0.28	-0.4	-0.27	-0.002
15	58	6x13	0.51	-4.64	0.54	-164.15	-604.68	-0.26	-0.05	-1.25	-0.006
16	93	10x19	0.65	-0.12	-3.34	-369.19	-274.19	-0.23	-0.16	-0.24	-0.002
17	87	9x19	-0.31	-11.25	0.73	-817	-543.14	-0.22	-0.16	-0.68	-0.005
18	80	8x19	0.85	-16.11	-18.26	-2431.85	-1454.2	-0.2	-0.39	-1.16	-0.005
19	48	5x13	1.27	5.23	4.24	-554.87	-673.45	-0.19	-0.35	-0.86	-0.006
20	61	6x16	0.72	-13.82	-13.05	-1254.65	-1319.98	-0.19	-0.59	-1.17	-0.006

Inbred lines 10,19,12,18 and 20 gave very positive GCA values for yield, but for the Specific combining ability, where these lines are used in the single cross formation combinations, all of them did not give positive SCA values for yield. Qadri et al. (1983) reported significant SCA for yield. Entries 10, 18 and 20 gave positive SCA values in their single crosses (Table 4.5). This can indicate that GCA is not a reliable basis for the estimation of specific combining ability of a variety. Similar observation was made by Borojevic (1990).

Table 4.6 Estimates of specific combining ability effects of the 20 best single crosses grown at Embu under *Busseola fusca* infestation.

Rank	Entry	Crosses	Anthesis Silking interval (days)	Plant height (cm)	Ear Height (cm)	Yield (t/ha)	Yield Loss (t/ha)	Insect damage Score(1-9)	Exit Holes (no.)	Tunnel Length (cm)	Tunnel length plant height ratio
1	11	1x16	-0.75	-18.84	-16.95	-859.56	-976.39	-0.57	-0.05	-0.77	-0.006
2	79	8x18	1.32	21.89	17.22	268.41	-399.77	-0.48	-0.44	-1.38	-0.01
3	67	7x14	0.42	-4.4	-10.9	-1156.1	-976.35	-0.43	-0.65	-1.05	-0.004
4	53	5x18	0.25	5.89	0.74	91.74	-175.4	-0.41	-0.05	0.84	0.004
5	25	3x10	0.5	-4.41	-12.77	-1510.1	1153.09	-0.39	-0.67	-1.79	-0.007
6	28	3x13	-0.21	-3.6	3.41	740.1	704.01	-0.38	-0.09	-1.44	-0.007
7	2	1x7	0.99	28.04	18.03	349.92	596.82	-0.36	0.42	-0.98	-0.007
8	84	9x16	0.25	11.47	10.38	410.55	69.45	-0.33	-0.26	-0.93	-0.007
9	57	6x12	0.03	0.23	1.7	-991.16	107.96	-0.32	-0.72	-1.31	-0.007
10	8	1x13	1.44	-4.62	-9.14	-1603.2	-609.57	-0.29	0.02	0.21	0.002
11	23	3x8	0.16	-0.55	-9.75	-1502.2	-660.48	-0.29	0.33	-1.08	-0.005
12	62	6x17	-0.51	-2.03	1.28	567.35	1135.58	-0.29	-0.88	-1.1	-0.007
13	58	6x13	-0.03	-8.43	1.71	318.98	-432.37	-0.28	-0.26	-1.1	-0.005
14	89	10x15	-0.38	4.06	4.81	1147.63	560	-0.28	-0.4	-0.28	-0.002
15	56	6x11	0.51	-4.65	0.54	-164.15	-604.69	-0.26	-0.05	-1.26	-0.006
16	91	10x17	0.65	-0.12	-3.35	-369.19	-274.19	-0.23	-0.16	-0.25	-0.002
17	85	9x17	-0.31	-11.25	0.74	-817.01	-543.15	-0.22	-0.17	-0.69	-0.005
18	59	6x14	0.73	-13.83	-13.06	-1254.7	-1319.98	-0.2	-0.59	-1.17	-0.006
19	78	8x17	0.85	-16.12	-18.26	-2431.9	-1454.21	-0.2	-0.39	-1.16	-0.005
20	33	3x18	1.04	-3.18	0.9	-316.32	137.22	-0.19	-0.68	-0.34	-0.002

Other traits that were looked at exhibited positive and negative SCA effects (Tables 4.5 and 4.6) in Embu and Kiboko. Significant positive SCA effects were observed for yield in both Embu and Kiboko. Crosses 4x18, 3x13, 4x16, and 12x20 exhibited highly positive SCA effects at both

Kiboko and Embu. For yield loss the single crosses exhibited positive and negative effects, crosses 1x16 and 5x18 exhibited highly significant negative SCA effect at Embu (Table 4.6). The significance of GCA and SCA indicated that both additive and non-additive gene effects were important for the control of these characters (Prasad et al., 1988).

4.3 CORRELATIONS

Results of phenotypic correlations between yield and yield components at Kiboko and Embu are presented in tables 4.7 (a),(b),(c),(d) ,(e),(f),(g),and (h).

4.3.1 Correlations between yield and yield components of the F1 hybrids.

At Kiboko under infestation with *Chilo partellus*, highly significant positive correlations were observed between yield and plant height (r =0.44), ear height (r =0.33) and ear aspect (r =0.60) (P= 0.001) and between yield and number of ears (r =0.26) (P=0.001) in the first season treatment one (infested).Jenkins, (1929), Odongo, (1986) and Trifunovic, (1988) also found a positive correlation between yield, plant height and ear height. In treatment two (protected) highly significant positive correlations were observed between yield and plant height (r =0.48), ear height (r =0.35), number of ears (r =0.49), EPP (r =0.09) and ear aspect (r =0.51) (P= 0.001)

Yield had highly significant negative (P=0.001) correlation with 50% days to anthesis (r = -0.40), 50% days to silking (r = -0.24), ear rot (r = -0.42). Yield and insect damage had a negative correlation (r =-0.04). A non significant negative correlation between yield and shoot lodge (r =-0.02) was also observed.

In treatment two significant negative correlation was observed between yield and 50% days to anthesis (r =-0.33) and non significant negative correlation between yield and 50% days to silking (r =-0.15), shoot lodge (r =-0.13) (P=0.001) and (P=0.05) respectively.

Similar observations were made by Chopra (2001), yield is negatively correlated to early maturity. A highly significant negative correlation was observed between yield and ear rot (r =-0.28) (P= 0.001). Butron et al. (1999) observed total independence between stem tunneling damage and the ear damage.

Table 4.7(a) Phenotypic correlations among yield and yield components for the F1 hybrids at Kiboko under infestation with *Chilo partellus* season one.

	AD	*SD*	*ASI*	*RL*	*SL*	*NP*	*NE*	*EA*	*ER*	*PH*	*EH*	*EXH*	*TNL*	*EPP*	*YLD*	*TLPH*	*SBD2*
AD																	
SD	0.83																
ASI	0.15	0.67															
RL	-0.13	0.00	0.17														
SL	0.03	0.03	0.01	0.37													
NP	-0.03	-0.04	-0.03	0.04	0.19												
NE	0.14	0.14	0.06	0.15	0.17	0.74											
EA	-0.25	-0.16	0.04	0.02	0.06	0.33	0.17										
ER	0.16	0.08	-0.07	0.05	0.07	0.10	0.15	-0.56									
PH	-0.29	-0.26	-0.08	0.01	-0.01	0.27	0.25	0.36	-0.24								
EH	-0.18	-0.18	-0.09	-0.02	-0.05	0.24	0.31	0.28	-0.22	0.89							
EXH	0.11	0.24	0.28	-0.08	-0.05	-0.04	-0.09	0.04	-0.19	0.21	0.10						
TNL	-0.21	-0.15	0.02	-0.02	-0.17	0.07	0.09	-0.02	-0.03	0.16	0.08	0.31					
EPP	0.26	0.25	0.10	0.12	0.01	-0.30	0.38	-0.19	0.11	-0.06	0.04	-0.08	-0.01				
YLD	-0.40	-0.24	0.11	0.09	-0.02	0.40	0.26	0.60	-0.42	0.44	0.33	0.03	0.10	-0.21			
TLPH	-0.20	-0.20	-0.09	-0.08	-0.16	0.10	0.15	-0.05	0.05	0.17	0.13	0.20	0.88	0.02	0.08		
SBD2	0.05	0.21	0.30	0.01	0.00	-0.06	-0.11	0.09	-0.11	-0.02	0.00	0.46	0.12	-0.05	-0.04	0.03	

Keys:

ASI = Anthesis silking interval.
EH = Ear height in centimeters.
TNL = Tunnel length.
PH = Plant height in centimeters.
RLP = Root lodge percentage.
YLD = Yield in tonnes per hectare.
EXH = Exit holes.

SBD = Stem borer damage
TLPH = Tunnel length plant height ratio.
Y-LOSS = Yield loss in tonnes per hectare
ER = Ear rot (number of rotten ears).
SLP = Shoot lodge percentage.

Table 4.7(b) Phenotypic correlations among yield and yield components for the F1 hybrids at Kiboko Protected from stem borer damage season one.

	AD	*SD*	*ASI*	*PH*	*EH*	*RL*	*SL*	*NP*	*NE*	*EPP*	*EA*	*ER*	*YLD*
AD													
SD	0.82												
ASI	0.15	0.67											
PH	-0.34	-0.31	-0.08										
EH	-0.21	-0.21	-0.09	0.88									
RL	-0.11	0.02	0.11	-0.02	0.00								
SL	0.08	0.23	0.22	-0.13	-0.15	0.25							
NP	-0.05	0.08	0.21	0.16	0.21	-0.04	-0.01						
NE	0.00	0.13	0.21	0.13	0.18	0.07	0.08	0.75					
EPP	-0.01	0.01	0.00	-0.02	-0.03	0.18	0.12	-0.30	0.38				
EA	-0.33	-0.20	0.09	0.37	0.26	0.00	-0.07	0.25	0.22	0.01			
ER	0.14	0.06	-0.04	-0.32	-0.19	0.00	-0.07	0.29	0.24	-0.10	-0.40		
YLD	-0.33	-0.15	0.15	0.48	0.35	0.00	-0.13	0.47	0.49	0.09	0.51	-0.28	

Keys:

ASI = Anthesis silking interval.

EH = Ear height in centimeters.

TNL = Tunnel length.

PH = Plant height in centimeters.

RLP = Root lodge percentage.

YLD = Yield in tonnes per hectare.

EXH = Exit holes.

.SBD = Stem borer damage

TLPH = Tunnel length plant height ratio.

Y-LOSS = Yield loss in tonnes per hectare

ER = Ear rot (number of rotten ears).

SLP = Shoot lodge percentage.

Table 4.7 (c) Phenotypic correlations among yield and yield components for the F1hybrids at Kiboko under infestation with *Chilo partellus* season two.

	AD	*SD*	*ASI*	*PH*	*EH*	*RL*	*SL*	*NP*	*NE*	*EPP*	*EA*	*ER*	*YLD*	*EXH*	*TNL*	*TLPH*	*SBD*
AD	1																
SD	0.89	1.00															
ASI	0.30	0.70	1.00														
PH	-0.29	-0.27	-0.12	1.00													
EH	-0.14	-0.09	0.03	0.87	1.00												
RL	0.05	-0.01	-0.10	-0.19	-0.21	1.00											
SL	0.02	-0.01	-0.04	0.00	-0.04	0.00	1.00										
NP	-0.26	-0.24	-0.09	0.31	0.28	-0.24	-0.09	1.00									
NE	-0.26	-0.21	-0.04	0.38	0.42	-0.29	-0.15	0.67	1.00								
EPP	-0.09	-0.05	0.04	0.20	0.30	-0.17	-0.13	-0.04	0.71	1.00							
EA	-0.51	-0.49	-0.23	0.66	0.49	-0.12	0.00	0.25	0.20	0.03	1.00						
ER	0.15	0.15	0.08	-0.23	-0.22	0.03	0.06	0.01	0.01	0.00	-0.38	1.00					
YLD	-0.58	-0.59	-0.34	0.77	0.60	-0.20	0.05	0.41	0.45	0.21	0.79	-0.23	1.00				
EXH	0.29	0.23	0.04	0.05	0.00	0.21	0.14	-0.16	-0.20	-0.11	-0.12	0.10	-0.01	1.00			
TNL	0.05	-0.03	-0.14	0.19	0.14	0.03	0.07	0.00	-0.09	-0.11	-0.01	0.14	0.15	0.54	1.00		
TLPH	0.13	0.03	-0.13	0.19	0.17	-0.03	0.08	-0.01	-0.04	-0.03	-0.08	0.16	0.11	0.54	0.89	1.00	
SBD	0.22	0.18	0.03	-0.02	-0.08	0.24	0.11	-0.11	-0.18	-0.13	-0.11	0.12	0.00	0.77	0.54	0.49	1

Keys:

ASI = Anthesis silking interval.

EH = Ear height in centimeters.

TNL = Tunnel length.

PH = Plant height in centimeters.

RLP = Root lodge percentage.

YLD = Yield in tonnes per hectare.

EXH = Exit holes.

.SBD = Stem borer damage

TLPH = Tunnel length plant height ratio.

Y-LOSS = Yield loss in tonnes per hectare

ER = Ear rot (number of rotten ears).

SLP = Shoot lodge percentage.

able 4.7 (d) Phenotypic correlations among yield and yield components for the F1 hybrids at Kiboko protected from stem borer damage season two.

	AD	*SD*	*ASI*	*PH*	*EH*	*RL*	*SL*	*NP*	*NE*	*EPP*	*EA*	*ER*	*YLD*
AD													
SD	0.89												
ASI	0.30	0.70											
PH	-0.25	-0.23	-0.10										
EH	-0.10	-0.06	0.02	0.85									
RL	0.13	0.12	0.06	-0.01	0.08								
SL	-0.04	-0.01	0.03	-0.12	-0.13	-0.07							
NP	-0.11	-0.15	-0.14	0.16	0.07	0.07	-0.17						
NE	-0.27	-0.27	-0.14	0.27	0.28	-0.11	-0.15	0.54					
EPP	-0.22	-0.20	-0.07	0.16	0.24	-0.16	0.01	-0.22	0.69				
EA	-0.40	-0.41	-0.24	0.59	0.44	-0.08	0.01	0.22	0.15	-0.01			
ER	0.27	0.37	0.34	-0.23	-0.18	0.07	0.12	-0.15	-0.18	-0.09	-0.35		
YLD	-0.46	-0.47	-0.27	0.79	0.59	-0.15	-0.05	0.22	0.32	0.17	0.74	-0.39	1

At Embu treatment one, yield was positively and highly significant correlated with plant height (r =0.49), ear height (r =0.50), EPP (r =0.17), ear aspect (r = 0.49) and grain weight (r = 0.81) (P=0.001) (Tables 4.7e &g). Yield had a highly significant negative correlation with 50% days to anthesis (r = -0.37), and 50% days to silking (r = -0.38) at 0.1% probability level. Yield had a highly significant negative correlation with the insect damage (r = -0.59) (P=0.001). A non-significant negative correlation between yield and anthesis silking interval (r = -0.02) was also observed. In treatment two yield exhibited a significant positive correlation with grain weight (r =0.67), plant height (r = 0.36), ear height (r =0.36), ear aspect (r =0.45), number of ears (r =0.44) and ears per plant (r =0.19) (Tables 4.7 f& h). Significant negative correlation was observed between yield and 50% days to anthesis (r = -0.26) and 50% days to silking (r = -0.25) (P=0.05) and (P=0.01) respectively. Non-significant negative correlation was observed between yield and anthesis silking interval (r = -0.02).

