# CHAPTER 1

## GENERAL INTRODUCTION

Cereal crops are a vitally important source of food for humans and their livestock and contribute significantly to local and national economies (Smith & Wiedenmann 1997). Maize (*Zea mays* L.), sorghum (*Sorghum bicolor* (L.) Moench) and pearl millet (*Pennisetum glaucum* (L.) R. Br.) are three of the most important gramineous crops in Africa (Polaszek & Khan 1998). These species are grown over varied climatic zones and their yields vary between regions (Gahukar 1994). In Africa, the highest level of cereal production was recorded in 1988 with maize yielding 30 313 million tonnes, followed by sorghum with 15 280 million tonnes, and millet (13 330 million tonnes) which ranked fourth after wheat (13 630 million tonnes) (Chantereau & Nicou 1991).

### Maize

Maize originated in central America and by the 16th century was already cultivated in parts of West and southern Africa (Polaszek & Khan 1998). It is a staple food in most countries in southern Africa (Okech *et al*. 1994) and is used as both human and livestock food (Polaszek & Khan 1998). Although sub-Saharan African countries such as Kenya, South Africa, Tanzania, Ethiopia and Nigeria are principal producers of maize, South Africa is the only country that regularly exports maize (Polaszek & Khan 1998). Maize in Africa is mostly grown by subsistence farmers and yields are generally low, averaging less than half of Asian and Latin American yields (Polaszek & Khan 1998). The average yield for industrialized countries is 6.2 t/ha, compared to only 2.5 t/ha for developing countries (Dowswell *et al*. 1996). In South Africa, maize has, since 1950, become one of the most important agricultural crops with a production exceeding ten million tons in favourable years (Van Rensburg *et al*. 1987). The average maize yield is 2.0 t/ha in South Africa which is nonetheless low compared to 7.5 t/ha, 7.1 t/ha, and 7.8 t/ha in developed countries in the United States of America (U.S.A), France, and Italy respectively (Dowswell *et al*. 1996) in which better technologies are employed.

### Sorghum

Sorghum, originated in Africa (Gebrekidan 1985) in the border regions of Sudan and Ethiopia (Polaszek & Khan 1998) approximately 3 000 BC (Chigumira 1992). Today, the most important African sorghum producing countries are Burundi, Kenya, Rwanda, Somalia, Tanzania and Uganda (Seshu Reddy & Omolo 1985) as well as Nigeria, Sudan, and Ethiopia (Seshu Reddy & Omolo 1985; Polaszek & Khan 1998). Sorghum, a staple diet in Africa and Asia (Murty 1992; FAO & ICRISAT 1996), is mainly grown in the semi-arid tropics which are characterized by low and erratic rainfall (Jordan & Sullivan 1982; Van den Berg 1994).

The use of sorghum varies from one country to another. In Africa and Asia sorghum is used for human consumption, while it is grown mainly for animal feed in the U.S.A. (Leuschner 1985; Murty 1992). In addition to its use for animal and human consumption, sorghum is used for fuel, house and fence building (Polaszek & Khan 1998). Major products of sorghum are bread or porridge, prepared from flour (Wills & Ali 1992) and beer in developing countries, for example Nigeria (Koleoso & Olatunji 1992).

There is also variation in the production of sorghum from one region to another. In Africa and Asia the crop tends to be grown in traditional farming systems, whereas in developed countries it is largely produced on a commercial basis (FAO & ICRISAT 1996). Although sorghum supports millions of people in Africa (Seshu Reddy & Omolo 1985), its yields are generally low and often unpredictable (Van den Berg 1994). The grain yields from fields of resource-poor farmers in southern Africa range from 600 to 900 kg/ha (Sithole 1989) which is low compared to 3 705 kg/ha in the U.S.A. (Seshu Reddy & Omolo 1985). Nonetheless the production per hectare in South Africa is higher than in other southern African countries, for example, the average grain yield is 2.05 t/ha in South Africa (FAO & ICRISAT 1996), which is high compared to the 0.4 t/ha in Botswana (Nicholson 1992) and 0.52 t/ha and 0.33 t/ha in Zimbabwe and Mozambique (FAO & ICRISAT 1996) respectively.

### Pearl millet

Four main kinds of millet are cultivated in Africa. These are pearl millet (*P. glaucum*), finger millet (*Eleusine coracana* (L.) Gaertn), teff (*Eragrostis tef* (Zucc.), and fohio (*Digitaria exilis* (kipp.) and *D. iburua* (Stapf.)). Pearl millet is by far the most important of these crops (Polaszek & Khan 1998) and Africa accounts for almost half of its global production (FAO & ICRISAT 1996). Like sorghum, pearl millet originated in Africa and spread throughout the world (Polaszek & Khan 1998). Today, pearl millet, a descendent of a wild west-African grass, became a staple food in East Africa and India and is now grown in Europe and the U.S.A. In Africa, the major pearl millet producing countries include Nigeria, Niger, Burkina Faso, Chad, Mali, Mauritania and Senegal in the west, and Sudan and Uganda in the east. In southern Africa, although partially displaced by maize, pearl millet is grown in Madagascar, Namibia (Polaszek & Khan 1998), South Africa (Kumar & Rao 1987), and an estimated 341 244 ha in Zimbabwe (Rao & Mushonga 1987). Pearl millet is grown on 14 million hectares in Africa and 14 million hectares in Asia and is said to support at least 500 million people.

Pearl millet, with its high water use efficiency, fast growth and tolerance to heat, survives better than maize and sorghum (Polaszek & Khan 1998). Pearl millet can survive and reliably produce at rainfall levels as low as 300 mm per annum. This is low compared with the minimum water requirements of 400 mm for sorghum and 500-600 mm for maize (FAO & ICRISAT 1996). Pearl millet is almost entirely a subsistence crop in Africa. Production varies from one region to another (De Wet 1987) with an average yield of 600 kg/ha in Africa.

This crop is consumed in many different forms. In Africa it is used as a whole, cracked, or ground flour, a dough, or grain like rice. In the U.S.A., it is used as feed for beef cattle, young pigs, and poultry. All indications are that animals fed on pearl millet grain have growth rates that were similarly or better than those fed on maize.

## Stem borer species attacking cereal crops

Maize, sorghum, and pearl millet, grown by a large proportion of world's poorest people, are attacked by a wide range of insect pests, especially stem borers (Lepidoptera) (Seshu Reddy 1990). In Africa low yields resulting from damage caused by these insect pests reach high levels, particularly in traditional subsistence farming systems (Gebrekidan 1985). Seventeen stem borer species in two families (Pyralidae and Noctuidae) have been found to attack sorghum and maize in various parts of Africa (Khan *et al.* 1997a) causing yield losses ranging from 0-100% depending on infestation levels (Bosque-Perez & Schulthess 1998). *Chilo partellus* Swinhoe (Lepidoptera: Crambidae), *Busseola fusca* Fuller (Lepidoptera: Noctuidae), *Sesamia calamistis* Hampson (Lepidoptera: Noctuidae), and *Eldana saccharina*

Walker (Lepidoptera: Pyralidae) are the most damaging stem borer species in Africa (Pathak 1985; Khan *et al.* 1997a). *Chilo partellus* attacks crops such as sorghum and maize (Duerden 1953; Berger 1989a,b, 1992; Das & Agrawal 1993; Kumar 1994), and pearl millet (Polaszek & Khan 1998). The control of stem borers is important to reduce the populations to levels below economic injury levels. However, in South Africa stem borer control is complicated by the occurrence of mixed populations of *C. partellus* and *B. fusca* in maize and sorghum producing areas (Bate *et al.* 1990). Mixed populations of these two species have occurred as a result of the spread of the highly competitive *C. partellus* to high altitude areas previously known to be dominated by *B. fusca* (Kfir 1997).

In South Africa both maize and sorghum are produced by resource-poor farmers in the Northern Province (Matthee *et al.* 1974) where these crops are attacked by stem borers from the stage of planting up until harvesting. In South Africa the average annual yield loss caused by stem borers to maize is 10%, although between 25% - 75% loss has been recorded (Duerden 1953, Matthee *et al.* 1974).

## Origin and distribution of *Chilo partellus*

*Chilo partellus* originated in India (Kfir 1992) and had since spread to East Africa (Mohyuddin & Greathead 1970). In southern Africa it occurs in Botswana, Lesotho, Malawi, Mozambique, Swaziland, Zimbabwe and South Africa (Sithole 1989). *Chilo partellus* is found in warm, low-lying regions (Van Hamburg 1979a,b; Gebrekidan 1985; Kfir 1997) and restriction of *C. partellus* to low altitude was probably due to temperature limits (Ingram 1958). In South Africa *C. partellus* was first reported by A. Barnard near Naboomspruit (24° 31S, 28° 41E), Transvaal on 12 March 1958 (Van Hamburg 1979a) and has now become widely distributed throughout the Springbok Flats (Matthee *et al.* 1974; van Hamburg 1979a). Its distribution also extends from western grain producing areas (Bate *et al.* 1991) to coastal areas of Natal (van Hamburg 1979a). When host plants are available and temperature is favourable for the development of *C. partellus*, this species develops continuously throughout the year (Kfir 1997). Although Ingram (1958) found that it was restricted to altitudes below 1 500 m above mean sea level (amsl.)in Uganda, he speculated that *C. partellus* should be able to spread to regions higher than 1 500 m amsl. This statement was confirmed later by Bate *et al.* (1991), when they found *C. partellus* at 1 650 m amsl. in the western part of the Highveld at Potchefstroom (26° 43S, 27° 06E). Kfir (1997) also found *C. partellus* near Delmas (25° 09S, 28° 41E; 1 600 m amsl.) in the eastern highveld region of South Africa, an area previously known to be dominated by *B. fusca*. Van Hamburg (1979a) also reported the occurrence of this species in high lying areas such as Potchefstroom.

## Biology and behaviour of *Chilo partellus*

Most stem borers have very similar life cycles (Gahukar 1994). That of *C. partellus* is completed in approximately 45 days (6 weeks) (Van den Berg 1997a). In South Africa, moths of *C. partellus* start fly from the beginning of September to the end of may (Fig. 1) and can have up to five overlapping generations (Van den Berg 1997a). *Chilo partellus* moths of both sexes (Fig. 2a) live for approximately four to six days (Berger 1989b). The moths are buff-coloured and nocturnal (Young & Teets 1977). Mating commences after midnight on the night of emergence, reaches a peak between five a.m. and seven a.m. and then declines on successive nights (Kumar & Saxena 1985). Observations by Päts (1992) revealed low flight activity of *C. partellus* female moths on the night of moth emergence. According to Päts (1992) mate finding of one day old female moths is therefore enhanced by high flight activity of two to three days old male moths. The activity of mated female moths increases gradually and is higher between three to eight hours after the onset of the scotophase (the dark period (night) during a 24 hour period of light and dark) (Ramachandran & Saxena 1991). This behavioural activity is related to oviposition site selection (Ramachandran & Saxena 1991), and is influenced by physical (trichomes) and chemical (surface waxes) factors of the plant (Roome *et al.* 1960). Presence of these factors on host plants could inhibit oviposition by stem borers. *Chilo partellus* moths lay 50-100 eggs (Agrawal *et al.* 1990) per batch (Fig. 2b) on the upper and lower surfaces of all leaves including leaf sheaths (Alghali 1985). The whitish eggs of *C. partellus*, are flattened, scale like and ovoid (Ampofo & Saxena 1989).

Hatching of eggs takes place in the morning (Chapman *et al.* 1983; Leuschner 1990) approximately four to six days after oviposition (Van Hamburg 1979a; Agrawal *et al.* 1990; Gahukar 1991). On hatching larvae feed gregariously for a short time (Kfir 1992), after which they migrate upwards to feed in the whorls of the crop plant (Van den Berg 1997a). This climbing behaviour of *C. partellus* larvae is due to a positive response to light (positive phototaxis) (Bernays *et al.* 1983; Bernays *et al.* 1985; Leuschner 1990). The creamy white larvae, which are characterized by dark spots on the body (Fig. 2c) pass through five instars, which last for six, four, five, three and seven days, respectively (Gahukar 1991).

Since larvae have to climb their way to the whorl, the climb is hazardous and not all larvae survive (Bernays *et al.* 1983). The success of climbing of the first instar larvae depends on the weather conditions, physical and chemical characteristics of the leaf and stem surfaces (Bernays *et al.* 1983; Woodhead & Taneja 1987; Leuschner 1990). The physical characteristics such as curled and floppy leaves (Bernays *et al.* 1985), taller cultivars (Chapman *et al.* 1983), degree of detachment of sheaths (Bernays *et al.* 1983), trichome density and chemical characteristics e.g. cyanoglycoside dhurrin which release HCN as a deterrent in sorghum (Woodhead & Bernays 1977), play an important role in the behaviour of *C. partellus* during its establishment in a plant. The rate at which the larvae climb the plant is influenced by the cultivar and the age of the plant (Leuschner 1990). When the larvae reaches the tip of the outer whorl leaf, downward movements are initiated only when the larvae perceives the dark area of the funnel contrasting with the light from the sky (Bernays *et al.* 1983). At the third instar stage, larvae migrate from the whorl to bore down into the stem (Ampofo & Saxena 1989; Leuschner 1990; Agrawal *et al.* 1990). Larval migration from hatching sites to feeding sites or between feeding sites is important for larval survival (Berger 1993). Older larvae reaching the stem feed in the inter-nodes where they later develop into pupae (Fig. 2d). These larvae may only migrate to neighbouring plants as a result of food deterioration (Berger 1994), decrease in food quality and increase in contact between larvae (Berger 1992). Van Hamburg (1979a) claimed that larval migration from a single plant to another is due to overcrowding on individual plants. Development of larvae of *C. partellus* into pupae is only interrupted by diapausing larvae during winter (Gahukar 1991). The full grown larvae of *C. partellus* prepares a circular exit hole for the moth just before pupation (Ampofo & Saxena 1989). Harsh winter conditions are survived by hibernation in stems, low down in the plants and in stem bases beneath the soil. The hibernation sites provide insulation and shelter (Kfir 1997). A rise in temperature and the arrival of the first spring rains seem to be the two most important factors responsible for breaking diapause of overwintering larvae (Van Hamburg 1979b). The pupal period for *C. partellus* takes eight to ten days (Ampofo & Saxena 1989) after which adult moths emerge to complete the cycle.

## Origin and distribution of *Busseola fusca*

*Busseola fusca* originated in Africa (Wahl 1926; Matthee *et al.* 1974) and it is not known to occur anywhere outside the African continent (Harris & Nwanze 1992). Although Matthee *et al.* (1974) could not trace the origin of *B. fusca* in Africa, Kfir & Bell (1993) reported it to be native to sub-Saharan Africa. *Busseola fusca* is also known to occur in West Africa (Benin, Burkina Faso, Cameroon Côte d'Ivoire, Ghana, Guinnea, Mali, Nigeria and Sierra Leone), eastern Africa (Ethiopia, Kenya, Somalia, Tanzania and Uganda) and southern Africa (Angola, Botswana, Lesotho, Malawi, Mozambique, Rwanda, Swaziland, Zaire, Zimbabwe, Zambia and South Africa) (Harris & Nwanze 1992).

Unlike *C. partellus*, *B. fusca* is found at high altitudes (Wahl 1926; Ingram 1958; Gebrekidan 1985; Ebenebe 1998). Ingram (1958) noted that this species was more common at altitudes above 1 200 m amsl and that its population levels were influenced by intensity of cultivation of crops such as maize and sorghum. Although *B. fusca* was abundant at altitudes between 1 200-1 500 m amsl in the Central Plateau in Tanzania it was also recorded at very high altitudes (2 700 m amsl) in the northern and southern highland areas (Swaine 1957). Distribution of *B. fusca* to lowveld regions in Tanzania is limited mainly by high temperatures experienced at lower altitudes (Swaine 1957).

## Biology and behaviour of *Busseola fusca*

The biology of *B. fusca* has been studied extensively (Ingram 1958; Unnithan 1987) and much of this work was first done in South Africa (Harris & Nwanze 1992). *Busseola fusca* has three generations per season (Wahl 1926). In South Africa the moths from the overwintering larvae start appearing in the spring from October to December, the second generation moths from January to February and the third generation from the end of February until the commencement of frost in May (Van Rensburg *et al.* 1987) (Fig. 1). *Busseola fusca* moths are seldom seen in the field as they are inactive during the day resting on plants and plant debris (Harris & Nwanze 1992). Unnithan (1987) reported that the adult male and female moths of *B. fusca* live for 8.7 and 6.9 days respectively. Mating activity takes place the same night after eclosion (Unnithan 1987). Female moths (Fig. 3a), which are bigger than male moths release a pheromone to attract males (Harris & Nwanze 1992). Eggs (Fig. 3b) of *B. fusca* are laid behind leaf sheaths (Barrow 1989; Azerefegne & Gebre-Amlak 1994) and under the ear husk leaves of maize plants (Barrow 1989). The greatest number of eggs of *B. fusca* moths are laid on plants between three and five weeks old (Van Rensburg & Van Rensburg 1993). The eggs, which are laid in batches of 30-100 are hemispherical with about 70 crenolutions (ridges) on the egg shell (chorion) (Harris & Nwanze 1992). The eggs (0.6 mm in diameter) (Matthee *et al.* 1974) are laid within the sheaths of any one of the fifth to tenth leaves on maize plants ranging in height from 26 to 75 cm with a distinct preference for plants between 26 to 45 cm (Barrow 1989). The high infestation on certain plants compared with others is due to the ability of *B. fusca* moths to select a suitable host plant on which to lay eggs (Matthee *et al.* 1974). There is a variation in the number of eggs laid per batch and the incubation period for *B. fusca*. The incubation period is influenced by ambient temperatures (Barrow 1989) and lasts for five to six days under 23-27°C (mean 25°C) (Unnithan 1987). The eggs of *B. fusca* hatch at night and the larvae that emerge are found in aggregate dense groups (Van Rensburg & Van Rensburg 1993). The young larvae have a dark brown colour which turns lighter on maturity (Fig. 3c). The neonate larvae migrate to the whorls. Older larvae leave the whorl to feed on the stem. Unlike *C. partellus* which has five instars, the measurements of the head capsule width (mm) done by Unnithan (1987) revealed that this species may have six to seven instars.

