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Interference between silverleaf nightshade (*Solanum elaeagnifolium* Cav.) and alfalfa (*Medicago sativa* L.) cultivars

I.S. Travlos*, A. Gatos and P.J. Kanatas

Summary Alfalfa (*Medicago sativa* L.) is the most widely grown forage legume in Greece and other Mediterranean countries. The successful establishment of the crop is crucial for its overall productivity. Weed infestations are a common problem, especially in spring-seeded alfalfa, with silverleaf nightshade (*Solanum elaeagnifolium* Cav.) being one of the most noxious weeds. The main objective of the field experiment conducted in Greece in 2010 and 2011 was to evaluate the differences among three alfalfa cultivars (Gea, Dimitra and Hyliki) regarding their competitiveness against silverleaf nightshade and their forage yield during the first crucial year of crop establishment. Moreover, density and fresh weight data of *S. elaeagnifolium* were also recorded. Our results showed that the presence of this weed caused an annual yield loss ranged from 8 to 26%, depending on the year and the cultivar. In particular, Hyliki was the most productive cultivar, while even with the presence of nightshade it produced significantly higher biomass than the other cultivars (up to 28%). Furthermore, Hyliki was the cultivar with the highest regrowth rate after each cutting. Weed density and biomass were also significantly reduced in the case of Hyliki, while Gea was the less competitive cultivar. The results of the present study confirm that the competitive ability of the alfalfa cultivars might have a substantial range and can be a helpful weed management tool for the growers, especially against noxious species such as *S. elaeagnifolium*.

Additional keywords: alfalfa cultivars, integrated weed management, noxious weeds, regrowth, competition

Introduction

Alfalfa or lucerne (*Medicago sativa* L.), the most widely grown forage legume in Greece, could play a key role in organic crop-livestock systems, owing to its suitability to low input, rainfed conditions, its positive effects on soil fertility and nitrogen balance, and the high protein content and quality of its forage (Entz *et al*., 2001; Karamanos *et al*., 2009). The successful establishment of the crop is crucial for its overall productivity (Stout *et al*., 1992). Established stands of alfalfa are fairly competitive with weeds. However, new alfalfa seedlings are less competitive and more susceptible to weed invasion (Annicchiarico and Pecetti, 2010). In fact, weed competition is one of the most limiting factors during crop establishment and early growth (especially in spring-seeded alfalfa), since the emerging crop plant is not a vigorous competitor and weeds emerging shortly after seeding can reduce alfalfa productivity (Pike and Stritzke, 1984; Fischer *et al*., 1988; Zimdahl, 2004). The ability of several alfalfa cultivars to suppress weed growth may allow crop producers to reduce total costs (Ominski *et al*., 1999; Arregui *et al*., 2001; Dillehay *et al*., 2011).

During the last years, there have been complaints from several regions of Greece for reduced efficacy of herbicides or increased competitiveness of many alien or recently problematic species (Travlos, 2009; Travlos and Chachalis, 2010). Silverleaf nightshade (*S. elaeagnifolium* Cav.) is one of these species, already present for many years in the country (Economidou and Yannitsaros, 1975), with an ongoing dispersal in Greece especially during the last decade, according to extensive weed surveys (Travlos *et al*., 2011; Travlos, 2013). Silverleaf nightshade has spread in many arid regions of the world

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(Boyd *et al*., 1984) and is a deep-rooted, perennial, broadleaf weed that propagates by seed, root segments, and creeping lateral roots (Cuthbertson *et al*., 1976). Moreover, *S. elaeagnifolium* is now considered as a noxious and invasive alien weed, against which international measures have to be taken in many areas (OEPP/EPPO, 2004).

Quantitative information regarding the potential suppressive effect of alfalfa cultivars on weeds in current cropping systems is rather lacking. Therefore, the objectives of this study were to evaluate the differences among three alfalfa cultivars (Gea, Dimitra and Hyliki) regarding their competitiveness against the noxious weed *S. elaeagnifolium* and their productivity (forage yield) during the first year of crop establishment.

Materials and Methods

A field experiment was conducted during 2010 (and repeated in 2011) in the experimental field of Agricultural University of Athens (37° 59′ 12′′ N, 23° 42′ 96′′ E, 29 m altitude) in order to study the competitive ability of three alfalfa cultivars (Gea, Dimitra and Hyliki) against silverleaf nightshade.

