Australian Journal of Crop Science AJCS
AJCS 8(2):178-182 (2014) ISSN:1835-2707

Effects of fertilization and salinity on weed flora in common bean (*Phaseolus vulgaris* L.) grown following organic or conventional cultural practices

Dimitrios Bilalis[1]*, Anestis Karkanis[2], Dimitrios Savvas[1], Charis-Konstantina Kontopoulou[1], Aspasia Efthimiadou[3]

[1]Department of Crop Science, Agricultural University of Athens, Iera Odos 75, 11855 Athens, Greece
[2]Department of Agriculture Crop Production and Rural Environment, University of Thessaly, Fytokou Str, 38446, Nea Ionia, Magnesia, Greece
[3]Open University of Cyprus, Nicosia, Cyprus

[*]Corresponding Author: bilalisdimitrios@yahoo.gr

Abstract

Two field experiments were conducted to assess the effects of cultural system and irrigation water salinity on weed flora in a common bean crop (*Phaseolus vulgaris* L. cv. Contender). The experiments were designed as split plot designs with the cropping system as main plot (organic or inorganic fertilization), the level of water salinity as sub-plot (good quality or saline irrigation water with 0.5 or 10mM NaCl, respectively) and four replications per treatment. The lowest weed density was recorded in the saline water treatment. The results of the study showed that the order of weed sensitivity to salinity is redroot bigweed > bermudagrass > common lambsquarters > barnyardgrass >common purslane >purple nutsedge. Moreover, differences in nitrogen availability of the fertilizers had a large effect on weed density and biomass. The highest weed biomass (in 2011: 454 kg ha^{-1} for saline water treatment and 759 kg ha^{-1} for control; and in 2012: 331 kg ha^{-1} for saline water treatment and 578 kg ha^{-1} for control) was recorded in the plots treated with inorganic fertilizers. These results indicated that organic fertilization and saline water could be used for the suppression of weeds in organic common bean crops.

Keywords: Common bean, inorganic fertilization, organic, salinity, weed control.
Abbreviations: OF_rganic fertilization; IF_inorganic fertilization; SW_saline water.

Introduction

Growth and yield of common bean are considerably reduced by weed competition for nutrients, water and light. Weeds respond dynamically to all cropping practices, and therefore, the design and function of cropping systems plays a central role in the composition of weed communities (Buhler, 2003). Widespread use of herbicides to control weeds resulted in serious environment pollution, and, therefore, the search for alternative weed control methods is currently a priority in agriculture (Zulkaliph et al., 2011). Moreover, there is a keen interest in developing alternative weed control methods in organically grown crops, as weed remain one of the most significant agronomic challenges in the production of organic crops (Bilalis et al., 2010). Low-input crop fertilization practices may be an important component of integrated weed management systems (Blackshaw et al., 2005). Davis and Liebman (2001) reported that weed growth is suppressed by the use of organic nitrogen sources compared with inorganic nitrogen. Moreover, irrigation using saline water proved to be an effective alternative method to herbicides for controlling several weed species. Zulkaliph et al. (2011) found that *Tridax procumbens* L., *Hedyotis corymbosa* (L.) Lamk and *Borreria latifolia* (Aubl) K. Schum were the most salt-sensitive weed species and were completely killed when the level of external salinity was 24 dSm^{-1}. Four broadleaved weeds [*Ageratum conyzoides* L., *Euphorbia prunifolia* (Jacq), *Desmodium triforum* (L.) DC, and *Lindernia crustacea* F. Muell], and two sedges [*Cyperus iria* L. and *Fimbristylis globulosa* (Retz.) Kunth] were less sensitive at 24 dSm^{-1}, but were severely injured when the level of salinity reached 48 dSm^{-1}. On the other hand, Papiernik et al. (2003) reported that irrigation with saline water had no effect on growth or survival of four weed species. Growth of yellow nutsedge (*Cyperus esculentus* L.) was reduced when the plants were irrigated using saline water. Moreover, Nandula et al. (2006) observed that horseweed (*Conyza canadensis L.*) germination was >20% at <40 mM NaCl concentration and lowest (4%) at 160 mM NaCl. Hassan et al. (2010) also reported that soil saturated with 75 mM NaCl resulted in complete absence of *Striga* emergence. Sorghum treated with 50 mM NaCl in the irrigation water sustained the least *Striga* infestation, which was reduced by 74 and 55% after 45 and 60 days, respectively. *Ceratocarpus arenarius* seeds reached germination rates >20% at high levels of salinity (800 mM) and osmotic potential (−1 MPa), indicating that this species is tolerant to saline conditions and drought stress during germination and early seedling growth (Ebrahimi and Eslami, 2012). Therefore, the objectives of the present study were to examine (a) the effects of organic vs. conventional fertilization practices under normal or saline conditions on weed flora in common bean cultivation and (b) the sensitivity of local weed species to salinity stress under different salt concentrations.

