STUDIES ON STALK BORERS OF MAIZE AND SORGHUM IN LESOTHO

by

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CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

Maize, *Zea mays* L. (Graminaceae) and sorghum, *Sorghum bicolor* (L.) Moench. (Graminaceae) are among the world's most important crops. Both maize and sorghum are grown mainly in the semi-arid tropics and subtropics. World production figures of cereals of 1986 show that maize was grown on 131 million hectares, ranking it third after wheat and rice which occupied 229 and 145 million hectares respectively (Doggett, 1988). Sorghum was grown on 47 million hectares, which placed it fifth after barley which was grown on an estimated 79 million hectares (Doggett, 1988).

In Lesotho (28° to 38° S, 27° to 30° E), maize, followed by sorghum, wheat, beans and peas are the major crops, with maize and sorghum being the major staple grains of the Basotho people (Brokken *et al.*, 1986; Anon., 1994, 1995; Majoro, 1995). It is estimated that, of the total annual cultivated area in Lesotho, maize occupies an average of 60 %, while sorghum and wheat occupy 10 % each. Beans and peas collectively occupy an estimated 6 % (Anon., 1995).

Maize grain is produced primarily for human consumption in the tropics, although it has long been used as a major source of monogastric animal feed in temperate regions (Rouanet, 1987). The crop is also important where whole maize plants may be ensiled for feeding ruminant livestock, while the grains are of industrial importance in the preparation of various packaged foods and snacks, starch and sugars (Rouanet, 1987). In Lesotho, maize grain is mainly used for the preparation of a staple food called 'papa', a stiff porridge eaten mainly with vegetables and/or meat.

Production and average yield of maize vary greatly from one region to another. For instance, whereas the United States of America (USA) alone produced nearly half of the world's maize in 1982, with average yields of 7185 kg/ha, the whole of Africa accounted for only 3.5 % of the total world figure, with average yields of 1094 kg/ha (Rouanet, 1987). Production figures for Lesotho show that annual maize yields are also highly variable. For example, mean annual yields varied between 326 kg/ha to 1359 kg/ha during the period 1976/77 to 1993/94, with an average yield of 746 kg/ha over the same period (Anon., 1994). This is well below the continental average of 1094 kg/ha and represents only about a third of yields achieved in the neighbouring Free State province of South Africa (Anon., 1995). As a result of the low yields, Lesotho is only able to produce less than half of its maize needs annually (Brokken *et al.*, 1986; Anon., 1995).

Sorghum is known by different names depending on where it is grown. For instance, it is known as guinea-corn in West Africa, durra in the Sudan, mtama in eastern Africa, jowar or cholam in India, kaoling in China and milo or milo-maize in America (Doggett, 1988). In Lesotho it is called 'mabele' in the Sesotho language.

Sorghum is a staple diet of many people in Africa. In Lesotho, however, it is used mainly for the preparation of an alcoholic beverage called 'joala', although it is also used to make both soft and stiff porridges. Various types of sorghum may also be grown for such other purposes as animal feed and for the preparation of sugars, syrups and dye (Doggett, 1988).

The stalks of tall, stout varieties are commonly used as fencing and roofing materials by rural people in West Africa, as well as a source of fuel.

Sorghum yields on peasant farms in Africa are generally low and often unpredictable (Van den Berg, 1994). Average yield of sorghum in Africa is 683 kg/ha, as compared to 734 kg/ha in India, 2900 kg/ha in Mexico and 3300 kg/ha in the USA (Leuschner, 1985). Average yield of sorghum on commercial farms in neighbouring South Africa is 1738 kg/ha, with yields of up to 2495 kg/ha in some years (Van den Berg, 1994). The average yield for Lesotho for the period 1976/77 to 1991/92 was 761 kg/ha, with most annual averages being below 800 kg/ha (Anon., 1994).

Several factors, among them pests, are often individually or collectively responsible for low crop yields. With regard to cereal crops, stalk borers have been reported as the most widespread and in some cases also the most important group of pests (Ajayi, 1989; Saxena *et al.*, 1989; Seshu Reddy, 1990; Vogel *et al.*, 1993). For instance, there are 23 species of lepidopterous stalk borers infesting sorghum the world over, of which 17 species belonging to six genera attack sorghum in Africa (Seshu Reddy, 1983, 1991). Many of these species also attack maize, but the species of stalk borers that attack both maize and sorghum vary in importance from one geographical area to another. *Busseola fusca* (Fuller) (Lepidoptera: Noctuidae), *Sesamia calamistis* (Hamps.) (Lepidoptera: Noctuidae), *Eldana saccharina* (Wlk.) (Lepidoptera: Pyralidae), and *Chilo partellus* (Swinhoe) (Lepidoptera: Pyralidae) are the predominant species of stalk borers in eastern and southern Africa (Seshu Reddy, 1989; Sithole, 1989). *C. agamemnon* Bleszynski, *C. diffusilineus* (J. de Joannis), *C. orichalcociliellus* Strand and *C. aleniella* (Strand) are other species of *Chilo* that attack cereal crops in east Africa (Seshu Reddy, 1990). In West Africa, cereal stalk borers that have been reported include *B. fusca*, *S. calamistis*, *E. saccharina* (Harris, 1962; Ajayi, 1989), *S. poephaga* Tams and Bowden, *S. penniseti* Tams and Bowden, and *Acigona ignefusalis* Hampson (Ajayi, 1989). In neighbouring South Africa, *B. fusca*, *C. partellus* and *S. calamistis* are the most important stalk borers that attack maize (Walters *et al.*, 1976). Generally though, *B. fusca* and *C. partellus* are regarded as the most important stalk borers of maize and sorghum in most parts of sub-Saharan Africa (Ajayi, 1989; Saxena *et al.*, 1989; Sithole, 1989; Seshu Reddy, 1990; Vogel *et al.*, 1993). These two species have also been reported to attack maize and sorghum in Lesotho (Qhobela *et al.*, 1986).

B. fusca is indigenous to Africa and its principal host is maize, although it also causes serious losses in sorghum (Seshu Reddy, 1983; Skoroszewski & Van Hamburg, 1987). *C. partellus* originated in western Asia and was first reported in South Africa in 1958 (Van Rensburg & Van Hamburg, 1975).

Most species of stalk borers cause similar damage and symptoms (Seshu Reddy, 1991). The first indication of stalk borer attack is small holes in the leaf surface, with the plant eventually becoming ragged as the size of larvae and associated feeding symptoms increase (Walters *et al.*, 1976; Seshu Reddy, 1991). Quite often, plant tissue is not eaten clear through, leaving a transparent layer of leaf (Seshu Reddy, 1991).

The females of *B. fusca* lay their eggs mostly behind the leaf sheaths of young maize or sorghum plants, although oviposition does occur on older plants (Annecke & Moran, 1982; Revington *et al.*, 1984; Van Rensburg, Walters & Giliomee, 1987). Eggs are also deposited under bracts of ears on older maize plants (Mally, 1920; Walters *et al.*, 1976; Annecke &

Moran, 1982). The females of *C. partellus* prefer to oviposit on the leaf surface (Van Rensburg & Van Hamburg, 1975; Alghali, 1985; Bate & Van Rensburg, 1990).

Upon hatching, young larvae of *B. fusca* and *C. partellus* move to the leaf whorl where they begin to feed on young furl leaves (Weaving, 1964; Van Rensburg & Van Hamburg, 1975; Chapman *et al.*, 1983). Sometimes, tunnelling in the growing points of young plants may lead to the formation of 'dead hearts' (Alghali, 1985; Van Rensburg, Walters & Giliomee, 1987). Eventually, larvae leave the leaf whorl and proceed to bore into the main stem or tillers where they continue to feed until they pupate (Barrow, 1987; Van Rensburg, Walters & Giliomee, 1987). Larvae pupate inside the stem of the plant and prior to pupation, each larva cuts an exit hole leaving only a very thin circular membrane of plant tissue through which the adult will emerge (Harris, 1962; Walters *et al.*, 1976). Although *C. partellus* larvae usually pupate inside stems, pupation may occur in leaf axils (Doggett, 1988).

There are two to three generations of *B. fusca* per year (Harris, 1962; Walters *et al.*, 1976; Gebre-Amlak, 1989). In the case of *C. partellus*, there are overlapping generations in the field, although two main peak flights per year have been reported in South Africa (Van Rensburg & Van Hamburg, 1975; Van Hamburg, 1980). Both *B. fusca* and *C. partellus* spend the off-season (winter or dry season) as mature larvae in a state of diapause inside sorghum/maize stalks and stubble, from where adult moths emerge to oviposit on crops early in the following growing season (Van Rensburg & Van Hamburg, 1975; Kfir, 1990c).

Generally, stem tunnelling by larvae leads to disruption in the normal flow of water and nutrients through the plant, which may in turn lead to diminished plant performance with a consequent loss in yield (Appert, 1970; Barrow, 1987; Van Rensburg *et al.*, 1988, 1988c). Yield loss also results when dead hearts occur, especially in young plants (Appert, 1970). In the case of maize plants, larvae of stalk borers may bore into the ears, thereby causing direct damage (Appert, 1970; Revington *et al.*, 1984; Van Rensburg *et al.*, 1988, 1988b, c). When attack occurs after panicle emergence in sorghum, larval feeding in the peduncle may result in the breakage of the panicle or the formation of partial or complete chaffy heads (Harris, 1962; Alghali, 1985). Early leaf senescence and lodging of plants, resulting from attack by stalk borers, are other causes of crop losses (Appert, 1970). In general, higher yield losses are sustained when plants are attacked at a young age than when infestation takes place at a later stage of plant development (Alghali, 1985, 1986; Van Rensburg *et al.*, 1988c; Sithole, 1989; MacFarlane, 1990).

Estimates of yield loss due to stalk borer damage vary considerably. In South Africa, yield loss due to *C. partellus* can be as high as 58 % depending on planting date (Van den Berg & Van Rensburg, 1991; Van den Berg, 1994), while yield losses in maize due to *B. fusca* damage is estimated at between 5 % and 72 % (Annecke & Moran, 1982). Usua (1968a) reported yield loss estimates of 10 % to 100 % in Nigeria. In general though, the incidence (and consequently pest status) of stalk borers vary from one region to another (Sagnia, 1983; Seshu Reddy *et al.*, 1990), and from one season to another within the same area, even between fields within the same growing season (Bate *et al.*, 1990; Seshu Reddy *et al.*, 1990; Kfir, 1992; Van Rensburg & Van den Berg, 1992).

Recommended management practices against stalk borers of cereals fall into four broad categories. These are chemical control, use of resistant or tolerant varieties, cultural control, and biological control. Chemical control still remains the main tool in pest management (Sharma, 1985). In South Africa for example, the control of stalk borers on large-scale commercial farms is heavily reliant on insecticides (Van den Berg *et al.*, 1994a). However, the use of insecticides has some limitations. One of these is that it is both impractical and too expensive for subsistence farmers (Seshu Reddy, 1983; Saxena *et al.*, 1989). It is also not desirable because, among other reasons, farmers often do not have the necessary skills to use the chemicals (Saxena *et al.*, 1989). Even for large-scale farmers, chemical control of stalk borers, especially in programme sprays, is often ineffective or uneconomical, because the levels of infestation often vary between, as well as within seasons (Kfir, 1992; Van Rensburg & Van den Berg, 1992). The occurrence of mixed populations of stalk borers with differences in biological characteristics on the same crop also complicates insecticidal control measures and increases production costs (Van den Berg, 1994). Despite the limitations of chemical control, however, it is likely to continue to play an important role in the control of stalk borers especially for large-scale farmers. However, it is recommended that insecticide application on commercial farms be based on economic threshold levels which rely on monitoring levels of oviposition, visible plant damage or moth flight activity (Van Rensburg *et al.*, 1987; Van Rensburg, 1990; Van den Berg, 1994; Krause *et al.*, 1996). This will minimise input costs by ensuring that insecticides are applied only when it is economically justifiable. It will also reduce their undesirable effect on the environment.

The use of resistant crop varieties is perhaps the most desirable pest control measure, both economically and environmentally (Ajayi, 1989). According to Doggett (1988), farmers in the non-affluent world should rely largely upon the use of resistant varieties as they can do little about other management practices. Plant resistance is a particularly relevant method of pest control since it requires no skill in application, neither does it involve cash investments

(Sharma, 1985). It is also very effective (Seshu Reddy, 1985a). For instance, Van den Berg (1994) reported that although a 12 % yield gain was achieved in susceptible sorghum plants through the use of insecticides against *C. partellus*, the overall yield was still below that of resistant plants. However, the use of host plant resistance has certain limitations. It takes much time and resources to identify or develop a resistant variety which is agronomically suited to a particular environment, as well as being acceptable to consumers. Furthermore, resistance of a variety against one pest species does not necessarily imply resistance against another (Van den Berg, 1994), and insect pests can eventually overcome resistant varieties. Another limitation is that resistance levels of genotypes can vary between seasons (Tingey & Singh, 1980; Van den Berg, 1994), thereby causing variations in the levels of damage and yield loss.

Cultural control is considered the first line of defence against pests (Van den Berg *et al.*, 1998). It is also considered the most relevant and economic method of pest control for the majority of farmers in Africa. This is due to cultural control practices being readily available to the farmers, while many other existing pest control options such as insecticides and resistant crop varieties are not (Van den Berg *et al.*, 1998). Cultural control practices are primarily aimed at reducing the number of stalk borer individuals that are carried over from one season to the next. This mainly involves the destruction of hibernating larvae in crop residues (Walters, 1975; Adesiyun & Ajayi, 1980; Gahukar & Jotwani, 1980; Sagnia, 1983; Sharma, 1985; Kfir *et al.*, 1989; Saxena *et al.*, 1989; Seshu Reddy, 1990). Some cultural practices are also aimed at reducing the levels of stalk borer infestations within the season. These include planting date adjustment (Swaine, 1957; Harris, 1962; Abu, 1986; Gebre-Amlak *et al.*, 1989), use of short-season varieties (Van Rensburg *et al.*, 1988b; Van den Berg *et al.*, 1990, 1994b), removal and destruction of infested plant whorls (Seshu

Reddy, 1985b) and intercropping (Amoako-Atta & Omolo, 1983; Amoako-Atta *et al.*, 1983; Dissemond & Hindorf, 1989; Saxena *et al.*, 1989).

Despite the obvious benefits of cultural control practices, some of the recommended practices are labour- and cost-intensive (Alghali, 1985). Also, some of the practices have to be adopted widely in the target area for them to be effective, otherwise any remaining insect populations in the area will attack available hosts (Ajayi, 1989; Seshu Reddy, 1990).

There are several reports of natural biotic enemies (parasitoids, predators, pathogens) of stalk borers that occur in various regions in Africa. Among the most commonly reported natural enemies is *Cotesia sesamiae* Cameron (*Apanteles sesamiae*) (Hymenoptera: Braconidae), a parasitoid of the larvae of *B. fusca*, *C. partellus* (Du Plessis & Lea, 1943; Mohyuddin & Greathead, 1970; Van Rensburg & Van Hamburg, 1975; Seshu Reddy, 1983; Van Rensburg *et al.*, 1988a; Kfir, 1995, 1997a), *E. saccharina* and *S. calamistis* (Seshu Reddy, 1983). Other parasitoid species that have been reported on various developmental stages of cereal stalk borers include *Stenobracon* spp. and *Bracon* spp. (both Hymenoptera: Braconidae) on stalk borer larvae in the Gambia (Sagnia, 1983) and *Dentichasmias busseolae* Heinrich (Hymenoptera: Ichneumonidae) on *Chilo* pupae in South Africa (Van Rensburg & Van Hamburg, 1975) and Kenya (Seshu Reddy, 1983; Saxena *et al.*, 1989). *Pediobius furvus* Gahan (Hymenoptera: Eulophidae), a pupal parasitoid, has been reported on *C. partellus*, *B. fusca* and *Sesamia* sp. in East Africa (Mohyuddin & Greathead, 1970; Saxena *et al.*, 1989), on *C. partellus* in South Africa (Van Rensburg & Van Hamburg, 1975; Kfir, 1992) and on *B. fusca* and other stalk borers in West Africa (Harris, 1962; Gahukar, 1981). *Euvipio* spp. (*Iphiaulux* spp.) (Hymenoptera: Braconidae) have been reported as larval parasitoids of *C. partellus* (Van Rensburg & Van

Hamburg, 1975; Kfir, 1990b) and *B. fusca* (Walters *et al.*, 1976; Kfir, 1995) in South Africa. Other reported parasitoids are *Telenomus busseolae* Gahan (*Platytelenomus busseolae*) (Hymenoptera: Scelionidae) on *B. fusca* eggs in South Africa and Nigeria (Harris, 1962; Walters *et al.*, 1976; Van Rensburg *et al.*, 1988a; Kfir, 1995), *Trichogramma* spp. (Hymenoptera: Trichogrammatidae) on eggs of *C. partellus* in Uganda (Mohyuddin & Greathead, 1970) and Kenya (Saxena *et al.*, 1989), and *Tetrastichus atriclavus* Waterston (Hymenoptera: Eulophidae) on the pupae of *B. fusca* and *Sesamia* sp. in Nigeria (Harris, 1962). Earwigs (*Diaperasticus erythrocephala* Olivier) (Dermaptera: Forficulidae), and black ants [*Camponotus rufoglaucus* (Jerdon)] (Hymenoptera: Formicidae) have been reported to prey on eggs and larvae of *C. partellus*, *E. saccharina* and *B. fusca*, while ladybird beetles (*Cheilomenes* spp.) (Coleoptera: Coccinellidae) prey on eggs and larvae of *C. partellus* and other stalk borers in Kenya (Seshu Reddy, 1983). Red ants are also reported as predators of stalk borer larvae in South Africa (Walters *et al.*, 1976).

Among pathogens that attack stalk borers are the bacteria *Bacillus thuringiensis* Berliner (Harris, 1962; Gahukar, 1981; Ajayi, 1989; Medvecky & Zalom, 1992; Hoekstra & Kfir, 1995, 1997), *Serratia marcescens* Bizio, *Streptococcus* sp. (Hoekstra & Kfir, 1995, 1997) and a microsporidian protozoan *Nosema* sp. (Saxena *et al.*, 1989; Walters & Kfir, 1993; Hoekstra & Kfir, 1995, 1997; Kfir & Walters, 1997). The fungus *Beauveria bassiana* (Balsamo) Vuillemin has been reported as a pathogen of *B. fusca* larvae in South Africa (Van Rensburg *et al.*, 1988a; Hoekstra & Kfir, 1995, 1997) and Kenya (Maniania, 1991), as well as of *C. partellus* larvae in South Africa (Hoekstra & Kfir, 1995, 1997) and Kenya (Maniania, 1991). The fungus *Entomophora* sp. has been recorded on both *B. fusca* and *C. partellus* in South Africa, while another fungus *Aspergillus* sp. has been recorded on *C.*

partellus in South Africa (Hoekstra & Kfir, 1995, 1997) and on the larvae and pupae of *B. fusca* in West Africa (Harris, 1962; Gahukar, 1981; Ajayi, 1989). Also in South Africa, Hoekstra & Kfir (1995, 1997) reported the Nuclear polyhedrosis virus, Granulosis virus and Cytoplasmic polyhedrosis virus on *B. fusca*, and the Cytoplasmic polyhedrosis virus, as well as the Entomopox virus on *C. partellus*.

However, despite the widespread occurrence of indigenous natural enemies, they are not always able to significantly reduce stalk borer populations during the crop growing season due to the generally low rate of parasitism under natural conditions (Harris, 1962; Van Rensburg & Van Hamburg, 1975; Ajayi, 1989).

Because of the various limitations associated with individual stalk borer control measures, researchers are increasingly advocating for the development of sustainable integrated pest management (IPM) strategies. The use of host plant resistance, cultural practices and natural enemies along with minimal use of insecticides is advocated, especially for subsistence farmers in low-input farming systems (Sharma, 1985; Van den Berg, 1994). IPM would limit the use of insecticides, as well as improve the efficiency of cultural control practices (Alghali, 1985).

One major characteristic of the agricultural sector in Lesotho is that it is largely undertaken at the subsistence level, under a rigid land tenure system (Anon., 1995). The crop production sub-sector in particular is constrained in a number of ways. For instance, of the estimated total land area of 30,355 km^2, only 9 % to 10 % is arable, the rest being largely covered by mountain ranges, gorges and deep river valleys (Majoro, 1995). Although over 50 % of the country's estimated population of about 2 million depends directly on agriculture for livelihood, agricultural productivity in Lesotho is one of the lowest in the sub-region (Anon., 1995). Consequently, the country has on average imported over half its maize requirements during the past 10 to 15 years (Anon., 1995). Among the factors responsible for this low productivity in the crop sub-sector are low and often erratic rainfall, severe soil erosion, low soil fertility and inadequate use of organic fertilizers, poor land preparation, inadequate weeding, delayed harvesting, inadequate credit facilities and development funds, and inconsistent and/or ill-conceived policies (Anon., 1995).

Although several problems have been cited as responsible for low crop productivity in Lesotho (Anon., 1995), the effect of pests and diseases (especially of field crops) has received very limited mention. For instance, no research had been done on the major insect pests of sorghum in Lesotho (Pomela *et al.*, 1988). Furthermore, a survey of available literature including that by Anon. (1991b), revealed limited information on field pests of maize and sorghum, including stalk borers.

In view of the significance of maize and sorghum in the economy of Lesotho (Brokken *et al.*, 1986; Anon., 1994, 1995; Majoro, 1995), the importance of stalk borers in many parts of Africa (Dabrowski, 1985; Ajayi, 1989; Saxena *et al.*, 1989; Sithole, 1989; Vogel *et al.*, 1993), and the dearth of researched information on these pests in Lesotho, there is a need for research and development of stalk borer control strategies in this country.

The aim of this study was to investigate the pest status of maize and sorghum stalk borers in Lesotho, to study current crop production practices which can influence stalk borer damage, and to make recommendations with regard to possible solutions to the problems. These objectives were addressed by studying the distribution, relative abundance and infestation patterns of stalk borers in the country, farmers' perceptions of stalk borer problems, insecticide use, and farm management practices and their possible implications on the pest status of stalk borers. In order to provide tools for use in pest management systems, studies were conducted on the effect of planting date and intercropping on pest damage, and on the natural enemy complex of stalk borers. The levels of stalk borer resistance of maize and sorghum varieties grown in Lesotho were assessed in order to identify possible varieties for use in pest management programs. Furthermore, the efficacy of currently available insecticides was determined and related infrastructure assessed. Results of this study are presented in the form of eleven papers dealing with:

- Distribution and abundance of stalk borers in Lesotho.
- Moth flight activity of the maize stalk borer, *Busseola fusca.*
- Performance of maize under natural infestation of *B. fusca.*
- Resistance mechanisms and screening of maize under artificial infestation with *B. fusca.*
- Performance of sorghum under natural infestation of stalk borers.
- Resistance mechanisms and screening of sorghum under artificial infestation with *Chilo partellus.*
- A survey of management practices and farmers' perspectives of maize and sorghum pests.
- Constraints to the effective use of insecticides for stalk borer control.
- Effect of planting date of maize on *B. fusca* damage.
- Effect of intercropping with beans on *B. fusca* damage in maize.
- Natural enemies of stalk borers in Lesotho.

CHAPTER 2

DISTRIBUTION AND RELATIVE ABUNDANCE OF STALK BORERS OF MAIZE AND SORGHUM IN LESOTHO.

ABSTRACT

The geographical distribution and relative abundance of stalk borers of maize and sorghum in Lesotho were studied through field surveys. Results showed that *Busseola fusca* (Fuller) (Lepidoptera: Noctuidae) and *Chilo partellus* (Swinhoe) (Lepidoptera: Pyralidae) are the only species that occur on these crops in this country. Whereas *B. fusca* occurred throughout the country, *C. partellus* was recorded in the central lowland areas only. The survey also showed that *B. fusca* is important on both maize and sorghum, while *C. partellus* attacks only sorghum in parts of the central lowlands.

Key words: *Busseola fusca*, *Chilo partellus*, maize, sorghum, stalk borers.

INTRODUCTION

Lepidopterous stalk borers are generally considered to be serious pests of maize [*Zea mays* L.] and sorghum [*Sorghum bicolor* (L.) Moench] in many parts of the world. Species that are considered to be of importance vary from one region to another. For instance, whereas *Chilo partellus* (Swinhoe), *Ostrinia furnacalis* (Guenee) and *Sesamia inferens* (Walker) are regarded as the most important species in India and Southeast Asia (Chundurwar, 1989), *Diatraea* spp. are the most important stalk borers of maize and sorghum in Central and South America (Reyes, 1989). Even within a continent, the status of individual borer species may vary from one sub-region to another. *Busseola fusca* (Fuller) is considered the most important stalk borer species of maize and sorghum in West Africa (Ajayi, 1989), while *Chilo partellus*, *Chilo orichalcocilliellus* (Strand), *Eldana saccharina* (Walker), *B. fusca*, *Sesamia calamistis* (Hampson) and *Sesamia cretica* (Lederer) are regarded as most important in eastern Africa (Seshu Reddy, 1989). In southern Africa, *B. fusca*, *C. partellus* and *S. calamistis* are the most important species which occur on both maize and sorghum (Dabrowski, 1985; Saxena *et al.*, 1989; Sithole, 1989, Van Hamburg, 1979).

The geographical distribution of stalk borer species in various regions is influenced by altitude (Seshu Reddy, 1983), temperature (Ingram, 1958; Seshu Reddy, 1983; Bate *et al.*, 1991), as well as by rainfall patterns (Seshu Reddy, 1983; Van Rensburg *et al.*, 1987; Ajayi, 1989). Although Qhobela *et al.* (1986) reported *B. fusca* and *C. partellus* to attack maize and sorghum respectively in Lesotho, their geographical distribution in the country has not been described. Furthermore, the possibility of *B. fusca* attacking sorghum, and of *C. partellus* attacking maize, or the possibility of the two species occurring in mixed populations on a single crop, have all not yet been investigated in this country.

The objective of this study was to investigate the geographical distribution of *B. fusca* and *C. partellus* in Lesotho, as well as to evaluate the relative abundance of both stalk borer species on maize and sorghum in various parts of the country. Results will enable farmers to know the specific pest they are confronted with on a specific crop in their areas, which will in turn enable them to employ specific management measures.

MATERIAL AND METHODS

The study was conducted through field surveys during the 1995/96 and 1996/97 growing seasons. Surveys were carried out on maize and sorghum fields at 17 localities across the four agro-ecological zones of Lesotho (Fig. 2.1). These zones are the lowlands (1520-1830 m above sea level (asl), consisting of a narrow strip of land along the country's western border), the foothills (>1830-2130 m asl, east of the lowland plains), the mountains (above 2130 m asl) (Anon., 1981), and the Senqu River valley (a narrow strip of land that flanks the banks of the Senqu or Orange River) (Anon., 1995). Most of the surveyed localities were situated within the lowland and foothill zones, where approximately 79 % of the country's population occur, and where most crop production takes place (Anon., 1981, 1995).

Field surveys were conducted mainly at harvest (June/July) in order to ensure the availability of plant samples. During each survey, plants were examined for symptoms of borer infestation (borer entrance/exit holes). A minimum of 100 infested stems of maize and of sorghum were then collected randomly at each locality. These were dissected and the number of larvae and pupal cases of each stalk borer species recorded separately for each crop. The relative importance of a given species of stalk borer was determined as the total number of individuals of that species, calculated as a percentage of the total population of all stalk borer individuals collected from each crop, at each locality.

RESULTS AND DISCUSSION

This investigation showed that *B. fusca* and *C. partellus* were the only stalk borers occurring on maize and sorghum in Lesotho, with either *B. fusca*, *C. partellus* or both occurring in each of the four agro-ecological zones of the country. The localities surveyed and the species of stalk borers recorded at each are indicated in Fig. 2.1. *B. fusca* was the more widely distributed of the two species, having been recorded at all 17 localities surveyed. Furthermore, whereas *B. fusca* was recorded at both the lowest and the highest altitudes surveyed [Seaka Bridge (1460 m asl) and Semonkong (2458 m asl) respectively], *C. partellus* was recorded only at 5 of the 17 localities, all of which were situated in the central lowlands of the country. The highest altitude at which *C. partellus* was recorded was at Roma (1660 m asl).

Results pertaining to the occurrence of *B. fusca* and *C. partellus* on maize and sorghum in Lesotho are presented in Tables 2.1 & 2.2. *B. fusca* attacked both maize and sorghum wherever these crops were cultivated, while *C. partellus* attacked sorghum in parts of the lowland areas only, although it was occasionally recorded in small numbers on maize as well (Table 2.1). Wherever *C. partellus* occurred, it did so in mixed populations with *B. fusca*. The relative abundance of each species varied from one season to the other. Whereas

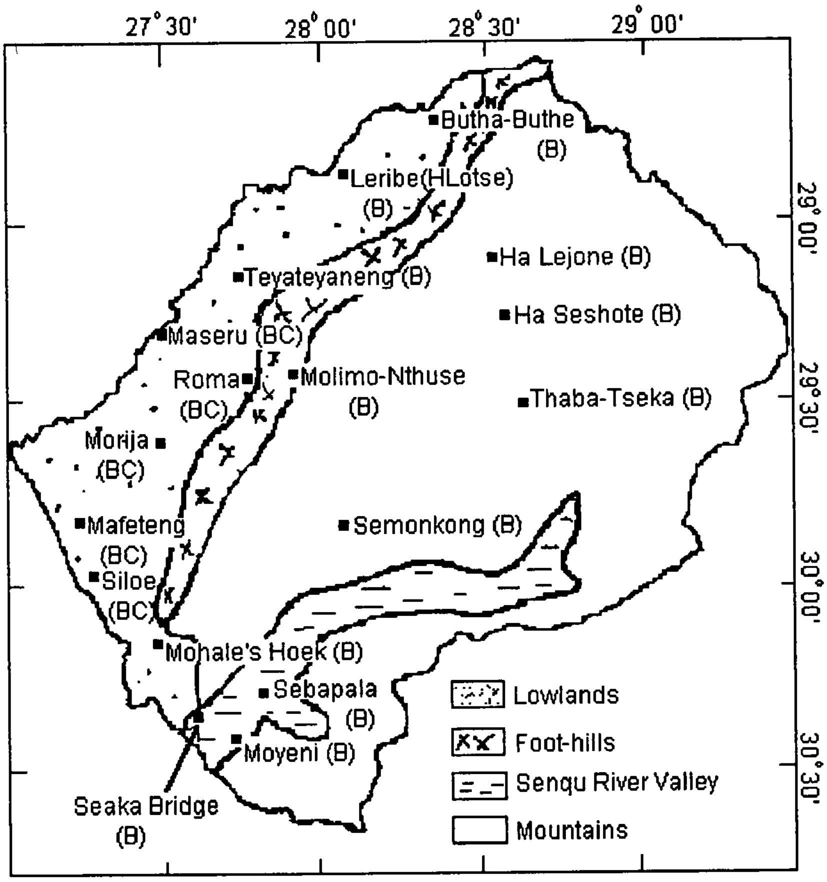

Fig. 2.1: Geographical distribution of *Busseola fusca* (B) and *Chilo partellus* (C) in Lesotho. (Map modified from Anon., 1989).

Table 2.1: Proportional occurrence of *Busseola fusca* and *Chilo partellus* in **maize** at 17 localities surveyed in Lesotho, during the 1995/96 and 1996/97 growing seasons.

Locality	1995/96			1996/97		
	Sample size	% *B. fusca*	% *C. partellus*	Sample size	% *B. fusca*	% *C. partellus*
Lowlands						
Butha-Buthe	78	100	0.0	93	100	0.0
Hlotse	112	100	0.0	76	100	0.0
Teya-Teyaneng	69	100	0.0	83	100	0.0
Maseru	134	98.5	1.5	141	99.3	0.7
Roma	969*	99.7	0.3	753*	100	0.0
Morija	86	100	0.0	89	100	0.0
Mafeteng	63	98.4	1.6	104	100	0.0
Siloe	58	100	0.0	81	100	0.0
Mohale's Hoek	65	100	0.0	66	100	0.0
Moyeni	87	100	0.0	79	100	0.0
Foothills						
Molimo-Nthuse	62	100	0.0	83	100	0.0
Senqu River valley						
Seaka Bridge	74	100	0.0	92	100	0.0
Sebapala	63	100	0.0	61	100	0.0
Mountains						
Ha Lejone	52	100	0.0	63	100	0.0
Ha Seshote	43	100	0.0	67	100	0.0
Thaba-Tseka	68	100	0.0	77	100	0.0
Semonkong	41	100	0.0	52	100	0.0

* Sample size was exceptionally large due to the availability of plants on experimental plots.

C. partellus was recorded on maize at three localities during the 1995/96 season, it was recorded at only one locality in the 1996/97 season (Table 2.1). Similarly, the proportion of *C. partellus* on sorghum was higher during the 1995/96 than the 1996/97 season (Table 2.2).

These variations were probably due to changes in seasonal environmental conditions and their effect on the two species. Results also showed that *C. partellus* was not important on maize, even at localities where it occurred on sorghum in close proximity to maize. This probably indicates that sorghum was the preferred host of *C. partellus*. Sorghum has been reported as the preferred host of *C. partellus* in South Africa (Van den Berg & Van Rensburg, 1992; Kfir, 1997b).

Table 2.2: Proportional occurrence of *Busseola fusca* and *Chilo partellus* in **sorghum** at 17 localities surveyed in Lesotho, during the 1995/96 and 1996/97 growing seasons.

Locality	1995/96			1996/97		
	Sample size	% *B. fusca*	% *C. partellus*	Sample size	% *B. fusca*	% *C. partellus*
Lowlands						
Butha-Buthe	73	100	0.0	102	100	0.0
Hlotse	65	100	0.0	88	100	0.0
Teya-Teyaneng	109	100	0.0	72	100	0.0
Maseru	166	38.0	62.0	102	88.2	11.8
Roma	181	69.6	30.4	354*	97.7	2.3
Morija	114	77.2	22.8	128	87.5	12.5
Mafeteng	76	79.5	20.5	82	70.7	29.3
Siloe	44	43.2	56.8	75	96.0	4.0
Mohale's Hoek	49	100	0.0	78	100	0.0
Moyeni	68	100	0.0	69	100	0.0
Foothills						
Molimo-Nthuse	73	100	0.0	107	100	0.0
Senqu River valley						
Seaka Bridge	74	100	0.0	69	100	0.0
Sebapala	54	100	0.0	83	100	0.0
Mountains						
Ha Lejone	61	100	0.0	53	100	0.0
Ha Seshote	47	100	0.0	39	100	0.0
Thaba-Tseka	58	100	0.0	46	100	0.0
Semonkong	36	100	0.0	59	100	0.0

* Sample size was exceptionally large due to the availability of plants on experimental plots.

Observations on the distribution of *B. fusca* (Fig. 2.1) indicated that efforts aimed at developing management strategies for the control of this species would need to target maize and sorghum producing areas throughout the country.

It has been reported that *C. partellus* is the only stalk borer of importance on sorghum in Lesotho (Qhobela *et al.*, 1986). However, this investigation has shown *B. fusca* to be the main stalk borer of sorghum (Table 2.2), and that *C. partellus* occurs only in parts of the central lowlands (Fig. 2.1, Tables 2.1 & 2.2). Knowledge about the geographical distribution of these species would enable farmers in various areas to focus attention on the stalk borer species that is of importance in their farming areas. This will in turn facilitate informed decision making with regard to which stalk borer management actions to adopt. For instance, chemical control recommendations for *C. partellus* and *B. fusca* are different (Krause *et al.*, 1996).

Based on this study, it can be deduced that maize farmers throughout Lesotho (Table 2.1), as well as sorghum farmers in areas other than the central lowland areas (Table 2.2) currently need only to be concerned about *B. fusca* infestations. These farmers may adopt practices such as the adjustment of planting date, in order to ensure that their crops escape severe damage by *B. fusca*. Similar observations were made by Harris (1962), Walters *et al.* (1976), Gebre-Amlak *et al.* (1989) and Vogel *et al.* (1993) who reported that this cultural practice can reduce *B. fusca* damage. Similarly, decisions such as which crop variety to grow and which insecticide to apply in order to control infestations, can be made more efficiently when the pest problem is properly identified.

The occurrence of *B. fusca* and *C. partellus* in mixed populations in certain parts of Lesotho (Fig. 2.1, Tables 2.1 & 2.2) is important, since mixed populations of *B. fusca* and *C. partellus* cause more damage and yield loss than single populations of either species at similar infestation levels (Van den Berg *et al.*, 1991). In Lesotho, therefore, farmers who grow sorghum in the central lowlands (where *C. partellus* occurs) should be aware of the occurrence of mixed populations of *B. fusca* and *C. partellus*, at least during some seasons.

In Uganda, Ingram (1958) found *C. partellus* to occur only at altitudes below 1524 m (5000 ft), while in South Africa, the highest altitude at which *C. partellus* was found was 1650 m (Bate *et al.*, 1991). The observation that *C. partellus* was also recorded at Roma (1660 m above sea level) confirms that this species is indeed capable of adapting to higher altitudes. This confirms earlier speculation by Ingram (1958) that *C. partellus* should be able to spread to areas higher than 1524 m (5000 ft).

The occurrence of *C. partellus* at an elevation of 1660 m (Roma) suggests that this species could still spread to other localities, especially in the lowland areas of Lesotho. It may eventually attain a higher pest status, especially on sorghum in these areas. Such a change in pest status has been reported in South Africa where it is presently one of the most important pests of both sorghum and maize (Skoroszewski & Van Hamburg, 1987; Kfir, 1990a, b, 1992, 1997b; Van den Berg, 1994). One of the factors responsible for the change in the pest status of *C. partellus* is its efficiency as a colonizer (Kfir, 1997b). For example, in just seven years, *C. partellus* increased its population on sorghum from 0.08 % to 59 % of the total stalk borer population at Delmas in the eastern Highveld region of South Africa (Kfir, 1997b). There is also the possibility of *C. partellus* becoming more important on maize in Lesotho, although at present it rarely occurs on this crop (Table 2.1). A similar change in pest status on maize has also been reported in neighbouring South Africa (Van Rensburg & Bate, 1987; Kfir, 1997b). Also, in view of the fact that *C. partellus* has been able to adapt to higher altitude areas in South Africa (Bate *et al.*, 1991), where it was first recorded in 1958 (Van Rensburg & Van Hamburg, 1975), the possibility exists that it could spread to higher-lying areas of Lesotho. However, low temperature may be a limiting factor to the spreading of this species to higher elevations (Ingram, 1958; Bate *et al.*, 1991).

CONCLUSION

In general, this study confirmed reports from elsewhere that *B. fusca* predominates over *C. partellus* at cooler and higher altitudes. The study also demonstrated the need for detailed surveys on the distribution and relative abundance of stalk borer species in all countries in Africa. Such information is useful in establishing the pest status of each species within a country, as well as in monitoring changes in relative importance and abundance of species.

CHAPTER 3

SEASONAL MOTH FLIGHT ACTIVITY OF THE MAIZE STALK BORER, *BUSSEOLA FUSCA* (FULLER) (LEPIDOPTERA: NOCTUIDAE), IN LESOTHO.