The full life cycle of *B. fusca* takes approximately 66 days (9 weeks) (Ingram 1958; van den Berg 1997a). The period spent by *B. fusca* from hatching to pupation is about thirty days, except for over-wintering larvae which takes longer (Wahl 1926; van den Berg 1997a). Female pupae are bigger than male pupae and can be differentiated by the position of the genital scars found on sternum eight in females and on sternum nine in males (Harris & Nwanze 1992). Pupation of *B. fusca* which lasts for about a fortnight in summer (Wahl 1926). However, not all fully grown larvae of *B. fusca* pupate. Some larvae enter diapause. The state of maturity of a host plant, and not climatic factors appear to induce diapause in *B. fusca* larvae (Unnithan 1987). Diapause occurs in tunnels in dry maize or sorghum or other similar crop residues (Gebre-Amlak 1988). In the maize production areas of South Africa diapausing of *B. fusca* and *C. partellus* takes place during the dry winter months (April–October) (Kfir 1991). The dry stems and stubble, which are important for the survival of *B. fusca* throughout the dry season are potential sources of infestation of stem borers for the next season (Gebre-Amlak 1988). Diapausing of larvae (Fig. 3d) of *B. fusca* takes place in the lower parts of dry stalks (Matthee *et al.* 1974) approximately 10 cm below the soil surface (Walters & Drinkwater 1976). Diapause larvae have a higher survival rate at the base of the stem than in exposed stalks (Unnithan & Seshu Reddy 1989) possibly due to protection of larvae from natural enemies and unfavourable conditions (Kfir 1991). Laboratory studies done by Van Rensburg & Van Rensburg (1993) revealed that temperature, humidity and photoperiod play an important role in triggering termination of diapause on *B. fusca* larvae. Like *C. partellus*, the larva of *B. fusca* prepares an exit hole on the internode of the stem before pupation to enable the moth to escape when it emerges from the pupal case (Wahl 1926). Pupating larvae is shown in Fig. 3e.

### Damage caused by *Chilo partellus* and *Busseola fusca* to host plants

The first symptoms of attack by *C. partellus* on young sorghum plants may be noticed from three weeks after germination (Alghali 1985) until harvest and all above ground plant parts may be attacked (Agrawal *et al.* 1990). The symptoms caused by early instar larval feeding are "shot holes" or irregular shaped holes (Fig. 4) in the whorl of sorghum plants (Agrawal *et al.* 1990). Foliar damage, which occurs when whorl leaves are attacked, is caused by first and second instar larvae resulting in reduction in total leaf area and photosynthetic capacity of the maize plant (Ampofo & Saxena 1989). Larval feeding resulting in damage to the growing point of sorghum plants may result in a "dead heart" (Fig. 5) which is the drying of the central leaves (Ampofo *et al.* 1986). Dead heart and severe foliar damage may result in the death of a plant (Ampofo & Saxena 1989).

The second type of damage is caused by older instars i.e. from third instar onwards (Ampofo and Saxena 1989). In older maize plants *C. partellus* causes stem tunneling (Fig. 6) (Pathak & Othieno 1990) as well as tunnelling and feeding on the grain inside the enclosed panicle in the case of sorghum (Mlambo 1983). *Chilo partellus* may also tunnel the peduncle and move up to the panicle (Agrawal *et al.* 1990). Tunnelling not only weakens and causes breakage of stems of sorghum plants but also interferes with supply of nutrients to the developing grains by destroying the plant's vascular system and resulting in chaffy panicles (Agrawal *et al.* 1990; Kishore 1987). Other secondary expressions of stem tunnelling are poor pollen production and reduction in fertilization (Ampofo & Saxena 1989). The production of tillers of sorghum plants is stimulated by damage to other stems or when dead hearts are formed (Van Rensburg & Van den Berg 1992a). Sorghum plants infested two weeks after germination produced the maximum number of tillers and juvenile panicles (Alghali 1987) and also had the lowest number of productive tillers, most stunted plants and lowest yields (Alghali 1985). Gahukar (1991) estimated average yield reductions per plant at 0.4-1.0% for each percentage increase in stem tunnelling. In Africa and Asia, the damage caused to maize and sorghum crops may lead to yield reductions of 50% or more (Berger 1989a).

*Busseola fusca* was first recognised as a pest of maize in South Africa (Harris & Nwanze 1992). *Busseola fusca* also attacks crops such a sorghum, pearl millet, sugarcane, and some wild grasses (Harris & Nwanze 1992). The damage caused by *B. fusca* is similar to that caused by C. *partellus* (Gahukar 1991). The larvae attack the growing points, resulting in dead hearts (Harris & Nwanze 1992). Like *C. partellus* the larvae of *B. fusca* may tunnel in maize cobs and stems and are known to cause indirect yield loss in sorghum because of tunnelling and breakage of peduncles (Harris & Nwanze 1992).

## INTEGRATED PEST MANAGEMENT OF STEM BORERS

To suppress stem borer populations in maize based production systems, an integrated pest management program should be employed (Van den Berg 1997a). Integrated pest management is a management system that utilizes all suitable techniques and methods in as compatible a manner as possible to reduce pest populations and maintain them at levels below those causing economic injury (Kumar 1984). This integrated management system combines components such as cultural, chemical, biological and host plant resistance (Akinsola 1990). However, there is also a need to develop IPM tactics for stem borers in South Africa using a habitat management approach.

### Chemical control

In eastern and southern Africa most maize and sorghum hybrids grown are susceptible to stem borer and yield losses are high (Pathak 1991). Chemical control is the most powerful tool currently available for the control of stem borers (Azerefegne & Gebre-Amlak 1994). However, due to species differences in infestation patterns with regard to the distribution of immature development stages in time after crop emergence and location in the plant (Van Rensburg & Van den Berg 1992b) and as a result of the occurrence of mixed populations effective chemical control of *C. partellus* and *B. fusca* is difficult to obtain (Bate *et al.* 1991; Van den Berg 1997b). To ensure cost effective chemical control measures, Van den Berg (1997b) recommended an economic threshold level (ETL) for control of *C. partellus* and *B. fusca* on sorghum plants. This ETL is reached when 10 % of the plants in the field show whorl damage.

A cost effective method of control is the application of insecticide granules in plant whorls as soon as damage is observed. Van den Berg & Van Rensburg (1993) observed 78.2% reduction in larval numbers and a 25.2% decrease in yield loss when a persistent granular insecticide such as betacyfluthrin was applied in plant whorls. However, Van den Berg (1997b) stated that, although granular insecticide application is effective and economical it is not always practical when crop fields are large.

The pest status of *C. partellus* in South Africa is increasing while chemical control is not always effective and sometimes too expensive (Kfir 1990). Due to high costs of insecticides (Pathak 1985) subsistence farmers cannot afford to buy chemicals (Pathak 1991). Despite the popularity of insecticides, there is a lack of information amongst farmers on application methods and efficacy of available insecticides for the control of stem borers (Ebenebe 1998). Therefore, chemical control may not be a viable option for use by resource poor farmers to control stem borers.

### Host plant resistance as a control measure for stem borers

Host plant resistance is the heritable qualities possessed by a plant that enables it to avoid, tolerate or recover from the attacks of insects under conditions that would cause greater injury to other plants of the same species (Kumar 1984). Manipulation of host plant resistance appears to be the most economic and efficient control method, and can be used alone (Pathak 1990) or as a component of an overall pest management strategy (Gebrekidan 1985). Under low input and poor management conditions the use of insect-resistant cultivars is the cheapest and safest means of pest control (Pathak 1985). Van den Berg (1994) observed increased efficacy of insecticides against *C. partellus* and *B. fusca* when resistant host plants were used. Plant resistance is available at no extra cost to the farmer, requires little skill and it is cheaper to develop resistant crop varieties than it is to develop new pesticides (Kumar 1984). Although plant resistance proved to be a potential control method, the absence of complete resistance in host plants and the breakdown of resistance by insect pests

(Dent 1991) may have played an important role in not bringing about the complete success of this method.

**Biological control**

Biological control is generally man's use of a specially chosen living organism to control a particular pest. The chosen organism might be a predator, parasite or pathogen of insect pests. Although biological control is a highly profitable method in terms of costs and economic returns, it is not always effective in controlling insect pests in the field (Kumar 1984). Several parasitoids such as *Cotesia flavipes* (Cam.) (Hymenoptera: Braconidae), introduced into South Africa for the biological control of *C. partellus* failed to become established (Kfir 1994). In other cases, parasitoids that established themselves in the field failed to reduce populations of *C. partellus* below economic damage levels (Kfir 1994). Farmers should have a greater understanding of the biology of both pest and its enemies which could help them to understand the behaviour of the pest in the field.

**Habitat management**

Although chemical control, host plant resistance and biological control play an important role in the control of insect pests, some limitations to complete success of these practices have been mentioned above which could prevent success in resource poor farming. Habitat management is a management strategy that could be developed for resource poor farmers. In a habitat management system wild host plants could be used as trap crops around maize fields to control stem borers. This habitat management system also promotes survival, fecundity, longevity, and behaviour of natural enemies to increase their effectiveness (Landis *et al.* 2000) i.e. attack stem borers in the field in order to reduce their populations to below economic injury levels. A habitat management system for stem borers was developed for resource-poor farmers in Kenya (Khan *et al.* 1997a; Khan *et al.* 2000). This habitat management system reduces stem borer damage and increases predation and parasitism of stem borers in the field (Khan *et al.* 1997b).

This habitat management system, also referred to as a "push-pull" or stimulo-deterrent diversionary strategy (Fig. 7) was developed to repel stem borers from the maize crop and attract them to a highly attractive barrier around the maize crop (Khan *et al.* 1997a; Khan *et al.* 2000). The two most important trap (pull) crops used are

*Pennisetum purpureum* (Napier grass) and *Sorghum vulgare sudanense* (Sudan grass), both fodder crops of economic importance. These crops could be grown around maize fields. Two non-host forage plants, *Melinis minutiflora* (molasses grass) and *Desmodium uncinatum* (silver leaf) are also used in this system (Khan *et al.* 1997a; Khan *et al.* 2000). These non-hosts are intercropped with maize, produce volatile compounds which repel (push) gravid female borers from the field. However, *Melinis minutiflora* attracted parasitoids when planted as an intercrop with maize (Khan *et al.* 1997a; Khan *et al.* 2000). This management system which involves manipulation of wild host plants on field margins could fit in well in resource poor farming compared to other control methods. It is perceived to be less costly compared with other control methods since it uses only wild host plants to control stem borers with has some added benefits such soil erosion and the use for livestock feeding of host plants (Khan *et al.* 1997a; Khan *et al.* 2000).

This habitat management system is now being adapted for use by resource-poor farmers in South Africa (Van den Berg *et al.* 2001) and other trap crops will be identified through surveys. To develop a habitat management system it is necessary to understand the interactions between insects pests, cultivated crops and wild grasses that could be used in habitat management. Antixenosis and antibiosis mechanisms of resistance could also be used to improve the efficiency of this habitat management system in the control of stem borers. In this case resistant sweet sorghum varieties which possess these mechanisms could be evaluated for use as trap while resistant maize could be grown as main crop in this management system. Antixenosis denotes the presence of plant characters such as morphological (trichomes) and chemical plant factors (surface waxes) that affect the behaviour of insects, orientation, oviposition and feeding of insects (Kumar 1997). Antibiosis is used when plants cause adverse effects on the biology of insects e.g. survival, development and reproduction (Kumar 1997).

Studies were done on the interactions between stem borer, crops and wild host plants. Field surveys of wild host plants were conducted and the colonization process of crops and wild host plants studied. These studies, dealing with aspects related to habitat management are reported in the following chapters:

1. Wild host plants and their stem borers in the Limpopo and northern Mpumalanga Provinces.
2. Colonization of cultivated and wild graminaceous host plants by *Busseola fusca* (Fuller) (Lepidoptera: Noctuidae) and *Chilo partellus* (Swinhoe) (Lepidoptera: Crambidae) under field conditions.
3. Oviposition preference of *Chilo partellus* (Swinhoe) (Lepidoptera: Crambidae) for cultivated and wild graminaceous host plants
4. Preference of *Chilo partellus* (Swinhoe) (Lepidoptera: Crambidae) larvae for cultivated and wild graminaceous host plants.
5. Growth and development of *Chilo partellus* (Swinhoe) (Lepidoptera: Crambidae) on cultivated and wild graminaceous host plants.
6. Leaf feeding resistance and oviposition preference of *Busseola fusca* (Fuller) (Lepidoptera: Noctuidae) and *Chilo partellus* (Swinhoe) (Lepidoptera: Crambidae) moths for sweet sorghum (*Sorghum bicolor*) varieties.
7. Field evaluation of a forage sorghum (*Sorghum bicolor* x *S. sudanensis*) and *Pennisetum purpureum* (Napier grass) as trap crops in a habitat management system.

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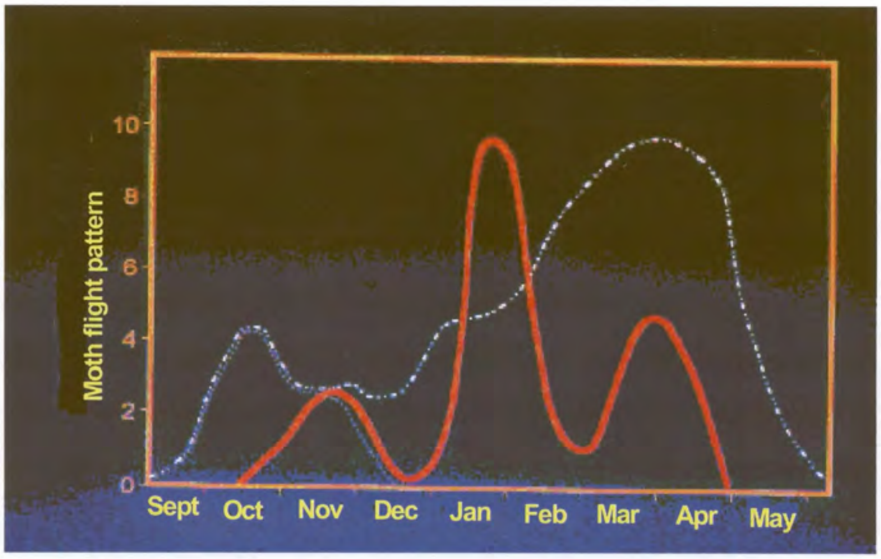
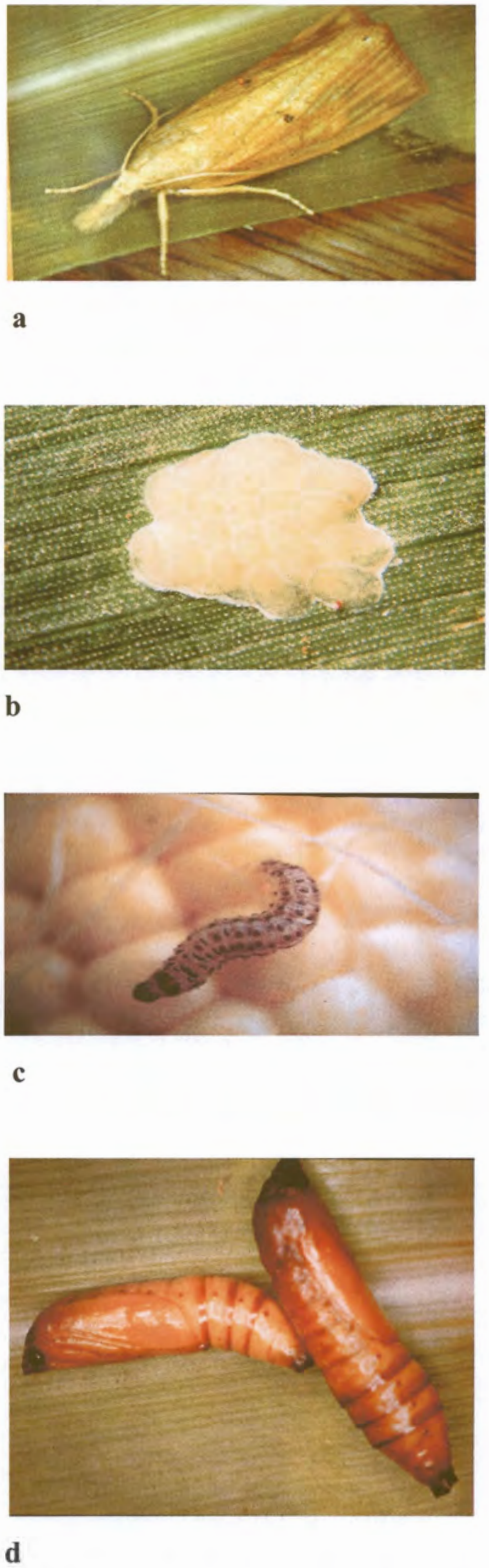
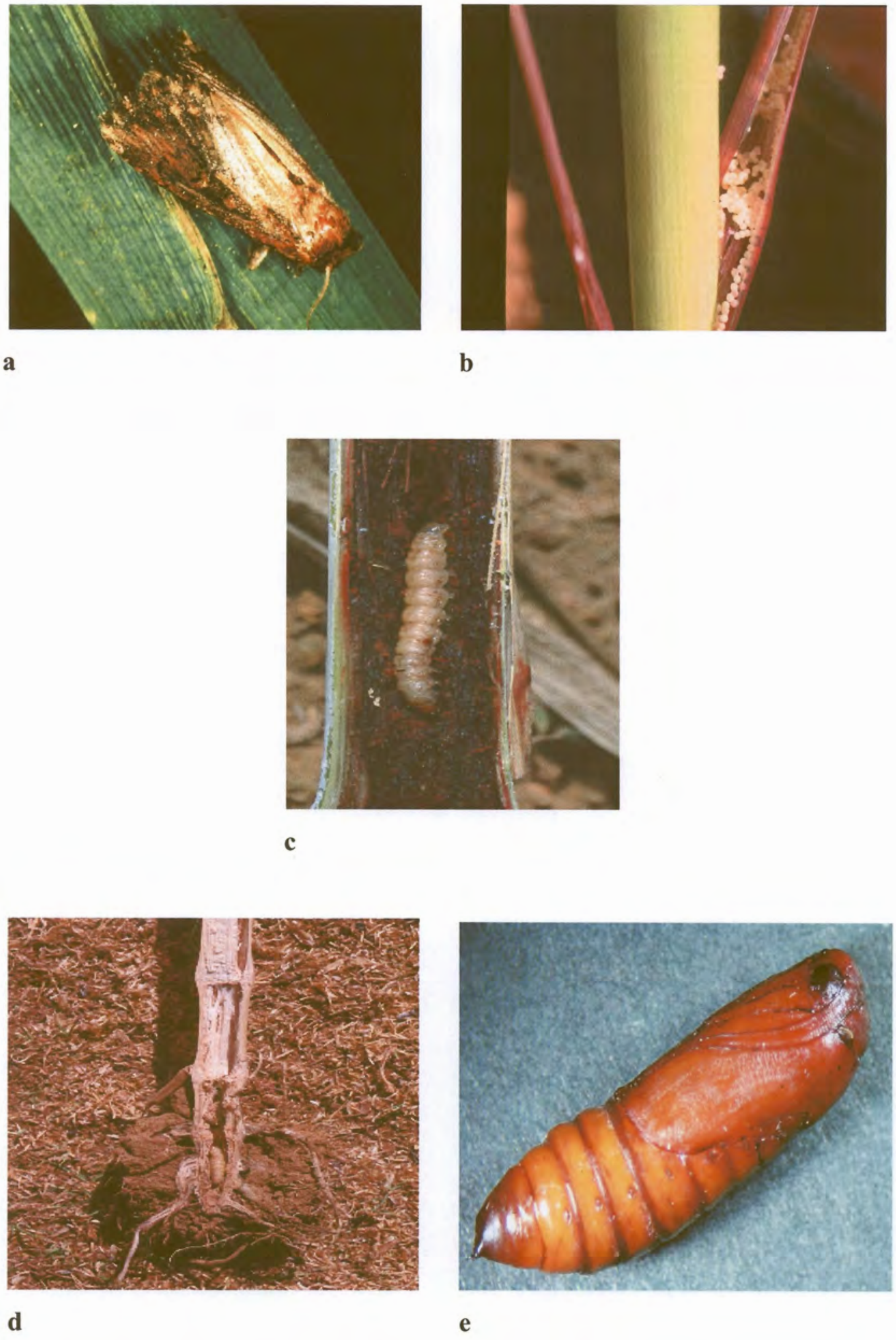


**Fig. 1**. Moth flight pattern of *Chilo partellus* (dotted line) and *Busseola fusca* (solid line). Source: Van den Berg 1997a.