Table 4.7 (e) Phenotypic correlations among yield and yield components for the F1 hybrids at Embu under infestation with *Busseola fusca* stem borer season one.

	AD	*SD*	*ASI*	*PH*	*EH*	*RL*	*SL*	*NP*	*NE*	*EPP*	*EA*	*ER*	*YLD*	*SBD*	*EXH*	*TNL*
AD																
SD	0.84															
ASI	0.48	0.88														
PH	-0.19	-0.29	-0.30													
EH	0.09	-0.02	-0.12	0.77												
RL	-0.03	0.01	0.03	-0.15	-0.19											
SL	-0.11	-0.07	-0.02	-0.49	-0.45	0.03										
NP	-0.15	-0.19	-0.17	0.54	0.46	-0.30	-0.29									
NE	-0.02	-0.19	-0.30	0.50	0.58	-0.13	-0.26	0.49								
EPP	0.04	-0.16	-0.29	0.31	0.45	-0.02	-0.15	0.11	0.91							
EA	-0.24	-0.40	-0.43	0.58	0.47	-0.18	-0.12	0.43	0.43	0.30						
ER	-0.03	0.11	0.20	-0.13	-0.19	0.05	-0.07	-0.03	-0.10	-0.11	-0.70					
YLD	-0.21	-0.44	-0.53	0.71	0.63	-0.18	-0.40	0.45	0.59	0.47	0.76	-0.48				
SBD	0.28	0.23	0.13	-0.02	-0.12	-0.04	0.01	0.05	-0.05	-0.09	-0.04	-0.09	0.00			
EXH	0.30	0.19	0.05	0.14	0.02	-0.07	-0.14	0.02	0.03	0.02	0.02	-0.06	0.12	0.80		
TNL	0.08	-0.02	-0.10	0.19	0.03	-0.07	-0.10	0.20	0.01	-0.07	0.14	-0.06	0.18	0.57	0.71	
TLPH	0.00	-0.08	-0.13	0.21	0.04	-0.09	-0.03	0.18	0.04	-0.03	0.16	-0.11	0.20	0.50	0.63	0.90

Keys:

ASI = Anthesis silking interval.

EH = Ear height in centimeters.

TNL = Tunnel length.

PH = Plant height in centimeters.

RLP = Root lodge percentage.

YLD = Yield in tonnes per hectare.

EXH = Exit holes.

SBD = Stem borer damage

TLPH = Tunnel length plant height ratio.

Y-LOSS = Yield loss in tonnes per hectare

ER = Ear rot (number of rotten ears).

SLP = Shoot lodge percentage.

Table 4.7(f) Phenotypic correlations among yield and yield components for the F1 hybrids at Embu protected from stem borer damage season one.

	AD	*SD*	*ASI*	*PH*	*EH*	*RL*	*PRL*	*SL*	*PSL*	*NP*	*NE*	*EPP*	*EA*	*ER*	*GW*	*MOI*
AD																
SD	0.71															
ASI	-0.29	0.47														
PH	-0.14	-0.12	0.01													
EH	-0.18	-0.19	-0.02	0.81												
RL	0.05	0.10	0.07	-0.02	0.01											
SL	0.03	0.03	0.00	-0.04	-0.01	0.05	0.03									
NP	-0.11	-0.18	-0.10	0.17	0.27	0.10	-0.03	0.04	0.03							
NE	0.00	-0.06	-0.08	0.16	0.27	0.06	-0.01	0.13	0.09	0.71						
EPP	0.08	0.10	0.04	0.03	0.07	-0.03	0.00	0.23	0.15	-0.10	0.60					
EA	-0.24	-0.29	-0.10	0.23	0.27	-0.09	-0.09	-0.10	-0.13	0.29	0.22	-0.02				
ER	-0.12	-0.22	-0.14	0.11	0.07	-0.18	-0.18	0.02	0.04	0.26	0.31	0.13	-0.27			
YLD	-0.26	-0.25	-0.02	0.36	0.36	-0.05	-0.03	-0.06	-0.05	0.38	0.44	0.19	0.45	0.11	0.67	0.33

Keys:

ASI = Anthesis silking interval.

EH = Ear height in centimeters.

PH = Plant height in centimeters.

ER = Ear rot (number of rotten ears).

RLP = Root lodge percentage.

SLP = Shoot lodge percentage.

YLD = Yield in tonnes per hectare.

Table 4.7(g) Phenotypic correlations among yield and yield components for the F1 hybrids at Embu under infestation with *Busseola fusca* stem borer season two.

	AD	*SD*	*ASI*	*PH*	*EH*	*RL*	*SL*	*NP*	*NE*	*EPP*	*EA*	*ER*	*YLD*	*SBD*	*EXH*	*TNL*
AD																
SD	0.84															
ASI	0.48	0.88														
PH	-0.19	-0.29	-0.30													
EH	0.09	-0.02	-0.12	0.77												
RL	-0.03	0.01	0.03	-0.15	-0.19											
SL	-0.11	-0.07	-0.02	-0.49	-0.45	0.03										
NP	-0.15	-0.19	-0.17	0.54	0.46	-0.30	-0.29									
NE	-0.02	-0.19	-0.30	0.50	0.58	-0.13	-0.26	0.49								
EPP	0.04	-0.16	-0.29	0.31	0.45	-0.02	-0.15	0.11	0.91							
EA	-0.24	-0.40	-0.43	0.58	0.47	-0.18	-0.12	0.43	0.43	0.30						
ER	-0.03	0.11	0.20	-0.13	-0.19	0.05	-0.07	-0.03	-0.10	-0.11	-0.70					
YLD	-0.21	-0.44	-0.53	0.71	0.63	-0.18	-0.40	0.45	0.59	0.47	0.76	-0.48				
SBD	0.28	0.23	0.13	-0.02	-0.12	-0.04	0.01	0.05	-0.05	-0.09	-0.04	-0.09	0.00			
EXH	0.30	0.19	0.05	0.14	0.02	-0.07	-0.14	0.02	0.03	0.02	0.02	-0.06	0.12	0.80		
TNL	0.08	-0.02	-0.10	0.19	0.03	-0.07	-0.10	0.20	0.01	-0.07	0.14	-0.06	0.18	0.57	0.71	
TLPH	0.00	-0.08	-0.13	0.21	0.04	-0.09	-0.03	0.18	0.04	-0.03	0.16	-0.11	0.20	0.50	0.63	0.90

Keys:

ASI = Anthesis silking interval.

EH = Ear height in centimeters.

TNL = Tunnel length.

PH = Plant height in centimeters.

RLP = Root lodge percentage.

YLD = Yield in tonnes per hectare.

EXH = Exit holes.

.SBD = Stem borer damage

TLPH = Tunnel length plant height ratio.

Y-LOSS = Yield loss in tonnes per hectare

ER = Ear rot (number of rotten ears).

SLP = Shoot lodge percentage.

Table 4.7(h) Phenotypic correlations among yield and yield components for the F1 hybrids at Embu protected from stem borer damage season two.

	AD	*SD*	*ASI*	*PH*	*EH*	*RL*	*SL*	*NP*	*NE*	*EPP*	*EA*	*ER*
AD												
SD	0.84											
ASI	0.48	0.88										
PH	-0.17	-0.29	-0.31									
EH	0.09	-0.04	-0.15	0.78								
RL	0.10	0.10	0.07	-0.29	-0.16							
SL	0.00	0.04	0.06	-0.53	-0.46	0.21						
NP	0.05	-0.10	-0.20	0.26	0.29	-0.17	-0.16					
NE	-0.01	-0.16	-0.25	0.34	0.42	-0.13	-0.30	0.61				
EPP	-0.04	-0.14	-0.20	0.26	0.34	-0.04	-0.28	0.18	0.88			
EA	-0.18	-0.35	-0.41	0.48	0.43	-0.14	-0.25	0.15	0.26	0.22		
ER	-0.10	0.04	0.15	-0.05	-0.22	-0.06	-0.07	0.13	0.15	0.12	-0.65	
YLD	-0.25	-0.47	-0.54	0.69	0.59	-0.25	-0.36	0.32	0.41	0.30	0.72	-0.42

Keys:

ASI = Anthesis silking interval.

EH = Ear height in centimeters.

TNL = Tunnel length.

PH = Plant height in centimeters.

RLP = Root lodge percentage.

YLD = Yield in tonnes per hectare.

EXH = Exit holes.

.SBD = Stem borer damage

TLPH = Tunnel length plant height ratio.

Y-LOSS = Yield loss in tonnes per hectare

ER = Ear rot (number of rotten ears).

SLP = Shoot lodge percentage.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

5.1.1 Mean performance of genotypes

Most of the F1 hybrids performed well and yielded more than the two local checks in Kiboko and Embu. The F1 hybrids were early maturing compared to PH3253 and H513. Higher yields were obtained in the F1 hybrids under infestation due to their ability to resist insect damage. The yield losses margin for the F1 hybrids was minimal compared to the two local checks. The F1 hybrids performed differently due to the differences in parents combinations and as a result crosses which were susceptible to insect damage were exhibited, e.g. a cross between inbred line 8 and 14 gave a big yield loss margin compared to the rest of the F1 hybrids. The F1 hybrids were early maturing compared to the two local checks and this makes them suitable to be grown in the mid-altitude areas. The F1 hybrids which showed intermediate to high resistance levels as well as good agronomic quality can be tested for potential use by farmers while the ones which were showing high levels of resistance but lacking in agronomic performance can be used in breeding programs to incorporate resistance into more adapted but susceptible materials.

5.1.2 Combining ability

Significant general combining ability indicates contribution of additive genes for insect resistance. Thus, populations or lines of superior insect resistance can be developed from the inbred lines having good general combining ability effects, through a recurrent selection strategy, which increases the frequency of favorable genes with additive effects.

Significant positive phenotypic correlations were observed between yield and plant height, ear height, number of ears, ear aspect, exit holes and tunnel length. For the ear number, Khaemba, 1992 observed similar results. Jenkins, (1929), Odongo, (1986) and Trifunovic, (1988), also found a positive correlation between yield, plant height and ear height. Correlations among yield components indicated significant associations of plant height with ear height, ears per plant, ear aspect and tunnel length plant height ratio. A negative significant correlation between plant height and stem borer damage was observed, it was also found out that plants with higher insect damage scores stunted while the ones with a score of 9 became 'dead hearts' (Mutinda, 1996).

Plant height was found to have non-significant correlations with duration to flowering; Odongo (1986) made similar observation. In this investigation, selection for resistant varieties to stem borers would result in correlated responses for increased yield.

5.2 RECOMMENDATIONS

The recommendations that may be drawn from this study are;

1. Synthetics or composites can be formed from the inbred lines with good combining ability for resistance to *C. partellus* and *B. fusca* stem borers especially those involving entry 3 as the male, this could then be maintained by open pollination for two to three seasons (Chopra, 2001).
2. Good F1 hybrids resistant to stem borers could be obtained from crosses which included entry 3 as one of the parents and especially as the male parent. It gave crosses which showed consistent resistance to stem borers in both sites. These crosses were; 3x9, 3x10, 3x13, 3x14 and 3x18.

3. The F1 hybrids are early maturing compared to the two local checks and are therefore well suited to lowlands and medium potential areas and hence these hybrids can be recommended for further evaluation in these zones.
4. A synthetic composed of the F1 hybrids could be grown during both long and short rains in both medium potential and lowland areas where we have bimodal rainfall pattern since these hybrids mature earlier than H513 and PH3253, the farmers would benefit in terms of yield due to less yield loss margin from the F1 hybrids.
5. Not all of the 20 inbred lines were able to impart the resistance to stem borers' damage to their progenies, as would have been expected. Therefore more evaluations are needed and may be more screening towards insect resistance to both *C. partellus* and *B. fusca*. Crosses from lines which were closely related lost the vigor and hence they were not able to resist the damage from the stem borers.

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7.0 APPENDICES

Appendix I.

Mean performance of the 108 F1's and two local checks (PH3253 and H513) infested with *Chilo partellus* stem borer at Kiboko, Kenya.

ENT	ASI	PH	EH	NP	NE	EPP	EA	ER	YLD	Y-loss	SBD	EX	TNL	TLPH
1	1.5	164.1	92.1	8.3	10.2	1.2	6.0	0.2	5.6	1.6	2.5	1.1	2.7	0.02
2	2.3	150.7	84.1	6.7	8.5	1.4	5.7	2.0	4.6	1.1	2.8	1.2	2.8	0.02
3	1.5	169.0	87.4	7.0	7.0	1.0	7.8	0.2	6.0	2.0	2.9	0.8	1.4	0.01
4	1.2	166.6	90.5	7.0	7.7	1.1	6.2	0.5	6.1	1.2	3.0	1.0	2.8	0.02
5	1.0	140.6	75.4	7.2	7.3	1.1	5.5	1.0	4.3	1.6	3.3	1.4	3.7	0.03
6	0.7	141.3	74.8	7.8	7.7	1.0	5.7	1.0	4.2	0.6	2.5	1.2	3.4	0.02
7	1.7	160.3	80.8	8.0	8.0	1.0	6.7	1.2	5.2	1.8	3.1	2.0	5.3	0.03
8	1.7	140.5	74.8	6.2	6.5	1.1	5.8	0.2	4.4	1.0	3.1	1.1	3.7	0.02
9	1.2	150.7	81.2	6.2	6.5	1.0	6.0	0.3	4.6	1.0	2.7	0.4	1.0	0.01
10	0.0	122.0	67.3	5.0	6.3	1.3	3.7	1.5	2.1	1.0	2.4	0.7	3.2	0.02
11	0.7	125.1	64.3	7.0	7.5	1.1	4.0	3.2	2.2	0.8	2.6	0.9	3.2	0.02
12	0.8	144.0	68.2	8.2	8.0	1.0	5.5	0.7	4.4	1.5	2.8	1.5	4.8	0.03
13	1.2	153.0	88.4	7.5	8.0	1.1	7.0	0.5	4.7	0.8	2.4	0.7	2.4	0.01
14	2.2	180.9	95.4	7.5	7.7	1.0	5.2	0.7	4.1	4.1	5.3	3.5	11.1	0.06
15	2.2	180.9	95.4	7.5	7.7	1.0	5.2	0.7	4.1	4.1	5.3	3.5	11.1	0.06
16	0.0	149.5	82.0	8.2	8.2	1.0	6.2	0.8	5.8	1.3	2.5	0.6	1.9	0.01
17	1.8	162.3	93.2	7.0	8.8	1.3	6.8	0.7	5.9	1.6	2.5	1.2	3.3	0.02
18	1.3	167.1	85.7	7.8	8.2	1.0	6.8	1.0	5.1	0.5	2.8	0.8	2.4	0.01
19	1.8	175.3	96.4	7.3	8.7	1.2	6.2	0.5	6.4	1.3	2.8	0.8	1.8	0.01
20	-0.8	147.5	82.1	7.7	8.2	1.1	6.2	0.8	5.2	1.2	2.8	2.7	7.7	0.05
21	1.2	138.6	74.7	7.0	7.7	1.1	5.3	1.3	4.1	1.2	2.6	0.8	2.9	0.02

