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COVER CROPS AGAINST HERBICIDE-RESISTANT INVASIVE WEEDS

Ilias S. TRAVLOS, Charis-Konstantina KONTOPOULOU, Panagiotis J. KANATAS, Maria PANAGOPOULOU, Dimitrios J. BILALIS

Agricultural University of Athens, 75, Iera Odos Street, GR 118 55 Athens, Greece

Corresponding author email: htravlos@yahoo.gr

Abstract

A field experiment was conducted to evaluate the effects of several cover crops against a serious invasive weed, Conyza albida. The particular species is characterized by a wide dispersal, an enormous seed production and a high trend for glyphosate-resistance development. In the present study, four different cover crops were tested, namely Lolium multiflorum, L. perenne, Festuca arundinacea and Trifolium repens. The experiment was performed as a randomized complete design and several measurements on soil coverage and weed growth and density were taken. Soil coverage was faster and higher for L. multiflorum, followed by F. arundinacea and T. repens. On the contrary, canopy development for the perennial L. perenne was 62-72% lower than the other cover crops. This rapid and high canopy development especially of L. multiflorum and T. repens resulted to the significant reduction of C. albida density (lower by 87 and 83%, respectively) and also to weeds' growth suppression (plant height reduction up to 50%). Consequently, the specific species could be certainly used, solely or in mixtures of cover crops for the effective management of invasive and herbicide-resistant weeds.

***Key words**: invasive plants, cover crops, glyphosate-resistance, Conyza albida.*

INTRODUCTION

Invasive species infestation has been recognized as one of the largest threats for native species and biodiversity across the world, especially under the observed and expected climate changes (Kriticos et al., 2003; Williamson, 1996). Such species have already or are likely to spread into new habitats, become dominant or disruptive to those areas and sometimes turn to be weeds of high agronomic importance (Reichard and White, 2001; Travlos, 2013). Understanding requirements and identifying environmental resources that promote or restrict the success of invasive species during the critical life stages can be used to prevent introduction and manage them properly (Speziale and Ezcurra, 2011). Many authors have suggested that higher genotypic diversity and phenotypic plasticity are likely to confer greater invasiveness (Gray, 1986; Williams et al., 1995). Once established, these plants have the potential to become troublesome and noxious weeds and pose long-term environmental problems and economic costs (Alpert et al., 2000; Richardson et al., 2000).

According to the review of Bresch et al. (2013), the Mediterranean ecosystem could be considered less prone to invasion than similar ecosystems on other continents. However, factors such as the human population density and the climatic changes may lead to a progressive invasion of the areas of Mediterranean basin (Sanz-Elorza, 2006; Vilà et al., 2008; Celesti-Grapow et al., 2010). Indeed, climate change might induce fluctuations of water availability and thus affect species distributions (Lavorel et al., 1998).

The genus of *Conyza* comprises more than 50 annual and perennial species. In Greece there have been reported the three following species: hairy fleabane (*C. bonariensis* L.), horseweed (*C. canadensis* L. Cronq.), and fleabane (*C. albida* Willd. ex Spreng), with the last one being the most recently introduced (Yannitsaros, 1997). Indeed, fleabane is a weed originated from South America that recently has been reported to invade in urban, natural and agricultural ecosystems. In Greece, it is characterized by a rapid growth and high dispersal potential that enables its establishment as a permanent weed of the urban landscape as well as in many crops. *C.*

albida is now among the most widespread species found in waste dumps, vineyards, orchards, roadsides and natural ecosystems in a variety of regions (Thebaud and Abbot, 1995).
The extended use of herbicides like glyphosate has greatly increased the risks of their reduced efficacy on several weeds. Unfortunately, this is the case also in Greece, with many reports of reduced efficacy of glyphosate against increasingly problematic weeds, such as *Conyza* spp. Today, there are many reports from Greek farmers that *Conyza* spp. has become increasingly difficult to control with several herbicides, especially in no-tillage or minimum-tillage systems, with biotypes of all the three species already confirmed to be resistant (Travlos and Chachalis, 2010; 2012; 2013).
Cover crops are among the agronomic practices with a high weed suppressive ability in perennial crops (Guerra and Steenwerth, 2012). Moreover, they improve water infiltration, carbon sequestration, nutrient supply and retention, increase earthworm populations, reduce water runoff and soil erosion (Smith et al., 2008; Mazzoncini et al., 2011). However, the selection of the most suitable species of cover crop is crucial for the competition with the main crop (Smith et al., 2008; Travlos, 2010).
Limited data are available regarding the performance of several cover crops against invasive and herbicide-resistant weeds under Mediterranean conditions. Therefore, the main objective of this study was to evaluate the efficacy of four cover crops on the suppression of a glyphosate-resistant biotype of the invasive *C. albida*.