**Figs 2**. Life stages of *Chilo partellus*. **a**, moth; **b**, eggs; **c**, larvae; **d**, pupae. (Not according to scale)



**Figs 3**. Life stages of *Busseola fusca*. **a**, moth; **b**, eggs; **c**, larvae; **d**, diapausing larva; **e**, pupae. (Not according to scale)

**Fig. 4**. Symptoms of whorl damage on maize (Shot holes on leaves are visible).

**Fig. 5**. Dead heart symptoms (Dead whorl leaves are visible).

**Fig. 6**. Symptoms of stem damage.

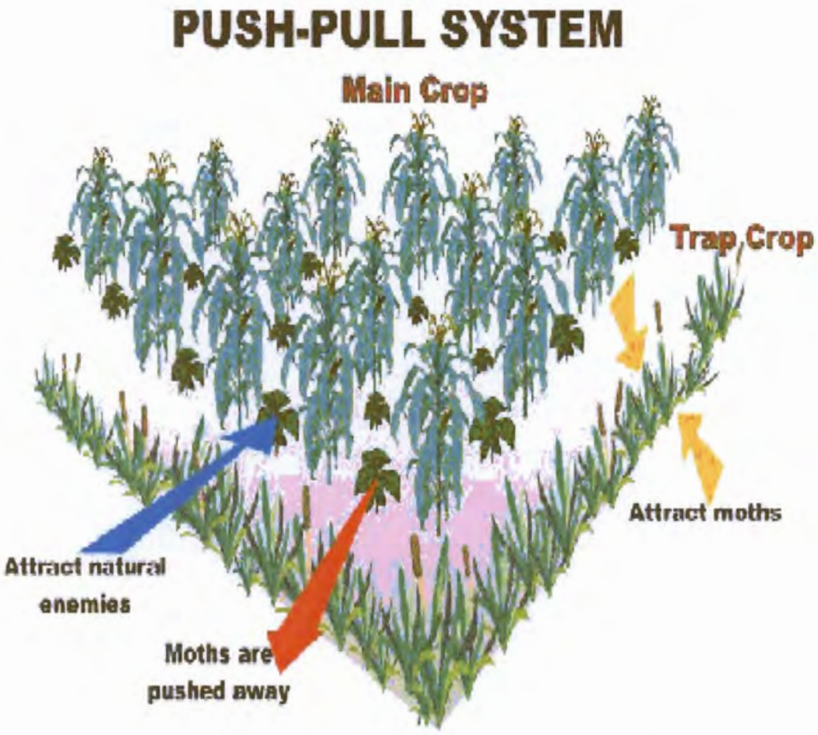


**Fig. 7**. Diagrammatic representation of a "push-pull" system. Pull crop = Trap crop for stem borers which forms a border around the main crop. Push crop = intercropped with main and produces an unpleasant odour which pushes stem borers away from the main crop.

Source: Agricultural Research Council-Grain Crops Institute.

# CHAPTER 2

# Wild host plants and their stem borers (Lepidoptera) in the Limpopo and northern Mpumalanga Provinces

## ABSTRACT

There is evidence that some wild host plants could be used in maize based farming systems to control stem borers a management system that could benefit resource poor farmers. A survey of wild host plants of stem borers was done during the 1998/99 and 1999/2000 growing seasons. The study was carried out in the Limpopo and northern Mpumalanga Province of South Africa. The surveys were conducted in four rainfall regions, 400-600 mm, 601-800 mm, 801-1000 mm and greater than 1000 mm per annum. The sites were located in subsistence farming areas, undisturbed grassland, previously cultivated areas and nearby forestry plantations. For each grass species 50 tillers were collected randomly and dissected. Plant species belonging to two families, Gramineae and Typhaceae were recorded as hosts plants to one or more species of stem borers. Of the wild host plants recorded wild sorghum and *Pennisetum purpureum* Schumach. (Gramineae) were recorded as hosts in more than one rainfall region. The stem borers found on the host plants were *Busseola fusca* Fuller (Lepidoptera: Noctuidae), *Chilo partellus* (Swinhoe) (Lepidoptera: Crambidae) and *Sesamia calamistis* Hampson (Lepidoptera: Noctuidae). While the distribution of *B. fusca* was found to be restricted to high altitudes, *C. partellus* and *S. calamistis* were found from low to high lying regions.

**Keywords**: *Busseola fusca*, *Chilo partellus*, *Sesamia calamistis*, wild host plants, distribution.

## INTRODUCTION

Most graminaceous stem borers are polyphagous and have several host plants including both cultivated and wild plants (Ingram 1958, Khan *et al.* 1997, Polaszek & Khan 1998). Before the extensive cultivation of maize (*Zea mays* L.) and sorghum (*Sorghum bicolor* (L.) Moench) in Africa, the African cereal stem borers such as *Busseola fusca* Fuller (Lepidoptera: Noctuidae), *Chilo orichalcociliellus* Strand (Lepidoptera: Crambidae), *Eldana saccharina* Walker (Lepidoptera: Pyralidae) and *Sesamia calamistis* Hampson (Lepidoptera: Noctuidae) were of no economic importance (Khan *et al.* 1997, Polaszek & Khan 1998). These stem borers survived on wild host plants. For example, *B. fusca* is assumed to have evolved and survived on wild sorghum and millets which originated in Africa (Harris 1962). Lists of wild host plants of stem borers have been provided by several authors (Wahl 1926; Ingram 1958; Duerden 1953; Harris 1962; Sithole 1990; Khan *et al.* 1997; Polaszek & Khan 1998). Today, stem borers such as *B. fusca* and *C. partellus* attack a wide range of graminaceous crops. Endemic west African stem borers of maize which are assumed to have co-evolved with native grasses started to attack maize after its introduction approximately 400 years ago (Shanower *et al.* 1993).

Little is known of wild graminaceous host plants of maize and sorghum stem borers in South Africa. The objectives of this study were thus to determine which grass species host stem borers and which stem borers occur in different regions in the Limpopo and northern Mpumalanga Provinces where resource-poor farmers cultivate sorghum, maize and pearl millet (*Pennisetum glaucum* (L.) R. Br.).

Information on wild host plants of stem borers could be used in the development of habitat management system for stem borer pest species. Wild host plants of stem borers have previously been considered both as a source of the pest that should be destroyed (Seshu Reddy 1983) and as a refuge that harboured natural enemies of stem borers (Khan & Polaszek 1998). Since some wild host plants are highly attractive to stem borers when compared to maize, this has led to the development of pest management systems in which wild host plants are used as trap crops (Khan *et al.* 2000). Similar pest management systems are being developed in South Africa and there is a need for information on wild host plants of maize and sorghum stem borers in this country.

The occurrence of stem borers in different areas is influenced by environmental conditions and this study also provides a general idea of which stem borers to expect in different regions. The paper also provides information on possible uses and value of wild host plants identified in this survey.

## MATERIAL, METHODS AND STUDY SITES

To expand knowledge on the occurrence of stem borers in wild host plants, destructive sampling surveys were undertaken randomly on wild grasses in the Limpopo Province in 34 sites and four more sites were selected in the northern parts of the Mpumalanga Province (Fig. 1). The survey of host plants was conducted coincide with the period of stem borer activity i.e. September to may for *C. partellus* and October to April for *B. fusca*. This was done during the 1998/1999 and 1999/2000 growing seasons. The areas surveyed were classified into four rainfall categories i.e. 400–600 mm, 601–800 mm, 801-1000 mm and > 1000 mm per annum. Surveys were conducted in selected sites in each of these rainfall categories (Table 1). The sites were located in subsistence farming areas, undisturbed grassland, previously cultivated areas as well as in and around forest plantations in the high rainfall areas. Since access to private land was difficult the sites were mostly alongside dirt roads. Host plant species of stem borers available at each site were collected and identified. The extent of each site was determined by the availability of host plant species. For each host plant species 50 tillers were collected randomly and dissected.

Plants in which stem borers of any life stage were found were recorded. The larvae of each stalk borer species were recorded separately for each host plant species. Larvae and pupae collected were kept until moths emerged and species identities could be confirmed. A comprehensive list of all wild host plants of stem borers was compiled. At each site altitude was recorded to determine the distribution of stem borers across low and high lying regions.

## RESULTS

The distribution of the areas surveyed is provided in Fig. 1. The presence or absence of host plants stem borers in study sites in these areas is reflected in Table 2. Host plant species belonging to two families, Gramineae and Typhaceae were recorded as hosts to one or more species of stem borers (Table 3). Thick stemmed grasses were scarce and largely confined to areas where land has been disturbed (e.g. roadsides and abandoned maize or sorghum fields). Small-scale farming activities in the Limpopo Province largely take place in areas with an annual rainfall below 500 mm. However, a number of wild host plant species occurred in the isolated high rainfall areas where forestry is the main land-use activity.

Three species of stem borers, *B. fusca*, *C. partellus* and *S. calamistis* were associated with several wild grasses and 13 wild host plant species were recorded (Table 3). No stem borers were recovered on the following commonly occurring plants *Kyllinga* sp., *Schoenoplectus corymbosus* (Roth. ex Roem. & Schult.), *Setaria megaphylla* (Steud.) Dur. & Schinz., *Eragrostis* sp., *Cyperus immensus* C.B. CL. and *Phragmites australis* (Cav.) Steud. Grass species such as *Aristida sciurus* Stapf, sedges (Cyperacea) and other *Cyperus* sp. exhibited symptoms of leaf and stem damage but, no stem borers were recovered.

Wild sorghum (*Sorghum arundinaceum* (Desv.) Stapf which usually occurred on disturbed ground, was found in all the rainfall regions (Table 4). In all these regions *S. arundinaceum*, was infested with stem borers. Similar results were found with *Typha capensis* (Rohrb.) NE. Br. However, this species was not found in areas with 400 to 600 mm rainfall (Table 4). *Sorghum arundinaceum* and *T. capensis* occurred in low as well as high lying regions (Table 5). Other wild hosts were *S. halepense* (L.) Pers. and *S. versicolor* Anderss. Stem borers were found on *Hyparrhenia tamba* (Steud.) in high rainfall regions and relatively high altitude areas (Table 4, 5). *Pennisetum purpureum* Schumach. (Napier grass) was restricted to high rainfall and high altitude areas (Table 4).

While *B. fusca* was recorded at high altitudes starting from 722 m a.s.l., *C. partellus* and *S. calamistis* were recorded from low to high altitude areas (Table 5). The results indicate that a number of wild host plants were attacked by one or more species of stem borers.

The value for grazing and uses of other wild grasses recorded during the survey is provided in Table 6. This knowledge could help in selecting a suitable host plant which could be used in pest management systems. Various wild host plants of stem borers including those listed in this study have been provided by other researchers as hosts for *C. partellus*, *B. fusca* and *S. calamistis* (Table 7).

## DISCUSSION

Thick stemmed grasses such as the wild sorghums which comprise *S. arundinaceum*, *S. bicolor* and *S. versicolor* were largely confined to areas where land has been disturbed (e.g. roadsides and abandoned maize and sorghum fields). Wild sorghums and *H. tamba* were found in low as well as high rainfall regions. This indicates that these grasses are able to survive in different climatic conditions and so host stem borers.

The wild grasses have been used in such systems in east Africa (Khan *et al.* 2000). However, before these grasses could be used the feasibility of planting them, their adaptability to different climatic conditions as well as advantages in crop fields needs to be assessed. *Hyparrhenia tamba*, a thatching grass, is not considered to be a forage grass and is unpalatable to animals (Van Oudtshoorn 1999). This is likely to make it a poor candidate for use in a pest management system.

Napier grass occurred in the Limpopo Province in small stands next to roads and in wet patches. However, the main constraint to using this grass is its high rainfall requirement, 600-1500 mm (Van Oudtshoorn 1999). Therefore, in the Limpopo Province its use would be limited to areas that receive rainfall above 600 mm per annum. In this study Napier grass was found in areas with rainfall above 800 mm. The Bana grass variety of Napier grass, however, is reported to be more drought tolerant than other varieties and will grow at rainfall as low as 350 mm per annum, making it another option for use in drought prone areas. This grass also grows well in high rainfall areas.

The absence of stem borers on wild host plants *Kyllinga* sp., *S. corymbosus*, *S. megaphylla*, *Eragrostis* sp., *C. immensus*, *A. sciurus*, other *Cyperus* sp. and sedges (Cyperaceae) possibly indicate that these plants were not suitable for stem borer colonization. However, *Kyllinga* spp. was recorded as an host for stem borers such as *E. saccharina* and *S. calamistis* in east Africa (Seshu Reddy 1983).

*Busseola fusca* is found at high altitudes (Wahl 1926; Ingram 1958; Walters & Drinkwater 1976; Gebrekidan 1985; Ebenebe 1998). Ingram (1958) noted that this species was more common at altitudes above 1 200 m. Kalule *et al.* (1997) reported *B. fusca* to occur from 1000 m a.s.l. In this study *B. fusca* was found at relatively high altitude starting from 722 m. These results possibly indicate that there might have been some changes in the distribution of *B. fusca*. Although *B. fusca* was abundant at altitudes between 1 200-1 500 m in the Central Plateau in Tanzania it was also recorded at very high altitudes (2 700 m) in the Northern and Southern highland areas (Swaine 1957). Distribution of *B. fusca* to lowveld regions is limited mainly by high temperatures experienced at lower altitudes (Swaine 1957).

*Chilo partellus* is found in warm, low-lying regions (Van Hamburg 1979a,b; Gebrekidan 1985; Kfir 1997) and restriction of *C. partellus* to low altitudes is probably due to temperature limits (Ingram 1958; Kfir 1997). Although Ingram (1958) found that *C. partellus* species was restricted to altitudes below 1 500 m in Uganda, he speculated that *C. partellus* might spread to regions higher than 1 500 m. This statement was confirmed later by Bate *et al.* (1991), when they found *C. partellus* at 1 650 m above sea level. Similar results were found in this study where *C. partellus* was found from 429 m to 1676 m above sea level. Kfir (1997) also found *C. partellus* in the eastern highveld region (1 600 m above sea level) of South Africa, an area previously known to be dominated by *B. fusca*. Van Hamburg (1979b) also reported the occurrence of this species in high lying areas such as Potchefstroom. Observations on *C. partellus* made at high altitude and harsh winter areas of South Africa indicate that this species is highly adaptable (Kfir 1997).

The occurrence of *S. calamistis* at low as well as high altitude possibly indicate that this species is also highly adaptable. Similar results in which *S. calamistis* was recovered from sea level up to high altitudes (1432 m a.s.l.) were reported by Seshu Reddy (1983).

In this study several new records of host plants of three Lepidoptera pest stem boring species were identified. Wild sorghums and *P. purpureum* were identified as possible candidates for use in pest management. However, the effect of these grasses on stem borer colonisation of cultivated crops and survival on the grasses needs to be determined in further studies before they could be used in pest management systems.

