International Journal of Manures and Fertilizers Vol. 2 (10), pp. 393-402, October, 2013. Available online at www.internationalscholarsjournals.org © International Scholars Journals

Full Length Research Paper

Effects of legume crops, for organic green manure, on weed flora, under Mediterranean circumstances: Competitive ability of five winter season weed species

Junaid O. Goldfin, Mladen Roli and Gian Effie

Department of Crop Science, Faculty of Agriculture, Agricultural University of Athens, Athens, Greece.

Accepted 03 September, 2013

Field experiments were conducted to determine the effects of vetch (*Vicia sativa* c.v lexander) and red clover (*Trifolium pratense* c.v Nemaro) on weed flora. The design of the experiment was randomized complete block with 4 replicates and 3 treatments (a: vetch crop, b: red clover crop and c: control (fallow)). Both legume crops suppressed weed biomass. The lowest number and dry weight of weeds was found in vetch plots. The highest height of weeds was found in control plots. Moreover, the highest multiplied dominance ratio (MDR) of weeds was found in the control plot. Vetch was the most competitive legume crop. The number of shoots per plant and dry weight were considered suitable attributes for weed suppression, although competitiveness is a relative rather an absolute characteristic. In addition, red clover is considered a poor competitor because of lack of seedling vigour and slow establishment. Statistically significant negative correlation between the fraction of photosynthetically active radiation (PAR) intercepted by the canopy, weed density and weed biomass was observed. The MDR of weeds (*Lamium aplexicaule*, *Papaver rhoeas*, *Sinapis arvensis*, *Chamomilla recutita* and *Phalaris minor*) had a good correlation with dry weight of weeds. Analysis of MDR demonstrated that *L. aplexicaule* and *C .recutita* are poor competitors because of small leaves and low height. Final, *S. arvensis* and *P. minor* were the most competitive weeds.

Key words: Multiplied dominance ratio, photosynthetically active radiation, vetch, red clover, weed flora.

INTRODUCTION

Agricultural production has become heavily reliant, over the past 50 years, on the use of synthetic fertilizers. Management methods that decrease requirement for agricultural chemicals are needed to reduce adverse environmental impacts (Bilalis et al., 2009). Vetch and red clover are both legume species, which are well adapted to the soil and climate conditions of Greece. They can also be cultivated as plants for green manure (Karkanis et al., 2007), during the period between two major crops (intermediate crop) in the common rotation system of Greece (Sidiras et al., 1999), such as wheat/ cotton, wheat/tobacco, etc. Vetch and red clover can be seeded at the beginning of October and then cut and incorporated into the soil at the end of April.

*Corresponding author. E-mail: Junaid57@gmail.com.

The use of green manure is one of the basic cultivation techniques of Organic Agriculture. Thus, knowledge of competitive ability of green manure crops and weeds is desirable for development of economically and environmentally acceptable integrated or organic cultural systems.

The development of an integrated weed management system requires detailed information on weed: crop interactions, including the relative competitive ability of the crop during various phases off development on weed growth (Tollenaar et al., 1994). A major component of integrated weed management is the use of more competitive crops (Lemerle et al., 1996). With current pressures to reduce herbicide usage but maintain cost-effective weed control, the innate ability of crops to suppress weed growth has become increasingly important.

Appropriate crop and cultivar selection has the potential to significantly influence the level of weed control.

Table 1. Monthly mean temperatures (°C), monthly mean relative humidity (%) and monthly precipitation (mm) during the cultivation period of legumes.

	Temperature (°C)		**Relative humidity (%)**		**Precipitation (mm)**	
	2004-05	**2005-06**	**2004-05**	**2005-06**	**2004-05**	**2005-06**
December	11.2	12.9	70	69	14.5	15.6
January	7.4	9.8	68	72	69.4	61.2
February	8.5	9.4	67	71	46.8	45.8
March	12.3	12.3	65	70	25.6	60.8
April	15.1	16.5	56	60	3.2	16.8
Total					154.5	200.2

Characters such as growth rates, shading ability (Lemerle et al., 2001), tillering capacity, crop height (Korres and Froud-Williams, 2002), leaf area (Seavers and Wright, 1999), upright growth, long stem, high biomass (Ross et al., 2001), allelopathy (Khanh et al., 2005; Seavers and Wright, 1999) affect crop: weed interactions. Allelopathy crops (i.e. red clover) (Ohno et al., 2000; Ohno and Doolan, 2001) when used as green manures or grown in rotational sequences are helpful in reducing noxious weeds.

It is well established that weed species vary in their competitive effects on crops. Although shoot morphologies obviously may differ considerably among weed species, the quantitative effects of this variation on crop: weed competition have not been evaluated precisely. Caton et al. (2001) reported that weed competitiveness for light is improved by being taller, having a more skewed vertical leaf area distribution (grater F_{top}: is the fraction of leaf area in the top half of the plant) and having more planophile leaves (greater k_{leaf}). Leaf angle specifies the orientation of leaves to incoming radiation and, therefore, strongly affects light capture. Leaf angles were quantified as leaf light extinction coefficients (k_{leaf}), which vary from erectophile (nearer to 0) to planophile (nearer to 1). Moreover, Cavero et al., (1999) reported that competitive ability of *Datura stramonium* L. for light was mainly due to its growth habit, with the leaves concentrated in the upper part of the canopy (more than 75% of LAI in the upper 25% of height).

Vegetation data in this study were analyzed based on the multiplied dominance ratio (MDR). MDR (m^3/m^2) is calculated by multiplying the coverage (m^2/m^2) and height (m) of each of the weed species (Kobayashi et al., 2003; Kobayashi et al., 2004). Furthermore, MDR may be a better indicator of how intense is the competition between weeds and crops in comparison to the dry weight, because competition over light has recently been recognised to be more important than that of nutrients (Kobayashi et al., 2003).

The aim of this study was to determine the effects of two green manure crops on weed vegetation. Final, the objective of the present study was to clarify the competitive ability of five winter season weed species.

MATERIALS AND METHODS

Experimental design

The experiment was conducted in the experimental field (outdoors) of the Agricultural University of Athens (23.43E, 34.58N), Greece, from November to April in two consecutive years (2005, 2006). The soil was clayloam (29.8% clay, 34.3% silt and 35.9% sand) with pH 7.24, 1.17% organic matter and 0.54 $mScm^{-1}$ of EC. Some meteorological data of the experimental site are presented in Table 1. Prior to this study, the field was under wheat cultivation. The management of site follows organic production legislation EN 2092/91.