ABSTRACT

Seasonal moth flight activity of *Busseola fusca* (Fuller) was monitored at six localities in Lesotho during the 1995/96, 1996/97 and 1997/98 growing seasons, using a sex pheromone-based monitoring system. The study indicated the existence of distinct periods of moth flight activity, with seasonal flight generally commencing in October and ending in April/May, despite the pronounced variation in altitude of localities used in this study (1530 m to 2458 m above sea level). Three generations of *B. fusca* moths per year were recorded in the lower-lying areas, while two to three generations were observed in the mountains. Generally, the first, second and third generation flights peaked in November, February and April respectively. The observed differences between the lower-lying areas and the mountains, both in terms of the cessation of seasonal moth flight activity and the number of generations per year, were attributed to variations in the duration of the summer season (longer in the lowlands than in the mountains). There was also a north-south decrease in the magnitude of individual flights in the lowlands. This was attributed to a north-south decrease in average annual summer rainfall. Based on the existence of a distinct *B. fusca* moth flight pattern, the potential of planting date adjustment as a cultural management measure against *B. fusca* is discussed.

Key words: *Busseola fusca*, moth flight pattern, pheromone.

INTRODUCTION

The maize stalk borer, *Busseola fusca* (Fuller), is an important pest of maize and sorghum in sub-Saharan Africa (Ajayi, 1989; Seshu Reddy, 1989; Sithole, 1989). Studies carried out in some countries showed that seasonal activity by *B. fusca* moths is often characterized by distinct periods of flight activity, separated by periods of low or no flight activity. In South Africa, two to three generations of *B. fusca* moths per season have been reported (Van Rensburg *et al.*, 1985; Van Rensburg, 1997). Three seasonal moth flights have also been reported in Ethiopia (Gebre-Amlak, 1989) and Nigeria (Harris, 1962). The existence of distinct periods of *B. fusca* moth flight activity has been reported to influence the level of infestation in a host crop, depending on the time of planting (Van Rensburg, Walters & Giliomee, 1987; Gebre-Amlak *et al.*, 1989).

Although *B. fusca* has been reported as an important pest of maize in Lesotho (Qhobela *et al.*, 1986), no investigation has been conducted on its seasonal moth flight activity. The aim of this investigation was to determine the general pattern of seasonal flight activity of *B. fusca* moths in various parts of the country. The investigation provided information on the period of activity of *B. fusca* moths, both within and across seasons at various localities. Results also provided some idea on the potential threat posed by *B. fusca* to maize and sorghum crops in the various study areas, based on the relative magnitudes of seasonal moth flight. This investigation presents the first report of seasonal activity of *B. fusca* moths in Lesotho.

MATERIAL AND METHODS

Moth trapping was conducted during the 1995/96, 1996/97 and 1997/98 growing seasons at Maseru (1530 m above sea level = asl) , Siloe (approx. 1650 m asl), and Roma (1660 m asl) (Fig. 3.1) . In addition to these sites, moth trapping was done at Leribe (1740 m asl), Thaba-Tseka (2160 m asl) and Semonkong (2458 m asl) (Fig. 3.1) during the 1996/97 and 1997/98 seasons. Trapping sites were selected to include localities in both the lowlands (Leribe, Maseru, Roma and Siloe) and the mountains (Thaba-Tseka and Semonkong), as well as to ensure a north - south variability (Leribe - Maseru - Siloe), due to the occurrence of a temperature gradient with change in altitude, as well as a north - south rainfall gradient in the country (Anon., 1981).

Moth trapping was done by means of an omni-directional trap, which is commercially available in South Africa under the trade name 'Biotrap' (Van Rensburg, 1992). On the first of September (the beginning of the trapping season each year), a single plastic capsule containing synthetic female sex pheromone (tetradecenyl acetate 25 mg a.i. capsule^{-1}) [obtained from AgrEvo South Africa (Pty) Ltd, Kempton Park, South Africa] was suspended from under the roof of each trap. Three traps were mounted close to maize fields at each trapping site. Traps were situated approximately 150 m away from one another. Each trap was mounted on a pole at a height of 1.5 m above ground. Trapping sites were generally surrounded by maize and/or sorghum fields. Moth numbers were monitored on a weekly basis, beginning one week after traps were mounted and continued until the end of June, by which time moths were no longer being caught at any trapping site. At Roma, traps were left on throughout the year in order to monitor moth activity during the period from the end of June to September. During each moth counting exercise, the trap receptacle

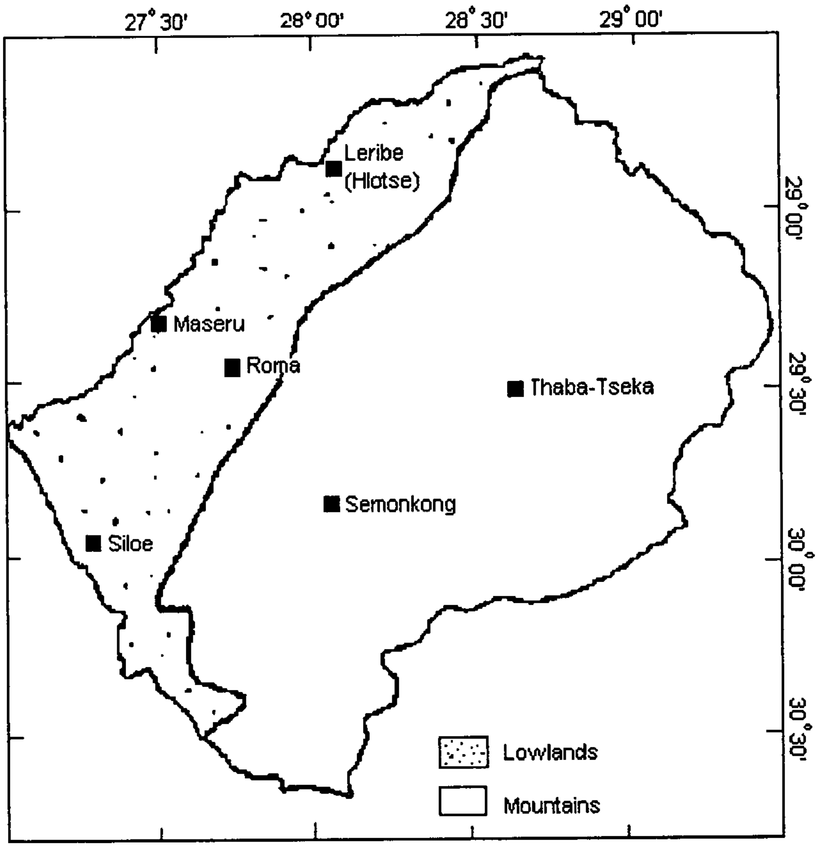

Fig. 3.1: Localities at which *Busseola fusca* moth flight activity was monitored, using omni-directional pheromone traps during the months of September to June, 1995/96, 1996/97 and 1997/98. (Map modified from Anon., 1989).

was removed, the number of moths recorded, and moths destroyed and discarded. The trap receptacle was then reinstalled.

The mean weekly moth catch was determined for each trapping site. At the end of each season, the number of generations of moths at each trapping site was determined as the number of discrete flight peaks which were separated from one another by periods of no or very low moth flight activity.

The total number of moths caught during each trapping season was determined for each trapping site, in order to compare magnitudes of seasonal flight activity between localities. This was done by adding all the mean weekly moth catches for each trapping season (September to June) at each locality. Results were then compared along the lowland-mountain and north-south ecological gradients.

RESULTS AND DISCUSSION

The seasonal activity of *B. fusca* moths in Lesotho was largely characterized by distinct periods of high and low moth flight activity (Figs. 3.2 to 3.7). Data for the month of September have been excluded for all trapping sites except Thaba-Tseka, since no moths were caught at these sites during this period.

Moth flight patterns in the lowlands (Fig. 3.1) were similar, the only major difference being the duration of periods with no or very low trap catches between generations. Seasonal moth flight activity in Lesotho generally commenced in October (Figs. 3.2 to 3.7), despite the pronounced variation in altitude (1530 m - 2458 m asl). This suggests that in general, the conditions required to terminate larval diapause were attained at about the same time in spring throughout the country. The observation that seasonal moth flight activity commenced at about the same time in October indicates that maize and sorghum with similar planting dates would be subject to *B. fusca* infestations during the same period.

The flight patterns at Maseru (Fig. 3.2), Siloe (Fig. 3.3) and Roma (Fig. 3.4) consisted of three distinct peaks during each season, indicating three seasonal moth flights (generations). The results also showed that the earliest moths to emerge from over-wintering larvae (first generation moths) began flying from mid-October onwards to December, with peak activity during November. The first and second flights were separated by periods of up to two weeks of no moth flight activity at Maseru and Roma, while the period of low moth activity at the most southern locality, Siloe, was up to four weeks. Whereas both the onset and decline of the first generation moth flight were gradual, onset of the second generation flight was more abrupt. The second generation was active from January to March, with peak flight in February. The second and third flights were separated by a pronounced decline in moth numbers, and very low numbers of moths were recorded throughout this period. Both the onset and peak flight of the third generation moths occurred in April. Also, while peak flight of the second generation was consistently the highest of the three peaks at Maseru, the first generation peaks were the highest at Roma and Siloe. The peak of the third generation was consistently the smallest at all the localities. Seasonal moth activity at Maseru and Roma ceased in May and that at Siloe in May/June (Fig. 3.3).

At Leribe, seasonal moth flight also commenced in the second half of October (Fig. 3.5). However, while there were only two distinct moth flights during the 1996/97 season, with

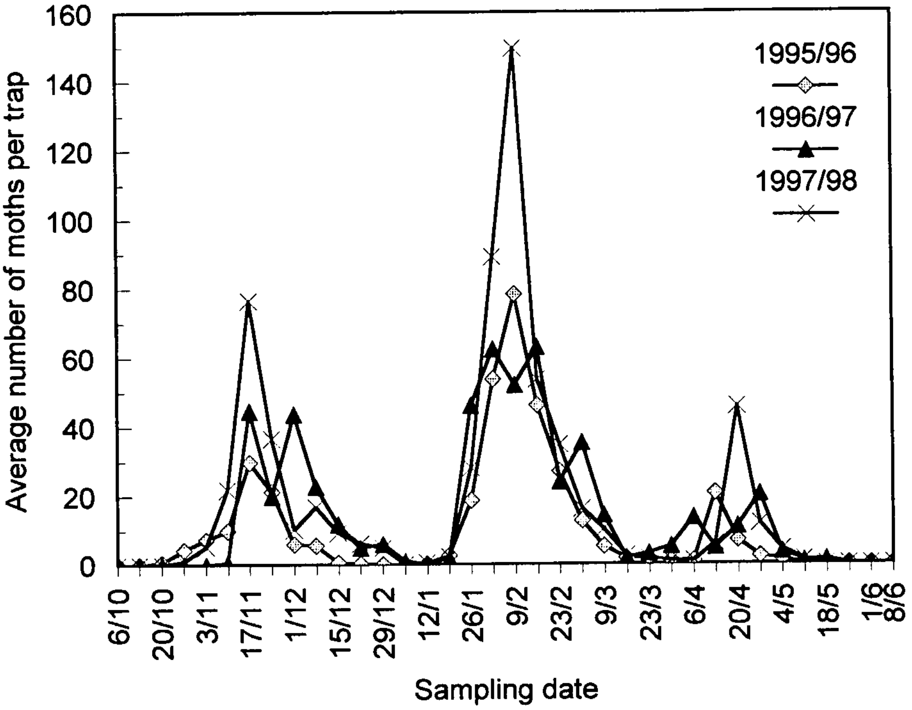

Fig. 3.2: Average number of *Busseola fusca* moths caught in pheromone traps at **Maseru** (1530 m asl) during the 1995/96, 1996/97 and 1997/98 seasons.

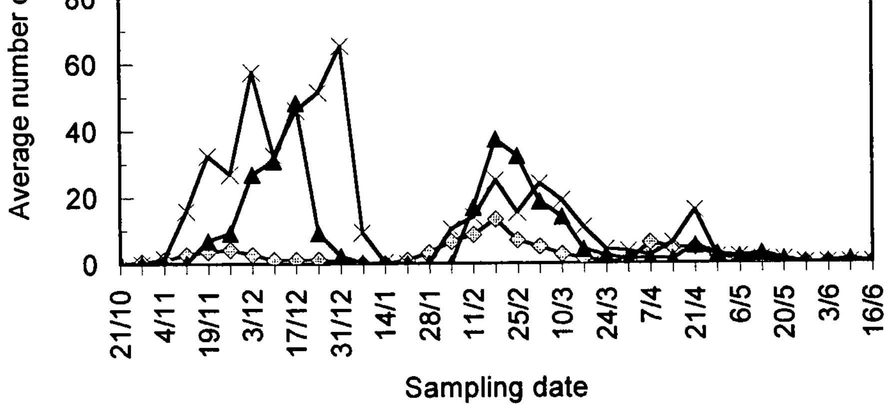

Fig. 3.3: Average number of *Busseola fusca* moths caught in pheromone traps at **Siloe** (1650 m asl) during the 1995/96, 1996/97 and 1997/98 seasons.

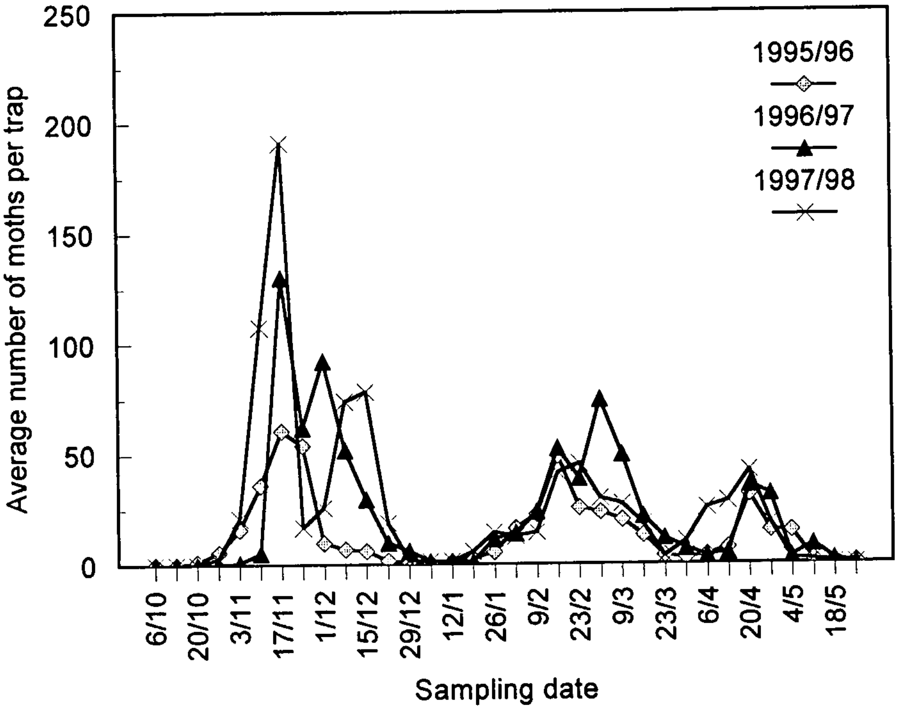

Fig. 3.4: Average number of *Busseola fusca* moths caught in pheromone traps at **Roma** (1660 m asl) during the 1995/96, 1996/97 and 1997/98 seasons.

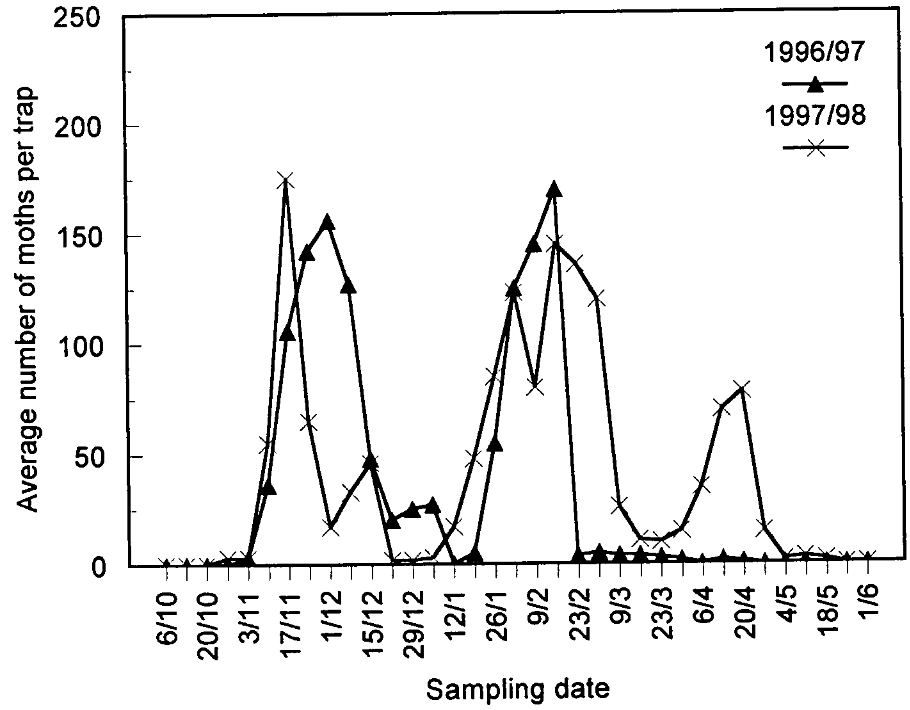

Fig. 3.5: Average number of *Busseola fusca* moths caught in pheromone traps at **Leribe** (1740 m asl) during the 1996/97 and 1997/98 seasons.

peaks in November and February, three generations were recorded in the 1997/98 season. A sudden decline in moth numbers occurred immediately after the February peak during the 1996/97 season. It is not certain what caused the sudden decline in the numbers of the second generation moths during the 1996/97 season, since low moth flight activity still continued after the decline, ceasing only in April. During both seasons, the peak of the second moth flight was only slightly lower than that of the first flight. Although seasonal moth activity ceased in April during 1996/97, moth activity continued until mid-May during 1997/98 (Fig. 3.5).

Seasonal flight activity at Thaba-Tseka (2160 m asl) also started in October during the 1996/97 season, but commenced approximately one month earlier during the 1997/98 season (Fig. 3.6). There were only two generations of moths during the 1996/97 season, with first generation moth activity peaking in early December. Also during the 1996/97 season, the second generation flight was active from January to March. During the 1997/98 season, the first flight occurred from September to December, with a peak in November. Similar to the observation in the 1996/97 season, the onset of the second generation flight also occurred in January during the 1997/98 season (Fig. 3.6). At this locality, the first and second moth generations were separated by two to five weeks of no moth catches. Whereas moth flight ceased abruptly after the second peak flight in March during the 1996/97 season, flight activity continued until May during the 1997/98 season, with a small third peak in April (Fig. 3.6). The sudden and early cessation of moth activity observed during the 1996/97 season was possibly due to a sudden drop in temperature, which caused larvae to go into diapause earlier during this season.

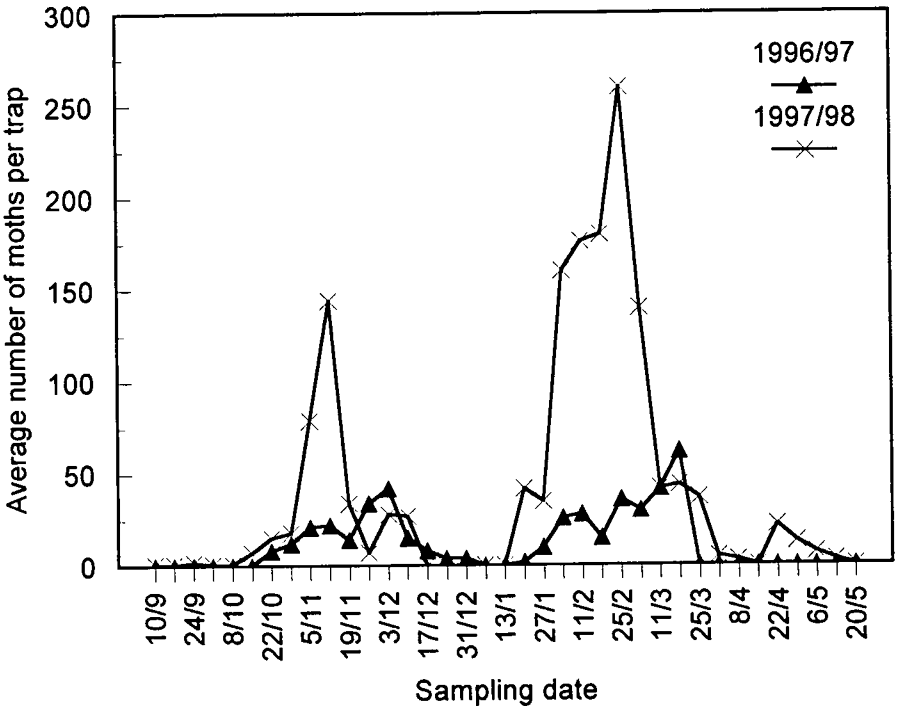

Fig. 3.6: Average number of *Busseola fusca* moths caught in pheromone traps at **Thaba-Tseka** (2160 m asl) during the 1996/97 and 1997/98 seasons.

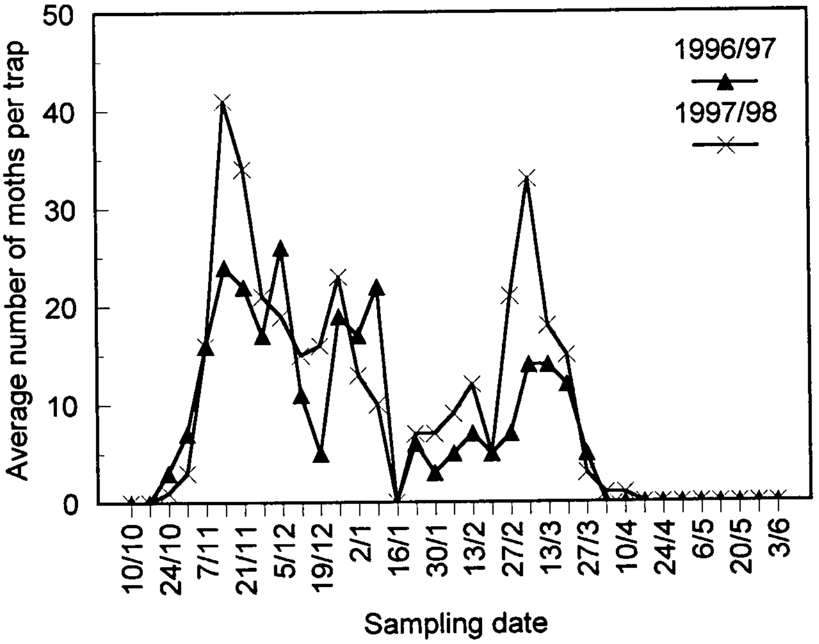

Fig. 3.7: Average number of *Busseola fusca* moths caught in pheromone traps at **Semonkong** (2458 m asl) during the 1996/97 and 1997/98 seasons.

Unlike observations at other localities, the seasonal moth flight pattern at Semonkong, which was the highest altitude in this study (2458 m asl), had no very distinct peaks in moth flight activity (Fig. 3.7). The general pattern, however, indicated the possible existence of two generations of moths, with activity of the second generation peaking late in the season (March) (Fig. 3.7).

Whereas moth flight largely ceased in May in the lower-lying areas (*e.g.* Maseru, Roma, Siloe), it may terminate much earlier at higher altitudes (*e.g.* in March during the 1996/97 season at Thaba-Tseka and Semonkong) (Figs. 3.6 & 3.7). The earlier cessation of seasonal moth flight activity at higher elevations is possibly due to the shorter summer period experienced in the mountain regions of the country. Although weather conditions were not monitored at the various sites during this study, the number of days between the last and first frosts is generally shorter in the mountain regions (average 187 days in the lower mountains areas, with an extreme low of 74 days) than in the lowlands (average 241 days with an extreme low of 128 days) (Anon., 1981). Therefore, earlier onset of frost (which dries up host plants) at higher elevations, may indirectly cause *B. fusca* larvae to enter diapause earlier than larvae in the lower-lying areas where the growing season is longer, thereby resulting in earlier cessation of moth flight activity at the former. This is possibly responsible for the near absence of the third generation moth flight in the mountain region (Figs. 3.6 & 3.7). Cessation of seasonal flight activity has also been linked with the onset of frost in South Africa (Van Rensburg *et al.*, 1985).

Another possible reason for the early termination of seasonal moth flight at higher altitudes is that, due to a shorter growing season in the mountain regions (Anon., 1981), maize and sorghum planting may take place earlier than in the lowlands. This would result in earlier maturing of plants in the mountain areas. The cultivation of earlier maturing crop varieties, due to the shorter growing period in the mountain regions, would also result in earlier ageing of plants. Since ageing of host plants can induce larval diapause (Usua, 1968b), earlier planting or the use of short-season varieties in the mountain localities may partly describe the presence of only two moth flights.

It has also been suggested that temperature conditions affect the length of *B. fusca* life cycle (Van Rensburg *et al.*, 1985). Since there is a pronounced difference in mean summer temperatures between the lowland (21 °C) and the mountain (15 °C) areas of Lesotho (Anon., 1981), it is possible that lower temperatures in the mountains may result in a longer duration of the life cycle, thereby resulting in only two seasonal flights (Figs. 3.6 & 3.7), as compared to three in the lowlands (Figs. 3.2 to 3.5). Temperature gradient has been used to explain the occurrence or absence of the third generation moth flight in parts of the maize producing areas of South Africa (Van Rensburg *et al.*, 1985).

The existence of distinct periods of *B. fusca* moth flight activity at most of the localities, suggests that planting date will influence the severity of infestations by this pest. For instance, seasonal moth flight activity usually began after mid-October in the lowlands, with the first flight activity peaking in November (Figs. 3.2, 3.4 & 3.5). Maize planted early in November would, therefore, largely escape severe infestations by the first generation moths, as they would be too young to be oviposited on. Maize plants are most attractive for oviposition between the ages of three to five weeks (Van Rensburg, 1980). By the time the second generation moths reach peak flight, this early planting would be too old and relatively unattractive for oviposition. Furthermore, such old plants will be less susceptible to damage by larvae arising from these moths, as plant tissue will be tough and unsuitable for consumption by young larvae (Van Rensburg *et al.*, 1988c). However, maize planted early in October may be severely infested by moths of the first generation, while maize planted after November may be severely damaged by larvae from second generation moths, of which flight activity usually peaked in February. Manipulation of planting date could, therefore, be useful in reducing damage by *B. fusca*, as has been reported elsewhere (Van Rensburg, Walters & Giliomee, 1987; Gebre-Amlak *et al.*, 1989). Knowledge of *B. fusca* moth flight pattern in a given area will also enable farmers to know when to scout for infestations in their fields, in order to determine the need for and timing of chemical control.

In South Africa, it has been reported that the magnitudes of the second and third moth flights increase with change in locality from east to west, due to a temperature gradient (Van Rensburg *et al.*, 1985). Such a relationship was not observed between the localities in the east and west in this study (Thaba-Tseka - Roma - Maseru) (Figs. 3.6, 3.4 & 3.2). Also, the relative magnitude of seasonal moth flight between the lowland and mountain localities was not consistent. Whereas Thaba-Tseka (in the mountains) recorded one of the smallest seasonal flights during the 1996/97 season, it recorded the highest flight in the 1997/98 season (Fig. 3.8).

It was observed that the size of individual moth flights tended to decrease with change of locality from north to south (Leribe - Maseru - Siloe) (Figs. 3.5, 3.2, 3.3). A north-south decrease in the magnitude of seasonal flights was also observed (Fig. 3.9). Since adequate rainfall favours the occurrence of large moth flights (Van Rensburg *et al.*, 1987), the observed north-south difference in magnitude of seasonal flights could possibly be attributed to a north-south variation in total summer rainfall. The northern lowlands receive

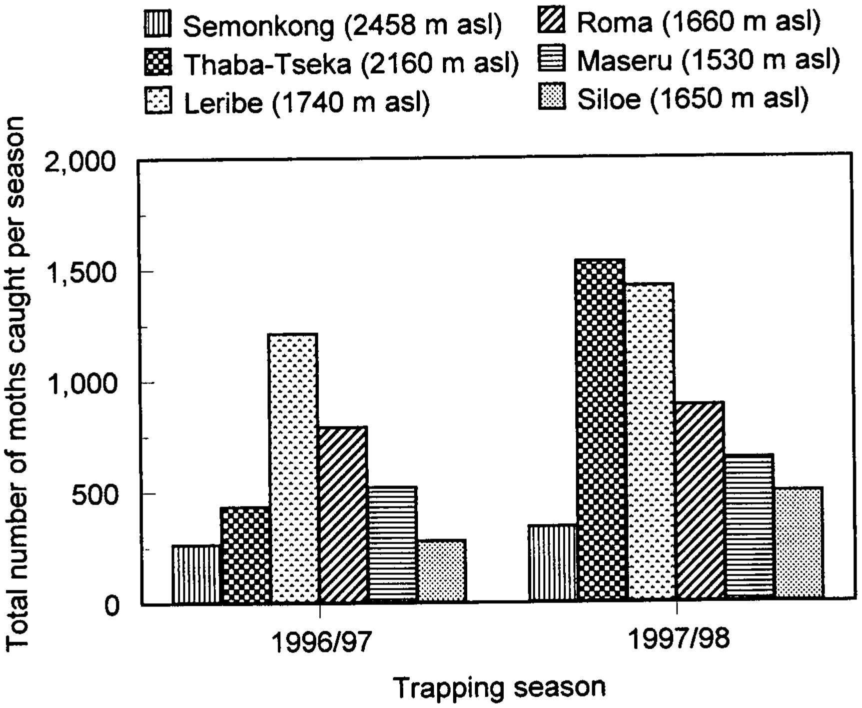

Fig. 3.8: Total number of *Busseola fusca* moths caught in pheromone traps at each locality during the 1996/97 and 1997/98 seasons.

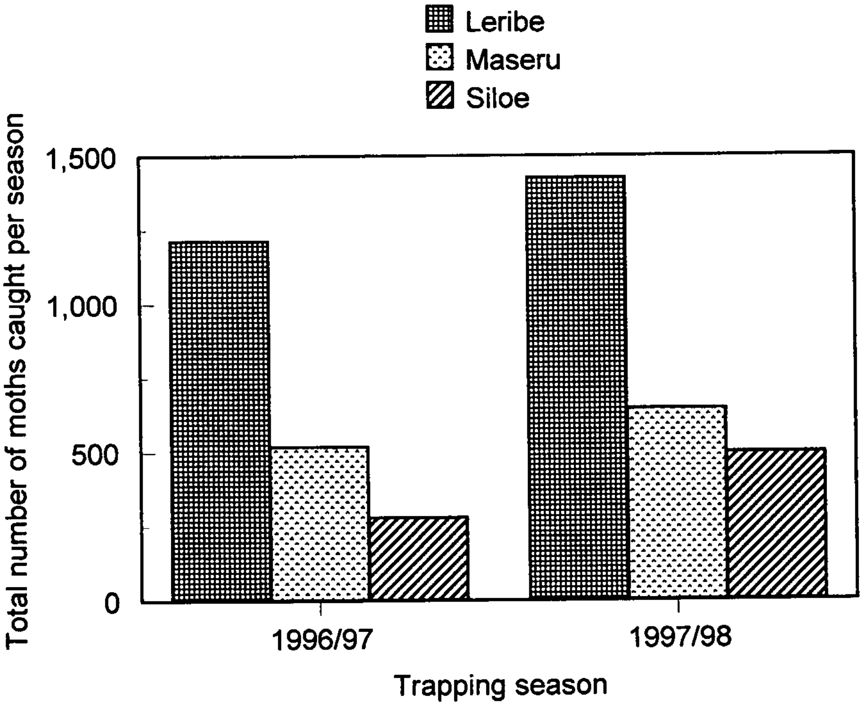

Fig. 3.9: Total number of *Busseola fusca* moths caught in pheromone traps at Leribe, Maseru and Siloe during the 1996/97 and 1997/98 seasons.

higher summer rainfalls (average 819 mm) than the southern lowlands (average 725 mm) which is also more prone to drought (Anon., 1981, 1989). Furthermore, because drought conditions can lead to population depletion (Van Rensburg *et al.*, 1987), it is possible that more frequent drought conditions in the southern region can lead to reduced pest status of *B. fusca*. Also, while the northern lowlands are characterized by fertile soils which support good crop productivity, the southern lowlands have infertile soils (Anon., 1995). As such, the overall environment in the southern lowlands is less conducive to host crop development and could lead to the sustenance of relatively small populations of *B. fusca*.

The magnitude of seasonal moth flights at each moth trapping site varied over seasons. Flight magnitudes were generally larger during the 1996/97 season than in the 1995/96 season at Maseru, Siloe and Roma (Figs. 3.2, 3.3 & 3.4). They were also larger during the 1997/98 season than in the 1996/97 season at all localities (Figs. 3.8 & 3.9). Seasonal variation in magnitude of moth flight has been attributed to variations in total summer rainfall, with higher moth flights occurring during seasons with favourable rainfall (Van Rensburg *et al.*, 1987). The observed variations in this study may also be attributed to variations in the amount of summer rainfall received over the study period. The 1994/95 summer, which was the agricultural year preceding this investigation, was drought stricken (Anon., 1996). This possibly caused a depletion of stalk borer populations, thereby resulting in a small carry-over population into the 1995/96 season. This, presumably, resulted in the relatively low seasonal moth flight observed during the 1995/96 season. However, the 1995/96 season experienced good rains (Anon., 1996), so did 1996/97 and 1997/98. Therefore, these successive years of good rains seem to be responsible for the steady increase observed in seasonal *B. fusca* moth populations.

Although rainfall affects the magnitude of moth flights (Van Rensburg *et al.*, 1987), variation in altitude, with its associated temperature gradient, appears to have played an important role in determining the sizes of *B. fusca* moth flights in this study. For instance, the lowland areas of Lesotho receive a lower average summer rainfall, with averages of 725 mm and 819 mm for the southern and northern lowlands respectively (Anon., 1981), than the mountain areas which receive approximately 1200 mm (Anon., 1995). Yet, moth flight at the mountain locality of Semonkong was smaller than those of the lower altitude sites (Fig. 3.8). While winters are cold in Lesotho's lowland areas, with only occasional snowfalls, the mountain regions experience extremely low winter temperatures, sometimes as low as -20 °C, with frequent snowfalls (Anon. 1995). The occurrence of *B. fusca* under such extreme environmental conditions indicates that it is well adapted to cold climates and high altitudes, as observed by Usua (1968b) and Seshu Reddy (1983). Therefore, the low incidence of *B. fusca* at Semonkong may be partly ascribed to limited host availability due to relatively small areas of maize and sorghum cultivated at such a high altitude (Anon., 1981, 1995).

Based on the magnitude of seasonal moth flights, it can be concluded that *B. fusca* is capable of limiting maize and sorghum production both in the lowland and mountain areas. In the lowlands, the stalk borer seems to be potentially more important in the northern and central lowlands than in the southern lowlands. Due to the observed variations in magnitudes of seasonal moth flight within localities over seasons, and between localities during the same season, *B. fusca* activities need to be monitored for each locality during each growing season. To this effect, the pheromone-based moth flight monitoring system will be relevant, especially to the few but increasing number of commercial farmers in Lesotho. This system can be used to monitor moth flight on a localised basis. It does not demand any power supply, requires little maintenance, and needs only to be monitored on a weekly basis (Revington *et al.*, 1984).

No *B. fusca* moths were caught during June to September at Roma. This indicates the existence of a winter diapause period. This suggests that farmers in Lesotho could adopt certain cultural practices aimed at reducing carry-over populations of stalk borers. These practices include slashing and deep ploughing of crop residues (Kfir, 1990c), partial burning of stalks, complete burning of crop residues, and exposure of hibernating larvae to extreme cold, desiccation and predation through cultivation of fields during the winter months (Van den Berg *et al.*, 1998).

CONCLUSION

The observation that seasonal *B. fusca* moth flight activity in Lesotho generally commenced in October, despite the pronounced variation in altitude (1530 m to 2458 m asl in this study), indicated that maize and sorghum with similar planting dates would be subject to infestations during the same period. Lesotho farmers can, therefore, benefit from the use of certain stalk borer management procedures, which are based on knowledge of the pest's seasonal pattern of activity. Distinct moth flight patterns also indicated that *B. fusca* infestations need only be monitored at certain times during the season, so as to determine the need for and proper timing of insecticide application. This will save time and facilitate the cost-effective use of insecticides, as well as minimising environmental pollution caused by pesticide application.

Further investigation is recommended to provide long-term data on seasonal *B. fusca* moth flight activity in the country. Research should be done to assess the influence of changes in environmental factors on seasonal variations in moth flights. Such long-term information relating environmental changes with population fluctuations will be useful in predicting potential high risk seasons with regard to *B. fusca* infestation.

CHAPTER 4

RESPONSE OF LOCAL MAIZE VARIETIES AND COMMERCIAL HYBRIDS IN LESOTHO TO DAMAGE CAUSED BY *BUSSEOLA FUSCA* (FULLER) (LEPIDOPTERA: NOCTUIDAE).

ABSTRACT

The pest status of *Busseola fusca* (Fuller) was evaluated during the 1995/96 and 1996/97 growing seasons, using maize varieties and hybrids commonly grown in Lesotho. The incidence of plant damage, number of damaged internodes, number of *B. fusca* individuals that successfully colonized plants, and grain yield were determined. All the varieties and hybrids evaluated were susceptible to damage by *B. fusca*, and most sustained yield losses similar to that of the susceptible check hybrid. Results also indicated that varieties generally suffered lower yield losses than hybrids. Differences in yield losses between maize varieties and hybrids were ascribed to length of growing season requirements and the extent of damage to ears. The potential benefit of breeding for maize resistance for Lesotho farmers was emphasised.

Key words: *Busseola fusca*, maize, pest status.

INTRODUCTION

The production of maize, which is the most important crop grown in Lesotho, is often faced with a number of constraints, as a result of which annual yields are often low and subject to extreme fluctuations. For example, from the 1976/77 to the 1993/94 growing seasons, annual maize yields in the country averaged between 326 kg/ha and 1359 kg/ha, with a long term average of 746 kg/ha (Anon., 1994). This is well below the continental average of 1094 kg/ha (Rouanet, 1987), and represents only about a third of the yields achieved in the neighbouring maize producing areas of South Africa (Anon., 1995). As a result of this, Lesotho is only approximately 43 % self-sufficient in maize production (Anon., 1995).

Factors contributing to low yields are drought, low soil fertility, soil erosion and poor crop management practices (Anon., 1995). Although Qhobela *et al.* (1986) reported *Busseola fusca* (Fuller) (Lepidoptera: Noctuidae) as an important stalk borer of maize in Lesotho, the role of this pest in maize production in this country has not yet been investigated. Generally, stalk borers are regarded as important pests of maize and sorghum in various parts of Africa (Harris, 1962; Seshu Reddy, 1985a, 1989, 1990; Ajayi, 1989; Saxena *et al.*, 1989; Vogel *et al.*, 1993). However, quantitative estimates of yield loss due to *B. fusca* attack on maize are few and vary widely. In South Africa, Walters *et al.* (1976) reported an average loss of approximately 10 %, while Annecke & Moran (1982) put the figure at between 5 % and 72 %. In Nigeria, Usua (1968a) estimated yield loss to be between 10 % and 100 %.

This investigation was aimed at assessing the impact of *B. fusca* damage on the yield of some maize varieties and hybrids commonly grown in Lesotho. This provided quantitative information on the pest status of *B. fusca* on maize in this country.

MATERIAL AND METHODS

Two field trials were conducted at Roma (29° 27′ S, 27° 44′ E, 1660 m above sea level), Lesotho, during the 1995/96 and 1996/97 growing seasons. Maize seeds were obtained from agricultural supply agencies and from local farmers who annually plant seeds which they saved from the previous season's harvest. Table 4.1 shows varieties and hybrids (entries) used in the trials.

Table 4.1: Sources of maize varieties and hybrids included in trials conducted at Roma, Lesotho.