The soil was clay loam (Bouyoucos, 1962), with pH 7.29 (1:1 H_2O), 15 g/kg organic matter (Wakley and Black, 1934) and 160 g/kg $CaCO_3$. Hand-sowing took place at the rate of 20 kg/ha on 28 March, 2010 and 23 March, 2011. The field was fertilized with P_2O_5 and K_2O as recommended by soil analysis for alfalfa (Hall, 2008). Alfalfa crop was mown each time it reached 10% bloom. This resulted in four harvests each year at 65, 100, 145 and 210 days after sowing (DAS). Rhizomes of *S. elaeagnifolium* (5-6 cm in length) were uniformly planted horizontally (12-15 g/m^2 in a depth of 4-5 cm), while other weed species emerged within the experimental area were removed by hand-hoeing.

The experimental design was a split-plot in a randomized complete block with four blocks (replicates). Alfalfa cultivar was the main plot factor and the weed presence (or absence) was the subplot factor. Main plot and subplot sizes were 6 by 4 m and 2.5 by 4 m, respectively.

Irrigation and other common cultural practices were conducted as needed during the growing seasons. Mean monthly temperature and rainfall data are given in Table 1. In each cutting, forage yield was measured, while the total first-year cumulative yield was also recorded. The dry weight of forage was determined after oven drying at 70°C for 48 h. In the same days (65, 100, 145 and 210 DAS) measurements of the density and biomass of silverleaf nightshade were also taken. Visual estimation of regrowth ability of each cultivar was also conducted 15 days after each harvest (cutting) by means of a scale, comparing the most vigorous stands (high and dense, scored as 5) with the lowest and fewer plants (scored as 1).

An analysis of variance (ANOVA) was conducted for all data and differences between means were compared at the 5% level of significance using the Fisher's Protected LSD test. Linear regression was also performed for the three cultivars relating the forage yield and silverleaf nightshade biomass. All statistical analyses were conducted using the Statistica 9 software package (StatSoft, Inc. 2300 East 14th Street, Tulsa, OK 74104, USA).

Results and Discussion

The analysis of variance of our data revealed that alfalfa forage yield and silverleaf nightshade growth (density and biomass production) were significantly affected by the alfalfa cultivar and the presence or absence of the weed. The year was also a significant factor for the forage yield of the crop and for the density of *S. elaeagnifolium* plants, while it had no significant effect on the fresh weight of the weed. Moreover, the interaction between the above-mentioned factors was significant for most parameters except the biomass of silverleaf nightshade on individual plant's level (Table 2).

In particular, the harmful effects of silverleaf nightshade on the forage yield of alfalfa are shown in Table 3. The presence of *S. elaeagnifolium* was responsible for significant reductions, up to 26, 15 and 14% in the annual yields of the cultivars Gea, Dimitra and Hyliki, respectively. The higher yields of all three alfalfa cultivars during the second year of experimentation (2011) compared with the first year (2010) were probably due to the significantly higher precipitation (38%) during 2011 (Table 1). It has also to be noted that the maximum yield reductions were observed in the second and third harvest. This finding may be attributed to the vigorous growth of silverleaf nightshade during summer (mostly July and August) and is in full accordance with previous studies (Travlos, 2012). Our results also proved that even in the presence of silverleaf nightshade, the annual forage yield of Hyliki was 23 to 28% and 12 to 13% higher than the yield of Gea and Dimitra, respectively.

Regarding the density of silverleaf nightshade, the weed was present at densities ranging between 2 and 7 plants/m^2 in the plots of Gea during the first year, while for Hyliki the maximum density was only about 3 plants/m^2 (Table 4). The mean density of the weed plants in the case of Hyliki was 31-34 and 51-57% lower than the corresponding values for Dimitra and Gea, respectively. The more rainfalls during 2011 resulted to a higher weed density compared with the first, drier year of experimentation.

Concerning the weed biomass, the mean growth of individual silverleaf nightshade plants in the plots with Hyliki was 43 and 60% lower than the corresponding values for Dimitra and Gea, respectively. Additionally, in the fourth harvest of alfalfa (210 DAS), the number of *S. elaeagnifolium* plants in the case of Hyliki was 65% lower than that of Gea, while the fresh weight per plant was also significantly lower (82%), as shown in Table 5.