The experiment was a randomized complete block design with 4 replicates and 3 treatments (a: vetch crop (*Vicia sativa* L. cv. Alexandros), b: red clover crop (*Trifollium pratense* L. cv. Nemaro) and c: control (fallow)). The experiment was set up in an area of 483 m^2. The plot size was 35 m^2 (3.5 m x 10 m). Vetch and red clover were sown by hand in rows (20 cm distance from row to row) in depth 1.5 cm. The field was sown at 4 November (in 2004 and 2005). The rate was 100 $Kgha^{-1}$ for vetch and 20 $Kgha^{-1}$ for red clover. During growth, plants were not fertilized.

Samplings, measurements and methods

Legumes

Crop height, length of stems, number of shoots per plant, leaf area index (LAI) and biomass.

The samplings were made 76, 110, and 170 DAS (days after sowing). Plants were sampled at random (10 plants per plot) and leaf area was measured using an automatic leaf area meter (Delta-T Devices Ltd). The measurements on a plant basis were converted into leaf area index (LAI: m^2m^{-2}) by multiplying it on the average crop density of each plot. Length of stems was also determined by measuring 10 plants per plot. Height of crop was calculated by taking ten measurements per plot. To define biomass (dry weight) the plants of 1 m^2 were cut in 2 different spots of each plot.

Photosynthetically active radiation (PAR)

Canopy interception of incident photosynthetically active radiation (PAR) was calculated by taking ten readings in rapid succession above the canopy and ten readings below the canopy at the soil surface using a 60 cm Sunfleck Ceptometer (Decagon devices, Pullman, Washington State, USA). The samplings were made 76, 110, and 170 DAS (days after sowing). The fraction of the incident PAR intercepted by the canopy (F_{int} PAR) was calculated with the following equation:

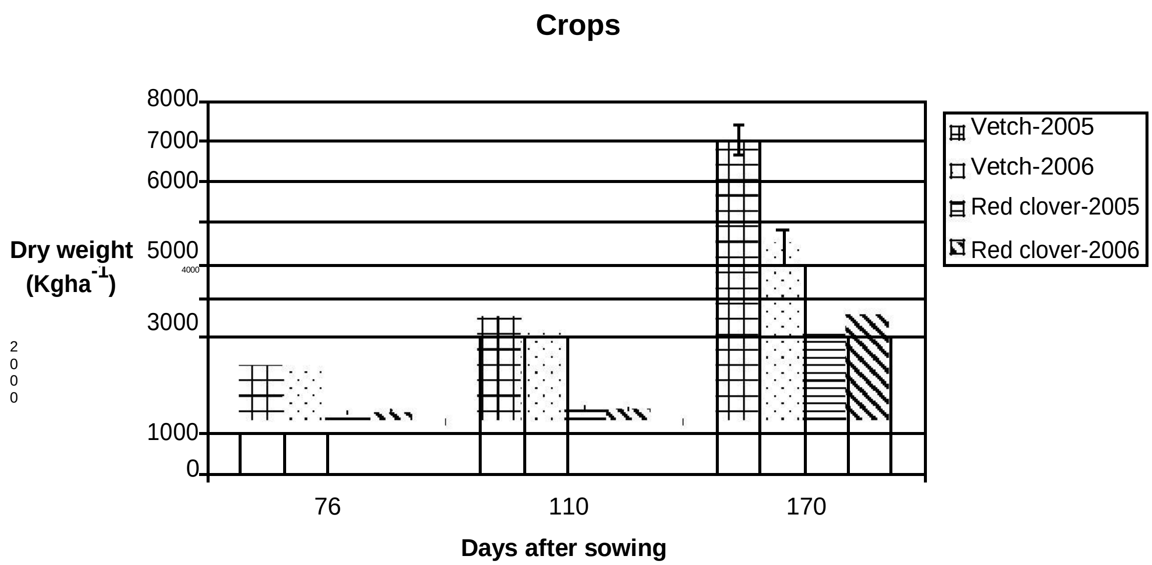

Figure 1. Dry weight ($Kgha^{-1}$) of legume crops (vetch and red clover) 76, 110 and 170 DAS. Error bars indicate the standard errors (n=4).

$$\%F_{int}\,PAR = 1 - \frac{PAR\_belowcanopy}{PAR\_abovecanopy} \times 100$$

Weeds

The height, number and dry weight of dominant weeds (Henbit: *Lamium aplexicaule* L., Corn poppy: *Papaver rhoeas* L., Wild mustard: *Sinapis arvensis* L., Wild chamomile: *Chamomilla recutita* (L.) Rauschert and Littleseed canarygrass: *Phalaris minor* Retz.) were assessed. Weeds were measured three times (76, 110 and 170 DAS) during the cultivation period. A 1 m x 1 m quadrate was used, 3 times per plot. All weeds were collected from the measured area and weighted to determine the dry matter. The MDR index was calculated as an indicator of weed volume for each weed species as follows:

$$MDR(cmm^2\,m^{-2}) = \text{cov}\,erage(m^2\,m^{-2})xheight(cm)$$

Statistical analysis

The data were subjected to the analysis of variance appropriate to the experiment design. Significant differences between the treatments means were separated by means of the least significant difference (*LSD*) at the 5% level of probability, using StatSoft (1996) software.

RESULTS

Crop growth

Vetch plants demonstrated rapid growth every year. The biomass (Figure 1), leaf area index (Figure 5) and crop height (Figure 3) of vetch crop, 170 DAS, was higher than the biomass of red clover. In addition, red clover had the lowest number of shoots per plant (Figure 2) and length of stems (Figure 4).

Vetch crop had the highest dry weight (7010 $Kgha^{-1}$). The biomass of vetch crop, 170 DAS, was 40-69% higher than the biomass of red clover. Final, the LAI ranged between 1.17 and 4.01 vetch crop and 0.06- 2.26 red clover crop. The LAI of vetch crop, 170 DAS, was 31-48% higher than the LAI of red clover.