Maize variety/hybrid	Source of seeds
Silver King	Local farmer at Buasono, Berea district, Lesotho
Hlakaleboea (Highland maize)	Local farmer at Siloe, Mafeteng district, Lesotho
Lehakoana (White Bushman)	Local farmer at Tloutle, Maseru district, Lesotho
Natal-8-Row	Local farmer at Ha Makhaketsa, Leribe district, Lesotho
Kalahari	Local farmer at Ha Makhaketsa, Leribe district, Lesotho
Borotho (Bread maize)*	Local farmer at Siloe, Mafeteng district, Lesotho
PAN473 (commercial hybrid)	Agrivet agencies, Maseru, Lesotho
A1556 (commercial hybrid)	Agrivet agencies, Maseru, Lesotho
Rival NUT20828 (sweet corn)	Agrivet agencies, Maseru, Lesotho
PAN6363 (commercial hybrid)	Agrivet agencies, Maseru, Lesotho
Experimental susceptible check hybrid	ARC-Grain Crops Institute, Potchefstroom, South Africa
Experimental resistant check hybrid	ARC-Grain Crops Institute, Potchefstroom, South Africa

* only included in the 1996/97 season.

Eleven entries were evaluated during the 1995/96 season. In addition to these, 'Borotho' (Bread maize), which was collected from a local farmer in Siloe, was also included during the 1996/97 season, providing a total of 12 entries for that season.

In both trials, seeds were sown during the second week of December. The experimental design was a randomized complete block with four replications. Each plot consisted of a single 15 m-row. Intra-row and inter-row plant spacing were 0.3 m and 1.0 m respectively. Plants in one half of each plot (sub-plot) were routinely treated with the granular insecticide Kombat (carbaryl GR 25 g a.i./kg) at the rate of 4 kg granules per hectare. Insecticide treatment commenced three weeks after crop emergence (WAE), and was repeated fortnightly until the onset of flowering. The other half of the row was not treated with the insecticide. All plants were subjected to natural infestation by *B. fusca*. Infestation by another stalk borer, *Chilo partellus* (Swinhoe) (Lepidoptera: Pyralidae) was absent or negligible in maize at Roma.

Data collected for each entry in both seasons included the number of plants with dead heart symptoms, number of infested plants, level of infestation, degree of internal plant damage, incidence of ear damage, number of ears produced, grain yield and 100-kernel mass. The length of growing season requirement of each entry was also determined as the number of weeks to 50 % flowering.

The number of plants with dead heart symptoms was determined in each untreated sub-plot at 3, 5 and 7 WAE.

The number of infested plants was determined *in-situ* in each untreated sub-plot at fortnightly intervals, from 4 WAE to 20 WAE, and again at harvest. The incidence of infestation was determined as the number of plants with visible symptoms of larval feeding on whorl leaves, stems and ears, calculated as a percentage of the total number of plants sampled.

The level of infestation, taken as the total number of individuals of *B. fusca* that successfully colonized plants in each entry, was determined at harvest. This was done by sampling 15 plants at random from each untreated sub-plot, dissecting them, collecting and counting all the larvae, pupae, and pupal cases present inside the stems and ears.

The number of damaged internodes per plot, calculated as a percentage of the total number of internodes, was determined from the same plants used for the evaluation of level of infestation. In order to determine the severity of internal plant damage, mean percentage damaged internodes was calculated for each entry.

The incidence of ear damage was determined as the number of damaged ears per sub-plot, calculated as a percentage of the total number of ears per sub-plot. This was determined from the same 15 plants per sub-plot dissected for the evaluation of levels of infestation and severity of internal plant damage. Similar data was also determined for carbaryl-treated sub-plots. The mean number of ears produced per plant was also determined for carbaryl-treated and untreated plots of each entry.

Yield was determined for each entry at harvest. This was done by harvesting all ears from the same plants used for the evaluation of incidence of ear damage, as well as from those plants collected from the insecticide-treated sub-plots. These ears were shelled and the grain mass determined separately for each sub-plot. Yield loss was determined as the difference in yield between plants in the insecticide-treated and the untreated sub-plots, calculated as a percentage in relation to the yield of the insecticide-treated sub-plot.

Hundred-kernel mass was determined for both treated and untreated plants of each entry. This was done by determining the mass of each of five sets of 100 maize kernels, which were taken at random from each sub-plot. The mean mass was calculated for each sub-plot. The hundred-kernel mass of treated and untreated plants for each entry was calculated as the mean of four replications.

Data were subjected to analyses of variance, and differences between means were separated using Duncan's Multiple Range Test at P=0.05. Simple t-tests were conducted to test for significant differences between insecticide-treated and untreated plots, in terms of number of ears produced, incidence of damaged ears, and 100-kernel mass.

RESULTS AND DISCUSSION

No dead heart symptoms were recorded in any entry during both seasons. This was attributed to the late crop developmental stage at which *B. fusca* infestation set in (Tables 4.2 & 4.3), resulting in plants being no longer susceptible to dead heart formation. Dead hearts can be formed as a result of severe larval feeding in whorls of young plants (Harris, 1962; Alghali, 1986).

Significant differences (P<0.05) in the incidence of infested plants were only observed among the entries from 14 WAE onwards in the 1995/96 season (Table 4.2) and from 12 WAE onwards in the 1996/97 season (Table 4.3). During both seasons, the incidence of infested plants was generally lower in varieties than in hybrids. The hybrids PAN6363 and PAN473 suffered high incidences of infestation in both seasons, comparable to that of the susceptible check hybrid. The sweet corn hybrid, Rival NUT20828, showed significantly lower incidences of infestation than the susceptible check. At harvest, only Rival NUT20828 (Tables 4.2 & 4.3) and A1556 (Table 4.2) had significantly lower ($P<0.05$) incidences of infestation than the susceptible check hybrid.

Table 4.2: Incidence of infestation by *Busseola fusca* with time after emergence of maize grown at Roma (1995/96 growing season).

Maize variety/hybrid	Percentage infested plants (weeks after emergence)							
	8	10	12	14	16	18	20	Harvest
PAN6363	0.0	0.9	3.8	6.5 ab	10.0 ab	13.0	16.4	21.2 abc
PAN473	0.0	0.9	2.7	4.6 ab	9.9 ab	14.8	19.9	28.7 a
Hlakaleboea	0.0	0.0	0.6	1.6 b	3.1 b	5.1	9.9	12.7 bc
Kalahari	0.0	0.0	0.4	1.7 b	3.7 b	5.3	8.0	10.5 bc
Lehakoana	0.0	1.3	2.6	4.6 ab	8.0 ab	10.1	12.7	16.7 abc
Rival NUT20828	0.0	0.0	0.5	1.3 b	2.3 b	4.6	6.6	8.7 c
Susceptible check	0.0	3.7	7.0	9.0 a	13.9 a	17.1	19.5	25.6 ab
Resistant check	0.0	0.0	1.7	3.6 b	5.5 b	10.3	15.6	21.1 abc
Silver King	0.0	0.0	1.0	1.7 b	2.8 b	7.7	11.8	14.6 abc
Natal-8-Row	0.0	0.0	3.5	5.0 ab	6.2 b	7.1	10.5	13.0 bc
A1556	0.0	1.3	1.8	3.6 b	4.2 b	5.8	6.7	8.2 c
F-value	-	1.34	1.96	2.26	2.45	2.00	1.53	2.21
P-value	-	0.2560	0.0757	0.0409	0.0283	0.0700	0.1765	0.0456
LSD (P=0.05)	-	n.s.*	n.s.	4.6	6.9	n.s.	n.s.	13.3

Means within the same column followed by the same letter are not significantly different at P=0.05 (Duncan's Multiple Range Test). n.s.* = not significant (P>0.05).

Table 4.3: Incidence of infestation by *Busseola fusca* with time after emergence of maize grown at Roma (1996/97 growing season).

Maize variety/hybrid	Percentage infested plants (weeks after emergence)							
	8	10	12	14	16	18	20	Harvest
PAN6363	0.0	3.8	41.8 a	42.8 a	49.9 a	69.1 a	84.6 a	95.0 a
PAN473	0.0	6.0	34.8 abc	39.3 a	49.2 a	61.5 ab	80.2 ab	90.0 a
Hlakaleboea	0.0	1.4	24.7 abcd	33.0 abc	32.7 ab	50.9 abcd	62.5abcd	90.0 a
Kalahari	0.0	0.0	17.4 bcd	25.4 abc	43.5 a	54.5 abc	66.8 abcd	85.5 a
Lehakoana	0.0	1.6	24.6 abcd	24.1 abc	44.1 a	65.6 a	68.3 abc	87.6 a
Borotho	0.0	0.0	36.3 ab	44.3 a	52.6 a	66.4 a	67.5 abcd	96.7 a
Rival NUT20828	0.0	0.0	15.0 cd	16.3 c	15.0 b	30.4 cd	31.7 e	60.0 b
Susceptible check	0.0	6.3	36.2 ab	38.7 ab	41.8 a	65.8 a	80.6 ab	96.7 a
Resistant check	0.0	1.1	14.2 cd	17.4 bc	29.6 ab	33.4 bcd	41.4 de	80.0 a
Silver King	0.0	0.0	16.0 bcd	12.6 c	30.9 ab	46.0 abcd	60.0 abcd	98.3 a
Natal-8-Row	1.3	2.8	21.2 abcd	28.0 abc	38.0 ab	49.6 abcd	56.0 bcde	86.7 a
A1556	0.0	0.0	10.9 d	12.2 c	15.5 b	24.7 d	42.5 cde	80.0 a
F-value	-	1.74	2.06	2.42	2.10	2.37	3.15	3.46
P-value	-	0.1067	0.0533	0.0264	0.0493	0.0274	0.0052	0.0028
LSD (P=0.05)	-	n.s. *	20.9	21.7	24.9	28.6	14.9	9.4

Means within the same column followed by the same letter are not significantly different at P=0.05 (Duncan's Multiple Range Test). n.s.* = not significant (P>0.05).

In terms of incidence of infestation, all the local varieties and commercial hybrids were susceptible to infestation by *B. fusca* (Tables 4.2 & 4.3). However, the hybrids A1556 and Rival NUT20828 appeared to be less susceptible to infestation during crop development, although the number of infested plants in these entries increased sharply towards the end of the season.

The number of infested plants continued to increase in all the entries even after 20 WAE (Tables 4.2 & 4.3). The increased number of infested plants towards the end of the growing season was attributed to inter-plant larval migration. This observation differs from the report by Van Rensburg *et al.* (1988), that the number of damaged plants remained more or less constant after tasselling. This difference could be attributed to the observation that the larvae responsible for infestation in this trial were the diapause generation (arising from the second generation moth flight -see chapter 3). It has been reported that the number of infested plants increases rapidly towards the end of the season as larvae migrate to neighbouring uninfested plants to find shelter as diapause larvae (Walters *et al.*, 1976).

The level of infestation for all entries (number of *B. fusca* individuals that successfully colonized plants) was generally higher during the 1996/97 season than during the 1995/96 season (Table 4.4). This was to be expected, since the second generation *B. fusca* moth flight, which is responsible for infestations in maize planted after October in Lesotho (see chapter 10), was higher during the 1996/97 season than in the 1995/96 season (see chapter 3). The magnitude of moth flight has been used to explain differences in infestations in plantings (Van Rensburg *et al.*, 1985; Van Rensburg, Walters & Giliomee, 1987).

Table 4.4: Total number of *Busseola fusca* individuals colonizing maize grown under field conditions at Roma (1995/96 & 1996/97 growing seasons).

Maize variety/hybrid	Mean number of larvae/pupae/pupal cases per plot	
	1995/96	1996/97
PAN473	4.3 a	14.0
Susceptible check	3.5 ab	14.5
PAN6363	3.0 abc	13.0
Resistant check	3.0 abc	10.0
Lehakoana	2.3 bcd	9.5
Silver King	2.3 bcd	11.5
Kalahari	1.5 cd	10.3
A1556	1.5 cd	9.8
Hlakaleboea	1.3 cd	8.8
Rival NUT20828	1.0 d	7.5
Natal-8-Row	1.0 d	7.5
Borotho	-[1]	11.3
F-value	3.46	1.32
P-value	0.0040	0.2593
LSD (P=0.05)	1.7	n.s.*

Means within the same column followed by the same letter are not significantly different at P=0.05 (Duncan's Multiple Range Test).
-[1] = entry not included in the 1995/96 trial. n.s.* = not significant (P>0.05).

Significant differences (P<0.05) in the number of larvae colonizing plants were observed among the entries during the 1995/96 season (Table 4.4). During this season, the hybrid PAN473 hosted significantly more *B. fusca* individuals than all the other entries except the susceptible check hybrid, PAN6363, and the resistant check hybrid. Rival NUT20828 and Natal-8-Row hosted the lowest number of individuals (Table 4.4), although they were statistically similar to most of the other entries in the trial. During the 1996/97 trial, there were no significant differences (P>0.05) in the level of infestation among the different entries (Table 4.4). However, as was the case during the 1995/96 season, the susceptible check hybrid, PAN473, and PAN6363 again had the highest numbers of *B. fusca* individuals during this season, while Rival NUT20828 and Natal-8-Row had the lowest numbers.

These differences in infestation levels might be partly explained by the differences in the length of growing season of these two categories of entries. One common characteristic of

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the susceptible check hybrid, PAN473, and PAN6363 is that they have relatively long growing seasons, while Rival NUT20828 and Natal-8-Row have shorter growing season requirements (Table 4.5). It is possible that due to the late onset of infestation (Tables 4.2 & 4.3), the long-season maize entries may have been attractive to moths for oviposition over a more extended period of time compared to the short-season entries, thereby resulting in the former harbouring more *B. fusca* individuals. Van Rensburg *et al.*, (1988b) reported that *B. fusca* causes more damage in long-season cultivars than in short-season cultivars under similar conditions of infestation. Also, although data was not collected on stalk dimensions in this study, it was observed that the susceptible check hybrid, PAN473, and PAN6363 were more robust plants than Rival NUT20828 and Natal-8-Row. This factor might also have contributed to the observed differences in infestation levels between these two sets of entries. It has been reported that more and larger egg batches are laid on maize with thicker stalks than on those with thinner stalks (Van Rensburg *et al.*, 1989), a situation which would result in more individuals colonizing thick-stalked plants. In general, the tendency during both seasons was that entries which recorded higher numbers of damaged plants (Table 4.3) also had higher levels of infestation (Table 4.4).

Table 4.5: Time to 50 % flowering of some maize varieties and hybrids in Lesotho.

Maize variety/hybrid	Time to 50 % flowering (Weeks after emergence)
Lehakoana	8-9
Hlakaleboea	8-9
Borotho	10-11
Natal-8-Row	8-9
Kalahari	9-10
Silver King	8-9
PAN6363	10-11
PAN473	10-11
Rival NUT20828	7-8
A1556	9-10
Susceptible check	10-11
Resistant check	10-11

No significant differences (P>0.05) in percentage damaged internodes were observed among the entries (Table 4.6). Numerically, however, the hybrid A1556 sustained the lowest level of damage, while PAN473 had the highest level of damage during the 1995/96 season. During the 1996/97 season, the hybrid A1556 and the resistant check hybrid showed the lowest levels of internal damage (Table 4.6).

Table 4.6: Percentage damaged internodes and percentage ears with damage at harvest, in maize varieties and hybrids naturally infested by larvae of *Busseola fusca*, at Roma during the 1995/96 and 1996/97 growing seasons.

Maize variety/hybrid	Mean percentage damaged internodes		Mean percentage ears with damage	
	1995/96	1996/97	1995/96	1996/97
PAN6363	5.0	34.2	6.7	45.4
PAN473	7.3	32.8	6.2	56.6
Hlakaleboea	3.3	30.7	4.8	46.8
Kalahari	2.6	33.4	2.3	50.0
Lehakoana	5.5	34.9	5.1	49.8
Borotho	-[1]	34.9	-[1]	57.3
Rival NUT20828	2.8	21.1	1.1	17.3
Susceptible check	5.2	35.3	4.3	61.8
Resistant check	5.4	15.9	4.2	23.1
Silver King	3.5	24.3	2.2	26.2
Natal-8-Row	3.0	30.5	3.2	41.6
A1556	1.4	18.2	3.2	38.9
F-value	1.51	1.66	0.67	1.36
P-value	0.1856	0.1279	0.7459	0.2388
LSD (P=0.05)	n.s.*	n.s.	n.s.	n.s.

-[1] = variety not included in the 1995/96 trial. n.s.* = not significant (P>0.05).

No significant differences (P>0.05) in the number of damaged ears were observed among the entries during either of the seasons (Table 4.6). However, the trend was that entries which had higher incidences of infestation (Tables 4.2 & 4.3) also had higher percentages of ear damage (Table 4.6). The possibility that higher populations *of B. fusca* would lead to higher levels of ear damage has been reported by Van Rensburg *et al.* (1988). Therefore, the higher moth populations observed during the 1996/97 season as compared to 1995/96 (chapter 3) probably explains the higher proportion of ears damaged during the former season.

There were no significant differences (P>0.05) in the yield loss sustained by the entries during the 1995/96 season (Table 4.7). This was expected due to the generally low incidence of infestation during this season (Table 4.2). Numerically, however, the entries A1556, Rival NUT20828 and Natal-8-Row sustained the lowest levels of loss, while the susceptible check hybrid recorded the highest loss.

Table 4.7: Yield loss due to natural infestations by *Busseola fusca* in maize grown at Roma during the 1995/96 and 1996/97 growing seasons.

Maize variety/hybrid	Yield loss (%)	
	1995/96	1996/97
Borotho	-[1]	39.4 a
Hlakaleboea	4.7	38.1 ab
PAN473	6.1	25.1 abc
A1556	0.9	23.9 abc
Susceptible check	10.5	22.3 abc
Silver King	2.4	18.1 abcd
PAN6363	3.0	17.5 bcd
Kalahari	5.4	14.7 cd
Lehakoana	3.5	12.0 cd
Rival NUT20828	1.4	11.6 cd
Resistant check	6.4	10.3 cd
Natal-8-Row	1.4	0.0 d
F-value	0.75	2.94
P-value	0.6760	0.0081
LSD (P=0.05)	n.s.*	19.0

Means within the same column followed by the same letter are not significantly different at P=0.05 (Duncan's Multiple Range Test).
-[1] = variety not included in the 1995/96 trial. n.s.* = not significant (P>0.05).

During the 1996/97 season, significant differences (P<0.05) in yield loss were observed. The local variety Borotho sustained the highest yield loss, while Natal-8-Row showed no losses (Table 4.7). The hybrid A1556 had one of the highest yield losses during the 1996/97 trial. This was despite the observation that it almost consistently sustained one of the lowest incidences of infestation (Table 4.2) and the second lowest level of internal plant damage (Tables 4.6) during the 1996/97 season. The observed yield loss in A1556 (Table 4.7) was, therefore, attributed to its relatively high incidence of ear damage (Table 4.6). Yield losses were generally not proportionate to the incidences of infestation at harvest. This could be attributed to the late crop developmental stage at which infestation set in for all entries (Tables 4.2 & 4.3). It has been reported that attack by *B. fusca* during the late crop growth stage is relatively less damaging to plants than early infestation (Walters *et al.*, 1976; Van Rensburg *et al.*, 1988c).

A significant difference ($P<0.0001$) existed between the carbaryl-treated and the untreated plots in terms of the incidence of ear damage (Table 4.8). No significant difference ($P>0.05$) was observed in terms of the mean number of ears per plant and the 100-kernel mass (Table 4.8). This seems to indicate that damage to ears was the main factor responsible for yield losses in this trial, while infestations did not appear to have significantly affected the total number of ears produced or the efficiency of grain formation. The result also shows that although infestations in all entries started relatively late during crop development (Tables 4.2 & 4.3), insecticide treatment was still effective in reducing the incidence of damage to ears (Table 4.8). This observation might be of importance in a crop that is grown for green maize, as blemishes caused by insect damage are less tolerated in such a crop.

In general, this study indicated that both the local varieties and the commercial hybrids grown in Lesotho are susceptible to *B. fusca* infestation, though to varying degrees. This means that, depending on factors such as infestation level and planting date (see chapter 10), high yield losses can be sustained in any of these varieties and hybrids.

Table 4.8: Number of ears produced, incidence of ear damage by *Busseola fusca*, and 100-kernel mass, in carbaryl-treated and untreated plots of maize, grown under natural field conditions at Roma during the 1996/97 growing season.

Maize variety/hybrid	Mean number of ears/plant		% ears with *B. fusca* damage/plot		100-kernel mass (g)	
	Treated	Untreated	Treated	Untreated	Treated	Untreated
Kalahari	1.08	1.03	17.4	50.0	33.20	31.22
Rival NUT20828	1.20	1.15	11.1	17.3	20.92	14.25
Silver King	1.28	1.29	16.4	26.2	41.90	35.66
Borotho	1.13	1.10	12.9	57.5	28.50	34.50
Resistant check	1.58	1.83	3.0	23.1	29.02	23.26
PAN6363	1.48	1.45	16.6	45.4	25.48	24.62
Lehakoana	1.14	1.16	15.0	49.8	25.75	29.25
PAN473	1.48	1.35	3.5	56.6	19.50	20.25
Hlakaleboea	1.08	0.98	8.9	46.8	32.40	27.86
Susceptible check	0.87	0.98	8.3	61.8	19.75	19.42
A1556	1.05	0.98	2.5	38.9	33.25	29.00
Natal-8-Row	1.30	1.15	5.0	41.6	31.50	31.25
Mean	1.22	1.20	10.1	10.1	28.43	26.71
Standard deviation	0.21	0.25	5.6	5.6	6.62	6.48
t-value	0.5794		7.6272		1.4997	
P-value	0.5740		<0.0001		0.1618	

Assessment of the pest status of an insect under natural infestation has certain limitations which complicate the interpretation of results. Such limitations include varietal escapes, moth preference for oviposition on certain varieties (Barrow, 1985; Van Rensburg *et al.*, 1989), differential oviposition on varieties solely as a result of chance (Van Hamburg, 1980; Barrow, 1985) and seasonal variation in borer infestation (Harris, 1962; Ajayi, 1989). Therefore, since maize cultivars with short growing season requirements suffer less yield losses than those with longer growing seasons under identical circumstances of infestation (Van Rensburg *et al.*, 1988b), a short-season variety like Natal-8-Row, which recorded the lowest yield loss in the trial, might simply have escaped damage. Similarly, Rival NUT20828, which recorded one of the lowest levels of infestation (Table 4.4), might also have escaped infestation, as it was already in tassel (Table 4.5) before the first symptoms of infestation were observed in any entry (Tables 4.2 & 4.3).

As the entries had varying lengths of period to maturity (Table 4.5), and since all the entries were exposed to infestation at about the same time, the plant development stage at which infestation set in was not uniform for all the entries. Consequently, varietal response to such infestations might have been influenced by this factor. Therefore, the status of resistance of each entry to *B. fusca* would be better clarified by exposing it to infestation during the early stages of crop development.

CONCLUSION

Generally, the local varieties and hybrids grown in Lesotho exhibited susceptibility to *B. fusca* damage and sustained yield losses similar to that of the experimental susceptible check hybrid. This indicates that Lesotho farmers will benefit from a resistance breeding programme. Also, late onset of infestation, which was observed in this study, indicates that adjusting the planting date of maize, in order to ensure that plants will be in the late growth stages when infestation sets in, may result in crops largely escaping damage, thereby reducing yield losses.

CHAPTER 5

RESPONSE OF LOCAL MAIZE VARIETIES AND HYBRIDS OF LESOTHO TO ARTIFICIAL INFESTATION WITH THE STALK BORER, *BUSSEOLA FUSCA* (FULLER) (LEPIDOPTERA: NOCTUIDAE).

ABSTRACT

A glasshouse trial and two field trials were conducted during the 1996/97 and 1997/98 growing seasons to evaluate the status of resistance to *Busseola fusca* (Fuller) of maize varieties and hybrids grown in Lesotho. Plants were artificially infested with newly hatched *B. fusca* larvae. An assessment was also made of the yield of the varieties and hybrids, both in the presence and absence of *B. fusca* infestations. Results of the glasshouse trial indicated generally low levels of antibiosis and antixenosis resistance to larvae in all the entries evaluated. The field trials also showed both varieties and hybrids to be susceptible to damage by *B. fusca*, having all recorded substantial yield losses. Generally, the hybrid maize entries yielded higher than the open-pollinated varieties, both in the presence and absence of *B. fusca* infestations. Therefore, farmers of Lesotho could improve their maize yields substantially by adopting hybrid maize. The importance of taking several parameters into consideration, and of assessing yield potentials when breeding or selecting pest resistant varieties is emphasised.

Key words: *Busseola fusca*, maize, resistance, yield.

INTRODUCTION

The maize stalk borer, *Busseola fusca* (Fuller) occurs in virtually all countries south of the Sahara (Appert, 1970; Harris, 1989a, b) where it is the most important stalk borer of maize and sorghum (Walker & Hodson, 1976; Harris, 1989a, b). Although maize is a major food grain in several parts of Africa, its production is largely undertaken by small-scale, resource-poor farmers. As a result, many recommended stalk borer control measures such as insecticides or certain agronomic practices are too costly or impractical for these farmers to adopt (Ajayi, 1989; Saxena *et al.*, 1989; Seshu Reddy, 1989).

Plant resistance, where available, is a desirable pest control option in terms of affordability, ease of application (since no special skill is required), effectiveness, as well as it being environmentally safe to use (Alghali, 1985; Ajayi, 1989; Sharma, 1985; Sithole, 1989). Furthermore, the use of even moderate levels of resistance or tolerance can improve the effectiveness of other control measures, in addition to limiting the use of insecticides (Alghali, 1985; Sharma, 1985; Van den Berg *et al.*, 1994a).

According to Smith (1989), plant resistance to insects involves the possession of genetically inherited qualities (morphological or physical) by a plant cultivar or species, which results in it being less damaged than a susceptible cultivar or species that lacks these qualities. According to the same author, plant resistance can be manifested either as antibiosis (when the biology of the insect is adversely affected), or as antixenosis (when the plant acts as a poor host, and the insect selects an alternate host). The term ‘tolerance’ refers to another form of plant response to an insect pest that is not resistance in the strictest sense.

According to Smith (1989), tolerance to a pest is the inherent genetic qualities of a plant that may afford it the ability to withstand or recover from insect damage.

Prior to this study, there was no report of any investigation into the status of resistance to *B. fusca* (which is currently the only important stalk borer of maize in this country -see chapter 2) of maize varieties and hybrids grown in Lesotho. Lesotho's farmers have, therefore, not been privileged to make informed decisions with regard to their choice of maize varieties, and the potential benefits/problems that may be associated with the use of a given variety, in terms of stalk borer infestations. Also, the open-pollinated varieties have been used for a long period of time in the absence of chemical control. Therefore, the question was whether natural selection could have contributed towards improved resistance to stalk borers, compared to modern hybrids.

The aim of this study was to obtain basic information on the status of resistance to *B. fusca*, of some maize varieties and hybrids commonly grown in Lesotho. Yields of these hybrids and varieties, both in the presence and absence of *B. fusca* infestation were also compared. Such information will facilitate making recommendations with regard to choice of varieties, management of stalk borers, as well as in assessing the progress of crop improvement programs, especially those involving the local open-pollinated varieties which are still being grown by farmers in Lesotho.

MATERIAL AND METHODS

A glasshouse study and two field trials were conducted at the ARC-Grain Crops Institute, Potchefstroom (26°43′ S, 27° 6′ E), South Africa, during the 1996/97 and 1997/98 growing seasons. Ten maize varieties and hybrids (entries) were used in the glasshouse study, while 18 maize entries were used in the field studies. Details of entries used in the glasshouse and field trials are presented in Tables 5.1 & 5.2 respectively.

Table 5.1: Maize varieties and hybrids evaluated for resistance to *Busseola fusca*, in a glasshouse study during the 1996/97 growing season.

Maize variety/hybrid	Source of seeds
Silver King	Local farmer at Buasono, Berea district, Lesotho
Hlakaleboea (Highland maize)	Local farmer at Siloe, Mafeteng district, Lesotho
Lehakoana (White Bushman)	Local farmer at Tloutle, Maseru district, Lesotho
Natal-8-Row	Local farmer at Ha Makhaketsa, Leribe district, Lesotho
Kalahari	Local farmer at Ha Makhaketsa, Leribe district, Lesotho
Borotho (Bread maize)	Local farmer at Siloe, Mafeteng district, Lesotho
SAFFOLA RO419 (commercial hybrid)	Agrivet agencies, Maseru, Lesotho
PAN473 (commercial hybrid)	Agrivet agencies, Maseru, Lesotho
Experimental susceptible check hybrid	ARC-Grain Crops Institute, Potchefstroom, South Africa
Experimental resistant check hybrid (cross between a local elite line and an unadapted exotic resistant line)	ARC-Grain Crops Institute, Potchefstroom, South Africa

Table 5.2: Maize varieties and hybrids evaluated for resistance to *Busseola fusca*, in a field study during the 1996/97 and 1997/98 growing seasons.

Maize variety/hybrid	Source of seeds
Silver King	Local farmer at Buasono, Berea district, Lesotho
Hlakaleboea (Highland maize)	Local farmer at Siloe, Mafeteng district, Lesotho
Lehakoana (White Bushman)	Local farmer at Siloe, Mafeteng district, Lesotho
Natal-8-Row	Local farmer at Roma, Maseru district, Lesotho
Kalahari	Local farmer at Ha Makhaketsa, Leribe district, Lesotho
Natal-8-Row	Local farmer at Ha Makhaketsa, Leribe district, Lesotho
Lehakoana (White Bushman)	Local farmer at Tloutle, Maseru district, Lesotho
Borotho (Bread maize)	Local farmer at Siloe, Mafeteng district, Lesotho
Natal-8-Row	Local farmer at Siloe, Mafeteng district, Lesotho
Local 1	Local farmer at Roma, Maseru district, Lesotho
Hlakaleboea (highland maize)	Local farmer at Ha Lebamang, Maseru district, Lesotho
PAN6363 (commercial hybrid)	Agrivet agencies, Maseru
A1556 (commercial hybrid)	Agrivet agencies, Maseru
PAN473 (commercial hybrid)	Agrivet agencies, Maseru
SAFFOLA RO419 (commercial hybrid)	Agrivet agencies, Maseru
Rival NUT20828 (sweet corn hybrid)	Agrivet agencies, Maseru
Experimental susceptible check hybrid	ARC-Grain Crops Institute, Potchefstroom, South Africa
Experimental resistant check hybrid (cross between a local elite line and an unadapted exotic resistant line)	ARC-Grain Crops Institute, Potchefstroom, South Africa

For the glasshouse trial, maize seeds were sown in a temperature-controlled, commercial glasshouse (with day and night temperatures ranging between 18° C and 30° C). The experimental design was a randomized complete block with three replications. Plots were single 2 m-rows, with inter-row and intra-row plant spacing of 1.0 m and 0.2 m respectively. Only one plant per hill was allowed to establish.

At five weeks after crop emergence (WAE), plants were artificially infested with *B. fusca* larvae. This was done by placing 10 neonate larvae (carried in corn-cob grits) into the whorls of each plant by means of a "bazooka" mechanical dispenser (Wiseman *et al.*, 1980).

In order to evaluate for antibiosis and antixenosis (non-preference) resistance to *B. fusca* larvae, seven plants were removed at random from each plot and dissected, 14 days after inoculation with larvae (7 WAE). For each plot, surviving larvae were collected, counted, and their mass determined. Mean number of surviving larvae per plot and mean larval mass were determined for each entry.

For each field trial, experimental design was a randomized complete block with three replications. Each plot was a 7 m-row, with inter-row and intra-row spacing of 1.5 m and 0.2 m respectively. At 4 WAE (mid-whorl stage), all plants in half (3.5 m) of each plot were artificially infested with 10 neonate *B. fusca* larvae, using the same procedure as described for the glasshouse trial. Plants in the uninfested half of each plot were treated with an insecticide mixture of endosulfan (35 % EC) and deltamethrin (2.5 % EC), at the rate of 7.5 ml / 0.4 ml respectively, applied in 2.4 l of water per 100 m row length, using a knapsack sprayer.

Ten days after infestation, leaf-feeding damage in the inoculated half was evaluated on a scale of 1 to 9 (Guthrie *et al.*, 1960), in order to assess the level of leaf-feeding resistance. Entries were classified as resistant (1.0 to 3.9 rating), intermediate (4.0 to 6.9 rating), and susceptible (7.0 to 9.0 rating) to leaf feeding. In order to assess the effect of *B. fusca* damage on yield of the various entries, ears from infested and uninfested halves of each plot were harvested separately when plants were mature and dry. The ears were de-husked, shelled and grain mass determined separately for the infested and uninfested halves of each plot. Average yield was determined for infested and uninfested plants of each entry. Yield loss was calculated as the difference in yield between plants in the uninfested and in the infested halves of each plot, calculated as a percentage of the yield of the uninfested plants.

Data from both glasshouse and field trials were subjected to analyses of variance and differences between means tested using Duncan's Multiple Range Test at P=0.05.

RESULTS AND DISCUSSION

The maize variety Lehakoana, had the lowest number of surviving larvae (even lower than the resistant check), while Hlakaleboea had the highest (higher than the susceptible check) in the glasshouse study (Table 5.3). However, statistical analysis showed that these differences were not significant (P>0.05).

With regard to mean larval mass, larvae on the entry Hlakaleboea (Siloe), which recorded the highest number of larvae per plot, had the lowest mean mass, while larvae on Borotho had the highest mean mass (Table 5.3). However, these differences were also not significant

Table 5.3: Number of larvae and mean larval mass of *Busseola fusca* on maize plants artificially infested in a glasshouse with 10 larvae per plant at five weeks after crop emergence.

Maize variety/hybrid	Mean number of larvae per plot	Mean larval mass (g)
Lehakoana (Tloutle)	24.33	0.0082
Kalahari	35.33	0.0074
Experimental resistant check hybrid	35.67	0.0051
Natal-8-Row (Ha Makhaketsa)	37.00	0.0053
PAN473	38.00	0.0085
SAFFOLA RO419	41.67	0.0097
Silver King	42.33	0.0063
Experimental susceptible check hybrid	49.33	0.0064
Borotho	50.33	0.0100
Hlakaleboea (Siloe)	52.33	0.0040
F-value	1.648	1.194
P-value	0.1753 n.s.*	0.3562 n.s.

n.s.* = not significant (P>0.05).

(P>0.05). Nevertheless, these results show that certain resistance mechanisms, which were present in varying degrees in the various entries, influenced both the survival and growth of larvae following infestation. Thus, although larvae on Hlakaleboea (Siloe) did not suffer as high a level of mortality as those on Lehakoana (Tloutle), certain factor(s) (physical or chemical) at the feeding site prevented the larvae either from feeding and gaining in mass (antixenosis), or from deriving the nourishment they needed to develop normally (antibiosis) (Table 5.3). On the other hand, larvae feeding on Lehakoana (Tloutle) appeared to have derived a relatively adequate nutrition which enabled them to grow faster than those on Hlakaleboea (Siloe) (Table 5.3). The local entry Borotho appeared to have been the best host of *B. fusca* of all the entries evaluated, since it recorded the highest larval mean mass and the second highest rate of larval survival (Table 5.3). This suggests that this entry had the lowest level of both antixenosis and antibiosis resistance of all the entries evaluated. The lack of significant difference in terms of mean larval numbers and mean larval mass possibly indicated generally low levels of antibiosis and antixenosis resistance to *B. fusca* larvae.

With regard to foliar damage, only the experimental resistant check was rated as resistant to leaf feeding during both growing seasons, while all other entries were rated intermediate (Table 5.4). The hybrids SAFFOLA RO419 and PAN6363, and the variety Local 1 sustained among the highest levels of leaf damage during both seasons. No entry was rated susceptible during the 1996/97 season, but Borotho and Rival NUT20828 were rated as such during 1997/98. It has been reported that the extent of leaf-feeding damage is an indication of the degree of establishment of the first and second instar larvae (Davis, 1985). Therefore, the effect of resistance factor(s) on larval feeding was probably more in the experimental resistant check, resulting in it recording the lowest foliar damage rating (Table 5.4). Although changes were observed in the leaf-damage ratings of some entries, each entry maintained its rating category during both seasons, except Borotho, whose status changed from intermediate resistance in the 1996/97 season to susceptible during the 1997/98 season (Table 5.4). Seasonal changes in the expression of resistance by genotypes has been reported (Tingey & Singh, 1980; Seshu Reddy, 1985a; Van den Berg, 1994). Such changes occur whenever the resistance is additively inherited, due to the effect of variable environmental factors (Tingey & Singh, 1980).

The observation that most entries exhibited resistant to intermediate foliar damage ratings is important, since such resistance during the whorl stage can reduce the injuriousness of larvae during the early stages of crop development (Verma *et al.*, 1992). However, it has been reported that, in sorghum, late instar larvae which survive moderate leaf-feeding resistance during the whorl stage may still cause yield loss during the later stages of crop development (Van den Berg, 1994). Therefore, it is possible that varieties like Borotho and Hlakaleboea (Siloe) may eventually suffer high losses due to a relatively high rate of larval survival (Table 5.3).

Table 5.4: Leaf-feeding damage on maize varieties and hybrids artificially infested in the field with larvae of *Busseola fusca*, during the 1996/97 and 1997/98 growing seasons.

Maize variety/hybrid	Leaf-feeding rating	
	1996/97	1997/98
Experimental resistant check hybrid	2.7	3.7
Lehakoana (Tloutle)	4.0	5.7
Natal-8-Row (Roma)	4.5	5.3
Hlakaleboea (Siloe)	4.7	4.7
Kalahari	4.7	4.0
A1556	4.7	5.7
Natal-8-Row (Ha Makhaketsa)	4.7	4.0
Experimental susceptible check hybrid	4.7	6.3
Hlakaleboea (Ha Lebamang)	5.0	5.3
PAN473	5.0	6.0
Silver King	5.0	5.3
Borotho	5.3	7.0
Lehakoana (Siloe)	5.3	5.0
Natal-8-Row (Siloe)	5.3	4.7
SAFFOLA RO419	6.0	6.3
PAN6363	6.0	6.0
Local 1	6.0	6.3
Rival NUT20828	-*	7.0

*...Entry failed to germinate during this season.

Yield loss assessment showed that there were no significant differences (P>0.05) amongst the entries during both seasons, despite the wide range in average yield loss sustained by the various varieties and hybrids (Tables 5.5 & 5.6). This lack of significant difference was attributed to variability observed within some entries. Nevertheless, the results show that infestation caused yield loss in all the entries, indicating that all the entries evaluated were susceptible to damage by *B. fusca*, albeit to varying degrees. The local entry Borotho recorded the highest yield loss during the 1996/97 season (Table 5.5), as well as one of the highest losses during the 1997/98 season (Table 5.6). This is consistent with the observation that Borotho sustained the highest mean larval mass, as well as the second highest number of surviving larvae in the glasshouse trial (Table 5.3). The fact that Borotho recorded the highest yield loss under both natural infestation (see chapter 4) and artificial infestation (Table 5.5) also confirmed that this was the most susceptible of all the entries evaluated in these trials.

Table 5.5: Yield and yield loss of maize artificially infested in the field with larvae of *Busseola fusca*, during the 1996/97 growing season.