MATERIALS AND METHODS

A field experiment was carried out in an olive orchard (cv. Kalamon) in Etoliko region, in western Greece (Latitude: 38°29′39.39″ N, Longitude: 21°17′49.75″ E, Altitude: 13 m above sea level) from February to June 2013. The experiment was established as a randomized complete design with four replicates and a plot size of 6 m^2. The cover crops were *Lolium multiflorum*, *L. perenne*, *Festuca arundinacea* and *Trifolium repens*, while there were also some untreated (control) plots. Sowing of cover crops was performed on 4^{th} of February, 2013. The mean monthly temperature during the experimental period was ranged from 10.4 to 21.6 °C (February and May, respectively). Precipitation was highest on February (167.2 mm) and lowest on June (31.8 mm).
Visual estimations of the soil coverage in the several plots were conducted at 15, 30, 45, 60, 75 and 90 days after sowing (DAS). The weed flora comprised mainly of the invasive *C. albida,* but also a few *Papaver rhoeas, Bromus tectorum, Plantago major*, *Scabiosa lucida*, *Stellaria media*, *and Vicia villosa* also occured. In order to evaluate the weed suppressive ability of the cover crops, plant density of *C. albida* was counted three times within each plot by a 0.1 m^2 frame at 30, 60 and 90 DAS. Measurements of plant height were also made the same days. Data obtained from the field trial were subjected to ANOVA using the randomized block design. Treatment means were separated using Fisher's protected LSD test at a significance level of *P* = 0.05.

Table 1. The physical and chemical properties of the soil in the experimental field

Parameter	Etoliko
Sand (%)	51
Clay (%)	18
Silt (%)	31
Characterization	Sandy loam
pH (1:2 H_2O)	6.6
Total $CaCO_3$ (%)	0
Organic matter (%)	1.5
Nitrogen (g kg^{-1})	0.12
Phosphorus (g kg^{-1})	0.14
Potassium (g kg^{-1})	1.9
Iron (g kg^{-1})	0.37
Electrical conductivity (mS cm^{-1})	0.58

RESULTS AND DISCUSSIONS

ANOVA showed that the density of *Conyza* spp. was significantly (p<0.05) affected by the different cover crops (data not shown). Concerning cover crop coverage, there were some significant differences between the several plants as shown in Figure 1. Noticeable high soil coverage was observed in *L. multiflorum* and *F. arundinacea*, even from 15

DAS. Overall, soil coverage was faster and higher for *L. multiflorum*, followed *by F. arundinacea* and *T. repens*. On the contrary, canopy development for *L. perenne* was rather low reaching only 70 % of the soil at 90 DAS. It is noteworthy that even at 45 DAS, soil coverage for *L. perenne* was 62-72% lower than the other cover crops (Figure 1).
These data are in accordance with previous studies reporting significant differences in the canopy development of several cover crops (Kunz et al., 2017). Such differences could be due to several environmental factors, plant requirements and agronomic practices as stated by Teasdale (1996).
Moreover, it should be taken into account that as stated by Phatak (1992), seeds of species destined for cover crops should germinate at lower temperature than those of common weeds and as showed by our results this is not the case for *L. perenne*.

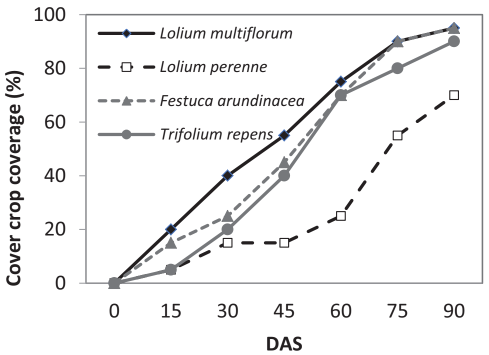

Figure 1. Soil coverage of cover crops over a period of 90 days after sowing (DAS)

Regarding the efficacy of the several cover crops on the emergence and growth of *Conyza* spp. there were also some significant differences between the treatments (Figure 2). In particular, the high density of *C. albida* (up to 81 plants/m^2) confirms the wide dispersal and dominance of this particular species and the high potential for vast seed production and further spread (Travlos and Chachalis, 2010; 2013).
Previous studies have already indicated that invasive plants can form dense monocultures (Petitpierre et al., 2012). *L. multiflorum*, *T. repens* and *F. arundinacea* reduced weed density by 87, 83 and 77%, respectively. The moderate weed suppression observed in *L. perenne* treatment (54% lower plant number compared to the untreated at 60 DAS) was probably due to the slow canopy development of this perennial species.