Photosynthetically active radiation (PAR)

The fraction of the Photosynthetically active radiation (PAR) intercepted by the canopy (F_{int} PAR) under the cultivation plants (that was available for the weeds) are presented in Figure 6. After 110 DAS, the percentage of the fraction of PAR that intercepted started to diminish statistically more on vetch crop. The highest fraction of PAR intercepted was observed at vetch crop (about 90% for both years, at 170 DAS). Moreover, there were statistically significant positive correlation (r = 0.93, p < 0.001) between leaf area index and fraction of the photosynthetically active radiation (PAR) intercepted by the canopy (F_{int} PAR).

Number of weeds

The number of weeds (Table 2) in the vetch and red cover plots was less than in the control plots in both years. The lowest number of weeds was recorded in vetch crops. Also, higher number of weeds was recorded in 110 and 170 DAS than in 76 DAS for both years in every treatment. Moreover, the number of weeds was higher in 2006 in comparison to 2005. The dominant species in the vetch plots was *P. rhoeas*; whereas *S. arvensis* was second. The most abundant weeds in the control plots, throughout the experimental periods, were *P. rhoeas, S. arvenis* and *C. recutita*.

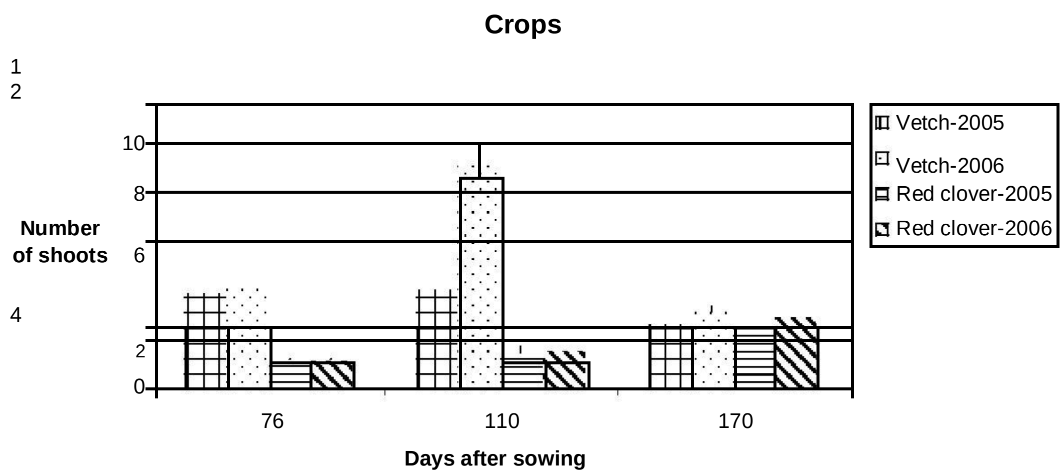

Figure 2. Number of shoots of legume crops (vetch and red clover) 76, 110 and 170 DAS. Error bars indicate the standard errors (n=4).

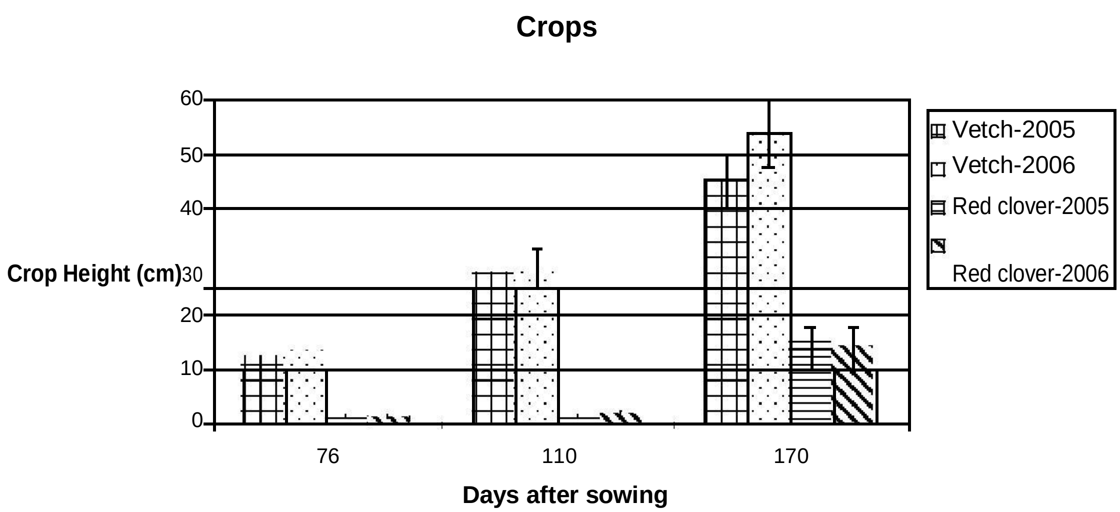

Figure 3. Crop height (cm) of legume crops (vetch and red clover) 76, 110 and 170 DAS. Error bars indicate the standard errors (n=4).

Dry weight of weeds

The dry weight of weeds in the vetch and red cover plots was less than in the control plot every year. The lowest biomass of weeds (Table 3) was assessed in vetch plots. Also, much higher biomass were recorded in 110 and 170 days after sowing (DAS) than in 76 DAS for 2 years in every treatment. Also, the dry weight of weeds was higher in 2006 in comparison to 2005.

In the vetch plots, 170 DAS, the biomass of *S. arvensis* and *P. minor* was generally higher than that of *P. rhoeas, L. aplexicaule* and *C. recutita*. Final, in the red clover plots, 170DAS, the biomass of *S. arvensis, P. rhoeas* and *C. recutita* was generally higher than that of *P. minor* and *L. aplexicaule*.

Height of weeds

The height of weeds in the vetch and red cover plots was less than in the control plot every year. The lowest height (Table 4) was recorded in vetch crops. Also, higher height was recorded in 110 and 170 days after sowing (DAS) than in 76 DAS. This was the case for both years in all treatments. Also, the height of weeds was higher in 2006 in comparison to 2005.

In the vetch and red clover plots, 170DAS, the height of *S. arvensis* and *P. minor* was generally higher than that of *P. rhoeas, L. aplexicaule* and *C. recutita*. Final, in the control plots, 170 DAS, the height of *S. arvensis, P. rhoeas* and *P. minor* was generally higher than that of *C. recutita* and *L. aplexicaule*.

