Acta Sci. Pol. Hortorum Cultus, 18(1) 2019, 23–38

www.acta.media.pl ISSN 1644-0692 e-ISSN 2545-1405 DOI: 10.24326/asphc.2019.1.3

ORIGINAL PAPER

Accepted: 25.05.2018

EFFECT OF DIFFERENT CROP ROTATIONS ON WEED INFESTATION AND YIELD OF SILAGE MAIZE (*Zea mays* L.) AND MUSKMELON (*Cucumis melo* L.) IN ORGANIC CULTIVATION

Koray Kaçan

Department of Plant and Animal Production, Ortaca Vocational School, Mugla University, Turkey

ABSTRACT

In our study, we investigated how crop rotation of a spinach (*Spinacia oleracea* L.), broccoli (*Brassica oleracea* L. var. *italica*), vetch (*Vicia sativa* L.) and barley (*Hordeum vulgare* L.) mixture and faba bean (*Vicia faba* L.) with maize (*Zea mays* L.) and muskmelon (*Cucumis melo* L.) products affected the weed density and coverage area in organic crop production. The weed coverage areas and densities (weeds m^{-2}) of summer crops produced in rotation with winter crops were compared with those of control plots in the experimental area. As a result of this comparison, the most effective winter crops for reducing weed density in silage maize were found to be broccoli (50.4%), barley + vetch (48.3%) and faba bean (45.3%). When the effect of winter crops on weeds in terms of muskmelon production was examined, barley + vetch (53.2%), broccoli (36.1%) and faba bean (33.4%) were found to reduce the density of weeds. In contrast, the application of barley + vetch (67.0%), faba bean (65.3) and broccoli (62.0%) was the most effective applications for the muskmelon product in terms of weed coverage area; spinach (24.7%) and constantly weedless (16.8%) applications were less effective. When the silage maize and muskmelon yield results were examined, it was determined that yield differences were statistically significant. It was also determined that the highest yield was obtained from the barley + vetch rotations. This application effectiveness was followed by that of the faba bean, constantly weedless, broccoli and spinach applications.

Key words: organic farming, rotation, weed management, weed density, coverage, yield

Novelty statement. Recently, non-chemical applications have been considered for weed control due to growing concerns about herbicide resistance and chemical residues in the environment. Moreover, organic crop systems are gradually developing. One of the options for weed control in organic farming is crop rotation. In this study, we found that crop rotations controlled weeds effectively in organic farming.

INTRODUCTION

Pesticide residues damage the soil flora and fauna that play an important role in the soil. They also pass from soil to crops and from there to humans and animals, causing harmful effects within the food chain. Pesticides enter the groundwater and through evaporation, mix with the atmosphere, causing populations of fish, birds and many other organisms to deteriorate by adversely affecting their reproductive abilities [Kortekamp 2011]. It is known that 0.015−6% of the pesticides used in agriculture reach the target organisms and that the remaining 94.0–99.9% mix with the ecosystem [Yıldız et al. 2005]. Inorganic pesticides in particular, have high persistence properties in the environment. As the use of pesticides increases, it is

✉ koraykacan@gmail.com

also inevitable that environmental and human health problems will also increase, as pesticides (along with heavy metal pollution in the soil and water) contribute to acute and chronic environmental toxicity [Kortekamp 2011]. All these adverse effects have accelerated the search for alternative agricultural production systems. One alternative production system that has been identified is organic agriculture. Organic agriculture includes human and environmentally friendly production systems aimed at restoring the natural balance that is lost after the misapplication of pesticides in the ecological system. It has been determined that organic products contain higher net protein, vitamin C, antioxidants and nitrogen than traditionally produced products [Petr et al. 2004, Langenkämper et al. 2006, Kapoulas et al. 2011].

Like in traditional production, weed management composes the highest production cost in organic production. In addition to many other forms of damage, the most important damage by weeds is a decrease of crop growth in agricultural areas. Weeds are considered the largest problem in organic vegetable farming systems [Reddiex et al. 2001, Peruzzi et al. 2004, Uygur and Lanini 2006, Peruzzi et al. 2007].

Weeds are responsible for 5, 10, and 25% losses in agriculture in the most developed, less developed, and least developed countries, respectively. Farmers in industrialized countries spend more money for weed control than for pest control [Akobundu 1987]. Despite all the control measures taken by farmers worldwide, weeds are responsible for a 13% loss in agricultural production. If no action is taken to control weeds, these losses will increase to 30% [Oerke et al. 1994]. Therefore, weed management is vital, as crop yield losses caused by weeds (approximately 32%) are higher than those caused by pests (18%) or pathogens (15%) [Oerke and Dehne 2004]. Similarly, weeds are responsible for an average yield loss of 34% to major crops that are grown worldwide, which is higher than that caused by pests [Khawar et. al. 2015].