Appendix I continued

ENT	ASI	PH	EH	NP	NE	EPP	EA	ER	YLD	Y-loss	SBD	EX	TNL	TLP
22	1.3	144.2	76.2	8.2	9.3	1.1	6.2	0.8	5.0	1.3	2.8	1.0	4.0	0.03
23	1.5	143.1	72.4	5.5	6.8	1.3	6.0	0.3	2.5	1.3	2.7	0.8	1.8	0.01
24	0.5	150.6	83.2	6.5	6.5	1.0	6.0	0.2	4.3	1.4	2.3	0.4	0.8	0.01
25	1.0	122.0	62.5	6.0	6.5	1.1	3.8	1.3	3.4	1.3	2.8	1.1	3.0	0.03
26	0.7	144.0	74.5	7.0	7.5	1.1	5.5	1.0	3.2	1.2	2.9	1.0	2.6	0.02
27	0.8	175.4	92.9	7.0	7.0	1.0	6.7	0.3	5.6	1.0	2.8	1.2	4.9	0.03
28	1.0	155.0	86.3	8.2	8.8	1.1	5.2	1.5	4.9	0.8	2.5	1.2	3.4	0.02
29	0.5	157.6	81.2	8.0	8.2	1.0	6.0	0.8	5.2	1.1	2.3	0.6	1.7	0.01
30	1.5	163.9	93.1	6.0	7.2	1.2	6.5	1.0	4.7	1.7	2.7	1.1	2.7	0.02
31	1.5	161.8	92.5	6.5	8.5	1.4	5.5	0.8	5.2	1.3	2.6	2.0	5.7	0.03
32	-0.3	178.9	96.0	8.2	8.7	1.1	7.3	0.2	6.5	1.3	2.4	1.8	4.8	0.03
33	-1.0	152.4	82.8	7.5	8.0	1.1	6.5	0.5	5.6	1.1	3.0	1.3	6.4	0.04
34	1.3	161.9	81.6	8.2	8.0	1.0	6.5	0.5	5.0	0.9	2.7	1.1	3.3	0.02
35	1.5	144.8	77.1	7.0	7.3	1.1	5.8	0.5	4.1	1.5	2.6	2.1	7.6	0.05
36	1.5	144.3	76.2	6.0	6.7	1.1	5.8	0.3	4.8	2.0	2.9	1.5	3.3	0.02
37	0.8	147.6	80.5	7.5	7.7	1.0	6.3	0.3	4.2	0.7	2.5	1.5	3.9	0.03
38	0.5	157.4	88.8	6.5	7.0	1.1	6.5	0.5	4.5	1.3	2.3	1.4	3.8	0.02
39	0.5	136.7	71.9	6.2	6.0	0.9	5.2	0.7	3.6	2.0	2.3	0.6	2.7	0.02
40	0.5	159.8	90.8	7.7	8.3	1.1	6.0	0.5	4.6	0.7	2.3	1.1	4.3	0.03
41	0.7	150.4	76.1	6.8	7.0	1.0	5.7	1.0	4.7	1.1	2.9	1.0	4.0	0.03
42	0.0	157.2	82.8	7.5	7.2	0.9	6.0	0.5	4.1	2.0	2.4	1.2	3.2	0.02
43	1.2	162.2	95.6	7.2	7.3	1.0	6.3	0.7	6.0	1.4	2.7	2.3	6.6	0.04
44	0.7	151.6	76.3	7.8	8.7	1.1	5.3	1.5	4.5	1.6	2.7	1.1	3.0	0.02
45	-0.2	174.8	90.5	7.5	7.3	1.0	7.2	0.7	6.2	1.6	3.0	1.0	2.2	0.01
46	1.0	159.3	77.6	7.2	8.2	1.2	6.2	0.8	5.6	1.2	3.1	2.5	6.6	0.04
47	2.0	145.4	76.9	7.8	8.7	1.1	5.5	0.5	4.6	1.0	2.3	1.3	3.6	0.02
48	1.0	138.8	70.8	6.2	7.3	1.4	5.5	0.7	4.2	0.8	2.3	0.5	1.1	0.01
49	1.7	141.3	72.0	6.0	6.5	1.2	4.8	0.3	3.6	1.2	2.5	1.5	3.4	0.02
50	1.0	141.0	74.6	6.5	6.5	1.0	5.7	0.7	3.4	1.3	2.4	1.2	4.0	0.03
51	0.5	149.9	83.3	6.5	6.5	1.0	5.8	0.2	4.0	2.0	2.6	0.5	1.9	0.01
52	0.8	151.5	85.6	8.2	8.3	1.0	5.5	2.2	4.4	0.8	2.5	0.5	1.6	0.01

Appendix I continued

ENT	ASI	PH	EH	NP	NE	EPP	EA	ER	YLD	Y-loss	SBD	EX	TNL	TLP
53	-0.5	155.6	84.8	5.7	5.8	1.0	5.3	1.5	3.8	1.9	2.5	0.9	1.7	0.01
54	0.5	172.3	89.2	6.3	7.0	1.1	6.0	0.3	6.1	2.0	2.6	0.9	2.2	0.01
55	0.0	170.3	100.5	7.3	9.5	1.3	5.7	0.8	4.7	1.6	2.3	1.9	6.4	0.04
56	1.0	159.4	85.6	6.2	6.3	1.1	5.0	0.7	3.7	1.0	3.1	2.3	6.5	0.04
57	0.2	186.0	95.5	8.0	8.3	1.0	6.3	0.8	5.3	2.5	2.8	1.2	3.1	0.02
58	0.5	150.0	77.7	7.2	7.8	1.1	5.7	1.0	4.9	0.9	2.6	1.1	2.7	0.02
59	1.2	147.3	76.1	6.5	7.8	1.2	5.5	1.0	4.6	1.6	2.5	1.1	3.0	0.02
60	1.3	132.3	66.3	6.7	6.5	1.0	5.2	1.2	3.1	1.4	2.8	1.2	2.9	0.02
61	1.7	139.9	69.9	7.3	7.7	1.1	6.0	0.8	4.0	1.0	3.0	0.9	3.3	0.02
62	0.8	146.0	78.7	8.0	7.8	1.0	6.3	1.3	3.9	1.1	2.6	1.1	3.7	0.03
63	1.5	168.4	101.0	7.5	8.3	1.1	6.2	0.5	4.7	0.9	2.5	0.8	1.8	0.01
64	-0.3	164.5	91.1	6.5	7.0	1.1	5.5	0.5	4.8	1.2	2.9	1.2	3.2	0.02
65	-0.3	159.8	85.9	7.0	7.8	1.1	6.3	0.7	4.8	1.7	2.5	1.0	2.9	0.02
66	-0.2	157.2	89.0	7.2	9.3	1.3	5.3	1.0	4.8	0.8	2.5	1.5	6.2	0.04
67	0.8	158.0	75.4	6.8	7.0	1.0	6.2	0.7	5.3	1.1	3.3	2.6	5.5	0.03
68	0.7	177.6	91.1	7.0	7.8	1.1	7.5	0.2	7.0	1.1	2.1	0.6	2.2	0.01
69	0.3	145.8	74.6	5.7	6.2	1.1	6.3	0.3	4.6	1.2	2.7	2.3	5.5	0.04
70	2.0	143.4	73.1	6.5	6.7	1.0	5.8	0.3	4.3	1.5	2.6	0.8	2.6	0.02
71	1.3	139.7	72.2	6.7	7.2	1.1	4.5	2.0	4.0	0.7	2.3	1.2	3.3	0.02
72	1.7	144.8	78.3	7.5	8.0	1.1	6.3	0.3	4.6	1.4	2.4	0.7	2.7	0.02
73	2.5	155.0	88.9	5.5	5.5	1.0	5.2	0.0	3.9	2.0	2.7	0.4	1.0	0.01
74	0.7	160.4	92.8	7.7	8.0	1.0	5.5	1.3	4.5	1.2	2.8	1.6	5.2	0.03
75	-0.2	161.5	89.7	7.0	8.5	1.3	6.0	0.8	4.8	1.6	2.6	1.0	3.2	0.02
76	0.7	172.2	94.8	7.3	8.5	1.2	6.5	0.5	5.7	1.5	2.7	1.2	3.7	0.02
77	1.5	150.7	75.5	6.7	7.0	1.1	6.5	0.8	4.5	1.7	2.8	1.9	5.0	0.03
78	-0.2	181.8	93.7	7.8	8.0	1.0	7.5	0.5	6.5	1.5	2.3	1.1	3.6	0.02

Appendix I continued

ENT	ASI	PH	EH	NP	NE	EPP	EA	ER	YLD	Y-loss	SBD	EX	TNL	TLPH
79	1.2	140.4	70.0	8.0	7.8	1.0	6.7	0.3	5.2	0.9	2.3	1.0	2.8	0.02
80	1.2	145.5	75.1	7.0	7.2	1.1	5.5	1.3	3.8	0.9	2.6	0.6	1.6	0.01
81	1.2	133.6	70.4	6.7	5.8	0.9	4.8	0.8	3.3	1.4	3.0	1.2	3.7	0.03
82	3.3	170.2	103.8	7.7	10.0	1.3	6.2	0.2	4.6	0.9	2.5	0.6	1.9	0.01
83	1.0	158.8	90.1	6.8	6.8	1.0	6.3	0.7	4.3	1.0	2.4	0.7	1.8	0.01
84	1.0	160.2	85.6	6.8	7.3	1.1	6.5	0.2	5.5	1.2	3.0	1.4	3.8	0.02
85	0.7	154.3	86.5	7.8	8.8	1.2	6.2	0.3	5.2	0.8	2.4	2.3	6.1	0.04
86	1.2	150.7	73.1	7.3	7.5	1.0	6.2	1.5	5.3	2.1	2.3	0.9	2.4	0.02
87	0.2	174.4	86.6	7.7	8.2	1.1	6.8	0.3	5.9	1.3	2.4	1.4	4.6	0.02
88	0.3	143.9	76.1	7.8	8.2	1.0	6.8	0.0	5.5	1.1	3.0	1.8	4.0	0.03
89	1.5	139.2	73.9	7.8	8.0	1.0	5.3	1.3	4.4	1.1	2.4	0.8	2.2	0.02
90	1.3	183.2	105.3	8.2	9.3	1.1	5.8	0.3	3.7	2.5	4.7	2.0	7.2	0.04
91	1.3	183.2	105.3	8.2	9.3	1.1	5.8	0.3	3.7	2.5	4.7	2.0	7.2	0.04
92	1.3	153.6	85.9	7.7	8.2	1.1	5.3	1.3	4.6	1.4	2.4	0.5	1.2	0.01
93	0.8	157.7	87.6	6.8	8.3	1.3	5.8	1.2	4.0	1.4	2.5	1.2	2.6	0.02
94	0.7	149.8	78.2	6.2	6.2	1.0	6.2	0.8	4.6	1.2	2.3	1.4	3.8	0.03
95	0.8	152.1	79.4	6.8	6.8	1.1	7.0	0.5	5.5	1.0	2.2	0.8	3.2	0.02
96	0.7	162.7	82.2	7.5	7.5	1.0	7.0	0.2	6.3	1.5	2.7	1.0	2.3	0.01
97	0.2	148.0	76.8	7.5	8.0	1.1	6.5	0.5	5.5	0.8	2.7	2.1	5.9	0.04
98	2.7	151.9	87.7	6.8	7.0	1.1	6.0	0.8	4.0	1.5	2.9	1.0	2.6	0.02
99	1.2	160.0	90.9	7.8	8.8	1.1	5.3	1.5	5.0	0.8	2.2	1.6	4.5	0.03
100	1.0	158.0	86.9	7.2	9.0	1.3	6.0	1.3	5.8	0.7	2.4	1.4	5.0	0.03
101	0.3	150.9	81.9	7.3	7.0	0.9	6.3	0.5	5.9	0.8	2.5	1.4	4.0	0.03
102	1.8	150.1	74.5	7.0	6.8	1.0	6.3	0.5	5.7	1.6	2.7	1.4	4.5	0.03
103	0.3	180.6	97.5	7.7	7.3	1.0	6.7	0.5	5.4	1.4	2.6	0.8	2.7	0.01
104	1.2	164.6	96.0	7.7	8.3	1.1	6.3	0.3	5.6	0.8	2.6	1.6	4.6	0.03
105	1.0	150.4	81.6	6.2	7.0	1.1	6.2	0.2	4.9	1.2	2.5	1.1	2.8	0.02
106	1.3	146.9	79.1	6.5	7.2	1.1	6.2	0.7	5.8	1.0	2.7	1.0	2.8	0.02
107	0.7	151.2	81.0	7.8	7.8	1.0	6.5	0.7	4.9	0.7	2.7	2.4	6.0	0.04
108	1.0	157.7	81.9	5.8	6.8	1.3	6.3	0.7	4.2	2.0	2.3	0.9	2.3	0.01

Appendix I continued

ENT	ASI	PH	EH	NP	NE	EPP	EA	ER	YLD	Y-loss	SBD	EX	TNL	TL PH
109	0.8	158	84	7.7	8.0	1.1	5.0	0.7	5.2	1.4	2.5	2.0	6.3	0.04
110	0.7	157	87	7.8	8.7	1.1	7.0	0.0	6.0	1.2	2.7	1.0	2.7	0.02
MEAN	0.9	155	83	7.1	7.6	1.1	6.0	0.7	4.8	1.3	2.7	1.3	3.7	0.02
CV	77.1	7.52	10.36	21.8	24.9	20	19.12	140	21.3	67.8	22.86	89.52	98.9	97.2
LSD	1.161	0.176	0.4857	2.973	2.143	2.143	2.009	15.94	12.01	0.4656	1.312	3.202	0.944	
SIGN	***	***	***	*	**	*	***	***	***	***	***	***	**	**

Entry 14= PH 3253, entry 90=H513. * =0.05, ** =0.01, *** =0.001

Appendix II.

Mean performance of the 108 F1's and two local checks (PH3253 and H513) at Kiboko, Kenya protected from stem borer damage.