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**Table 1**. Localities where stem borers were surveyed in the four rainfall categories in the Limpopo province and northern Mpumalanga Provinces.

| Rainfall category (mm) | Magisterial district | Locality |
|---|---|---|
| > 1000 | 1. Witrivier* | Hazyview (25° 02' 00"S 31° 13' 00"E; 722 m a.s.l.) |
| | 2. Letaba 1 | Tzaneen (23° 48' 10"S 30° 07' 37"E; 553 m a.s.l.) |
| | 3. Letaba 1 | De Hoek (23° 49' 08"S 30° 03' 57"E; 1086 m a.s.l.) |
| | 4. Pietersburg | Broederstroom (23° 54' 01"S 29° 57' 29"E; 1029 m a.s.l.) |
| | 5. Pietersburg | Rietfontein (23° 55' 39"S 29° 56' 05"E; 1029 m a.s.l.) |
| | 6. Pietersburg | Brae (23° 51' 51"S 30° 00' 25"E; 969 m a.s.l.) |
| | 7. Pietersburg | Reisigerstrust (23° 55' 29"S 29° 54' 32"E; 1034 m a.s.l.) |
| | 8. Pietersburg | Tomason (23° 51' 37"S 29° 54' 28"E; 1751 m a.s.l.) |
| 801-1000 | 9. Pietersburg | Spitskop (23° 57' 00"S 29° 55' 00"E; 1676 m a.s.l.) |
| | 10. Pilgrim's rest* | Sabie (25° 07' 00"S 30° 47' 00"E; 1109 m a.s.l.) |
| | 11. Thohoyandou | Masikhwa (22° 51' 27"S 30° 38' 24"E; 457 m a.s.l.) |
| | 12. Thohoyandou | Rembander (23° 02' 51"S 30° 21' 37"E; 900 m a.s.l.) |
| | 13. Dzanani | Siloam (22° 54' 49"S 30° 12' 55"E; 876 m a.s.l.) |
| | 14. Dzanani | Knunda (22° 58' 60"S 30° 08' 31"E; 1070 m a.s.l.) |
| | 15. Soutpansburg | Mashao (23° 08' 15"S 30° 10' 44"E; 750 m a.s.l.) |
| 601-800 | 16. Belfast* | Dullstroom (25° 24' 00"S 30° 07' 00"E; 2034 m a.s.l.) |
| | 17. Warmbad | Settlers (24° 56' 00"S 28° 30' 00"E; 1050 m a.s.l.) |
| | 18. Pietersburg | Paardedrift (23° 46' 35"S 29° 56' 20"E; 1430 m a.s.l.) |
| | 19. Pietersburg | Paardedrift (23° 46' 35"S 29° 56' 52"E; 1364 m a.s.l.) |
| | 20. Pietersburg | Paardedrift (23° 45' 58"S 29° 56' 26"E; 1550 m a.s.l.) |
| | 21. Pietersburg | Welgevonden (23° 43' 51"S 29° 59' 34"E; 972 m a.s.l.) |
| | 22. Letaba 1 | Vreedsaam (23° 41' 55"S 30° 00' 24"E; 850 m a.s.l.) |
| | 23. Letaba 1 | Taganashoek (23° 46' 03"S 30° 27' 58"E; 429 m a.s.l.) |
| | 24. Thohoyandou | Tshaphele (22° 54' 31"S 30° 39' 10"E; 468 m a.s.l.) |
| | 25. Soutpansberg | Plesankhoek (23° 00' 44"S 30° 05' 56"E; 1333 m a.s.l.) |
| | 26. Soutpansberg | Shefeera (23° 02' 05"S 30° 06' 59"E; 1165 m a.s.l.) |
| | 27. Soutpansberg | Shefeera (23° 02' 54"S 30° 05' 53"E; 889 m a.s.l.) |

| | | |
|---|---|---|
| | 28. Vuvani | Masethe (23° 16' 16"S 30° 04' 55"E; 631 m a.s.l.) |
| 400-600 | 29. Potgietersrus | Zebediela (24° 19' 00"S 29° 15' 0"E; 1250 m a.s.l.) |
| | 30. Sekhukhuneland | Jane Furse (24° 43' 00"S 29° 52' 00"E; 1414 m a.s.l.) |
| | 31. Groblersdal* | Marble Hall (24° 59' 00"S 29° 17' 00"E; 1065 m a.s.l.) |
| | 32. Letaba 1 | Rioma (23° 46' 52"S 30° 31' 34"E; 547 m a.s.l.) |
| | 33. Letaba 1 | Mamotzapi (23° 40' 06"S 30° 36' 49"E; 385 m a.s.l.) |
| | 34. Thabamoopo | Turfloop (23° 50' 04"S 29° 41' 38"E; 1318 m a.s.l.) |
| | 35. Pietersburg | Pietersburg (23° 53' 00"S 29° 25' 00"E; 1266 m a.s.l.) |
| | 36. Pietersburg | Snymansdrift (24° 01' 59"S 29° 17' 10"E; 1318 m a.s.l.) |
| | 37. Pietersburg | Rietvlei (24° 04' 60"S 29° 14' 45"E; 1460 m a.s.l.) |

* Mpumalanga province

**Table 2**. Plant species that were examined for the presence or absence of stem borers in different districts in the Limpopo and northern Mpumalanga Provinces.

| Magisterial District | Locality | Plant species | BF | CP | SC |
|---|---|---|---|---|---|
| Belfast | Dullstroom | *Typha capensis* | - | + | + |
| Dzanani | Siloam | *T. capensis* | - | + | - |
| Dzanani | Knunda | *Pennisetum purpureum* | + | - | - |
| Letaba 1 | Tzaneen | *Pennisetum purpureum* | + | - | - |
| | | *Sorghum bicolor* subsp. *arundinaceum* | | | |
| | De Hoek | *T. capensis* | - | - | - |
| | Vreedsaam | *T. capensis* | - | - | - |
| | Taganashoek | *Phragmites australis* | - | - | - |
| | | *T. capensis* | - | + | - |
| | | *Cyperus immensus* | - | - | - |
| | Rioma | *Sorghum arundinaceum* | - | - | + |
| Pietersburg | Spitskop | *Sorghum halepense* | + | + | - |
| | Pietersburg | *T. capensis* | - | - | - |
| | | *Schoenoplectus corymbosus* | - | - | - |
| | | *Cyperus* sp. | - | - | - |
| | | *Kylinga* sp. | - | - | - |
| | Rietfontein | *Hyparrhenia* sp. | + | - | - |
| | Broederstroom | *Setaria megaphylla* | - | - | - |
| | Brae | *Sorghum arundinaceum* | + | - | - |
| | Reisigersrust | *Panicum* sp. | - | - | - |
| | | *Hyparrhenia* sp. | - | - | - |
| | | *Paspalum urvillei* | - | - | - |
| | | *Eragrostis* sp. | - | - | - |
| | Tomason | *Setaria megaphylla* | - | - | - |
| | Paardedrift | *Hyparrhenia* sp. | - | - | - |
| | | *Panicum* sp. | - | - | - |
| | Welgewonden | *Panicum maximum* | - | - | - |

| | | | | | |
|---|---|---|---|---|---|
| | | *Hyparrhenia* sp. | - | - | - |
| | Welgewonden | *Sorghum arundinaceum* | + | + | + |
| | Snymansdrift | *Sorghum arundinaceum* | - | - | - |
| | Rietvlei | *Sorghum arundinaceum* | - | - | - |
| Pilgrim's rest | Sabie | *Panicum maximum* | + | + | - |
| Ritavi | KaXihoko | *Sorghum arundinaceum* | - | - | - |
| Sekhukhuneland | Jane Furse | *Phragmites australis* | - | + | + |
| Soutpansburg | Plesankhoek | *Setaria megaphylla* | - | - | - |
| | Shefeera | *Paspalum urvillei* | + | + | - |
| | | *Pennisetum purpureum* | - | - | - |
| | Shefeera | *Sorghum arundinaceum* | - | - | - |
| | Mashao | *Sorghum arundinaceum* | - | - | - |
| Thabamoopo | University of the North Reasearch farm | *T. capensis* | - | - | - |
| | | *Setaria verticillata* | - | + | - |
| Thohoyandou | Tshaphele | *Sorghum arundinaceum* | - | + | - |
| | | *Panicum* sp. | - | + | + |
| | Masikhwa | *Panicum* sp. | - | - | - |
| | Rembander | *Sorghum arundinaceum* | + | - | - |
| | Rembander | *Panicum* sp. | - | - | - |
| Vuvani | Masethe | *P. australis* | - | - | - |
| Warmbad | Settlers | *Arundo donax* | + | + | + |
| Witrivier | Hazyview | *H. tamba* | + | + | - |

+, Recorded as host, -, not recorded as host. BF, *Busseola fusca*; CP, *Chilo partellus*; SC, *Sesamia calamistis*.

**Table 3**. Wild host plants of stem borers recorded in the Limpopo and northern Mpumalanga Provinces of South Africa during 1998/1999 and 1999/2000 seasons.

| Plant species | Common name | *Busseola fusca* | *Chilo partellus* | *Sesamia calamistis* |
|---|---|---|---|---|
| **Gramineae (Poaceae)** | | | | |
| *Arundo donax* | Giant reed/ Wild cane | + | + | + |
| *Hyparrhenia tamba* | Blue thatching grass | + | + | - |
| *Hyparrhenia* sp. | | + | - | - |
| *Panicum maximum* | Guinea grass | + | + | |
| *Panicum* sp. | | | + | + |
| *Paspalum urvillei* | Vasey grass | + | + | - |
| *Pennisetum purpureum* | Napier grass/ Elephant grass | + | - | - |
| *Phragmites australis* | Common reed | - | + | + |
| *Setaria verticillata* | Bur bristle grass | - | + | - |
| *Sorghum halepense* | Johnson grass | + | + | - |
| *S. versicolor* | Black-seed sorghum | - | + | - |
| *S. bicolor* subsp. *arundinaceum* | Common wild sorghum | + | + | + |
| **Typhacea** | | | | |
| *Typha capensis* | Bullrush | - | + | + |

+, recorded as host; -, not recorded as host.

**Table 4**. Occurrence in different rainfall regions of wild host plants and their stem borers in the Limpopo and northern Mpumalanga Provinces.

| Rainfall (mm) | Host plant | *Busseola fusca* | *Chilo partellus* | *Sesamia calamistis* |
|---|---|---|---|---|
| >1000 | *Hyparrhenia* sp. | + | - | - |
| | *Sorghum arundinaceum* | + | - | - |
| | *Hyparrhenia tamba* | + | + | - |
| | *Pennisetum purpureum* | + | - | - |
| | *Typha capensis* | - | + | - |
| 801-100 | *S. arundinaceum* | + | - | - |
| | *P. purpureum* | + | - | - |
| | *S. halepense* | + | + | - |
| | *Panicum maximum* | + | + | - |
| | *T. capensis* | - | + | - |
| 601-800 | *S. arundinaceum* | + | + | + |
| | *Paspalum urvillei* | + | + | - |
| | *T. capensis* | - | + | + |
| | *Arundo donax* | + | + | + |
| | *Panicum* sp. | - | + | + |
| 401-600 | *S. arundinaceum* | - | + | + |
| | *Phragmites australis* | - | + | + |
| | *Setaria verticillata* | - | + | - |

+, recorded as host; -, not recorded as host.

**Table 5**. Occurrence at different altitudes (m a.s.l.) of stem borers recorded on wild hosts in the Limpopo and northern Mpumalanga Provinces.

| Altitude (m) | Host plant | *Busseola fusca* | *Chilo partellus* | *Sesamia calamistis* |
|---|---|---|---|---|
| 429 | *Typha capensis* | - | + | - |
| 468 | *Panicum* sp. | - | + | + |
| 468 | *Sorghum arundinaceum* | - | + | - |
| 468 | *Sorghum arundinaceum* | - | + | + |
| 547 | *Sorghum arundinaceum* | - | - | + |
| 553 | *T. capensis* | - | + | - |
| 722 | *Hyparrhenia tamba* | + | + | - |
| 876 | *T. capensis* | - | + | - |
| 900 | *Sorghum arundinaceum* | + | - | - |
| 969 | *Sorghum arundinaceum* | + | - | - |
| 972 | *Sorghum arundinaceum* | + | + | + |
| 1029 | *Hyparrhenia* sp. | + | - | - |
| 1029 | *Pennisetum purpureum* | + | - | - |
| 1050 | *Arundo donax* | + | + | + |
| 1070 | *P. purpureum* | + | - | - |
| 1109 | *Panicum maximum* | + | + | - |
| 1165 | *Paspallum urvillei* | + | + | - |
| 1318 | *Setaria vercitillata* | - | + | - |
| 1414 | *Phragmites australis* | - | + | + |
| 1676 | *Sorghum halepense* | + | + | - |
| 2034 | *T. capensis* | - | - | + |

+, recorded as host; -, not recorded as host.

**Table 6**. Forage value, and uses of the wild host plants recorded during the survey.

| **Plant species** | Disadvantages/uses | Value for grazing |
|---|---|---|
| ***Arundo donax* | Serious invader, difficult to eradicate. | No value for grazing |
| *Hyparrhenia tamba* | Used as a thatching grass. | Hard and unpalatable with low forage value |
| *Panicum maximum* | Persistent weed, difficult to eradicate later when the tufts have reached maturity. | Valuable forage grass. |
| ***Paspalum urvillei* | Palatability diminishes as the plant matures. | Utilised as a cultivated pasture. |
| *Pennisetum purpureum* | Prevent soil erosion. | Excellent grazing and silage. |
| *Phragmites australis* | Grows only near sources of water. Use for light construction, as a thatching grass, for mats, baskets and arrows. | Little value for grazing. |
| *Setaria verticillata* | Persistent weed which can spread uncontrollably in gardens. | Palatable grass even when it is dry, but delivers limited production. |
| ***Sorghum halepense* | Serious weed that is difficult to control once established. | Grazing and silage. |
| *Sorghum versicolor* | Contain prussic acid and there is a danger of poisoning particularly when it is subjected to drought stress and then grazed. | Palatable grass but limited leaf production. |
| *Sorghum arundinaceum* | An important weed. Contain prussic acid, poisoning can occur especially when the plants suffer from drought | Grazing and silage. |

| | | |
|---|---|---|
| | stress.<br>Used as thatching grass. | |
| *Typha capensis* | *Found in mud and slow flowing water. Breeding sites for mosquitoes and harbours bilharzia-carrying snails. | No value for grazing. |

Source: Van Oudtshoorn, 1999; *Bromilow, 1995. **Exotic species.

**Table 7**. The three stem borers found during the present study in the Limpopo and Mpumalanga Provinces, and the wild host plants in which they have been recorded by other researchers.

| Host species | *Chilo partellus* | *Busseola fusca* | *Sesamia calamistis* |
|---|---|---|---|
| *Andropogon* spp. | x[3,8] | - | x[1] |
| *Andropogon muricatus* | - | - | x[3] |
| *Arundo donax* | x[9] | x[9] | x[9] |
| *Andropogon. sorghum* | - | x[5] | - |
| *Beckeropsis uniseta* | - | - | x[2] |
| *Cenchrus  ciliaris* | x[1,7**] | - | x[1] |
| *Cenchrus echinatus* | - | - | x[3] |
| *Coix lachryma-jobi* | x[1] | - | x[1,3] |
| *Cyperus distans* | - | - | x[2] |
| *Dactylosternium bogdanii* | x[1] | - | - |
| *Echinocloa* sp. | x[1] | - | - |
| *Echinocloa haploclada* | x[1,7**] | - | x[1,7**] |
| *Echinicloa pyramidalis* | - | x[1] | x[1,2] |
| *Eleusine coracana* | x[2] | x[2] | - |
| *Hyparrhenia cymbaria* | - | x[1] | - |
| *Hyparrhenia* sp. |  | x[9] |  |
| *Hyparrhenia filipendula* | x[1] | - | x[1] |
| *Hyparrhenia pilgerana* | x[1] | x[1] | - |
| *Hyparrhenia rufa* | x[1,2] | x[1,2] | x[1,2] |
| *Hyparrhenia tamba* | x[9] | x[9] |  |
| *Lepturus repens* | x[7**] | x[7**] | x[7**] |
| *Launaea cornuta* | x[7*] | - | - |
| *Kylinga* spp. | - | - | x[7**] |
| *Panicum deustum* | x[1] | x[1] | - |
| *Panicum maximum* | x[1,2,4,6,7,8,9] | x[1,2,7,9] | x[1,2,3,4,7**,9] |
| *Panicum crus-galli* | - | x[5] | - |
| *Pennisetum* sp. | - | x[1,] | - |
| *Pennisetum purpureum* | x[1,2,4,6,7,9] | x[1,2,5,7,9] | x[1,2,4,7,9] |

| | | | |
|---|---|---|---|
| *Pennisetum trachyphyllum* | x$^{1}$ | x$^{1}$ | - |
| *Pennisetum Typhoides* | x$^{2}$ | x$^{2}$ | - |
| *Paspalum urvillei* | x$^{9}$ | x$^{9}$ | - |
| *Phragmites australis* | x$^{9}$ | - | x$^{9}$ |
| *Phragmites* sp. | x$^{1}$ | - | x$^{1}$ |
| *Rottboellia cochinchenensis* | x$^{1}$ | x$^{1}$ | x$^{1}$ |
| *Rottboellia compressa* | x$^{2}$ | - | x$^{2}$ |
| *Rottboellia. exaltata* | - | - | x$^{4}$ |
| *Setaria inrassata* | x$^{1}$ | x$^{1}$ | - |
| *Setaria sphacelata* | - | x$^{1}$ | x$^{1}$ |
| *Setaria splendida* | - | - | x$^{2,4}$ |
| *Sorghum arundinaceum* | x$^{1,7,9}$ | x$^{1,7}$ | x$^{1,7,9}$ |
| *Sorghum halepense* | x$^{6,8,9}$ | x$^{5,9}$ | x$^{3}$ |
| *Sorghum versicolor* | x$^{1,9}$ | x$^{1}$ | x$^{1}$ |
| *Sorghum verticilliflorum* | x$^{2,6,8,9}$ | x$^{2}$ | x$^{2}$ |
| *Sorghum vulgare* | x$^{1,2}$ | x$^{1,2}$ | x$^{1,2}$ |
| *Sporobolus pyramidalis* | - | x$^{1}$ | - |
| *Sporobolus marginatus* | x$^{1,7}$ | x$^{1}$ | - |
| *Tripsacum laxum* | - | x$^{1}$ | x$^{4}$ |
| *Saccharum officinarum* | x$^{2}$ | x$^{2}$ | x$^{2}$ |
| *Vosia* spp. | - | - | x$^{1}$ |
| *Vosia cuspidata* | x$^{2}$ | x$^{2}$ | x$^{2}$ |
| *Cyperus distans* | - | - | x$^{1}$ |
| *Cyperus immensis* | - | - | x$^{1}$ |
| *Cyperus papyrus* | - | - | x$^{1}$ |
| *Typha domingensis* | - | x$^{1}$ | x$^{1}$ |
| *Typha capensis* | x$^{9}$ | - | x$^{9}$ |

1, Polaszek & Khan 1998, Khan *et al*. 1997; 2, Ingram 1958; 3, Mathee *at al*. 1974; 4, Harris 1962; 5, Wahl 1926; 6, Harris 1990; 7, Seshu Reddy 1983; 8, Sithole 1990; 9, Wild host plants found in South Africa.

[*], Only eggs were seen. [**], Appears to be a new host record.

-, not recorded as host.

