Agriculture, Ecosystems and Environment 250 (2017) 72–80

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

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

Research Paper

Exotic plants growing in crop field margins provide little support to mango crop flower visitors

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ARTICLE INFO

Keywords:
Competition vs. facilitation
Crop pollination
Flower visitors
Indirect effects
Pollination networks
Plant-plant interactions

ABSTRACT

Introduced plant species integrate into native trophic networks, often disrupting flower-visitation patterns. Although non-native invasive plants frequently occur in disturbed natural vegetation bordering crop fields, their impact on crop pollination has not been studied. We investigated whether an invasive plant (*Lantana camara*) influences flower visitation to mango (*Mangifera indica*), a pollinator-dependent crop, and whether the invasive supports mango pollinators when mango is not flowering. We surveyed insect flower-visitation in mango orchards bordering natural vegetation and within adjacent natural vegetation, with and without *L. camara* present, before, during and after mango flowering. We used these data to calculate the indirect effect of *L. camara* on mango through shared flower visitors before, during and after mango flowering, and the effects of the invasive on crop productivity. *Lantana camara* had a positive effect on mango flower visitation at low to medium mango flower density, but not at high mango flower densities. Although *L. camara* and mango shared flower visitor species, the frequency with which these flower visitor species visited the crop and the invasive differed markedly before, during and after mango flowering. Furthermore, the potential indirect effect of *L. camara* on mango via shared visitors was greatest when mango was flowering, but significantly lower before and after mango flowering, suggesting that the invasive is unimportant in the diet of mango flower visitors when the crop is not flowering. Contrary to findings in previous studies using native species in mango fields, there was a trend (not significant) for lower mango fruit production in fields with *L. camara*. This suggests that *Lantana* does not contribute to an increase in successful pollination of mango. Although our focal alien invasive plant species facilitated flower visitation of crops, it had no effect on mango production, and provided little support to mango flower visitor species that live longer than the crop's flowering period. Given that *L. camara* is detrimental to grazing and was not associated with increased mango production, the removal of this invasive is advisable.

1. Introduction

Non-native (alien) species can integrate into native plant-flower visitor networks (Carvalheiro et al., 2008; Lopezaraiza-Mikel et al., 2007). When invasive, these species can shrink natural capital, compromise ecosystem stability and endanger economic productivity (Pejchar and Mooney, 2009; Richardson and van Wilgen, 2004). The presence of invasive alien plants on pollination networks can have negative (competition), positive (facilitation) or neutral effects on flower visitation to native plant populations (Bartomeus et al., 2008; Lopezaraiza-Mikel et al., 2007; Memmott and Waser, 2002; Morales and Traveset, 2009; Vilà et al., 2009; Hansen et al., 2017), and hence influence pollination success of natural flora.

Natural vegetation borders crop fields, and this natural habitat can support crop pollinators (Carvalheiro et al., 2010; Geslin et al., 2016) and predators of crop pests (Ehlers Smith et al., 2015; Henri et al.,

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http://dx.doi.org/10.1016/j.agee.2017.09.002
Received 5 January 2017; Received in revised form 4 September 2017; Accepted 6 September 2017

2015; Morgan et al., 2016; Moxley et al., 2017). Invasive alien plants are often found in the disturbed margins on the edges of crop fields (Vardien et al., 2012), however. These species can integrate into pollination networks, luring pollinating insects away from crops (Potts et al., 2003), potentially posing a risk to crop pollination (Cook et al., 2007). Alternatively, they may attract insects, or support crop flower visitors when the crop is not flowering, and thus facilitate crop pollination. The demand for animal-pollinated crops, which represent approximately 35% of the world's crop production, is increasing (Aizen et al., 2009; Klein et al., 2007), so a broad understanding of factors influencing pollinator assemblages within agricultural systems is needed (Burd, 1994; Free, 1970). Little work has been done to date on the effects (facilitative or competitive) of invasive plant species on pollinator-dependent crops, which are often also introduced species.

Mango (*Mangifera indica*) is an important crop worldwide which requires insect pollinators for good seed and fruit set; previous work has shown that exclusion of flying and crawling flower visitors is associated with a 79% decrease in fruit set (Carvalheiro et al., 2010). Several alien plant species (e.g., *Lantana camara*, *Melia azedarach*, and *Bidens pilosa*) have become well-integrated into pollination networks in the Limpopo area, north-eastern South Africa (Carvalheiro et al., 2010), and it is possible that these invasive species could facilitate or compete with crops for pollinators.

Lantana camara (hereafter referred to as *Lantana*) is an aggressive weed originating from Central and South America that has invaded many areas of South Africa where mango plantations occur (Vardien et al., 2012). It has adverse effects on natural ecosystems and native plant species diversity (Vardien et al., 2012), forming large stands, often along the boundaries of agricultural land and nearby natural vegetation (ARC, 2010).