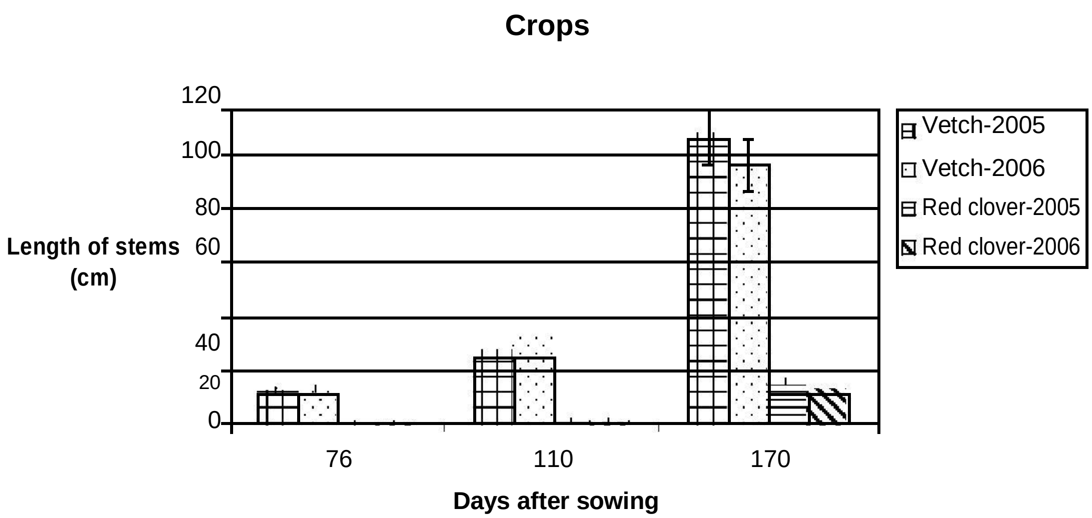

Figure 4. Length of stems (cm) of legume crops (vetch and red clover) 76, 110 and 170 DAS. Error bars indicate the standard errors (n=4).

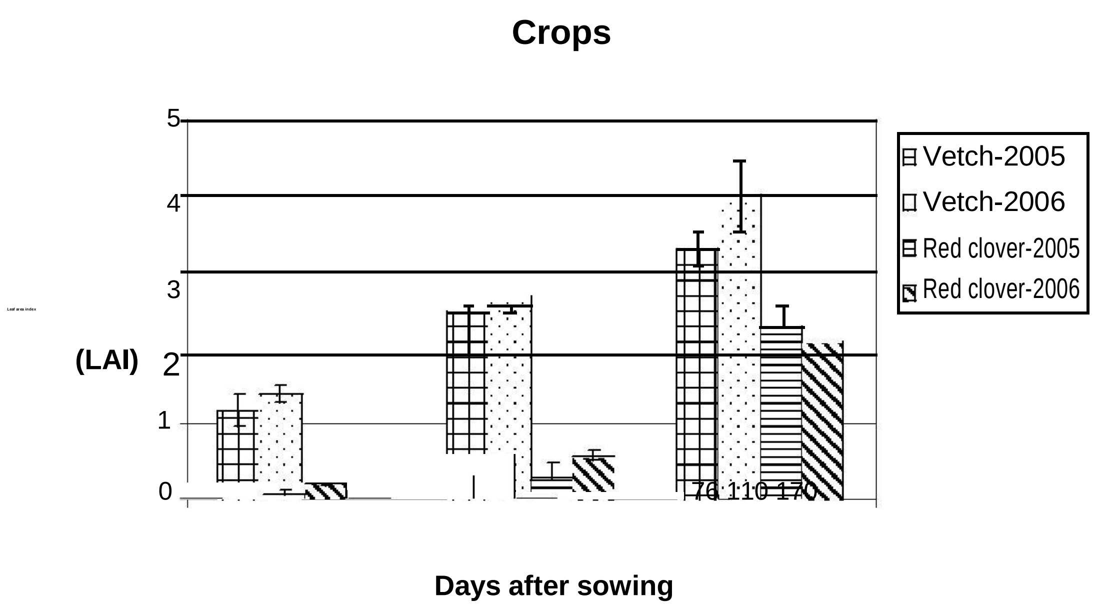

Figure 5. Leaf area index of legume crops (vetch and red clover) 76, 110 and 170 DAS. Error bars indicate the standard errors (n=4).

Multiplied dominance ratio (MDR) of weeds

The MDR of weeds in the vetch and red cover plots was less than in the control field every year. The lowest MDR of weeds (Table 5) was recorded in vetch crops. Also, much higher MDR was recorded in 170 days after sowing (DAS) than in 76 and 110 DAS for 2 years in every treatment. Also, the MDR of weeds was higher in 2006 in comparison to 2005.

The MDR of *S. arvensis, P. rhoeas* and *P. minor* was generally higher than that of *L. aplexicaule* and *C. recutita*. Moreover, in 2005, 170 DAS, the total MDR (sum of MDR of each weed species) of weeds was 38.51, 7.45 and 20.17 for control, vetch and red clover, respectively.