ENTRY	AD	SD	ASI	PH	EH	RL	SL	NP	NE	EPP	EA	ER	YLD
1	54.0	55.5	1.5	171.3	97.1	0.0	0.0	8.8	11.8	1.3	6.7	0.2	7.2
2	57.2	59.5	2.3	161.6	89.5	0.0	0.5	8.2	9.7	1.2	6.2	0.7	5.2
3	54.8	56.7	1.3	182.1	97.1	0.0	0.0	10.0	9.8	1.0	8.0	0.2	8.0
4	55.8	57.0	1.2	162.0	88.4	0.0	0.2	10.0	10.7	1.0	7.7	2.5	7.1
5	56.5	57.5	1.0	152.7	81.7	0.0	0.0	9.5	10.3	1.1	6.5	2.3	5.8
6	55.8	56.5	0.7	148.3	79.8	0.0	0.2	8.7	8.8	1.0	6.5	1.7	4.8
7	56.5	58.2	1.7	170.7	88.3	0.0	0.0	9.0	9.8	1.1	7.5	0.5	7.1
8	57.3	59.0	1.7	147.5	79.3	0.0	0.0	8.8	10.2	1.1	6.7	1.7	5.4
9	56.3	57.5	1.2	155.3	85.9	0.0	0.0	9.0	9.7	1.1	6.7	0.3	5.6
10	57.2	57.2	0.0	138.1	74.5	0.0	0.0	6.5	6.7	1.1	5.5	0.7	3.0
11	57.7	58.3	0.7	135.1	70.7	0.0	0.0	8.0	7.7	1.0	5.5	2.0	3.1
12	55.7	56.5	0.8	151.3	75.4	0.0	0.0	8.7	9.2	1.1	6.7	0.3	5.9
13	56.2	57.3	1.2	162.7	91.3	0.0	0.0	7.8	7.7	1.0	6.8	0.0	5.5
14	58.7	60.8	2.2	192.1	101.7	0.0	0.0	8.7	9.0	1.0	6.7	0.3	8.9

ppendix II continued

NTRY	AD	SD	ASI	PH	EH	RL	SL	NP	NE	EPP	EA	ER	YLD
15	55.2	55.2	0.0	160.8	83.5	0.0	0.0	9.0	8.7	1.0	7.2	1.2	7.0
16	55.8	57.7	1.8	172.2	103.8	0.0	0.0	9.8	14.0	1.4	7.0	1.7	7.5
17	55.0	56.3	1.3	172.0	92.1	0.0	0.0	7.7	8.3	1.1	7.5	1.0	5.7
18	55.2	57.0	1.8	183.6	101.8	0.0	0.0	7.7	8.5	1.2	7.3	0.5	7.7
19	55.7	55.0	-0.7	161.7	87.5	0.0	0.0	7.8	9.2	1.2	6.8	0.8	6.4
20	56.0	57.2	1.2	153.2	83.5	0.0	0.2	8.2	9.5	1.2	6.7	0.2	5.3
21	55.3	56.7	1.3	161.5	78.3	0.0	0.0	9.2	8.8	1.0	6.5	0.3	6.9
22	56.8	58.2	1.3	152.2	81.3	0.0	0.0	9.0	9.7	1.1	6.5	0.7	6.3
23	56.8	58.3	1.5	153.9	79.3	0.0	0.0	6.5	6.5	1.0	6.5	0.0	3.8
24	56.3	56.8	0.5	154.5	84.7	0.0	0.0	7.7	7.7	1.0	6.2	0.3	5.7
25	57.7	58.7	1.0	125.4	67.7	0.2	0.0	8.2	8.0	1.0	5.2	2.2	4.6
26	56.3	57.2	0.8	143.1	79.1	0.0	0.2	8.3	9.0	1.1	6.2	1.0	4.4
27	56.0	56.8	0.8	181.6	99.5	0.0	0.0	10.0	10.3	1.0	7.5	0.2	6.6
28	55.0	56.0	1.0	160.3	91.5	0.0	0.0	8.5	7.8	0.9	6.2	0.8	5.7
29	55.3	55.8	0.5	170.4	92.8	0.0	0.0	7.8	8.7	1.1	7.3	0.5	6.3
30	55.2	56.7	1.5	167.3	94.1	0.0	0.2	8.7	9.8	1.1	7.5	0.7	6.5
31	54.3	55.8	1.5	164.4	92.3	0.3	0.2	7.3	8.2	1.2	7.2	1.0	6.5
32	54.7	54.3	-0.3	186.7	100.8	0.0	0.0	9.0	9.0	1.0	8.5	0.0	7.7
33	56.2	55.5	-0.7	160.7	89.4	0.0	0.0	8.3	9.5	1.1	7.3	0.3	6.8
34	56.3	57.7	1.3	169.1	88.2	0.0	0.0	8.2	8.8	1.1	7.2	0.0	5.9
35	55.8	57.3	1.5	147.5	79.0	0.0	0.0	7.8	8.5	1.1	6.5	0.2	5.6
36	56.2	57.8	1.3	151.5	79.8	0.0	0.0	10.3	11.0	1.1	7.2	0.5	6.8
37	55.2	56.0	0.8	153.2	79.5	0.0	0.0	8.3	7.8	0.9	7.5	0.3	4.9
38	56.3	56.7	0.3	156.3	90.0	0.0	0.0	8.3	9.5	1.1	6.3	0.7	5.7
39	56.3	57.0	0.7	142.8	78.3	0.0	0.0	8.5	9.2	1.1	6.5	1.3	5.6
40	56.0	56.5	0.5	166.3	98.3	0.2	0.0	9.0	9.0	1.0	7.0	1.5	5.3
41	55.0	55.7	0.7	158.6	81.7	0.0	0.0	6.8	7.0	1.0	6.3	0.5	5.7
42	55.8	55.8	0.0	162.0	85.6	0.0	0.0	7.0	7.2	1.0	6.7	0.3	6.1
43	54.5	55.7	1.2	175.7	104.7	0.0	0.0	10.2	10.7	1.1	6.8	0.5	7.4
44	55.5	56.2	0.7	158.5	83.5	0.0	0.0	8.5	9.5	1.1	6.2	1.8	6.1
45	55.3	55.2	-0.2	178.7	96.8	0.0	0.0	8.0	10.0	1.3	7.7	0.5	7.8
46	55.3	56.2	0.8	168.1	81.8	0.0	0.2	8.5	8.5	1.0	7.5	0.2	6.8

ppendix II continued

NTRY	AD	SD	ASI	PH	EH	RL	SL	NP	NE	EPP	EA	ER	YLD
47	56.8	58.8	2.0	150.8	78.8	0.2	0.0	8.8	10.8	1.2	6.7	0.8	5.6
48	55.7	56.7	1.0	142.0	73.2	0.0	0.0	8.0	8.2	1.0	6.2	0.8	4.9
49	56.7	58.3	1.7	151.7	80.5	0.0	0.2	8.8	10.3	1.1	6.2	0.8	4.8
50	57.0	58.0	1.0	144.1	75.7	0.0	0.3	7.7	7.8	1.0	6.8	0.5	4.7
51	57.0	57.5	0.5	158.5	88.5	0.0	0.0	8.0	7.8	1.0	6.7	0.2	6.0
52	56.5	57.3	0.8	164.6	96.8	0.0	0.0	8.2	8.0	1.0	6.8	1.0	5.3
53	54.8	54.3	-0.5	165.3	90.4	0.2	0.0	9.3	9.0	1.0	6.2	2.0	5.7
54	55.2	55.7	0.5	180.5	94.4	0.0	0.0	9.7	10.2	1.1	7.2	0.7	8.2
55	54.5	54.3	-0.2	178.5	103.7	0.0	0.0	8.3	9.3	1.1	7.2	0.5	6.3
56	55.8	56.8	1.0	165.6	88.7	0.0	0.0	7.3	7.3	1.0	7.2	1.7	4.8
57	55.2	55.3	0.2	193.8	96.9	0.0	0.2	8.3	7.8	0.9	7.8	0.0	7.8
58	55.8	56.3	0.5	157.9	83.7	0.0	0.0	7.8	9.3	1.3	7.3	0.5	5.8
59	55.7	56.8	1.2	170.5	83.5	0.0	0.0	7.8	8.8	1.2	7.2	0.0	6.1
60	55.3	56.7	1.3	145.1	74.3	0.0	0.2	9.5	9.8	1.0	6.2	1.2	4.5
61	57.0	58.7	1.7	154.2	81.6	0.0	0.0	7.8	9.2	1.2	6.7	0.5	5.0
62	56.7	57.5	0.8	150.6	78.6	0.0	0.0	8.2	8.2	1.0	6.5	1.0	5.0
63	56.8	58.3	1.5	165.3	99.3	0.0	0.2	7.3	7.3	1.0	6.7	0.7	5.6
64	55.0	55.0	0.0	168.0	96.3	0.0	0.0	9.3	10.2	1.1	6.3	2.5	6.1
65	56.2	55.8	-0.3	166.3	94.1	0.0	0.0	9.3	10.5	1.1	7.3	2.2	6.4
66	56.2	56.0	-0.2	164.4	97.5	0.0	0.2	7.2	9.7	1.4	6.7	0.5	5.5
67	54.7	55.5	0.8	168.5	85.1	0.0	0.0	7.7	7.8	1.1	7.3	0.5	6.4
68	54.2	54.8	0.7	178.6	91.6	0.0	0.0	10.2	10.0	1.0	8.2	0.3	8.0
69	55.2	55.5	0.3	146.1	72.5	0.0	0.0	6.3	7.8	1.3	6.7	0.5	5.8
70	56.0	58.0	2.0	145.3	72.8	0.0	0.0	8.2	9.0	1.1	6.5	1.7	5.8
71	55.7	57.0	1.3	146.3	76.8	0.0	0.0	9.7	9.5	1.0	6.8	1.3	4.7
72	57.2	58.8	1.7	149.7	82.0	0.0	0.0	8.8	10.3	1.2	7.2	0.8	6.0
73	56.5	59.0	2.5	159.9	94.5	0.0	0.0	9.8	10.0	1.0	7.2	0.8	6.4
74	54.7	55.3	0.7	168.7	99.3	0.0	0.0	8.0	7.8	1.0	6.7	0.8	5.7
75	56.7	56.5	-0.2	169.0	96.8	0.0	0.0	8.2	9.3	1.1	6.5	1.3	6.4
76	55.3	56.0	0.7	174.1	93.7	0.0	0.0	8.7	8.2	0.9	6.7	0.7	7.1
77	55.2	56.7	1.5	161.0	82.0	0.2	0.5	9.0	9.0	1.0	7.3	0.8	6.2
78	54.5	54.3	-0.2	186.0	94.1	0.0	0.0	8.0	8.5	1.1	7.5	0.0	7.9

Appendix II continued

ENTRY	AD	SD	ASI	PH	EH	RL	SL	NP	NE	EPP	EA	ER	YLD
79	55.0	54.8	-0.2	146.5	75.6	0.0	0.2	7.8	8.2	1.1	7.0	0.5	6.0
80	56.7	57.8	1.2	150.2	78.3	0.0	0.0	8.0	8.5	1.1	6.2	1.3	4.7
81	56.5	57.7	1.2	141.5	74.3	0.0	0.0	8.8	9.2	1.0	6.7	0.8	5.2
82	57.0	60.3	3.3	175.8	104.9	0.0	0.0	8.0	8.3	1.1	6.7	1.7	5.4
83	56.0	57.0	1.0	163.1	90.6	0.0	0.0	8.8	8.8	1.0	7.2	1.8	5.3
84	55.3	56.3	1.0	170.6	94.6	0.0	0.0	9.5	9.7	1.0	7.3	0.7	6.8
85	54.0	55.8	0.7	162.1	91.4	0.2	0.3	8.0	9.8	1.2	6.7	0.0	6.0
86	55.2	56.3	1.2	155.4	78.5	0.0	0.2	8.7	9.2	1.1	7.8	0.7	7.3
87	55.0	55.2	0.2	182.7	92.9	0.0	0.0	8.3	9.0	1.1	7.3	0.2	7.2
88	55.3	55.8	0.3	149.4	79.8	0.0	0.0	8.3	8.7	1.1	7.7	0.5	6.5
89	56.7	58.2	1.5	149.8	77.9	0.0	0.0	8.5	9.5	1.1	6.3	1.2	5.5
90	59.2	60.5	1.3	188.4	109.0	0.0	0.0	9.2	9.0	1.0	6.7	0.3	6.7
91	59.2	60.5	1.3	188.4	109.0	0.0	0.0	9.2	9.0	1.0	6.7	0.3	6.7
92	56.3	57.7	1.3	159.4	91.0	0.0	0.0	8.7	9.5	1.1	6.8	1.2	6.0
93	56.0	56.8	0.8	162.7	88.7	0.0	0.0	8.7	8.2	1.0	7.2	1.2	5.4
94	54.7	55.3	0.7	160.5	87.4	0.0	0.0	9.3	10.2	1.1	7.3	1.0	5.7
95	54.5	55.3	0.8	163.2	83.0	0.0	0.2	7.3	8.2	1.2	8.0	0.2	6.5
96	55.3	56.0	0.7	179.9	93.1	0.0	0.0	8.2	8.5	1.0	8.0	0.0	7.8
97	55.2	55.3	0.2	154.1	82.8	0.0	0.0	8.7	9.3	1.1	7.5	0.3	6.3
98	56.3	59.0	2.7	166.0	98.1	0.2	0.0	8.8	8.7	1.0	7.0	1.2	5.5
99	55.3	56.5	1.2	163.1	90.7	0.0	0.0	8.0	8.0	1.0	6.7	1.5	5.8
100	56.2	57.2	1.0	169.2	94.9	0.0	0.0	7.2	9.3	1.3	7.0	0.5	6.5
101	54.2	54.5	0.3	157.3	84.9	0.0	0.0	8.3	9.0	1.1	6.8	0.3	6.7
102	53.8	55.7	1.8	156.1	77.6	0.0	0.0	7.8	8.0	1.1	7.3	0.5	7.3
103	54.8	55.2	0.3	180.6	99.6	0.0	0.0	8.8	9.2	1.0	8.0	0.5	6.8
104	55.2	56.3	1.2	169.6	97.0	0.0	0.0	8.2	9.2	1.1	7.0	0.3	6.4
105	55.0	56.2	1.2	159.4	89.9	0.0	0.0	7.7	7.5	1.0	6.7	0.7	5.9
106	55.2	56.5	1.3	159.7	87.5	0.2	0.0	9.3	10.7	1.1	6.7	0.7	6.9
107	55.8	56.3	0.5	157.4	88.8	0.0	0.0	8.2	9.2	1.1	7.0	0.2	5.6
108	55.5	56.5	1.0	154.9	80.5	0.0	0.0	8.1	7.7	1.0	6.9	1.1	6.6
109	54.7	55.7	1.0	185.8	108.9	0.0	0.0	9.3	10.0	1.1	7.5	0.3	7.6
110	55.7	56.5	0.8	158.7	88.2	0.0	0.0	8.5	8.0	0.9	6.3	0.8	6.6

Appendix II continued

ENTRY	AD	SD	ASI	PH	EH	RL	SL	NP	NE	EPP	EA	ER	YLD
MEAN	**55.8**	**56.7**	**0.9**	**162.2**	**88.0**	**0.0**	**0.0**	**8.4**	**9.0**	**1.1**	**6.9**	**0.8**	**6.1**
CV	**2.24**	**2.35**	**76**	**6.99**	**9.73**	**841**	**552.8**	**19.5**	**23.1**	**17.2**	**14.2**	**147.7**	**17.4**
LSD	2.142	2.047	1.155	12.99	10.73	0.251	0.76	3.03	4.183	0.839	1.648	2.221	1.315
SIGN	***	***	***	***	***	NS	*	***	***	***	***	***	***

Entry 14 =PH3253, entry 110=H513, *=0.05, ** =0.01, *** =0.001

Appendix III.

Mean performance of the 108 F1's and two Local checks (PH3253and H513) at Embu, Kenya infested with *Busseola fusca* stem borer.