In Turkey, the average yield loss is known to vary from 10–50% depending on weed species and density [Tepe 1998], and this loss is even larger in vegetable cultivation.

Also, with the use of established applications in organic weed control, cultivators' crop loss due to weeds will be eliminated and the continuity of Turkey's valuable natural diversity will be ensured. Workforce losses in agricultural production will also be removed by mulch and other applications determined to be effective. The identified practices will be at a level that will put organic and integrated weed management guidelines, leading to sustainable agricultural potential in our vegetable production [Kaçan and Boz 2014].

This study was carried out to investigate the effects of winter crops of spinach, broccoli, faba bean and vetch + barley, which have been added to crop rotations as a way to control weeds in organic agriculture, on the density and coverage areas of weeds in plots of organic maize and muskmelon grown in summer in order to determine the most suitable rotation for vegetable production in terms of sustainable agriculture.

MATERIAL AND METHODS

Experimental material

This study was carried out in the organic experiment area (Turkey) (38°36'36"N, 27°6'10"E) between 2012–2016. The study comprised hydropriming broccoli (*Brassica oleracea* L. var. *italica*) seeds of the AG 3317 variety, faba beans (*Vicia faba* L.) of the Sevilla variety, spinach (*Spinacia oleracea* L.) of the Matador variety, common vetch (*Vicia sativa* L.) of the Kubilay-82 variety and barley (*Hordeum vulgare* L.) of the Akhisar-98 variety.

Akhisar-98 is a barley variety registered by the Aegean Agricultural Research Institute, with a yield of 5000–6000 kg·ha^{-1}. It is recommended for the whole Aegean region and for growing in the mild winters of the coastal belt.

Kubilay-82 is a disease-resistant variety of vetch (*Vicia sativa* L.) that is registered by the Aegean Agricultural Research Institute. The dry grass yield of this variety is 8,000–10,000 kg ha^{-1}. It is recommended for winter sowing in coastal areas, and summer sowing in other areas.

Matador is a cold-resistant variety of vetch (*Spinacia oleracea* L.). It is a variety preferred by growers. The plant structure is with dark green colour, medium vertical, large leaf, bubble, short stem, long oval to rounded leaf shape. It is a durable variety to transport for long distances and remains intact.

The faba bean variety is produced by the Aegean Agricultural Research Institute and has a yield of 20–25 tons ha^{-1}, and the number of grains is 8–10 in pod.

This variety is appropriate for fresh consumption. It is suitable for planting in all regions.

Kırkağaç-637 is a variety of muskmelon (*Cucumis melo* L.), which is a summer crop. This variety is registered by the Aegean Agricultural Research Institute. The plant structure is strong, highly branched, with abundant leaves, long oval fruit. The fruit is dark green on dark yellow, rough surface, with whitish inner parts. The fruit is approximately 3 kg in weight, and the skin is 1–1.5 cm thick. The harvest period is approximately 80–90 days.

Silage maize (*Zea mays* L.) is another summer crop. Ada-9510 is a maize variety that has been developed by the Sakarya Agricultural Research Institute. It is a mid-tier hybrid recommended for the Aegean region, with a silage yield of 80–90 tons ha^{-1}.

Climate and soil

Typical Mediterranean climate of the experiment persists, where the effects of climate are seen. The data are summarized in Table 1 [TURKMETSER 2016]. As seen in Table 1, 2012–2016. The precipitation points in the growing years are significantly different between long years average. In terms of temperature, the mean temperatures of the growing season in the experimental area were almost the same over the long year average.