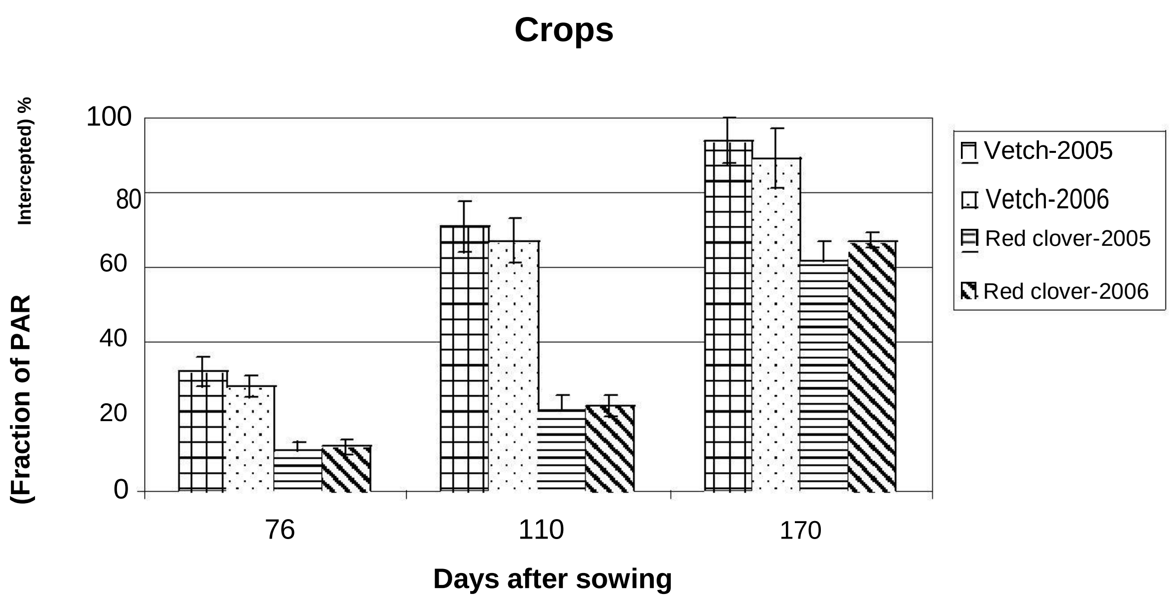

Figure 6. The fraction of PAR intercepted (%) during the growing season, for legume-crops 76, 110 and 170 DAS. Error bars indicate the standard errors (n=4).

Table 2. Influence of legume crops (vetch, red clover and control) on number of weeds (nom^{-2}) 76, 110 and 170 DAS.

	Lamiumaplexicaule	*Papaver rhoeas*	*Sinapis arvensis*	*Phalaris minor*	*Chamomillarecutita*	*Lamiumaplexicaule*	*Papaver rhoeas*	*Sinapis arvensis*	*Phalaris minor*	*Chamomillarecutita*
76 DAS	**2005**					**2006**				
Control	47.5a	105a	17.5a	4.0a	77.5a	102.5a	95.0a	22.5a	20.0a	367a
Vetch	10.0b	52.5b	15.0a	2.5a	22.5b	42.5b	65.0b	25.0a	7.5b	90b
Red clover	40.0a	65.0b	17.5a	4.5a	31.0c	77.5a	80.0a	27.5a	18.5a	177c
$LSD_{5\%}$	18.43	15.65	4.21	2.30	4.25	26.5	22.5	4.5	9.5	52.5
110 DAS	**2005**					**2006**				
Control	55.0a	110a	40.0a	19.5a	80.0a	115a	207a	65.0a	67.5a	757a
Vetch	15.0b	77.5b	12.5b	7.5b	27.5b	45.0b	67.5b	35.0b	12.5b	102b
Red clover	60.0a	75.0b	30.0a	17.5a	40.0c	87.5c	85.0b	45.0b	20.0b	257c
$LSD_{5\%}$	7.45	15.24	12.42	3.52	12.86	25.54	32.78	11.87	10.21	87.91
170 DAS	**2005**					**2006**				
Control	15.0a	65.0a	37.5a	17.0a	115a	32.5a	120a	65.0a	62.5a	232a
Vetch	2.5b	40.0b	22.5b	5.0b	5.0b	7.5b	50.0b	32.5b	27.5b	17.5b
Red clover	17.5a	37.5b	35.0a	12.5c	50.0c	12.5c	87.5c	50.0c	34.5b	85.0c
$LSD_{5\%}$	5.21	8.23	4.76	3.67	21.78	5.2	20.5	17.45	8.32	24.56

Values in columns represent mean values of four replications. Values followed by the same letter are not significantly different according to LSD test, P 0.05.

Table 3. Influence of legume crops (vetch, red clover and control) on dry weight of weeds (Kgha^{-1}) 76, 110 and 170 DAS.

	Lamiumaplexicau le	***Papaver rhoeas***	*Sinapisarvensis*	***Phalaris minor***	*Chamomillarecuti ta*	*Lamiumaplexicaul e*	***Papaver rhoeas***	*Sinapisarvensis*	***Phalaris minor***	*Chamomillarecutit a*
76 DAS			**2005**					**2006**		
Control	43.5a	36.0a	43.0a	60.7a	63.7a	241.5a	121a	194.5a	105.2a	396.7a
Vetch	10.0b	17.2b	19.2b	5.5b	4.5b	35.5b	94.0a	72.5b	46.5b	49.2b
Red clover	29.7c	37.2a	47.7a	20.7c	38.2c	201.2a	123.7a	123.2c	49.7b	129.7c
$LSD_{5\%}$	11.32	9.87	15.91	12.21	18.21	57.89	34.5	22.5	12.76	56.78
110 DAS			**2005**					**2006**		
Control	66.5a	278.2a	160.2a	184.5a	162a	430a	653.8a	961a	265.3a	1360a
Vetch	15.0b	43.7b	67.7b	23.7b	24.7b	32.5b	228.0b	296b	130.5b	125b
Red clover	38.5c	154.7c	155.5a	69.7c	53.2b	197.8c	425.0c	838a	197.8b	490c
$LSD_{5\%}$	13.45	88.5	26.78	33.21	35.6	102.1	111.34	124.5	78.5	102.5
170 DAS			**2005**					**2006**		
Control	38.0a	876.0a	1196a	1488.2a	376.5a	196.0a	2401a	1840a	2394a	743a
Vetch	7.5b	342.5b	411b	71.7b	18.7b	27.2b	580b	411b	550b	120b
Red clover	16.5b	410.5c	967a	877.2c	263.6c	78.6b	1092c	1529c	701b	319c
$LSD_{5\%}$	10.32	67.87	385.21	345.73	85.5	42.34	340.5	330.1	202.5	115.24

Values in columns represent mean values of four replications. Values followed by the same letter are not significantly differ ent according to LSD test, P 0.05.

Table 4. Influence of legume crops (vetch, red clover and control) on weed height (cm) 76, 110 and 170 DAS.