ENT	ASI	PH	EH	RL	SL	NP	NE	EPP	EA	ER	YLD	Y-LOSS	SBD	EXH	TNL	TLPH
1	2.3	171	92	0.2	0.5	8.3	11.3	1.9	5.7	1.0	3.6	2.6	2.7	1.6	3.1	0.02
2	1.8	182	95	1.0	0.2	7.5	9.5	13.7	5.5	1.3	3.1	2.7	2.5	1.1	1.8	0.01
3	1.3	211	109	0.3	0.0	9.5	10.7	3.3	6.7	2.7	4.7	2.2	2.9	2.2	3.7	0.02
4	1.7	196	105	0.7	1.2	9.2	10.3	7.7	6.3	0.8	4.1	1.7	2.5	1.2	3.7	0.02
5	3.0	181	92	1.2	0.8	8.3	8.8	14.6	5.7	1.0	3.3	2.4	2.5	0.9	2.1	0.01
6	2.0	179	96	0.5	1.8	9.0	9.5	6.0	5.8	1.2	2.9	1.5	2.5	0.6	1.9	0.01
7	3.3	201	111	0.2	0.2	9.0	9.8	1.9	5.8	1.5	3.5	2.5	2.8	0.8	2.1	0.01
8	3.0	173	91	0.8	0.3	8.8	8.8	10.0	5.5	2.2	2.3	1.6	2.5	1.1	2.7	0.02
9	3.3	178	100	0.0	1.7	8.5	9.0	0.0	6.3	1.0	3.0	1.6	2.5	0.6	2.1	0.01
10	2.3	158	83	1.0	1.5	4.7	6.0	30.6	4.0	1.7	1.2	2.6	2.4	0.6	2.0	0.01
11	2.5	146	78	1.7	1.5	8.0	7.8	24.5	4.2	1.2	1.9	2.6	2.8	1.9	4.6	0.03
12	2.8	189	92	0.0	1.0	8.7	8.2	0.0	5.2	1.5	2.8	1.6	2.9	1.7	3.7	0.02
13	3.3	188	106	0.7	0.3	8.8	8.5	6.7	6.7	1.0	3.6	2.3	2.6	1.1	2.2	0.01
14	2.5	222	110	0.3	0.7	8.2	8.7	3.7	5.8	0.3	3.3	4.8	6.4	5.0	9.8	0.04
15	2.5	222	110	0.3	0.7	8.2	8.7	3.7	5.8	0.3	3.3	4.8	6.4	5.0	9.8	0.04
16	0.8	192	96	0.7	0.2	9.0	9.8	8.1	5.3	2.8	4.0	2.6	2.4	1.7	3.4	0.02
17	1.5	198	111	0.2	0.5	9.3	13.8	2.1	6.5	1.5	4.7	2.6	2.5	1.0	2.8	0.01
18	2.7	199	98	0.0	0.3	8.2	9.3	0.0	7.3	0.0	4.4	1.9	2.5	1.2	2.6	0.01
19	2.3	225	117	0.0	0.3	8.3	11.5	0.0	5.7	3.3	3.6	2.1	2.2	0.7	2.4	0.01

Appendix III continued

ENTRY	ASI	PH	EH	RL	SL	NP	NE	EPP	EA	ER	YLD	Yloss	SBD	EXH	TNL	TLPH
20	2.3	176.2	89.2	1.0	0.8	7.0	7.7	12.9	5.2	1.2	2.5	2.0	2.5	0.5	1.4	0.01
21	3.0	187.7	94.4	0.3	0.5	8.7	9.0	3.9	6.2	1.2	3.5	2.2	3.2	3.0	6.3	0.03
22	2.3	173.8	91.9	0.2	1.0	8.2	9.0	2.4	5.8	1.5	3.1	2.0	2.8	0.8	1.8	0.01
23	2.7	163.3	89.4	0.0	0.2	6.3	6.2	0.0	6.0	0.3	1.9	3.2	2.8	1.1	3.1	0.02
24	3.3	189.2	103.1	0.0	0.8	8.0	7.0	0.0	4.5	3.2	2.3	1.4	2.6	0.9	1.8	0.01
25	2.7	161.9	84.8	0.7	2.3	7.3	7.8	9.5	4.3	1.5	1.8	3.2	2.5	1.3	3.7	0.02
26	2.5	166.8	87.8	0.2	0.5	7.7	7.5	1.7	5.5	2.3	2.6	0.9	2.4	0.5	1.7	0.01
27	2.8	214.2	108.5	0.0	0.3	9.2	9.2	0.0	7.2	1.2	4.7	2.3	2.8	1.6	4.6	0.02
28	1.8	184.5	99.9	0.3	0.5	8.7	8.5	3.3	6.3	0.5	3.2	3.2	2.5	0.1	0.9	0.01
29	1.0	192.4	102.5	1.2	0.2	8.2	9.0	14.6	6.5	1.0	4.1	3.5	2.3	0.9	2.1	0.01
30	2.3	190.8	100.6	0.5	0.0	7.7	9.7	5.6	6.2	0.5	4.0	2.0	2.4	1.0	1.9	0.01
31	3.2	204.7	110.5	0.7	0.2	8.2	10.2	6.9	6.5	0.0	3.9	2.9	2.0	0.5	0.8	0.00
32	1.2	212.5	116.6	0.2	0.5	9.0	12.7	1.9	6.0	4.0	4.2	2.7	2.9	2.0	7.3	0.04
33	1.5	191.6	107.2	0.0	1.0	8.0	9.5	0.0	6.2	0.7	4.2	2.0	2.6	0.4	1.0	0.00
34	1.8	189.5	100.2	0.2	0.5	7.8	9.5	2.4	5.3	1.5	3.2	1.6	2.6	1.6	2.9	0.02
35	3.5	170.7	92.5	0.3	0.5	8.0	8.2	4.2	5.3	1.5	2.8	1.6	2.6	1.1	1.8	0.01
36	3.2	170.0	92.3	0.5	1.2	8.2	9.7	9.1	5.5	1.0	2.5	2.2	2.7	1.7	2.9	0.02
37	2.7	165.6	88.0	0.3	0.7	9.0	8.5	3.3	4.7	3.5	2.0	1.8	2.5	1.5	2.5	0.02
38	3.3	178.5	103.2	0.2	0.5	9.0	8.8	2.1	5.3	2.0	3.2	1.9	2.3	1.1	3.0	0.02
39	2.3	147.5	90.5	0.5	1.3	7.3	7.3	10.0	4.8	2.8	2.2	2.0	2.6	0.9	3.6	0.05
40	3.5	205.2	111.1	0.0	0.2	8.8	9.0	0.0	6.5	0.5	3.7	2.4	2.6	0.8	2.1	0.01
41	1.7	198.6	101.3	0.0	0.3	8.0	7.8	0.0	6.3	0.2	2.9	2.6	2.8	1.8	3.5	0.02
42	2.7	197.8	106.9	0.0	0.5	8.8	9.7	0.0	5.8	0.8	3.6	2.4	2.5	1.0	4.3	0.02
43	1.7	194.6	111.5	0.0	0.3	9.0	10.2	0.0	6.5	0.8	4.5	1.8	2.4	1.3	2.5	0.01
44	1.2	206.4	103.2	1.0	0.3	8.8	10.0	11.4	6.8	0.2	4.5	3.1	2.6	1.4	4.1	0.02
45	1.8	215.7	110.7	1.3	0.0	8.7	11.5	14.8	6.0	1.7	5.3	2.0	2.6	1.4	4.7	0.02
46	1.5	204.7	98.8	0.0	0.3	8.0	9.0	0.0	6.2	0.5	4.4	2.3	2.7	0.5	1.5	0.01
47	3.5	176.2	94.6	0.0	0.5	8.5	9.7	0.0	5.0	2.2	2.9	2.5	2.6	1.5	3.0	0.02
48	2.0	162.5	85.8	0.0	2.7	7.3	8.2	0.0	5.3	0.7	2.6	1.7	2.9	2.2	4.5	0.03
49	3.7	173.6	91.1	0.5	0.3	8.8	8.7	6.1	4.2	3.0	2.1	2.3	2.6	2.4	4.6	0.03
50	3.0	158.2	82.6	0.0	0.7	8.2	8.3	0.0	5.2	1.8	2.7	2.3	2.8	1.5	4.1	0.03
51	2.3	184.9	99.5	0.0	0.8	7.7	8.0	0.0	5.0	3.0	2.9	2.5	2.4	1.0	1.5	0.01

Appendix III continued

ENTRY	ASI	PH	EH	RL	SL	NP	NE	EPP	EA	ER	YLD	YLOSS	SBD	EXH	TNL	TLPH
52	3.0	196.8	104.3	0.2	0.2	8.5	8.7	1.9	5.8	2.0	3.1	2.8	2.7	1.7	3.3	0.02
53	2.0	193.8	103.1	0.5	0.7	6.7	7.8	5.8	5.7	1.0	2.9	1.6	2.3	0.4	1.4	0.01
54	1.8	210.6	107.2	0.3	0.5	7.5	8.7	3.5	5.7	0.8	4.3	2.6	2.6	1.0	4.2	0.02
55	1.2	187.4	100.1	0.2	1.0	8.3	10.5	1.7	6.2	1.3	3.7	2.9	2.5	0.6	2.1	0.01
56	1.8	203.3	102.6	0.3	1.0	7.2	8.3	3.9	6.2	1.0	3.6	2.9	2.8	1.4	4.9	0.02
57	1.8	219.8	103.7	0.0	0.3	9.2	9.3	0.0	6.0	1.8	4.4	2.4	3.0	1.8	4.6	0.02
58	1.5	179.1	99.1	0.0	1.5	7.3	8.0	0.0	6.5	0.2	3.6	2.2	2.7	0.7	2.5	0.01
59	3.0	170.1	87.7	0.5	0.7	5.8	7.2	7.2	5.0	0.8	2.2	2.5	2.4	0.9	2.1	0.01
60	2.8	169.3	91.5	1.2	1.5	8.5	9.0	12.9	5.0	2.3	2.4	2.4	2.7	1.6	4.2	0.03
61	3.3	177.6	98.6	1.2	0.0	7.7	7.2	15.3	5.0	1.8	2.7	2.3	2.5	0.7	1.7	0.01
62	2.5	171.5	90.6	0.2	1.0	8.7	9.0	2.1	5.3	2.5	3.4	0.7	2.5	2.3	4.1	0.03
63	4.3	194.5	104.2	0.5	0.2	6.8	7.0	8.1	5.2	1.2	3.0	1.9	2.4	0.9	2.5	0.01
64	1.7	190.3	108.4	1.2	0.5	7.7	8.7	14.5	5.7	1.3	3.9	1.6	2.3	0.8	1.9	0.01
65	1.8	192.5	96.9	0.8	0.3	8.2	9.3	9.6	6.0	0.5	4.2	2.1	2.5	0.9	2.4	0.01
66	1.5	187.3	99.5	0.7	0.2	7.8	8.8	7.7	6.0	1.5	3.7	2.3	2.5	1.0	3.3	0.02
67	1.7	206.2	98.6	0.7	0.2	9.5	9.3	6.7	6.7	0.7	3.6	2.5	2.9	1.5	3.9	0.02
68	2.3	199.4	98.9	0.3	0.2	8.2	9.8	3.7	6.3	2.8	4.6	1.7	2.6	2.0	4.2	0.02
69	1.3	178.6	92.3	0.2	2.2	7.2	9.0	5.6	6.7	0.3	3.2	2.6	2.6	1.8	5.7	0.03
70	3.3	179.4	92.4	0.7	1.2	8.7	8.7	6.9	4.7	2.7	2.8	1.6	2.6	1.6	4.1	0.02
71	2.0	160.1	81.6	0.5	2.7	7.8	9.0	8.3	5.3	0.7	2.8	1.9	2.7	0.7	1.1	0.01
72	3.2	172.1	95.9	0.0	1.0	9.2	9.2	0.0	5.5	2.8	3.3	1.2	2.7	1.6	3.2	0.02
73	3.8	204.9	107.0	0.7	0.2	9.0	8.7	6.9	5.2	1.5	3.4	2.5	2.5	0.5	1.8	0.01
74	2.3	190.3	106.7	0.2	0.0	8.0	8.0	2.1	5.7	1.8	3.6	1.4	2.6	0.5	1.3	0.01
75	1.8	191.3	102.7	1.0	0.3	8.2	10.2	10.6	5.7	1.8	3.1	2.4	2.2	0.5	2.1	0.01
76	1.8	200.0	103.1	0.0	0.2	8.7	9.3	0.0	6.5	1.2	4.1	1.7	2.9	3.4	8.1	0.04
77	2.7	204.3	102.6	0.0	2.2	8.5	9.2	0.0	7.3	0.3	4.1	2.1	2.7	1.1	2.5	0.01
78	1.7	209.6	107.9	0.0	0.5	8.5	9.2	0.0	6.3	0.8	5.1	2.2	2.5	1.1	2.5	0.01
79	1.3	178.0	93.3	1.0	1.7	7.8	9.3	13.8	5.2	2.0	3.8	1.7	2.4	0.8	1.9	0.01
80	4.3	162.8	86.3	0.8	1.0	7.8	8.3	10.9	5.0	1.0	2.3	2.5	2.8	1.3	2.6	0.02
81	3.0	165.8	81.8	0.3	1.0	8.3	8.8	3.8	5.7	2.2	2.9	1.9	2.6	0.9	1.6	0.01
82	4.8	203.7	116.5	0.2	0.5	8.3	10.2	2.4	6.0	1.3	3.7	1.8	2.3	0.4	1.1	0.01
83	1.3	178.6	94.1	0.5	0.5	8.0	9.0	6.7	6.2	1.2	3.1	1.5	2.4	0.3	1.0	0.01

Appendix III continued

ENTRY	ASI	PH	EH	RL	SL	NP	NE	EPP	EA	ER	YLD	Yloss	SBD	EXH	TNL	TLPH
84	1.5	210.0	115.3	0.0	0.3	8.3	9.5	0.0	5.8	1.8	4.1	1.7	2.2	0.5	1.5	0.01
85	1.2	189.4	103.1	0.0	0.2	8.8	9.8	0.0	6.2	0.5	5.0	1.3	2.7	2.1	4.6	0.02
86	2.5	192.2	91.3	0.2	1.0	7.7	7.0	1.7	6.3	0.2	3.9	2.0	2.6	1.3	3.6	0.02
87	1.5	214.6	103.2	0.2	0.5	9.2	9.2	1.9	5.3	4.7	4.0	1.7	2.4	1.0	2.0	0.01
88	1.8	173.9	94.8	0.5	2.2	7.7	7.7	7.2	5.2	1.3	3.2	1.6	2.6	2.2	4.1	0.03
89	2.5	172.0	91.7	1.0	1.2	8.0	8.3	11.7	5.5	1.3	3.3	0.7	2.7	1.2	2.5	0.01
90	1.8	223.6	123.7	0.0	0.3	8.7	11.3	0.0	6.7	0.7	2.7	4.5	6.2	1.4	4.2	0.02
91	1.8	223.6	123.7	0.0	0.3	8.7	11.3	0.0	6.7	0.7	2.7	4.5	6.2	1.4	4.2	0.02
92	2.2	197.0	110.2	0.0	0.2	8.8	10.0	0.0	5.2	0.5	4.3	1.4	2.5	1.3	2.9	0.01
93	1.8	196.0	103.6	0.3	0.2	8.3	9.2	3.7	5.7	2.0	3.9	1.6	2.5	0.8	3.0	0.02
94	1.2	190.6	101.0	0.0	0.8	8.3	9.0	0.0	6.5	0.5	4.1	2.1	2.5	0.8	2.1	0.01
95	3.2	196.6	94.3	0.7	1.8	7.5	6.7	8.1	6.5	0.5	3.8	1.5	2.8	1.5	3.2	0.02
96	2.0	206.1	105.5	0.0	0.3	9.0	8.8	0.0	5.7	2.0	4.5	1.2	2.9	2.3	4.3	0.02
97	1.8	185.0	99.9	0.2	2.0	8.8	9.8	1.7	5.3	2.3	3.5	0.8	2.6	1.3	3.3	0.02
98	5.2	207.9	114.9	0.0	0.0	8.5	9.7	0.0	5.7	0.7	3.2	1.2	2.6	1.1	3.2	0.02
99	2.0	188.8	107.6	0.5	0.7	8.0	10.2	6.1	5.5	1.0	3.8	1.4	2.4	1.1	1.7	0.01
100	3.0	203.3	107.0	0.8	0.7	8.8	13.3	9.2	5.5	2.0	4.1	1.6	2.6	1.4	2.8	0.02
101	1.7	187.0	101.4	0.5	0.7	9.2	8.7	5.2	5.3	2.2	3.6	1.9	2.3	0.8	1.9	0.01
102	3.0	191.9	79.9	0.0	1.7	8.2	7.7	0.0	6.3	0.7	3.4	1.6	2.7	0.9	1.8	0.01
103	2.0	204.7	109.8	0.5	0.2	8.5	10.2	5.6	5.2	4.0	3.7	1.6	2.5	0.9	2.6	0.01
104	1.2	197.3	110.1	0.3	0.2	8.8	9.8	4.1	5.7	1.7	5.4	1.1	2.3	0.4	1.1	0.01
105	2.0	191.5	111.1	0.7	0.7	8.7	10.0	6.7	5.8	0.7	3.2	1.7	2.5	1.0	2.6	0.01
106	2.2	190.6	106.3	0.0	0.3	8.2	10.2	0.0	5.5	1.0	3.7	3.0	2.6	0.8	2.3	0.01
107	1.2	184.6	102.9	0.0	0.8	8.7	8.8	0.0	6.3	0.7	4.2	1.7	2.2	0.9	2.0	0.01
108	2.2	180.7	89.5	0.7	1.3	8.2	8.3	7.4	6.5	0.7	3.5	1.8	2.9	2.1	5.3	0.03
109	2.5	221.7	117.1	0.2	0.0	8.7	10.0	2.1	5.3	4.0	3.8	1.4	2.4	1.1	3.9	0.02
110	1.2	178.8	99.6	0.0	0.2	8.0	9.5	0.0	5.5	0.7	3.7	2.2	2.4	0.7	2.2	0.01

