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Geographic distribution, host range and perennation of *Cotesia sesamiae* and *Cotesia flavipes* Cameron in cultivated and natural habitats in Kenya

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ABSTRACT

Field surveys were carried out in four agroecological zones to assess the geographic distribution, host range and perennation of *Cotesia sesamiae* and *Cotesia flavipes* in cultivated and natural habitats in Kenya. The distribution of the two *Cotesia* species in different ecological regions was most affected by the suitability of the local stem borer species for parasitoid development, and temperature, as both species were found in localities dominated by their suitable host(s) where temperature favoured their occurrence. Fourteen years after its release, *C. flavipes* has maintained a high level of specificity to its target host *Chilo partellus* on maize and sorghum in cultivated habitats and on *Sorghum arundinaceum* in natural habitats. *Cotesia flavipes* appeared to be an appropriate biological control agent against *C. partellus* in eastern Africa, with minimal or no effects on non-target hosts in different habitats. Conversely, *C. sesamiae* lacked host specificity in different habitats, as its stem borers or host plants varied with both locality and habitat type. Perennation by both *Cotesia* species occurred mainly in cultivated habitats. Furthermore, natural habitats played a role in sustaining some individuals of *C. flavipes* during both rainy and dry seasons. These areas acted as refuges for *C. flavipes*, but not for *C. sesamiae*, because its hosts were scarce on natural host plants. The availability of these *Cotesia* species across seasons was mainly influenced by the presence of actively feeding stem borers on cereal plants during different seasons, as well as the duration of the dry season in different localities.

1. Introduction

The braconid *Cotesia sesamiae* (Cameron) is the most common indigenous gregarious larval endoparasitoid of cereal stem borers in Kenya (Mohyuddin and Greathead, 1970; Zhou et al., 2003). However, the generational mortality of the invasive stem borer pest *Chilo partellus* (Swinhoe) inflicted by *C. sesamiae* on maize at the Kenya Coast was typically less than 0.5% (Overholt et al., 1994b). Therefore, *C. flavipes* Cameron, a native of the Indo-Australian region was introduced to coastal Kenya in 1993 (Overholt et al., 1994b). *Cotesia flavipes* has become established and is playing a key role in suppressing *C. partellus* in coastal Kenya (Zhou et al., 2001, 2003). The two *Cotesia* species attack medium and large larval instars of stem borers belonging to two economically important families, Noctuidae and Crambidae (Overholt and Smith, 1990; Zhou et al., 2003). Though *C. sesamiae* and *C. flavipes* occupy an ecologically similar niche (Omwega et al., 1995; Kimani-Njogu and Overholt, 1997), laboratory studies suggest differences in their host range and their attraction to various graminaceous plant species (Ngi-Song et al., 1995, 1996). Thus, the two *Cotesia* species can partition resources and coexist (Sallam et al., 2001; Jiang et al., 2008).

The distribution of both *Cotesia* species is influenced by climate, in that *C. sesamiae* is common in wetter regions (Mohyuddin and Greathead, 1970), and *C. flavipes* is common in dry and warm regions (Songa, 1999; Songa et al., 2001; Niyibigira, 2003). Thus far, both *C. sesamiae* and *C. flavipes* have been reported in cultivated and natural habitats in Kenya (Khan et al., 1997; Overholt, 1998; Songa et al., 2002). However, whereas information on the distribution, stem borer and plant host range for the two *Cotesia* species

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are available for cultivated cereals (Bonhof et al., 1997; Oloo, 1989; Zhou et al., 2003), similar information for natural host plants is very scarce (Khan et al., 1997; Songa et al., 2002). Furthermore, the details of stem borer and plant host specificity for both *Cotesia* species in different ecological habitats are lacking.

The importance of natural habitats adjacent to cultivated crops as refuges for parasitoids, especially during the non-cropping season, has long been recognized (Powell, 1986; Landis et al., 2005; Wilkinson and Landis, 2005). In Africa, cereal fields are usually small (i.e., $\leqslant$1 ha) and surrounded by patches of natural habitats that harbour wild host plants of cereal stem borers and have higher stem borer diversity than the cultivated habitats (Le Ru et al., 2006a,b). It is therefore important to understand the role of natural habitats in the population ecology of parasitoids and their effect on levels of parasitism of stem bores in cereal crops.

In this study, field surveys were carried out over 2 years in both cultivated (in maize (*Zea mays* L.) and sorghum (*Sorghum bicolor* L.)) and natural (in all potential natural host plants) habitats in four agroecological zones in Kenya. Data obtained were used to examine: (i) the geographic range of *C. sesamiae* and *C. flavipes*, (ii) the range of stem borer and plant hosts for both *Cotesia* species, as well as the specificity of these parasitoids to their hosts, and (iii) seasonal variations in the number of cocoon masses for both *Cotesia* species.