Table 1. Some meteorological parameters in experimental area, Menemen (2012−2016)

Months	Temperature (°C)		Total precipitation (mm)	
	2012–2016	LYA	2012–2016	LYA
December	11.7	10.3	144.8	123.2
January	9.4	7.9	108.8	89.1
February	11.6	8.8	119.6	71.9
March	11.7	11.0	20.2	62.6
April	15.7	15.0	31.0	42.1
May	20.6	20.0	23.4	25.1
June	24.2	24.7	4.6	5.7
July	33.7	28.2	2.2	1.7
August	32.5	27.6	3.2	2.9
September	25.3	23.6	16.4	13.7
October	19.8	18.7	56.3	43.8
November	14.4	14.0	95.6	93.1

LYA – long year average

Table 2. Chemical and physical characteristics of the soil in the experiment field (0–30 cm soil layer)

Evaluated characters	Values	Evaluated characters	Values
pH (1 mol KCL dm^{-3})	7.42	K (mg kg^{-1})	493.3
Salt (dS/m^{-1})	0.12	Ca (mg kg^{-1})	6400
Lime (%)	8.21	Mg (mg kg^{-1})	483.3
Organic matter (%)	1.20	Fe (mg kg^{-1})	5.68
N (%)	0.10	Cu (mg kg^{-1})	2.92
P (mg kg^{-1})	2.31	Zn (mg kg^{-1})	0.68
Soil type	Clay-loamy	Mn (mg kg^{-1})	6.36

Amount of precipitation in the experiment were nearly 17–66% higher level than long years average in December, January and February. However, the precipitation amount of during the growing season was lower by 23–67% (Tab. 1).

Weather-related parameters for this area were as follows: average annual rainfall, 626 mm; average annual temperature, 19.2°C; average temperature in the coldest month, 9.4°C; average temperature in the warmest month, 33.7°C (Tab. 1).

The physicochemical characteristics of the soil samples are given in Table 2. The soil analyzed showed that the experimental field was slightly alkaline, had a low salt content, was abundant in limestone, had a low amount of organic matter, and was in a clayey-tinned area (Tab. 2).

Experimental methods

The experiments were carried out according to the complete randomized block design with four repetitions, with 4 × 5 m plots. Weed coverage data were estimated by visual observation using the percentage of surface infested by weeds, but can also be estimated by processing digital images taken from the field. Total weed count and coverage data were recorded 28 and 58 days after sowing each year. In silage maize, the weed determinations were made when they were 28–30 cm high with 5–6 leaves with open flag leaf sheath. On the other hand, the measurements were carried out at 6–8 leaves during the flowering period for muskmelon.

The experiment area was prepared by hoeing and passing disc harrow in the autumn. The applications included in the experiment were spinach, broccoli, barley + vetch and faba bean as the winter crops, and maize and muskmelon as the summer crops. Every year in the autumn, vetch (30 kg ha^{-1}) + barley (40 kg ha^{-1}) and faba bean (200 kg ha^{-1}) were sown in September. Faba bean seeds were also sown at the spacing of 45 × 10 cm.

The spinach seeds were sown at a planting distance of 10 × 30 cm in September. Broccoli seeds were sown in August for seedlings. In September, the broccoli seedlings were transferred to the fields, while they were in the four-leaf period.

A mixture of vetch and barley seeds were sown at 100 kg·ha^{-1} (80% vetch + 20% barley) seeds at a distance of 20 cm between rows.

Broccoli was sown in the planting distance of 60 × 70 cm. Starting from the time when the plants were germinated, weed control was carried out by hand hoeing in the meantime, they were singled. The weed control was performed three times between the rows until the plants harvest.

In weedless plots, which are left continuously without weeds, the weeds were continuously removed four times by hand hoeing during the growing season.

Muskmelon seeds and maize seeds were sown at planting distances of 140 × 80 cm and 70 × 15 cm, respectively, in May. Composting applications were made to plots before and after sowing-planting, not to exceed 17 kg N ha^{-1} per year.

In all the plots in the experiment area, the density and coverage areas of weeds were determined by randomly throwing a 0.5 × 0.5 m frame 2 times at each plot. Irrigation was carried out when the amount of water in the root zone of plants approached lower than half of the field capacity using a soil tensiometer to determine the irrigation times of the plots.

Statistical analysis

The data collected during four years of experiment were analyzed statistically by Fisher's analysis of ANOVA technique [Steel et al. 1997]. A least significant difference (Duncan) test was used to compare the differences among treatment means at $P < 0.005$ probability. The years' effect on weed population and the interactive effects of crop rotations were also determined. In addition, years have been evaluated separately.