Results and discussion

Weed density and biomass

The most common weed species in both experiments were the broadleaved weeds redroot bigweed (*Amaranthus*

Table 1. Influence of fertilization (Organic fertilization:OF, Inorganic fertlization: IF) and salinity level in the irrigation water (Control, Saline water:SW) on population density of weeds (plants m^{-2}) in a bean crop (50 days after sowing).

2011	OF		IF		LSD_{sal}	LSD_{fert}
	Control	SW	Control	SW		
Amaranthus retroflexus	21.75^{ac}	15.50^{b}	26.5^{a}	16.25^{bc}	3.29	7.25
Chenopodium album	6.5^{bc}	6.25^{bd}	8.5^{ac}	8.25^{ad}	0.49	2.07
Portulaca oleracea	5.5^{b}	5.25^{b}	7.25^{a}	7.5^{a}	0.71	1.38
Echinochloa crus-galli	15.75^{ab}	13.50^{b}	17.75^{a}	14.25^{b}	1.24	3.19
Cynodon dactylon	3.25^{a}	3.5^{a}	3.5^{a}	2.75^{a}	0.62	0.73
Cyperus rotundus	6.5^{a}	7.25^{a}	7.75^{a}	6.50^{a}	1.76	1.57
Total	59.25^{b}	51.25^{c}	71.25^{a}	55.50^{c}	4.58	5.92
2012	**OF**		**IF**		LSD_{sal}	LSD_{fert}
	Control	SW	Control	SW		
Amaranthus retroflexus	15.5^{a}	8.25^{b}	14.5^{a}	7.50^{b}	3.71	1.44
Chenopodium album	4.25^{a}	2.75^{b}	5.5^{a}	4.50^{b}	0.75	2.68
Portulaca oleracea	7.5^{a}	6.25^{ac}	6.75^{a}	5.25^{c}	1.38	1.26
Echinochloa crus-galli	12.25^{a}	8.75^{b}	11.5^{a}	6.50^{b}	1.79	3.56
Cynodon dactylon	3.75^{a}	3.25^{ac}	2.75^{bc}	4.25^{a}	2.41	0.72
Cyperus rotundus	7.75^{a}	6.50^{bd}	6.5^{ad}	5.25^{cb}	0.82	1.45
Total	51.00^{a}	35.75^{b}	47.50^{a}	33.25^{b}	6.41	3.38

The LSD ($P \leq 0.05$) for fertilization and salinity levels are also sown. Means in each row followed by the same letter are not significantly different.