Appendix III continued

ENT	ASI	PH	EH	RL	SL	NP	NE	EPP	EA	ER	YLD	Yloss	SBD	EXH	TNL	TLP
MEAN	2.3	190	100.	0.4	0.7	8.3	9.1	4.8	5.8	1.4	3.5	2.1	2.7	1.2	3.0	0.02
CV	61.8	7.75	10.5	214	152.	16.1	20.3	19.9	16.9	93	26.1	52.2	17.5	102	101	104.
LSD	1.63	16.3	11.9	0.93	1.22	1.5	2.1	0.25	1.1	1.5	1.67	1.23	0.53	1.39	3.37	0.02
SIG.	***	***	***	**	***	***	***	***	***	***	***	***	***	***	***	**

Entry 14= PH 3253, entry 90=H513. * =0.05, ** =0.01, *** =0.001

Appendix IV.

Mean performance of the 108 F1's and two Local checks (PH3253and H513) at Embu, Kenya protected from stem borer damage.

ENT.	AD	SD	ASI	PH	EH	RL	SL	NP	NE	EPP	EA	ER	YLD
1	62.8	64.7	1.8	195.1	104.4	0.0	0.3	8.2	8.5	1.0	6.2	1.3	6.2
2	63.2	66.0	2.8	208.4	112.3	0.7	0.2	6.7	7.8	1.2	6.5	0.8	5.9
3	64.2	65.8	1.7	202.2	104.8	0.5	0.2	7.0	9.2	1.3	6.2	2.0	6.8
4	62.8	65.3	2.5	198.7	105.2	0.7	0.3	6.8	8.5	1.2	6.0	1.5	5.7
5	63.5	66.5	3.0	185.5	96.7	1.0	0.2	6.7	8.3	1.2	5.7	1.8	5.7
6	63.8	65.2	1.3	180.7	99.9	0.3	0.5	6.3	6.7	1.1	6.0	0.8	4.4
7	64.3	66.8	2.5	199.4	105.6	0.2	0.2	6.8	8.0	1.2	5.8	1.7	6.0
8	63.0	66.0	3.0	180.7	94.1	0.3	0.0	7.2	6.8	1.0	5.0	1.7	3.8
9	62.7	65.8	3.2	181.2	100.0	0.2	0.5	6.5	7.0	1.1	5.5	1.8	4.6
10	62.8	66.0	3.2	185.9	97.5	1.2	0.5	7.2	8.2	1.1	5.3	2.5	3.8
11	64.3	65.8	1.5	173.3	90.1	0.7	0.8	7.3	7.2	1.0	5.8	0.8	4.5
12	62.0	65.0	3.0	180.5	86.1	0.0	0.0	7.0	8.0	1.1	5.0	2.3	4.4
13	62.2	66.0	3.8	203.3	111.0	0.2	0.2	7.5	7.8	1.0	6.7	0.8	5.9
14	63.5	66.8	3.3	207.8	109.0	0.2	0.3	6.8	6.8	1.0	6.3	0.8	7.8
15	62.2	64.2	2.0	196.3	100.7	0.0	0.8	7.2	8.5	1.2	6.2	1.5	6.6
16	62.8	64.0	1.2	203.6	117.3	0.5	0.2	7.0	9.7	1.4	6.0	0.7	7.2
17	62.8	65.2	2.3	203.0	100.2	0.2	0.0	6.2	8.3	1.3	7.0	0.2	6.3
18	63.0	65.5	2.5	203.6	99.3	0.3	0.0	7.3	8.0	1.1	5.8	2.8	5.6

Appendix IV continued

ENTRY	AD	SD	ASI	PH	EH	RL	SL	NP	NE	EPP	EA	ER	YLD
19	63.2	65.3	2.2	171.3	92.7	0.2	0.7	7.0	7.5	1.1	6.2	1.0	5.7
20	63.7	66.0	2.3	185.5	96.0	1.5	0.3	6.2	6.2	1.0	5.3	0.8	4.5
21	63.0	66.8	3.8	189.4	97.2	0.5	0.0	6.7	7.7	1.2	6.3	1.2	5.6
22	63.2	65.5	2.3	178.2	94.4	0.2	0.2	7.5	7.8	1.0	5.7	1.5	5.2
23	63.5	65.2	1.7	182.0	97.9	0.3	0.0	7.5	8.5	1.1	6.0	2.0	5.1
24	64.0	66.3	2.3	183.9	101.5	0.3	0.3	6.8	7.3	1.1	5.5	2.3	3.7
25	61.8	64.2	2.3	189.9	98.1	0.8	1.0	7.3	7.7	1.0	6.0	1.3	5.0
26	63.3	66.2	2.8	178.9	94.8	0.7	0.8	6.7	7.3	1.2	5.3	2.3	3.5
27	62.7	65.5	2.8	216.6	111.0	0.2	0.2	7.3	7.7	1.1	7.2	1.2	7.0
28	62.5	64.7	2.2	197.9	99.3	0.3	0.3	7.3	7.5	1.0	7.2	0.5	6.4
29	63.2	64.2	1.0	207.1	110.0	1.2	0.2	8.3	10.0	1.2	7.0	0.7	7.6
30	63.3	66.5	3.2	192.7	101.0	0.2	0.0	7.2	7.7	1.1	6.5	0.8	6.0
31	62.8	65.3	2.5	194.1	105.8	0.0	0.2	7.0	9.3	1.3	7.2	1.5	6.8
32	62.5	64.8	2.3	210.6	109.3	0.2	0.3	6.5	7.2	1.1	6.2	1.3	6.9
33	63.0	64.8	1.8	194.9	101.9	0.7	0.2	7.0	7.7	1.1	6.7	0.8	6.2
34	62.8	64.0	1.2	196.1	103.1	0.3	0.0	6.2	6.3	1.0	6.0	1.8	4.7
35	62.2	65.0	2.8	175.6	91.3	0.0	0.7	6.5	7.0	1.1	6.0	1.2	4.4
36	63.2	66.8	3.7	186.7	102.8	0.2	0.5	6.7	7.8	1.2	6.2	1.2	4.8
37	63.2	66.2	3.0	176.2	89.8	0.3	0.5	6.2	6.7	1.1	5.8	1.8	3.8
38	62.7	65.7	3.0	182.7	104.4	1.0	0.3	6.7	7.5	1.1	6.3	0.8	5.0
39	63.0	65.2	2.2	183.0	99.8	0.7	0.8	7.7	7.5	1.0	5.7	2.0	4.2
40	63.7	65.7	2.0	197.5	107.8	0.3	0.0	7.2	8.0	1.1	6.7	1.3	6.1
41	64.0	65.7	1.7	190.9	96.7	0.3	0.3	7.2	9.0	1.2	5.8	1.3	5.5
42	62.7	64.7	2.0	207.1	111.7	0.0	0.2	7.5	9.7	1.3	6.3	1.7	6.0
43	62.5	64.8	2.3	198.9	109.4	0.0	0.2	7.8	8.0	1.0	6.2	2.0	6.4
44	62.0	63.7	1.7	211.9	108.9	0.7	0.0	7.7	9.7	1.2	7.0	1.5	7.6
45	61.8	64.0	2.2	197.9	100.0	0.3	0.0	6.7	7.3	1.1	6.7	1.7	7.3
46	62.0	64.2	2.2	206.8	103.7	0.3	0.3	7.3	7.8	1.1	6.7	1.0	6.7
47	62.5	65.7	3.2	184.7	95.6	0.0	0.5	6.8	7.5	1.1	6.2	1.2	5.4
48	63.2	65.7	2.5	175.1	91.7	0.3	0.8	6.2	6.3	1.0	5.8	0.3	4.3
49	62.5	65.8	3.3	197.0	101.5	0.7	0.5	6.5	7.2	1.1	5.2	3.0	4.4
50	63.3	65.8	2.5	181.6	94.0	0.2	0.0	7.8	8.2	1.1	6.2	1.5	5.0

Appendix IV continued

ENTRY	AD	SD	ASI	PH	EH	RL	SL	NP	NE	EPP	EA	ER	YLD
51	62.7	65.0	2.3	190.1	99.9	0.7	0.5	8.0	8.0	1.0	4.8	2.5	5.4
52	63.7	66.0	2.3	202.0	106.6	0.0	0.2	6.7	7.5	1.1	6.5	0.7	5.9
53	62.8	65.5	2.7	178.9	99.5	1.5	0.2	7.2	7.3	1.0	6.7	1.0	4.5
54	62.7	64.5	1.8	199.6	103.3	0.7	0.0	7.3	10.5	1.4	6.7	1.5	6.9
55	63.2	65.0	1.8	197.5	99.2	1.2	0.0	6.7	8.5	1.3	6.7	1.2	6.6
56	62.7	65.0	2.3	192.5	99.5	1.2	0.2	7.0	8.0	1.2	6.5	0.8	6.5
57	62.2	64.0	1.8	206.0	103.2	0.3	0.2	7.7	7.8	1.0	6.7	1.7	6.7
58	63.2	64.7	1.5	191.9	100.5	0.5	0.7	7.3	7.8	1.1	6.7	0.0	5.8
59	63.2	65.8	2.7	184.5	97.1	0.8	0.3	7.0	8.3	1.2	6.2	0.7	4.7
60	63.0	66.0	3.0	180.3	92.9	1.2	0.3	6.7	7.0	1.0	5.5	2.3	4.7
61	63.2	66.0	2.8	184.7	106.2	0.8	0.7	6.8	7.7	1.1	5.7	1.5	4.9
62	63.2	66.2	3.0	181.6	94.5	0.5	0.7	7.5	8.5	1.1	5.3	2.0	4.1
63	64.3	67.8	3.5	198.7	108.9	0.5	0.0	7.7	8.2	1.1	6.2	0.5	4.8
64	62.2	65.2	3.0	208.5	114.1	1.5	0.3	7.3	8.7	1.2	6.2	0.5	5.5
65	60.8	63.5	2.7	194.8	98.7	0.7	0.2	6.3	8.8	1.4	6.5	1.3	6.3
66	61.5	63.3	1.8	196.5	104.5	0.8	0.0	6.8	8.0	1.2	6.8	1.3	6.0
67	62.5	64.2	1.7	194.5	97.6	0.8	0.0	6.7	7.5	1.1	6.2	1.0	6.1
68	60.7	62.3	1.7	206.2	106.3	0.0	0.0	6.7	8.3	1.3	6.3	2.2	6.4
69	62.5	63.3	0.8	190.2	99.0	0.7	1.3	7.0	6.7	1.0	6.5	0.3	5.8
70	62.2	64.8	2.7	196.7	102.4	1.0	0.2	6.8	7.3	1.1	5.7	2.2	4.4
71	63.7	66.5	2.8	181.7	97.2	1.0	1.8	6.2	7.3	1.2	6.0	0.5	4.6
72	63.3	66.2	2.8	186.4	95.5	0.2	0.0	6.8	7.2	1.0	5.3	1.8	4.5
73	64.3	67.0	2.7	197.4	109.1	0.7	0.7	7.5	9.0	1.2	6.3	1.8	5.9
74	63.5	66.2	2.7	197.2	109.3	0.5	0.0	6.8	8.5	1.3	5.8	1.2	5.0
75	63.7	65.2	1.5	193.7	97.3	1.0	0.0	7.3	8.3	1.1	6.3	1.8	5.5
76	63.2	65.0	1.8	190.5	95.7	0.0	0.0	6.7	8.5	1.3	5.5	2.3	5.8
77	61.3	64.3	3.0	210.5	105.2	0.3	0.3	6.0	6.2	1.0	7.2	0.0	6.3
78	62.7	64.0	1.3	206.8	107.8	0.2	0.0	7.2	7.7	1.1	6.8	0.8	7.3
79	61.8	63.0	1.2	188.0	95.1	0.5	1.2	6.8	7.2	1.1	6.7	1.2	5.4
80	63.2	66.3	3.2	186.7	98.5	0.8	0.8	6.7	7.8	1.2	6.8	1.2	4.8
81	62.8	65.3	2.5	183.2	86.8	0.5	1.0	6.3	7.7	1.2	5.3	1.7	4.8
82	64.0	68.0	4.0	214.5	122.2	0.3	0.0	6.3	6.7	1.1	6.5	0.5	5.5