2. Materials and methods

2.1. Study site description

From December 2005 to December 2007, field surveys were conducted in four agroecological zones in Kenya (Corbett, 1998), namely in Kakamega (Kakamega District) in the moist transitional agroecological zone in the Western region of Kenya, Mtito Andei (Makueni District) in the dry mid-altitudes in the Eastern region, Muhaka (Kwale District) in the lowland tropics in the Coastal region and Suam (Trans-Nzoia District) in the highland tropics in the Rift Valley region (Fig. 1). Kakamega (0°13′N, 34°56′E) is 1655 metres above sea level (masl) and has a bimodal rainfall distribution with two main cropping seasons occurring from March to August and October to December. Average annual rainfall and temperature are 1570 mm and 21 °C, respectively (Corbett, 1998). The vegetation mosaic is of the Guineo-Congolian rain forest type (White, 1983). Kakamega is a moderate production region (Muhammad and Underwood, 2004), with 43.3% of the area under cereal cultivation. Cereals were grown at subsistence levels, with an average field size of 0.28 ha located in open forest patches, or scattered around non-compact homesteads, and also along forest edges and the river bank. The area of natural habitats was 51.9%, of which the total relative cover of all potential wild host plants of stem borers was 0.5% and 0.3% during the rainy and dry seasons, respectively (Otieno et al., 2006).

Mtito Andei (2°39′S, 38°16′E, 760 masl) has a single cropping season lasting from November to January. Average annual rainfall and temperature are 665 mm and 23 °C, respectively (Corbett, 1998). The vegetation consists of Somalia-Masai Acacia-Commiphora deciduous bushland and thicket (White, 1983). Mtito Andei is a minor production region with cereals grown at subsistence level (Muhammad and Underwood, 2004). Area under cereal cultivation was 27.3%, with an average field size of 0.37 ha. The area of natural habitats was 72.7%, of which the total relative cover of all potential wild host plants of stem borers was 13.0% and 8.0% during the rainy and dry seasons, respectively (Otieno et al., 2008).

Muhaka (4°18′S, 39°31′E, 40 masl) has a bimodal rainfall distribution with two main cropping seasons typically occurring from April to August and from October to December. Average annual rainfall and temperature are 1210 mm and 26 °C, respectively (Corbett, 1998). Local vegetation is the East African coastal grassy and woody mosaic bordering the undifferentiated Zanzibar-Inhambane forest type (White, 1983). Muhaka is a moderate growing region (Muhammad and Underwood, 2004), with about 10.7% of the area under cereal cultivation, and an average field size of 0.15 ha. The area of natural habitats was 72.3%, of which the total relative cover of all potential wild host plants of stem borers was 2.2% and 1.0% during the rainy and dry seasons, respectively (Otieno et al., 2006).

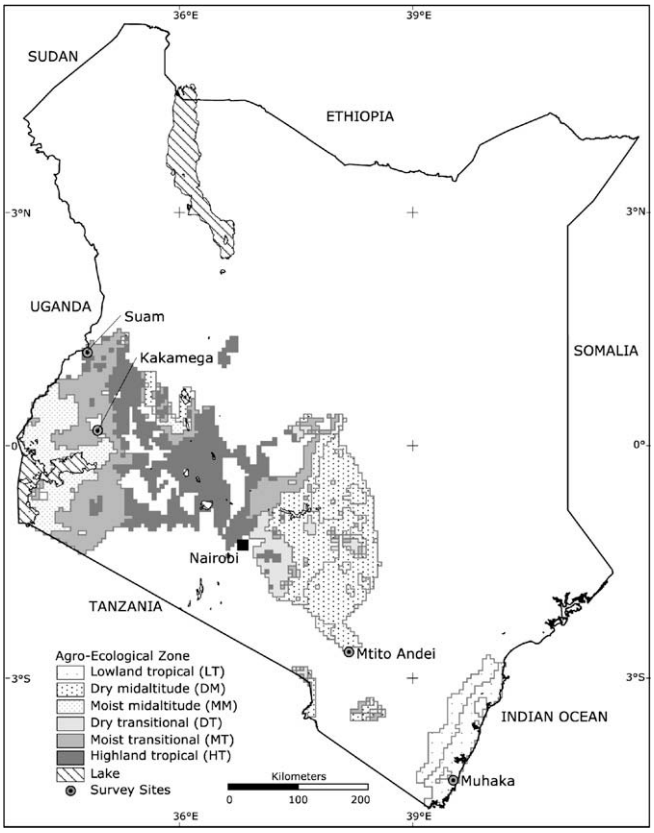

Fig. 1. Map of Kenya showing surveyed sites in four agroecological zones.

Suam (1°11′N, 34°47′E, 1995 masl) has a single cropping season that lasts from March to November. Average annual rainfall and temperature are 1190 mm and 19 °C, respectively (Corbett, 1998). Local vegetation is characterized by a mosaic of both rain forest and secondary grassland (White, 1983). Suam is a major production region (Muhammad and Underwood, 2004), where 50% of the area is under cereal cultivation at commercial scale mainly with an average field size of 3.4 ha. The area under natural habitats was 50%, of which the total relative cover of all potential wild host plants of stem borers was 11.2% and 10.9% during the rainy and dry seasons, respectively (Otieno et al., 2008).

For Kakamega and Muhaka, in addition to the two main cropping seasons, cereal crops were usually available in the fields in between the main cropping seasons, because of brief rain spells experienced during dry seasons. Also, cereal crops were sometimes planted in marshy areas usually bordering streams or rivers. Besides the single cropping seasons in Mtito Andei and Suam, during the dry season, irrigation was practiced in the former locality (in a few fields surrounding the local water reservoir) as opposed to the latter locality.

2.2. Field collections

2.2.1. Random sampling in cultivated habitats

Based on the sampling plan developed by Overholt et al. (1994a) and the proportion of land under cultivation (Guihéneuf,