Agriculture, Ecosystems and Environment 188 (2014) 289–293

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

journal homepage: www.elsevier.com/locate/agee

Short communication

Effects of landscape complexity and habitat management on stemborer colonization, parasitism and damage to maize

Charles A.O. Midega[a,*], Mattias Jonsson[b], Zeyaur R. Khan[a], Barbara Ekbom[b]

[a] International Centre of Insect Physiology and Ecology (icipe), P.O. Box 30772, Nairobi, Kenya
[b] Swedish University of Agricultural Sciences, Department of Ecology, P.O. Box 7044, SE-750 07 Uppsala, Sweden

ARTICLE INFO

Article history:
Received 17 October 2013
Received in revised form 6 February 2014
Accepted 22 February 2014

Keywords:
Busseola fusca
Conservation biological control
Grassland cover
Push–pull system

ABSTRACT

Lepidopteran stemborers are a serious constraint to efficient production of maize in sub-Saharan Africa. One of the most effective ways of managing these pests is through a habitat management system called push–pull. Landscape complexity has been shown to enhance biological control of insect pests, and therefore may influence effectiveness of habitat management systems designed to control pests. We studied the relative importance of the push–pull cropping system as a local effect and proportional cover of grassland as a landscape effect on (i) stemborer population density and damage to maize, and (ii) parasitism and mortality of stemborer life stages in western Kenya. We found a significant interactive effect between cropping system and grassland cover on abundance of stemborer larvae and pupa, and a near significant interactive effect of these variables on rates of egg parasitism. Cropping system had the largest effect on larval and pupal abundance in more complex landscapes, whereas it affected egg parasitism most strongly in the simplest landscapes. Grasslands appeared to primarily function as a source for the pests, rather than for natural enemies. However, sites from landscapes with a larger range of grassland cover need to be studied to fully explore the combined effects of cropping system and landscape complexity on pest control in this system. The push–pull cropping system significantly suppressed stemborer colonization of the maize and enhanced activity of stemborer parasitoids, with significant reductions in crop damage and increase in grain yield.

1. Introduction

Landscape complexity has been shown to enhance abundance and/or diversity of natural enemies, but the impact on pests is less clear (Chaplin-Kramer et al., 2011). The cover of semi-natural grasslands such as permanent pastures is a landscape variable often used as a proxy for landscape complexity and has been shown to correlate positively with natural enemy abundance and diversity (Purtauf et al., 2005). However, grasslands may also provide alternative hosts for pests and thus increase colonization of pests in crops (Thies et al., 2005).

Lepidopteran stemborers are major pests of cereal crops in sub-Saharan Africa (SSA) where they cause significant yield losses (Kfir et al., 2002). One of the most effective ways of managing these pests is through a habitat management approach, dubbed 'push-pull', which combines repellent and attractive stimuli to repel pests away from a crop ('push') and lure them toward an attractive source ('pull'). It involves intercropping cereal crops with repellent plants in the genus *Desmodium* and planting an attractive crop such as Napier grass, *Pennisetum purpureum* Schumach, around this intercrop. This system has shown strong positive effects on crop yield and is rapidly being adopted by smallholder farmers in East Africa (Khan et al., 2008).

It is likely that the impact of habitat management depends on landscape complexity. Tscharntke et al. (2012) suggested that the effects of local habitat management should be largest in moderately simple landscapes, but less effective in complex and extremely simplified landscapes (the intermediate landscape complexity hypothesis). This would occur because in complex landscapes, diversity is high everywhere and therefore local management has little effect; in extremely simple landscapes the pool of species is small and local management will again have little effect; and finally in moderately simple landscapes species survive but lack important resources that can be provided by habitat management.

The aim of this study was to establish the relative importance of the push–pull cropping system as a local effect and proportional cover of grassland as a landscape effect on stemborer infestation of maize (*Zea mays* L.) in western Kenya since grasses play an

---

[*] Corresponding author. Tel.: +254 59 22216/7/8; fax: +254 59 22190.
E-mail address: cmidega@icipe.org (C.A.O. Midega).

http://dx.doi.org/10.1016/j.agee.2014.02.028
0167-8809/

important role on population dynamics of cereal stemborers in the region (Khan et al., 1997). The extent of grassland cover was used as a proxy for landscape complexity since studies have established the existence of a wide diversity of stemborer host grass species belonging to the family Gramineae in the studied area (e.g. Kanya et al., 2004). Results from this study are expected to assist in further development of integrated pest management strategies for the various landscape regimes in SSA. Specifically, we tested the 'intermediate landscape complexity hypothesis' and addressed the following questions: (i) does habitat management through push–pull at the local scale and grassland cover in the landscape affect stemborer population density and damage to maize in the field? (ii) What is the relative importance of push–pull cropping system and grassland cover in the landscape on parasitism and mortality of stemborer life stages?