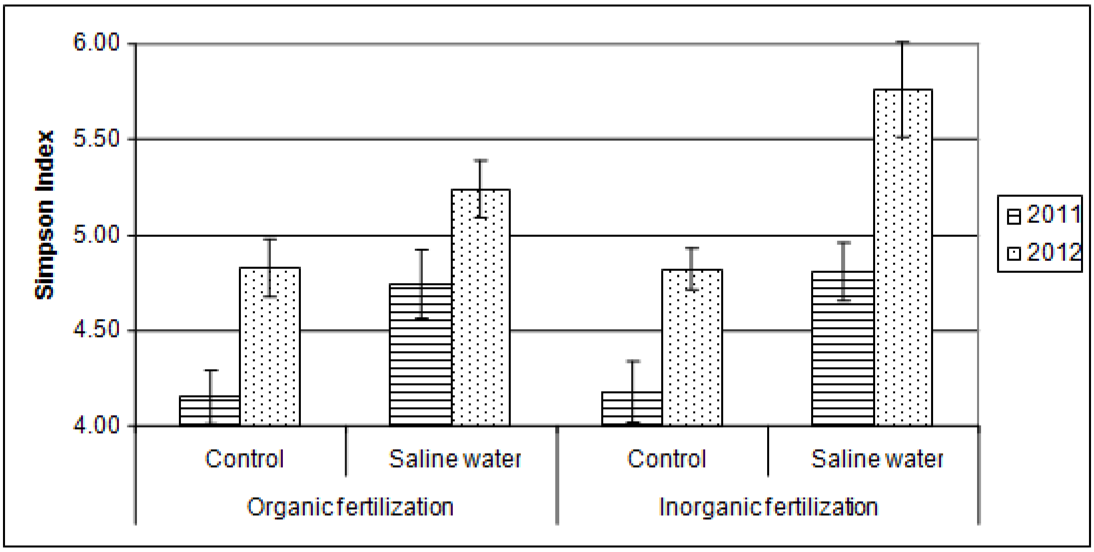

Fig 1. Simpson index of weed populations as influenced by different fertilization and salinity treatments (Mean±SE).

retroflexus L.), common purslane (*Portulaca oleracea* L.), common lambsquarters (*Chenopodium album* L.) and the grass weeds barnyardgrass (*Echinochloa crus-galli* (L.) P. Beauv.), bermudagrass (*Cynodon dactylon* (L.) Pers) and purple nutsedge (*Cyperus rotundus* L.). There were statistically significant differences between saline water treatment and control concerning the total weed density and biomass. The lowest weed density (in 2011: 51.25 plants m^{-2} for organic fertilization and 55.5 plants m^{-2} for inorganic fertilization; and in 2012: 35.75 plants m^{-2} for organic fertilization and 33.25 plants m^{-2} for inorganic fertilization) and biomass were recorded in the saline water treatment (Tables 1 and 2, respectively). Little information is currently available on the salt tolerance of weeds. The interaction of edaphic factors and the occurrence of specific weed species is an area of considerable speculation (Buhler, 2003).

The order of weed sensitivity to salinity was redroot bigweed>bermudagrass>common lambsquarters>barnyard-dgrass>common purslane >purple nutsedge. *Echinochloa crus-galli*, a wide-spread, persistent C_4 weed species of agricultural importance, is reported to tolerate high levels of salinity (Wilson and Read, 2006).Yamamoto et al. (2003) also observed that an increase in proline and changesin polyamines relates to the salt tolerance of *E. crus-galli*. Moreover, Nguyen et al. (2005) reported that *Echinochloa oryzicola* was more salt-tolerant than rice. When exposed to salt stress, *E.oryzicola* had the ability to limit the accumulation of sodium ions (Na^+), maintained high potassium ion (K^+) content and had a constantly higher K^+/Na^+ratio than rice. Kafi and Rahimi (2011) reported that *Portulaca oleracea* has the capacity to maintain growth under salt stress conditions. Bilski and Foy (1988) observed that *Echinochloa crus-galli* was exceptionally tolerant to NaCl, salinity and *Chenopodium album* and *Avena fatua*were moderately tolerant to NaCl. In contrast, *Convolvulus arvensis* and *Amaranthus retroflexus* were very sensitive to NaCl. Moreover, in 2012, weed biomass and density were reduced in comparison to the previous year. The highest weed biomass and density in 2011 may be attributed to precipitation during the experimental period. As shown in Fig. 2, the precipitation in May 2011 (116 mm) was higher than in 2012 (46 mm). Moreover, the highest values

Table 2. Influence of fertilization (Organic fertilization:OF, Inorganic fertlization: IF) and salinity level in the irrigation water (Control, Saline water: SW) on weed dry matter (kg ha^{-1}) in a bean crop (50 days after sowing).