This less vigorous and less dense presence of the weed in the plots of Hyliki is probably due to the recorded faster regrowth rate of this cultivar of alfalfa, compared with the other two cultivars. Indeed, according to our observations the regrowth ability of Hyliki after each harvest was significantly higher (scored as 4) than the other two cultivars (scored as 2). It is considered that differences among alfalfa cultivars in their ability to develop canopy structures early in the season could affect weed emergence (Huarte and Benech Arnold, 2003). Alfalfa has the

Table 1. Mean monthly rainfall and temperature during the field experiment in 2010 and 2011.

Month	Rainfall		Temperature	
	2010	2011	2010	2011
	mm		°C	
January	-	-	-	-
February	-	-	-	-
March	11	25.6	14.4	12.2
April	0	40	17.9	15.5
May	7	40.8	22.2	20.3
June	12	30.4	25.9	25.5
July	0	0	29.3	29.7
August	0	0.6	28.4	28.8
September	22.6	3.4	24.9	26.6
October	81.8	38.4	19	17.5
November	15.6	2.2	18.4	12.3
December	25	100.8	13.7	12
Total	175	282.2	-	-

Table 2. Analysis of variance for alfalfa cultivar (A), presence of *Solanum elaeagnifolium* (S), and year (Y) effects on alfalfa forage yield, density and biomass of the weed plants.

Source	df	Alfalfa forage yield	Silverleaf nightshade density	Silverleaf nightshade biomass
A	2	**	*	*
S	1	**	**	**
A x S	1	*	*	*
Y	2	*	*	ns
Y x A	2	*	*	ns
Y x S	1	*	*	ns
Y x A x S	2	*	*	ns

* Significant at the 0.05 level
** Significant at the 0.01 level

Table 3. Forage yield of three alfalfa cultivars (Gea, Dimitra, Hyliki) (dry weight in tn/ha) with the presence of *Solanum elaeagnifolium* and under a weed-free situation in a two-year field experiment (2010, 2011). Each number represents the mean yield of a cultivar per cutting or the total mean yield of a cultivar in 2010. In parentheses the corresponding values for 2011 are also shown.

With *S. elaeagnifolium*			
	Gea	Dimitra	Hyliki
Cuttings	Dry weight (tn/ha)		
65 DAT	2.84 (3.3) b	3.35 (3.89) a	3.66 (4.04) a
100 DAT	1.88 (2.2) d	2.49 (2.63) cd	2.81 (3.09) c
145 DAT	1.67 (1.88) f	2.21 (2.29) ef	2.58 (2.82) e
210 DAT	2.55 (3.01) h	2.91 (3.04) h	3.36 (3.61) g
Total	8.94(10.39) k	10.96 (11.85) j	12.41 (13.56) i
Without weeds			
	Gea	Dimitra	Hyliki
Cuttings	Dry weight (tn/ha)		
65 DAT	3.72 (3.98) m	4.36 (4.14) l	4.21 (4.29) l
100 DAT	2.66 (2.82) o	2.97 (3.13) no	3.52 (3.38) n
145 DAT	2.35 (2.42) q	2.43 (2.77) q	3.05 (3.25) p
210 DAT	3.38 (3.44) rs	3.15 (3.3) s	3.71 (3.82) r
Total	12.11 (12.66) u	12.91 (13.34) tu	14.49 (14.74) t

Means within a row followed by the same letter are not significantly different ($p < 0.05$) according to Fischer's LSD test.

Table 4. Density of *Solanum elaeagnifolium* plants in plots of three alfalfa cultivars (Gea, Dimitra, Hyliki) in a two-year experimental field (2010, 2011). Each number represents the mean number of weed plants for an alfalfa cultivar per cutting or the total mean number of weed plants for each cultivar in 2010. In parentheses the corresponding values for 2011 are also shown.

Density of *S. elaeagnifolium* (plants/m^2)			
Cuttings	Gea	Dimitra	Hyliki
65 DAT	2.2 (3.1) a	1.2 (2.1) b	1.3 (2.1) b
100 DAT	5.3 (7.2) c	2 (3.6) d	2.2 (3.4) d
145 DAT	7.1 (7.4) e	5.2 (4.5) e	3 (3.1) f
210 DAT	3.4 (4.1) g	3.3 (5.4) g	1.2 (2.1) h
Mean	4.5 (5.45) i	2.9 (3.9) ij	1.9 (2.7) j

Means within a row followed by the same letter are not significantly different ($p < 0.05$) according to Fischer's LSD test.

Table 5. Biomass of *Solanum elaeagnifolium* plants (fresh weight in g/plant) in plots of three alfalfa cultivars (Gea, Dimitra, Hyliki) in a two-year experimental field (2010, 2011). Each number represents the mean fresh weight of weeds for a cultivar per cutting in both experimental years or the total mean fresh weight of weeds for each cultivar.