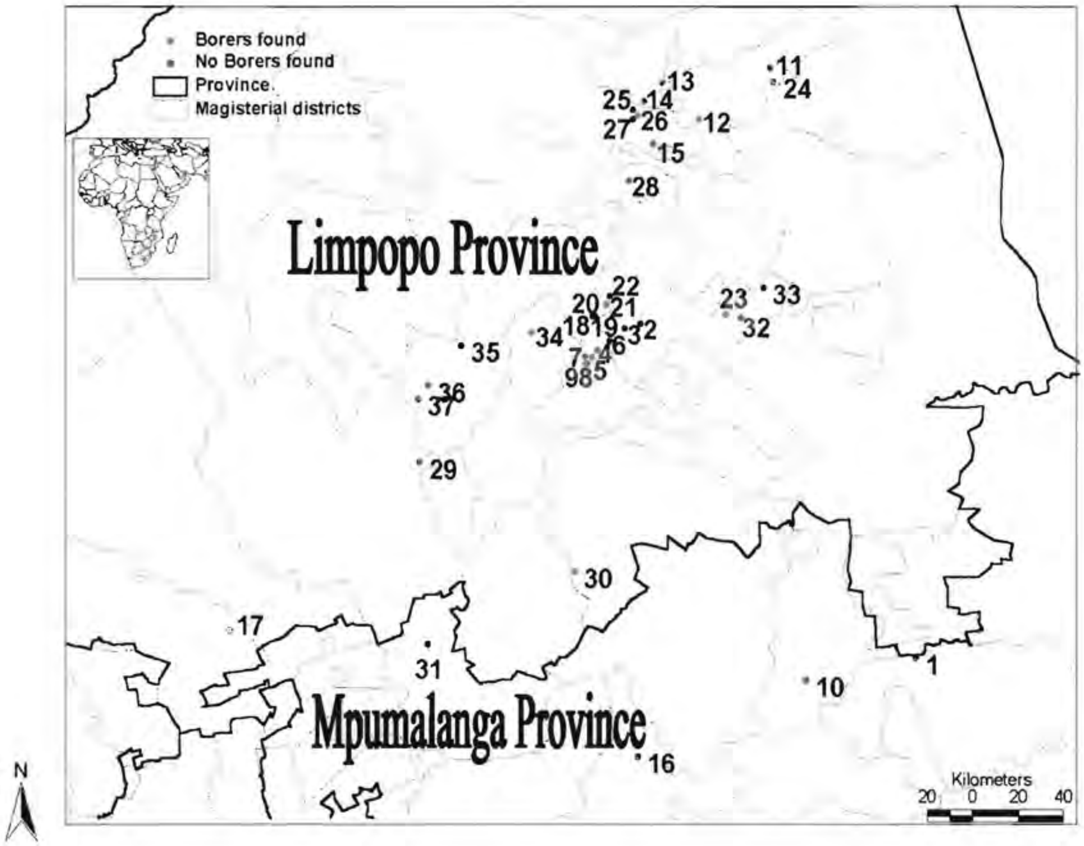

**Fig. 1**. Geographical distribution in the Limpopo and northern Mpumalanga Provinces of the areas where wild grasses were surveyed. Names of magisterial districts/sites, refer to Table 1.

# CHAPTER 3

## Colonization of cultivated and wild graminaceous host plants by *Busseola fusca* Fuller (Lepidoptera: Noctuidae) and *Chilo partellus* (Swinhoe) (Lepidoptera: Crambidae) under field conditions

## ABSTRACT

Stem borers are generally polyphagous, attacking cultivated as well as wild host plants. In this study we look at the interactions among cultivated crops, wild grasses and stem borers. Two field trials, incorporating four cultivated cereal crops and two wild grasses, were conducted. The first trial established at Potchefstroom consisted of *Zea mays* L. (maize), *Sorghum bicolor* (L.) Moench (sorghum), (*Sorghum bicolor* (L.) Moench) sweet sorghum, *Pennisetum glaucum* (L.) R. Br. (pearl millet), *Hyparrhenia tamba* (Steud) (Blue thatching grass) and, *Panicum maximum* (Jacq.) (Guinea grass). During the following two seasons *P. maximum* was replaced by *Pennisetum purpureum* Schumach. (Napier grass). The other trial was established in Pietersburg. In this trial, *P. purpureum* was replaced by *P. maximum*. In each trial plots (5 m x 5 m) were arranged in a six by six Latin Square Design. Natural infestation by stem borers was allowed to take place. The stem borers of economic importance found on host plants were *Chilo partellus* (Swinhoe) (Lepidoptera: Crambidae) and *Busseola fusca* Fuller (Lepidoptera: Noctuidae). The incidence of whorl damage, dead heart and stem damage observed indicated that all host plants were susceptible to stem borer attack. Cultivated host plants showed higher incidences of whorl and stem damage than the wild grasses. The low incidence of whorl damage on the grasses may possibly be ascribed to larval antixenosis at the feeding site. Development of stem borers was better on cultivated crops than the wild grasses. The low numbers or absence of *C. partellus* and *B. fusca* on the stems of the wild hosts compared to crops may be ascribed to poor survival of the stem borers on the grasses. The results of this study indicated better colonization of cultivated crops by the stem borers compared to the grasses.

**Keywords:** *Busseola fusca*, *Chilo partellus*, colonization, wild grasses, pest management.

## INTRODUCTION

Phytophagous insects are able to discriminate between plants that are acceptable for oviposition and feeding, and those which are not (Den Otter & Kahoro 1983). The host selection process in phytophagous insects includes host habitat location, host location and recognition, host acceptance, and host suitability (Kogan 1975). Volatile compounds are generally employed by insects in this process of host plant selection (Bernays & Chapman 1994). The response of Lepidoptera stem borers to volatiles produced by their host plants have been studied by several researchers (Den Otter & Kahoro 1983; Waladde 1983; Waladde *et al.* 1985). The success of stem borers in the colonisation process is based on the interactions between sensory cells and the physical and chemical characteristics of the plant (Waladde *et al.* 1990). Colonisation processes such as oviposition, larval arrest, establishment, feeding, larval growth and development were used by Kumar *et al.* (1993) and Ampofo *et al.* (1986) to evaluate resistance of maize cultivars to the lepidopterous stem borer *Chilo partellus* (Swinhoe) (Lepidoptera: Crambidae). Similar studies were done by Saxena (1990) on sorghum. Kumar *et al.* (1993), Ampofo *et al.* (1986) and Saxena (1990) observed differences in levels of antixenosis and antibiosis resistance on different maize and sorghum cultivars. These studies were important since mechanisms of resistance may influence colonisation of crop cultivars by *C. partellus* (Saxena 1990).

The wild grass, *Pennisetum purpureum* Schumach. (Napier grass) affects larval establishment and survival of stem borers such as *Busseola fusca* Fuller (Lepidoptera: Noctuidae) and *C. partellus* (Khan *et al.* 2000; Ndemah *et al.* 2000). Laboratory studies have shown that wild host plants are preferred to maize for oviposition by moths (Khan *et al.* 2000; Van den Berg *et al.* 2001). Wild host plants of *B. fusca* and *C. partellus* have successfully been used in stem borer management in east Africa where these highly attractive grasses are planted around crops to attract gravid female moths away from crops (Khan *et al.* 1997; Khan *et al.* 2000). A similar habitat management system in which wild host plants are used as trap crops for stem borers is therefore being investigated in South Africa (Van den Berg *et al.* 2001).

In this study, colonisation responses of these stem borer adults, *B. fusca* and *C. partellus* were studied in field trials to examine ecological relationship between stem borers and their cultivated and wild host plants. The abundance of stem borers is also investigated in the areas of study. This information will contribute to the development of a low-cost pest management system aimed at resource-poor farming systems for controlling stem borers.

## METHODS AND STUDY SITES

To study the colonization process of stem borers on host plants, two field trials, incorporating four cultivated cereal crops and two wild grasses, were conducted. One trial was conducted at the Agricultural Research Council-Grain Crops Institute in Potchefstroom over three growing seasons (1998/1999-2000/2001). During the 1998/1999 season the trial consisted of maize (*Zea mays* L.) (Cultivar CRN3414), sorghum (*Sorghum bicolor* (L.) Moench) (SNK3860), sweet sorghum (*Sorghum bicolor* (L.) Moench) (SA4479), pearl millet (*Pennisetum glaucum* (L.) R. Br.) (Okashana-1), *Hyparrhenia tamba* (Steud.) (Blue thatching grass) and, *Panicum maximum* (Jacq.) (Guinea grass). During the 1999/2000 and 2000/2001 seasons *P. maximum* was replaced by *Pennisetum purpureum* (Napier grass). The other trial was established at the University of the North's Research farm in Pietersburg during the 1999/2000 growing season. In this trial *P. purpureum* was replaced by *P. maximum*.

To ensure that the grasses were fully established at the beginning of the growing season, the wild grasses were grown first, six weeks before pearl millet, sorghum and sweet sorghum. Maize was planted ten days after the latter crops.

At Potchefstroom maize was planted in mid-February, mid-November and early-December of the 1998/1999, 1999/2000 and 2000/2001 growing seasons respectively. At Pietersburg maize was planted mid-November.

In each trial 36 blocks (5 m x 5 m) were arranged in a 6 x 6 Latin Square Design. Each host plant was replicated six times and each block consisted six rows with an inter-row spacing of 1 m. Crops were grown at an intra-row spacing of 0.3 m such that the population was maintained at 100 plants per block. The distance between blocks was 3 m to allow movement of machinery for irrigation and/or weeding.

Natural infestation of host plants by stem borers was allowed to take place and no pest control measures were applied. Destructive sampling of host plants was done five times. The first sampling began when the maize plants were four weeks old. Each sampling was done at two weeks intervals while the fifth sampling was done at physiological maturity 18-21 weeks after emergence of maize (WAE). However, data at physiological maturity for the 1998/1999 season at Potchefstroom is not provided.

Collection of data was done by removing ten randomly selected stems from each plot. The incidence of plants exhibiting whorl damage symptoms, the incidence of damaged stems as well as plants with dead heart symptoms was determined at each sampling. Shot holes on the young leaves and inner leaf whorls reflected leaf damage. Stem damage was recognized by dissecting and examining stems of host plants. Drying or dying inner leaf whorls reflected dead heart. No whorl damage was determined beyond 11 WAE. The data collected on each plant reflected interactions among stem borers and their cultivated plants and wild hosts.

The immature stages found on host plants were categorised into small, medium and large larvae and pupae. To study the growth and development of stem borer larvae on different host plants, the numbers and different categories (small, medium, large and pupae) of each borer species recovered from host plants were recorded. The presence of different immature stages of stem borers in each host plant was taken to represent the differential development rate and suitability of the specific host plants for borers.

Data on the incidence of whorl damage and dead heart symptoms as well as stem damage obtained during the 1998/1999 and 1999/2000 growing seasons at Potchefstroom and Pietersburg respectively were analysed using analysis of variance. Since the host plants used in the field trial at Potchefstroom during the 1999/2000 and 2000/2001 growing season were similar, data on dead heart symptoms, stem and whorl damage for these seasons were analysed by means of factorial analysis with season and plant species as main effects. Data on larval numbers was also analysed using analysis of variance to determine differences in infestation levels on host plants.

## RESULTS

### Stem borer species recorded on host plants

The stem borers that colonised cultivated and wild host plants were *B. fusca* and *C. partellus*. *Sesamia calamistis* (Hampson) (Lepidoptera: Noctuidae) larvae were also observed, however, population levels were extremely low. This species was only recorded during the 1999/2000 growing season in sweet sorghum and sorghum at Potchefstroom and sweet sorghum at Pietersburg. In Potchefstroom, *B. fusca* was the dominant species during the 1999/2000 growing season, while *C. partellus* was the dominant species during the other two growing seasons (Table 1). *C. partellus* dominated during the 1999/2000 growing season in Pietersburg (Table 1).

Very few egg batches of both stem borer species were observed during this study and no data on oviposition is thus provided.

## Whorl damage

Significant differences in the incidence of whorl damage was observed between host plants (Tables 2, 3 & 4). The incidence of whorl damage was significantly lower in the wild grasses and pearl millet than in maize, sorghum and sweet sorghum in most of the cases.

The results from the 1999/2000 growing season at Pietersburg also showed significant differences in the incidence of whorl damage (Table 5). The incidence of whorl damage was high in maize, sorghum and sweet sorghum compared to *H. tamba* and *P. maximum*. The low incidence of whorl damage observed in *H. tamba* and *P. maximum* did not differ significantly from each other.

## Dead heart

In the 1998/1999 season dead hearts were observed in maize, sorghum, sweet sorghum and *H. tamba* four and 11 WAE (Table 2). *Hyparrhenia tamba* and sorghum had significantly more dead hearts than the other crops four & 11 WAE respectively (Table 2). In the 1999/2000 season *P. purpureum* had the highest incidence of dead heart (Table 3) while sorghum and sweet sorghum had most dead hearts in 2000/2001 season (Table 4). These results indicated that all host plants were susceptible to dead hearts.

## Stem damage

In the 1998/1999 season significant differences in the incidence of stem damage was observed among host plants (Table 2). The incidence of stem damage in maize, sorghum and sweet sorghum was generally high compared to that observed in pearl millet, *P. maximum* and *H. tamba*. Although incidence of stem damage was high in *H. tamba* 4 WAE compared to other host plants, it was not statistically different from maize. The incidence of stem damage increased in maize, sorghum and sweet sorghum from the fourth week onwards (Table 2).

In the 1999/2000 and 2000/2001 seasons significant differences in the incidence of stem damage were also observed among host plants (Table 3 & 4). Sorghum and sweet sorghum generally had a higher incidence of stem damage compared to other host plants. Low incidence of stem damage observed in *P. purpureum* in the sixth and 11 WAE were not statistically different from most of the other plants.

In the 1999/2000 season in Pietersburg the incidence of stem damage was generally high in maize, sorghum and sweet sorghum followed by pearl millet compared to *P. maximum* and *H. tamba* (Table 5). The incidence of stem damaged in maize, sorghum, sweet sorghum and pearl millet plants increased over time from 4 WAE onwards. The results suggested that the wild grasses were less attacked than the cultivated crops such as maize and sorghum.

### Occurrence and development of the larvae of *Chilo partellus* and *Busseola fusca* on host plants

During the 1998/1999 growing season at Potchefstroom significant differences between host plants were observed in infestation by *C. partellus* within sampling periods (4 WAE: F = 5.28, d.f. = 30, P = 0.0014; 11 WAE: F = 9.82, d.f. = 30, P = 0.0001; 13 WAE: F = 12.75, d.f. = 30, P = 0.0001; 15 WAE: F = 8.04, d.f. = 30, P = 0.0001). *Chilo partellus* larvae were found in relatively high numbers in maize, sorghum and sweet sorghum throughout the growing season (Fig. 1). Larval numbers were low in pearl millet, *H. tamba* and *P. maximum*. The first pupae were recovered in maize 11 WAE. Larvae of all sizes were recovered from maize, sorghum and sweet sorghum. In *P. maximum* and *H. tamba* only small larvae were found. No medium and large larvae or pupae were found on these grasses.

During the 1998/1999 growing season at Potchefstroom significant differences between host plants were also observed in infestation by *B. fusca* within sampling periods (4 WAE: F = 4.90, d.f. = 30, P = 0.0021; 13 WAE: F = 8.04, d.f. = 30, P = 0.0001; 15 WAE: F = 4.12, d.f. = 30, P = 0.0058). *Busseola fusca* larvae were found in all plant species except *P. maximum* and *P. millet* (Fig. 2). Large larvae of *B. fusca* were found in maize, sorghum and sweet sorghum 11 WAE onwards. Only small and medium sized larvae were observed on *H. tamba*.

Significant differences between host plants in infestation by *C. partellus* were observed during the 1999/2000 season at Potchefstroom (4 WAE: F = 6.78, d.f. = 30, P = 0.0002; 6 WAE: F = 2.72, d.f. = 30, P = 0.0383; 8 WAE: F = 3.33, d.f. = 30, P = 0.0163; 11 WAE: F = 6.23, d.f. = 30, P = 0.0004; 21 WAE: F = 5.33, d.f. = 30, P = 0.0013). *Chilo partellus* larval numbers increased from 4 WAE to 11 WAE and then declined 21 WAE (Fig 3). *Chilo partellus* pupae were observed in maize, sorghum and sweet sorghum from 8 WAE onwards. The greatest number of pupae were observed in sorghum 11 WAE. While few large sized larvae of *C. partellus* were recovered from *H. tamba* plants, no larvae were found in *P. purpureum*.

Significant differences between host plants were again found in infestation by *B. fusca* during the 1999/2000 season (4 WAE: F = 6.24, d.f. = 30, P = 0.0004; 6 WAE: F = 16.56, d.f. = 30, P = 0.0001; 8 WAE: F = 15.04, d.f. = 30, P = 0.0001; 11 WAE, F = 13.72, d.f. = 30, P = 0.0001; 21 WAE: F = 2.93, d.f. = 30, P = 0.0287). *Busseola fusca* occurred on all host plants 4 WAE with the highest numbers on sorghum followed by sweet sorghum, pearl millet and maize (Fig. 4). *Busseola fusca* pupae were found in maize (11 WAE), sorghum, and sweet sorghum, eight and 11 WAE. At harvest (21 WAE) *B. fusca* larvae were still observed in all host plants with the exception of *H. tamba* (Fig. 4). The greatest number of pupae was observed on sorghum and sweet sorghum. Few large larvae were found on *H. tamba* 11 WAE, however, none were observed on *P. purpureum*. While very few *B. fusca* pupae were found in *P. purpureum* 11 and 21 WAE, none were observed in *H. tamba*.

Significant differences were again found in infestation by *C. partellus* during 2000/2001 growing season at Potchefstroom (6 WAE: F = 4.99, d.f. = 30, P = 0.0019; 8 WAE: F = 14.95, d.f. = 30, P = 0.0001; 10 WAE: F = 6.04, d.f. = 30, P = 0.0006; 18 WAE: F = 14.59, d.f. = 30, P = 0.0001). Sweet sorghum and sorghum were the crops with the highest numbers of *C. partellus* larvae throughout the growing season (Fig. 5). No *C. partellus* larvae were observed on *H. tamba* and *P. purpureum* throughout the growing season. Colonisation of maize started only at 6 WAE. *Chilo partellus* pupae were found on sweet sorghum 18 WAE and on sorghum from 6 WAE onwards.

During 2000/2001 growing season *B. fusca* was found in all the crops with the exception of *H. tamba* and *P. purpureum* (Fig. 6). While large larvae of *B. fusca* were observed in maize, sorghum and sweet sorghum, pupae were found only in sorghum and sweet sorghum.

Significant differences were again found between host plants in infestation by *C. partellus* during 1999/2000 growing season at Pietersburg (4 WAE: F = 11.19, d.f. = 30, P = 0.0001; 6 WAE: F = 19.17, d.f. = 30, P = 0.0001; 8 WAE: F = 5.79, d.f. = 30, P = 0.0001; 11 WAE: F = 8.81, d.f. = 30, P = 0.0001; 21 WAE: F = 9.57, d.f. = 30, P = 0.0001). However, infestation by *B. fusca* was not significant (6 WAE: F = 0.80, d.f. = 30, P = 0.5559) Throughout the 1999/2000 growing season at Pietersburg the greatest number of *C. partellus* larvae were found in maize, sorghum and sweet sorghum (Fig. 7). No *C. partellus* larvae were found on *H. tamba* and *P. maximum*. *Chilo partellus* pupae were observed in all cultivated host plants 11 WAE.

*Busseola fusca* larval numbers were low and larvae were found in sorghum, sweet sorghum, pearl millet and *H. tamba* (Fig. 8). No *B. fusca* was found on *P. maximum* and maize. The majority of large larvae were observed on sorghum and sweet sorghum. Pupae were found in sweet sorghum 11 WAE.