2011	OF		IF		LSD_{sal}	LSD_{fert}
	Control	SW	Control	SW		
Amaranthus retroflexus	276^{b}	157^{c}	350^{a}	155^{c}	56.81	34.21
Chenopodium album	35^{ac}	25^{b}	41^{a}	29^{bc}	3.89	6.78
Portulaca oleracea	46^{b}	41^{b}	58^{a}	52^{a}	6.23	4.17
Echinochloa crus-galli	154^{b}	121^{c}	221^{a}	156^{b}	23.21	21.09
Cynodon dactylon	38^{b}	25^{d}	65^{a}	44^{c}	7.17	12.57
Cyperus rotundus	23^{a}	18^{a}	24^{a}	21^{a}	6.75	3.29
Total	572^{b}	387^{d}	759^{a}	454^{c}	95.34	60.71
2012	OF		IF		LSD_{sal}	LSD_{fert}
	Control	SW	Control	SW		
Amaranthus retroflexus	180^{b}	105^{d}	252^{a}	110^{dc}	76.43	19.78
Chenopodium album	27^{b}	15^{c}	44^{a}	27^{b}	4.23	3.67
Portulaca oleracea	57^{b}	42^{c}	68^{a}	48^{c}	10.12	2.62
Echinochloa crus-galli	120^{b}	86^{d}	148^{a}	98^{c}	21.23	10.21
Cynodon dactylon	44^{a}	27^{b}	45^{a}	31^{b}	6.89	5.68
Cyperus rotundus	28^{a}	24^{ab}	21^{ab}	17^{b}	5.23	8.34
Total	456^{b}	299^{d}	578^{a}	331^{c}	71.86	22.09

The LSD ($P \leq 0.05$) for fertilization and salinity levels are also shown. Means in each row followed by the same letter are not significantly different.

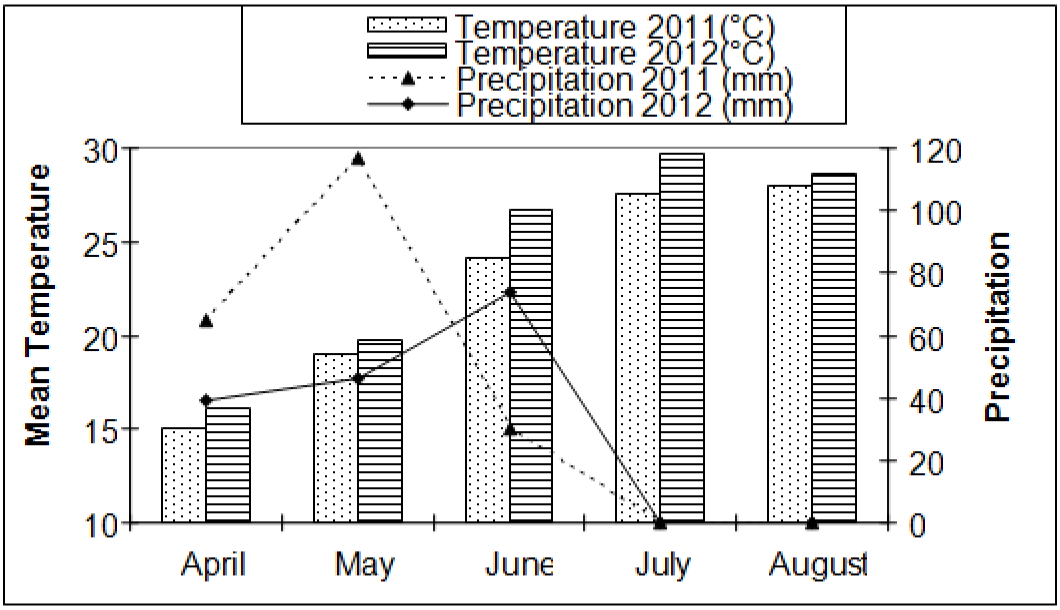

Fig 2. Meteorological data for the experimental site during the experimental periods (April-August, 2011 and 2012).