Maize variety/hybrid	Yield/plot (g) Uninfested	Yield/plot (g) Infested	Yield loss (%) (arcsin)
Natal-8-Row (Ha Makhaketsa)	893.0 a	546.0 ab	34.6
Borotho	941.0 a	351.5 a	52.3
Hlakaleboea (Siloe)	948.7 a	768.7 abc	24.6
Lehakoana (Siloe)	1019.7 a	743.3 abc	30.3
Natal-8-Row (Roma)	1268.0 ab	1058.5 abcd	24.0
Kalahari	1284.0 ab	1250.5 abcd	12.8
Lehakoana (Tloutle)	1292.0 ab	705.5 abc	41.3
Local 1	1527.7 abc	1273.3 bcd	23.1
Silver King	1605.0 abcd	1385.5 bcde	18.2
Natal-8-Row (Siloe)	1619.7 abcd	1348.7 bcd	24.0
SAFFOLA RO419	1915.3 bcde	1420.3 cdef	28.5
A1556	1952.0 bcde	1705.7 defg	18.4
Experimental resistant check hybrid	2121.7 bcde	1807.3 defg	28.0
Hlakaleboea (Ha Lebamang)	2221.0 cde	2298.0 eg	-4.6
PAN6363	2255.3 cde	1821.3 defg	23.2
Experimental susceptible check hybrid	2407.3 de	2361.0 g	16.0
PAN473	2653.0 e	1639.7 defg	32.7
F-value	3.829	3.921	0.908
P-value	0.0011	0.0090	0.5701 n.s.*

Means within the same column followed by the same letter are not significantly different at P=0.05 (Duncan's Multiple Range Test). n.s.* = not significant (P>0.05).

Table 5.6: Yield and yield loss of maize artificially infested in the field with larvae of *Busseola fusca*, during the 1997/98 growing season.

Maize variety/hybrid	Yield/plot (g) Uninfested	Yield/plot (g) Infested	Yield loss (%) (arcsin)
Hlakaleboea (Siloe)	180.4 h	117.7 f	37.1
Borotho	296.3 h	214.0 ef	39.3
Rival NUT20828 (sweet corn)	304.7 h	181.3 ef	39.7
Natal-8-Row (Ha Makhaketsa)	629.0 gh	480.7 def	51.5
Lehakoana (Tloutle)	680.4 gh	326.7 ef	41.3
Kalahari	874.3 fgh	402.3 def	45.6
Natal-8-Row (Roma)	885.4 fgh	501.7 def	15.5
Silver King	1300.0 efg	818.7 cde	38.0
Lehakoana (Siloe)	1308.0 efg	1059.0 bcd	22.6
Local 1	1459.0 def	1228.0 bc	18.6
Natal-8-Row (Siloe)	1581.0 cdef	1180.0 bc	28.9
SAFFOLA RO419	1612.0 bcdef	1301.0 bc	26.7
Hlakaleboea (Ha Lebamang)	1668.0 bcde	1059.0 bcd	37.1
A1556	1933.0 bcde	1364.0 bc	24.3
Experimental resistant check hybrid	2191.0 abcd	1171.0 bc	43.8
Experimental susceptible check hybrid	2241.0 abc	1361.0 bc	39.5
PAN6363	2365.0 ab	1694.0 ab	32.2
PAN473	2883.0 a	2206.0 a	27.0
F-value	10.99	8.22	1.00
P-value	<0.0001	<0.0001	0.4851 n.s.*

Means within the same column followed by the same letter are not significantly different at P=0.05 (Duncan's Multiple Range Test). n.s.* = not significant (P>0.05).

The resistant check sustained a substantial yield loss (Tables 5.5 & 5.6), despite recording the lowest foliar damage rating (Table 5.4) during both seasons. Also, Lehakoana (Tloutle) sustained the second highest and one of the highest yield losses during the 1996/97 (Table 5.5) and 1997/98 (Tables 5.6) seasons respectively, despite recording the lowest number of surviving larvae (Table 5.3) and intermediate foliar damage ratings (Table 5.4). A similar observation was made on Hlakaleboea (Siloe) which sustained substantial yield losses during both seasons (Tables 5.5 & 5.6), despite recording the lowest larval mass gain (Table 5.3) and intermediate leaf-feeding resistance (Table 5.4). These observations suggest that the effectiveness of resistance mechanisms (such as those which limit larval numbers, larval mass gain or foliar damage) may decline as plants get older. As a result of this decline, surviving larvae may eventually cause substantial damage during the later stages of crop development. Simple correlation between foliar damage ratings and yield loss (r= 0.02, P= 0.869 and r= -0.08, P= 0.577 during the 1996/97 and 1997/98 seasons respectively) showed a lack of significant relationship between these two parameters. Therefore, it is perhaps not surprising that hybrids which sustained the highest levels of leaf damage did not necessarily sustain the highest yield losses. High variability observed in yield losses might also have contributed to this lack of significant relationship. Changes in resistance status with plant age (Chapman, Woodhead & Bernays, 1983; Van den Berg *et al.*, 1994b), as well as poor correlation between leaf-feeding damage by stalk borers and yield loss (Singh *et al.*, 1983, Van den Berg, *et al.*, 1994b) have also been reported in sorghum. Such changes in resistance expression underscore the need to take into consideration the effect of other factors on yield responses when evaluating plant resistance. This observation was also made by Van den Berg *et al.* (1994b).

The entry Hlakaleboea (Ha Lebamang) recorded no yield loss due to borer damage, and an insignificant gain in yield was observed during the 1996/97 season (Table 5.5).

Natal-8-Row (Ha Makhaketsa), which recorded no yield loss under natural infestation (chapter 4), sustained a substantial loss during both seasons (Tables 5.5 & 5.6). This probably suggests that varietal escape, due to late onset of infestation was, at least partly, responsible for the result obtained under natural infestation (chapter 4). This observation also suggests that maize varieties can benefit from planting date adjustment in order to minimise damage by stalk borers. Generally, yield losses were higher during the 1997/98 than in 1996/97 season (Tables 5.5 & 5.6).

With the exception of Rival NUT20828 (sweet corn), all hybrid maize, including the experimental susceptible check, produced higher yields than most local varieties during both growing seasons, both in the presence and absence of *B. fusca* infestation (Tables 5.5 & 5.6). Some of these differences were significant ($P<0.05$). Even the infested plots of the hybrids yielded higher than the uninfested plots of most local entries. Similar observations were made during 1997/98, with infested hybrids yielding significantly higher ($P<0.05$) than most infested local entries (Table 5.6). The hybrid PAN473 produced the highest yield in the absence of *B. fusca* infestation during both seasons, as well as under *B. fusca* infestation during the 1997/98 season. Infested Borotho plants produced the lowest yield, and was significantly lower ($P<0.05$) than all the infested hybrids (Table 5.5).

These results have shown that the hybrids will perform better than the local varieties under identical conditions of infestation. It may therefore be more profitable for a farmer to plant hybrids (even susceptible ones) than local varieties, since these hybrids will produce higher yields even when infested by *B. fusca*. It was also observed that the susceptible check produced higher yields, although not significantly ($P>0.05$), than the resistant check (a cross between a local elite line and an unadapted exotic resistant line), both in the presence and absence of *B. fusca* infestation (Tables 5.5 & 5.6). These observations underscore the importance of maintaining yield potential when introgressing resistance into elite breeding material. However, resistant varieties can be beneficial through the reduction of pest populations (Van den Berg, 1994).

CONCLUSION

It is concluded that the maize varieties and hybrids currently grown in Lesotho, and which were evaluated, are susceptible to *B. fusca* damage. As such, control of this pest will have to involve the use of stalk borer management practices other than plant resistance. The development and promotion of stalk borer resistant maize varieties will benefit farmers in this country, and more focus is needed in these areas.

The hybrid maize evaluated in this study showed higher yield potentials than the local varieties, even when infested by stalk borers. Therefore, Lesotho's farmers will benefit from growing them. However, some small-scale, subsistence farmers in this country cannot afford to purchase hybrid seed and fertilizers annually, and will still prefer to save the seeds of the open-pollinated varieties which have been shown to have low yield potentials. Research is therefore needed to develop synthetics with increased yield potential and improved resistance to stalk borers, of which the seed may be saved for a number of generations without affecting yield potential significantly.

CHAPTER 6

EFFECT OF *BUSSEOLA FUSCA* (FULLER) (LEPIDOPTERA: NOCTUIDAE) INFESTATION ON THE PERFORMANCE OF SORGHUM VARIETIES AND HYBRIDS IN LESOTHO.

ABSTRACT

The impact of natural infestations of *Busseola fusca* in Lesotho on the yield of sorghum varieties and hybrids was assessed in two field trials during the 1995/96 and 1996/97 growing seasons. The study showed that natural stalk borer infestations can cause substantial yield losses in susceptible sorghum varieties and hybrids. For instance, a yield loss of 35.5 % was recorded in Segaolane, an open-pollinated sorghum variety which is widely grown in southern Africa. This observation should be taken into consideration by sorghum producers in Lesotho and by researchers who are involved in selecting or breeding sorghum for this country. Tenant White, an open-pollinated variety commonly grown in Lesotho, produced higher yields than the rest of the varieties and hybrids evaluated, even though they sustained similar levels of stalk borer infestation. This suggested that Tenant White might have some level of tolerance to the pest. Further research to investigate this finding was recommended.

Key words: *Busseola fusca*, sorghum, tolerance, yield loss.

INTRODUCTION

Grain sorghum, *Sorghum bicolor* (L.) Moench., is one of the world's most important cereal crops (Doggett, 1988). It is cultivated mainly in the semi-arid tropics and subtropics, and is a major staple food in many parts of Africa. Average sorghum yields in Africa are generally very low (683 kg/ha) when compared with those of Mexico (2900 kg/ha) and the United States of America (3300 kg/ha) (Leuschner, 1985).

As is the case with other crops, sorghum production in Lesotho is mostly undertaken by small-scale, resource-poor farmers (Anon., 1986). In recent years, average annual sorghum yields for Lesotho have mostly been below 800 kg/ha (Anon., 1994). Drought, poor soil conditions and inadequate crop management practices are often cited as reasons for low crop productivity in this country. However, it is generally acknowledged that pests are part of a complex of factors that act either individually or collectively to reduce crop productivity. With regard to sorghum, stalk borers have been reported as the most important and most widespread pests of the crop in Africa (Ajayi, 1989; Saxena *et al.*, 1989).

Although stalk borers are important pests of sorghum in Lesotho, there are no reports on the extent of damage caused by these pests under local conditions. This investigation was aimed at assessing the effect of natural infestations of stalk borers on the yield of some local sorghum varieties grown in Lesotho. Since the stalk borer, *Busseola fusca* (Fuller) was the only important pest of sorghum at the study site, this investigation was essentially dealing with this species. Results gave a quantitative insight into the importance of this pest on sorghum production in this country.

MATERIAL AND METHODS

Two field trials were conducted during the 1995/96 and 1996/97 growing seasons at Roma (29° 27′ S, 27° 44′ E, 1660 m above sea level), Lesotho. Seeds were obtained from local farmers in Lesotho, as well as from the Faculty of Agriculture of the National University of Lesotho at Roma. For the purpose of comparison, seeds of sorghum varieties and hybrids (entries), whose status of resistance/susceptibility to stalk borers are known, were included in the trials. These were obtained from the ARC-Grain Crops Institute, Potchefstroom, South Africa. Table 6.1 provides a summary of the sorghum entries used in this investigation. All entries except the hybrid ISS (Table 6.1) were evaluated during the 1995/96 growing season, while all 10 entries were planted during 1996/97. However, the entry Zulu 1 was eventually discarded during the 1996/97 season, due to poor seed germination.

Seeds were sown during early December of each growing season in order to improve the chances of obtaining high levels of infestation by second generation *B. fusca* moths. This is the predominant stalk borer of sorghum at the trial site (see chapter 2). The experimental design was a randomized complete block with four replications. Plots consisted of single rows, each 7 m long, with intra-row and inter-row spacing of 0.15 m and 1.0 m respectively. Three weeks after emergence (WAE), plants were thinned to one per hill, and each plot divided into two halves (sub-plots). Commencing 3 WAE, one half of each plot (sub-plot) was treated with Kombat insecticide (carbaryl GR 25 g a.i./kg) to prevent borer damage and to enable calculation of yield loss at harvest. The rate and frequency of application were 4 kg granules per hectare, applied into plant whorls at fortnightly intervals until flowering.

Table 6.1: Sorghum entries evaluated under natural infestations by *Busseola fusca* at Roma, Lesotho, during the 1995/96 and 1996/97 growing seasons.

Sorghum variety/hybrid	Source	Comments
White Seqhobane	Roma (Maseru district)	Lesotho land race
Red Seqhobane	Buasono village (Berea district)	Lesotho land race
Tenant White	Faculty of Agriculture of the National University of Lesotho	Open-pollinated, commonly grown in Lesotho
Segaolane	Faculty of Agriculture of the National University of Lesotho	ICRISAT variety widely grown in parts of southern Africa
IS18676	ARC-Grain Crops Institute, Potchefstroom, South Africa	Resistant check, inbred line
SA2541	ARC-Grain Crops Institute, Potchefstroom, South Africa	Performs well agronomically in Lesotho
NK283	ARC-Grain Crops Institute, Potchefstroom, South Africa	Commercial susceptible hybrid
SBR-1	ARC-Grain Crops Institute, Potchefstroom, South Africa	Grain Crops Institute resistant experimental hybrid
Zulu 1	ARC-Grain Crops Institute, Potchefstroom, South Africa	Variety local to Natal, South Africa, highly resistant
ISS	ARC-Grain Crops Institute, Potchefstroom, South Africa	Susceptible hybrid

Data were collected on the incidence of plants with dead heart symptoms, incidence of infested plants, level of internal plant damage, number of stalk borer individuals that colonized plants and grain yield.

The incidence of plants with dead hearts was assessed at 5 and 7 WAE. This was done by counting the number of plants with dead heart symptoms in the untreated sub-plot. Results were calculated as percentages of total plant population in each untreated sub-plot.

The incidence of infestation (percentage of all plants per plot with leaf or stem damage caused by stalk borers) was visually evaluated *in-situ* in the untreated sub-plot at fortnightly intervals, beginning from 4 WAE up to 20 WAE and again at harvest. Results were calculated as percentages of total plant population per untreated sub-plot.

In order to determine the level of internal plant damage (percentage damaged internodes) at harvest, fifteen plants were uprooted from each plot, split open vertically and the number of damaged internodes determined. Mean percentage damaged internodes per plant was then calculated for each untreated sub-plot.

The level of infestation (number of larvae, pupae and pupal cases) was determined from the same plants used for the assessment of internal plant damage. This was done by determining the total number of stalk borer individuals that had colonized plants in each untreated sub-plot.

Yield was determined from the same plants used for the evaluation of level of internal plant damage. For this purpose, all productive panicles in each sub-plot were harvested and the mass determined. Average yield per plot was determined for each entry. Yield of treated plants, sampled in the same manner as the untreated plants, was also determined for each entry in order to calculate yield loss. Yield loss in each entry was calculated as the difference in yield between insecticide-treated and untreated plants, expressed as a percentage of the yield of insecticide-treated plants. As *B. fusca* was the only important pest of sorghum at the study site, yield loss sustained by entries was attributed to damage by this stalk borer only.

Data obtained were subjected to analyses of variance. Differences between means were separated using Duncan's Multiple Range Test at P=0.05.

RESULTS AND DISCUSSION

No dead hearts were recorded during any of the two growing seasons. This was attributed mainly to the late onset as well as the low incidence of infestation, especially during the 1995/96 season. Dead heart formation occurs when infestation takes place at a young plant age, especially when the level of infestation is high (Alghali, 1985; MacFarlane, 1990).

The first evidence of plant damage was observed mostly behind flag leaf sheaths, from where young larvae bored into peduncles and eventually downwards into stems. This form of infestation is attributed to the late stage of development at which crops were infested. Similar observations were made by Alghali (1985) and MacFarlane (1990).

Due to the late onset (first damage symptoms were recorded at 14 WAE) and low incidence of infestation during the 1995/96 season, only the incidence of infestation (% infested plants) at harvest is presented (Fig. 6.1). This was higher during the 1996/97 season than in the 1995/96 season (Fig. 6.1). However, differences were not significant (P>0.05) among the entries during either season (LSD= 3.9, P= 0.5491 and LSD= 17.5, P= 0.3648 during the 1995/96 and 1996/97 seasons respectively). During 1996/97, when infestation was higher, the variety Segaolane, followed by the farmers' varieties Red Seqhobane and White Seqhobane, consistently sustained the highest incidence of *B. fusca* infestation throughout the season (Fig. 6.2). This indicates that these entries were highly susceptible to infestations, having had higher incidence of damage than even the hybrids ISS and NK283, both of which are known to be susceptible to stalk borers (Van den Berg, personal communication).

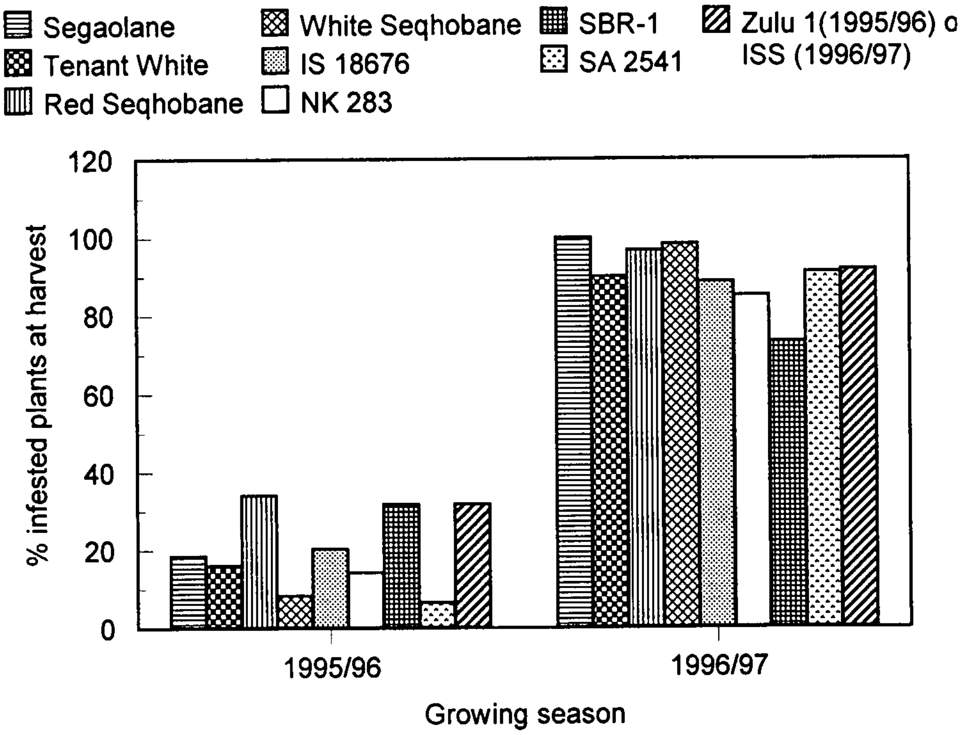

Fig. 6.1: Number of plants (%) infested by *Busseola fusca* at harvest in sorghum at Roma during the 1995/96 and 1996/97 growing seasons.

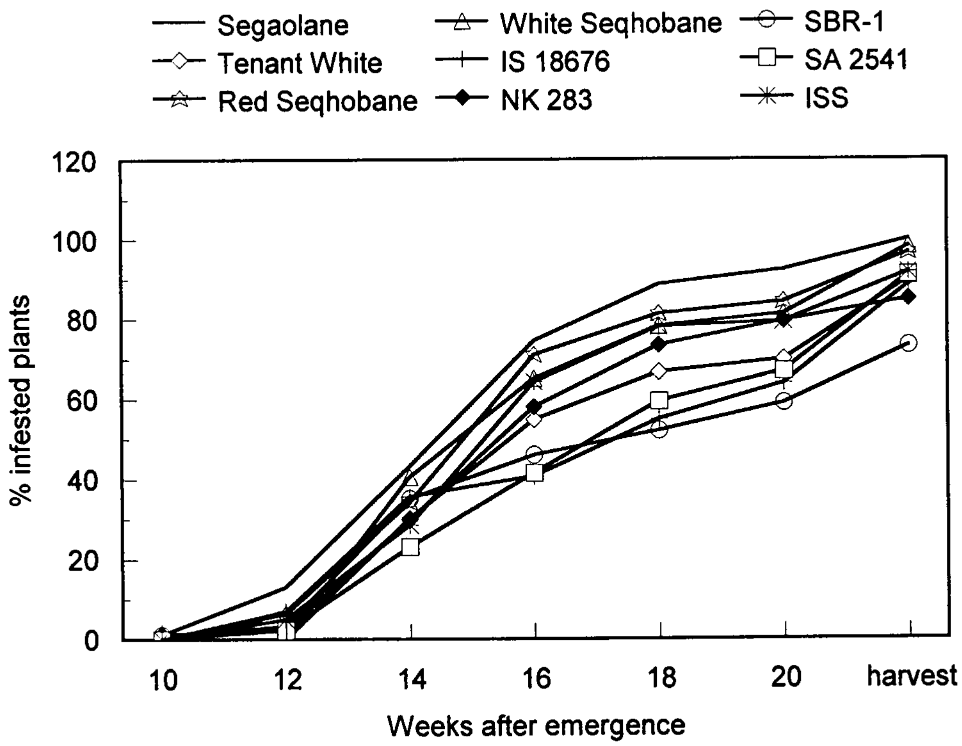

Fig. 6.2: Number of plants (%) infested by *Busseola fusca* in sorghum at Roma during the 1996/97 growing season.

The level of internal plant damage (percentage internodes damaged) was a reflection of the incidence of infestation during the two growing seasons. Thus, internal plant damage was very low during the 1995/96 season and higher during the 1996/97 season (Fig. 6.3). The varieties Red Seqhobane (1995/96) and Segaolane (1996/97) sustained higher levels of internal plant damage than the other entries (Fig. 6.3). This, together with the observation that Red Seqhobane and Segaolane also sustained high incidences of infestation (Fig. 6.1) further demonstrates their susceptibility to the stalk borers. No significant difference ($P>0.05$) in the level of internal plant damage was observed between entries during either season (LSD= 20.2, P= 0.4305 and LSD= 17.5, P= 0.3648 during the 1995/96 and 1996/97 seasons respectively).

The number of stalk borer individuals recovered from infested plants during the 1995/96 growing season was extremely low and only results for the 1996/97 season are presented (Fig. 6.4). Furthermore, it was observed that borer galleries in most infested plants did not contain larvae, pupae or pupal cases. It is not certain what happened to the stalk borer larvae that tunnelled these plants. However, it is possible that some of the larvae were destroyed by parasitoids and predators, as cocoons of the parasitoid, *Bracon sesamiae* (Braconidae), and dead individuals of the predatory ant, *Dorylus* sp., were observed in some of these borer tunnels. Van Rensburg *et al.* (1988) also reported the occurrence of maize plants which showed evidence of damage by *B. fusca*, but which had no larvae, pupae or pupal cases.

During the 1996/97 season, levels of infestation were relatively high (Fig. 6.4) and generally exhibited a pattern similar to the incidence of infestation at harvest (Fig. 6.1). Once again, the entry Segaolane hosted the highest number of stalk borer individuals, while the resistant

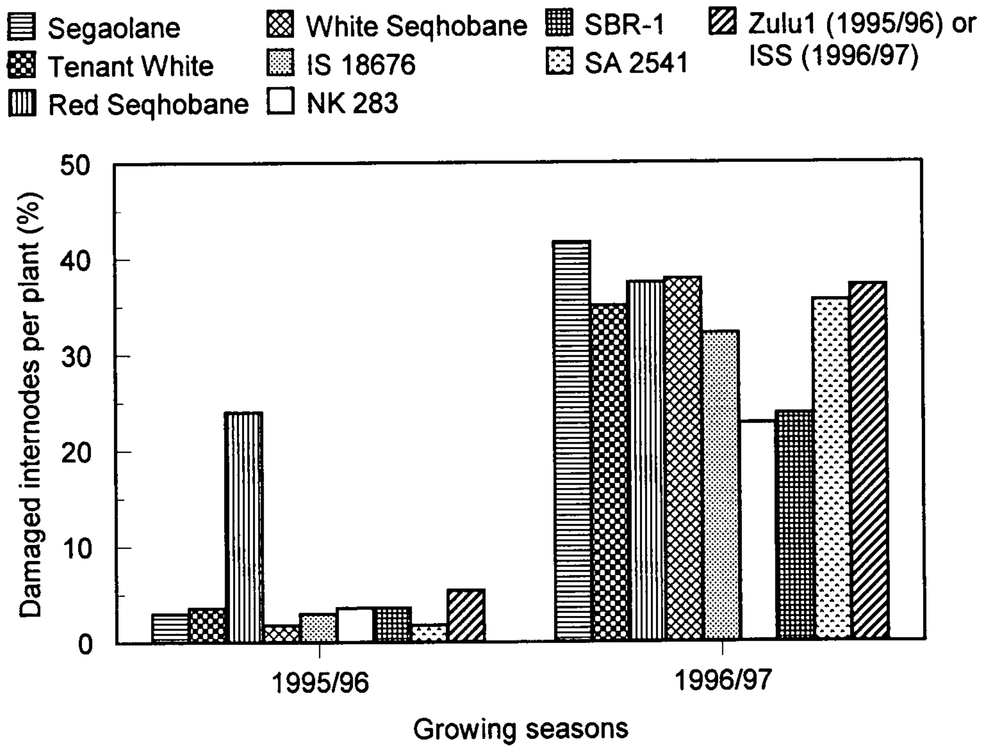

Fig. 6.3: Percentage damaged internodes in sorghum infested by *Busseola fusca* at Roma.

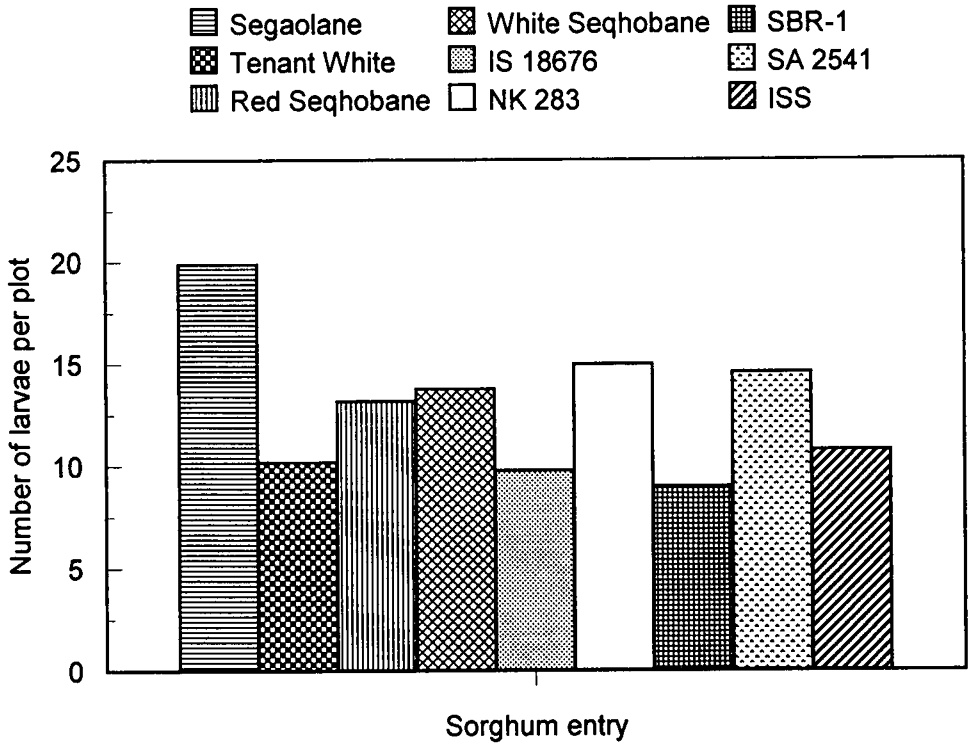

Fig. 6.4: Level of infestation by *Busseola fusca* in sorghum at Roma during the 1996/97 growing season.

hybrids IS18676 and SBR-1 had the lowest levels of infestation (Fig. 6.4). This further demonstrated the susceptibility of Segaolane to the stalk borers. Differences among the entries were, however, also not significant ($P>0.05$) ($LSD= 8.5$, $P= 0.2540$) despite the wide range.

Yield loss was very low for all entries during the 1995/96 season (Fig. 6.5) and differences were not significant ($LSD= 1.9$, $P=0.4056$). This was attributed to the late onset and low incidence of infestation during this season (Fig. 6.1). It has been reported that the greatest damage is sustained as a result of high stalk borer larval populations at an early plant growth stage (Alghali, 1985, 1986; MacFarlane, 1990). Although the incidence of infestation was higher during 1996/97 than in 1995/96, late onset of infestation during this season (Fig. 6.2) also meant that plants did not suffer damage during the early and most vulnerable stage of their development. This implies that susceptible entries were not affected as much as they might have been under optimum conditions of infestation. Therefore, the low levels of yield losses sustained by some entries during the 1996/97 season (Fig. 6.5), despite the high incidences of infestation, could be largely attributed to the late onset of infestation, and does not necessarily indicate resistance or tolerance.

Although it has been reported that attack in the upper part of plants after boot formation has little effect on grain mass (MacFarlane, 1990), some entries sustained substantial yield losses during 1996/97 (Fig. 6.5), despite the late onset of infestation (Fig. 6.2). Differences in yield loss among the entries were, however, not significant ($P>0.05$) during this season ($LSD= 26.6$, $P= 0.1578$). Numerically, the entry Segaolane, which recorded the highest incidence of infestation during the 1996/97 season (Fig. 6.2), recorded the highest yield loss during this season (Fig. 6.5). Also, the resistant inbred line, IS18676 (adapted to tropical

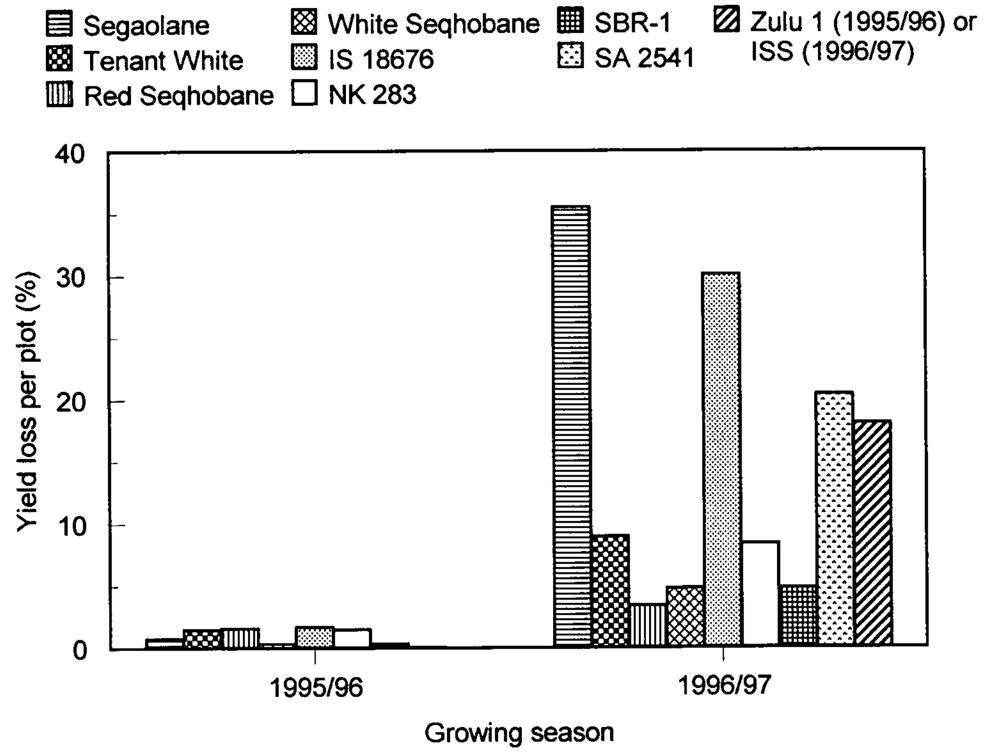

Fig. 6.5: Yield loss sustained by sorghum under natural infestation by *Busseola fusca* at Roma during the 1995/96 and 1996/97 growing seasons.

conditions) sustained the second highest yield loss (Fig. 6.5), despite sustaining one of the lowest incidences of infestation during the 1996/97 season (Fig. 6.2). Conversely, yield losses sustained by Red Seqhobane and White Seqhobane were among the lowest during the 1996/97 season (Fig. 6.5), despite the high incidences (Fig. 6.2) and high levels of internal plant damage (Fig. 6.3) sustained by these entries. Similarly, Tenant White produced a relatively high yield (Fig. 6.6) and sustained a low yield loss (Fig. 6.5) during the 1996/97 season, despite sustaining a high incidence of plant damage (Fig. 6.2) and high level of internal plant damage (Fig. 6.3). These varying relationships were probably attributable to differential reactions of sorghum varieties to stalk borer infestation at similar stages of crop development. It has been reported that some sorghum varieties are more tolerant to stalk borer attack during the early stages of crop development, while others are more tolerant during the later stages (Alghali, 1986; MacFarlane, 1990).

There were no significant differences (P>0.05) among entries in terms of yield of insecticide-treated plants (LSD= 45.4, P= 0.0953) during the 1995/96 season. Numerically, however, Red Seqhobane, followed by NK283, produced the highest yields, while IS18676 and Zulu 1 produced the lowest yields during this season (Fig. 6.6). The lack of significant difference (at P=0.05) in yield during this season, despite the wide range in yields (Fig. 6.6), was attributed to high variability observed among plots of similar entries, possibly due to local variations in soil conditions. Significant difference (P<0.05) in yields was observed during 1996/97. However, an early frost which prevented some entries from maturing during this season (1996/97), makes these comparisons unrepresentative of all the entries. The results are, however, representative of entries which were mature at the time of harvest, *i.e.* Tenant White, Red Seqhobane, SBR-1, White Seqhobane and SA2541. Among these, Tenant White produced a yield (Fig. 6.6) that was significantly higher (LSD= 21.5, P= 0.0002) than all other entries except Red Seqhobane and White Seqhobane.

According to Ntlou & Massey (1991), Tenant White is one of the high-yielding open-pollinated sorghum varieties grown in Lesotho. The finding that Tenant White sustained a relatively low yield loss, even during the 1996/97 season when infestations were high, seems to indicate that it has a relatively good potential where stalk borers are a problem. Such potential is desirable especially for the low-input subsistence level sorghum producers of Lesotho, who may not have access to stalk borer control inputs or to high yielding hybrid sorghums with their fastidious production demands. This is probably why Tenant White is an already popular variety in Lesotho (Ramakhula *et al.*, 1987).

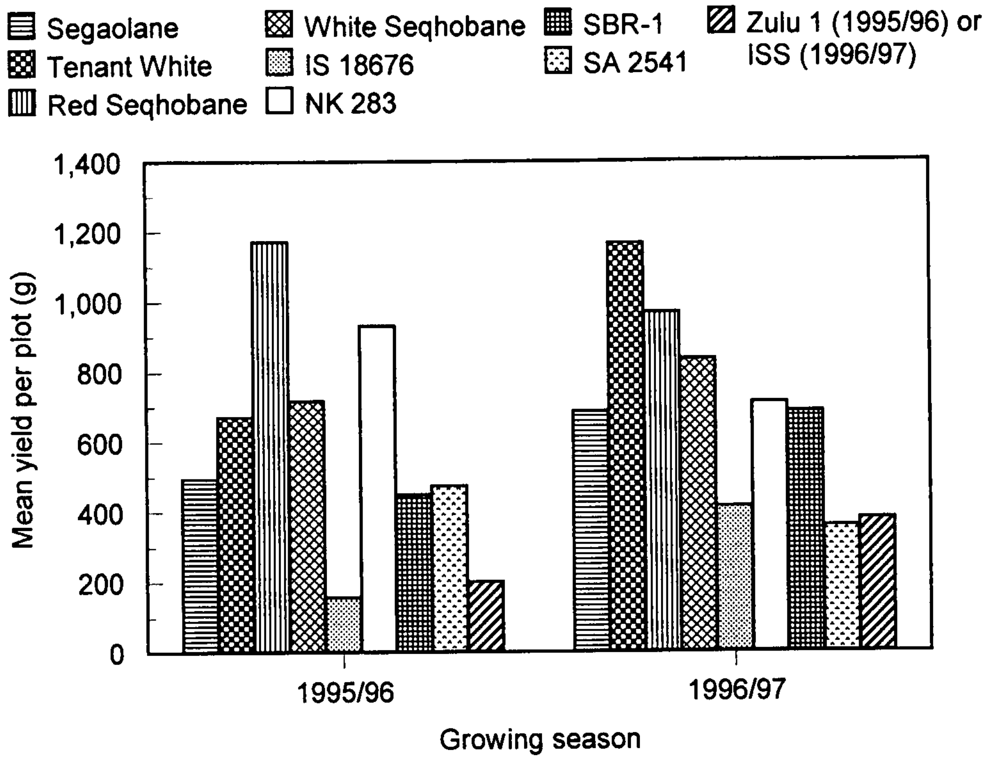

Fig. 6.6: Yield of insecticide-treated sorghum at Roma during the 1995/96 and 1996/97 growing seasons.

Due to the late onset of infestation observed during both the 1995/96 and 1996/97 growing seasons, the effect of stalk borer attack, which is most severe when plants are attacked early in their development, could not be fully assessed. Low incidence of infestation observed during the 1995/96 season also meant that plants were not challenged in such a way as to seriously affect their ultimate performance. Similar constraints associated with investigations under natural stalk borer infestation have been reported by Harris (1962) and Ajayi (1989). Nevertheless, results of this study have demonstrated, through observed yield losses during the 1996/97 season, that late infestation by stalk borers can lead to yield loss. Such yield loss occurs because larvae which feed on and tunnel in the peduncles and upper internodes may cause the formation of partial or complete chaffy heads, and panicle breakage (Harris, 1962; Alghali, 1985; Seshu Reddy, 1991).

CONCLUSION

This investigation demonstrated that natural infestations by stalk borers can lead to substantial yield losses in susceptible sorghum in this country. This should be taken into consideration by sorghum producers and researchers who are involved in selecting or breeding sorghum for this country.

Sorghum planting in Lesotho takes place over a period of several weeks, beginning in November and lasting till the end of December. Therefore, the late infestation observed in this study is not fully representative of the field situation. Depending on planting date, as well as on onset of infestation and magnitude of stalk borer populations, some sorghum plantings may sustain high levels of damage at an early age, which could lead to even higher yield losses than were observed in this investigation. Therefore, further investigation is recommended to assess the effect of early stalk borer infestations on the varieties and hybrids evaluated in this study, since sorghum varieties may react differently to infestations at early and late stages of crop development. Tenant White, which showed a relatively high yield potential and low yield loss may serve as a source of resistance in plant breeding.

CHAPTER 7

RESPONSE OF LOCAL SORGHUM VARIETIES OF LESOTHO TO ARTIFICIAL INFESTATION WITH THE SPOTTED STALK BORER, *CHILO PARTELLUS* (SWINHOE) (LEPIDOPTERA: PYRALIDAE).

ABSTRACT

Sorghum varieties (including those commonly grown in Lesotho) and hybrids were evaluated for resistance to *Chilo partellus* (Swinhoe) in one glasshouse and two field trails, through artificial infestation with newly hatched larvae. Yields of the varieties and hybrids, both in the presence and absence of *C. partellus* infestation, were assessed. Antibiosis was the main resistance mechanism determining the level of establishment of *C. partellus* larvae in sorghum plant whorls. The field trials showed that the sorghum varieties grown in Lesotho were susceptible to damage by *C. partellus*. Furthermore, the susceptible commercial sorghum hybrid NK283 generally yielded higher than the open-pollinated varieties under similar conditions of infestation, indicating the potential benefit of growing hybrid sorghum. The need for research to identify stalk borer resistant or tolerant non-hybrid sorghum with higher yield potentials than the existing ones for the benefit of Lesotho's resource-poor farmers is emphasised.