	Lamiumap lexicaule	*Papaverrhoe as*	*Sinapisarvensis*	*Phalarismin or*	*Chamomill arecutita*	*Lamiumaple xicaule*	*Papaverrhoe as*	*Sinapisarven sis*	*Phalarismin or*	*Chamomilla recutita*
76 DAS			**2005**					**2006**		
Control	4.58a	0.75a	4.50a	2.80a	1.09a	4.34a	1.34a	6.8a	4.43a	7.65a
Vetch	3.46a	0.97a	4.00a	1.22b	0.50a	3.78a	1.30a	5.4a	3.12b	5.78a
Red clover	3.27a	0.59a	4.25a	1.40b	0.75a	4.11a	1.12a	6.2a	3.89a	6.89a
$LSD_{5\%}$	1.32	0.51	0.62	1.11	0.64	0.71	0.32	1.53	0.63	3.12
110 DAS			**2005**					**2006**		
Control	10.25a	4.15a	34.17a	11.00a	15.56a	14.25a	7.75a	44.52a	25.67a	21.23a
Vetch	7.83b	1.77b	25.83b	6.08b	13.06b	9.78b	5.21b	32.50b	16.43b	14.54b
Red clover	10.00a	2.00b	29.12c	9.75a	14.17c	12.21c	6.78a	37.91b	25.98a	19.87a
$LSD_{5\%}$	1.42	1.32	3.21	2.84	1.02a	1.32	1.42	5.80	2.46	3.02
170 DAS			**2005**					**2006**		
Control	19.17a	54.79a	65.83a	116.0a	24.42a	21.23a	57.32a	70.23a	109.2a	28.80a
Vetch	11.12b	28.08b	49.00b	65.00b	21.00b	10.58b	22.47b	56.87b	53.13b	16.53b
Red clover	13.56b	37.33c	61.17a	84.00c	23.44a	14.56b	35.66c	65.78a	79.89c	22.76c
$LSD_{5\%}$	4.32	9.02	10.22	7.85	2.42	4.11	10.82	6.42	11.13	3.21

Values in columns represent mean values of four replications. Values followed by the same letter are not significantly differ ent according to LSD test, P 0.05.

Table 5. Influence of legume crops (vetch, red clover and control) on Multiplied Dominance Ratio (MDR: cm m^2m^{-2}) 76, 110 and 170 DAS.

	Lamiumaplexicaule	*Papaver rhoeas*	*Sinapis arvensis*	*Phalaris minor*	*Chamomillarecutita*	*Lamiumaplexicaule*	*Papaver rhoeas*	*Sinapis arvensis*	*Phalaris minor*	*Chamomillarecutita*
76 DAS			**2005**					**2006**		
Control	0.092a	0.039a	0.075a	0.06a	0.027a	0.551a	0.196a	0.930a	0.365a	0.987a
Vetch	0.044a	0.041a	0.130a	0.028a	0.003a	0.172b	0.129b	0.396b	0.142b	0.144b
Red clover	0.134a	0.012a	0.182a	0.04a	0.002a	0.415a	0.152a	0.765a	0.212c	0.352b
$LSD_{5\%}$	0.06	0.02	0.11	0.05	0.02	0.14	0.06	0.19	0.08	0.30
110 DAS			**2005**					**2006**		
Control	0.40a	0.55a	3.87a	1.24a	1.03a	2.786a	4.917a	11.78a	5.360a	11.85a
Vetch	0.06b	0.30b	1.12b	0.05b	0.15b	0.229b	1.281b	3.93b	1.352b	1.821b
Red clover	0.24c	0.43c	1.57b	0.31b	0.32b	0.884c	2.288b	7.67c	4.009a	2.011b
$LSD_{5\%}$	0.13	0.11	0.67	0.30	0.40	0.54	1.02	2.41	2.13	0.32
170 DAS			**2005**					**2006**		
Control	0.149a	15.53a	7.40a	14.81a	0.60a	0.722a	31.91a	18.88a	20.96a	1.345a
Vetch	0.006b	2.84b	2.65b	1.93b	0.018b	0.101b	3.472b	4.04b	4.19b	0.074b
Red clover	0.034b	4.48c	3.88c	11.59a	0.18b	0.373c	8.16c	15.60a	8.94c	0.330b
$LSD_{5\%}$	0.03	1.21	1.02	3.42	0.27	0.12	2.46	3.82	4.24	0.28

Values in columns represent mean values of four replications. Values followed by the same letter are not significantly different according to LSD test, P 0.05.

Moreover, the total MDR of weeds was higher in 2006 in comparison to 2005.

DISCUSSION

Although we cannot eliminate the use of herbicides (synthetic or organic), their use can be reduced by selection of crop species with superior weed suppression potential. Appropriate crop selection has the potential to significantly influence the level of weed control (Efthimiadou et al., 2009).

The germination of most of the studied weeds was inhibited by the presence of vetch crop. The lowest number and dry weight of weeds were found in vetch treatment. The highest fraction of PAR intercepted was observed at vetch crop (about 90% for both years, at 170 DAS). There were statistically significant positive correlation ($r = 0.93$, $p < 0.001$) between leaf area index of crops and fraction of the photosynthetically active radiation (PAR) intercepted by the canopy (F_{int} PAR). The presence of a crop canopy reduces the photon flux of all wavelengths relative to full daylight, much more in the photosynthetically active part of the spectrum (400–700 nm) than in the near infra-red (700-100 nm) because of strong absorption by chlorophylls (Kruk et al., 2006). Moreover, the decrease of the available light for the weeds led to the reduction of the weed number and dry matter in vetch crop, in comparison to the red clover crop or fallow treatment. High correlation (Table 6) between PAR intercepted and dry weight or number of weeds was observed.

Seed perceive the light environment through phytochromes (Kruk et al., 2006). Phytochromes have two photo-interconvertible forms: Pfr (usually the active far-red absorbing form), with maximum absorption at 735 nm, and Pr (the inactive red-absorbing form), with maximum absorption at 665 nm. Exposure of seed to light with a high red (R) to far-red (FR) ratio led to increase of Pfr : Pr ratios that might be high enough to trigger germination. Taylor et al., (2004) reported that germina-tion of *Phalaris paradoxa* seeds was stimulated by red but was inhibited by far-red light. In addition, germination of *Cuscuta capestris* (Benvenuti et al., 2005) and *Galium aparine* (Beres, 1994) seeds was not influenced by light. Moreover, the presence of a crop canopy reduces the thermal amplitude of the soil (Kruk et al., 2006) that prevent germination of species (*Solanum nigrum* L., *Thlaspi arvense* L., *Amaranthus retroflexus* L, *Chenopodium album* L. and *Echinochloa crus*-gal*li* L.) which require

Table 6. Correlation coefficients[1] between growth parameters of weeds.