RESULTS

Effect of winter crops on weed infestation in organic maize plots

Effects on weed coverage area in organic maize plots. When the results obtained from the crop rotation in the 4-year experiment in our study were examined, it was determined that the weed coverage areas of winter products were statistically significant, when statistically compared with the average weed coverage areas of all years in silage organic maize production (Tab. 3). When the average of four-year rotation experiments was compared with the control plots, in terms of weed coverage area, barley-maize crop rotation (22.1%), faba bean-maize (27.8%) and broccoli-

Table 3. Effects of winter crops on weed density and weed coverage in organic maize (2013–2016)

Treatments	Mean of years	
	weed density (weeds m^{-2})	weed coverage (%)
Barley + vetch	168.7 (b)	22.0 (b)
Faba bean	197.9 (b)	27.8 (b)
Broccoli	179.7 (b)	30.3 (b)
Weedless	460.8 (a)	38.6 (b)
Spinach	342.3 (a)	44.7 (ab)
Control	362.0 (a)	62.8 (a)
Duncan (p = 0.05)	<0.014	<0.001

Different letters between applications denote significant differences (Duncan test, $p < 0.05$)

Table 4. Effects of winter crops on weed density and weed coverage in organic maize among years

Years	Year means	
	weed density (weeds m^{-2})	weed coverage (%)
2016	342.4 (ab)	21.3 (b)
2013	398.0 (a)	25.8 (b)
2015	184.7 (c)	30.3 (b)
2014	253.6 (bc)	54.9 (a)
Duncan (p = 0.05)	<0.04	0.014

Different letters between years denote significant differences (Duncan test, $p < 0.05$)

maize rotation (30.3%) were the most effective applications in the silage maize experiment plots. However, spinach application caused the highest weed coverage rate (44.7%) in the following maize planting compared to other winter crops (Tab. 3).

When the weed coverage formed by the winter crops included in maize plots was examined in terms of differences among years, it was determined that the highest coverage area (62.8%) was shown in 2014, where the differences in weed coverage area among years were significant. It was also determined that differences among recurrence and summer practices in terms of weed coverage area were statistically insignificant at the 5% level. As a result of statistical analysis, it was determined that barley + vetch was effective at 64.9%, faba bean at 55.7%, broccoli at 51.8% and weedless plots at 38.5% when compared with control plots, in terms of weed coverage area in summer crops after winter applications (Tab. 3).

Table 5. Mean values of weed species density in organic maize plots over four years

Weeds	Winter crops and applications					
	barley + vetch (plants m^{-2})	faba bean (plants m^{-2})	broccoli (plants m^{-2})	weedless (plants m^{-2})	spinach (plants m^{-2})	control (plants m^{-2})
Alhagi pseudalhagi (Bıeb.) Desv.	16	31	22	18	46	0
Anthemis aciphylla Boiss.	0	2	0	21	0	4
Amaranthus albus L.	14	22	2	78	73	46
Amaranthus hybridus L.	76	30	112	64	100	0
Amaranthus retroflexus L.	12	26	4	27	16	23
Capsella bursa-pastoris (L.) Medik.	12	3	10	16	16	30
Carduus nutans L.	0	0	2	0	0	2
Chenepodium album L.	0	20	0	36	5	6
Chrozophora tinctoria (L.) Rafin.	0	0	0	6	8	5
Convolvulus arvensis L.	0	0	0	10	0	0
Cyperus rodunrus L.	0	0	0	14	0	16
Fumaria officinalis L.	4	6	4	6	16	3
Heliotropium europaeum L.	0	3	0	0	6	3
Hordeum murinum L.	2	4	0	0	4	0
Lamium purpureum L.	0	6	0	8	0	12
Malva sylvestris L.	0	4	0	0	6	27
Matricaria chamomilla L.	6	8	0	5	8	5
Papaver rhoeas L.	0	0	0	0	0	4
Poa annua L.	0	4	4	0	5	0
Portulaca oleracea L.	6	0	0	0	0	0
Rumex crispus L.	0	0	0	2	2	0
Solanum nigrum L.	12	10	6	4	8	5
Sonchus oleraceus L.	4	2.5	10	10	6	6
Sorghum halepense (L.) Pers.	0	0	6	3	4	4
Stellaria media (L.) Vill.	0	11	0	120	12	184
Veronica hederifolia L	0	2	0	0	8	2
Tribulus terrestris L.	3	0	2	2	0	0
Urtica urens L.	26	8	0	4	2	72

Effects on weed density in organic maize plots. When the weed densities in maize plots formed by the winter crops included in the rotation were examined, they were found statistically significant (Sig; <0.014). When the averages of all years were compared with those of the control plots, it was determined that the minimum weed density was found after the application of barley + vetch (168.7 weeds m^{-2}). This was followed by weed density after broccoli (179.7 weeds m^{-2}) and faba bean (197.9 weeds m^{-2}) plantings, respectively. Spinach (342.3 weeds m^{-2}) and constantly weedless (460.8 weeds m^{-2}) plots were determined to show higher weed density than the control plots (362.0 weeds m^{-2}). In the field of experiment, the weedless plots in organic maize had the most dense weed populations. For this reason, it is considered to be controlled by continuous hoeing of weeds in the winter season. Thus, the weed seeds under the ground were removed to the soil surface by hoeing and the seeds were encouraged to germinate. As a result, the density of annual weed populations had increased (Tab. 3).