Key words: *Chilo partellus*, resistance, sorghum.

INTRODUCTION

The cultivation of sorghum in Lesotho is largely undertaken by small-scale farmers. Although very little of the sorghum produced locally enters the formal market (Brokken *et al.*, 1986), the crop is, after maize, the most important food grain produced in the country (Anon., 1994; Majoro, 1995).

Yield of sorghum on peasant farms in Lesotho is very low, with averages below 800 kg/ha in recent years (Anon., 1994), as compared to an annual average of 1738 kg/ha on commercial farms in neighbouring South Africa (Van den Berg, 1994). Yields of sorghum on communal farms in other parts of southern Africa are also low, with averages of 493 kg/ha in Zimbabwe (Mushonga & Rao, 1986) and 735 kg/ha in Swaziland (Rohrbach & Malaza, 1993). Similar low yields have also been reported in other parts of Africa, as well as in India (Alghali, 1985). Stalk borers constitute one of the major constraints in sorghum production in Africa and Asia (Harris, 1962; Young & Teetes, 1977; Ajayi, 1989; Seshu Reddy, 1990; Vogel *et al.*, 1993). Although the stalk borer, *Chilo partellus* (Swinhoe), has been reported to attack sorghum in Lesotho (Qhobela *et al.*, 1986), its pest status is largely uninvestigated.

Surveys carried out in Lesotho over two growing seasons showed that, presently, *C. partellus* is found only in parts of the central lowland areas, where it occurs in mixed populations with the maize stalk borer, *Busseola fusca* (Fuller) (Lepidoptera: Noctuidae) (see chapter 2). There is, however, the possibility that with time, *C. partellus* could adapt and increase its distribution to new areas. Such an adaptation by *C. partellus* has been reported in neighbouring South Africa (Bate *et al.*, 1991).

The aim of this study was to assess the status of resistance to *C. partellus* of local sorghum varieties grown in Lesotho, and compare resistance levels with those of sorghum hybrids and varieties (from outside Lesotho) with known resistance levels. Knowledge about the status of resistance of these local varieties will play an important role in predicting the possibility of *C. partellus* becoming a more widespread pest in Lesotho, as well as facilitate the recommendation of varieties in areas where the pest already occurs. Results of this study will also be useful in the planning of sorghum breeding programs for Lesotho.

MATERIAL AND METHODS

A study in a commercial glasshouse and one field trial were conducted at the ARC-Grain Crops Institute, Potchefstroom (26° 43′ S, 27° 6′ E), South Africa, during the 1996/97 growing season. The field trial was repeated during the 1997/98 growing season. For the glasshouse trial, ten sorghum varieties and hybrids (entries) (Table 7.1) were used. The experimental design was a randomized complete block with three replications. Each plot was a 2 m-row, with spacing of 1.0 m between rows and 0.15 m within rows. Only one plant per hill was allowed to establish.

At five weeks after emergence (WAE), each plant within a plot was artificially infested with *C. partellus* larvae. This was done by inoculating 10 neonate larvae into the whorls of plants, using a Bazooka mechanical dispenser (Wiseman *et al.*, 1980). In order to evaluate for larval non-preference and antibiosis resistance to *C. partellus* larvae, the number of surviving larvae and mass of larvae were determined on seven plants per plot, fourteen days after infestation (7 WAE). For this purpose, larvae were recovered from each of the plants

Table 7.1: Sorghum varieties and hybrids evaluated for resistance to *Chilo partellus* in a glasshouse trial during the 1996/97 growing season.

Sorghum variety/hybrid	Source	Comments
White Seqhobane	Moyeni (Quthing district)	Lesotho land race
White Seqhobane	Roma (Maseru district)	Lesotho land race
Red Seqhobane	Buasono (Berea district)	Lesotho land race
Tenant White	Faculty of Agriculture of the National University of Lesotho	From the Faculty's sorghum breeding program
Segaolane	Faculty of Agriculture of the National University of Lesotho	ICRISAT variety widely grown in southern Africa (from the Faculty's sorghum breeding program)
IS18676	ARC-Grain Crops Institute, Potchefstroom, South Africa	Resistant check, highly resistant line
SA2541	ARC-Grain Crops Institute, Potchefstroom, South Africa	Performs well agronomically in Lesotho
NK283	ARC-Grain Crops Institute, Potchefstroom, South Africa	Commercial susceptible hybrid
SBR-1	ARC-Grain Crops Institute, Potchefstroom, South Africa	Grain Crops Institute resistant experimental hybrid
Zulu 1	ARC-Grain Crops Institute, Potchefstroom, South Africa	Variety local to Natal, South Africa, high antibiosis resistance

by first excising the leaves at the base of the leaf sheath and then collecting all live larvae behind the sheaths and in the whorl. Thereafter, the plant was split open longitudinally and live larvae within the stem collected. The total number of live larvae recovered per plot was counted and their mass determined. The mean number of surviving larvae per plot and mean larval mass were then calculated for each entry.

The same 10 entries used in the glasshouse trial were also planted in the field. An additional entry, White Seqhobane, obtained from Buasono village in the Berea district of Lesotho, was included in this experiment. The experimental design was a randomized complete block with three replications. Each plot consisted of a single 7 m-row, with an inter-row and intra-row plant spacing of 2.0 m and 0.15 m respectively. At 4 WAE (mid-whorl stage), all plants in one half (3.5 m) of each plot were artificially infested with 10 neonate larvae of *C. partellus* using the same method described for the glasshouse trial. An insecticide mixture of endosulfan (35 % EC) and deltamethrin (2.5 % EC) was applied to the uninfested half of each plot at the rate of 7.5 ml/0.4 ml per 100 m row length, in order to control natural infestation. Insecticide was applied by means of a knapsack sprayer delivering 2.4 l of water per 100 m row length.

Data collected from the field trials were leaf-feeding rating, extent of stunting, number of panicles produced and grain yield. As a result of extensive bird damage during the 1996/97 season, yield was not evaluated.

Evaluation of leaf-feeding damage was done on a scale of 1 to 9, ten days after artificial inoculation. Entries were classified as resistant (rating of 1.0 to 3.9), intermediate (rating of 4.0 to 6.9), or susceptible (rating of 7.0 to 9.0) to leaf-feeding by first instar larvae. The extent of stunting was rated at crop maturity on a scale of 1 to 4, with 1= no stunting, 2 = slight stunting, 3= moderate stunting, and 4= severe stunting. The number of panicles produced was also determined at crop maturity. The extent of reduction in the number of productive panicles was calculated in order to assess for tolerance and recovery resistance. This was done by determining the difference between the number of productive panicles produced by the uninfested plants in a plot and those produced by the infested plants in the same plot, calculated as a percentage of the number of panicles produced by the uninfested plants. Yield of uninfested and infested plants in each plot were determined separately at harvest. Yield loss was taken as the difference in yield between plants in the uninfested and infested halves of each plot, calculated as a percentage of the yield of the uninfested plants.

Data were subjected to analyses of variance, and differences between means separated using Duncan's Multiple Range Test at P=0.05.

RESULTS AND DISCUSSION

In the glasshouse trial (Table 7.2), the resistant check IS18676 had the lowest number of larvae per plot, while Tenant White had the highest larval survival, even superior to the commercial susceptible hybrid NK283. However, the observation that there were no significant differences (P>0.05) in the rate of larval survival (Table 7.2) suggests that larval non-preference (antixenosis) did not play a major role in determining the ultimate levels of infestation on the different entries. Furthermore, the observation that even the resistant check IS18676, had an average of 4.3 larvae per plant (30.3 larvae per 7 plants) after two weeks of feeding (Table 7.2) seems to support this point, since only two to four larvae per plant are usually maintained, regardless of the initial number that colonize a plant (Van Rensburg & Van Hamburg, 1975; Van Hamburg, 1980). The observation that only two to four larvae per plant are ultimately maintained has been attributed to increased migration and mortality, possibly due to some mechanism which prevents overcrowding of larvae in stems (Van Rensburg & Van Hamburg, 1975).

In this experiment, larvae were placed directly at their feeding sites in the leaf whorls. This might have excluded factors (antibiotic or antixenotic) possibly present in some entries, which could otherwise have been detrimental to the successful upward migration of first instar larvae into plant whorls, thereby enabling more larvae to establish successfully. This possibility was also reported by Woodhead & Taneja (1987). Among factors which reduce the rate of larval establishment following hatching on some sorghum genotypes are plant physical and chemical characteristics which hamper upward migration into leaf whorls after hatching. These include erect leaf orientation on stems (Woodhead & Taneja, 1987), large internodal length, pronounced ligular hairs which may trap young larvae (Taneja & Woodhead, 1989), and surface wax and its chemical composition (Bernays *et al.*, 1983; Taneja & Woodhead, 1989). Therefore, it is possible that more larvae survived on some entries than would otherwise have happened, had *C. partellus* larvae been placed on the lower parts of the stems and left to climb up to the whorls.

Table 7.2: Number and mass of *Chilo partellus* larvae recovered 14 days after artificial infestation of sorghum varieties and hybrids, in a glasshouse trial (1996/97 season).

Sorghum variety/hybrid	Mean number of larvae per plot	Mean larval mass (g)
Zulu 1	44.7	0.0258 a
White Seqhobane (Roma)	44.3	0.0280 ab
SBR-1	46.7	0.0343 abc
NK283	38.7	0.0348 abc
IS18676	30.3	0.0401 bcd
White Seqhobane (Moyeni)	36.3	0.0452 cd
SA2541	47.3	0.0482 d
Segaolane	43.7	0.0484 d
Tenant White	59.7	0.0499 d
Red Seqhobane	43.7	0.0519 d
F-value	1.219	5.164
P-value	0.3427	0.0015

Means within the same column followed by the same letter are not significantly different at P=0.05 (Duncan's Multiple Range Test).

With regard to mean larval mass (Table 7.2), there were significant differences ($P<0.05$) among some of the entries. Zulu 1 had the lowest mean larval mass of all entries, and was significantly lower than even IS18676 which is known to have a high level of antibiosis resistance (Van den Berg, 1995). This result confirms the presence of antibiosis resistance in Zulu 1 (Van den Berg, personal communication). According to Saxena (1985) and Smith (1989), antibiosis resistance mechanism in plants may involve factors which may, among other things, lead to reduced body mass. Mean larval mass on Tenant White, Segaolane, Red Seqhobane and White Seqhobane (Moyeni) were all statistically similar but significantly higher ($P<0.05$) than that of the commercial susceptible check, NK283 (Table 7.2). This indicated that these Lesotho varieties were highly susceptible to *C. partellus* larvae.

The glasshouse study indicated that antibiosis, and not antixenosis, was the main resistance mechanism affecting *C. partellus* larvae soon after infestation. Significant differences were observed in larval mass gain over the 14 day feeding period (Table 7.2). Antibiosis has previously been reported as the main resistance mechanism against *C. partellus* larvae in sorghum (Agrawal *et al.*, 1990; Sharma, 1993). This finding is important because, although larval antixenosis does reduce larval establishment on a host plant, it is the level of antibiosis that will determine the ultimate level of infestation (Sharma & Chatterji, 1971). According to Verma *et al.* (1992), a high level of antibiosis resistance during early vegetative stages of plant growth is beneficial in reducing the injuriousness of early infestations.

Non-suitability of a plant as a host to an insect, such as that manifested in low mass gain, does not necessarily mean that the insect is not causing damage to the plant. This is because insect response such as reduced body mass may simply be due to malnourishment. According to Smith (1989), a plant may lack adequate quantities of basic nutrients required by the insect, or it may contain high concentrations of some structural plant substances, such as lignin or silica, that reduce insect digestion. As such, the low mass gain observed on Zulu 1 (Table 7.2) does not necessarily mean that this entry suffered less physical damage than the rest of the entries. Therefore, plant response to insect damage should also be evaluated when assessing the resistance status of a genotype.

Leaf-feeding damage ratings indicated varieties and hybrids to be intermediate to susceptible to leaf feeding (Tables 7.3 & 7.4). However, SBR-1 was rated as resistant during the 1996/97 season (Table 7.3). Leaf-feeding damage was slightly higher during the 1997/98 season than during 1996/97. This probably indicates a general increase in the susceptibility of plants to leaf damage during the 1997/98 season. However, most entries were still rated in the same category during both growing seasons, although significant changes were observed in the ratings of some entries. For instance, whereas SBR-1 and NK283 were rated resistant and intermediate to foliar damage respectively during the 1996/97 season (Table 7.3), they were both rated susceptible during 1997/98 (Table 7.4). Conversely, Red Seqhobane was rated susceptible during the 1996/97 season (Table 7.3), but was rated as intermediate during 1997/98 (Table 7.4). The observed seasonal variation in resistance levels was possibly due to seasonal changes in environmental conditions, since the level of resistance in a plant is not only dependent on its genetic make-up, but also on environmental factors (Tingey & Singh, 1980).

The narrow range of leaf damage ratings among the entries (except SBR-1) during both seasons indicated a generally low level of leaf-feeding resistance in these sorghum varieties and hybrids.

With regard to extent of stunting, most entries exhibited slight (1.0 to 1.9) to moderate (2.0 to 2.9) stunting. Only the commercial susceptible hybrid NK283 and Red Seqhobane exhibited severe stunting (3.0 to 4.0) (Table 7.3). This further confirmed the moderate

Table 7.3: Leaf-feeding damage, stunting rating and percentage reduction in the number of productive panicles in sorghum artificially infested with *Chilo partellus* larvae in a field trial during the 1996/97 growing season.

Sorghum variety/hybrid	Leaf-feeding rating	Stunting rating	% reduction in productive panicles
White Seqhobane (Moyeni)	7.0	2.0	55.0 a
NK283	5.3	3.7	42.9 ab
SA2541	6.3	1.3	42.1 ab
Red Seqhobane	7.0	3.0	39.7 abc
White Seqhobane (Roma)	6.0	2.3	37.9 abc
White Seqhobane (Buasono)	6.0	1.7	34.9 abcd
Segaolane	6.0	2.0	28.7 bcd
IS18676	6.0	1.3	25.8 bcd
Zulu 1	5.3	1.8	22.9 bcd
Tenant White	6.3	2.0	13.9 cd
SBR-1	3.8	1.3	11.0 d
F-value	-	-	2.98
P-value	-	-	0.0278

Means within a column followed by the same letter are not significantly different at P=0.05 (Duncan's Multiple Range Test).

Table 7.4: Leaf-feeding damage, yield and yield loss of sorghum artificially infested with *Chilo partellus* larvae in a field trial during the 1997/98 growing season.

Sorghum variety/hybrid	Leaf-feeding rating	Yield per plot (g)		% Yield loss per plot
		Uninfested	Infested	
Segaolane	6.7	1225.0	336.0	72.6 c
SBR-1	7.0	836.0	773.0	8.2 a
Red Seqhobane	6.0	682.5	361.0	47.6 bc
White Seqhobane (Buasono)	6.3	718.0	511.0	23.7 ab
NK283	7.0	1226.3	1004.7	17.9 a
White Seqhobane (Moyeni)	6.7	964.3	736.7	19.0 a
Zulu 1	6.7	484.5	423.5	14.5 a
Tenant White	7.0	686.3	597.3	12.8 a
White Seqhobane (Roma)	6.7	1004.0	862.5	14.6 a
IS18676	5.7	785.0	754.0	3.9 a
SA2541	6.3	678.0	654.0	3.5 a
F-value	-	1.370	2.146	3.369
P-value	-	0.3345	0.1475	0.0491

Means within a column followed by the same letter are not significantly different at P=0.05 (Duncan's Multiple Range Test).

resistance observed in IS18676, SBR-1 and Zulu 1, in terms of larval survival, larval mean mass (Table 7.2) and leaf-feeding damage respectively (Table 7.3). It also confirmed the susceptibility of Red Seqhobane which showed high larval mass gain (Table 7.2) and high leaf-feeding damage (Table 7.3). However, NK283 which had a relatively low mean larval mass (Table 7.2) and leaf-feeding damage was very susceptible to stunting (Table 7.3). This observation further indicated that, although a host plant may not provide adequate nourishment for an insect, the host may still suffer damage.

Significant differences were observed in the extent of reduction in number of productive panicles evaluated during the 1996/97 season (Table 7.3). The experimental resistant hybrid SBR-1, sustained the lowest reduction in panicle numbers. This result further confirmed the resistance qualities earlier observed in SBR-1 (Table 7.2). The White Seqhobane (Moyeni) recorded the highest reduction (higher than the susceptible hybrid NK283) but was only significantly higher ($P<0.05$) than Segaolane, IS18676, Zulu 1, Tenant White and SBR-1 (Table 7.3).

Of all the Lesotho entries, Tenant White exhibited the least susceptibility to reduction in the number of productive panicles, being the only entry which had a lower reduction than the resistant check IS18676. Tenant White was also the only Lesotho entry which sustained a significantly lower ($P<0.05$) reduction than the commercial susceptible hybrid NK283 (Table 7.3). This was despite the observation that Tenant White recorded the highest number of surviving larvae, second highest mean larval mass (Table 7.2), and intermediate leaf-feeding and stunting ratings (Table 7.3). It has been reported that some sorghum varieties are capable of producing good yields despite high levels of stalk borer infestation (tolerance), while others are capable of compensating for damage through increased tiller or branch yield (recovery) (Dabroswki & Kidiavai, 1983; Van den Berg *et al.*, 1991, 1994b). Since the extent of reduction in the number of productive panicles produced is an indication of the level of tolerance to damage, it can be concluded that Tenant White exhibited the highest level of tolerance to damage by *C. partellus* larvae.

Since the formation of additional tillers due to stem damage by stalk borer larvae is an indication of recovery resistance (Singh & Rana, 1989), then no recovery resistance was observed during this trial. This is because no entry produced more productive panicles as a result of *C. partellus* infestation (Table 7.3). Therefore, tolerance seems to have been the major factor limiting reductions in productive panicles in this study. This is in agreement with reports by Pathak (1985) and Agrawal *et al.* (1990), that tolerance is one of the main resistance mechanisms against *C. partellus*. This observation serves to emphasise the need to distinguish between tolerance and recovery resistance as was indicated by Van den Berg (1994).

Significant differences in yield loss were observed between entries (Table 7.4). Segaolane sustained a significantly higher ($P<0.05$) yield loss than all other entries in the trial, except Red Seqhobane. This observation confirmed the susceptibility of Red Seqhobane, which was manifested in its low larval antibiosis (Table 7.2), high susceptibility to stunting (Table 7.3) and intermediate to susceptible leaf-feeding ratings (Tables 7.3 & 7.4). Red Seqhobane also sustained one of the highest reductions in the number of panicles produced under *C. partellus* infestation (Table 7.3). Tenant White sustained the lowest yield loss of all the Lesotho entries, although differences were not significant ($P>0.05$) (Table 7.4).

In terms of yield of uninfested plants, NK283 and Segaolane recorded the highest yields while Zulu 1 recorded the lowest yield (Table 7.4). Yield differences were, however, not statistically significant ($P>0.05$). Although Tenant White has been reported to be one of the high yielding open-pollinated varieties grown in Lesotho (Ntlou & Massey, 1990), it showed a low yield potential in this trial (Table 7.4). White Seqhobane (Roma) yielded higher than most of the Lesotho entries, although this difference was not significant (P>0.05).

There were no significant differences (P>0.05) in the yield of entries under infestation by *C. partellus*. Numerically, however, the susceptible commercial hybrid, NK283, yielded higher than most of the Lesotho entries (Table 7.4). The infested NK283 even yielded higher than most uninfested non-hybrids (Table 7.4). This indicated that the yield potentials of the Lesotho sorghum entries were generally low. Therefore, and although yield loss sustained by NK283 was similar to those of some non-hybrids, it was still considered superior due to the higher yield potential it exhibited. NK283 yielded moderately and sustained a relatively low yield loss under natural *B. fusca* infestation at Roma (see chapter 6).

Simple correlation analyses were conducted on results of the 1996/97 trial, in order to determine the relationship between leaf-feeding rating and percentage reduction in numbers of productive panicles ($r = 0.39$, $P = 0.044$), and between stunting rating and percentage reduction in numbers of productive panicles, ($r = 0.66$, $P < 0.0001$). These results show that both relationships were positive and significant, although the extent of stunting had a greater effect on the number of productive panicles produced by infested plants than did the extent of leaf-feeding. A similar analysis was conducted on the extent of leaf-feeding damage and yield loss during 1997/98 ($r = -0.69$, $P=0.001$). These significant relationships indicate that the extent of stunting and leaf-feeding damage in a sorghum variety/hybrid may be indicators of the extent of reduction in numbers of productive panicles and yield loss that would be sustained. This finding is contrary to the report by Starks & Doggett (1970), who referred to leaf-feeding rating as a poor indicator of expected grain yield, and by Leuschner (1989) who indicated that leaf-feeding rating has very little value in stem borer resistance screening.

This study also demonstrated the importance of employing several parameters for evaluating the status of resistance in sorghum genotypes, since a variety may manifest resistance to a particular form of damage and yet react differently to another. For instance, whereas SA2541 exhibited resistance to stunting due to *C. partellus* infestation, it manifested intermediate susceptibility to leaf feeding (Table 7.3). Similarly, the significantly higher level of larval antibiosis resistance observed in White Seqhobane (Roma), as compared to Tenant White (Table 7.2), did not prevent it from suffering a higher reduction in productive panicles than the latter (Table 7.3). According to Van den Berg *et al.* (1994b), resistance screening has generally been based on the evaluation of physical plant damage caused by insect feeding, or on the effects of host plants on insect biology. In practical terms, it might be more profitable for a farmer to grow a susceptible variety which has a high yield potential than a resistant one which has a much lower yield potential under similar conditions.

CONCLUSION

The susceptibility to *C. partellus* and the generally low yield potentials exhibited by the Lesotho sorghum varieties evaluated in this trial possibly indicate that sorghum productivity in parts of the lowland areas of the country can be seriously jeopardised. Therefore, there is a need for research to identify resistant or tolerant sorghum varieties with higher yield potentials than the existing ones under Lesotho conditions and which will be acceptable to farmers in this country. Non-hybrid resistant or tolerant sorghum varieties will be of particular benefit to resource-poor farmers who may not be able to purchase hybrid seeds annually.

The observation that the commercial susceptible hybrid sorghum, NK283 yielded higher than the non-hybrids under similar conditions of *C. partellus* infestation indicates that Lesotho's farmers could benefit from growing such hybrid sorghum, even in areas where this stalk borer occurs. Therefore, extension is needed to make farmers more aware of the potential benefits of such hybrid sorghum.

CHAPTER 8

A SURVEY OF FARM MANAGEMENT PRACTICES AND FARMERS' PERCEPTIONS OF STALK BORERS OF MAIZE AND SORGHUM IN LESOTHO.

ABSTRACT

A survey questionnaire and field studies/surveys were employed in order to gain an insight into the perceptions of Lesotho's farmers with regard to insect pests of maize and sorghum. The study also aimed to relate common maize and sorghum farm management practices to the pest status of stalk borers. Results indicated that farmers generally regard stalk borers as important pests which sometimes need to be controlled. However, most farmers never attempt to take control measures, with most citing lack of resources as the reason. Most farmers who do control stalk borers use commercial insecticides. The study also revealed that maize and sorghum farm management practices were not deliberately aimed at management of pests. Field studies/surveys showed that stalk borers survive the winter season as diapause larvae inside maize and sorghum residues. The practice of de-tasselling maize had no effect on the number of borer larvae present in plants at the end of the season. The need for research into alternative, non-chemical stalk borer management practices and for extension to raise farmer awareness on such practices is noted.

Key words: Farmers' perceptions, management practices, stalk borers.

INTRODUCTION

Agriculture directly supports the livelihood of over 55 % of Lesotho's population, and is a key source of employment which is estimated to engage over 60 % of the country's labour force (Anon., 1995). The agricultural sector is dominated by small-scale, subsistence-oriented farmers, whose average arable land holding stood at only 4.7 hectares per household at the end of the 1980s. It is conceivable that this figure has decreased substantially since then, as the country's total arable land has declined from 13 % in 1986 (Anon., 1986) to only about 9 % in 1995 (Anon., 1995). Furthermore, the country's population has increased from about 1.5 million in 1986 (Anon., 1986) to an estimated 2.1 million in 1995 (Anon., 1995).

Maize and sorghum, which constitute the country's staple food grains, dominate the crop production sector, but crop yields are often poor and erratic. Inefficient methods of crop husbandry, such as untimely planting, poor land preparation and inadequate weed control are among the factors responsible for the low crop productivity (Anon., 1995). In addition, however, the stalk borers *Busseola fusca* (Fuller) (Lepidoptera: Noctuidae) and *Chilo partellus* (Swinhoe) (Lepidoptera: Pyralidae) have been reported as important pests of maize and sorghum in Lesotho (Qhobela *et al.*, 1986). In view of declining arable land resources and of increasing human population in Lesotho, there is a need to address these causes of low crop productivity, in order to increase food production on the available land.

Apart from pest control measures *per se*, certain routine farm management practices may alleviate or exacerbate the pest status of stalk borers (Harris, 1962; Adesiyun & Ajayi, 1980; Van Rensburg *et al.*, 1988b; Van den Berg *et al.*, 1990, 1994b). As such, some farm management practices commonly employed by maize and sorghum farmers in Lesotho could impact significantly on the status of stalk borer infestations.

The aim of this study was to determine farmers' perception of stalk borers as pests of maize and sorghum in Lesotho. The study was also aimed at documenting some of the common farm management practices employed by farmers and to assess possible implications of these practices on the pest status of stalk borers. It is well-known that only when the existing management practices are known and understood, can researchers take effective steps aimed at improving, encouraging or changing the practices, with the overall aim of improving crop productivity. Furthermore, it is only by knowing what the farmers are already doing that researchers can assess the progress of their own research efforts.

In general, this study sought to provide an overview of the pest status of stalk borers in Lesotho, especially from the farmers' perspective, and of existing approaches to management of the pest problem at the subsistence farmers' level. This investigation represents the first study documenting small-scale farm management practices in relation to the problem of stalk borers in Lesotho.

MATERIAL AND METHODS

The investigation was conducted through the use of a survey questionnaire and field studies/surveys.

A. Survey questionnaire:

Copies of a survey questionnaire (Appendix A) were served to small-scale farmers in six of the ten districts of Lesotho during 1997. These were the districts of Leribe, Berea, Maseru, Mafeteng, Mohaleshoek (in the lowlands - 1520 m to 1830 m above sea level) (Anon., 1981) and Thaba-Tseka (in the mountains - over 2130 m above sea level) (Anon., 1981). Maize and sorghum production in Lesotho largely takes place in the lowlands (Anon., 1981, 1995), hence the choice of more districts in the lowlands than in the mountains. In each district, the questionnaire was served to 20 randomly selected farmers (men and women) in five villages, also selected at random. The questionnaire was read to individual farmers and their responses recorded. Because many of the farmers could not read or speak the English language, the services of a local, Sesotho-speaking person was engaged.

Questions were designed in such a manner as to elicit answers to such questions as farmers' perceptions of field pests of maize and sorghum in general and of stalk borers in particular, as well as common farm practices relevant to the stalk borer situation. Such questions included choice of crop varieties by farmers, cropping mixtures, tillage practices, crop residue disposal practices, and stalk borer control methods employed. Farmers were also asked whether they practised 'detasselling' of maize plants ('ho hela chakatsa', in the Sesotho language) and why they practise it. De-tasselling, which is a term used loosely here, involves the cutting off of the upper half of maize plants at maturity, usually just one internode above the one bearing the uppermost ear. During this exercise, the plant is usually still green and ears are in the hard-dough stage.

For each question, percentage of farmers who gave similar responses was calculated for each district. Those who did not respond were excluded from the percentages. In instances where a farmer indicated more than one reason, method or option, with regard to a given question, percentages were still calculated separately for each group of similar responses. As a result, percentages of responses to a given question within a district did not always add up to 100 %. Percentages of farmers in all six districts surveyed and who gave similar responses to a question were also calculated based on the total number of farmers who responded to each question. This was done in order to assess general trends among farmers in the country.

B. Field studies/surveys:

The field studies/surveys comprised of two main investigations. One was aimed at assessing the role of maize/sorghum stalks and stubble in the inter-seasonal survival of stalk borer larvae, while the other was aimed at assessing the impact of de-tasselling of maize on the populations of stalk borers at the end of the growing season.

i) Survival of stalk borers in maize and sorghum crop residues:

This study was considered to be of relevance because it has been reported elsewhere that stalks and stubble of maize and sorghum are important in sustaining carry-over populations of stalk borers (Harris, 1962; Van Rensburg & Van Hamburg, 1975; Kfir, 1990c). However, the relative importance of stalks and stubble varies between localities. Thus, whereas most over-wintering larvae occur above ground in stalks in Nigeria (Harris, 1962; MacFarlane, 1990), most hibernating larvae occur at the base of the stubble below soil level in South Africa (Kfir, 1990c) and East Africa (Unnithan & Seshu Reddy, 1989).

Field studies, aimed at assessing the survival of stalk borers across the winter months in the stalks and stubble of maize and sorghum in Lesotho were conducted at harvest (June) and in spring (September/October) during 1995, 1996 and 1997. Studies on maize were mainly carried out on an experimental plot at Roma (29° 27′ S, 27° 44′ E), while those on sorghum were conducted mainly at the SWACAP (Soil and Water Conservation and Agroforestry Programme) station at Siloe, approximately 15 km south of Mafeteng (29° 43′ S, 27° 14′ E).

In order to assess larval survival in maize stubble (part of plant which remains in the soil after most of the above ground portion of plant is cut), stubble was removed from the ground within a field during October. From among these, 50 infested pieces were obtained, dissected and the number of stubble harbouring live larvae and the total number of live larvae were determined. Similar data were obtained from 50 infested stalks (above ground portion of plants) of maize, which were cut and stacked upright outdoors after harvest. The number of infested stubble or stalks harbouring live larvae were expressed as percentages of the total number of infested stubble or stalks sampled. Similar procedures were carried out with sorghum stubble and stalks during September (before *C. partellus* moths emerged). The same procedures were repeated at each locality during the following September/October.

Surveys were also conducted at other localities during September/October in 1996 and 1997, in order to assess the level of survival of stalk borers in maize and sorghum stalks and stubble during the winter period. Except at Thaba-Tseka, which is located in the mountains where winters are much colder (Anon., 1986), other areas in this study experience milder winters with only occasional snow falls.

ii) De-tasselling of maize plants:

The practice of de-tasselling of maize plants was considered worth investigating because it is widely practised in Lesotho. The study was conducted at Roma during the 1995/96 and 1996/97 growing seasons. During each season, maize (PAN6363) was planted during the second week of December. There were 12 rows of plants, each row being 40 m long. Rows were 1 m apart and plants were 0.25 m apart within rows. Weed control was done mechanically and no insecticide was applied at any stage. Plants were subject to natural infestation by stalk borers. At 18 weeks after emergence, when ears were already mature but still green, plants in four of the central eight rows were de-tasselled, while the other four rows were left intact. Rows containing de-tasselled plants alternated with those with intact plants. Both de-tasselled and non-de-tasselled plants were left to dry in the field.

At harvest, 40 plants showing external symptoms of borer damage were obtained from each row and dissected, each row representing a replicate. The number of live larvae present was recorded separately for each row. A simple t-test was calculated to determine whether there was a significant difference between the mean number of live larvae in the de-tasselled and the non-de-tasselled plants.

RESULTS AND DISCUSSION

1. Farmers' perception of stalk borers:

The survey showed that most farmers considered stalk borers as the most important insect pests of maize and sorghum in Lesotho, while cutworms were considered to be the second most important pests (Tables 8.1 & 8.2). Some farmers indicated more than one pest group as being equally important. Generally, the majority of farmers regarded stalk borers as important pests which sometimes needed to be controlled (Table 8.3).

Table 8.1: Percentage of farmers in six districts of Lesotho indicating various insect species as economically important pests of <u>**maize**</u> crops.

Pest category	Percentages of farmers per district*						
	Leribe	Berea	Maseru	Mafeteng	Mohaleshoek	Thaba-Tseka	All districts
Cutworms[1]	0.0	20.0	40.0	20.0	47.4	26.7	28.2
African bollworm[2]	0.0	0.0	0.0	10.0	0.0	0.0	1.9
Stalk borers	100	70.0	60.0	90.0	52.6	73.3	71.8
Others[3]	0.0	10.0	5.0	0.0	0.0	0.0	2.9

[1] *Agrotis* sp. [2] *Helicoverpa armigera.* [3] Spotted maize beetle (*Astylus* sp.)

* Some respondents indicated more than one option (pest category) as equally important, thereby resulting in total percentages exceeding 100 % in some districts. This also applies to percentages in Tables 8.2, 8.4, 8.7 to 8.10, 8.12 & 8.20.

Table 8.2: Percentage of farmers in six districts of Lesotho indicating various insect species as economically important pests of <u>**sorghum**</u> crops.

Pest category	Percentages of farmers per district*						
	Leribe	Berea	Maseru	Mafeteng	Mohaleshoek	Thaba-Tseka	All districts
Cutworms	100	100	100	40.0	0.0	25.0	43.4
Aphids	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Stalk borers	0.0	0.0	50.0	40.0	100	75.0	56.5
Others**	0.0	0.0	0.0	20.0	0.0	0.0	4.3

* Some respondents indicated more than one pest category. **Birds.

Table 8.3: Percentage of farmers in six districts of Lesotho who consider stalk borers of <u>**maize**</u> and <u>**sorghum**</u> as important pests which need to be controlled.

Need control	Percentages of farmers per district						
	Leribe	Berea	Maseru	Mafeteng	Mohaleshoek	Thaba-Tseka	All districts
Yes	100	100	85.0	100	85.0	80.0	88.9
No	0.0	0.0	15.0	0.0	15.0	20.0	11.1

2. <u>Farm management practices:</u>

a) Choice of crop varieties

The survey showed that most Lesotho farmers grow maize and sorghum varieties which are readily available to them (Table 8.4). These are local varieties whose seeds can be saved for the following season's planting. However, a sizeable proportion of farmers indicated that they selected varieties which had good yield potentials. Some farmers gave more than one reason for planting a given variety. Pest resistance was, however, not indicated as a reason for choice of maize or sorghum variety.

Table 8.4: Reasons advanced for choice of maize and sorghum varieties by farmers in six districts of Lesotho.

District of respondents	Reason provided for choice of variety *				
	Yield Potential (%)	Drought resistance (%)	Pest resistance (%)	Preference as food item (%)	Only varieties available (%)
Leribe	70.0	0.0	0.0	10.0	20.0
Berea	60.0	0.0	0.0	20.0	20.0
Maseru	10.0	0.0	0.0	5.0	85.0
Mafeteng	60.0	0.0	0.0	30.0	30.0
Mohaleshoek	26.3	0.0	0.0	21.1	52.6
Thaba-Tseka	20.0	0.0	0.0	10.0	70.0
All districts	39.5	0.0	0.0	16.8	47.1

* Some respondents indicated more than one reason.

Pest problems may be alleviated through careful selection of planting material. For example, the use of resistant varieties can be an effective way of managing stalk borers (Alghali, 1985; Sharma, 1985; Van den Berg *et al.*, 1994b). Similarly useful is the use of short-season varieties, which ensures that plants pass through their most vulnerable stages of development before the pest population builds up (Van Rensburg *et al.*, 1988c; Seshu Reddy, 1990). Such cultural practices could be exploited by Lesotho's farmers. However, informal discussions with farmers during the course of this study revealed that the cost of purchasing improved seeds annually, together with the high fertilizer requirements by hybrids *vis-à-vis* the local varieties, are major obstacles in trying to promote improved varieties. The tendency for Lesotho's farmers to grow local varieties and the fact that this practice may be difficult to change, was also reported by Pomela *et al.* (1988). Therefore, the identification of high-yielding, open-pollinated varieties, the seeds of which can be saved for planting and which have some pest resistance qualities, may encourage farmers to accept new varieties.

b) Multi-cropping

Multi-cropping has long been practised by small-scale farmers in many parts of the world (Van Schoubroeck *et al.*, 1989). This study showed that Lesotho's farmers are no exception to this practice, although most indicated they did not usually intercrop maize (Table 8.5) or sorghum with other crops (Table 8.6). Results further indicated that farmers tended to intercrop maize rather than sorghum. Among those who practise intercropping, beans, pumpkins and potatoes were often used as intercrops. This study also showed that maize/beans (*Phaseolus* spp.) was the most common intercropping combination employed, followed by maize/pumpkins (Table 8.7). The most common cropping arrangement as indicated by the respondents is a situation where the crops are mixed within rows, although some farmers may grow the different crops in alternate rows (Table 8.8). Some farmers, who rely on hand hoeing as the only method of weed control, also indicated they may broadcast a mixture of various seed types at planting. Although some farmers indicated more than one reason for intercropping, most expressed the need to have a variety of crops at harvest as the main reason for the practice. Others indicated that intercropping served as security in the event of failure of some crops in the mixture (Table 8.9).

Intercropping a host with a non-host crop has been reported to alleviate stalk borer problems elsewhere (Amoako-Atta *et al.*, 1983; Dissemond & Hindorf, 1989; Saxena *et al.*, 1989; Seshu Reddy, 1990; Sharma, 1993). Intercropping maize and beans may, therefore, be a useful component in an integrated management system against stalk borers in Lesotho.

However, the merits of an intercropping system must be assessed based on the local pest situation.

Table 8.5: Percentage of farmers in six districts of Lesotho who grow **maize** in mixtures with other crops.

Maize intercropped	Percentages of farmers per district						
	Leribe	Berea	Maseru	Mafeteng	Mohaleshoek	Thaba-Tseka	All districts
Yes	66.7	30.0	15.0	30.0	26.3	25.0	28.4
No	33.3	70.0	85.0	70.0	73.7	75.0	71.6

Table 8.6: Percentage of farmers in six districts of Lesotho who grow **sorghum** in mixtures with other crops.

Sorghum intercropped	Percentages of farmers per district						
	Leribe	Berea	Maseru	Mafeteng	Mohaleshoek	Thaba-Tseka	All districts
Yes	0.0	50.0	0.0	0.0	20.0	20.0	13.6
No	100	50.0	100	100	80.0	80.0	86.4

Table 8.7: Percentage of farmers in six districts of Lesotho who practise various cropping mixtures in a maize- or sorghum-based intercrop system.

Cropping mixture	Percentages of farmers per district *						
	Leribe	Berea	Maseru	Mafeteng	Mohaleshoek	Thaba-Tseka	All districts
Maize/Sorghum	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Maize/Beans	33.3	66.7	33.3	66.7	100	100	66.7
Sorghum/Beans	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Maize/Sorghum/ Beans	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Maize/Potatoes	0.0	0.0	33.3	0.0	0.0	0.0	4.0
Maize/Pumpkins	50.0	66.7	100	33.3	0.0	0.0	35.7
Sorghum/Potatoes	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sorghum/Pumpkins	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Others	16.7	0.0	0.0	0.0	0.0	0.0	4.8

* Some respondents indicated practising more than one cropping mixture.

Table 8.8: Percentage of farmers in six districts of Lesotho who practise various cropping arrangements.

Cropping arrangement	Percentages of farmers per district *						
	Leribe	Berea	Maseru	Mafeteng	Mohaleshoek	Thaba-Tseka	All districts
Within row	100	33.3	100	100	100	100	87.1
Alternate row	0.0	33.3	33.3	0.0	0.0	0.0	9.7
Others**	0.0	33.3	0.0	0.0	0.0	0.0	6.5

* Some respondents indicated more than one cropping arrangement. **Broadcasting.