Fresh weight of *S. elaeagnifolium* (g/plant)			
Cuttings	Gea	Dimitra	Hyliki
65 DAT	2.3 a	2.6 a	2.4 a
100 DAT	9.8 b	6.4 c	5.2 c
145 DAT	12.4 d	8.4 e	4.8 f
210 DAT	11.9 g	8.6 g	2.2 h
Mean	9.1 i	6.5 j	3.7 k

Means within a row followed by the same letter are not significantly different ($p < 0.05$) according to Fischer's LSD test.

ability to suppress weed growth (Peters and Linscott 1988) and appears to exert a long-term effect on weed population dynamics (Ominski *et al*., 1999). Several weeds are expected to be effectively suppressed by *M. sativa*, and thus including alfalfa in crop rotations regime can be part of an integrated weed management strategy for weeds such as *Avena fatua*, *Brassica kaber*, *Cirsium arvense, Rumex crispus*, *Amaranthus quitensis* (Ominski et al. 1999; Huarte and Benech Arnold, 2003).

The inverse linear relationship (R^2 between 0.72 and 0.83) between alfalfa forage yield and *S. elaeagnifolium* biomass found in this study (Fig. 1) suggests that maintaining a high crop biomass is important to avoid the invasion of the silverleaf nightshade and this is in full accordance with previous studies showing a similar relationship between alfalfa and weeds (Grewal, 2010). Moreover, it could be said that the greater suppression of silverleaf nightshade in the case of Hyliki was partly due to the high productivity of this specific cultivar as previously shown in the weed-free situation in Table 3.

In moderate to severe weed infestations, alfalfa yield can be reduced through competition for light, water, and nutrients and the forage quality can be lowered by decrease

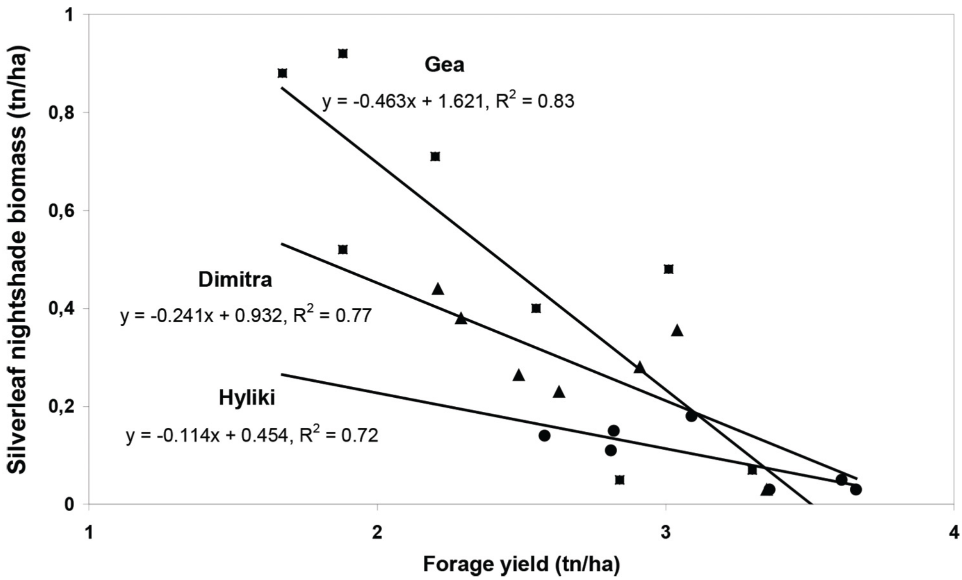

Figure 1. Relationship between forage yield of alfalfa and biomass of Solanum elaeagnifolium for three alfalfa cultivars (Gea, Dimitra, Hyliki) and four harvests during the first year of crop establishment.

in digestibility and protein content of the alfalfa hay (Cords 1973). Usually, alfalfa and weeds are harvested together and thus the quality of the hay is significantly degraded. This degradation is even higher, especially in the case of weeds such as silverleaf nightshade that animals are reluctant to graze because of the spiny leaves and stems (David *et al.*, 1945). For the effective control of silverleaf nightshade, several mechanical (David *et al.*, 1945), biological (Keeling and Abernathy, 1980; Parker, 1986), or chemical methods (Philips and Merkle, 1980; Eleftherohorinos *et al.*, 1993; Westerman and Murray, 1994) have been proposed. However, an integrated weed management approach based on a rotation regime with competitive alfalfa cultivars is rather required for an effective control of noxious species, such as silver nightshade.