## DISCUSSION

The study indicated that *C. partellus* and *B. fusca* were the most important stem borers that attack maize, sorghum, sweet sorghum and pearl millet in the areas where trials were conducted. The presence of these stem borers on *H. tamba* and *P. purpureum* indicated that these wild grasses also serve as hosts for *C. partellus* and *B. fusca*. The low numbers of *S. calamistis* in the crop and wild host plants used in this study indicate that this species was not of economic importance in the study areas. *Sesamia calamistis* was also recorded by Van den Berg (1997) on sorghum and reported to be of no economic importance.

Potchefstroom is a high lying area (1 345 m above sea level) (Van Hamburg 1979) and *B. fusca* is known to be a dominant species in high altitude areas (Ingram 1958, Gebrekidan 1985; Ebenebe *et al.* 1999). In this study *C. partellus*, which is known to be common in low-lying areas (Van Hamburg 1979; Gebrekidan 1985; Kfir 1997) was more dominant than *B. fusca* during the 1998/1999 and 2000/2001 growing seasons at Potchefstroom. Ingram (1958) speculated that *C. partellus* might spread to altitudes higher than 1 500 m. The high abundance of *C. partellus* compared to *B. fusca* during the 1998/1999 and 2000/2001 growing seasons at Potchefstroom, an area traditionally dominated by *B. fusca* (Van Rensburg *et al.* 1988), is ascribed to the competitive advantage of *C. partellus* over *B. fusca* (Kfir 1997). The life cycle of *C. partellus* is 45 days, while that of *B. fusca* is 66 days (Ingram 1958, Van den Berg 1997). *Busseola fusca* moths starts flying when the plants are already infested by *C. partellus* (Kfir 1997). *Chilo partellus,* which emerge from diapause at the beginning of September, a month prior the normal planting time, remain active for 17 weeks (Kfir 1997, Van den Berg 1997). *Busseola fusca* moths starts to fly at the beginning of October and the first generation moths remain active for two months (Van den Berg

1997). However, while *B. fusca* moth activity ceases by the end of April (Van den Berg 1997) *C. partellus* remain active for at least a month more (Kfir 1997).

During the 1999/2000 growing season at Potchefstroom *B. fusca* was the dominant species. Rainfall at Potchefstroom was 468 mm, 569 mm and 559 mm during the 1998/1999, 1999/2000 and 2000/2001 growing seasons respectively. *Busseola fusca* is known to adapt well in moist and humid areas (Kalule *et al.* 1997) and in South Africa *C. partellus* is also reported to be a good colonizer in different rainfall (Bate *et al.* 1991).

In Pietersburg high larval numbers of *C. partellus* was observed compared to *B. fusca*. This was ascribed to warmer temperatures at Pietersburg which favour the survival of *C. partellus*. *Busseola fusca* populations peak in cooler areas and the distribution of this species is limited by high temperatures (Swaine 1957). This may be the reason why *B. fusca* contributed only 1% of the stem borers that colonised plants during the 1999/2000 season at Pietersburg.

The higher incidence of whorl damage observed on cultivated host plants indicate that these crops were more suitable for feeding by the first and second instar larvae than the grasses. Since larval feeding in the whorls occur in the early stages of colonisation of a crop, larval antixenosis at this stage may prevent successful colonisation of plants such as grass. The number of eggs oviposited, number of larvae hatching, settling and developing on a plant determine the intensity of larval feeding which is reflected by the severity of damage as a result of the feeding (Ampofo *et al.* 1986). This suggests that the severity of whorl damage observed in these host plants may give a general idea of the numbers of eggs oviposited and/or the level of larval establishment in the leaf whorls. In laboratory studies stem borers have shown ovipositional preference for grasses compared to maize (Van Rensburg & Van den Berg 1990; Khan *et al.* 2000; Khan *et al.* 2000; Van den Berg *et al.* 2001). Therefore the absence and/or low incidence of whorl damage on the grasses in the field compared to the crops may possibly be due to poor survival of larvae on the grasses.

Dead hearts occur in young plant when the level of infestation is high (Alghali 1985). However, in this study due to the continuous production of tillers by plants, dead hearts were observed on host plants in more than one or two samplings. The data showed that symptoms of dead hearts, with the exception of *H. tamba* (1998/1999 season), was generally high in sorghum and sweet sorghum compared with other host plants. Although whorl damage was observed in *H. tamba*, the low incidence and/or absence of dead heart symptoms observed in this grass can be ascribed to larval antixenosis. Similar results were observed in pearl millet and *P. maximum* during the 1998/1999 growing season and in *P. maximum* during the 1999/2000 growing season at Potchefstroom and Pietersburg respectively. Since *C. partellus* was the dominant stem borer during the 1998/1999 and 2000/2001 growing seasons the higher incidence of dead hearts in sorghum and sweet sorghum compared with other host plants might have been caused by this species since these crops are readily attacked by *C. partellus*.

Since *B. fusca* is the stem borer mostly associated with maize (Polaszek & Khan 1998) the low incidence of whorl damaged plants observed throughout the season in maize compared with sorghum and sweet sorghum in an area dominated by *B. fusca* could not be explained. However, the general absence or low incidence of dead hearts observed in maize (1998/1999, 2000/2001) compared with sorghum further indicate that this crop was less susceptible to dead hearts compared to the sorghum species. Dead hearts observed in *H. tamba* in the 1998/1999 in Potchefstroom may have been caused mostly by the dominant medium sized *B. fusca* larvae found on the grass. Small *B. fusca* larvae which were found to be abundant in *H. tamba* may also have been responsible for the formation of dead hearts in this grass during the 1999/2000 growing season at Pietersburg. During 1999/2000 and 2000/2001 growing season no dead hearts were observed on *H. tamba*.

*Busseola fusca* was the only borer species found feeding on *P. purpureum* and symptoms of dead hearts observed on this grass during the 1999/2000 and the 2000/2001 growing season at Potchefstroom suggest that this species was responsible for the damage.

The dominance of *C. partellus* during the 1998/1999 and 2000/2001 growing seasons at Potchefstroom and during the 1999/2000 growing season (99%) at Pietersburg and high incidence of whorl damage indicate that maize and sorghum were more suitable than the grasses for larval feeding. The results of the 1998/1999 and 1999/2000 have shown that maize was attacked more intensively by *C. partellus* than by *B. fusca*. Although *C. partellus* is a pest of sorghum and maize, sorghum is highly preferred to maize (Kfir 1992; Van den Berg 1997).

Different sizes of larvae and pupae of *C. partellus* and *B. fusca* observed at different stages of host plant developments were taken to reflect growth and development of the stem borers on host plants. The occurrence of large numbers of small and medium larvae throughout the growing season was ascribed to continuous egg laying by *C. partellus* or *B. fusca* on host plants. This tendency was observed in more than one growing season in maize, sorghum and sweet sorghum. Few larvae were observed in pearl millet, *H. tamba*, *P. maximum* and *P. purpureum*. These results indicate that pearl millet, *H. tamba*, *P. maximum* and *P. purpureum* were less preferred and less suitable for development of small and medium sized larvae than crops such as maize and sorghum.

The higher numbers of large larvae and pupae of *C. partellus* or *B. fusca* observed on crops indicate better development on the crops compared to the grasses. While *B. fusca* and *C. partellus* larvae in maize, sorghum and sweet sorghum pupated during the 1999/2000 and 2000/2001 growing seasons the general absence of pupae on the same crops during the 1998/1999 growing season was ascribed to late planting. Only large larvae were found at the end of the growing season. Since it was nearing the end of the growing season it was expected that large larvae would go in to diapause instead of pupating. The lack of development of *C. partellus* larvae and the absence of *B. fusca* on *P. maximum* reveal that the colonisation by either *B. fusca* or *C. partellus* on this grass was unsuccessful. The presence of medium sized larvae of *B. fusca* in *H. tamba* during the 1998/1999 growing season in which only small sized larvae of *C. partellus* were found possibly suggest that this species developed better on this grass than *C. partellus*. The presence of higher numbers of large sized larvae and pupae of *B. fusca* on *P. purpureum* in which no *C. partellus* was found indicates that *B. fusca* can survive and develop better on *P. purpureum* than *C. partellus*. Ndema *et al.* (2000) observed a high survival rate of first instar *B. fusca* larvae on *P. purpureum*. Although few of large larvae of *B. fusca* and *C. partellus* were found in *H. tamba* during the 1999/2000 season at Potchefstroom no larvae of these stem borers were observed to be entering the pupal stage. The low numbers of the stem borers observed in *H. tamba* could be ascribed to the thin nature of the stem which could possibly not sustain the food demands of large larvae or unpalatability of this grass to larvae.

Cultivated crops were readily colonised by stem borers in the presence of the grasses. The low incidence of whorl damage and stem damage on the grasses compared to crops such as maize and sorghum may be ascribed to the larval antixenosis and/or antibiosis. Development of stem borers was better on cultivated crops compared to the wild grasses. The low incidence of whorl and stem damage on the grasses compared to the cultivated crops may be due to poor survival of larvae on the grasses. In this study no data on oviposition is available therefore further investigation need to be conducted to determine ovipositional preference between stem borers and cultivated crops.

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**Table 1**. Total number of *Busseola fusca* and *Chilo partellus* recorded during the three growing seasons.

| | Number of stem borers recorded | | | |
|---|---|---|---|---|
| | Potchefstroom | | Pietersburg | |
| Season | *Busseola fusca* | *Chilo partellus* | *Busseola fusca* | *Chilo partellus* |
| 1998/1999 | 159 | 717 | - | - |
| 1999/2000 | 583 | 313 | 27 | 2671 |
| 2000/2001 | 165 | 400 | - | - |

**Table 2.** Incidence of stem borer damage observed on host plant at different sampling dates at Potchefstroom during the 1998/1999 season (Mean±S.D.).

| | | **Incidence of whorl damage (%)** | | |
|---|---|---|---|---|
| Host plant | 4 WAE* | 11 WAE | 13 WAE | 15 WAE |
| Maize | 66.7±18.6c | 53.3±18.6c | | |
| Sorghum | 56.7±25.8c | 46.7±5.2c | | |
| Sweet sorghum | 56.7±13.7c | 40.0±15.5c | | |
| Pearl millet | 26.7±13.7b | 6.7±5.2ab | | |
| *P. maximum* | 3.3±5.2a | 0.0a | | |
| *H. tamba* | 30.0±8.9b | 16.7±13.7b | | |
| F | 13.93 | 21.76 | | |
| d.f. | 30.00 | 30.00 | | |
| P | 0.0001 | 0.0001 | | |
| | | **Incidence of dead heart (%)** | | |
| Maize | 0.0a | 10.0±8.9a | | |
| Sorghum | 3.3±5.2a | 23.3±20.7b | | |
| Sweet sorghum | 3.3±5.2a | 10.0±0.0a | | |
| Pearl millet | 0.0a | 0.0a | | |
| *P. maximum* | 0.0a | 0.0a | | |
| *H. tamba* | 20.0±8.9b | 10.0±8.9a | | |
| F | 16.40 | 4.55 | | |
| d.f. | 30.00 | 30.00 | | |
| P | 0.0001 | 0.0033 | | |
| | | **Incidence of stem damage (%)** | | |
| Maize | 16.7±10.3bc | 40.0±17.9c | 36.7±5.2b | 13.3±10.3b |
| Sorghum | 10.0±8.9ab | 26.7±10.3b | 6.7±5.2a | 13.3±13.7b |
| Sweet sorghum | 6.7±10.3ab | 23.3±22.3bc | 10.0±15.5a | 10.0±8.9ab |
| Pearl millet | 0.0a | 0.0a | 3.3±5.2a | 0.0a |
| *P. maximum* | 0.0a | 0.0a | 3.3±5.2a | 0.0a |
| *H. tamba* | 23.3±13.7c | 3.3±5.2a | 3.3±5.2a | 0.0a |
| F | 6.47 | 15.17 | 16.46 | 4.46 |
| d.f. | 30.00 | 30.00 | 30.00 | 30.00 |
| P | 0.0003 | 0.0001 | 0.0001 | 0.0001 |

Means within columns followed by a different letter are significantly different ($P<0.05$).

*WAE = Week after emergence of maize crop.

**Table 3**. Incidence of damage of each host plant observed at different sampling dates at Potchefstroom during the 1999/2000 season (Mean±S.D.).

| | | **Incidence of whorl damage (%)** | | | |
|---|---|---|---|---|---|
| Host plant | 4 WAE* | 6 WAE | 8 WAE | 11 WAE | 21 WAE |
| Maize | 3.3±5.2a | 6.7±5.2a | 6.7±5.2a | 18.3±11.7a | |
| Sorghum | 53.3±10.3d | 73.3±15.1c | 51.7±23.2b | 38.3±11.7b | |
| Sweet sorghum | 23.3±12.1c | 43.3±15.1b | 60.0±25.3b | 71.7±18.4c | |
| Pearl millet | 30.0±12.6c | 26.7±17.5ab | 1.7±4.1a | 10.0±12.7a | |
| *H. tamba* | 18.3±19.4bc | 36.7±28.8b | 6.7±8.2a | 18.3±16.0a | |
| *P. purpureum* | 8.3±8.2ab | 15.0±16.4a | 5.0±8.4a | 18.3±19.4a | |
| F | 13.13 | 10.71 | 18.56 | 13.39 | |
| d.f. | 30.00 | 30.00 | 30.00 | 30.00 | |
| P | 0.0001 | 0.0001 | 0.0001 | 0.0552 | |
| | | **Incidence of dead heart (%)** | | | |
| Maize | 0.0a | 0.0a | | | |
| Sorghum | 1.7±4.1a | 3.3±8.2a | | | |
| Sweet sorghum | 1.7±4.1a | 1.7±4.2a | | | |
| Pearl millet | 0.0a | 0.0a | | | |
| *H. tamba* | 0.0±0.0a | 0.0a | | | |
| *P. purpureum* | 0.0a | 10.0±12.7b | | | |
| F | 0.80 | 2.26 | | | |
| d.f. | 30.00 | 30.00 | | | |
| P | 0.5585 | 0.0739 | | | |
| | | **Incidence of stem damage (%)** | | | |
| Maize | 0.0a | 0.0a | 3.3± 8.2a | 15.0±13.8a | 41.7±19.4b |
| Sorghum | 10.0±12.6b | 43.3±15.1c | 35.0±33.3b | 70.0±14.1c | 76.7±16.3c |
| Sweet sorghum | 0.0±0.0a | 18.3±14.7b | 30.0±21.0b | 51.7±23.2b | 78.3±27.1c |
| Pearl millet | 1.7±4.0a | 0.0a | 5.0±12.3a | 6.7±8.2a | 66.7±28.8c |
| *H. tamba* | 0.0a | 1.7±4.1a | 6.7±8.2a | 10.0±11.0a | 18.3±17.2ab |
| *P. purpureum* | 0.0a | 1.7±4.1a | 0.0a | 5.0±5.5a | 0.0a |
| F | 3.26 | 11.40 | 4.47 | 23.84 | 15.27 |
| d.f. | 30.00 | 30.00 | 30.00 | 30.00 | 30.00 |
| P | 0.0180 | 0.0001 | 0.0037 | 0.0001 | 0.0001 |

Means within columns followed by a different letter are significantly different ($P<0.05$).

*WAE = Week after crop emergence.

**Table 4**. Incidence of damage of each host plant observed at different sampling dates at Potchefstroom during the 2000/2001 season (Mean±S.D.).

| | **Incidence of whorl damage (%)** | | | | |
|---|---|---|---|---|---|
| Host plant | 4 WAE* | 6 WAE | 8 WAE | 10 WAE | 18 WAE |
| Maize | 30.0±15.5b | 26.7±17.5b | 6.7±8.2bc | 20.0±17.9bc | |
| Sorghum | 36.7±17.5b | 30.0±12.6b | 28.3±11.7b | 33.3±28.8c | |
| Sweet sorghum | 35.0±13.8b | 56.7±16.3c | 43.3±27.3b | 63.3±13.7d | |
| Pearl millet | 3.3±8.2a | 6.7±12.1a | 6.7±12.1a | 3.3±5.2ab | |
| *H. tamba* | 5.0±5.5a | 1.7±4.1a | 0.0a | 0.0a | |
| *P. purpureum* | 6.7±5.2a | 10.0±15.5a | 0.0a | 0.0a | |
| F | 10.73 | 13.18 | 10.28 | 16.59 | |
| d.f. | 30.00 | 30.00 | 30.00 | 30.00 | |
| P | 0.0001 | 0.0001 | 0.0001 | 0.0001 | |
| | **Incidence of dead heart (%)** | | | | |
| Maize | 0.0a | 0.0a | | | |
| Sorghum | 16.7±18.6b | 11.7±11.7bc | | | |
| Sweet sorghum | 6.7±8.2a | 16.7±19.7c | | | |
| Pearl millet | 1.7±4.1a | 3.3±5.2ab | | | |
| *H. tamba* | 0.0a | 0.0a | | | |
| *P. purpureum* | 0.0a | 3.3±8.2ab | | | |
| F | 3.70 | 5.13 | | | |
| d.f. | 30.00 | 30.00 | | | |
| P | 0.0100 | 0.0016 | | | |
| | **Incidence of stem damage (%)** | | | | |
| Maize | 0.0a | 0.0a | 5.0±5.5ab | 6.7±5.2a | 53.3±16.3bc |
| Sorghum | 10.0±8.9b | 11.67±9.8b | 15.0±13.8b | 16.7±13.7c | 63.3±16.3c |
| Sweet sorghum | 16.7±18.6b | 1.7±4.1a | 8.3±13.3ab | 21.7±9.8c | 86.7±15.1d |
| Pearl millet | 0.0a | 0.0a | 6.7±12.1ab | 13.3±10.3c | 43.3±12.1b |
| *H. tamba* | 0.0a | 0.0a | 5.0±12.3ab | 0.0a | 15.0±23.5a |
| *P. purpureum* | 1.7±4.1a | 0.0a | 0.0a | 0.0a | 5.0±5.5a |
| F | 6.27 | 2.90 | 1.20 | 6.952 | 22.48 |
| d.f. | 30.00 | 30.00 | 30.00 | 30.00 | 30.00 |
| P | 0.0004 | 0.0300 | 0.3330 | 0.0002 | 0.0001 |

Means within columns followed by a different letter are significantly different (P<0.05).

*WAE = Week after crop emergence.