Appendix IV continued

ENTRY	AD	SD	ASI	PH	EH	RL	SL	NP	NE	EPP	EA	ER	YLD
83	63.5	65.5	2.0	174.2	92.9	0.3	0.2	6.8	7.2	1.0	6.5	0.3	4.7
84	64.0	65.2	1.2	229.3	112.6	0.3	0.2	6.0	6.5	1.1	5.8	1.8	5.8
85	62.5	64.5	2.0	179.7	91.7	0.0	0.3	6.7	8.0	1.2	6.5	0.7	6.3
86	63.0	65.5	2.5	184.5	94.0	0.2	0.5	6.8	7.7	1.1	6.8	0.8	5.9
87	62.3	64.2	1.8	204.8	105.6	0.2	0.0	7.3	8.7	1.2	6.2	2.3	5.7
88	63.5	64.5	1.0	188.1	98.6	0.5	0.5	6.2	6.7	1.1	6.5	1.0	4.8
89	63.2	65.0	1.8	182.4	88.9	0.0	0.5	6.3	6.8	1.1	6.5	2.5	4.0
90	63.7	67.0	3.3	203.9	107.0	0.0	0.0	7.0	9.3	1.3	6.8	1.5	5.9
91	63.7	67.0	3.3	203.9	107.0	0.0	0.0	7.0	9.3	1.3	6.8	1.5	5.9
92	63.7	66.0	2.3	196.2	108.2	0.0	1.0	7.3	9.5	1.4	6.3	0.3	5.6
93	63.5	66.3	2.8	198.5	100.1	0.5	0.2	6.8	7.5	1.1	6.3	1.0	5.5
94	63.0	64.7	1.7	196.1	103.6	0.2	0.0	6.8	7.7	1.1	6.8	0.7	6.2
95	63.2	65.0	1.8	185.7	91.8	0.5	0.8	6.0	7.8	1.4	6.3	0.3	5.3
96	63.3	65.7	2.3	198.6	101.9	0.3	0.0	7.3	7.8	1.1	6.7	0.7	5.8
97	62.7	64.7	2.0	185.7	96.1	0.7	1.2	6.5	6.3	1.0	5.8	1.5	4.3
98	64.7	69.0	4.3	193.7	100.9	0.0	0.0	5.7	6.2	1.1	5.8	0.7	4.5
99	63.8	65.2	1.3	185.8	104.9	1.0	0.2	6.2	7.5	1.3	5.7	1.0	5.2
100	63.2	65.5	2.3	207.7	105.9	0.2	0.0	7.2	8.7	1.2	6.0	2.2	5.6
101	62.0	64.3	2.3	194.6	105.5	0.5	0.2	6.0	7.2	1.2	6.3	1.0	5.5
102	62.0	64.2	2.2	192.2	96.0	0.3	0.7	6.0	6.8	1.1	6.3	0.2	4.9
103	61.8	63.8	2.0	210.5	104.1	0.2	0.0	5.8	5.8	1.0	5.7	2.2	5.3
104	63.0	66.0	3.0	205.0	107.0	0.5	0.2	7.8	8.3	1.0	6.8	1.0	6.5
105	64.2	65.5	1.3	196.8	104.3	0.8	0.0	7.0	7.2	1.0	6.5	0.8	4.9
106	63.0	65.2	2.2	198.8	112.8	0.0	0.2	7.7	11.5	1.5	6.5	1.5	6.7
107	62.5	64.2	1.7	184.9	99.4	1.2	0.2	6.5	6.8	1.0	6.2	0.7	5.9
108	62.3	64.5	2.2	192.6	95.7	0.3	0.0	6.5	7.2	1.1	6.8	0.5	5.4
109	63.7	66.5	2.8	217.6	112.4	0.0	0.0	6.0	6.2	1.0	5.5	1.2	5.2
110	62.3	63.8	1.5	186.6	103.5	1.5	0.0	7.3	8.8	1.2	5.8	1.2	5.9

Appendix IV continued

ENTRY	AD	SD	ASI	PH	EH	RL	SL	NP	NE	EPP	EA	ER	YLD
MEAN	63.0	65.3	2.3	193.8	101.6	0.5	0.3	6.9	7.8	1.1	6.2	1.3	5.5
CV	2.51	2.94	65.58	9.56	11.83	209.29	218.5	18.32	25.18	19.95	15.57	108.5	25.03
LSD	1.79	2.17	1.73	21	13.62	1.11	0.77	1.43	2.23	0.26	1.09	1.59	1.57
SIGNIF	**	***	**	***	***	NS	***	NS	***	***	***	*	***

Entry 14= PH 3253, entry 90=H513. * =0.05, ** =0.01, *** =0.001

Appendix V. Estimates of specific combining ability effects of the 108 single crosses grown at Kiboko under *Chilo partellus* infestation.

Entry	Crosses	ASI	PH	EH	Y-HA	Y-LOSS	INDS	EXH	TNL	TL-PH
		d	(cm)	(cm)	(tons)	(tons)	Score (1-9)	(No.)	(cm)	(ratio)
1	1x6	-0.36	-7.50	-2.00	82.48	-26.91	0.05	-0.08	0.32	0.002
2	1x7	0.99	28.04	18.03	349.92	596.82	-0.36	0.42	-0.98	-0.007
3	1x8	-0.94	11.99	1.79	923.53	378.79	0.18	0.44	0.41	-0.001
4	1x9	0.40	12.29	7.78	207.79	87.60	0.04	-0.04	0.39	0.000
5	1x10	0.64	-0.94	-0.79	-179.00	-521.68	0.03	0.11	0.48	0.006
6	1x11	-0.53	-11.55	-15.38	-1277.91	-132.43	0.23	0.02	0.43	0.003
7	1x12	0.03	18.16	9.74	292.88	861.73	0.01	-0.44	-0.93	-0.007
8	1x13	1.43	-9.14	-4.61	-1603.22	-609.57	-0.29	0.02	0.21	0.002
9	1x14	0.84	-5.41	2.48	-1271.20	299.46	0.44	1.02	1.72	0.012
10	1x15	0.81	1.90	2.37	-859.39	-316.38	-0.09	-0.60	-1.14	-0.007
11	1x16	-0.74	-16.95	-18.84	-859.56	-976.39	-0.56	-0.05	-0.77	-0.006
12	2x7	0.29	-8.18	-7.53	-1345.89	-311.85	0.02	0.68	0.53	0.002
13	2x8	1.02	12.12	10.17	843.66	-423.82	-0.06	-0.28	-0.15	-0.003
14	2x9	-0.32	1.58	-2.18	-199.64	65.04	-0.02	-0.02	0.06	-0.001
15	2x10	-1.27	3.81	13.43	669.59	3.74	0.05	-0.69	-0.15	-0.001
16	2x11	0.23	4.67	-0.31	316.14	721.86	0.08	-0.33	-0.21	-0.002
17	2x12	-0.22	13.03	4.79	-332.85	-111.62	0.20	0.98	1.84	0.008
18	2x13	0.33	-27.20	-20.47	-352.02	-133.61	0.46	1.27	2.16	0.014
19	2x14	-0.16	-11.96	-5.80	-971.97	-631.23	0.24	0.22	0.61	0.006
20	2x15	1.36	-12.27	-18.52	-460.88	-399.23	0.43	1.11	3.82	0.022
21	2x16	0.23	-17.91	-17.46	-332.65	-970.02	-0.07	-0.47	-0.40	-0.002
22	2x17	-0.65	-17.29	-3.91	-932.00	-444.43	-0.14	-0.29	0.62	0.004
23	3x8	0.15	-9.74	-0.54	-1502.02	-660.48	-0.28	0.33	-1.08	-0.005
24	3x9	0.14	-3.52	-0.82	20.63	-40.73	0.26	1.50	2.23	0.012
25	3x10	0.50	-12.76	-4.40	-1510.04	-1153.09	-0.39	-0.67	-1.78	-0.007
26	3x11	0.54	29.51	14.49	1367.70	556.36	0.17	0.50	1.80	0.002
27	3x12	-0.60	10.26	3.18	1134.91	684.23	0.24	0.05	-0.14	-0.001

Appendix V. Continued.

Entry	Crosses	ASI	PH	EH	Y-HA	Y-LOSS	INDS	EXH	TNL	TL-PH
		(d)	(cm)	(cm)	(tons)	(tons)	Score (1-9)	(No.)	(cm)	Ratio
28	3x13	-0.91	14.02	11.11	1973.50	2507.05	0.17	-0.22	-0.54	-0.005
29	3x14	0.58	5.76	3.88	534.99	745.03	-0.18	-0.18	-0.59	-0.005
30	3x15	-0.21	-3.59	3.41	740.10	704.01	-0.37	-0.08	-1.43	-0.007
31	3x16	0.11	8.58	-4.46	662.53	247.30	-0.17	0.15	1.25	0.006
32	3x17	-0.28	-0.12	0.55	616.25	42.00	0.21	0.41	0.64	0.004
33	3x18	-0.64	8.62	12.62	-34.05	-358.80	0.06	-0.26	-0.47	-0.003
34	4x9	0.16	-12.50	-8.97	-139.96	-502.48	0.26	0.24	-0.26	-0.001
35	4x10	1.03	-3.18	0.90	-316.32	137.21	-0.18	-0.67	-0.33	-0.002
36	4x11	0.21	-8.61	-2.63	-1621.87	-1243.45	-0.03	-0.21	-0.77	-0.005
37	4x12	0.16	-7.87	-0.26	-159.93	-352.99	-0.01	-0.07	0.57	0.002
38	4x13	0.13	-12.24	-7.16	-814.55	-861.99	0.40	0.30	0.72	0.002
39	4x14	-0.72	-7.77	3.99	770.43	639.61	-0.15	-0.62	-1.53	0.015
40	4x15	-1.37	0.52	12.788	202.35	373.58	0.23	0.84	1.18	0.004
41	4x16	-0.20	13.40	-4.89	1501.14	473.34	0.36	0.07	0.89	0.001
42	4x17	-0.43	9.13	9.39	903.87	292.72	0.22	0.61	1.06	0.003
43	4x18	-0.66	26.73	15.16	2928.36	1472.76	-0.02	0.78	2.97	0.010
44	4x19	0.03	-2.03	-2.30	100.02	893.08	0.34	0.99	2.58	0.015
45	5x10	-0.29	12.09	1.07	1021.90	-570.56	0.09	-0.60	-0.38	-0.002
46	5x11	1.18	-3.98	-3.93	-405.41	-186.05	0.08	-0.37	-0.70	-0.003
47	5x12	-0.13	-15.14	-13.46	-1292.87	-151.52	0.16	0.44	1.54	0.009
48	5x13	1.27	5.23	4.24	-554.87	-673.45	-0.19	-0.35	-0.86	-0.006
49	5x14	0.06	-11.14	-7.02	-464.18	313.91	0.01	0.53	0.98	0.007
50	5x15	0.01	-6.17	-4.09	291.40	308.94	-0.02	0.46	0.24	0.002
51	5x16	0.08	5.51	-5.71	53.95	290.23	0.11	0.13	-0.26	-0.002
52	5x17	0.08	-11.29	0.77	-176.25	-523.25	-0.02	-0.43	-1.08	-0.004
53	5x18	-0.10	10.74	14.20	1016.82	594.72	0.28	0.18	2.53	0.01
54	5x19	0.19	-2.52	-5.87	11.23	1108.00	0.67	1.06	1.97	0.01

Appendix V. Continued.

Entry	Crosses	ASI	PH	EH	Y-HA	Y-LOSS	INDS	EXH	TNL	TL-PH
		(d)	(cm)	(cm)	(tons)	(tons)	Score (1-9)	(No.)	(cm)	Ratio
55	5x20	0.25	5.89	0.74	91.74	-175.39	-0.41	-0.04	0.83	0.004
56	6x11	-0.38	16.07	4.67	1148.22	658.78	-0.13	-0.12	-0.68	-0.005
57	6x12	-1.44	-4.69	1.83	4.59	465.75	0.18	0.43	0.01	-0.003
58	6x13	0.51	-4.64	0.54	-164.15	-604.68	-0.26	-0.05	-1.25	-0.006
59	6x14	0.03	0.23	1.70	-991.15	107.95	-0.32	-0.71	-1.31	-0.007
60	6x15	-0.02	-8.42	1.71	318.97	-432.37	-0.28	-0.26	-1.09	-0.005
61	6x16	0.72	-13.82	-13.05	-1254.65	-1319.98	-0.19	-0.59	-1.17	-0.006
62	6x17	1.09	10.58	12.35	509.26	806.90	0.53	-0.96	-1.31	-0.006
63	6x19	1.23	7.34	11.52	-1065.10	-586.39	-0.02	0.08	1.23	0.004
64	6x20	-0.50	-2.03	1.28	567.35	1135.58	-0.28	-0.88	-1.09	-0.007
65	7x12	-0.81	6.49	5.97	736.77	-30.64	0.14	-0.15	0.84	0.002
66	7x13	-0.13	0.76	-13.46	850.75	-13.98	0.09	-0.09	-0.85	-0.003
67	7x14	-0.65	11.84	7.414	395.19	398.50	0.176	0.71	3.69	0.018
68	7x15	-1.38	2.29	1.31	-19.11	739.05	-0.05	-0.11	1.40	0.006
69	7x16	0.41	-4.40	-10.90	-1156.04	-976.35	-0.43	-0.65	-1.05	-0.004
70	7x17	0.86	-10.82	-2.76	-414.69	-38.64	0.04	0.06	-1.27	-0.005
71	7x18	0.87	-10.41	-2.22	-1335.94	-229.86	0.24	0.42	0.61	0.006
72	7x19	1.45	-3.28	3.13	-345.56	-541.61	-0.11	-0.34	-1.01	-0.005
73	7x20	0.58	4.03	10.75	28.52	-135.34	-0.11	-0.49	-1.59	-0.009
74	8x13	-0.42	4.27	2.58	399.64	329.97	-0.08	0.34	-0.10	-0.002
75	8x14	-0.79	-1.44	0.75	390.64	836.31	0.21	0.84	1.86	0.013
76	8x15	0.60	13.00	0.41	666.89	666.89	0.14	0.11	1.69	0.008
77	8x16	-0.47	10.23	-7.07	1156.47	-27.16	0.29	0.33	0.73	0.003
78	8x17	-1.12	-9.87	-6.07	161.13	-37.52	0.13	0.39	0.51	0.007
79	8x18	1.12	-4.40	5.37	451.57	-207.61	-0.01	-0.05	0.17	-0.001
80	8x19	0.85	-16.11	-18.26	-2431.85	-1454.20	-0.20	-0.39	-1.16	-0.005
81	8x20	1.32	21.88	17.22	268.41	-399.77	-0.47	-0.43	-1.37	-0.010

Appendix V. Continued.

Entry	Crosses	ASI	PH	EH	Y-HA	Y-LOSS	INDS	EXH	TNL	TL-PH
		(d)	(cm)	(cm)	(tons)	(tons)	Score (1-9)	(No.)	(cm)	Ratio
82	9x14	0.05	-15.90	0.92	-1309.69	-257.14	-0.05	-0.28	-0.83	-0.004
83	9x15	-1.05	26.25	8.65	-618.49	-619.65	-0.01	0.24	-0.86	-0.007
84	9x16	0.21	-13.53	-18.21	144.69	919.73	0.01	0.49	1.37	0.007
85	9x17	0.44	-0.01	0.46	543.43	-37.30	0.31	-0.15	0.43	0.001
86	9x18	0.24	11.47	10.37	410.54	69.45	-0.33	-0.25	-0.93	-0.007
87	9x19	-0.31	-11.25	0.73	-817.00	-543.14	-0.22	-0.16	-0.68	-0.005
88	9x20	-0.22	-9.79	-13.63	-1608.81	47.88	-0.14	-0.18	-1.27	-0.007
89	10x15	0.12	4.60	8.82	354.80	745.76	0.50	0.41	1.21	0.006
90	10x16	0.62	3.72	-5.16	-367.84	-1081.10	0.01	0.43	0.87	0.006
91	10x17	-0.39	4.05	4.81	1147.62	560.00	-0.28	-0.40	-0.27	-0.002
92	10x18	-0.14	-5.05	1.88	-408.47	-200.48	-0.08	0.02	0.01	0.001
93	10x19	0.65	-0.12	-3.34	-369.19	-274.19	-0.23	-0.16	-0.24	-0.002
94	10x20	-0.30	-9.02	-3.33	-541.21	-600.42	0.04	-0.02	0.27	0.002
95	11x16	2.19	-2.71	-10.19	-715.35	-137.86	-0.06	0.26	0.85	0.003
96	11x17	-0.62	-12.90	0.20	-30.51	-354.78	-0.05	-0.40	-0.43	0.002
97	11x18	0.18	19.94	12.10	278.93	502.88	0.14	-0.43	-0.59	-0.006
98	11x19	0.76	-4.61	0.60	-1151.09	-1031.75	-0.10	0.31	1.00	0.008
99	11x20	-0.45	0.93	-4.33	626.50	459.02	0.11	0.44	0.97	0.002
100	12x17	0.21	10.55	-8.13	-557.53	-44.40	0.16	0.37	1.10	0.002
101	12x18	0.71	9.32	77.28	6.49	1169.88	0.27	-0.27	-0.04	-0.001
102	12x19	0.19	-9.61	-15.63	-947.87	-950.25	-0.15	-0.32	-1.32	-0.006
103	12x20	-0.15	3.19	-0.22	1479.13	844.40	0.37	0.01	-0.37	-0.003
104	13x18	0.02	-0.72	13.74	829.93	950.15	0.16	-0.16	-0.06	-0.001
105	13x19	1.10	-15.54	-14.25	-1069.12	-1103.78	-0.07	-0.27	-0.87	-0.003
106	13x20	1.03	16.40	2.05	383.55	507.55	0.20	0.77	2.60	0.012
107	14x20	-0.52	-3.68	-7.48	114.39	169.45	0.06	-0.10	-0.86	-0.003
108	15x20	-0.69	1.31	-2.88	648.69	165.63	0.01	0.07	0.25	0.002

Appendix VI. Estimates of specific combining ability effects of the 108 single crosses grown at Embu under *Busseola fusca* infestation.

