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Management as a driver of functional patterns and alien species prominence in weed communities of irrigated orchards in Mediterranean areas

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ABSTRACT

Weed communities in irrigated orchards form spontaneous vegetative cover containing a remarkable presence of alien species. This plant cover can negatively affect the growth and productivity of orchards by reducing yield, but can also play a positive role by preventing soil erosion, increasing biodiversity and providing pollination services. Compositional and functional attributes of these weed communities are configured by management practices. Therefore, it is crucial to disentangle which differences in weed communities are mediated by management practices in order to establish management that promotes weed covers that enhance benefits while reducing negative effects on the orchards. In irrigated orchards of the Mediterranean area, management is dominated by irrigation (flood/drip) and weed control (mechanical/chemical). To identify how differences in irrigation and weed control modify weed communities in orchards, floristic surveys were carried out in mowed and herbicide-treated plots on drip and flood irrigated orchards. Weed community structure was evaluated in terms of species cover, diversity and the prominence of alien species for each management regime from a floristic and a functional approach. Results showed that irrigation system is the main factor influencing weed community structure. Compared to drip, flood irrigation is associated with a denser weed community with higher presence of alien weeds. Similarly, environmental conditions created by irrigation determine taxonomical and functional composition of weed communities and modulate the effect of weed control methods Flooding favours alien species, C_4, perennial grasses, clonal species, zoochorous and hydrochorous and wind-pollinated species, whereas drip irrigation selects mostly native C_3 forbs, non-clonal, wind-dispersed and insect pollinated species.

Therefore, this study provides insights into how modernizing irrigation method from a flood to a drip system can promote vegetative cover that maximizes benefits to the orchards and the environment while minimizing negative effects of the weeds and prominence of alien species within the weed community.

1. Introduction

Weed communities in perennial crops, such as orchards, play contrasting roles. On the one hand, their presence negatively affects yield (Kaya-Altop et al., 2016) by competing with trees for nutrients and water, especially in the first years of young orchards (Travlos, 2013; Oliveira et al., 2016), hosting pests and diseases that can affect the crop and favouring habitats for rodent development that can kill the trees (Lipecki, 2006).

On the other hand, it has been proven that weed communities in orchards can have positive effects such as promoting soil enrichment (Travlos, 2013), preventing soil erosion and mechanical compaction, acting as a source of organic matter and nitrogen (Lipecki, 2006), being natural antagonists of pest and diseases (Cicuzza et al., 2012) and providing ecosystem services, such as conservation of pollinators (García and Miñarro, 2014). Moreover, weed communities contribute to increasing the biodiversity of agroecosystems (Mas et al., 2007).

Weed communities in orchards configure a spontaneous vegetation cover which can play the same role as commercial seeded cover crops. However, spontaneous vegetation is more sustainable in the long-term due to their self-reseeding capability, their extended germination and their role in the promotion of biodiversity in agroecosystems (Mas et al., 2007). Nevertheless, the overall increase of global trade and the alteration of the environment have boosted the rate of alien plants present in crop weed communities (Pimentel et al., 2005). These alien weeds have negative effects in terms of crop yield losses and control method costs (Recasens et al., 2007). Additionally, they have perverse ecological impacts for both the agroecosystem (Vilà et al., 2004) and for the adjacent natural habitats (Juárez-Escario et al., 2016).

In order to maintain environmental sustainability of the orchards

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while optimizing fruit yield, it is thus crucial to promote a vegetative cover that maximizes the benefits for both the orchards and the environment, while simultaneously minimizing the exposed negative effects of weeds and the prominence of alien species within the weed community.

In this sense, floristic and functional structure of weed communities in crops are determined mainly by management practices (Gago et al., 2007; Mas et al., 2007; Cicuzza et al., 2012). In the case of fruit tree orchards in Mediterranean areas, management practices involve irrigation, that is traditionally by flooding and more recently drip irrigation, and floor management for weed control (mechanical and/or chemical) (Mas et al., 2007; Miñarro, 2012). The most extended weed management in irrigated orchards in Mediterranean area involves mowing in the alleys and herbicide application in the rows. Differences in weed management and the particular environmental factors that take place in these positions (e.g. differences in soil temperature, insolation, root architecture…) may influence the configuration of a particular weed community in each place. Besides, floor management affects microclimate conditions in the orchards. In this sense, it has been showed that tillage increases radiation surface and the possibility of evaporation of soil water, which modulates soil temperature. The same effect is produced by a vegetative lawn cover (Urbina, 2015). Regarding soil nutrients, mowing of the plant cover and amendment of pruning residues are a source of organic matter to the orchard's soil (Gómez-Muñoz et al., 2016). However, differences in weed communities taking into account management field location have been scarcely studied.