**Table 5**. Incidence of damage of each host plant observed at different sampling dates at Pietersburg during the 1999/2000 season (Mean±S.D.).

| | | **Incidence of whorl damage (%)** | | | |
|---|---|---|---|---|---|
| Host plant | 4 WAE* | 6 WAE | 8 WAE | 11 WAE | 21 WAE |
| Maize | 61.7±17.2d | 75.0±13.8c | 78.3±13.3c | 73.3±12.1c | |
| Sorghum | 73.3±17.5d | 86.7±8.2c | 73.3±15.1c | 45.6±20.7b | |
| Sweet sorghum | 30.0±15.5c | 76.7±38.3c | 93.3±8.2d | 76.7±10.3c | |
| Pearl millet | 20.0±12.7bc | 38.3±11.7b | 50.0±24.5b | 40.0±21.0b | |
| *H. tamba* | 5.0±8.4ab | 8.3±7.5a | 0.0a | 1.7±4.1a | |
| *P. maximum* | 0.0a | 0.0a | 1.7±4.1a | 3.3±5.2a | |
| F | 30.11 | 26.35 | 53.40 | 32.67 | |
| d.f. | 30.00 | 30.00 | 30.00 | 30.00 | |
| P | 0.0001 | 0.0001 | 0.0001 | 0.0001 | |
| | | **Incidence of dead heart (%)** | | | |
| Maize | 0.0a | 0.0a | | | |
| Sorghum | 6.7±8.2b | 3.3±5.2b | | | |
| Sweet sorghum | 0.0a | 0.0a | | | |
| Pearl millet | 0.0a | 0.0a | | | |
| *H. tamba* | 0.0a | 1.7±4.1ab | | | |
| *P. maximum* | 0.0a | 0.0a | | | |
| F | 4.00 | 1.615 | | | |
| d.f. | 30.00 | 30.00 | | | |
| P | 0.0067 | 1.863 | | | |
| | | **Incidence of stem damage (%)** | | | |
| Maize | 0.0a | 5.0±12.3ab | 45.0±21.7c | 56.7±20.7c | 65.0±16.4bc |
| Sorghum | 8.3±7.5bc | 25.0±13.8cd | 65.0±18.7d | 75.0±13.8d | 71.7±29.3c |
| Sweet sorghum | 5.0±5.5abc | 35.0±12.3d | 76.7±18.6d | 85.0±16.4d | 95.0±13.8d |
| Pearl millet | 10.0±6.3c | 13.3±8.2ab | 20.0±6.3b | 40.0±16.7b | 48.3±19.4b |
| *H. tamba* | 1.7±4.1a | 0.0a | 1.7±4.1a | 0.0a | 1.7±4.1a |
| *P. maximum* | 3.3±5.2ab | 0.0a | 0.0a | 15.0±5.5a | 6.7±12.1a |
| F | 3.157 | 9.802 | 31.174 | 33.607 | 26.810 |
| d.f. | 30.00 | 30.00 | 30.00 | 30.00 | 30.00 |
| P | 0.0209 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |

Means within columns followed by a different letter are significantly different (P<0.05).

*WAE = Week after crop emergence.

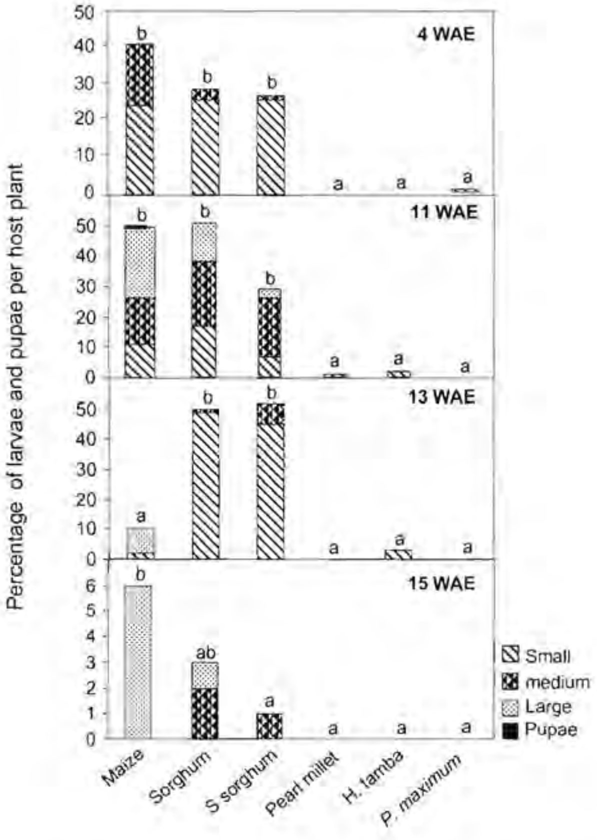

**Fig. 1**. Percetage of the total number of *Chilo partellus* larvae and pupae, and sizes of larvae on different host plants during the 1998/1999 growing season at Potchefstroom. Bars not accompanied by the same letter within sampling dates differ significantly (P<0.05). WAE = Weeks after emergence.

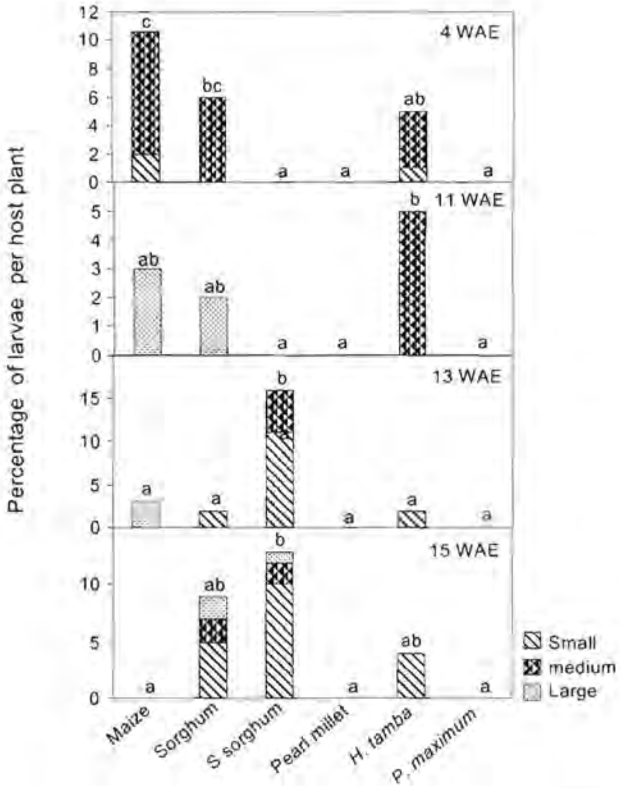

**Fig. 2.** Percentage of *Busseola fusca* larval numbers and sizes of larvae on different host plants during the 1998/1999 growing season at Potchefstroom. Bars not accompanied by the same letter within sampling dates differ significantly ($P<0.05$). WAE = Weeks after emergence.

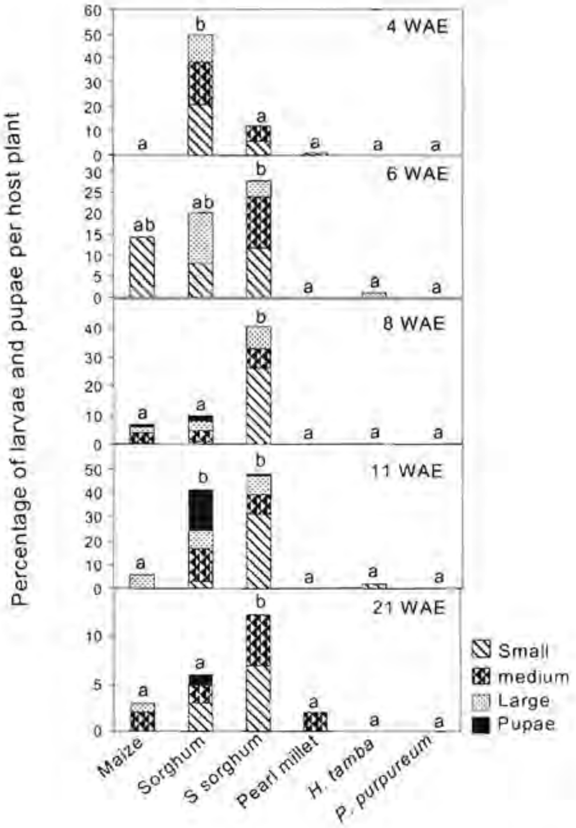

**Fig. 3**. Percentage of *Chilo partellus* larvae and pupae, and sizes of larvae on different host plants during the1999/2000 growing season at Potchefstroom. Bars not accompanied by the same letter within sampling dates differ significantly (P<0.05). WAE = Weeks after emergence.

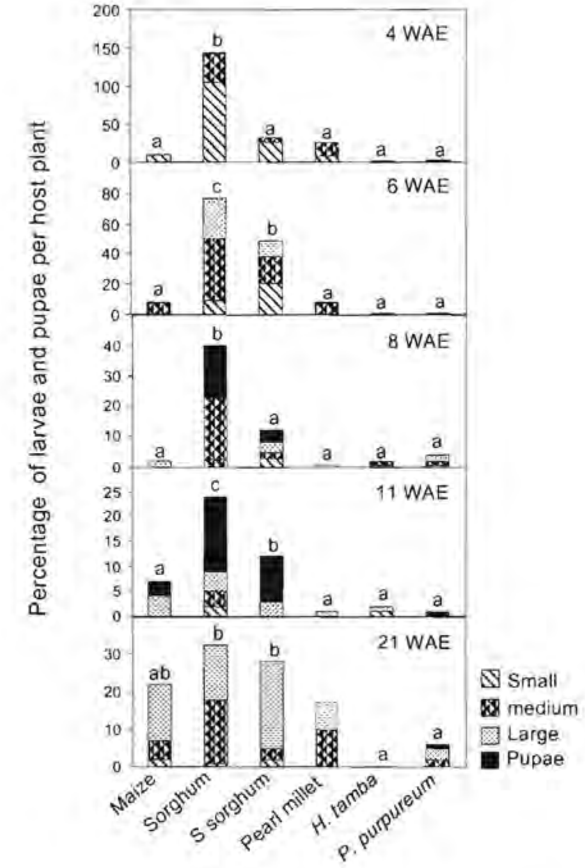

**Fig. 4**. Percentage of *Busseola fusca* larvae and pupae, and sizes of larvae on different host plants during the 1999/2000 growing season at Potchefstroom. Bars not accompanied by the same letter within sampling dates differ significantly ($P<0.05$). WAE = Weeks after emergence.

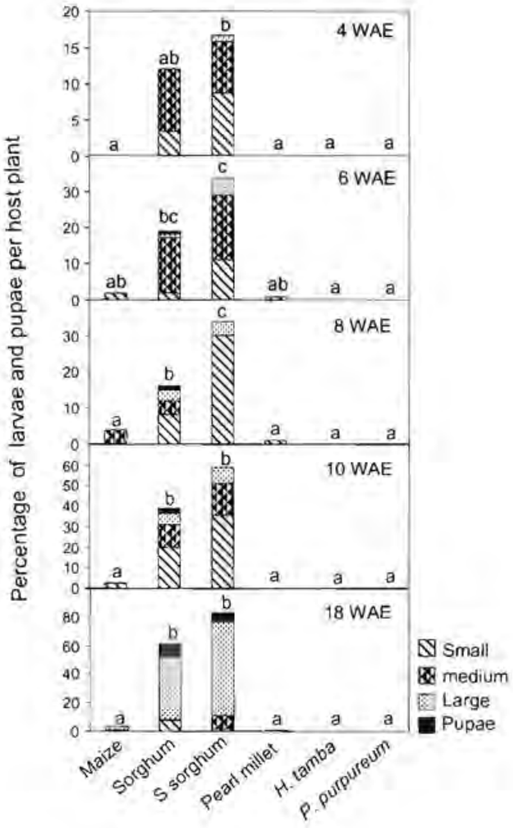

**Fig. 5**. Percentage of *Chilo partellus* larvae and pupae numbers and, sizes of larvae on different host plants during the 2000/2001 growing season at Potchefstroom. Bars not accompanied by the same letter within sampling dates differ significantly (P<0.05). WAE = Weeks after emergence.

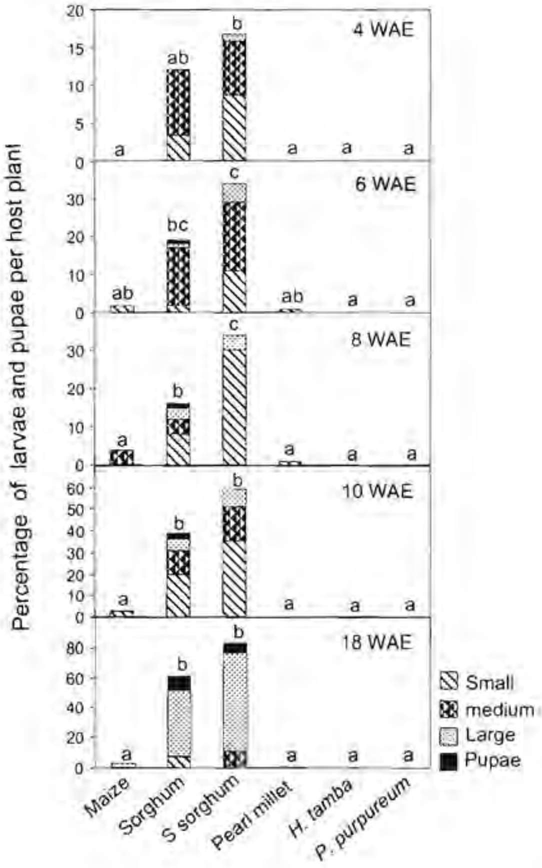

**Fig. 6**. Percentage of *Busseola fusca* larvae and pupae, and sizes of larvae on different host plants during the 2000/2001 growing season at Potchefstroom. Bars not accompanied by the same letter within sampling dates differ significantly (P<0.05). WAE = Weeks after emergence.

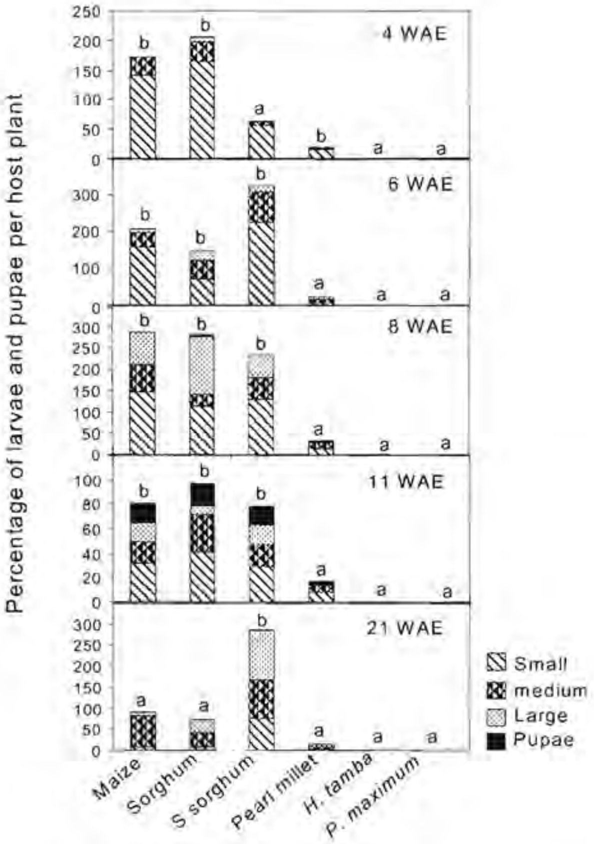

**Fig. 7**. Percentage of *Chilo partellus* larvae and pupae, and sizes of larvae on different host plants during the 1999/2000 growing season at Pietersburg. Bars not accompanied by the same letter within sampling dates differ significantly (P<0.05). WAE = Weeks after emergence.

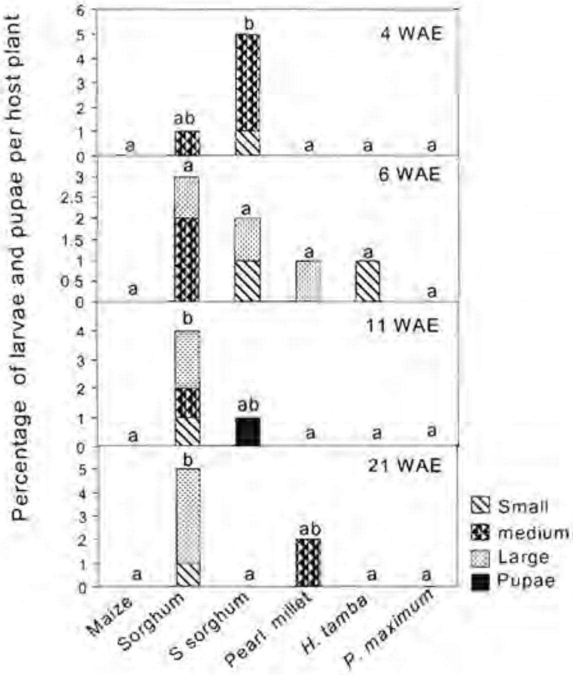

**Fig. 8**. Percentage of *Busseola fusca* larvae and pupae, and sizes of larvae on different host plants during the 1999/2000 growing season at Pietersburg. Infestation was not observed 8 WAE. Bars not accompanied by the same letter within sampling dates differ significantly (P<0.05). WAE = Weeks after emergence.

# CHAPTER 4

# Oviposition preferences of *Chilo partellus* (Swinhoe) (Lepidoptera: Crambidae) for cultivated and wild graminaceous host plants

## ABSTRACT

*Chilo partellus* (Swinhoe) (Lepidoptera: Crambidae) is known to oviposit on graminaceous crops as well as some wild graminaceous host plants. Oviposition preference of *C. partellus* moths for cultivated and wild host plants was evaluated in two-choice and multiple-choice tests under laboratory conditions. To predict the oviposition response of *C. partellus* moths on a single host plant, no-choice tests were conducted. All tests were done under cage conditions. The host plants were the wild grasses Blue thatching grass *Hyparrhenia tamba* (Steud.) and Napier grass *Pennisetum purpureum* Schumach., while crop hosts were maize (*Zea mays* L.), sorghum (*Sorghum bicolor* (L.) Moench), sweet sorghum (*Sorghum bicolor* (L.) Moench), and pearl millet (*Pennisetum glaucum* (L.) R. Br.). The mean number of eggs per plant, mean number of egg batches and mean number of eggs per batch differed significantly between host plants in multiple-choice tests. In no-choice tests only mean number of egg batches per plant were found not to differ significantly. In two choice-tests, significant differences were observed in mean number of eggs and mean egg batches per plant between maize and *H. tamba*, as well as maize and *P. purpureum* combinations. Significant differences were also observed in mean number of eggs per plant and mean number of egg batches per plant between *H. tamba* and sorghum, and *H. tamba* and sweet sorghum combinations. More eggs, egg batches and eggs per batch were recorded on *H. tamba* and *P. purpureum* than on maize and sorghum. The results indicate that the wild grasses, *H. tamba* and *P. purpureum*, were highly attractive for oviposition and that these grasses could possibly be used as trap crops in a habitat management system for *C. partellus*. Pearl millet was also highly preferred for oviposition by *C. partellus* moths.