2. Materials and methods

2.1. Study sites

The study was conducted during the main cropping season of 2012 in Trans Nzoia district (0°52′–1°18′ S, 34°38′–35°23′ E; altitude 1700–2400 m above sea level) in the North Rift region of western Kenya. This is the main maize producing region in the country, and where lepidopteran stemborer pests cause serious damage to the crop. The main stemborer species is *Busseola fusca* Füller (Noctuidae), although *Chilo partellus* (Swinhoe) (Crambidae) is also often encountered in field surveys.

2.2. Crop management and landscape composition

Nine farmers who had recently adopted the push–pull system were randomly selected from lists of farmers obtained through local public meetings, popularly known as *barazas*, and through consultation with local agricultural extension officers. Each of these farmers had two sets of plots, a push–pull and a maize monocrop (control). The push–pull plot comprised maize intercropped with silverleaf desmodium *D. uncinatum* jacq., with Napier grass planted around the plot, the two companion plants having been established in the previous cropping year. In both plots the long maturing maize variety hybrid H614 recommended for the highland regions was planted at inter and intra-row spacing of 75 cm and 30 cm respectively. Desmodium, being a perennial crop, was cut back at the beginning of the cropping season to allow for planting of maize. The plot sizes varied from farmer to farmer, ranging from 30 m by 25 m to 40 m by 40 m, but for each farmer in the study, the push–pull and control plots were of the same size.

Proportion cover of grassland was quantified within a 400-m radius of the center of each pair of plots using satellite imagery and ArcGIS 9.2 (ESRI, 2006). To produce the maps, the satellite imagery was inspected, and polygons dominated by grassland delimited by hand. The satellite imagery comprised Quickbird photos from August 2010 and December 2011. We selected a 400 m scale because a number of parasitoid species have been found to respond strongly to landscape composition at this spatial scale (Thies et al., 2005), and because this resulted in non-overlapping landscape sectors in all except one case, with a <3% final overlap.

2.3. Effects on stemborer colonization and crop damage

Stemborer colonization was assessed at the fourth and sixth week after crop emergence when shoots of twenty randomly selected maize plants in each plot were carefully inspected for stemborer eggs. This is the period during which plants are most attractive to gravid stemborer moths for oviposition and represents the main period of crop colonization by the pests (Van Rensburg et al., 1987). At four and eight weeks after crop emergence, fifty maize plants were randomly selected in each plot and inspected for any characteristic foliar damage caused by stemborer larval feeding. Additionally, from the eighth week after crop emergence to physiological maturity biweekly random samples of twenty maize plants were obtained from each plot. The stalk of each plant was split open to recover stemborer larvae and pupae and the tunnel length caused by larval feeding was measured and recorded.

2.4. Effects on stemborer natural enemy activity

All the egg batches recovered from the sampling procedure above were cut out with a portion of the leaf or sheath and put in individually labeled glass vials (0.06 m by 0.026 m). These batches were then counted under a dissecting microscope and observed until they hatched, parasitoids emerged, or failed to develop after two weeks. Additionally, both dead and live larvae and pupae recovered from the sampling procedure above were taken to the laboratory individually in similar vials for further observation. Live larvae were placed with pieces of maize stalks and reared until they pupated or died. Similarly, pupae were maintained until they emerged as adults or died. Each larva and pupa was observed daily for parasitoid emergence. Similarly, all the dead larvae and pupae obtained from the sampling program above and those that died while being held in the laboratory from causes other than parasitism were counted.

2.5. Effects on maize grain yield

At full physiological maturity, the maize was harvested and cobs sun-dried separately. The shelled grains were then dried to 12% moisture content and their weights taken individually for each plot, and converted into tons/hectare. The maize grain yields in the push–pull plots were calculated taking into account the entire plot including the area occupied by Napier grass.

2.6. Statistical analyses

We performed mixed effects models using the lme4 and nlme packages in R 2.14.0 to analyze the data. We included cropping system, grassland cover in the landscape and the interaction between the two variables as fixed factors, and farm as a random factor. This random factor was included in the model to account for the paired field design. We conducted separate analyses for the abundance of stemborer eggs, stemborer larvae and pupae, larval tunnel length, stemborer damage, egg parasitism, larval + pupal parasitism, other mortality factors and crop yield. For response variables that were repeatedly measured at each site, values were either pooled or averaged across time to account for small sample sizes. The glmer-function in the lme4-package was used to construct models with Poisson error structure to test effects on number of stemborer eggs, larvae and pupae, and models with binomial error structure to test effects on proportions of parasitized eggs, larvae and pupae, proportion of dead larvae and pupa, and proportion of plants with stemborer damage. An observation level random factor was included to account for over-dispersion (Bolker et al., 2009). Linear models were constructed with the lme function in the nlme-package to analyze tunnel length caused by larval feeding and crop yield.

3. Results

3.1. Effects on stemborer colonization and crop damage

Ninety-one percent of all stemborer eggs and 89% of all larvae and pupae were *B. fusca*, and only 11% and 9% respectively were