When the averages for the control plots for all years were compared to determine those of the applications most effective at reducing the weed density, the best results were obtained by the broccoli application (49.2%). This was followed by barley + vetch (48.3%), faba bean (43.7%) and spinach (2.0%) applications, respectively. Maximum weed infestation was determined in the plots that were kept weedless. The applications of broccoli and barley + vetch reduced the weed density in the control plots by half (Tab. 3).

When the weed densities of summer products formed by the winter crops included in the rotation were examined in terms of differences among years, the differences were statistically significant. It was determined that the highest weed density (398.0 weeds m^{-2}) was found in 2013. It was also determined that differences among recurrence and summer practices in terms of weed coverage area were statistically insignificant at a 5% level. Interaction among winter crops and years was found to be significant (Sig; 0.014) (Tab. 4).

We examined the results of the crop rotation over four years and determined the weed species found in organic maize plots (Tab. 5). In this four-year study, we identified the species and density of weeds in organic maize (Tab. 4). The most intensive perennial weed in all plots was camel thorn (*Alhagi pseudalhagi* (Bieb.) Desv.). In the spinach plots, the perennial weeds were approximately 1.1–3 times higher than the other weeds. Purple nutsedge (*Cyperus rotundus* L.) reached the most intensive growth in control plots, while Johnson grass (*Sorghum halepense* (L.) Pers.) was the most intensive in broccoli plots. Other important perennial weed was bindweed (*Convolvulus arvensis* L.), which was identified as the most dense in weedless plots.

Winter weeds had the highest density in control plots (324.3 weed m^{-2}), followed by weedless (200.1 weeds m^{-2}), spinach (77.0 weeds m^{-2}), faba bean (56.5 weeds m^{-2}), barley + vetch (54.3 weeds m^{-2}), and broccoli (30.2 weeds m^{-2}). In terms of the distribution of summer weed species, spinach plots (274.0 weeds m^{-2}) had the highest density, followed by weedless (254.0 weeds m^{-2}), control (168.64 weeds m^{-2}), broccoli (154.0 weeds m^{-2}) faba bean (146.0 weeds m^{-2}), and barley + vetch (139.0 weeds m^{-2}) plots.

Smooth pigweed (*Amaranthus hybridus* L.) is a dicot weed belonging to the *Amaranthaceae* family. In many countries, this weed has been found to be resistant to groups (B/2 (ALS inhibitors), G/9 (EPSP synthase inhibitors), Q4 (Synthetic Auxins), C1/5 (Photosystem II inhibitors) , C3/6 (PSII inhibitors)) in many crops [HRAC 2018]. Meanwhile, smooth pigweed is an invasive weed species [USDA 2018]. It has the ability to germinate without need to be dormant, and it is highly competitive, due to which it can reach very high densities. A single, vigorous *A. hybridus* plant may produce as many as 100,000 fruits with one seed per fruit. Seeds of this weed are dispersed by wind, by animals after ingestion, and as contaminants of crop seeds or farm machinery. In California, *Amaranthus retroflexus*, grown in rows 25 cm apart with 13 cm between plants, produced an average of 34,600 seeds per plant in fertilized field plots and 13,860 seeds per plant in unfertilized plots. Germination of the three species is under phytochrome control and is stimulated by light and/or high temperatures [Weaver and McWilliams 1980].

Effect of winter crops on weed infestation in organic muskmelon plots

Effects on weed coverage area in organic muskmelon plots. In our study, we investigated the weed coverage area of winter crop rotations, which can be used in the experimental production of organic muskmelons. After examining the results obtained, it was determined that the relationships of weed coverage areas in summer crops plots to the crops planted in winter rotations were statistically significant, when the average weed coverage areas for organic muskmelon production over all years were compared. When the averages of four-year rotation experiments were compared with the control plots, it was determined that barley and vetch (20.8%) was the most effective application for organic muskmelon plots in terms of weed coverage area. This was followed by faba bean (21.8%), broccoli (23.8%), spinach (47.3%), and constantly weedless applications (52.3%) respectively (Tab. 6).