Entry	Crosses	ASI	PH	EH	Y-HA	Y-LOSS	INDS	EXH	TNL	TL-PH
		d	(cm)	(cm)	(tons)	(tons)	Score (1-9)	(No.)	(cm)	(ratio)
1	1x6	-0.36	-7.50	-2.00	82.48	-26.91	0.05	-0.08	0.32	0.002
2	1x7	0.99	28.04	18.03	349.92	596.82	-0.36	0.42	-0.98	-0.007
3	1x8	-0.94	1.80	11.99	923.53	378.80	0.18	0.44	0.41	-0.001
4	1x9	0.41	7.79	12.29	207.79	87.60	0.05	-0.04	0.39	0.000
5	1x10	0.64	-0.79	-0.94	-179.00	-521.68	0.03	0.12	0.48	0.006
6	1x11	-0.53	-15.39	-11.56	-1277.91	-132.44	0.23	0.02	0.44	0.003
7	1x12	0.03	9.74	18.16	292.88	861.73	0.01	-0.44	-0.93	-0.007
8	1x13	1.44	-4.62	-9.14	-1603.22	-609.57	-0.29	0.02	0.21	0.002
9	1x14	0.84	2.48	-5.42	-1271.20	299.46	0.44	1.02	1.72	0.012
10	1x15	0.82	2.38	1.91	-859.40	-316.38	-0.10	-0.61	-1.14	-0.007
11	1x16	-0.75	-18.84	-16.95	-859.56	-976.39	-0.57	-0.05	-0.77	-0.006
12	2x7	0.30	-7.54	-8.19	-1345.89	-311.86	0.02	0.69	0.54	0.002
13	2x8	1.02	10.17	12.12	843.67	-423.82	-0.06	-0.29	-0.15	-0.003
14	2x9	-0.32	-2.18	1.58	-199.65	65.05	-0.03	-0.02	0.07	-0.001
15	2x10	-1.27	13.43	3.81	669.59	3.74	0.06	-0.70	-0.16	-0.001
16	2x11	0.23	-0.31	4.68	316.15	721.87	0.09	-0.34	-0.22	-0.002
17	2x12	-0.22	4.79	13.04	-332.86	-111.63	0.20	0.98	1.84	0.008
18	2x13	0.33	-20.47	-27.20	-352.03	-133.61	0.46	1.28	2.17	0.014
19	2x14	-0.17	-5.81	-11.97	-971.98	-631.23	0.24	0.22	0.61	0.006
20	2x15	1.36	-18.52	-12.27	-460.89	-399.23	0.44	1.12	3.82	0.022
21	2x16	0.23	-17.47	-17.92	-332.65	-970.03	-0.08	-0.47	-0.40	-0.002
22	2x17	-0.65	-3.91	-17.29	-932.00	-444.44	-0.14	-0.29	0.62	0.004
23	3x8	0.16	-0.55	-9.75	-1502.02	-660.48	-0.29	0.33	-1.08	-0.005
24	3x9	0.14	-0.82	-3.53	20.64	-40.73	0.27	1.50	2.23	0.012
25	3x10	0.50	-4.41	-12.77	-1510.05	1153.09	-0.39	-0.67	-1.79	-0.007
26	3x11	0.55	14.50	29.52	1367.71	556.37	0.17	0.51	1.81	0.002
27	3x12	-0.61	3.18	10.27	1134.91	684.23	0.25	0.05	-0.15	-0.001

Appendix VI. Continued.

Entry	Crosses	ASI	PH	EH	Y-HA	Y-LOSS	INDS	EXH	TNL	TL-PH
		(d)	(cm)	(cm)	(tons)	(tons)	Score (1-9)	(No.)	(cm)	Ratio
28	3x13	-0.21	-3.60	3.41	740.10	704.01	-0.38	-0.09	-1.44	-0.007
29	3x14	0.12	8.59	-4.47	662.54	247.31	-0.17	0.15	1.25	0.006
30	3x15	-0.29	-0.12	0.55	616.26	42.00	0.22	0.41	0.64	0.004
31	3x16	-0.64	8.62	12.63	-34.06	-358.81	0.07	-0.26	-0.48	-0.003
32	3x17	0.16	-12.50	-8.98	-139.97	-502.49	0.27	0.24	-0.26	-0.001
33	3x18	1.04	-3.18	0.90	-316.32	137.22	-0.19	-0.68	-0.34	-0.002
34	4x9	0.22	-8.62	-2.64	-1621.88	-1243.46	-0.04	-0.21	-0.77	-0.005
35	4x10	0.17	-7.87	-0.27	-159.94	-353.00	-0.02	-0.07	0.58	0.002
36	4x11	0.13	-12.25	-7.16	-814.55	-862.00	0.40	0.31	0.73	0.002
37	4x12	-0.72	-7.77	3.99	770.43	639.61	-0.16	-0.63	-1.53	0.015
38	4x13	-1.38	0.52	-12.79	202.36	373.59	0.24	0.85	1.19	0.004
39	4x14	-0.20	13.40	-4.89	1501.14	473.35	0.36	0.08	0.89	0.001
40	4x15	-0.44	9.14	9.39	903.88	292.72	0.23	0.62	1.06	0.003
41	4x16	-0.66	26.73	15.17	2928.36	1472.77	-0.02	0.79	2.98	0.010
42	4x17	0.03	-2.03	-2.31	100.02	893.08	0.35	1.00	2.58	0.015
43	4x18	-0.29	12.10	1.08	1021.90	-570.56	0.09	-0.60	-0.38	-0.002
44	4x19	1.18	-3.98	-3.93	-405.42	-186.06	0.08	-0.38	-0.70	-0.003
45	5x10	-0.13	-15.15	-13.46	-1292.87	-151.52	0.17	0.45	1.54	0.009
46	5x11	1.28	5.23	4.24	-554.88	-673.45	-0.19	-0.35	-0.86	-0.006
47	5x12	0.07	-11.14	-7.02	-464.18	313.92	0.01	0.53	0.98	0.007
48	5x13	0.01	-6.17	-4.09	291.40	308.95	-0.03	0.47	0.25	0.002
49	5x14	0.08	5.51	-5.71	53.95	290.24	0.12	0.13	-0.26	-0.002
50	5x15	0.09	-11.29	0.78	-176.25	-523.26	-0.02	-0.44	-1.08	-0.004
51	5x16	-0.10	10.75	14.20	1016.82	594.73	0.28	0.18	2.53	0.011
52	5x17	0.20	-2.53	-5.88	11.23	1108.00	0.68	1.06	1.97	0.011
53	5x18	0.25	5.89	0.74	91.74	-175.40	-0.41	-0.05	0.84	0.004
54	5x19	-0.38	16.08	4.67	1148.22	658.79	-0.14	-0.13	-0.68	-0.005

Appendix VI. Continued.

Entry	Crosses	ASI	PH	EH	Y-HA	Y-LOSS	INDS	EXH	TNL	TL-PH
		(d)	(cm)	(cm)	(tons)	(tons)	Score (1-9)	(No.)	(cm)	Ratio
55	5x20	-1.45	-4.70	1.84	4.60	465.76	0.19	0.43	0.02	-0.003
56	6x11	0.51	-4.65	0.54	-164.15	-604.69	-0.26	-0.05	-1.26	-0.006
57	6x12	0.03	0.23	1.70	-991.16	107.96	-0.32	-0.72	-1.31	-0.007
58	6x13	-0.03	-8.43	1.71	318.98	-432.37	-0.28	-0.26	-1.10	-0.005
59	6x14	0.73	-13.83	-13.06	-1254.65	-1319.98	-0.20	-0.59	-1.17	-0.006
60	6x15	1.10	10.58	12.36	509.26	806.91	0.54	-0.96	-1.32	-0.006
61	6x16	1.23	7.34	11.53	-1065.10	-586.40	-0.02	0.09	1.24	0.004
62	6x17	-0.51	-2.03	1.28	567.35	1135.58	-0.29	-0.88	-1.10	-0.007
63	6x19	-0.82	6.50	5.97	736.77	-30.65	0.14	-0.15	0.84	0.002
64	6x20	-0.13	0.77	-13.46	850.75	-13.98	0.10	-0.09	-0.85	-0.003
65	7x12	-0.65	11.84	7.41	395.20	398.50	0.18	0.72	3.70	0.018
66	7x13	-1.38	2.29	1.32	-19.12	739.06	-0.06	-0.11	1.41	0.006
67	7x14	0.42	-4.40	-10.90	-1156.05	-976.35	-0.43	-0.65	-1.05	-0.004
68	7x15	0.87	-10.82	-2.76	-414.70	-38.64	0.05	0.06	-1.27	-0.005
69	7x16	0.88	-10.42	-2.23	-1335.95	-229.86	0.24	0.42	0.62	0.006
70	7x17	1.46	-3.28	3.14	-345.56	-541.61	-0.11	-0.34	-1.02	-0.005
71	7x18	0.59	4.04	10.76	28.53	-135.34	-0.11	-0.50	-1.59	-0.009
72	7x19	-0.42	4.28	2.59	399.65	329.97	-0.08	0.34	-0.11	-0.002
73	7x20	-0.80	-1.45	0.76	390.64	836.31	0.21	0.85	1.86	0.013
74	8x13	0.60	13.01	0.42	666.89	666.90	0.14	0.12	1.69	0.008
75	8x14	-0.48	10.23	-7.07	1156.47	-27.16	0.29	0.33	0.74	0.003
76	8x15	-1.12	-9.87	-6.07	161.13	-37.52	0.14	0.39	0.52	0.007
77	8x16	1.12	-4.40	5.37	451.58	-207.62	-0.02	-0.05	0.17	-0.001
78	8x17	0.85	-16.12	-18.26	-2431.86	-1454.21	-0.20	-0.39	-1.16	-0.005
79	8x18	1.32	21.89	17.22	268.41	-399.77	-0.48	-0.44	-1.38	-0.010
80	8x19	0.05	-15.91	0.93	-1309.69	-257.15	-0.05	-0.28	-0.84	-0.004
81	8x20	-1.06	26.26	8.65	-618.49	-619.66	-0.02	0.24	-0.87	-0.007

Appendix VI. Continued.

Entry	Crosses	ASI	PH	EH	Y-HA	Y-LOSS	INDS	EXH	TNL	TL-PH
		(d)	(cm)	(cm)	(tons.)	(tons.)	Score (1-9)	(No.)	(cm)	Ratio
82	9x14	0.22	-13.53	-18.21	144.69	919.74	0.01	0.49	1.37	0.007
83	9x15	0.45	-0.01	0.47	543.44	-37.31	0.32	-0.15	0.43	0.001
84	9x16	0.25	11.47	10.38	410.55	69.45	-0.33	-0.26	-0.93	-0.007
85	9x17	-0.31	-11.25	0.74	-817.01	-543.15	-0.22	-0.17	-0.69	-0.005
86	9x18	-0.23	-9.79	-13.63	-1608.81	47.88	-0.15	-0.19	-1.27	-0.007
87	9x19	0.12	4.60	8.82	354.80	745.77	0.50	0.42	1.21	0.006
88	9x20	0.63	3.73	-5.16	-367.84	-1081.10	0.02	0.43	0.88	0.006
89	10x15	-0.38	4.06	4.81	1147.63	560.00	-0.28	-0.40	-0.28	-0.002
90	10x16	-0.15	-5.06	1.89	-408.48	-200.49	-0.08	0.03	0.02	0.001
91	10x17	0.65	-0.12	-3.35	-369.19	-274.19	-0.23	-0.16	-0.25	-0.002
92	10x18	-0.30	-9.02	-3.33	-541.21	-600.42	0.04	-0.03	0.27	0.002
93	10x19	2.19	-2.72	-10.20	-715.35	-137.87	-0.06	0.26	0.85	0.003
94	10x20	-0.62	-12.90	0.21	-30.52	-354.79	-0.05	-0.41	-0.43	0.002
95	11x16	0.19	19.94	12.10	278.94	502.88	0.14	-0.44	-0.60	-0.006
96	11x17	0.77	-4.62	0.61	-1151.10	-1031.75	-0.10	0.32	1.01	0.008
97	11x18	-0.45	0.94	-4.34	626.50	459.02	0.11	0.44	0.98	0.002
98	11x19	0.21	10.55	-8.13	-557.53	-44.40	0.16	0.37	1.11	0.002
99	11x20	0.71	9.33	77.28	6.49	1169.88	0.27	-0.27	-0.04	-0.001
100	12x17	0.20	-9.61	-15.63	-947.87	-950.25	-0.15	-0.33	-1.32	-0.006
101	12x18	-0.16	3.19	-0.22	1479.14	844.41	0.38	0.02	-0.37	-0.003
102	12x19	0.03	-0.73	13.74	829.93	950.15	0.17	-0.17	-0.06	-0.001
103	12x20	1.10	-15.54	-14.25	-1069.13	-1103.79	-0.07	-0.28	-0.87	-0.003
104	13x18	1.03	16.41	2.05	383.56	507.55	0.20	0.77	2.60	0.012
105	13x19	-0.52	-3.69	-7.49	114.40	169.46	0.07	-0.10	-0.86	-0.003
106	13x20	-0.69	1.32	-2.89	648.70	165.63	0.01	0.07	0.26	0.002
107	14x20	0.22	-13.53	-18.21	144.69	919.74	0.01	0.49	1.37	0.007
108	15x20	0.45	-0.01	0.47	543.44	-37.31	0.32	-0.15	0.43	0.001

Appendix VII.

Rainfall data for Kiboko Long rains 2003.

Month	**Temperature**		**Relative humidity**	**Rainfall**
	Max (mean)	Min (mean)	% (mean)	Mm (total)
January	33.7	16.7	84.4	5.0
February	35.7	16.8	74.7	15.5
March	33.2	18.9	75.5	28.0
April	31.9	19.6	79.5	61.0
May	29.2	18.4	80.1	39.0
June	28.4	14.8	75.1	0.0
July	27.4	13.9	75.8	0.0
August	27.7	14.6	78.5	0.0
September	29.8	16.5	73.5	1.5
October	31.1	18.1	71.7	23.5
November	30.5	17.5	72.5	20.5
December	29.9	16.5	72.5	10.5