Another critical thing to be taken into account is that for a perennial crop like alfalfa, high weed populations in the first year may adversely affect crop yield and quality in subsequent years (Smith *et al.*, 1990). It is well documented that controlling weeds during the establishment year reduces stress on alfalfa and ultimately increases yield in the following years (Stout *et al.*, 1992; Travlos, 2011). Consequently, the careful selection of the most productive and weed competitive alfalfa cultivars could be of great importance during the crucial year of crop establishment.

Conclusions

Our results showed that the weed competitive ability and forage yield of alfalfa cultivars might have a substantial range and should be certainly taken into account. Annual forage yield loss in the case of less weed competitive alfalfa cultivars was high and up to 26%, while after the selection of the most productive and competitive cultivar (i.e. Hyliki) the reduction was significantly lower and forage yield could be up to 28% higher, even with the presence of the noxious silverleaf nightshade. Similar studies should be continued including different alfalfa cultivars, soil and climatic conditions, weed species and weed densities. The ability of alfalfa to suppress weed growth can provide a viable alternative to chemical weed control and allow crop producers to reduce herbicide inputs. Moreover, our results highlight the underestimated importance of alfalfa cultivar selection for a successful establishment of the crop being also effective against noxious weeds. This is important, especially in cases of organic agriculture and in any other agricultural situations where herbicides are missing or they should not be applied.

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Αλληλεπιδράσεις μεταξύ του ζιζανίου σολανό (*Solanum elaeagnifolium* Cav.) και τριών ποικιλιών μηδικής (*Medicago sativa* L.)

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Περίληψη Σε συνθήκες αγρού διερευνήθηκε ο ανταγωνισμός μεταξύ τριών ποικιλιών μηδικής (*Medicago sativa* L.) και του ζιζανίου *Solanum elaeagnifolium* Cav. Συγκεκριμένα, στον αγρό του Εργαστηρίου Γεωργίας του Γ.Π.Α. έγινε πειραματισμός για δύο συνεχή έτη (2010, 2011) με τρεις ποικιλίες μηδικής (Gea, Δήμητρα, Υλίκη). Ίση ποσότητα ριζωμάτων του ζιζανίου ενσωματώθηκε ομοιόμορφα σε κάθε πειραματικό τεμάχιο, ενώ υπήρχαν και πειραματικά τεμάχια χωρίς την παρουσία του ζιζανίου (μάρτυρας). Μελετήθηκε η απόδοση των τριών ποικιλιών κατά τη διάρκεια των τεσσάρων κοπών για το κάθε έτος πειραματισμού, ενώ παράλληλα λαμβάνονταν μετρήσεις της πυκνότητας και του νωπού βάρους και του σολανού. Τα αποτελέσματα έδειξαν ότι το συνολικό ξηρό βάρος της παραγόμενης βιομάζας των ποικιλιών της μηδικής ανά έτος μειώθηκε παρουσία του ζιζανίου *S. elaeagnifolium* σε σχέση με τους μάρτυρες από 8 έως 26% και ανάλογα με τη χρονιά και την καλλιεργούμενη ποικιλία. Από τις τρεις ποικιλίες η Υλίκη ήταν η περισσότερο παραγωγική ακόμη και σε συνθήκες παρουσίας του σολανού με απόδοση σημαντικά υψηλότερη από τις άλλες. Η Υλίκη ήταν επίσης η ποικιλία με τον υψηλότερο ρυθμό αναβλάστησης μετά από κάθε κοπή. Επιπλέον, τα αποτελέσματα έδειξαν ότι η πυκνότητα και το νωπό βάρος του ζιζανίου ήταν σημαντικά μικρότερα στα πειραματικά τεμάχια της Υλίκης σε σχέση με τα αντίστοιχα της Gea. Η μελέτη αυτή επιβεβαιώνει τις διαφορές ως προς την ανταγωνιστική ικανότητα των ποικιλιών της μηδικής έναντι των ζιζανίων και τη σημασία της σωστής επιλογής της κατάλληλης ποικιλίας για την επιτυχή διαχείριση δυσεξόντωτων ζιζανίων όπως το σολανό, ιδιαίτερα μάλιστα σε βιολογικές καλλιέργειες.

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