Table 8.9: Reasons provided by farmers in six districts of Lesotho for growing maize or sorghum in mixtures with other crops.

District of respondents	Percentages of farmers per district who gave various reasons for intercropping *			
	Security in the event of crop failure (%)	To have a variety of crops at harvest (%)	To control pests/weeds (%)	Other reasons (%)
Leribe	16.7	83.3	0.0	0.0
Berea	75.0	25.0	0.0	0.0
Maseru	0.0	100	0.0	0.0
Mafeteng	33.3	66.7	0.0	0.0
Mohaleshoek	33.3	66.7	0.0	0.0
Thaba-Tseka	16.7	100	0.0	0.0
All districts	31.7	70.7	0.0	0.0

* Some farmers indicated more than one reason for intercropping.

c) Disposal of maize and sorghum residues

The method of disposal of maize and sorghum residues (stalks above ground) is fairly uniform throughout the country. The majority of farmers cut and remove stalks for animal feed, while some leave them standing in the field, eventually to be grazed upon by livestock (Table 8.10). Observations during field surveys showed that the former practice was common with maize, while the latter was more common with sorghum. Stalks may also be used as a source of fuel. Others indicated more than one method of residue disposal.

Table 8.10: Percentage of farmers in six districts of Lesotho who dispose of maize and sorghum residues in various ways.

District of respondents	Mode of disposal of residues *				
	Left in the field (%)	Removed for livestock feed (%)	Burned in the field (%)	Removed for fuel (%)	Others (%)
Leribe	10.0	90.0	0.0	10.0	0.0
Berea	10.0	90.0	0.0	40.0	0.0
Maseru	60.0	40.0	0.0	0.0	0.0
Mafeteng	20.0	80.0	0.0	20.0	0.0
Mohaleshoek	50.0	50.0	0.0	10.0	0.0
Thaba-Tseka	5.0	95.0	0.0	30.0	0.0
All districts	25.8	74.2	0.0	18.3	0.0

* Some respondents indicated more than one method of residue disposal.

d) Post-harvest tillage practices

Responses to the question on post-harvest tillage practices by farmers indicated that the majority of maize and sorghum fields were left unploughed until just before the next planting in summer (Table 8.11). For farmers who ploughed long before the next summer planting (*i.e.* autumn ploughing), the main reason provided was to conserve soil moisture, although winter cropping (of mostly wheat and peas) and weed control were also cited (Table 8.12). Some indicated more than one reason for autumn ploughing.

Table 8.11: Timing of ploughing of maize and sorghum fields after harvest, by farmers in six districts of Lesotho.

Time of ploughing	Percentage of farmers per district who practise ploughing at various times						
	Leribe	Berea	Maseru	Mafeteng	Mohaleshoek	Thaba-Tseka	All districts
Just before planting (spring/summer ploughing)	70.0	70.0	75.0	60.0	60.0	100	74.4
Soon after harvest (autumn ploughing)	30.0	30.0	25.0	40.0	40.0	5.0	25.6

Table 8.12: Reasons provided by farmers in six districts of Lesotho for ploughing maize and sorghum fields soon after harvesting (autumn ploughing).

Reason for autumn ploughing	Percentage of farmers per district *						
	Leribe	Berea	Maseru	Mafeteng	Mohaleshoek	Thaba-Tseka[+]	All districts
Winter cropping	14.3	28.6	20.0	16.7	33.3	0.0	22.8
Weed control	0.0	42.9	20.0	16.7	16.7	0.0	19.3
Pest control	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other**	85.7	71.4	100	83.3	83.3	0.0	82.5

* Some respondents indicated more than one reason for autumn ploughing. ** moisture conservation.

[+] All respondents in this district indicated practising spring/summer ploughing (Table 8.11).

The finding that the majority of farmers in Lesotho do not plough their maize and sorghum fields until they are about to plant a new crop (Table 8.11) is important since larvae in crop residues, especially those below soil level in stubble, can complete their life cycle undisturbed in unploughed fields. Emergent moths can then oviposit on early plantings.

Timely ploughing of maize and sorghum fields, when practised over a large area, could be an important cultural method of reducing initial populations of stalk borers in Lesotho. Furthermore, autumn ploughing has other advantages such as cutworm control and early decomposition of incorporated organic material (Anon., 1986) and should be encouraged. The advantages of ploughing, in order to bury stalks and stubble, so as to prevent the emergence of stalk borer adults, or in order to expose hibernating larvae to extremes of temperatures and to natural enemies has been reported elsewhere (Kfir, 1990c; Seshu Reddy, 1990). Farmers who need to preserve stalks for feeding livestock should be encouraged to destroy unused residues before the new planting season (Adesiyun & Ajayi, 1980; Seshu Reddy, 1990). Where the practice of minimum or no tillage is being advocated, alternative methods of destroying hibernating stalk borers (*e.g.* uprooting and shredding or composting residues) should be explored.

e) Stalk borer control measures employed by farmers

Although the majority of farmers indicated that stalk borers sometimes needed to be controlled (Table 8.3), most (70.3 %) farmers indicated that they never applied control measures against the pests (Table 8.13). Most farmers cited the high costs involved as the main reason they did not apply chemical control measures (Table 8.14). Some farmers indicated unavailability of insecticides, lack of knowledge about their use, and ineffectiveness of insecticides as the reason (Table 8.14). This suggests that increased extension efforts are needed in some areas.

For those farmers who controlled stalk borers, the majority used commercial insecticides (Table 8.15), although a small proportion of farmers indicated that they sometimes engaged the services of traditional 'doctors' who solved the problem for them. The farmers were not, however, prepared to explain precisely how this works. The survey also indicated that most farmers who applied control measures against stalk borers did so prophylactically, although a substantial proportion indicated that they normally waited for the first symptoms of larval infestation to appear (Table 8.16).

Table 8.13: Percentage of farmers in six districts of Lesotho who take control measures against stalk borers.

Control stalk borers	Percentage of farmers per district						
	Leribe	Berea	Maseru	Mafeteng	Mohaleshoek	Thaba-Tseka	All districts
Yes	22.2	20.0	35.3	30.0	50.0	75.0	29.7
No	77.8	80.0	64.7	70.0	50.0	25.0	70.3

Table 8.14: Percentage of farmers in six districts of Lesotho who gave various reasons for not controlling stalk borers in maize and sorghum crops.

Reasons advanced	Percentage of farmers per district						
	Leribe	Berea	Maseru	Mafeteng	Mohaleshoek	Thaba-Tseka	All districts
Lack of capital to purchase insecticides	66.7	100	85.7	83.3	66.7	46.7	68.0
Unavailability of insecticides	33.3	0.0	0.0	0.0	22.2	20.0	14.9
Lack of knowledge of control measures	0.0	0.0	0.0	0.0	0.0	20.0	8.5
Ineffectiveness of insecticides	0.0	0.0	14.3	16.7	11.1	0.0	4.3
Lack of need to control stalk borers	0.0	0.0	0.0	0.0	0.0	13.3	4.3

Table 8.15: Percentage of farmers in six districts of Lesotho indicating methods employed to control stalk borers of maize and sorghum.

Control method	Percentage of farmers per district						
	Leribe	Berea	Maseru	Mafeteng	Mohaleshoek	Thaba-Tseka	All districts
Insecticides	87.5	100	100	100	75.0	100	93.6
Traditional	12.5	0.0	0.0	0.0	25.0	0.0	6.4

Table 8.16: Percentage of farmers in six districts of Lesotho who choose various stages to apply control measures against stalk borers of maize and sorghum.

District of respondents	Timing of control application		
	Preventively (%)	When first symptoms appear (%)	When symptoms are severe and widespread (%)
Leribe	100	0.0	0.0
Berea	75.0	25.0	0.0
Maseru	27.3	63.6	9.1
Mafeteng	42.9	57.1	0.0
Mohaleshoek	70.0	10.0	20.0
Thaba-Tseka	20.0	80.0	0.0
All districts	57.1	36.8	6.1

3. Survival of stalk borers in maize and sorghum residues:

This investigation indicated that crop residues are important in sustaining the populations of stalk borers from one season to the next. Most carry-over populations of *B. fusca* and *C. partellus* survived the off-season (winter) as diapause larvae in maize and sorghum residues. Although each species of stalk borer utilized both stalks and stubble as hibernation sites, this study indicated that most over-wintering larvae of *B. fusca* occurred below soil level in the stubble of maize and sorghum (Tables 8.17 & 8.18).

This finding was further confirmed through surveys on maize fields at other localities during October 1997, which showed that 100 % (67), 100 % (98), and 96.3 % (87) of live larvae of *B. fusca* at Siloe, Leribe and Butha-Buthe respectively, occurred in stubble below soil level. The rest (3.7 % at Butha-Buthe) occurred in stalks. A similar survey on sorghum fields during the same period showed that 100 % (37), 100 % (53), and 95.5 % (46) of live *B. fusca* larvae at Leribe, Butha-Buthe and Seaka Bridge respectively (*C. partellus* was absent in sorghum at these localities), also occurred in stubble below soil level. Therefore, only a very small proportion of live *B. fusca* larvae were found in stalks in spring.

Table 8.17: Percentage of infested **maize** stalks and stubble at Roma, Lesotho, harbouring live *Busseola fusca* larvae in June and October during 1995, 1996 and 1997.

Sampling period	% of 50 infested maize stalks harbouring live *B. fusca* larvae	% of 50 infested maize stubble harbouring live *B. fusca* larvae
1995		
June	6.0 (4)*	76.0 (38)
October	0.0	26.0 (13)
1996		
June	6.0 (3)	78.0 (39)
October	2.0 (1)	56.0 (28)
1997		
June	12.0 (7)	48.0 (24)
October	2.0 (1)	36.0 (18)

*Figures in brackets indicate actual numbers of live individuals.

Table 8.18: Percentage of infested **sorghum** stalks and stubble at Siloe, Lesotho, harbouring live *Busseola fusca* and *Chilo partellus* larvae in June and September during 1995 and 1996.

Sampling period*	% of 50 infested sorghum stalks harbouring live larvae/pupae		% of 50 infested stubble harbouring live larvae/pupae	
	% with *B. fusca*	% with *C. partellus*	% with *B. fusca*	% with *C. partellus*
1995				
June	2.0 (1)**	18.0 (21)	42.0 (21)	6.0 (3)
September	0.0	12.0 (11)	28.0 (14)	4.0 (3)
1996				
June	6.0 (3)	12.0 (9)	34.0 (17)	6.0 (4)
September	0.0	4.0 (3)	22.0 (11)	2.0 (1)

*Only the results of 1995 and 1996 are presented due to extremely low populations of *C. partellus* during 1997. **Figures in brackets indicate actual numbers of live individuals present.

In the case of over-wintering populations of *C. partellus*, there were more surviving individuals in stalks than in the stubble of sorghum (Table 8.18). This was attributed to the observation that more than one *C. partellus* individual was often found in a single stalk, whereas only one individual normally occurred per stubble. Also, there were more stalks containing *C. partellus* than was the case with stubble. A possible reason for this observation is that *B. fusca* probably goes into hibernation earlier than *C. partellus*, thereby occupying the underground niche of a host plant before the latter. It should be noted that whereas *B. fusca* attacks both maize and sorghum in Lesotho, *C. partellus* was seldomly observed in maize. Also, *B. fusca* and *C. partellus* cohabit in sorghum (see chapter 2).

In order to further illustrate the importance of sorghum stalks in maintaining the populations of *C. partellus*, infested sorghum stalks were obtained from Mafeteng and stacked upright (outdoors) at Roma, throughout the winter period of 1996. These stalks were dissected in September and live stalk borer larvae counted. It was found that of the 47 live stalk borer individuals recovered, 89.4 % (42 individuals) were *C. partellus*, while only 10.6 % (5 individuals) were *B. fusca*.

This study has shown that maize and sorghum residues are important hibernation sites for over-wintering populations of both *B. fusca* and *C. partellus* in Lesotho (Tables 8.17 & 8.18). The study has also shown that maize and sorghum residues are useful as livestock feed, and that many farmers cut and take them home for storage as livestock feed (Table 8.10). Such removal of residues is an integral component of the cultural practices of many of Lesotho's farmers and should be encouraged. However, it was observed during field surveys that some heaps of maize stalks, which were removed at harvest and piled at home as livestock feed, still remained undestroyed well into the following growing season. Although this study showed that only a small proportion of *B. fusca* larvae hibernate in maize and sorghum stalks, these could still be important sources of infestations in early crops should there be many such stalks left in an area. The study also showed that most surviving *C. partellus* larvae occurred in sorghum stalks (Table 8.18). Therefore, sorghum stalks left undestroyed would serve as sources of infestations in new plantings. Therefore, timely destruction of crop residues would be an effective way of reducing carry-over populations of the stalk borers in an area.

Proper disposal of maize and sorghum crop residues, by burning, ploughing, shredding or composting of all unused stalks before the beginning of a planting season, have been reported to be effective in reducing carry-over populations (Harris, 1962; Adesiyun & Ajayi, 1980; Kfir, 1990c; Seshu Reddy, 1990).

4. De-tasselling of maize plants:

This study confirmed that de-tasselling is widely practised by farmers in Lesotho. Over 60 % of farmers who responded to the questionnaire indicated that they always or sometimes de-tasselled maize plants (Table 8.19). The main reason provided for this practice was that it provided fodder for livestock (Table 8.20), as most of the farmers indicated that they kept livestock in addition to growing maize, sorghum and other crops (Table 8.21).

Results of the field trials showed that de-tasselling did not affect larval survival as there was no significant difference (P>0.05) between the numbers of live larvae that were present in de-tasselled and non-de-tasselled plants at harvest (Table 8.22). This is attributed to the observation that de-tasselling of plants is done towards the end of the season when plants are already mature, and when most of the larvae in the stalks have already migrated downwards in search of winter hibernation sites (Walters *et al.*, 1976; Van Rensburg, Walters & Giliomee, 1987).

Table 8.19: Percentage of farmers in six districts of Lesotho who de-tassel maize plants.

De-tassel	Percentage of farmers per district						
	Leribe	Berea	Maseru	Mafeteng	Mohaleshoek	Thaba-Tseka	All districts
Yes	100	90.0	35.0	70.0	52.6	70.0	63.6
No	0.0	10.0	65.0	30.0	47.4	30.0	36.4

Table 8.20: Reasons provided by farmers in six districts of Lesotho for de-tasselling maize plants.

District of respondents	Percentage of farmers who gave various reasons for de-tasselling *				
	to feed livestock (%)	to increase yield (%)	to control pests (%)	to hasten drying (%)	other reasons (%)**
Leribe	100	0.0	0.0	0.0	0.0
Berea	100	0.0	0.0	0.0	0.0
Maseru	42.9	0.0	0.0	28.6	42.9
Mafeteng	100	0.0	0.0	0.0	0.0
Mohaleshoek	70.0	10.0	0.0	10.0	10.0
Thaba-Tseka	100	0.0	0.0	14.3	0.0
All districts	87.5	1.8	0	8.9	7.1

* Some respondents indicated more than one reason for de-taselling maize plants.

**to minimize frost damage to maize.

Table 8.21: Percentage of maize and sorghum farmers in six districts of Lesotho who also keep livestock.

Keep livestock	Percentage of farmers who keep livestock per district						
	Leribe	Berea	Maseru	Mafeteng	Mohaleshoek	Thaba-Tseka	All districts
Yes	85.0	90.0	80.0	80.0	75.0	95.0	83.9
No	15.0	10.0	20.0	20.0	25.0	5.0	16.1

Table 8.22: Mean number of live *Busseola fusca* larvae in 40 infested de-tasselled and 40 infested non-de-tasselled maize plants at harvest during 1995/96 and 1996/97 growing seasons.

Treatment	Mean number of surviving larvae	
	1995/96	1996/97
De-tasselled plants	34	5.0
Non-de-tasselled plants	36	4.0
t-value	-1.0000	0.5222
P-value	0.3559	0.6202

CONCLUSION

This study has shown that stalk borers are considered as important pests of maize and sorghum by farmers in Lesotho. Constraints (especially financial) related to the management of stalk borers, and which are faced by resource-poor farmers elsewhere in Africa, are also experienced by farmers in Lesotho. As a result, most of the farmers do not take control measures against the pests.

The observation that routine crop management practices were not aimed at the management of the pests is attributed to lack of information, which means that farmers are generally unaware of inexpensive stalk borer management strategies reported to be effective elsewhere. Therefore, research and extension are needed locally, in order to provide farmers with information regarding sustainable farm management practices that can reduce the incidence of stalk borer damage, and which can be adopted fairly easily and cheaply.

CHAPTER 9

CONSTRAINTS TO THE EFFECTIVE USE OF INSECTICIDES FOR THE CONTROL OF *CHILO PARTELLUS* (SWINHOE) (LEPIDOPTERA: PYRALIDAE) IN SORGHUM IN LESOTHO.

ABSTRACT

The efficacy of six insecticides used for the control of stalk borers in Lesotho were evaluated against the larvae of *Chilo partellus* (Swinhoe) (Lepidoptera: Pyralidae) on sorghum in a field trial. Knowledge regarding insecticides and control recommendations were assessed during the procurement of insecticides used in the study. Results indicated that each insecticide treatment resulted in significantly lower larval survival compared to the untreated control. Granular formulations (beta-cyfluthrin 0.05 % GR and carbaryl 2.5 % GR) resulted in the highest levels of larval mortality. Of the six insecticides evaluated, the granular formulations are considered as the best choice for use against stalk borers in plant whorls, especially for application on small-scale farms. A general lack of knowledge which would enhance safe and efficient use of insecticides among farmers was identified and the need to address the problem is highlighted.

Key words: Chemical control, Lesotho, stalk borers.

INTRODUCTION

Chemical control remains the most important curative pest control measure (Van Schoubroeck *et al.*, 1989), not only on large- but also on small-scale farms. For instance, insecticides are widely recommended for the control of important pests, such as stalk borers of maize and sorghum on commercial farms in South Africa (Krause *et al.*, 1996). They will probably continue to play a key role in pest management on large-scale commercial farms for quite some time (Van den Berg, 1994).

Maize and sorghum are the most important crops grown in Lesotho (Anon.,1994, 1995) and it has been reported that the stalk borers *Busseola fusca* (Fuller) (Lepidoptera: Noctuidae) and *Chilo partellus* (Swinhoe) (Lepidoptera: Pyralidae) are pests of these crops in the country (Qhobela *et al.*, 1986). A recent survey in the country (see chapter 8) indicated that 88.9 % of farmers regard stalk borers as important pests which sometimes need to be controlled. The same study showed that more than 90 % of farmers who did control stalk borers, employed commercially available insecticides. Despite this apparent popularity of commercial insecticides, a literature survey showed a lack of information on the relative efficacy of available insecticides for the control of stalk borers in the country. These insecticides are mostly obtained from private supply agencies in the country, on whom many consumers rely for information regarding the choice and use of the products.

In view of the importance of stalk borers and the dearth of current information on their chemical control in Lesotho, this study was conducted to evaluate the relative efficacy of some insecticides currently being sold in the country for use against stalk borers of both maize and sorghum. Results provided basic information which will contribute towards informed decision making by users, in terms of the relative efficacy of the insecticides.

MATERIAL AND METHODS

Six commercial insecticides were evaluated in a field trial at Potchefstroom (26° 43′ S, 27° 6′ E), South Africa, during the 1997/98 growing season (Table 9.1). All the insecticides, with the exception of Decis (deltamethrin 2.5 % EC), were sold for the control of stalk borers in Lesotho during the period of this study. K-O Guard (deltamethrin 1 % EC), which is not registered for the control of stalk borers of maize or sorghum in South Africa (Krause *et al.*, 1996), was also included, as it was being sold for use against stalk borers in Lesotho.

The sorghum hybrid, NK283, was used in this study. The experimental design was a randomized complete block with seven treatments replicated five times. Plots consisted of single rows, each 5 m long. Plot-rows were spaced 2.2 m apart. Plants were thinned to one per hill three weeks after emergence (WAE), with plants spaced 0.10 m apart within a row.

Ten plants per plot-row were artificially infested with *C. partellus* larvae 4 WAE (mid-whorl stage). This was done by placing 10 neonate larvae directly into individual plant whorls by means of a 'bazooka' mechanical dispenser (Wiseman *et al.*, 1980).

Larvae were allowed to feed in the whorls for five days, after which insecticides were applied. The various rates of insecticide application (Table 9.1) were based on the recommended rates (Krause *et al.*, 1996). Spray formulations were applied directly into plant whorls by means of a CO_2-pressurised portable sprayer delivering 2.4 l of insecticide mixture per 100 m row length, using a 35 (D4) solid cone nozzle at a pressure of 300 kPa. Granular formulations were applied directly into plant whorls by means of a bottle with perforated lid, at the rate of 40 g of product per 100 m row length. Unsprayed infested control plots were also included for comparative purposes.

The result of this experiment was evaluated by determining the number of surviving larvae in each treatment one week after insecticide application. This was done by removing and dissecting 10 infested plants in each plot and counting the number of live larvae in the whorls.

Data were subjected to analysis of variance and differences between means separated using Duncan's Multiple Range Test at $P=0.05$.

Also, in order to gain insight into the type of information that insecticide users get when purchasing the chemicals, such information, with regard to when and how to apply the chemicals, was sought and obtained from the suppliers during the procurement of the insecticides used in this study.

RESULTS AND DISCUSSION

The number of surviving larvae was significantly lower ($P<0.05$) in all insecticide treatments compared to the untreated control (Table 9.1). Significant differences in the efficacy of the various insecticides were also observed. Larval mortality was significantly higher ($P<0.05$) in plots treated with beta-cyfluthrin 0.05 % GR than in plots treated with any of the deltamethrin formulations (Decis EC and K-O Guard EC). Larval mortality with beta-cyfluthrin 0.05 % GR was, however, statistically similar to those obtained with carbaryl 2.5 % GR, cypermethrin 20 % EC and beta-cyfluthrin 5 % EC.

Table 9.1: Effect of various insecticide treatments on survival of *Chilo partellus* larvae, one week after insecticide treatment.

Insecticide	Active ingredient	Dosage (g a.i 100 m^{-1} row)	No. of surviving larvae per plant
Bulldock GR	Beta-cyfluthrin 0.05% GR	0.02	0.15 a
Kombat GR	Carbaryl 2.5 % GR	1.0	0.32 ab
Ripcord EC	Cypermethrin 20 % EC	0.7	0.36 ab
Bulldock EC	Beta-cyfluthrin 5 % EC	0.063	0.50 ab
Decis EC	Deltamethrin 2.5 % EC	0.05	0.84 b
K-O Guard EC	Deltamethrin 1 % EC	0.0125	1.92 c
Untreated control	-	-	3.72 d
F-value	-	-	45.07
P-value	-	-	<0.0001

Differences between means within the same column followed by the same letter are not significant at P=0.05 (Duncan's Multiple Range Test).

Van den Berg & Van Rensburg (1993) also found beta-cyfluthrin 0.05 % GR to be the most effective insecticide against *C. partellus* larvae during the late-whorl stage. They attributed the efficacy of this insecticide to its persistence. According to the same source, the efficacy of chemical control of late infestations of *C. partellus* could be increased through the use of such a persistent insecticide.

In general, the granular formulations (beta-cyfluthrin 0.05 % GR and carbaryl 2.5 % GR) were more effective against *C. partellus* larvae in plant whorls than were the spray formulations. Jotwani (1983) also found granular formulations to be more effective against larvae of *C. partellus*.

The finding that the granular formulations were more effective than the spray applications against *C. partellus* larvae, albeit numerically only, has an important relevance with regard to farmers in Lesotho. Granular formulations have certain practical advantages over spray formulations, since they do not require expensive sophisticated application equipment and they are cheaper and easier for unskilled resource-poor farmers to use. They are also easier to apply because they are ready for use when purchased (Krause *et al.*, 1996), *i.e.* they do not require further mixing before application. Another advantage over the spray formulations is that granular formulations are less prone to wind drift and spillage. Also, the granular formulations are placed directly in the whorls, whereas droplets from spray formulations inevitably reach areas other than the whorls, where non-target organisms may be sheltering. The granular insecticides are, therefore, less likely to harm the user (especially through inhalation and skin contact) and other non-target organisms such as beneficial insects and livestock. Furthermore, the spray formulations evaluated in this trial require large volumes of water for mixing (Krause *et al.*, 1996), whereas relatively smaller volumes of the granules are needed per treatment area. Crop production in Lesotho is largely carried out by small-scale, mainly subsistence-level farmers (Anon., 1995), who often lack the capital to invest in expensive pest control equipment and who may not possess sufficient skills to apply insecticides effectively and safely. To this extent, the granular formulations evaluated in this study (beta-cyfluthrin 0.05 % GR and carbaryl 2.5 % GR) are considered more suitable for the small-scale farmers of Lesotho.

The strict adherence to instructions contained on labels accompanying pesticides is absolutely necessary for their correct use (Krause *et al.*, 1996). However, it was observed during the procurement of insecticides for this trial that pesticides were often repackaged in smaller quantities for direct sale to end users. These packages sometimes carried no labels whatsoever, or if they did, only the trade name or the use of the chemical (*e.g.* 'cutworm bait') was provided. This implies that users of such products have no information regarding safety warnings, correct handling and effective application. This practice has the potential for increasing the misuse and abuse of pesticides. This situation is particularly of concern since pesticides are freely available in shops and that pesticide use is on the increase in Lesotho (Ansari, 1994).

Many of the end purchasers of insecticides in Lesotho depend on the suppliers for user instructions. However, it was observed during the procurement of insecticides that the advice received were often inadequate or even outright dangerous. For instance, one common recommendation made by some suppliers with regard to how to apply the spray formulations used in this trial was to mix the chemical according to the specifications on the label; after mixing, the spray should be applied using any available portable sprayer; where a sprayer was not available, the user was advised to use ordinary containers (such as cups, tins, etc.) to pour the insecticide mixture into plant whorls. Some subsistence-level farmers are not in a position to handle the calibration of insecticide application equipment or the quantities of insecticides required per unit area. This situation could easily lead to over- or under-dosage of pesticides which, in either case, would lead to wastage, among other problems. The use of household utensils for the mixing and application of insecticides could also increase the risk of pesticide poisoning. Furthermore, it was observed during field surveys that sometimes, insecticide application was conducted by an entire family, including very young children. This clearly demonstrated gross ignorance with regard to the potential hazards associated with pesticide use.

With regard to the timing of insecticide application, the advice from some insecticide suppliers was to do so when plants were knee-high irrespective of whether infestation was present. Another common recommendation was to apply insecticide when the first symptoms of attack were noticed. Such advice may encourage unnecessary application of pesticides, thereby increasing production costs.

The lack of adequate knowledge on the part of those who sell these chemicals was further manifested through the recommendation of K-O Guard (deltamethrin 1 % EC) for stalk borer control. This recommendation is not made on the insecticide label of this product. The insecticide formulation is also not registered for the control of stalk borers of either maize or sorghum in South Africa, even though it has the same active ingredient as Decis (deltamethrin 2.5 % EC) which is recommended (Krause *et al.*, 1996). The fact that K-O Guard (deltamethrin 1 % EC) proved to be the least effective against the stalk borer larvae indicates that farmers who have been purchasing this product for stalk borer control were not choosing the best available product for the intended purpose and were most likely wasting their money.

CONCLUSION

It is concluded that of the six insecticides evaluated, the granular formulations (beta-cyfluthrin 0.05 % GR and carbaryl 2.5 % GR) are the most effective for the control of *C. partellus* larvae in sorghum plant whorls. Because of their effectiveness against stalk borer larvae, their relative ease of application along with other advantages associated with the use of granular formulations, they are recommended for use by small-scale farmers in Lesotho when chemical control of stalk borers is needed.

The lack of adequate knowledge about insecticides amongst some suppliers and farmers limits the ability of the users of such products to employ them safely and efficiently, or even to choose the right chemical for a given purpose. This situation needs to be addressed through research, training of agricultural, health and other extension workers and through proper dissemination of relevant information to users. Research is needed to evaluate the relative effectiveness of insecticides being sold, in order to facilitate correct recommendations and to provide farmers with up-to-date information. Economic threshold levels need to be established for the various regions of the country and farmers need to be taught simple ways of determining these levels, in order to facilitate proper timing of insecticide application. Vigorous extension work is needed to make pesticide users aware of the potential hazards inherent in the improper handling of these products. Also, non-chemical stalk borer management strategies need to be explored and incorporated into a comprehensive integrated management system, in order to limit the use of insecticides.

CHAPTER 10

EFFECT OF PLANTING DATE OF MAIZE ON DAMAGE AND YIELD LOSS CAUSED BY THE STALK BORER, *BUSSEOLA FUSCA* (FULLER) (LEPIDOPTERA: NOCTUIDAE) IN LESOTHO.

ABSTRACT

The effect of time of planting of maize on the incidence of infestation and of yield loss caused by *Busseola fusca* (Fuller) was studied using five successive plantings (November to early January) during each of the 1995/96 and 1996/97 growing seasons. Data were collected on the incidence of infested plants, the degree of internal plant damage, the number of larvae that colonized plants, and grain yield. Since the earliest incidence of infestation was recorded in January, it was concluded that the second generation of *B. fusca* moths (whose flight activity peaks in February) was responsible for infestations in all the plantings. The incidence of infestation differed between plantings during the growing season, but was similar at harvest. Planting date had a significant effect on the incidence of damaged ears within a season. All plantings suffered yield loss but it was lowest in the November plantings. Early planting (in November) is therefore recommended, in order to minimise yield loss due to second generation infestation. Seasonal variation in yield loss due to *B. fusca* damage was also observed (0.4 % to 5.3 % and 12.7 % to 36.6 % during 1995/96 and 1996/97 respectively).

Key words: *Busseola fusca*, maize, planting date, yield loss.

INTRODUCTION

Maize is the single most important crop in Lesotho, and is the staple food of the Basotho people. Annually, this crop occupies approximately 60 % of the total area of cultivated land (Anon., 1995). However, as a result of low productivity of maize grown by farmers in Lesotho, most of the country's annual maize requirement is imported (Brokken *et. al.*, 1986; Anon., 1995). Although several reasons have been advanced as being responsible for the characteristically low yields (Gill, 1994; Anon., 1995), the role of pests and diseases has hitherto remained largely uninvestigated.

In neighbouring South Africa, the maize stalk borer, *Busseola fusca* (Fuller), is generally regarded as contributing significantly to yield losses in maize, and according to Annecke & Moran (1982), it is the most important pest of maize in that country; particularly in the cool, high-lying regions (Walters *et al.*, 1976). The importance of this stalk borer has also been reported in other parts of southern Africa, eastern Africa (Dabrowski, 1985; Sithole, 1989; Seshu Reddy, 1991), as well as in Nigeria (Harris, 1962). Although *B. fusca* has also been reported to attack maize in Lesotho (Qhobela *et al.*, 1986), no further study was conducted on the pest. Because of the importance of *B. fusca* as a limiting factor to maize production on the African continent, its biology, ecology and control have been extensively investigated elsewhere in Africa (Du Plessis & Lea, 1943; Harris, 1962; Usua, 1968b; Van Rensburg *et al.*, 1978, 1980, 1985, 1988, 1988c; Van Rensburg, Walters & Giliomee, 1987).

Time of planting was reported to have a pronounced influence on the levels of infestation and subsequent yield loss caused by stalk borers elsewhere (Swaine, 1957; Harris, 1962;

Abu, 1986; Van Rensburg *et al.*, 1985; Van Rensburg, Walters & Giliomee, 1987; Gebre-Amlak *et al.*, 1989; Ajayi, 1990). This phenomenon has been attributed to the occurrence of distinct periods of moth flight (Van Rensburg, Walters & Giliomee, 1987). Weekly monitoring of moth flights also revealed the existence of distinct periods of *B. fusca* moth flight in Lesotho (see chapter 3). In large scale commercial farming systems in neighbouring South Africa, maize is generally planted over a relatively short period and adapting planting date results in reduced *B. fusca* damage. This is obtained by planting the crop at such a time as to ensure that plants will be at the most susceptible stage (mid-whorl) when moth activity is low (Van Rensburg *et al.*, 1985).

In contrast to the practice on commercial farms in South Africa, maize planting in Lesotho is usually done over a considerably longer period of several weeks. It was estimated that 80 % to 90 % of maize fields in the lowland areas of Lesotho were planted between the second week of November and the second week of December during both the 1995/96 and 1996/97 growing seasons. Some planting also took place in October and after mid-December. It was observed that farmers who planted a mixture of maize and beans, and those who planted local (non-hybrid) maize varieties, tended to plant late in December. There were also isolated cases of maize plantings in September, particularly in home vegetable gardens.

The aim of this study was to determine the relationship between the time of planting of maize in Lesotho and the levels of infestation and damage caused by *B. fusca*, given that maize planting usually occurs over an extended period of time.

MATERIAL AND METHODS

The trial was conducted at Roma (29° 27′ S, 27° 44′ E, 1650 m above sea level), Lesotho, during the 1995/96 and 1996/97 growing seasons. A commercial hybrid maize, PAN6363, one of the hybrids commonly grown by farmers in Lesotho, was used throughout this investigation.

There were five plantings (P1 to P5) during each growing season. The first planting took place on the 11th of November of each season, a date that approximately coincided with the commencement of maize planting by farmers in the Roma area. Subsequent plantings followed at fortnightly intervals, with the last planting taking place on the 5th of January, well beyond the date that Lesotho farmers would still plant maize.

The experimental design was a randomized complete block, with four replications for each planting date (treatment). Each plot comprised 10 rows, each 10 m in length. Inter-row spacing was 0.75 m, with intra-row spacing of 0.3 m. Each plot was bordered by a 3 m-wide space and was subdivided into two halves (sub-plots). Plants in one half were treated with Kombat granules (carbaryl GR 25 g a.i./kg) at the recommended rate of 4 kg of product per hectare. Insecticide application was done at fortnightly intervals, commencing three weeks after crop emergence (WAE) and continued until flowering. Plants were subjected to natural infestation by *B. fusca*.

Data collection was executed in the same manner for all plantings, both with respect to how the data were collected, as well as with regard to the time of data collection relative to the date of planting. For each planting, data collected included the incidence of plants exhibiting whorl, stem and ear damage, the number of larvae present in plants, level of internal damage to stems, incidence of direct damage to ears, number of ears produced, and yield (grain mass).

The incidence of infestation (percentage plants exhibiting whorl damage, stem damage, ear damage) was determined through visual observation of all plants in the inner six rows of each untreated sub-plot. Evaluation was done at fortnightly intervals, beginning 4 WAE until 20 WAE, and at harvest. During each sampling, plants were examined *in situ*, and the percentage of plants showing evidence of damage by the stalk borer was calculated for each sub-plot.

The level of infestation, taken as the total number of *B. fusca* individuals that successfully colonized the plants, was evaluated at harvest. The aim was to determine the population of *B. fusca* individuals hosted by the plants in each planting during the entire growing season. This was done by uprooting 25 plants at random from the six innermost rows of each untreated sub-plot. These plants were dissected (split open vertically), and the number of larvae, pupae and pupal cases of *B. fusca* recorded for each plant. Thereafter, the total number of individuals was calculated for each sub-plot.

The level of internal damage to internodes (mean percentage of internodes damaged per plant) was also determined at harvest, making use of the same plant samples used for the assessment of levels of infestation. After dissecting each plant, the number of damaged internodes was counted and expressed as a percentage of the total number of internodes present. Average percentage damaged internodes was then calculated for each planting.

The incidence of damage to ears (percentage of ears damaged by *B. fusca*) was assessed at harvest. The plants used were the same as those employed in the assessment of levels of infestation and internal damage to internodes. The ears of these plants were harvested, and the proportion of ears exhibiting damage due to *B. fusca* was determined for each sub-plot. Average incidence of ear damage was determined for each planting.

In order to assess the extent of reduction in ear numbers caused by borer damage in each planting (1996/97 season only), the same plants used for the evaluation of incidence of ear damage were employed. This was done by determining the total number of ears produced in each untreated sub-plot. The total number of ears produced by 25 plants taken at random from the six innermost rows of each insecticide-treated sub-plot was also determined. The extent of reduction in the number of ears produced was determined as the difference between the number of ears produced by the treated and the untreated plants in each plot, calculated as a percentage of number of ears produced by the treated plants.

To determine yield loss, the same plants used in the assessment of extent of reduction in ear numbers were used. All ears were shelled and grain mass determined for each treated and untreated sub-plot. Yield loss was determined as the difference between the yield (grain mass) of the insecticide-treated and the untreated plants in each plot, calculated as a percentage of the yield of the treated plants.

Data were subjected to analyses of variance and differences between means were separated using the Least Significant Difference (LSD) test at P=0.05.

RESULTS AND DISCUSSION

Estimates of the incidence of whorl damage recorded on maize farms and home gardens planted during October of the 1996/97 growing season, ranged between 13 % and 71 % at Roma, 40 % and 75 % at Maseru, and 1 % and 10 % at Siloe. A few farmers in the Maseru and Roma areas had to abandon their crops due to severe stalk borer damage during this growing season.

In these trials, the earliest record of infestation during both seasons (1995/96 and 1996/97) was in January/February (Table 10.1). This indicates that the second generation of moths was responsible for infestation in all five plantings, irrespective of planting date. The first generation moths, of which flight activity begins in October (see chapter 3), is presumably only important on maize planted before November.

Table 10.1: Date of first record of infestation by *Busseola fusca* in maize planted on different dates at Roma, Lesotho, during the 1995/96 and 1996/97 growing seasons.

Planting date	1995/96			1996/97		
	First record of infestation	Weeks after emergence	Incidence of infestation	First record of infestation	Weeks after emergence	Incidence of infestation
P1 (Nov. 11)	07/03/1996	14	0.1 %	13/01/1997	8	1.0 %
P2 (Nov. 24)	29/02/1996	12	3.8 %	10/02/1997	10	0.4 %
P3 (Dec. 8)	26/02/1996	10	2.3 %	27/01/1997	6	0.3 %
P4 (Dec. 22)	26/02/1996	8	1.7 %	24/02/1997	8	3.8 %
P5 (Jan. 5)	23/02/1996	6	0.8 %	10/02/1997	4	0.3 %

Significant differences were observed in the incidence of infestation sustained by the five plantings during both growing seasons (Tables 10.2 & 10.3). During the 1995/96 season, P3 (early December planting) recorded a significantly higher ($P<0.05$) incidence of infested plants than the rest of the plantings for most of the season, in spite of infestation setting in later than in P4 and P5 (late December and early January plantings) (Table 10.2). During the 1996/97 growing season, beginning from 8 WAE until 20 WAE, there was an increase in the incidence of infestation with delayed planting date at each stage of plant growth (Table 10.3).

Table 10.2: Incidence of infestation by *Busseola fusca* in maize planted on different dates at Roma, Lesotho, during the 1995/96 growing season.

Planting date	Percentage of infested plants (weeks after emergence)									
	4	6	8	10	12	14	16	18	20	Harvest
P1 (Nov. 11)	0.0	0.0	0.0 b	0.0 c	0.0 c	0.1 d	0.7 c	1.4 c	2.6 c	3.9 c
P2 (Nov. 24)	0.0	0.0	0.0 b	0.0 c	3.8 bc	5.4 c	6.4 b	7.8 bc	10.4 bc	13.8 bc
P3 (Dec. 8)	0.0	0.0	0.0 b	2.3 b	8.9 a	12.4 a	16.1a	20.0 a	25.4 a	36.2 a
P4 (Dec. 22)	0.0	0.0	1.7 a	5.2 a	6.1 ab	8.7 b	9.2 b	11.9 b	13.6 b	16.7 b
P5 (Jan. 5)	0.0	0.8	2.1 a	2.8 b	3.3 bc	3.6 c	4.1bc	4.4 c	5.0 bc	5.9 c
F-value	-	2.40	6.22	13.37	6.72	9.54	10.27	9.12	8.74	15.39
P-value	-	0.1082	0.0060	0.0002	0.0044	0.0010	0.0008	0.0013	0.0015	0.0001
LSD (P=0.05)	-	n.s.*	1.3	1.8	3.9	4.7	5.6	7.4	9.3	10.1

Means within the same column followed by the same letter are not significantly different at P=0.05 (LSD).
n.s.* = not significant (P>0.05).