	MDR x Dry weight		Dry weight x LAI		Dry weight x Height	
	2005	2006	2005	2006	2005	2006
Lamium aplexicaule	0.80**	0.88***	0.86**	0.92***	ns	ns
Papaver rhoeas	0.94***	0.98***	0.69*	0.63*	0.93***	0.96***
Sinapis arvensis	0.88**	0.98***	ns	0.67*	0.81**	0.84**
Phalaris minor	0.98***	0.97***	0.79*	ns	0.89**	0.90***
Chamomilla recutita	ns	0.88**	ns	0.88**	0.67*	0.59*

	Number of weeds x PAR		Dry weight of weeds x PAR	
	2005	2006	2005	2006
Lamium aplexicaule	0.93***	0.95***	0.90***	0.97***
Papaver rhoeas	0.79*	0.82**	0.75*	0.78*
Sinapis arvensis	0.78**	0.80***	0.88**	0.83**
Phalaris minor	0.84**	0.87**	0.88**	0.87**
Chamomilla recutita	0.96**	0.98**	0.91***	0.94***

1: r was calculated using the linear equation, ns: no significant. *,**,***, significant at P=0.05, 0.01 and 0.001, respectively.

fluctuating temperatures to terminate dormancy (Benech-Arnold et al., 2000; Martinez-Ghersa et al., 1997; Wagenvoort and Van Opstal, 1979).

Moreover, the highest height and MDR of weeds was found in control plots. The number, height and biomass of weeds were higher in 2006 in comparison to 2005. This can be attributed to temperature. In 2006, temperature (Table 1) during growing season was higher than temperature in 2005. Weed competitiveness is an attribute that is influenced by environmental conditions. Thus, temperature can influence the crop-weeds interactions. The estimated base temperatures for shoot dry matter accumulation of *Alopecurus myosuroides* Hunds., *Stellaria media* L., *G. aparine* L. and *Triticum aestivum* L. were -0.8, -3.3, -1.4 and 0.2°C, respectively, and estimated base temperatures for increase in green area were 0.4, -1.7, 1.9 and 2.2°C, respectively (Storkey and Cussans, 2000). Moreover, in 2006, rainfall (200.2 mm) during the experiment was more than rainfall in 2005 (154.5 mm).

Weed competitiveness for light was a function of the combined morphological traits (Caton et al., 2001) . For example, tall weeds were less competitive if they also had a conical LAD (Leaf area density; $m^2 m^{-3}$) or erect leaves (low k_{leaf}). Likewise, weeds with very planophile leaves (that is k_{leaf}=0.8) were less competitive if they had conical LADs. Planophile leaves were particularly beneficial for short weeds. All three traits (height, leaf angle and leaf area distribution) were critical determinants of weed interference but no single morphological trait guaranteed competitiveness. High correlation (Table 6) between dry weight of weeds and LAI or height was observed.

Although shoot morphologies obviously may differ considerably among weed species, the quantitative effects of this variation on legume crops: weed competition have not been evaluated precisely. Analysis of MDR showed that *L. aplexicaule* L. and *C. recutita* L. are poor competitors because of small leaves and low height. Also, *S. arvensis* L. and *Phalaris minor* Retz. were the most competitive weeds. The competitive ability of *S. arvensis* L. was due to its height and planophile leaves. In addition, *P. minor* Retz. with erect leaves was less competitive. *L. aplexicaule* L. and *C. recutita* L. had a significantly lower dry weight than the *P. rhoeas* L.. This is related to *P. rhoeas* L. ability to photosynthesize even when under crop canopy, as a result of their large planophile leaves. It is well established that weed species vary in their competitive effects on crops. Van der Toorn and Pons (1988) reported that *Plantago major* L., in contrast to *Plantago lanceolata* L. was less competitive. The lower competitive ability was caused by the shorter leaves. Also, Torner et al., (2000) found that two grasses (*Avena sterils* L., *Bromus diandrus* Roth.) had similar competitive effects that were much greater than the effects of the two dicotyledonous weeds (*Galium tricornutum* Dandy and *Veronica hederrifolia* L.). The response of these weeds to competition seems to be well correlated with biomass and leaf area in the early stages of growth. Moreover, Afentouli and Eleftherohorinos (1996) reported that the competitive ability of *P. minor* Retz. and *Phalaris brachystachys* Link. in wheat was similar, though *P. minor* showed faster growth rate and formed more panicles than *P. brachystachys*.

Our results show that vetch was the most competitive legume crop. Red clover is considered poor competitor because of lack of seedling vigour and slow establishment. Vetch competitive ability was associated with high overall leaf area, greater height, length of stems, number of shoots per plant, biomass (Table 1) and upright growth. Vetch was more competitive at early growth stages. The leaf area index of vetch was 30-48% higher than those of red clover. The possible contribution of allelopathetic exudates of red clover to their suppressive ability is discussed.

Ross et al., (2001) reported that weed suppression by clovers was affected by site, the growth characteristics of clover species and management practices. Weed suppression by clovers was greater on the low-productivity site than on the high–productivity site. Berseem's clover (*Trifolium alexandrinum* L.) competitive ability is aided by an upright growth habit, long stems, high biomass production, and late flowering. Similarly, the upright growth and long stems of alsike clover (*Trifolium hybridum* L.) made it more competitive than the other perennial clovers (red and white clover (*Trifolium repens* L.). Also, Korres and Froud-Williams (2002) indicated that crop height and tillering capacity were suitable attributes for weed suppression. Moreover, Seavers and Wright (1999) reported that oats was the most suppressive species followed by barley and then wheat. At ear emergence, leaf areas were greatest for oats followed by wheat. In spite of their small leaf area, the barley cultivars were more suppressive than those of wheat probably because they had many more stems per square meter than the wheat cultivars and a greater overall height.

Because of resistance to herbicides, many farmers have had to adopt non-chemical control methods for weed control. One low cost-option is to grow competitive varieties to reduce weed growth (Lemerle et al., 2001). For this option to be successful, farmers need to know the relative ranking of varieties and species for competitive ability. They would then be able to choose strongly competitive varieties and species where weeds are expected to be a problem. Our results indicate that vetch crop was sufficient for weed suppression. The characteristics of vetch (long stems, high biomass, leaf area and number of shoots) would support its use as green manure, cover or intermediate crop in common rotation system. Analysis of MDR shows that MDR may be a better indicator of the intensity of competition between weeds and crops than dry weight or number of weeds. Correlation between MDR and Dry weight of weeds is statistically significant every year. Finally, weed competitive ability was associated with high leaf area, greater height, canopy structure and development.