It was determined that differences among recurrence and summer practices in terms of weed coverage area were statistically insignificant at a 5% level. As a result of statistical analysis, it was determined that barley + vetch reduced the weed coverage area by 66.9%, faba bean by 65.3%, broccoli by 62.0%, spinach by 24.7%, and weedless plots by 16.8%, when compared with control plots in terms of weed coverage area for summer crops after winter applications (Tab. 6).

It was determined that the highest weed coverage area (53.5%) was found in 2014 and the lowest weed coverage area (28.9%) was found in 2016, where differences in weed coverage area among years were significant (Tab. 7).

Effects on weed density in organic muskmelon plots. When weed density was examined for muskmelon plots produced by a rotation of winter products included in a four-year average, it was found to be statistically significant (Sig; <0.001). When the averages of all years for treatments were compared with those of the control plots, it was determined that the minimum weed density was found after the application of barley + vetch (134.7 weeds m^{-2}). This was followed by broccoli (229.1 weeds m^{-2}) and faba bean (236.5 weeds m^{-2}). Spinach (551.3 weeds m^{-2}) and constantly weedless (726.6 weeds m^{-2}) plots were determined to have higher weed density than control plots (496.9 weeds m^{-2}) (Tab. 6).

Table 6. Effects of winter crops on weed density and weed coverage in organic muskmelons (means from 2013–2016)

Treatments	Years means	
	weed density (weeds m^{-2})	weed coverage (%)
Barley + vetch	134.7 (c)	20.8 (c)
Faba bean	236.5 (bc)	21.8 (c)
Broccoli	229.1 (bc)	23.8 (c)
Weedless	726.6 (a)	52.3 (ab)
Spinach	551.3 (a)	47.3 (b)
Control	496.9 (ab)	62.8 (a)
Duncan (p = 0.05)	<0.001	<0.001

Different letters between applications denote significant differences (Duncan test, $p < 0.05$)

Table 7. Effects of winter crops on weed density and weeds among years in organic muskmelon plots

Years	Years means	
	weed density (weeds m^{-2})	weed coverage (%)
2016	714.7 (a)	28.9 (b)
2013	513.1 (b)	37.5 (b)
2015	164.2 (c)	32.5 (b)
2014	209.7 (bc)	53.5 (a)
Duncan (p = 0.05)	<0.001	<0.001

Different letters between years denote significant differences (Duncan test, $p < 0.05$)

Table 8. Mean values of weed species densities over four years of organic muskmelon plots (means from 2013–2016)

Weeds	Winter crops and applications					
	barley + vetch (weeds m^{-2})	faba bean (weeds m^{-2})	broccoli (weeds m^{-2})	weedless (weeds m^{-2})	spinach (weeds m^{-2})	control (weeds m^{-2})
Avena sativa L.	0	0	0	7	0	4.75
Alhagi pseudalhagi (Bıeb.) Desv.	6.5	6	22	8	46	10.25
Anthemis aciphylla Boiss.	0	7.5	0	33	13.33	8
Amaranthus albus L.	2	8	8	26	73	38.75
Amaranthus hybridus L.	22	46	86	100	28	42.33
Amaranthus retroflexus L.	0	26.33	3.5	102	16	4.5
Bromus tectorum L.	5.33	4.5	10	8.25	8.25	42.86
Capsella bursa-pastoris (L.) Medik.	6.5	16.33	12	48	3	4
Carduus nutans L.	0	0	0	0	14	4.5
Chenepodium album L.	8.25	4.5	0	36	6.75	6
Chrozophora tinctoria (L.) Rafin.	2	0	0	0	7.33	4
Convolvulus arvensis L.	9.33	0	0	4	18	12
Cyperus rotundus L.	4	2.5	4	26	4	3
Daucus carota L.	0	0	0	6	0	8.25
Echinochloa crus-galli (L.) P. Beauv.	2.33	3.33	0	12	6.25	0
Fumaria officinalis L.	2.5	0	0	6	14.33	3
Geranium molle L.	0	0	0	7	0	4.33
Heliotropium europaeum L.	0	4.33	0	0	24	13
Hordeum murinum L.	3.5	0	0	32	5.33	10
Lactuca serriola L.	0	0	0	24	0	
Lamium purpureum L.	0	0	0	5	5	3.5
Malva sylvestris L.	0	3.5	0	8.5	12	22
Matricaria chamomilla L.	6.25	12	4	32	0	
Papaver rhoeas L.	4	3.5	0	6	8.5	4
Phalaris sp.	0	0	0	12	8.33	0
Poa annua L.	6	6	6	6	6.75	18
Polygonum aviculare L.	4.33	8	7.55	26	8.5	16.5
Portulaca oleracea L.	6	16.5	6	24	6	16
Raphanus raphanistrum L.	0	0	0	21	0	0
Rumex crispus L.	0	2.5	0	6	9.33	2.5
Silybum marianum (L.) Gaertner	0	0	0	0	3.33	0
Sinapis arvensis L.	2	3	3	0	12.55	3
Solanum nigrum L.	0	2.5	4.33	6	4	2.5
Sonchus oleraceus L.	0	0	2.33	10	11.5	0
Sorghum halepense (L.) Pers.	0	0	0	6.33	12	0
Stellaria media (L.) Vill.	12.5	21	14.33	12	8.75	21.5
Veronica hederifolia L.	0	7.33	0	8.75	6.33	7.33
Tribulus terrestris L.	2.33	4	2.5	6.33	32	13
Urtica urens L.	13.5	12.5	16	18	36	12.5

