Introduction

*Chilo partellus* (Swinhoe), also known as the spotted stem borer (SSB), likely invaded Africa from India sometime before 1930 (Overholt et al. 1996). The pest now inhabits much of eastern and southern Africa. SSB is highly invasive, having partially displaced a related stem borer species, *C. orichalcociliellus* in several areas, including the low altitude and coastal maize regions of Kenya (Ofomata et al. 1999a; Ofomata et al. 2000; Mbapila et al. 2002). SSB also co-exists in many areas with another economically important maize stem borer, *Busseola fusca* (Lepidoptera: Noctuidae), particularly in the moist mid-altitude and moist transitional agroecological zones of Kenya (van den Berg et al. 1991; Polaszek 1998; Abate et al. 2000; De Groote et al. 2003). Interestingly, Kfir (1997) reported a partial displacement of *B. fusca* by SSB, in the eastern Highveld region of South Africa, at an elevation of 1600 m.

Known Distribution

SSB is currently known to occur in India, Pakistan, Afghanistan, Nepal, Bangladesh, Sri Lanka, Thailand, Laos, Vietnam, Yeman and portions of Indonesia (CABI 2007). In Africa, SSB is found in most eastern and southern sub-Saharan countries, including Botswana, Cameroon, Eritrea, Ethiopia, Kenya, Malawi, Mozambique, Somalia, Sudan, South Africa, Lesotho, Swaziland, Tanzania, Uganda, Zambia and the island, Comoros; SSB is also found in Madagascar (CABI 2007; De Groote et al. 2002; 2003; Haile and Hofsvang 2001; Kfir et al. 2002; Tefera 2004). There is one report of SSB in Australia (Ampofo and Saxena 1989). SSB distribution is highly influenced by altitude and moisture gradients. In Kenya, for example, SSB populations are most common in the dry mid-altitude and dry coastal areas, but the pest also occurs in the moist-transitional and moist mid-altitude (ca. <1500 m) agroecological zones (De Groote et al. 2003; Muhammad and Underwood 2004).
Description and Biology

SSB exhibits complete metamorphosis, including egg, larval, pupal and adult stages. SSB will complete 1, 2 or more generations per year, depending on the location and the number of maize crops or other hosts available throughout the year (Muhammad & Underwood 2004). One aspect of SSB biology, that is relevant to understanding its population dynamics and geographic distribution, is the strategy for diapause or the “resting period” (e.g., Kfir et al. 2002). In warm low-altitude regions, and with ample crop and grass hosts to maintain larval populations, SSB will cycle throughout the year. SSB will initiate diapause, in the larval stage, at higher elevations or during dry seasons (Kfir et al. 2002).

Female SSB moths typically prefer whorl (or “funnel”) stage plants for oviposition. Depending on temperature, eggs hatch in 7-10 days, larvae complete development in ca. 28-35 days, and pupae require ca. 8-10 days. SSB eggs are oval-shaped, flattened and laid in clusters, with total fecundity averaging 100-166 eggs/female (Ofomata et al. 2000). Most eggs in maize are found on the lower surfaces of the leaves, often near the midrib. Upon hatching, early instars move upwards on plants and into the whorl, where they begin feeding on leaf surfaces deep inside the whorl. Mid to late-instars boring into the midrib and stalk, respectively. They may also move down the outside of the stalk, and bore into the stalk just above an internode. In older plants larvae will sometimes feed on the developing tassel.

In many ways, the larvae look similar to those of B. fusca (maize stalk borer). The larvae have a cream to pink coloration, with dark spots along the dorsal surface; the head capsule is brown. When mature they are about 25 mm long. SSB larvae can be distinguished from B. fusca by the hooks on the prolegs. In C. partellus, the hooks are arranged in a complete circle, whereas in B. fusca the hooks are arranged in a crescent. SSB larvae pupate within the maize stalk. Prior to pupation the fully grown larva cuts out an exit hole to allow the adult moth to emerge from the plant.