Several studies focus on analysing weed community structure in irrigated orchards (Mas et al., 2007; Juárez-Escario et al., 2013) and on the influence of management practices such as fertilization and tree-row management (Miñarro, 2012). However, none of them analyse the effect of the irrigation system on the compositional and functional structure of the weed community, even when the influence of water availability in plant communities subjected to management in Mediterranean areas has been proven (Carmona et al., 2012). Accordingly, it has been shown that flood-irrigated orchards harbour a set of alien weed species that are filtered by possessing some functional traits (Juárez-Escario et al., 2013), but the prominence of alien species in weed communities in drip irrigated orchards and their functional characteristics remain unknown.

In this sense, clarifying the compositional and functional shifts of weed populations in orchards depending on the irrigation system and weed control management can facilitate the detection of troublesome species and functional groups under each management system (Gago et al., 2007). This is essential for providing meaningful guidelines for management strategies of weed control in order to maintain suitable plant cover that improves biodiversity and delivers ecosystem services to the orchards while minimizing weed competitiveness and the presence of alien plants.

Consequently, the aim of this work was to (1) determine the compositional and functional structure of the weed communities present in irrigated orchards on the Plain of Lleida (Catalonia, NE of Spain), (2) compare the effect of both irrigation and weed control systems on the diversity of total and alien weeds that compose these communities and (3) identify which combination of irrigation system and weed control management is related to the prominence of alien weeds in these communities.

2. Materials and methods

2.1. Study area

The study was conducted in an irrigated fruit production area within the plain of Lleida (41°25′–41°49′N, 0°20′–1°06′E), which is the main fruit production region in Catalonia (NE Spain, 32,108 km^2) (29,880 ha of irrigated orchards, 84.24% of the total production area in Catalonia) (Fig. 1).

The local climate is semiarid continental-Mediterranean with a mean annual temperature of 15 °C and annual rainfall of approximately 385 mm, concentrated in spring and autumn (Ninyerola et al., 2005). The soil moisture regime is xeric and the soil temperature is mesic. Land-use is dominated by irrigated crops over shallow chalky-clay soils with the presence of calcareous lutites and saline soils (Dalmau and Iglesias, 1999).

In the study area there are established flood and drip irrigated orchards. In recent years, the irrigated area has been enlarged and new drip irrigated orchards have been installed. The expansion of irrigation has been favoured by the morphological characteristics of the area, which does not present any significant barriers; it is a large floodplain surrounded by a series of small reliefs (Dalmau and Iglesias, 1999).

2.2. Selected fruit tree orchards

Selected sites were pome (pear and apple) and stone (peach and nectarine) orchards, irrigated either by flood or drip irrigation. Flood irrigated orchards were irrigated bi-weekly from April to early September (totalling 10–12 irrigation episodes) through an extensive established irrigation network circulating water from large canals drawn from the Segre and Noguera Ribagorçana rivers. Drip irrigated orchards were uniformly irrigated within tree rows daily (a minimum of 3–4 l/m^2 weekly) through a complex system that includes artificial

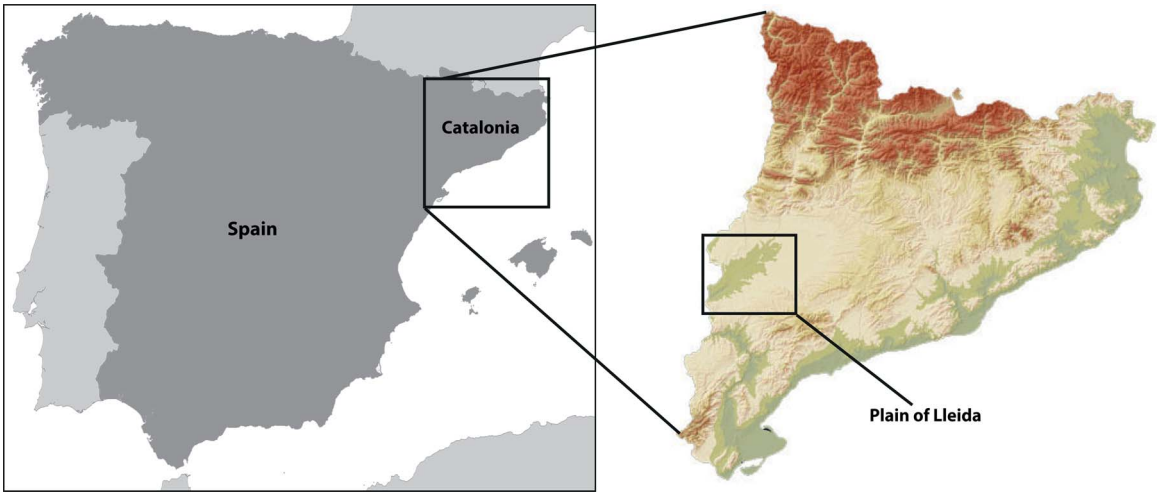

Fig. 1. Location of the Plain of Lleida in the Iberian Peninsula.