Mango and *Lantana* share floral characteristics: both species' flowers produce nectar, occur in inflorescences with small (diameter < 5 mm) whitish to pink flowers (although *Lantana* can also have yellow flowers), and have been found to share honey bees as flower visitors (Carvalheiro et al., 2010; Goulson and Derwent, 2004). The concentrations of nectar in the two species are comparable: mango at around 48% (Kajobe, 2007), *Lantana* at around 38% ± 9.4%; (Hainsworth et al., 1991). These shared characteristics may increase the possibility of interactive effects between the two plant species (Bjerknes et al., 2007). Thus, where *Lantana* and mango coexist, they could compete with or facilitate each other for pollinators.

This study makes use of the presence of *Lantana* near to mango crop fields to test whether invasive alien plants affect crop pollination. Given that previous studies show that mango visitation benefits from the presence of other floral resources (e.g. *Aloe greatheadii* and *Barleria obtusa*, see Carvalheiro et al., 2012), that *Lantana* has attractive floral attributes, similar floral traits to mango, as well as an extended flowering period (relative to mango) we expected this invasive plant to be associated with greater abundance and species richness of flower visitors to mango (hypothesis 1), that *Lantana* should share flower visitors with mango, supporting them outside mango flowering peak (hypothesis 2), and that the presence of *Lantana* would increase mango fruit production (hypothesis 3). Testing these hypotheses will allow us to determine whether there is any advantage for farmers to having *Lantana* present around the borders of mango orchards, which could help guide management practices.

2. Methods and materials

2.1. Study area and design

This study was conducted on three commercial mango farms near Hoedspruit, Limpopo Province, South Africa, within the Kruger to Canyons Biosphere Reserve (24°31′S 30°44′E). The natural vegetation is classified as Granite Lowveld (Mucina and Rutherford, 2011). The farms (Bavaria, Jonkmanspruit and Mohlatsi) share similar management practices (i.e., pesticide application of neonicotinoids or organophosphates, cropping system, irrigation, in-field weed control and harvesting period), and abiotic conditions (climate, soil and sunlight exposure). Soil water and nutrient content, important variables in crop production, are monitored throughout the year to keep conditions optimal for mango production (J. du Preez and G. Schoeman *pers. comm.*), presenting minimal variation in abiotic conditions (details on farms given in Table A1, online Appendix). The farms are divided into blocks of mango trees, approximately 150 m × 70 m of a single cultivar, within a grid of non-native trees (*Casuarina* sp.) that serve as windbreaks. The blocks of mango are surrounded by natural vegetation, which is mostly undisturbed, intact vegetation. Although it has lost its indigenous wild herbivores, this vegetation is grazed by livestock, mainly cattle. The disturbance associated with clearing for mango farming has enabled the non-native *Lantana* to establish in parts of the natural vegetation, particularly areas bordering mango fields.

On each farm, we carried out monthly flower visitation surveys in twenty pairs of fixed observational plots from June to October 2013, a period that includes mango flowering season (July-August). Each pair of plots consisted of one plot in mango orchard bordering natural vegetation and another plot located within the bordering natural vegetation (ca. 15 m from one another, within natural vegetation areas $> 200\ m^2$; Fig. 1 shows the layout of these plots on one of the farms, Bavaria Estates, as an example). Ten of these pairs had *Lantana* present in the bordering vegetation, representing various densities of *Lantana*, the other ten bordered natural vegetation without *Lantana.* The pairs of plots were between 100 and 400 m apart from one another, and included five mango cultivars (i.e. Kent, Keitt, Sensation, Tommy Atkinson and Shelly; Table A1 in Online Appendix). All plots were at least 150 m away from large water bodies. Honey bees (*Apis mellifera scutellata* Lepeletier) are brought in to ensure pollination, although previous studies have found the presence of honey bee hives to have little influence on mango production (Carvalheiro et al., 2010). All sites in this study had managed honey bee colonies present during the mango flowering season (i.e., July–August), at densities of approximately one colony per hectare.

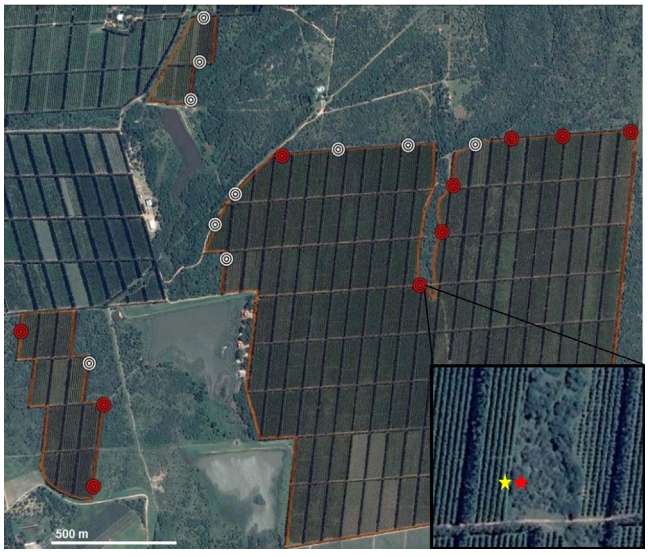

Fig. 1. Map showing paired observational plots on Bavaria Fruit Estate, where mango plots border natural vegetation with *Lantana* (white circles) and without *Lantana* (red circles). One such paired plot is depicted (bottom right) where the mango orchard border (yellow star) is near natural vegetation margin (red star) (Google Inc., 2014). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)