Weeds with a density below 2 were not taken into account

When compared with control plots, barley + vetch applications reduced the weed density by 52.4%, broccoli by 35.3%, and faba bean by 32.6%. Considering the application differences among years, the highest density of weeds emerged in 2016 (714.7 weeds m^{-2}), whereas the lowest density was obtained in 2015 (164.2 weeds m^{-2}) (Tab. 7).

We identified the weed species in organic muskmelon plots following the crop rotation of the four-year experiment (Tab. 8).

Table 9. Effects of winter crops on yield of organic maize

Treatments	Maize yield	
	yield per plant (g $plant^{-1}$)	yield (kg ha^{-1})
Barley + vetch	901.9 (c)	40420.7 (c)
Broccoli	753.1 (b)	34387.3 (b)
Faba bean	818.0 (bc)	39817.8 (c)
Spinach	782.5 (b)	37904.4 (bc)
Weedless	802.2 (b)	38039.0 (bc)
Control	540.9 (a)	27140.1 (a)
Duncan ($p = 0.05$)	0.000	0.000

Different letters between applications denote significant differences (Duncan test, $p < 0.05$)

Table 10. Effects of winter crops on organic maize yield averages among years

Years	Year means	
	yield of per plant (g $plant^{-1}$)	Yield (kg ha^{-1})
2016	785.3 (a)	31516.8 (b)
2013	772.2 (a)	39715.6 (a)
2015	722.0 (c)	33476.6 (b)
2014	786.2 (a)	40430.5 (a)
Duncan ($p = 0.05$)	<0.294	<0.000

Different letters between years denote significant differences (Duncan test, $p < 0.05$)

Weed species in organic muskmelon plots were identified (Tab. 5). Green amaranth (*A. hybridus*) weeds grew with the highest density in organic muskmelon plots (324.3 weeds m^{-2}), followed by pigweed amaranth (*Amaranthus albus*) (155.7 weeds m^{-2}), redroot amaranth (*A. retroflexus*) (152.3 weeds m^{-2}). Perennial weeds were found to be about 2–5 times higher in the spinach plots than in all other plots, followed by weedless, control, broccoli, barley + vetch, and faba bean plots. Faba bean plots had the lowest density of perennial weeds.

Johnson grass (*S. halepense*), bindweed (*C. arvensis*), musk thistle (*Carduus nutans* L.), and camel thorn (*A. pseudalhagi* (Bieb.) Desv.) were important perennial weeds present in organic muskmelon. They were present at the highest density in spinach plots. Purple nutsedge (*C. rotundus*) was another perennial weed that had the highest density in the weedless plots.

Winter weeds were distributed with the highest density in weedless plots (294.71 weeds m^{-2}), followed by spinach (174.63 weeds m^{-2}), control (129.34 weeds m^{-2}), faba bean (80.13 weeds m^{-2}), barley + vetch (61.36 weeds m^{-2}), and broccoli (57.34 weeds m^{-2}). Summer weeds were distributed with the highest density in the spinach plots (375.78 weeds m^{-2}), followed by the control (232.94 weeds m^{-2}), weedless (211.13 weeds m^{-2}), broccoli (151.84 weeds m^{-2}), faba bean (139.98 weeds m^{-2}), and barley + vetch (69.66 weeds m^{-2}) applications.