of Simpson index (Fig. 1) were observed in salinity plots (SW), hence weed flora in SW plots had high species evenness because salinity controlled the redroot bigweed, which had the highest density in control plots. Differences of the fertilizers (organic and inorganic) in nitrogen availability had a large effect on weed growth. Controlled release of nitrogen from organic fertilizers may be a useful practice for managing weeds (Efthimiadou et al., 2012). The highest weed biomass was recorded in the plots treated with inorganic fertilizers. There were no significant differences between organic and inorganic fertilization concerning purple nutsedge biomass. According to Davis and Liebman (2001) weed growth is suppressed by use of organic nitrogen sources compared to treatment with inorganic nitrogen.

Crop yield

Abiotic stresses (i.e. extreme temperatures, low or high pH, high salinity and drought) comprise some of the major factors causing extensive losses to crop production worldwide (dos Reis et al., 2012). Soil salinity is one of the most important factors that influence distribution and productivity of crops. Today, 20% of irrigated arable lands in the world have been reported to be adversely influenced by high soil salinity (Sahi et al., 2006). Seed yield was influenced by both the salinity and fertilization. There were statistically significant differences between saline water treatment and control concerning the seed yield. The lowest yield (Table 3) was found in the salinity treatment (in 2011: 893 kg ha^{-1} for organic fertilization and 785 kg ha^{-1} for inorganic fertilization; and in 2012: 835 kg ha^{-1} for organic fertilization and 741 kg ha^{-1} for inorganic fertilization). Salinity reduces the ability of plants to take up water, and this quickly causes reductions in growth rate, along with a suite of metabolic changes identical to those caused by water stress (Munns, 2002). Bayuelo-Jiménez et al. (2003) reported that salinity had a significant impact on *Phaseolus* growth. There were also significant differences between the organic and inorganic

Table 3. Influence of fertilization (Organic fertilization:OF, Inorganic fertlization: IF) and salinity level in the irrigation water (Control, Saline water: SW) on dry bean yield (kg ha^{-1}).

	OF		IF		LSD_{sal}	LSD_{fert}
	Control	SW	Control	SW		
Yield 2011	1230^{b}	893^{d}	1458^{a}	785^{c}	110.21	96.81
Yield 2012	1118^{a}	835^{b}	1186^{a}	741^{c}	137.76	80.45

The LSD (P≤0.05) for fertilization and salinity levels are also shown. Means in each row followed by the same letter are not significantly different.

fertilization. In salinity plots, the highest dry bean yield was found under the organic fertilization treatment. On contrast, in control plots, the highest seed yield was observed under the inorganic fertilization treatment. Moreover, in 2012, yields were reduced in comparison to the previous year. The main reason for the lowest yield in 2012 may be attributed to the least favourable temperature conditions. As shown in Fig. 2, the temperature in 2012 was always higher than that recorded in 2011.

Materials and Methods

Plant material-Site description

Two field experiments were carried out in western Greece (Agrinio, Lat: 38°35', Long: 21°25') in 2011 and 2012. The experimental site was an organic farm that has been certificated by the Greek certification body DIO since 2003. The characteristics of the soil were as follows: clay loam (24.9% clay, 61.2% silt, and 13.9% sand) with pH 6.7, organic matter 1.45%, EC 0.63 mS cm^{-1}.The soil was prepared according to the local practices for common bean production. The experimental farm was mouldboard plowed to a depth of 20-25 cm followed by two rotary-harrowings. The preceding crop in both experiments was vetch (*Vicia sativa* L. cv. Alexandros). Thus, vetch was sown in all experimental plots in to incorporate the produced biomass to the soil as green manure by the end of winter. Common bean (*Phaseolus vulgaris* L. cv. Contender) was used as test plant. Common bean was sown by hand at a depth of 2 cm. Plant spacing within rows of common bean was50 cm. Common bean was sown on 30 April 2011 and 25 April 2012 at a rate of 70 kg ha^{-1}. Crop emergence began about 10 days after planting. Some meteorological data of the experimental site are presented in Fig. 2.