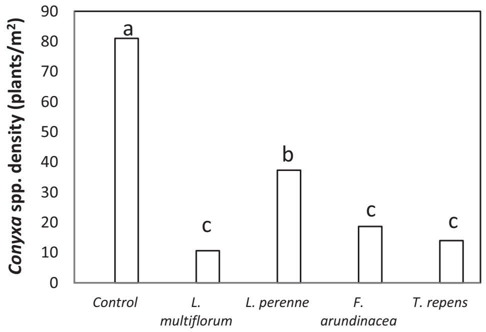

Figure 2. Weed density at the several plots at 60 days after sowing (DAS). Different low case letters indicate significant differences, based on Fisher's LSD test (P<0.05)

Another interesting finding is related with the growth of the emerged weeds. As shown in Table 2, there was not any significant difference for the plants' height at 60 DAT in the untreated plots and plots shown with *L. perenne* and *F. arundinacea*.
The explanation for that has to do with the slow development of *L. perenne* and the absence of potential allelopathic effects from *F. arundinacea*. On the other hand, our study revealed that *L. multiflorum* and *T. repens* had a rapid canopy development which resulted not only to the significant reduction of *Conyza* spp. weeds but also to their growth suppression.
The measurement shown in Table 2 is rather indicative; however, it depicts the superiority of the particular cover crops.
This could be attributed to the high competitive ability of the specific species and probably to their allelopathic effects (Macfarlane et al., 1982; San Emeterio et al., 2004). Indeed, the inhibition of neighboring plants by the release of allelochemicals is called allelopathy and it may affect other species directly or indirectly via changes to the soil microbial community (Callaway et al., 2008; Inderjit Wardle et al., 2011).

Table 2. Mean height of *Conyza* spp. plants in the several plots at 60 DAT. Different low case letters indicate significant differences, based on Fisher's LSD test (P<0.05)

Cover crop	*Conyza* spp. height (cm)
Control	18 a
L. multiflorum	12 b
L. perenne	22 a
F. arundinacea	17 a
T. repens	9 b

Our results revealed some significant differences between the perennial and the annual species in terms of their establishment, canopy development and weed competition. This is in full agreement with previous studies in which annual species established well and suppressed weeds from the first year, while perennial plants did not provide any early weed suppression but rather during the later years (Miglécz et al. 2015). Nonrhizomatous spread is also desired for cover crops in order to avoid the competition with the main crop (Newenhouse and Dana, 1989). Furthermore, another issue that should be taken into account is that the main competition between the main crop and cover crops is for soil moisture and nutrients (Hatch et al., 2011), with perennial species being more competitive for nutrients as shown by Celette et al. (2009). Unfortunately, many cover crops consume large quantities of water valuable for the main crop (Ruiz-Colmenero et al., 2011) and as stated by Celette et al. (2009) these concerns of sever competition make farmers cautious about cover crops. As indicated in many studies, the most important feature for cover crops is drought resistance (Paine and Harrison, 1993; Leary and DeFrank, 2000).

Consequently, a good idea would be that for the rain fed perennial crops (olive and citrus orchards, vineyards etc) of the Mediterranean regions, annual cover crops which end their growth early in the summer are preferable compared to perennial species which are also present in the summer. Additionally, the presence of glyphosate-resistant *Conyza* ssp. populations is a serious, ongoing phenomenon in various Mediterranean countries, which endangers the adoption of conservation tillage systems and impacts weed management in many crops. Among the most sustainable and promising methods for the management of this problem is the use of cover crops along with other cultural practices and therefore more research is needed towards the optimization of this valuable tool by means of the evaluation of several cover crops and mixtures in a wide range of soil and climatic conditions.

CONCLUSIONS

The results of the present study indicate that specific cover crops could be efficiently used for the control of some invasive and herbicide-resistant weeds, such as *C. albida*. Among the four tested species *L. multiflorum* and *T. repens* had a rapid crop development and significantly reduced weed density and growth. On the other hand, perennial species like *L. perenne* may have poor and slow establishment and therefore are not suitable for weed control from the first year. Among the priorities set in EU Directives is to prevent new introductions or further spread of invasive plants, to promote their early detection and eradication and to manage them. In the case that such species are also herbicide-resistant, the challenge of their management is even bigger, with a clear need for use and integration of all the available practices like cover crops.

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