Table 10.3: Incidence of infestation by *Busseola fusca* in maize planted on different dates at Roma, Lesotho, during the 1996/97 growing season.

Planting date	Percentage of infested plants (weeks after emergence)									
	4	6	8	10	12	14	16	18	20	Harvest
P1 (Nov. 11)	0.0	0.0	1.0 b	1.0 b	1.0 b	2.1 d	19.5 c	26.3 b	36.5 b	85.0
P2 (Nov. 24)	0.0	0.0	0.0 b	0.4 b	3.2 b	21.9 cd	27.3 bc	37.5 b	52.3 ab	70.0
P3 (Dec. 8)	0.0	0.3	0.3 b	4.4 b	25.1 a	36.4 bc	48.5 ab	64.8 a	67.7 a	80.5
P4 (Dec. 22)	0.0	0.0	3.8 b	27.4 a	35.5 a	48.7 ab	59.0 a	66.0 a	70.4 a	77.0
P5 (Jan. 5)	0.3	3.7	26.8 a	35.7 a	41.0 a	60.2 a	63.5 a	69.8 a	70.8 a	91.0
F-value	1.00	2.82	26.49	13.47	10.89	11.77	7.40	9.24	5.69	1.63
P-value	0.4449	0.0732	<0.0001	0.0002	0.0006	0.0004	0.0030	0.0012	0.0083	0.2312
LSD (P=0.05)	n.s.*	n.s.	6.9	13.9	7.1	0.4	2.0	19.9	19.3	n.s.

Means within the same column followed by the same letter are not significantly different at P= 0.05 (LSD).
n.s.* = not significant (P>0.05).

There were significant differences (P<0.05) in the incidence of infestation observed in the different plantings at harvest during the 1995/96 growing season, with P3 recording the highest incidence. However, the incidence of infestation at harvest was similar in all the plantings during 1996/97 (Tables 10.2 & 10.3). For each corresponding planting date, the incidence of infestation was lower during the 1995/96 season than during 1996/97 (Tables 10.2 & 10.3). The incidence of deadheart was negligible in all plantings during both seasons.

The observation that infestations generally commenced earlier in the later plantings (Tables 10.2 & 10.3) is in agreement with the report by Walters *et al.* (1976), that young maize plants are more susceptible to attack by *B. fusca* than older plants. This indicates that late plantings of maize, in the study area, are more likely to suffer increased incidence of infestation during the early stages of crop development, than early plantings. The observation that the earliest infestation set in during January/February (Table 10.1) confirms the existence of distinct periods of moth flight. All the plantings were attacked by the same generation of moths, whose flight period was preceded by either a period of no moth flight activity, or by a period of reduced flight activity. This would explain the observation that the earlier plantings escaped infestation during the early stages of crop development. Based on the time of onset of infestation (Table 10.1) and on the annual moth flight patterns (see Chapter 3), the *B. fusca* moths responsible for infestations in all the plantings were identified as belonging to the second generation. The observation that the incidence of infestation at harvest was statistically similar for all plantings during the 1996/97 season (Table 10.3), can be ascribed to migration of larvae to neighbouring plants late in the season.

It was also observed that the percentage of infested plants increased steadily with a delayed planting date, irrespective of stage of crop development. This corresponds to the finding by Van Rensburg *et al.* (1988c), that the incidence of plant damage declines with increased plant age. However, the observation that an increase in the incidence of infestation continued even after 20 WAE, as evidenced by higher incidences of infestation at harvest in all the plantings (Tables 10.2 & 10.3), is contrary to the report by Van Rensburg *et al.* (1988), that the number of damaged plants remained more or less constant after tasselling. This disparity is possibly due to the wide range of planting dates used by Van Rensburg *et al.* (1988), which provided plants of optimal age for oviposition over an extended period of time. The late increase in incidence of infestation observed in this trial was attributed to increased larval migrations in search of winter hibernation sites. Similar observations have been reported by Walters *et al.* (1976).

The higher incidence of infestation during the 1996/97 trial, was largely attributed to the higher moth population during that year, as observed in weekly moth trappings (see chapter 3). Inter-seasonal variability, in terms of magnitude of moth flights, has been reported to occur in other localities (Sagnia, 1983; Van Rensburg *et al.*, 1985). Such variability has been attributed to seasonal variation in climatic conditions and parasitism which may influence the hatching of eggs and larval survival (Van Rensburg, Walters & Giliomee, 1987).

Significant differences ($P<0.05$) were observed in the total number of *B. fusca* individuals that colonized plants in the 1995/96 season (Table 10.4). P3 of the 1995/96 season hosted significantly ($P<0.05$) more larvae than any of the other plantings during that season. However, these differences were not observed during the 1996/97 season (Table 10.4). The level of infestation during the 1996/97 season was higher than that of 1995/96 for each corresponding planting date (Table 10.4), and a t-test (at $P=0.05$) confirmed that the differences were significant ($t=6.6917$, $P=0.0026$).

Table 10.4: Number of *Busseola fusca* individuals hosted by maize planted on different dates at Roma, Lesotho, during 1995/96 and 1996/97 growing seasons.

Planting date	Number of larvae/pupae/pupal cases per plot at harvest.	
	1995/96	1996/97
P1 (Nov. 11)	1.00 c	20.00
P2 (Nov. 24)	3.00 bc	16.25
P3 (Dec. 8)	8.00 a	16.75
P4 (Dec. 22)	4.50 b	13.75
P5 (Jan. 5)	0.75 c	17.50
F-value	14.51	0.32
P-value	0.0002	0.8601
LSD (P=0.05)	2.40	n.s.*

Means within the same column followed by the same letter are not significantly different at P=0.05 (LSD). *n.s...not significant (P>0.05).

The observation that P3 (planted in December) hosted significantly more individuals during 1995/96 but not in 1996/97 (Table 10.4), suggests that under natural infestation, the final level of infestation is related to the incidence of infestation sustained during plant development. Thus, P3, which recorded the highest incidence of infestation during the 1995/96 season, also hosted significantly more individuals of *B. fusca* than all the other plantings in that season, while during 1996/97, when all the plantings had similar incidences of infestation at harvest, the levels of infestation in all five plantings were also similar.

The similar levels of infestation in all the plantings at harvest, observed during 1996/97 (Table 10.4), also suggest that late oviposition and subsequent larval survival on the early plantings were high; thereby resulting in all plantings eventually having similar levels of infestation. However, the relationship between the degree of egg-laying and level of larval infestation is relatively weak (Van Rensburg, Walters & Giliomee, 1987). This is possibly due to factors such as increased intra-specific competition between larvae, and the greater effect of mortality factors such as parasitism at higher levels of infestation. Climatic factors and parasitism may also affect the hatching of eggs as well as the establishment and survival of larvae (Van Rensburg, Walters & Giliomee, 1987). These factors play a role in determining the numbers of individuals of *B. fusca* that ultimately colonize a planting successfully.

A significantly higher ($P<0.05$) proportion of internodes were damaged by *B. fusca* larvae in P3 than in any other planting at harvest during the 1995/96 season (Table 10.5), but all five plantings had statistically similar levels of damage at harvest during 1996/97. All plantings in the 1996/97 season recorded higher levels of damage than plantings during the 1995/96 season (Table 10.5).

Table 10.5: Percentage of internodes damaged by larvae of *Busseola fusca* in maize planted on different dates at Roma, Lesotho, during the 1995/96 and 1996/97 growing seasons.

Planting date	Mean damaged internodes per plant (%)	
	1995/96	1996/97
P1 (Nov. 11)	0.7 b	24.9
P2 (Nov. 24)	2.7 b	20.2
P3 (Dec. 8)	10.7 a	23.5
P4 (Dec. 22)	3.8 b	20.4
P5 (Jan. 5)	1.1 b	27.4
F-value	13.85	1.07
P-value	0.0002	0.4136
LSD (P=0.05)	3.3	n.s.*

Differences between means within the same column followed by the same letter are not statistically significant at P=0.05 (LSD).
n.s.*..... not significant ($P>0.05$).

The third planting (P3) sustained a significantly higher ($P<0.05$) proportion of damaged ears than other plantings during the 1995/96 season (Table 10.6). No ear damage was recorded in the last planting (P5) of this season. By contrast, there were no significant differences ($P>0.05$) in the percentages of ear damage sustained by the five plantings during the 1996/97 season, although the late plantings (P4 & P5) recorded lower incidences than the earlier plantings (Table 10.6).

Table 10.6: Average number of ears produced per plot and percentage of ears damaged by larvae of *Busseola fusca* in maize planted on different dates at Roma, Lesotho, during the 1995/96 and 1996/97 growing seasons.

Planting date	Average number of ears produced per plot		Percentage of ears damaged per plot	
	1995/96	1996/97	1995/96	1996/97
P1 (Nov. 11)	25.8	24.0 a	4.2 bc	36.7
P2 (Nov. 24)	27.8	25.5 a	6.1 b	39.4
P3 (Dec. 8)	25.0	26.0 a	12.6 a	40.4
P4 (Dec.22)	26.8	19.3 a	6.5 b	25.7
P5 (Jan. 5)	26.5	11.8 b	0.0 c	23.5
F-value	0.88	6.88	7.52	2.90
P-value	0.5023	0.0041	0.0028	0.0685
LSD(P=0.05)	n.s.*	7.0	5.1	n.s.

Means within the same column followed by the same letter are not significantly different at P=0.05 (LSD). n.s.* ....not significant (P>0.05).

A higher incidence of ear damage was associated with earlier plantings in the 1996/97 season (Table 10.6), in spite of late plantings having higher incidences of infestation than the early plantings, prior to tasselling (9-10 WAE) and up to 20 WAE (Table 10.3). This observation is in contrast to a report by Van Rensburg *et al.* (1988c), that the highest incidence of ear damage relates to oviposition occurring before tasselling. This disparity could be due to differences in methodology, since the observation in this study was based only on damage to ears that were formed, not taking into account ears which failed to be produced as a result of severe early infestation of the relatively young plants in later plantings. Thus, the late plantings of 1996/97 produced fewer ears than the earlier plantings, whereas the number of ears produced were similar for all plantings during 1995/96 when infestations were generally low (Table 10.6). This explanation would be vindicated by the report by Van Rensburg *et al.* (1988), that damage to ear stems at an early stage could lead to total loss of such ears, without assigning this loss to *B. fusca*.

The high incidence of ear damage in the November plantings (P1 & P2) during 1996/97, indicates that direct damage to ears does occur in both early and late plantings. This could be quite high even in early plantings, particularly during seasons with generally high moth activity. Van Rensburg *et al.* (1988) reported similar findings.

Yield loss was generally low during the 1995/96 season, and differences among the plantings were not significant (P>0.05) (Table 10.7). Numerically, however, P3 sustained the highest loss during that season. During 1996/97, P3 also recorded the highest yield loss and was significantly higher (P<0.05) than P1 and P2 (Table 10.7). Generally, yield losses during the 1996/97 season were higher in later plantings than in earlier plantings. This was despite observations that similar levels of internode damage occurred in both early and late plantings (Table 10.5), and even though incidence of ear damage was higher in the early plantings (Table 10.6). This was ascribed to the onset of damage in the earlier plantings occurring at relatively late plant growth stages, when plants were less susceptible to damage, and to a higher severity of ear damage in the late plantings. Van Rensburg *et al.* (1988) reported that ear damage was more severe in late than in November plantings.

Table 10.7: Yield loss due to damage by *Busseola fusca* in maize planted on different dates at Roma, Lesotho, during the 1995/96 and 1996/97 growing seasons.

Planting date	Yield loss (%)		% reduction in number of ears produced (1996/97)
	1995/96	1996/97	
P1 (Nov. 11)	1.3	18.3 bc	8.5 b
P2 (Nov.24)	1.7	12.7 c	7.7 b
P3 (Dec. 8)	5.3	36.6 a	6.2 b
P4 (Dec. 22)	3.6	26.0 abc	22.3 ab
P5 (Jan. 5)	0.4	31.4 ab	41.3 a
F-value	1.44	3.36	5.28
P-value	0.2795	0.0461	0.0109
LSD(P=0.05)	n.s.*	16.2	20.0

Means within the same column followed by the same letter are not significantly different at P=0.05 (LSD). n.s.* = not significant (P>0.05).

Late plantings (P4 and P5) showed higher reductions in the number of ears produced than other plantings, although only P5 differed significantly ($P<0.05$) (Table 10.7). This was also attributed to the relatively early stages at which these plants were infested, as compared to the late onset of infestation in the earlier plantings. Van Rensburg *et al.* (1988c) reported similar findings.

Generally, results in Table 10.7 suggest that in the study area, substantial yield losses can occur both in early (November) and late (December/early January) plantings during seasons with high incidence of infestation. Considering the relatively late onset of infestation in early plantings, results also indicate that damage to plants after tasselling could be important.

Of the two direct causes of yield loss *viz*: reduction in the number of ears produced per plant and direct damage to ears, the latter appeared to be the main factor responsible for losses in the earlier (November and early December) plantings. This is because it was observed that P3 sustained a higher yield loss than P1 and P2 (Table 10.7), despite observations that percentage of damaged ears and reduction in ear numbers were similar for all three plantings (Tables 10.6 & 10.7). It can, therefore, be deduced that direct damage to ears was more severe in P3 than in P1 and P2. In the case of the late plantings (late December and early January plantings), both factors appeared to be important, although reduction in the number of ears produced seems to have played a more important role. This was due to both parameters being quite high in both of these plantings. However, reduction in ear numbers is particularly important in late plantings, since infestation resulting in the development of fewer ears amounts to an absolute yield loss, whereas the importance of direct damage to ears in a planting is largely dependent on the severity of such damage (*i.e.* the extent of damage to kernels).

CONCLUSION

Infestation by *B. fusca* could result in yield loss in both early and late planted maize in Lesotho, although, the extent of yield loss in a planting may vary from season to season.

Within a given planting season, the incidence of infestation and consequent yield loss tended to increase with delay in planting date. It is therefore recommended that planting early in November should be practised to minimise stalk borer damage. However, early onset of infestation and/or high second generation moth flight activity, as well as late planting due to delayed rainfalls could lead to high yield losses unless additional control measures are employed. The effective use of this information by extension services can impact significantly on maize production in Lesotho.

CHAPTER 11

EFFECT OF INTERCROPPING WITH BEANS (*PHASEOLUS VULGARIS* L.) ON DAMAGE AND YIELD LOSS IN MAIZE, CAUSED BY THE STALK BORER, *BUSSEOLA FUSCA* (FULLER) (LEPIDOPTERA: NOCTUIDAE) IN LESOTHO.

ABSTRACT

The effect of intercropping maize with beans (*Phaseolus vulgaris* L.) on damage and yield loss caused by *Busseola fusca* (Fuller) in maize was studied in two field trials, during the 1995/96 and 1996/97 growing seasons. Data collected were incidence of plant damage, number of borer individuals that colonized plants, degree of internal plant damage, incidence of damaged ears and grain yield. Maize in intercrops sustained less damage and yield loss compared to maize in monocrops. Alternating rows of maize with rows of beans was more effective in limiting damage and yield loss due to *B. fusca* than when the two crops were alternated within a row. In the absence of *B. fusca* infestation, maize in an alternate-row cropping arrangement produced yields comparable with that of a high-density monocrop maize. There was also the advantage of a beans harvest in the maize/beans intercrop. Therefore, maize/beans intercropping appears to have a good prospect as a cultural management strategy against *B. fusca* in Lesotho.

Key words: *Busseola fusca*, intercropping, maize, *Phaseolus vulgaris*, yield loss.

INTRODUCTION

Intercropping is a widespread practice in traditional farming systems in many parts of the world (Seshu Reddy, 1990). Reasons for practising intercropping include safeguarding, through crop diversification, against total crop failure in the event of natural disasters such as droughts and pest outbreaks, and to produce a variety of crops needed for subsistence on a small holding. Research has shown that intercropping also has other benefits. These include reduction in the populations of pests of one or more of the crops included in the cropping mixture (Amoako-Atta *et al.*, 1983; Uvah & Raheja, 1985; Seshu Reddy, 1990; Andow, 1991; Alghali, 1993), reduction in the severity of some diseases (Kikoka *et al.*, 1989), improved weed control (Adeyemi, 1989; Dissemond & Hindorf, 1989) and increased total yields (Amoako-Atta & Omolo, 1983). Intercropping may also result in a reduction in the amount of insecticides needed for the effective management of pests (Alghali, 1993), thereby reducing production costs, as well as the negative effects of pesticides on the environment.

Agriculture in Lesotho is largely of a subsistence nature (Anon., 1986), and intercropping is practised by some farmers in this country. A survey carried out at various localities in the country during the 1996/97 growing season (see chapter 8) indicated that close to 30 % of the farmers intercropped maize (the staple food grain of the Basotho people) with crops such as beans, pumpkins, potatoes and sorghum. The survey also showed that the most commonly practised cropping mixture is maize with common beans (*Phaseolus* spp.). A similar trend was indicated in earlier reports on crop production in Lesotho (Anon. 1991a, 1996).

Productivity of maize in Lesotho is often constrained by, among other factors, lack of pest control (Anon., 1986). Among the important pests of maize in this country is the stalk borer, *Busseola fusca* (Qhobela *et al.*, 1986). Reports from elsewhere have shown that some intercropping patterns reduce the incidence of infestation by stalk borers (Altieri *et al.*, 1978; Amaoko-Atta & Omolo, 1983; Mahadevan & Chelliah, 1986; Lambert *et al.*, 1987; Dissemond, 1990). However, other reports have indicated that intercropping has only a limited effect on pest populations. Skovgård & Päts (1996) reported that growing maize together with cowpea had only limited potential as a means of controlling the main pests of maize. Reports also indicated that some intercropping patterns may actually lead to higher incidence of crop damage by pests (Amoako-Atta *et al.*, 1983; Dissemond & Hindorf, 1989) and diseases (Dissemond & Hindorf, 1989; Kikoka *et al.*, 1989). Therefore, in view of these diverse findings, the merits of a given intercropping system should be based on the pest/disease situation in the target locality. In Lesotho, there is no report on the effect of intercropping on stalk borer infestations in maize.

The aim of this study was to assess the potential of a cereal/non-cereal intercropping system as a cultural pest management measure against *B. fusca* in Lesotho. The focus of the investigation was the evaluation of the effect of intercropping maize with beans (*P. vulgaris* L.) on the incidence of plant damage and extent of yield loss caused by *B. fusca* in maize grown in a maize/beans intercrop relative to maize grown as monocrop. The study also considered the effect of row spacing of maize on the above parameters.

MATERIAL AND METHODS

Two field trials were conducted at Roma (29°27′ S, 27° 44′ E), Lesotho, during the 1995/96 and 1996/97 growing seasons. Four cropping arrangements (treatments) were employed during each season. These were maize (commercial hybrid PAN6363) and beans alternated within the same row (maize/beans intra-row), maize and beans arranged in alternate rows within a plot (maize/beans alternate row), and two sole maize treatments, each at a different plant population density.

The experimental design was a randomized complete block with four replications. Plot size for each treatment was 6 m (width) x 12 m (length). For the maize/beans intra-row mixture (T1), maize and beans were alternately sown 0.3 m apart within rows which were 1.0 m apart. Each plot in this treatment consisted of seven rows of plants. Plant spacing for the maize/beans alternate row treatment (T2) was 0.3 m within rows for both crops, and 1.0 m between alternating rows of maize and beans. Thus, there were seven rows of plants per plot, with alternation beginning with a maize row in each plot. One sole maize treatment (T3) comprised of seven rows of plants, with plants spaced 0.3 m apart within rows and 1.0 m between rows. Another sole maize treatment (T4) comprised of 4 rows of plants with intra- and inter-row spacing of 0.3 m and 2.0 m respectively. Each plot was bordered on all sides by a 3.0 m-wide open space.

Seeds were planted manually during early December of each season. Only one plant was allowed per hill for both maize and beans. At three weeks after emergence (WAE), each plot was divided into two halves (sub-plots) across its width. Maize plants in each sub-plot were protected against stalk borer damage through treatment with Kombat granules (carbaryl 25 g a.i./kg) at the rate of 4 kg of product per hectare. Insecticide treatment, which was applied at fortnightly intervals, commenced at 3 WAE, and continued until flowering. In order to calculate yield loss, plants in the other sub-plot were not treated with the insecticide and were subjected to natural *B. fusca* infestation.

Data collected on maize plants were incidence of plant damage by *B. fusca*, level of infestation, level of internal plant damage, incidence of ear damage and grain yield.

The incidence of infestation by *B. fusca* (percentage plants with whorl damage, stem damage, ear damage) was determined by *in-situ* visual assessment at fortnightly intervals, beginning at 4 WAE, continued until 20 WAE and again at harvest. During each sampling, all maize plants in the two central rows of the unprotected sub-plots of the maize/beans alternate-row and sole maize (2.0 m inter-row spacing) treatments were investigated for symptoms of infestation. For the maize/beans intra-row mixture and the sole maize (1.0 m inter-row spacing) treatments, all maize plants in the third and fifth rows of the unprotected sub-plots were investigated for symptoms of infestation.

The level of infestation (number of *B. fusca* individuals that successfully colonized plants) was assessed on 25 plants taken at random from each unprotected sub-plot at harvest. For the maize/beans alternate row and the sole maize (2.0 m row spacing) treatments, plant samples were taken from the two central rows of each unprotected sub-plot, while plants were sampled from the third and fifth rows of each unprotected sub-plot in the maize/beans intra-row and the sole maize (1.0 m row spacing) treatments. Plants were dissected and the number of larvae, pupae and pupal cases was determined for each sub-plot.

The level of internal plant damage (percentage internodes damaged by *B. fusca*) was determined at harvest. For this purpose, the same 25 plants dissected for the assessment of level of infestation were evaluated. The total number of internodes and percentage of those damaged by borers were determined for each unprotected sub-plot. The mean percentage of damaged internodes per plant was then calculated for each unprotected sub-plot.

The incidence of ear damage (percentage of ears damaged by *B. fusca*) was also assessed at harvest for each unprotected sub-plot. For this, all ears were harvested from the same 25 plants used for the evaluation of the level of internal plant damage. The total number of ears produced and the number of those exhibiting borer damage were determined. The percentage of ears damaged by borers was then calculated for each unprotected sub-plot.

Grain yield was assessed for both insecticide-treated and untreated sub-plots at harvest. For the unprotected sub-plots, the same ears harvested for the assessment of incidence of ear damage were shelled and grain mass determined. For the insecticide-treated sub-plots, 25 plants were removed from each sub-plot using the same procedure described for the unprotected sub-plots. Ears from these plants were also harvested, shelled and grain mass determined for each sub-plot. Yield loss was determined as the difference between the yield of plants in the insecticide-treated and the unprotected halves of each plot, calculated as a percentage of the yield of plants in the insecticide-treated half.

Data were subjected to analyses of variance and differences between means separated using the Least Significance Difference (LSD) test at P=0.05.

RESULTS AND DISCUSSION

The maize/beans intercrops (T1 and T2) were practically consistent in sustaining lower incidences of *B. fusca* infestation in maize than the maize monocrops (T3 and T4) during both growing seasons (Figs. 11.1 & 11.2). T2 (maize/beans alternate row arrangement) showed the lowest incidence of infestation during the 1996/97 season (Fig. 11.2). However, the differences among the treatments were not statistically significant (P>0.05), except at 18 WAE during the 1995/96 season when T3 recorded a significantly higher (LSD= 2.4, P= 0. 0199) percentage of infested plants than all the other cropping arrangements. These observations seem to suggest that the presence of beans in the intercrops (T1 and T2) served to reduce the incidence of infestation in these treatments. This finding is in agreement with the report that intercropping maize with a non-cereal crop reduces the incidence of infestation by stalk borers of maize (Amoako-Atta *et al.*, 1983).

The observation by Van Rensburg *et al.* (1988b), that maize with wider row spacing sustained lower incidence of borer damaged plants, was generally corroborated by these results when maize/beans intercrops and maize monocrops were compared separately. Thus, the maize/beans alternate-row mixture (T2) generally sustained lower incidences than the maize/beans intra-row mixture (T1), while the low-density monocrop maize (T4), had lower incidences of infestation than the high-density monocrop maize (T3) (Figs. 11.1 & 11.2). The observed differences were either a result of higher levels of oviposition in the treatments with closer spacing of maize plants, or/and due to higher rate of larval dispersal and survival at the higher maize population. Van Rensburg *et al.* (1988b) ascribed similar observations to higher larval migration at higher host plant densities.

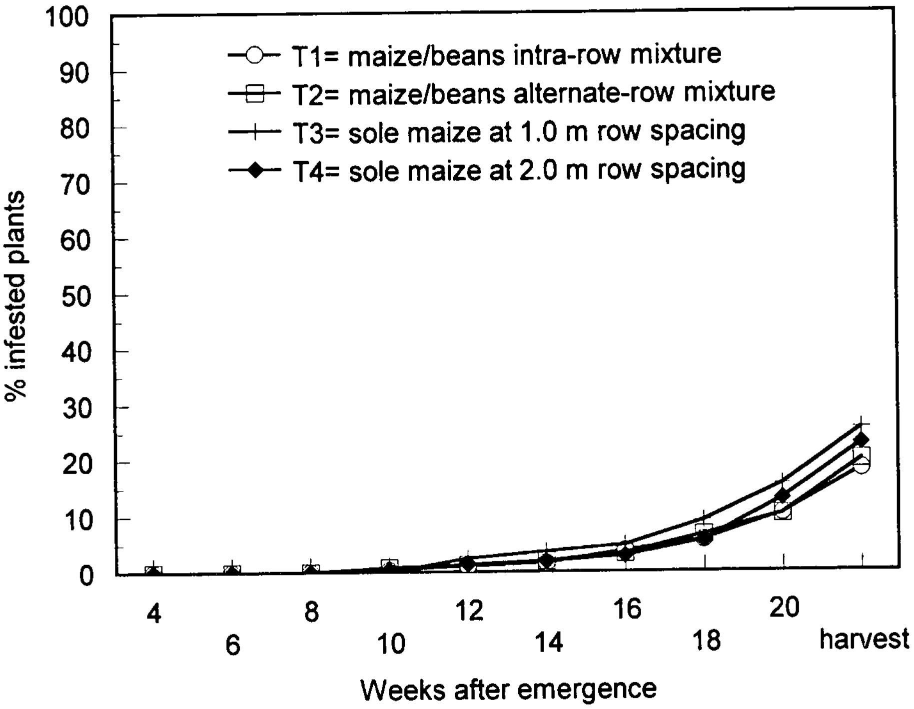

Fig. 11.1: Number of plants (%) infested by *Busseola fusca* in sole maize and maize/beans intercrops planted at Roma, Lesotho, during the 1995/96 season.

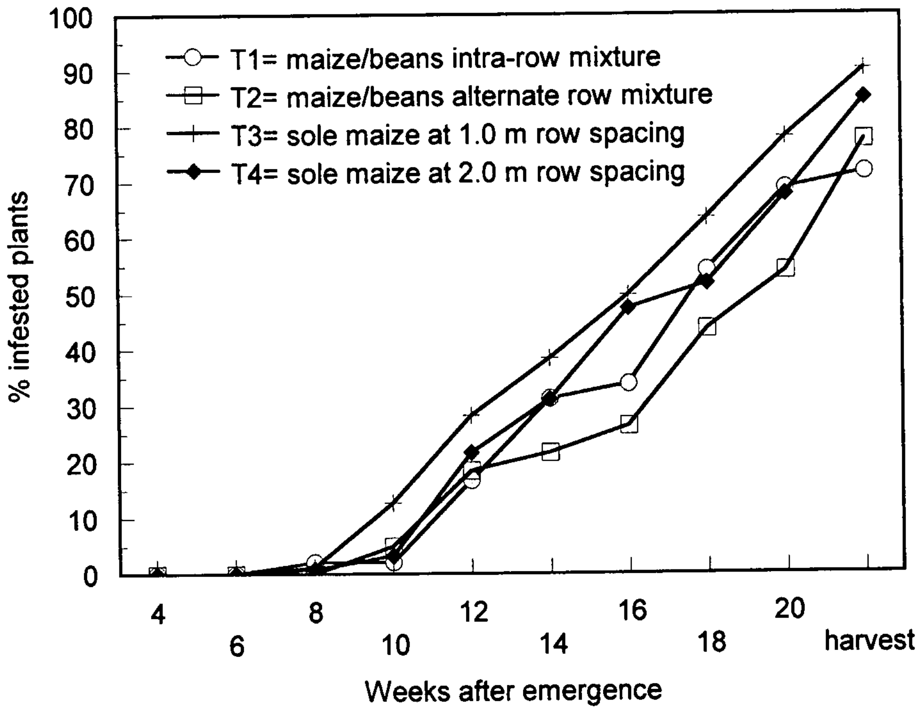

Fig. 11.2: Number of plants (%) infested by *Busseola fusca* in sole maize and maize/beans intercrops planted at Roma, Lesotho, during the 1996/97 season.

Results with respect to the level of internal plant damage, level of *B. fusca* infestation and percentage ear damage (Table 11.1) followed a similar trend as the incidence of infestation (Figs. 11.1 & 11.2). The maize/beans mixtures (T1 and T2) showed lower levels of internal plant damage, hosted fewer *B. fusca* individuals and sustained lower incidences of ear damage than both sole maize treatments (T3 and T4) (Table 11.1). The high-density sole maize crop (T3) had the highest values for all these parameters. Dissemond (1990) and Skovgård & Päts (1996) reported similar findings in terms of levels of infestation in maize/cowpea intercrops in Kenya. However, the differences in this study were not significant (P>0.05).

Table 11.1: Level of internal plant damage, level of *Busseola fusca* infestation, and percentage ear damage in sole maize and maize/beans intercrops planted at Roma, Lesotho, during the 1995/96 and 1996/97 growing seasons. (T1= maize/beans intra-row mixture, T2= maize/beans alternate row mixture, T3= sole maize at 1.0 m row spacing, T4= sole maize at 2.0 m row spacing).

Cropping pattern	Average number of damaged internodes per plant (%)		Average number of larvae/pupae/pupal cases per plot		Average number of damaged ears per plot (%)	
	1995/96	1996/97	1995/96	1996/97	1995/96	1996/97
T1	8.0	21.1	4.8	15.8	5.7	30.9
T2	7.7	22.0	4.1	17.8	4.5	25.5
T3	11.2	31.0	5.8	25.3	8.0	58.5
T4	6.9	26.2	3.3	19.5	3.8	34.0
F-value	0.61	0.94	0.35	2.00	0.27	1.37
P-value	0.6279	0.4622	0.7892	0.1845	0.8457	0.3140
LSD (P=0.05)	5.6 n.s.*	14.9 n.s.	4.0 n.s.	9.8 n.s.	9.0 n.s.	39.9 n.s.

n.s.*= not significant (P>0.05).

With regard to maize yields, only figures for the 1996/97 season are presented (Table 11.2), as *B. fusca* infestation was very low during the 1995/96 season (Fig. 11.1). Generally, the insecticide-treated sub-plots of T2 and T4 (both with maize in rows spaced 2.0 m apart) yielded higher than those of T1 and T3 (with maize in rows spaced 1.0 m apart) (Table 11.2). T2 (maize/beans alternate row mixture) produced slightly lower yields than T4 (sole maize at 2.0 m row spacing), while T1 (maize/beans intra-row mixture) yielded only slightly higher than T3 (sole maize at 1.0 m row spacing). However, differences were not significant (P>0.05). Nevertheless, these observations seem to suggest that in the absence of *B. fusca* infestation, the mere presence of beans did not influence the yield of maize in the intercrops. This appears to indicate that the main factor which influenced the yield of maize plants in the insecticide-treated sub-plots was the difference in row spacing which, presumably, reduced plant competition for resources in the rows with wider spacing. Van Rensburg *et al.* (1988b) also reported similar findings and attributed the differences to increased competition for soil and water at higher plant population density.

Table 11.2: Yield of maize (1996/97 growing season) and yield loss due to *Busseola fusca* infestation (1995/96 and 1996/97 growing seasons) in sole maize and maize/beans intercrops planted at Roma, Lesotho. (T1= maize/beans intra-row mixture, T2= maize/beans alternate row mixture, T3= sole maize at 1.0 m row spacing, T4= sole maize at 2.0 m row spacing).

Cropping pattern	Average yield per plot (g) (1996/97)		Average yield loss per plot (%)	
	Treated plants	Unprotected plants	1995/96	1996/97
T1	2532.3	2017.8 bc	2.0	21.8
T2	4039.3	3403.0 a	1.8	13.1
T3	2429.0	1442.5 c	3.0	37.2
T4	4219.8	2798.8 ab	2.3	31.7
F-value	2.90	4.60	1.14	1.47
P-value	0.0941	0.0325	0.3836	0.2867
LSD (P=0.05)	1795.7 n.s.*	1285.1	1.7 n.s.	28.2 n.s.

Means within the same column followed by the same letter are not significantly different at P=0.05 (LSD). n.s.*= not significant (P>0.05).

In the unprotected sub-plots, the maize/beans alternate-row intercrop (T2) yielded higher than all the other cropping arrangements in the study, and was significantly higher (P<0.05) than those of T1 and T3 (Table 11.2). Yield in unprotected T2 was more than double that in unprotected T3. T1 (maize/beans intra-row mixture) also yielded higher than T3, even though maize was spaced in rows 1.0 m apart in both treatments. These observations seem to indicate that, whereas row spacing was the main factor influencing maize yields in the absence of *B. fusca* infestation, the combined effects of row spacing and the presence of beans determined plant performance under *B. fusca* infestation.

Yield loss due to *B. fusca* damage during the 1995/96 season was low compared to that in the 1996/97 season. This was attributed to the low incidence of *B. fusca* infestation and damage during the former season (Fig. 11.1). Generally, maize in the maize/beans intercrops (T1 and T2) sustained lower yield losses than those in the monocrops (T3 and T4) during both seasons (Table 11.2). T2 (maize/beans alternate-row mixture) sustained the lowest yield loss, while the high-density maize monocrop, T3, sustained the highest loss during both seasons. This is in line with the observation that T3 recorded the highest incidence of plant damage (Fig. 11.2), level of internal plant damage, level of infestation and incidence of ear damage (Table 11.1) during both growing seasons. This finding differs from that by Van Rensburg *et al.* (1988b) under artificial *B. fusca* infestation, who found that yield loss decreased with increased plant population, an observation which they attributed to a higher rate of larval dispersal at higher plant population. This resulted in fewer larvae per plant during the early stages of crop development, thereby resulting in reduced net yield loss.

The mechanism by which the maize/beans intercrops reduced *B. fusca* infestation, plant damage and yield loss was not investigated in this study. However, it has been speculated that the presence of cowpea in a cowpea/cereal mixture might affect the visual stimuli or perceptions which attract borer moths to their hosts during the early stages of crop growth (when both crops are of similar heights) (Amoako-Atta *et al.*, 1983). This possibility does not appear to have played an important role in this investigation, since onset of infestation was generally late (Figs. 11.1 & 11.2), by which time maize plants were much taller than the bean plants. However, lower incidence of infestation in the intercrops suggests that oviposition was lower in these treatments. It has been reported that more egg batches of another stalk borer pest of maize, *Chilo* spp., were laid in monocrop maize than in maize/cowpea intercrop in Kenya (Päts *et al.*, 1997). This is probably because female stalk borer moths may locate suitable hosts more easily in monocrops than in intercrops, a situation that probably causes the moths to deposit fewer eggs in intercrops (Skovgård & Päts, 1996; Päts *et al.*, 1997). Another possible reason for the observed differences is due to higher secondary infestations in the monocrops than in the intercrops. This, presumably, is possible because it would be easier for larvae to successfully migrate to new hosts when the plants are standing closer to each other (as in the monocrop maize), than when plants are further apart (as in the intercrops). Larvae would not be exposed for too long to predators, parasites and unfavourable weather conditions during this process at closer host plant spacing. Van Rensburg *et al.* (1988b) reported that stalk borer larval migration is favoured by an increase in host plant population

The lack of statistical significance (at P= 0.05) for some of the parameters considered in this study may be attributed to the characteristically irregular pattern of distribution of plant damage under natural borer infestation. This causes high variability. Nevertheless, a general pattern was observed namely, that intercropping maize with beans reduced damage and yield loss caused by *B. fusca* in maize. In this respect, the maize/beans alternate row cropping arrangement was more effective. The unprotected plants in this cropping arrangement produced yields which more than doubled that of the unprotected high-density monocrop maize, which is the most commonly employed maize cropping arrangement employed by farmers in Lesotho. There was also an additional beans harvest in the intercrop. This finding is important, particularly if one takes into consideration the fact that most of Lesotho's farmers are small-scale and resource-poor. Such category of farmers would benefit from any low-cost cultural practice that could contribute towards increased yields and reduced crop losses.

CONCLUSION

The potential of maize/beans intercropping, especially as a component of an integrated stalk borer management system in Lesotho, appears to be promising and deserves to be investigated further. It might also be worthwhile to investigate the effect of other cropping mixtures (such as maize/sunflower, maize/pumpkin, maize/potato -all of which are also employed by farmers in Lesotho) on stalk borer infestations. This might identify possible effective intercropping alternatives for farmers.

CHAPTER 12

THE INCIDENCE OF *DORYLUS* ANTS AND PARASITOIDS AS MORTALITY FACTORS OF THE MAIZE STALK BORER, *BUSSEOLA FUSCA* (FULLER) (LEPIDOPTERA: NOCTUIDAE), AND THE SPOTTED STALK BORER, *CHILO PARTELLUS* (SWINHOE) (LEPIDOPTERA: PYRALIDAE), IN LESOTHO.

ABSTRACT

Natural enemies of stalk borers were collected during field surveys conducted in Lesotho. Parasitoids and ants were sampled at regular intervals in field trials. Two braconid species, *Bracon sesamiae* Cameron and *Cotesia sesamiae* (Cameron), were found to parasitize the larvae of the stalk borers, *Busseola fusca* (Fuller) and *Chilo partellus* (Swinhoe) in maize and sorghum. Two other species, *Euvipio* sp. and *Habrobracon brevicornis* (Wesmael), were reared from *B. fusca* larvae. *B. sesamiae* was the most abundant and most widespread of the four larval parasitoids. Pupal parasitism was rare, and only three individuals of an unidentified ichneumonid species were reared from *C. partellus* pupae in sorghum. Egg parasitism was not observed. Red ants (*Dorylus* sp.) were found to be important and widely distributed predators of both *B. fusca* and *C. partellus* larvae. Because the activities of these natural enemies increased towards the end of the growing season, they were presumed not to exert a pronounced effect on stalk borer populations during most of the host plants' growing period. However, their possible collective role in reducing the size of carry-over populations is emphasised.

Key words: *Busseola fusca*, *Chilo partellus*, parasitoids, predators.

INTRODUCTION

The African maize stalk borer, *Busseola fusca*, is indigenous to Africa (Skoroszewski & Van Hamburg, 1987; Harris & Nwanze, 1992) and occurs in all mainland countries south of the Sahara (Appert, 1970; Kfir, 1997a, b). Although its principal host is regarded to be maize, it is damaging to sorghum as well as pearl millet and some wild grasses (Seshu Reddy, 1983; Kfir, 1995).