Experimental design

A two-factorial split-plot experimental design was applied with fertilization practice (organic or inorganic) randomly assigned to eight main plots (four plots per fertilization treatment corresponding to four replications). Each plot was divided into two subplots irrigated either with good-quality (control treatment) or salt-enriched water, which contained either 0.5 or 10 mM NaCl, respectively. The plots treated with inorganic fertilizers (conventional cropping system) were managed with the following practices that are typical in the surrounding area. In particular, a conventional inorganic fertilizer (N: 11%, K_2O: 15%, P_2O_5: 15%) was homogenously dispersed onto the whole plot surface and incorporated to the soil prior to sowing at the rate of 276 kg ha^{-1}. In the organically-treated plots, a compost was applied (N: 1%; P_2O_5: 15%, K_2O: 5%; MgO: 1.65%) following identical incorporation practices as in the conventionally-treated plots, at the rate of 618 kg ha^{-1}. Synthetic pesticides were not used in either of the farming systems. Weeds were removed by hand hoeing, although the local practice is to use mechanical means and chemicals to control weeds. The four replicates were randomly allocated in four blocks; each block had 4 subplots occupying an area of 59.76 m^2. The size of the total experimental area including the gangways between the four main plots was 1225 m^2. The crop was irrigated using a drip irrigation system to apply the two different salinity treatments. The drip irrigation system included: i) a main tank (3 m^3) for irrigation water storage, ii) a tank (0.3 m^3) filled with a stock solution of NaCl (1 M; 17.4 kg NaCl/0.3 m^3), iii) a venturi injector used to automatically mix irrigation water with the stock solution of NaCl in the salinity treatments, iv) a pump, v) two main pipes used to supply irrigation water to the two different salinity treatments and vi) lateral pipes with emitters spaced at intervals of 10 cm along each lateral.

Sampling, measurements and methods

The number and dry weight of the dominant weeds were assessed. A wooden square quadrat (40 ×40 cm) was placed at random three times in each plot. Weeds in the 40 ×40 cm area were counted for each species present, and fresh and dry matter determined. Weed assessments were made at 30 and 60 days after sowing (DAS) as follows:
1. Density of each weed species per area unit (no m^{-2}).
2. Dry weight (g m^{-2}). Weeds were cut and roots discarded. The shoot was inserted in paper bags and placed in an oven at 65 ^{o}C for 72 hours. Dry matter was then determined. After the weed measurements were made, all remaining weeds were destroyed manually. The common bean seed yield was also determined by manually harvesting the plants in the two centre rows of each plot, 100 days after sowing.

Statistical analysis

The data were subjected to statistical analysis according to the split-plot design. Differences between treatment means were compared at *P*=5% by applying ANOVA to asses significance of main effects and interactions between the two experimental factors. The statistical analysis of the data was performed using the STATGRAPHICS Plus 5.1 logistic package. The species diversity of weed groups was characterized using Simpson index (Krebs, 1978; Booth et al., 2003):

$$D = 1/\sum Pi^2$$

Where,
Pi is the fraction of the weed density belonging to the i^{th} species in a given group. This index is increased either by having additional unique species, or by having greater species evenness. The population has a maximum index only when each species in the population is evenly represented. For calculation of this index the software Species Diversity and Richness III (Pisces Conservation Ltd.) was used.

Conclusion

Our results show that the lowest weed density and biomass were recorded in the saline water treatment. Both experiments showed that the order of weed sensitivity to salinity is as redroot bigweed>bermudagrass>common lambsquarters>barnyardgrass>common purslane >purple nutsedge. Barnyardgrass and common purslane are reported to tolerate high levels of salinity. Moreover, the highest values of Simpson index were observed in salinity plots, hence weed flora in these plots had high species evenness because salinity controlled the weed redroot bigweed, which had the highest density. Finally, the highest weed biomass was recorded in the plots treated with inorganic fertilizers. Controlled release of nitrogen from organic fertilizers may be a useful practice for managing weeds.

Acknowledgements

This research was supported by the European Commission through the FP-7 research project LEGUME FUTURES (Legume-supported cropping systems for Europe. Grant agreement no. 245216 CP-FP).

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