Primary Host Crops and Plants

Maize (Zea mays L.), Sorghum (Sorghum bicolor L.), Rice (Oryza sativa); Sugarcane (Saccharum officinarum) and several millets including Pearl millet (Pennisetum glaucum); several grasses including Sudan grass (Sorghum vulgare sudanense), Napier grass (Pennisetum purpureum), and Sorghum arundinaceum (Devs.) Stapf (CABI 2007; Kahan et al. 2000; Kfir et al. 2002; Matama-Kauma et al. 2008).
Damage and Economic Impact to Maize

SSB injury to maize includes leaf feeding, tunnelling within the stalk, disruption of the flow of nutrients to the ear, and subsequent development of “deadhearts” (see photo). The first symptoms of SSB damage is the appearance of “shot-hole” injury to whorl leaves. “Deadhearts” result from larval feeding injury to the growth point of maize plants; this damage is most important during the first 2-3 weeks after seedling emergence. Yield loss is attributed to the physiological effects on final ear size, lodging or the complete loss of ears. Larval tunnelling within the stalk may also predispose plants and ears to infection by fungal pathogens, further compromising the long-term storability, and quality of food products (Polaszek 1998; Kfir et al. 2002).

Yield loss estimates for SSB vary greatly depending upon the country, season, maize variety and fertilization (e.g., Overholt et al. 1996; Kfir et al. 2002; De Groote et al. 2003). However, in studies with SSB alone, yields in east Africa were reduced by 15-45% (Seshu Reddy and Sum 1992). In South Africa, yield losses in maize and sorghum have exceeded 50% (Kfir et al. 2002). More recently, following an extensive survey of farmer fields in Kenya, with and without insecticidal control, De Groote et al. (2003) found that all stem borer species caused average annual losses of 13.5%, valued at US$ 80 million. Of this total, losses to SSB were estimated at ca. US$ 23 million/year; the majority of other stem borer losses were attributed to B. fusca. The analysis was based on maize prices of $193/ton.

Potential Geographic Distribution of C. partellus using CLIMEX

Parameter Estimation

CLIMEX is a flexible modelling and mapping tool for integrating plant or animal species biology and ecology, relative to temperature and moisture regimes that support or limit population establishment and growth (e.g., Sutherst et al. 1999; Venette and Hutchison 1999; Venette and Cohen 2006). CLIMEX can also be used to “match” the climate of a given species current distribution, with the climate of one or more additional countries of interest, for example to assess the risk of exotic pest introductions (e.g., Koch et al. 2006).

The CLIMEX map for SSB was developed using a two-step process. We first used the known distribution of SSB throughout the diverse agro-ecological zones in Kenya to assess the potential distribution for all African countries. We then relied on the extensive literature for SSB biology and ecology, to “fine-tune” parameter estimates for temperature-dependent developmental rate, and sensitivity to moisture and heat stress (Ochieng et al. 1995; Polaszek 1998; Ofomata et al. 1999a; Ofomata et al. 1999b; Ofomata et al. 2000; Kfir et al. 2002; Mbapila et al. 2002).

CLIMEX Maps, Results

The maps generated in CLIMEX are based on known or inferred relationships between population growth and
temperature, soil moisture, heat, cold, and drought, using 30-yr average monthly temperature and rainfall data available for each country (Venette and Hutchison 1999). Within CLIMEX, an Ecoclimatic Index (EI) >24 is considered highly favourable “on average” for year-round persistence of a species in a given geographic area. As the EI increases, the potential population size also increases. The EI for *C. partellus* in Africa is shown in Fig. 1. As expected, we found good agreement with the projected EI results for Kenya’s agro-ecological zones and recent survey results (De Groote et al. 2003). The EI values are greatest in Kenya for the coastal, low-altitude, dry mid-altitude, moist transitional areas, with some EI in the highlands.

The model was also validated qualitatively by reviewing the predicted distribution range for SSB for most south Asian countries (Fig. 2). These results did indicate SSB presence in India and Pakistan, and further south to Indonesia. The Asia map also suggests potential distribution areas within China.

The results for several eastern and southern African countries are in agreement with known distribution records (e.g., Kfir et al. 2002; De Groote et al. 2003; Tefera 2004; Matama-Kauma et al. 2008). Interestingly, the CLIMEX model also projects possible future expansion of SSB into several western African countries, where the pest is not currently known to occur. These results are similar to those of Overholt et al. (2000), who used a GIS model to predict future distributions of SSB in west Africa, based on the climate of the known SSB locations. Additional analyses are planned using individual years of weather data to further explore the variance associated with the CLIMEX results over time.

In addition to the CLIMEX maps for Africa and Asia, we provide a global map for the expected distribution of *C. partellus* using the same parameter estimates for climate-matching and pest biology. The global analysis does indicate that many additional countries could be conducive for stem borer establishment in North, Central and South America, the Caribbean and Europe. Additional aspects of this analysis will be published in future Harvest Choice publications.
Selected References