ACKNOWLEDGMENT

The second author thanks the Greek State Scholarships Foundation (I.K.Y) for funding.

REFERENCES

Afentouli CG, Eleftherohorinos IG (1996). Littleseed canarygrass (*Phalaris minor*) and short-spiked canarygrass (*Phalaris brachystachys*) interference in wheat and barley. Weed Sci. 44: 56-565.

Benech-Arnold RL, Sanchez RA, Forcella F, Kruk BC, Ghersa CM (2000). Enviromental control of dormancy in weed seed banks in soil. Field Crops Res. 67: 105-122.

Benvenuti S, Dinelli G, Bonetti A, Catizone P (2005). Germination ecology, emergence and host detection in *Cuscuta campestris*. Weed Res. 45: 270-278.

Beres I (1994). Effect of light, temperature, soil depth and water stress on germination of *Galium aparine* L. Zeitschrift fuer Pflanzenkrankheiten und Pflanzenschutz (Germany). 14: 37-40.

Bilalis D, Karkanis A, Efhimiadou A, Konstantas AR, Triantafyllidis V (2009). Effects of irrigation system and green manure on yield and nicotine content of Virginia (Flue-cured) Organic tobacco (*Nicotiana tabaccum*), under Mediterranean conditions. Ind. Crops Prod. 29: 388-394.

Caton BP, Mortimer AM, Foin TC, Hill JE, Gibson KD, Fischer AJ (2001). Weed shoot morphology effects on competitiveness for light in direct-seeded rice. Weed Res. 41: 155-163.

Cavero J, Zaragoza C, Suso ML, Pardo A (1999). Competition between maize and *Datura stramonium* in an irrigated field under semi-arid conditions. Weed Res. 39: 225-240.

Efthimiadou AP, Karkanis AC, Bilalis DJ, Efthimiadis P (2009). Review: The phenomenon of crop-weed competition; a problem or a key for sustainable weed management. J. Food Agric. Environ. 7: 861-868.

Karkanis A, Bilalis D, Efthimiadou A (2007). The effect of green manure and irrigation on morphological and physiological characteristics of Virginia (flue-cured) organic tobacco (*Nicotiana tabacum*). Int. J. Agric. Res. 2: 910-919.

Khanh TD, Chung MI, Xuan TD, Tawata S (2005). The exploitation of crop allelopathy in sustainable Agricultural production. J. Agron. Crop Sc. 191: 172-184.

Kobayashi H, Miura S, Oyanagi A (2004). Effects of winter barley as a cover crop on the weed vegetation in a no-tillage soybean. Weed Biol. Manage. 4: 195-205.

Kobayashi H, Nakamura Y, Watanabe Y (2003). Analysis of weed vegetation of no-tillage upland fields based on the multiple dominance ratio. Weed Biol. Manage. 3: 77-92.

Korres NE, Froud-Williams RJ (2002). Effects of winter wheat cultivars and seed rate on the biological characteristics of naturally occurring weed flora. Weed Res. 42: 417-428.

Kruk B, Insausti P, Razul A, Benech-Arnold R (2006). Light and thermal environments as modified by a wheat crop: effects on weed seed germination. J. Appl. Ecol. 43: 227-236.

Lemerle D, Verbeek B, Orchard B (2001). Ranking the ability of wheat varietes to compete with *Lolium rigidum*. Weed Res. 41: 197-209.

Lemerle D, Verbeek B, Cousens RD, Coombes NE (1996). The potential for selecting wheat varieties strongly competitive against weed. Weed Res. 36: 505-513.

Martinez-Ghersa MA, Satorre EH, Ghersa CM (1997). Effect of soil water content and temperature on dormancy breaking and germination of three weeds. Weed Sci. 45: 791-797.

Ohno T, Doolan KL (2001). Effects of red clover decomposition on phytotoxicity to wild mustard seedling growth. Appl. Soil Ecol. 16: 187-192.

Ohno T, Doolan K, Zibilske LM, Liebman M, Gallandt ER, Berube C (2000). Phytotoxic effects of red clover amended soils on wild mustard seedling growth. Agric. Econ. Environ. 78: 187-192.

Ross SM, King GR, Izaurralde RC, O' Donovan JT (2001). Weed suppression by several clover species. Agron. J. 93: 820-827.

Seavers GP, Wright KJ (1999). Crop canopy development and structure influence weed suppression. Weed Res. 39: 319-328.

Sidiras N, Avgoulas C, Bilalis D, Tsougrianis N (1999). Effects of tillage and fertilization on biomass, roots, N-accumulation and nodule bacteria of vetch (*Vicia sativa* cv. Alexander). J. Agron. Crop Sci. 182: 209-216.

Statsoft Inc (1996). Statistica for Windows, Statsoft, Inc., 2300 East 14th Street, Tulsa, OK.

Storkey J, Cussans JW (2000). Relationship between temperature and the early growth of *Triticum aestivum* and three weed species. Weed Sci. 48: 467-473.

Taylor IN, Peters NCB, Adkins SW, Walker SR (2004). Germination response of *Phalaris paradoxa* L. seed to different light qualities.

Weed Res. 44: 254-264.
Tollenaar M, Dibo AA, Aqilera A, Weise SF, Swanton CJ (1994). Effect of crop density on weed interference in maize. Agron. J. 86: 591-595.
Torner C, Sanchez Del Arco MJ, Satorre E, Fernanndez-Quintanilla C (2000). A comparison of the growth patterns and competitive ability of four annual weeds. Agron. 20: 147-156.
Van Der Toorn J, Pons TL (1988). Establishment of *Plantago lanceolata* L and Plantago major L. among grass. II. Shade tolerance of seedlings and selection on time of germination. Oecol. 76: 341-347.
Wagenvoort WA, Van Opstal NA (1979). The effect of constant and alternating temperatures, rinsing, stratification and fertilizer on germination of some weed species. Sci. Hortic. 10: 15-20.