The spotted stalk borer, *Chilo partellus*, is another important cereal crop pest. It is regarded as the most damaging stalk borer of sorghum in eastern Africa, as well as in India (Young & Teetes, 1977; Harris, 1989b; Overholt *et al.*, 1994). Currently, it is one of the most important pests of sorghum in South Africa (Van den Berg, 1994). It is also damaging to maize and millets (Doggett, 1988; Harris, 1989b). Indigenous to Asia , *C. partellus* was first recorded in Malawi, East Africa in 1932 (Tams, 1932). From East Africa, it spread to southern parts of the continent (Annecke & Moran, 1982).

Several studies have been done on the biology, ecology and control of *B. fusca* and *C. partellus*. Although chemical control still remains the main tool for their control, especially on large-scale commercial farms, it is not the most desirable option. This is due to the high costs involved, as well as the negative impact of pesticides on the environment. Furthermore, chemical control is often ineffective and uneconomical to use (Kfir, 1990c; Van den Berg, 1994). Research on chemical control of stalk borers has, therefore, been scaled down in recent years (Harris, 1989b) and researchers are focusing more on the development of integrated pest management systems. This involves the use of non-chemical pest control methods, with the aim of limiting insecticide use. Such non-chemical methods include the use of natural enemies such as parasitoids and predators.

Although parasitoids and predators of *B. fusca* and *C. partellus* have been reported elsewhere in Africa (Mohyuddin & Greathead, 1970; Sagnia, 1983; Seshu Reddy, 1983; Van Rensburg *et al.*, 1988a; Bonhof *et al.*, 1997; Kfir, 1990b, 1995, 1997a), no such information has been obtained in Lesotho. The aim of this study was to identify, as well as determine the geographical occurrence of species of parasitoids and predators which attack *B. fusca* and *C. partellus* in Lesotho. This study provides some basic information which should be useful in planning a sustainable integrated management system for these stalk borers in Lesotho.

MATERIAL AND METHODS

Field and laboratory study and field surveys were conducted in the lowland and mountain regions of Lesotho to collect natural enemies of stalk borers.

The field and laboratory study was aimed at identifying the species of parasitoids of *B. fusca* and *C. partellus* and at determining their period of activity through regular sampling on an experimental plot at Roma (elevation 1660 m above sea level =asl). Being situated in the lowland region of Lesotho, Roma experiences warm rainy summers and cold dry winters during which night temperatures often fall below freezing. Snow falls are, however, occasional. For this investigation, maize (PAN6363, a commercial hybrid) and sorghum (White Seqhobane, a local variety) were planted in November of the 1995/96 and 1996/97 growing seasons on an experimental plot. The plot size for maize was 20 rows, each 45 m in length. Plant spacing was 0.75 m between rows and 0.25 m within rows. Sorghum plots consisted of 8 rows, each 45 m in length. Plant spacing was 0.75 m between rows and 0.15 m within rows. Plants were subject to natural infestation of stalk borers and neither herbicides nor insecticides were applied at any stage. Because of the relatively small size of the experimental plots and the need for destructive sampling of plants, samples were often supplemented with those obtained from other maize and sorghum plots in the vicinity of the experimental area.

Commencing at four weeks after emergence, both maize and sorghum plants were observed at weekly intervals for eggs of *B. fusca* and *C. partellus*. Egg batches were collected and kept at room temperature, in petridishes lined with tissue paper which were kept moist with a few drops of water as often as necessary, in order to prevent desiccation of eggs. Eggs were observed daily for the emergence of insects other than stalk borer larvae, or until they hatched.

In order to identify the species that parasitized the larvae and pupae of *B. fusca* and *C. partellus* and to determine their period of activity, larvae and pupae were collected from infested sorghum and maize plants at fortnightly intervals. The number of larvae and pupae collected during each sampling was largely determined by the incidence of infestation.

Larvae and pupae were kept at room temperature in clear glass jars with cotton wool plugs until parasitoids or stalk borer moths emerged, or until they died. Only specimens of the same species were kept in the same jar and pupae were kept separate from larvae. Sections of fresh maize or sorghum stems were placed inside each jar to serve as food for the larvae, as well as to increase the relative humidity in the jars, thereby preventing pupae from desiccating. Specimens were observed for parasitism on a daily basis and were transferred into clean jars with fresh stem cuttings as often as necessary. The number of larvae or pupae from which parasitoids emerged was recorded during each observation and emergent parasitoids were identified. Percentage parasitism was determined as the number of larvae or pupae parasitized, calculated as a percentage of the total number of larvae or pupae sampled. During winter and early spring (July to November), specimens were collected from stalks and stubble on and around the experimental plots, while larvae and pupae collected from early maize (October plantings) in the Roma area were observed for parasitoids during the months of November to February.

Since ants are known predators of stalk borers (Walters *et al.*, 1976; Seshu Reddy, 1983), and *Dorylus* ants were often observed in maize and sorghum fields, their activity around infested maize plants and residues was recorded at fortnightly intervals over two seasons at Roma. Since the incidence of infested plants varied during the season, sample size of plants varied accordingly. Incidence of ant activity was determined by counting the number of plants with *Dorylus* ants on and around their stems, and expressing it as percentage of the total number of infested plants observed.

The relative importance of each parasitoid/predator species during the growing season was determined at Roma on both maize and sorghum at harvest. Mortality of stalk borers caused by parasitoids, *Dorylus* ants and those due to unknown causes was determined at harvest (end of June). This was done by dissecting and collecting batches of parasitoid cocoons, live and dead larvae, and by determining the number of infested plants that showed evidence of ant activity (partially consumed larva and/or dead ants) in empty stalk borer galleries in the case of *Dorylus* ants. It was assumed that each batch of parasitoid cocoon represented one dead larva, while ant activity in an empty stalk borer gallery represented a single dead larva. Therefore, the total number of larvae assessed on each crop was taken as the number of live larvae, parasitoid batches, larvae killed by *Dorylus* ants and those killed by unknown causes, *i.e.* larvae whose death could not be attributed to either parasitoids or ants. The overall percentage stalk borer larval mortality was determined as the combined mortality due to all the factors, calculated as a percentage of the total number of larvae assessed per crop. The percentage mortality due to each factor was taken as a measure of its relative importance. This was determined as the number of host individuals (larvae) killed by each parasitoid species (as evidenced by the presence of parasitoid cocoons), *Dorylus* ants (as evidenced by the presence of dead or live ants inside stalk borer galleries) and unknown causes, calculated as a percentage of the total number of larvae assessed per crop.

Field surveys aimed at identifying the parasitoid species that occurred in the lowland and mountain regions were conducted during the 1995/96 and 1996/97 growing seasons. Stalk borer larvae and pupae were sampled at nine localities in the lowlands and at three localities in the highlands. Stalk borer larvae and pupae were collected from maize fields at various localities and reared at room temperature. Specimens were kept until parasitoids or moths emerged. However, due to difficulties associated with access to farmers' fields during the growing season, only a few plant samples could be obtained at a time, and sampling could not be done at regular intervals. As such, parasitoids obtained from such plant samples were used for identification purposes only. In order to assess parasitism which occurred during the growing season, at least 50 infested stems of each of maize and sorghum plants were obtained from each of 12 localities at harvest (July). These stems were dissected and all parasitoid cocoons were collected. The total number of batches of each parasitoid species per crop was recorded. Each parasitoid batch was taken as representing a single larva which was parasitized during the growing season. The relative importance of each parasitoid species in each crop and at each locality was determined by its abundance. This was determined as the number of batches of each parasitoid species, calculated as a percentage of the total number of parasitoid batches collected.

Identification of insect specimens was done by the Biosystematics Division of the Plant Protection Research Institute, Agricultural Research Council, Pretoria, South Africa.

RESULTS AND DISCUSSION

Two species of larval parasitoids were identified from the field/laboratory study at Roma. These were *Bracon sesamiae* Cameron (Hymenoptera: Braconidae), and *Cotesia sesamiae* (Cameron) (Hymenoptera: Braconidae). Each of these parasitoids was found to parasitize the larvae of both *B. fusca* and *C. partellus*, although *B. sesamiae* was the predominant parasitoid species at this locality. No parasitoids emerged from eggs of either *B. fusca* or *C. partellus* collected at Roma. Similarly, no pupal parasitoids emerged.

The period of activity of *B. sesamiae* (larvae) was studied on maize and sorghum at Roma (Tables 12.1 & 12.2). *B. sesamiae* was found to be active during the months of January to May (Tables 12.1 & 12.2). Its activity during the winter months could not be verified in this study, since it did not emerge from diapause larvae collected during June to October. Only moths emerged from such larvae during the following spring. However, *B. sesamiae* larvae and cocoons containing live individuals of the parasitoid were occasionally observed in infested sorghum stems during the month of July. Parasitism by *B. sesamiae* tended to be higher in sorghum than in maize, but was generally low in both crops (Tables 12.1 & 12.2), except during the months of April and May, when up to 31 % parasitism was recorded on sorghum in the 1996/97 season. The reason for this variation on the crops was not known. In South Africa, parasitism rates on *C. partellus* were found to be higher in maize than in sorghum (Kfir, 1992).

Table 12.1: Parasitism of *Busseola fusca* larvae by *Bracon sesamiae* in maize and sorghum at Roma, Lesotho, during the 1995/96 growing season.

Sampling date	Maize		Sorghum	
	Sample size (No. of *B. fusca* larvae)	Parasitism by *B. sesamiae* (%)	Sample size (No. of *B. fusca* larvae)	Parasitism by *B. sesamiae* (%)
15/11/95	4*	0.0	3*	0.0
30/11/95	0*	0.0	1*	0.0
14/12/95	0*	0.0	0*	0.0
31/12/95	14	0.0	0	0.0
15/01/96	26	0.0	5	0.0
31/01/96	38	0.0	12	0.0
14/02/96	15	0.0	19	0.0
28/02/96	24	0.0	17	5.9
15/03/96	38	5.3	39	5.1
31/03/96	54	3.7	43	11.6
15/04/96	65	6.2	52	7.7
30/04/96	74	4.1	58	10.3
15/05/96	57	3.5	46	19. 6
30/05/96	46	0.0	53	20.8
14/06/96	67	0.0	41	0.0
30/06/96	41	0.0	32	0.0
15/07/96	38	0.0	42	0.0
31/07/96	33	0.0	49	0.0
15/08/96	42	0.0	32	0.0
30/08/96	27	0.0	27	0.0
15/09/96	31	0.0	24	0.0
30/09/96	19	0.0	29	0.0
15/10/96	23	0.0	18	0.0
31/10/96	19	0.0	21	0.0

*... Samples are small because during this period, diapause larvae had mostly pupated or emerged as adult moths, while new infestations were still rare.

Table 12.2: Parasitism of *Busseola fusca* larvae by *Bracon sesamiae* in maize and sorghum at Roma, Lesotho, during the 1996/97 growing season.

Sampling date	Maize		Sorghum	
	Sample size (No. of *B. fusca* larvae)	Parasitism by *B. sesamiae* (%)	Sample size (No. of *B. fusca* larvae)	Parasitism by *B. sesamiae* (%)
15/11/96	2*	0.0	1*	0.0
30/11/96	0*	0.0	0*	0.0
14/12/96	2*	0.0	0*	0.0
31/12/96	15	0.0	0*	0.0
15/01/97	26	3.8	9	0.0
31/01/97	26	0.0	15	0.0
14/02/97	17	0.0	31	9.7
28/02/97	32	3.1	42	2.4
15/03/97	68	5.9	62	3.2
31/03/97	56	4.8	57	5.3
15/04/97	63	5.4	49	16.3
30/04/97	71	4.2	64	31.3
15/05/97	58	6.9	2	9.5
30/05/97	62	6.5	51	5.9
14/06/97	53	0.0	34	0.0
30/06/97	59	0.0	49	0.0
15/07/97	62	0.0	31	0.0
31/07/97	50	0.0	23	0.0
15/08/97	54	0.0	28	0.0
30/08/97	49	0.0	33	0.0
15/09/97	36	0.0	26	0.0
30/09/97	29	0.0	32	0.0
15/10/97	24	0.0	29	0.0
31/10/97	33	0.0	25	0.0

*... samples are very few because during this period, diapause larvae had mostly pupated or emerged as adult moths, while new infestation were still rare.

C. sesamiae and *B. sesamiae* were also recorded at other localities (Tables 12.3 & 12.4). It is assumed that the result on maize (Table 12.3) represents parasitism on *B. fusca*, being the only stalk borer attacking maize at all localities. However, that of sorghum (Table 12.4) does not differentiate between the two stalk borer species, as *B. fusca* and *C. partellus* often cohabited in sorghum plants at Maseru (1530 m asl), Mafeteng (1610 m asl), Siloe (1650 m asl) and Roma (1660 m asl). Results indicate that, whereas parasitism was recorded on maize at all the lowland localities, none was recorded on this crop at the mountain localities *e.g.* Semonkong (Table 12.3). Also, *B. sesamiae* was generally more predominant at each locality, and was more widespread than *C. sesamiae* (Table 12.3).

Similar observations were made on sorghum, although one batch each of *B. sesamiae* cocoons was found in this crop at Ha Lejone (2180 m asl) and Thaba-Tseka (2160 m asl) during the 1996/97 season (Table 12.4).

Table 12.3: Relative abundance of *Cotesia sesamiae* and *Bracon sesamiae* cocoon batches in **maize** at 12 localities in Lesotho, during the 1995/96 and 1996/97 growing seasons.

Locality	1995/96			1996/97		
	No. of parasitoid batches	% *C. sesamiae*	% *B. sesamiae*	No. of parasitoid batches	% *C. sesamiae*	% *B. sesamiae*
Lowlands						
Maseru	32	37.5	62.5	27	33.3	66.7
Siloe	12	100	0.0	9	0.0	100
Roma	51	11.8	88.2	87	0.0	100
Hlotse	18	0.0	100	23	0.0	100
Seaka Bridge	0	0.0	0.0	5	0.0	100
Teyateyaneng	24	0.0	100	28	0.0	100
Butha-Buthe	21	0.0	100	15	0.0	100
Mafeteng	30	40.0	60.0	22	18.2	81.8
Moyeni	0	0.0	0.0	2	0.0	100
Mountains						
Semonkong	0	0.0	0.0	0	0.0	0.0
Ha Lejone	0	0.0	0.0	0	0.0	0.0
Thaba-Tseka	0	0.0	0.0	0	0.0	0.0

Table 12.4: Relative abundance of *Cotesia sesamiae* and *Bracon sesamiae* cocoon batches in **sorghum** at 12 localities in Lesotho, during the 1995/96 and 1996/97 growing seasons.

Locality	1995/96			1996/97		
	No. of parasitoid batches	% *Cotesia sesamiae* (batches)	% *Bracon sesamiae* (batches)	No. of parasitoid batches	% *Cotesia sesamiae* (batches)	% *Bracon sesamiae* (batches)
Lowlands						
Maseru	29	55.2	44.8	35	40.0	60.0
Siloe	9	88.9	11.1	12	0.0	100
Roma	24	0.0	100	126	0.8	99.2
Hlotse	13	0.0	100	28	0.0	100
Seaka Bridge	0	0.0	0.0	3	0.0	100
Teyateyaneng	11	0.0	100	39	0.0	100
Butha-Buthe	3	0.0	100	24	0.0	100
Mafeteng	14	35.7	64.3	45	11.1	88.9
Moyeni	3	0.0	100	0	0.0	0.0
Mountains						
Semonkong	0	0.0	0.0	0	0.0	0.0
Ha Lejone	0	0.0	0.0	1	0.0	100
Thaba-Tseka	0	0.0	0.0	1	0.0	100

In addition to *C. sesamiae* and *B. sesamiae*, *Euvipio* sp. (Hymenoptera: Braconidae) and *Habrobracon brevicornis* (Wesmael) (Hymenoptera: Braconidae) were found to parasitize the larvae of *B. fusca* at Maseru and Mafeteng. Three individuals of an unidentified Ichneumonid species were also recorded on the pupae of *C. partellus*, which were collected at the end of March from infested sorghum stems at Mafeteng.

Aspects of the eco-biology of parasitoids and ants recorded during this study:

a) *Bracon sesamiae*

This species occurred as a gregarious larval ectoparasitoid of both *B. fusca* and *C. partellus*. During this study, between 2 to 14 individuals of *B. sesamiae* were recorded per host, with most (88.5 % of 61 batches in the 1995/96 season and 91.0 % of 133 batches in the 1996/97 season) occurring in batches of 10 individuals or less. Four to eight individuals per host have been reported in South Africa, where it is the second most abundant larval parasitoid of *B. fusca* (Kfir, 1995, 1997a). The parasitoid larvae were observed attached to the host upon which they fed until they pupated. *B. sesamiae* was found to be the most widespread parasitoid species during this study, having been recorded at 9 of the 12 localities (Tables 12.3 & 12.4). However, its occurrence on each crop varied seasonally at each locality. The parasitoid seems to be relatively more important on stalk borers in Lesotho than in commercial maize and sorghum farming areas in neighbouring South Africa, where parasitism level of this species is much lower (Kfir, 1992; Kfir & Bell, 1993). Also, compared to *C. sesamiae*, *B. sesamiae* seems to be more abundant in Lesotho than in South Africa where it is rare (Kfir, 1990b, 1992).

b) *Cotesia sesamiae*

This is a gregarious endoparasitoid of *B. fusca* and *C. partellus* larvae. In contrast to its wide distribution and importance in South Africa, this species was less widespread than *B. sesamiae*, and was only recorded at Siloe, Mafeteng, Maseru, and Roma. Its occurrence at Roma was, however, very rare during this study (Tables 12.3 & 12.4). Fully grown parasitoid larvae emerged through the skin of the host larva and, shortly afterwards, made small whitish cocoons (about 3 to 4 mm long) inside which they pupated. Cocoons were usually found next to, or surrounding the body of the host. Between eight and 79 individuals were recorded on a single *B. fusca* and nine to 62 individuals per *C. partellus* host. Similar observations have been reported elsewhere, although higher numbers of parasitoid individuals per host have been observed (Mally, 1920; Mohyuddin, 1971; Kfir, 1990b). It was also observed that a parasitized larva, which became very sluggish, did not die immediately after the emergence of parasitoid larvae through its skin, but remained alive for a few more days. Active *C. sesamiae* were only recorded from March to May. It was not reared from diapause larvae collected during and kept throughout the winter months (June-October). It has been reported that, in areas where the hosts are forced into hibernation due to cold weather, this parasitoid over-winters in the cocoon stage or as larvae inside diapausing host larvae (Mohyuddin, 1971).

C. sesamiae is widespread in Africa, having been reported to occur in South Africa (Van Rensburg & Van Hamburg, 1975; Kfir, 1990b), East Africa (Mohyuddin & Greathead, 1970; Minja, 1990), and West Africa (Harris, 1962). Van Rensburg *et al.* (1988a) described it as the only parasitoid of special importance in South Africa, while Kfir (1992) referred to it as the most abundant larval parasite of *C. partellus*. However, whereas Van Rensburg *et al.* (1988a) reported that *C. sesamiae* contributes mainly to borer mortality during winter months in South Africa, Kfir (1990b, 1992) reported that it is active throughout the season and it causes high larval mortality towards the end of the growing season.

c) *Euvipio* sp.

This was a large, solitary larval parasitoid which was recorded on *B. fusca* larvae in sorghum, towards the end of April at Maseru. The parasitoid larva consumed the entire host, after which it spun a cocoon inside the sorghum stalk where it pupated. Similar observations were reported by Kfir (1990b). In South Africa, this parasitoid species has been reported to attack *B. fusca* (Walters *et al.*, 1976; Annecke & Moran, 1982) and *C. partellus* (Van Rensburg & Van Hamburg, 1975; Kfir, 1990b). It hibernates in its cocoon inside the stalk during winter (Kfir, 1990b).

d) *Habrobracon brevicornis*

This species was reared from fully grown larvae of *B. fusca* collected at the end of March from infested sorghum plants at Mafeteng. It was observed to be gregarious in habit. Elsewhere, it is reported to have a very wide host range (Kfir, 1995).

e) *Dorylus* sp.

Red ants, *Dorylus* sp., were observed to prey on stalk borer larvae inside maize and sorghum plants. Their period of activity in maize is presented in Table 12.5. The ants were active from March to May, although live individuals were occasionally observed inside the underground parts of infested plants up to the end of June. During their active period, scores of ants were often seen near the bases of infested plants.

Close observation revealed that the ants gained access to a host larva through the borer entrance hole on the lower part of the stem, approximately one to four internodes above the soil surface. Inside the stems, ants consumed late instar larvae which were either still in above-ground galleries or in galleries below soil level. Dissection of such plants often revealed several ants attacking a single stalk borer larva. Even when live ants were no longer present inside the stalk borer galleries in plants, cadavers of larvae with dead ants still attached to them were often observed. The ants were not observed on the upper half of a normal growing plant (*i.e.* plants that were not stunted).

Table 12.5: Incidence of *Dorylus* (red) ants on maize plants infested by *Busseola fusca* at Roma, Lesotho, during the 1995/96 and 1996/97 seasons.

Approximate sampling date	1995/96		1996/97	
	No. of infested plants sampled	Incidence of red ants (%)	No. of infested plants sampled	Incidence of red ants (%)
04/11*	0	0.0	0	0.0
18/11*	0	0.0	1	0.0
02/12*	0	0.0	6	0.0
16/12	0	0.0	23	0.0
30/12	0	0.0	56	0.0
13/01	0	0.0	3	0.0
27/01	0	0.0	4	0.0
10/02	0	0.0	6	0.0
24/02	19	0.0	49	0.0
10/03	111	0.0	181	0.0
24/03	87	1.1	171	5.3
07/04	73	4.1	183	18.0
21/04	102	10.8	251	31.1
05/05	69	2.9	156	9.6
19/05	61	0.0	207	2.4
02/06	53	0.0	128	2.3
16/06	81	1.2	97	0.0
30/06	47	2.1	193	0.5
14/07	56	0.0	36	0.0
28/07	18	0.0	41	0.0
11/08	13	0.0	32	0.0
25/08	16	0.0	27	0.0
08/09	22	0.0	19	0.0
22/09	9	0.0	12	0.0
06/10	7	0.0	17	0.0
20/10	13	0.0	19	0.0

*...Sampling was done on maize planted in October.

...Other samplings were done on maize planted in November.

The onset of activity by *Dorylus* sp. generally coincided with the onset of downward migration by stalk borer larvae as they sought out winter hibernation sites. Therefore, the role of these ants seems to be in reducing the populations of over-wintering larvae.

Although the activity of the ants was not studied at other localities, there was evidence (*e.g.* dead ants inside stalk borer galleries, ant tunnels near the base of infested stems) that they were active at all the localities surveyed. Ants have also been reported as predators of stalk borer larvae in South Africa (Walters *et al.*, 1976; Kfir, 1997a), and East Africa (Mohyuddin & Greathead, 1970; Seshu Reddy, 1983; Dwumfour, 1990).

The relative importance of *B. sesamiae*, *C. sesamiae* and *Dorylus* sp. as mortality factors of stalk borers seemed to vary in the two crops (Table 12.6). Whereas *B. sesamiae* appeared to be more important as a larval mortality factor than *C. sesamiae* and *Dorylus* sp. in sorghum, *Dorylus* sp. seemed to be more important in maize. Mortality due to *C. sesamiae* was rare at Roma (Table 12.6).

Table 12.6: Relative importance of *Cotesia sesamiae*, *Bracon sesamiae* and *Dorylus* ants as mortality factors of *Busseola fusca* larvae in maize and sorghum at Roma, Lesotho, during the 1995/96 and 1996/97 growing seasons.

Season/ Crop	Total no. of larvae	Overall mortality (%)	Mortality due to *C. sesamiae* (%)	Morality due to *B. sesamiae* (%)	Mortality due to *Dorylus* sp. (%)	Mortality due to unknown causes (%)
1995/96						
Maize	481	21.4	0.2	1.9	7.5	11.9
Sorghum	237	74.3	0.0	59.9	8.4	5.9
1996/97						
Maize	748	63.6	0.0	3.3	37.6	22.7
Sorghum	457	74.0	0.4	27.1	11.8	34.6

Generally, the impact of *Dorylus* sp. might have been underestimated, since larvae that leave a plant in search of another could be killed by predators (Berger, 1992). The relative importance of each species also varied between seasons (Table 12.6). For instance, whereas mortality of stalk borers due to *B. sesamiae* in sorghum was higher during the 1995/96 season than in 1996/97, *Dorylus* sp. caused less mortality during the 1995/96 season than in 1996/97 (Table 12.6). Seasonal variability in the rate of parasitism has been reported elsewhere (Oloo & Ogeda, 1990; Bonhof *et al.*, 1997). Larval mortality was generally high and those due to causes other than parasitoids and ants were also important (Table 12.6).

The level of activity of parasitoids and of *Dorylus* sp. as observed at Roma was generally low during the greater part of the growing season (Tables 12.1, 12.2 & 12.5). As such, they did not appear to be particularly important in reducing the populations of stalk borers during the growing period of the host plants. The fact that activities of natural enemies are generally too low to keep stalk borer populations at sufficiently low levels has been reported by Harris (1962), Van Rensburg & Van Hamburg (1975), Ajayi (1989), Oloo & Ogeda (1990), Kfir & Bell (1993), Kfir (1995) and Bonhof *et al.* (1997). However, the observed increase in activity towards the end of each season probably contributes significantly in reducing carry-over populations of stalk borer larvae, which could reduce the size of the first generation moth flight during the following spring. Therefore, their importance should not be underestimated.

CONCLUSION

This study has shown that, like in many parts of Africa, indigenous natural enemies of stalk borers are active in Lesotho. Their widespread occurrence probably implies that natural enemies could play an important role as components of a sustainable integrated stalk borer management system in the country. However, the level of activity of the natural enemies is generally low for most part of the growing season. As such, they cannot be solely relied upon to reduce stalk borer populations to sufficiently low levels during the development of the host crop. Nevertheless, their increased level of activity towards the end of the season can contribute to reduced initial populations during each succeeding season. Future research should consider the ecology of the natural enemies under local conditions, in order to identify factors that influence their population dynamics. This will enable the identification and promotion of farm management practices that would improve their efficiency as natural enemies.

SUMMARY

Investigations on various aspects of stalk borers of maize and sorghum were conducted in Lesotho during the 1995/96, 1996/97 and 1997/98 growing seasons. Aspects investigated were their distribution and relative abundance on these two crops; seasonal moth flight pattern of *Busseola fusca*; impact of natural stalk borer populations on maize and sorghum; response of some maize and sorghum varieties/hybrids to artificial infestations with *B. fusca* and *Chilo partellus* respectively; farmers' perceptions and farm management practices with regard to the management of stalk borers; relative efficacy of insecticides used for *C. partellus* control in Lesotho; effect of planting date of maize on *B. fusca* infestations; effect of intercropping with beans on *B. fusca* infestations in maize, and relative abundance of natural enemies of *B. fusca* and *C. partellus*. These investigations provided the following results:

B. fusca was distributed throughout Lesotho and was important on both maize and sorghum. *C. partellus* occurred only in the central lowlands where it attacked only sorghum.

Seasonal *B. fusca* moth flight activity was characterised by distinct periods of high and low activity, with three and two to three generations of moths per season in the lowlands and mountains respectively.

Infestations of *B. fusca* in Lesotho caused substantial yield losses in susceptible maize varieties and hybrids. Lesotho's maize varieties and hybrids were observed to be susceptible, with yield losses of up to 39.4% observed under field conditions. Their

susceptibility was further demonstrated through artificial infestations in glasshouse and field studies. The glasshouse study showed that the levels of antibiosis and antixenosis resistance to *B. fusca* in these varieties and hybrids were low, while the field studies showed only moderate resistance to foliar damage.

Lesotho's sorghum varieties exhibited susceptibility to stalk borer damage, both under field conditions and artificial infestations with *C. partellus*. A glasshouse study also found antibiosis to be the main resistance mechanism against *C. partellus* larvae in whorls of resistant sorghum genotypes. The variety Tenant White, exhibited tolerance to damage, both under natural and artificial infestations.

Lesotho's farmers regarded stalk borers as important pests. The commonly employed control measure was insecticide application. Although the use of routine farm management practices has potential for suppressing borer populations, they were not utilised in this regard.

Comparison of the efficacy of six insecticides used for stalk borer control in Lesotho indicated granular formulations beta-cyfluthrin 0.05 % and carbaryl 2.5 % to be more effective against *C. partellus* larvae in sorghum whorls than spray formulations.

Early planting of maize (in November) substantially reduced damage and yield loss caused by *B. fusca*.

Intercropping maize with beans reduced damage and yield loss caused by *B. fusca* in maize. Furthermore, alternating rows of maize with rows of beans was more effective than alternating maize with beans within a row.

The braconids *Bracon sesamiae*, *Cotesia sesamiae*, *Euvipio* sp. and *Habrobracon brevicornis* parasitized *B. fusca* larvae. Only *B. sesamiae* and *C. sesamiae* were recorded on *C. partellus* larvae. An unidentified ichneumonid was reared from *C. partellus* pupae, while a red ant species *Dorylus* sp. (Formicidae) was recorded as a predator of both *B. fusca* and *C. partellus* larvae. However, the activity of these natural enemies was generally low, increasing only towards the end of the growing season.

These investigations have shown that stalk borer infestations are economically important in Lesotho. However, adopting such cultural practices as planting date adjustment, intercropping and destruction of crop residues can limit infestations. These practices, together with limited insecticide use, should form components of an integrated stalk borer management system. Future research efforts in Lesotho need to include the identification and development of maize and sorghum varieties and hybrids with high yields even under stalk borer infestations. Where such varieties are open-pollinated, they will be of particular benefit to the resource-poor farmers, who may not be able to afford hybrid seeds.

OPSOMMING

Ondersoeke na verskeie aspekte van sorghum en mieliestamboorders in Lesotho is gedurende die 1995/96, 1996/97 en 1997/98 seisoene gedoen. Ondersoek is gedoen na die verspreiding en talrykheid van stamboorders op hierdie gewasse; seisoenale motvlugpatroon van *Busseola fusca*; die impak van natuurlike stamboorderpopulasies op mielies en sorghum; die reaksie van mielie en sorghum varieteite en basters op kunsmatige besmetting van *B. fusca* en *Chilo partellus* respektiewelik; boere se persepsie van stamboorders asook boerderypraktyke wat verband kan hou met bestuur van stamboorders; die relatiewe effektiwiteit van insekdoders wat gebruik word vir stamboorderbeheer in Lesotho; die effek van plantdatum van mielies op *B. fusca* skade; die effek van inter-verbouing met boontjies op *B. fusca* voorkoms en skade in mielies asook die voorkoms en talrykheid van natuurlike vyande van *B. fusca* en *C. partellus*. Hierdie ondersoeke het die volgende bevindinge opgelewer:

B. fusca kom voor in alle produksiegebiede in Lesotho en is belangrik op mielies en sorghum. *C. partellus* kom slegs in die sentrale laaglande voor waar dit net sorghum beskadig.

Die seisoenale aktiwiteit van *B. fusca* word gekenmerk deur afgebakende periodes van hoë en lae motvlugaktiwiteit. Drie motgenerasies per seisoen kom in die laaglande voor en twee tot drie generasies in die hoogliggende bergagtige gebiede.

B. fusca besmetting veroorsaak aansienlike oesverliese in mielievarieteite en basters. Plaaslike Lesotho mielievarieteite en basters is vatbaar vir stamboorderskade en oesverlies

van tot 39.4 % is onder veldtoestande waargeneem. Vatbaarheid van hierdie varieteite en basters is bevestig deur evaluasies onder kunsmatige besmettings onder glashuistoestande. Glashuis-studies het aangetoon dat die vlakke van antibiose en antixenose weerstand in hierdie varieteite en basters laag is, terwyl veldstudies slegs geringe blaarvoedingsweerstand getoon het.

Plaaslike Lesotho sorghum varieteite was vatbaar vir stamboorderskade, onder beide veldtoestande en kunsmatige besmetting van *C. partellus*. 'n Glashuis-studie het getoon dat antibiose die belangrikste weerstandsmeganisme was tydens die kelkstadium van die weerstandbiedende genotipes wat as kontroles ingeluit is. Die varieteit, Tenant White, het verdraagsaamheid vir skade getoon, beide onder natuurlike en glashuistoestande.

Boere in Lesotho beskou stamboorders as belangrike plae. Die mees algemene metode van beheer is deur gebruik te maak van chemiese insekdodertoediening. Alhoewel die benutting van roetine boerderypraktyke potensiaal het om plaagpopulasies en stamboorderskade te onderdruk, word dit geensins in hierdie verband aangewend nie.

Evaluasie van die effektiwiteit van ses insekdoders wat beskikbaar is vir *C. partellus* beheer in Lesotho het getoon dat die korrelformulasies, beta-siflutrien 0.05 % en karbaril 2.5 %, meer effektief is as spuitformulasies.

Vroeë mielieaanplantings (in November) het 'n betekenisvolle afname in *B. fusca* skade en oesverlies tot gevolg gehad.

Interverbouing van mielies met boontjies het veminderde *B. fusca* skade en geassosieërde oesverlies tot gevolg gehad. Afwisselende rye van mielies en boontjies was meer effektief in die vermindering van *B. fusca* skade as wanneer mielie- en boontjieplante afwisselend binne die ry geplant word.

Die braconids *Bracon sesamiae, Cotesia sesamiae, Euvipio* sp. en *Habrobracon brevicornis* is waargeneem as parasiete van *B. fusca* larwes. Slegs *Bracon sesamiae* en *Cotesia sesamiae* is waargeneem as parasiete van *C. partellus* larwes. 'n Ongeïdentifiseerde icneumonid is uit 'n *C. partellus* papie uitgeteel en 'n rooimier, *Dorylus* sp. (Formicidae) is as 'n predator van beide *B. fusca* en *C. partellus* aangeteken. Die aktiwiteit van natuurlike vyande was oor die algemeen laag en het slegs teen die einde van die produksieseisoen toegeneem.

Tydens hierdie studie is gevind dat stamboorders ekonomies belangrik is in Lesotho. Die benutting van kulturele praktyke soos aanpassing in plantdatum, interverbouing en vernietiging van plantreste kan stamboorderbesmettings onderdruk. Hierdie praktyke, tesame met die minimum gebruik van insekdoders, behoort in 'n geïntegreerde beheerstelsel ingeskakel te word. Toekomstige navorsingsaksies in Lesotho moet gemik wees op die identifisering en ontwikkeling van mielie en sorghumvarieteite en basters met hoë opbrengspotensiaal onder stamboorderbesmettings. Veral oopbestuifde varieteite sal tot die voordeel van hulpbron-arm boere wees wat nie bastersaad kan bekostig nie.

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Farm management practices
by small-scale maize/sorghum farmers of Lesotho.

SURVEY QUESTIONNAIRE

Stalk borers are known to attack maize and sorghum in Lesotho. In our quest to determine the importance of these pests in this country, we seek your support. We therefore request you to kindly provide answers to the questions below. Please provide answers as accurately as possible.

Name of farmer (optional)..

Village/Town of farmer...

District of farmer..

Gender: Male [ ] Female [ ]

Instruction: Please tick (✓) applicable answer(s) only.

1. Which insect or insects do you consider as the most important pest/s on your **maize**?

a. Cutworms [ ]
b. Stalk borers [ ]
c. Earworm (African bollworm) [ ]
d. Other [ ] (specify)...

2. Which insect or insects do you consider as the most important pest/s on your **sorghum**?

a. Cutworms [ ]
b. Stalk borers [ ]
c. Aphids (greenflies) [ ]
d. Other [ ] (specify)..

3. Do you consider stalk borers of maize/sorghum as pests that need to be controlled ?

   a. Yes [ ]   b. No [ ]

4. If your response to question 3 is yes, do you control stalkborers?

   a. Yes [ ]   b. No [ ]

5. If you **do** control stalk borers, what control method do you employ:

   a. on **maize** ?
   - Insecticides [ ]
   - Traditional methods [ ] (specify) ......
   ....

   b. on **sorghum** ?
   - Insecticides [ ]
   - Traditional methods [ ] (specify).......
   ....

6. If you **do** control stalk borers in your crop, when do you carry out the exercise?

   a. Before symptoms of infestation are observed [ ]
   b. When first symptoms of damage are observed [ ]
   c. When symptoms of damage are severe and widespread [ ]
   d. Other [ ] (specify)...

7. If you **do not** control stalk borers, why not?

   a. Lack of money to purchase insecticides [ ]
   b. Insecticides are not available [ ]
   c. Lack of knowledge of how to control stalk borers [ ]
   d. Insecticides are not effective [ ]
   e. Lack of need to control stalk borers [ ]
   f. Other reason [ ] (specify)...

8. On what basis do you choose which maize or sorghum variety to plant ?

   a. Capacity for high yield [ ]
   b. Anticipation of drought [ ]
   c. Resistance to insect pests [ ]
   d. Preference for the variety as food item [ ]
   e. Because they are the only varieties available [ ]
   f. Other reason [ ] (specify)..

9. Do you grow **maize** mixed with other crops (*i.e.* in the same field at the same time)?

   a. Yes [ ]   b. No [ ]

10. Do you grow **sorghum** mixed with other crops (*i.e.* in the same field at the same time)?

    a. Yes [ ] b. No [ ]

11. If you **do** grow maize or sorghum in mixture with other crops, why do you do so?

    a. It serves as security in the event of failure of some crops [ ]
    b. To have a variety of crops at harvest [ ]
    c. To reduce crop damage by pests [ ] (specify)...
    d. For weed control [ ]
    e. Other reason [ ] (specify)...

12. What cropping mixtures do you practice ?

    a. Maize and sorghum [ ]
    b. Maize and beans [ ]
    c. Sorghum and beans [ ]
    d. Maize, sorghum and beans [ ]
    e. Maize and potatoes [ ]
    f. Maize and pumpkins [ ]
    g. Sorghum and potatoes [ ]
    h. Sorghum and pumpkins [ ]
    i. Other [ ](specify)...........................
    ....

13. Do you mix the crops ....

    (a)...within rows? [ ]
    (b)...in alternate rows? [ ]
    (c)...other [ ] (specify)...

14. In addition to growing maize/sorghum, do you keep livestock (cattle, sheep, goats, horse, donkey)?

    a. Yes [ ] b. No [ ]

15. Some farmers in Lesotho cut off the upper parts of maize plants (de-tasselling) at crop maturity (but long before harvest). Do you engage in this practice ?

    a. Yes [ ] b. No [ ]

16. If your response to question 15 is yes, why do you de-tassel maize plants?

a. To use as livestock feed [ ]
b. It increases the yield of the maize crop [ ]
c. To control pest/s in the crop [ ] (specify)..
d. It facilitates faster drying of the maize crop for harvesting [ ]
e. Other reason [ ] (specify)..

17. After harvest, what do you do with maize and sorghum stalks ?

a. Abandon them in the field [ ]
b. Cut and remove them from the field as livestock feed [ ]
c. Burn them off in the field [ ]
d. Cut and remove them for fencing [ ], roofing [ ], fuel [ ] (tick those that apply)
e. Other [ ] (specify)...

18. When do you plough your maize and sorghum fields ?

a. Soon after harvest (in autumn) [ ]
b. Just before planting (in spring/summer) [ ]

19. If you plough in **autumn**, why ?

a. In preparation for winter cropping [ ] (specify crop/s).......................................
c. For pest control [ ] (specify which pest/s)...
b. For weed control [ ]
d. Other reason [ ] (specify)..