**Key words**: *Chilo partellus*, wild grasses, *Pennisetum purpureum*, maize, habitat management.

## INTRODUCTION

The exotic stem borer, *Chilo partellus* (Swinhoe) (Lepidoptera: Crambidae) is a serious pest of maize and sorghum in South Africa. To develop a sound management system for *C. partellus*, its interaction with alternative host plants must be investigated. These alternative hosts could potentially be used as trap crops for *C. partellus* in pest management systems.

In the Limpopo Province of South Africa, maize (*Zea mays* L.) and sorghum (*Sorghum bicolor* (L.) Moench) which are widely grown by resource-poor farmers, are attacked by lepidopterous stem borers such as *Busseola fusca* Fuller (Lepidoptera: Noctuidae) and *C. partellus*. Oviposition by *C. partellus* moths has been extensively studied on sorghum (Singh & Rana 1984; Saxena 1987; Alghali 1988, Van den Berg & van der Westhuizen 1997) and maize (Ampofo 1985; Kumar 1988, 1992a,b, 1993, 1997; Kumar *et al.* 1993). Pearl millet (*Pennisetum glaucum* (L.) R. Br.) was also recorded as host for *C. partellus* (Ingram 1958; Sithole 1990), while sweet sorghum (*Sorghum bicolor* (L.) Moench) appeared to be a promising trap crop for *B. fusca* (Wahl 1926; Rebe *et al.* 1999) and *C. partellus* (Rebe *et al.* 2001). In addition to these cultivated crops, several wild host plants have been reported (and documented in this study, Chapter 2) to be attacked by stem borers (Wahl 1926; Ingram 1958; Sithole 1990; Khan *et al.* 1997; Polaszek & Khan 1998).

Previous studies have shown that some wild grasses are highly preferred by stem borers over cultivated host plants such as maize and sorghum (Van Rensburg & Van den Berg 1990; Khan *et al.* 1997; Khan *et al.* 2000). The oviposition response of *B. fusca* moths to graminaceous fodder crops, maize and sorghum was evaluated under laboratory conditions by Van Rensburg & Van den Berg (1990). They found that fodder crops such as fodder sorghum and pearl millet were highly preferred for oviposition compared to maize and grain sorghum. However, little information is available on the preference of *C. partellus* for wild grasses in South Africa.

The objective of this study was thus to determine the oviposition response and preference of *C. partellus* moths to cultivated and wild graminaceous host plants under laboratory conditions. Results of this study could help in identifying a suitable trap crop for the control of *C. partellus* in maize and sorghum fields.

## MATERIAL AND METHODS

Oviposition response of *C. partellus* was evaluated by allowing the moths to oviposit on a single host plant while in preference tests moths were given a choice to oviposit on two or more host plants. The oviposition response of moths was determined using no-choice tests, while oviposition preference of this species were evaluated in two-choice and multiple-choice experiments.

### No-choice test

The host plants used in bioassays were maize (Cultivar CRN3414), sorghum (SNK3860), sweet sorghum (SA4479), pearl millet (Okashana-1), *Hyparrhenia tamba* (Steud.) (Blue thatching grass) and *Pennisetum purpureum* Schumach. (Napier grass).

Five plants per pot of each of these varieties and species were grown in 2 litre (L) pots. As a result of differences in the growth rate of the different host plants, planting dates were manipulated to provide moths with plants of each host plant species that were approximately the same size and height during the experiment (Van Rensburg & Van den Berg 1990). *Hyparrhenia tamba* and *P. purpureum* were planted first and allowed to establish in pots. Pearl millet, sweet sorghum and sorghum were planted six weeks later, followed by maize ten days thereafter. Three weeks after emergence cultivated host plants were thinned to one plant per pot.

Six different host plant species were transferred to the laboratory when they reached a height of 30 cm. Each pot of each host plant species was placed singly in a wire mesh cage (45 cm x 52 cm x 82 cm). The cages were placed on the floor and their positions were completely randomised (Fig. 1).

Five pairs of one day old female and male *C. partellus* moths were released in each cage and the female moths were allowed to oviposit for 48 hours. Plants were then removed from cages and the number of eggs laid on each host plant recorded. The experiment was repeated six times in a period of 12 days.

### Two-choice test

This experiment was also conducted in the laboratory in similar cages as the no-choice test. However, in this case each cultivated host plant (maize, sorghum, sweet sorghum and pearl millet) was paired with each wild host plant (*P. purpureum* or *H. tamba*).

The following combinations of plants were used: maize vs. *P. purpureum*, maize vs. *H. tamba*; pearl millet vs. *P. purpureum*, pearl millet vs. *H. tamba*; sorghum vs. *P. purpureum*, sorghum vs. *H. tamba*; sweet sorghum vs. *P. purpureum* and sweet sorghum vs. *H. tamba*.

For each combination of host plants the positions of the cages were completely randomised (Fig. 1). Ten pairs of one day old female and male *C. partellus* moths were released in each cage, which contained one cultivated and one wild host plant located at opposite ends of the cage. Plants were removed and checked for egg batches two days after release of the moths. The total number of eggs were recorded on each host plant. For each combination of host plants the experiment was replicated six times.

### Multiple-choice test

A multiple-choice test for ovipositional preference was also conducted under similar conditions to the no-choice and two-choice tests. Six pots, each with a different host plant species, were transferred to one cage (80 cm x 70 cm x 110 cm) (Fig. 2). The plants were placed in a circular arrangement equal distances apart. Fifteen pairs of one day old female and male *C. partellus* moths were released in the centre of each cage and the female moths were allowed to oviposit on host plants. To eliminate positional bias by the moths the host plants were rearranged inside the cages in each replicate. The number of eggs on each host plant was counted 48 hours after moths were released. The experiment was replicated six times.

In no-choice and two-choice tests significant differences between the mean number of eggs, mean number of egg batches per plant and mean number of eggs per batch found on different host plants were determined with analysis of variance and t-tests respectively. Oviposition preference data from the multiple-choice test was log (X+1) transformed before analysis.

## RESULTS

### No-choice test

Significant differences in mean number of eggs per plant between host plants were observed (F = 2.75, d.f. = 30, P = 0.0369). In no-choice tests, the greatest number of *C. partellus* eggs per plant was observed on the wild grass, *H. tamba* (Table 1). The number of eggs laid on *H. tamba* was significantly higher than those laid on maize, sweet sorghum or sorghum, but not significantly greater than those laid on *P. purpureum* and pearl millet. Although no significant differences in the mean number of egg batches per plant (F = 1.09, d.f. = 30, P = 0.3855) were observed, differences in the mean number of eggs per batch were significant (F = 3.582, d.f. = 30, P = 0.0117) (Table 1).

### Two-choice tests

No significant differences were observed in mean number of eggs per plant (F = 0.49, d.f. = 10, P = 0.5084) and mean number of egg batches per plant (F = 0.26, d.f. = 10, P = 0.6246) when pearl millet was paired with *H. tamba* or *P. purpureum* (Table 2). Similar results were observed with sorghum and sweet sorghum when paired with *P. purpureum* (Table 2). Maize had significantly lower mean number of eggs per plant and lower mean number of egg batches per plant than *H. tamba* (eggs: F = 11.58, d.f. = 10, P = 0.0067; batches: F = 1.10, d.f. = 10, P = 0.007) or *P. purpureum* (eggs: F = 13.81, d.f. = 10, P = 0.0040; batches: F = 7.56, d.f. = 10, P = 0.0205). Sorghum also had significantly lower numbers of eggs per plant (F = 11.94, d.f. = 10, P = 0.0062) and lower mean egg batches per plant (F = 9.76, d.f. = 10, P = 0.0108) than that recorded for *H. tamba*. Similar results were found for sweet sorghum. The numbers of eggs per batch were not significantly different between sorghum (F = 0.21, d.f. = 10, P = 0.6639) or sweet sorghum (F = 1.58, d.f. 10, P = 0.237) and *H. tamba*.

### Multiple-choice test

Significant differences in number of eggs (F = 6.50, d.f. = 30, P = 0.0003), number of eggs per batch (F = 3.76, d.f. = 30, P = 0.0092) and number of batches per plant (F = 5.52, d.f. = 30, P = 0.0010) were found among host plants. The greatest proportion of eggs was laid on *H. tamba* (Table 3). However, the numbers were not significantly higher than those of eggs laid on *P. purpureum*, pearl millet and sweet sorghum (Table 3). *Hyparrhenia tamba* and *P. purpureum* had significantly more eggs compared to eggs on maize and sorghum (Table 3). The fewest eggs per plant of all host plants was observed on maize and sorghum. *Hyparrhenia tamba* and *P. purpureum* had significantly more egg batches per plant and eggs per batch than both maize or sorghum (Table 3).

## DISCUSSION

Although *C. partellus* moths were not provided with choice of host plants in no-choice tests, the results were similar to those obtained in the multiple-choice test. The most eggs laid on the wild grass *H. tamba* indicated acceptance and high suitability of this grass for oviposition by *C. partellus*. In addition to other *Hyparrhenia* species in Kenya (Khan *et al*. 1997; Polaszek & Khan 1998), *H. tamba* seems to be an important host plant for *C. partellus*. The selection of an oviposition site seems to be a critical stage in the choice of a host plant (Khan 1997). Since oviposition preference is influenced by attractiveness of a plant (Khan 1997) it can be reasoned that the differences in egg numbers in two-choice and multiple-choice tests were due to contact perceivable characters such as surface waxes and the presence of trichomes (Ampofo 1985; Kumar 1997). Leaf surface waxes may contribute significantly to host specificity in which the presence of certain compounds on the leaf may elicit oviposition (Bernays & Chapman 1994). *Hyparrhenia tamba* which was highly preferred to *P. purpureum* for oviposition in no-choice and multiple-choice tests is devoid of trichomes. Trichomes are known to prevent some insect species from ovipositing on plants (Bernays & Chapman 1994). In contrast corn earworm, *Helicoverpa zea* (Boddie) (Lepidoptera: Noctuidae) lays more eggs on hairy surfaces simply because the female is able to hold on to the hairs during oviposition (Bernays & Chapman 1994). Kumar (1992b) observed significantly higher oviposition by *C. partellus* on the hairless leaf side of the maize cultivar ICZ-T than on the side with trichomes. Roome *et al*. (1977) reported that selection of smooth surfaces for oviposition by *C. partellus* might play an important role in preventing desiccation and dislodging of the eggs.

*Hyparrhenia tamba* has thin stems that can have a negative effect on the survival of *C. partellus* larvae. For example, stalk borer larvae of *Papaipema nebris* (Guenée)

(Lepidoptera: Noctuidae) have been observed moving from small stemmed grasses to thick stemmed suitable host plants such as maize (Lasack & Pedigo 1986). *Pennisetum purpureum*, which was also highly preferred for oviposition by *B. fusca* and *C. partellus* moths does not promote larval survival (Van Rensburg & Van den Berg 1990, Khan *et al.* 2000). These results support findings by Roome *et al.* (1977) which show choice of oviposition site seems to favour egg survival rather than to promote larval survival indicating that larvae are able to disperse to more suitable feeding sites. Larval dispersal is an adaptive behaviour in which young larvae spin a silk thread and used it to migrate, get dispersed by wind (Van Hamburg 1980) and thereby transfer to adjacent plants (Chapman *et al.* 1983, Ampofo 1986, Berger 1989, Päts and Ekbom 1992).

Since more egg batches and eggs per batch were recorded on *H. tamba* and *P. purpureum* than on other host plants results reaffirm the attractiveness of these host plants for oviposition by *C. partellus*. In multiple-choice tests the high number of eggs per batch was recorded on *H. tamba* than on *P. purpureum*. Large egg clusters are likely to be drought resistant, while small clusters may lose water faster because water loss is dependent on the relationship between the surface area and the size of the egg batch (Berger 1989). It can be predicted that as a result of limited food resources for neonate larvae in highly preferred, thin stemmed grasses, mortality of larvae emerging from large clusters on these grasses is likely to be higher. This could possibly result in a reduction in the number of larvae migrating to nearby crops such as maize.

While no-choice and multiple-choice tests provided a general indication of moth's preference for grasses and cultivated host plants, preference for *P. purpureum* and *H. tamba* as suitable host plants for oviposition was confirmed in a two-choice test. Host plant preference studies conducted in the laboratory showed that *P. purpureum* was as favourable as maize for oviposition by *B. fusca* moths (Van Rensburg & Van den Berg 1990). Similar results in which *P. purpureum* was highly preferred over maize for oviposition by stem borers such as *B. fusca* and *C. partellus* have been obtained under field conditions (Khan *et al.* 2000, Ndemah *et al.* 2000). However, since *H. tamba* and *P. purpureum* were highly preferred for oviposition compared to maize, sorghum and sweet sorghum in two-choice tests, the results can be of particular importance in predicting the performance of *C. partellus* moths under field conditions. In the field in which wild grasses are grown as trap crops for stem borers around maize fields it can be predicted that frequency of oviposition of *C. partellus* moths will be higher on grasses than on the cultivated crops. Surprisingly *H. tamba* seem to be the most preferred grass for oviposition compared with all other host plants. These results encourage further studies on the use of *H. tamba* as a trap crop.

The pronounced preference of *C. partellus* moths for *P. purpureum* compared to maize confirm results of previous studies (Khan *et al.* 1997, Khan *et al.* 2000) that this grass can be used as a trap crop for stem borers. The role of *P. purpureum* in stem borer invasion of maize fields (Ndemah *et al.* 2000) and its role as trap crop for stem borers has been investigated (Khan *et al.* 1997; Ndemah *et al.* 2000). While Khan *et al.* (1997) indicated *P. purpureum* to be effective as a trap crop for *B. fusca* and *C. partellus* under field conditions in East Africa, Ndemah *et al.* (2000) discovered that *B. fusca* infestation of maize increased when *P. purpureum* was planted as a trap crop suggesting that this grass species was less suitable for use as a trap crop for *B. fusca.*

Pearl millet also attracted considerably more oviposition by *C. partellus* than any of the cultivated host plants. Pearl millet and *P. purpureum* are congeneric, which may explain the high preference of *C. partellus* for pearl millet.

The general preference of grasses for oviposition observed in this study is the first step towards developing a habitat management strategy for small scale farmers. It is therefore interesting to know whether the first instar larvae that hatch from the eggs would prefer to feed on the host.

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**Table 1**. Ovipositional response of *Chilo partellus* to various host plants species in no-choice test (± S.D.). n = 5 pairs of moths per plant per host plant.

| Host plant | Mean number of eggs/plant | Mean number of egg batches/plant | Mean number of eggs/batch |
|---|---|---|---|
| Sorghum | 114.83±149.19a | 10.00±13.78a | 9.98±7.66a |
| Sweet sorghum | 166.67±62.70ab | 7.67±5.99a | 30.90±16.65b |
| Maize | 168.17±156.90ab | 9.67±8.24a | 19.11±11.77ab |
| Pearl millet | 245.83±184.13abc | 10.17±8.26a | 29.68±22.17b |
| *Pennisetum purpureum* | 342.33±257.13bc | 14.00±12.88a | 25.86±12.78ab |
| *Hyparrhenia tamba* | 413.17±154.22c | 17.17±9.99a | 23.00±5.96ab |

Means within columns followed by different letters are significantly different (P<0.05).

**Table 2**. Ovipositional response of *Chilo partellus* to various host plant species in two-choice test (± S.D.). n = 10 pairs of moths for each two choice test.

| Host plant combinations | Mean number of eggs/plant | Mean number of egg batches/plant | Mean number of eggs/batch |
|---|---|---|---|
| Pearl millet | 429.17±372.01a | 16.50±18.60a | 30.98±18.60a |
| *Hyparrhenia tamba* | 309.83±192.34a | 12.33±7.79a | 28.40±10.17a |
| Pearl millet | 375.00±286.51a | 11.50±6.47a | 31.18±6.87a |
| *Pennisetum purpureum* | 232.83±154.34a | 9.33±5.65a | 23.94±5.03a |
| Sorghum | 84.33±68.27a | 4.50±3.67a | 20.81±23.79a |
| *Hyparrhenia tamba* | 362.17±184.71b | 14.00±6.48b | 25.41±4.06a |
| Sorghum | 50.50±46.75a | 2.67±2.73a | 17.19±13.30a |
| *Pennisetum purpureum* | 228.33±312.63a | 7.67±8.94a | 24.67±12.52a |
| Maize | 44.67±35.72a | 2.67±1.21a | 16.24±7.07a |
| *Hyparrhenia tamba* | 300.33±180.57b | 15.33±9.09b | 20.90±8.23a |
| Maize | 28.83±37.20a | 1.50±1.97a | 11.67±17.47a |
| *Pennisetum purpureum* | 206.17±110.79b | 1.67±5.13b | 33.33±19.66a |
| Sweet sorgum | 50.67±46.54a | 2.67±2.43a | 17.27±12.91a |
| *Hyparrhenia tamba* | 253.00±138.11b | 10.83±6.77b | 53.93±70.25a |
| Sweet sorgum | 71.67±123.79a | 2.17±3.06a | 13.46±24.16a |
| *Pennisetum purpureum* | 151.00±95.21a | 7.17±3.19a | 19.62±6.28a |

Means within columns (for each combination of two host plants) followed by a different letter are significantly different ($P<0.05$).

**Table 3**. Ovipositional response of *Chilo partellus* to various host plants species in multiple-choice test (± S.D.). n = 15 pairs of moths per six different plants of each host plant.

| Host plant | Mean number of eggs/plant | Mean number of egg batches/plant | Mean number of eggs/batch |
|---|---|---|---|
| Maize | 22.83±34.17a | 1.67±1.86a | 7.22±7.38a |
| Sorghum | 31.17±29.07ab | 1.33±1.21a | 19.42±21.14ab |
| Sweet sorghum | 64.00±52.14bc | 2.50±1.87ab | 26.75±15.83bc |
| *Pennisetum purpureum* | 79.50±53.05c | 2.83±1.60ab | 27.91±13.73bc |
| Pearl millet | 130.17±54.01c | 5.00±2.76bc | 40.69±40.26c |
| *Hyparrhenia tamba* | 242.33±155.45c | 8.50±5.68c | 29.37±6.09c |

Means within columns followed by different letters are significantly different ($P<0.05$).

**Fig. 1**. Cages in which no-choice and two-choice oviposition preference tests were done.

**Fig. 2**. A cage in which multiple-choice oviposition preference tests were done.