Maize yield

Maize green plant yields were examined in two steps including the yield per hectare and the yield per plant. As a result of statistical analysis, it was determined that maize green plant yield differences produced by winter crops per hectare and per plant were significant at a 5% level. When the yields of the winter crops per hectare in the experiment were examined, it was seen that barley + vetch (40,420.7 kg ha^{-1}) and faba bean (39,817.8 kg ha^{-1}) applications were the highest-yielding applications. This was followed by the weedless (38,039.0 kg ha^{-1}), spinach (37,904.4 kg ha^{-1}), and broccoli (34,387.3 kg ha^{-1}) applications, respectively. Whereas the control and broccoli applications were in separate statistical groups, other applications ranged through the same statistical group. When compared with the control application, the barley + vetch application increased maize green plant yield at a rate of 48.9% per hectare, while faba bean application increased maize green plant yield at a rate of 46.7% per hectare. The effects on yield increase for other applications varied between 26–40% (Tab. 9).

When maize green plant yield per plant of winter crops was examined, it was determined that the application of barley + vetch (901.9 g $plant^{-1}$) led to the highest yield. This was followed by the faba bean (818.0 g $plant^{-1}$), weedless (802.2 g $plant^{-1}$), spinach (782.5 g $plant^{-1}$), and broccoli (753.1 g $plant^{-1}$) applications, respectively. When compared with the control plot, barley + vetch application increased the yield of green plant per plant at a rate of 66.7%. Other applications increased the yield between 39% and 51%.

In the statistical analysis of maize yield differences among years, it was determined that the yield differences among years were important. The highest maize green plant yield increase among years was recorded in 2014 (40,430.5 kg ha^{-1}), whereas the lowest maize green plant yield was recorded in 2016 (Tab. 10).

Muskmelon yield

In our study, the effects for organic muskmelon cultivation of different rotations of winter crops on the yield of muskmelon per hectare were examined. As a result of statistical analysis, it was determined that differences produced by winter crops on the yield of muskmelon were significant at the 5% level (Tab. 11). When the yields of winter crops per hectare in the experiment were examined, it was seen that barley + vetch (44399.7 kg ha^{-1}) plots were the highest-yielding applications. This was followed by the faba bean (43,136.2 kg ha^{-1}), constantly weedless (40,735.7 kg ha^{-1}), broccoli (39,039.3 kg ha^{-1}), and spinach (34,917.7 kg ha^{-1}) applications, respectively. Whereas barley + vetch, faba bean and constantly weedless applications were in the same statistical group, other applications ranged across separate statistical groups. When compared with the control application, barley + vetch application increased the yield of muskmelon at a rate of 57.3%. The effects on yield increase for other applications varied between 23.7–52.8%.

When muskmelon yield per plant for winter crops was examined, it was determined that the faba bean application (2270.4 g $plant^{-1}$) had the highest yield. This was followed by broccoli (2115.7 g $plant^{-1}$), constantly weedless (2049.0 g $plant^{-1}$), barley + vetch

(1997.3 g plant^{-1}), and spinach (1510.1 g plant^{-1}) applications, respectively. When compared with the control plot, faba bean application increased the yield of melon per plant at a rate of 85.6%. Other applications increased the yield between 63.3% and 72.9% g plant^{-1}. When compared with the control plot, spinach plots increased the yield by only 23.4%. In the statistical analysis of muskmelon yield differences among years, it was determined that the yield differences among years were important.

The highest muskmelon yield increase among years was recorded in 2014 (42,123.7 kg ha^{-1}), whereas the lowest muskmelon yield was recorded in 2016 (Tab. 12).

Table 11. Effects of winter crops on yield of organic muskmelon

Treatments	Muskmelon yield	
	yield per plant (g plant^{-1})	yield (kg ha^{-1})
Barley + vetch	1997.3 (b)	44,399.7 (d)
Broccoli	2115.7 (b)	39,039.3 (c)
Faba bean	2270.4 (b)	43,136.2 (cd)
Spinach	1510.1 (a)	34,917.7 (b)
Weedless	2049.0 (b)	40,735.7 (cd)
Control	1223.5 (a)	28,229.6 (a)
Duncan (p = 0.05)	0.000	0.000

Different letters between applications denote significant differences (Duncan test, $p < 0.05$)

Table 12. Effects of winter crops on organic muskmelon yield averages among years

Years	Year means	
	yield of per plant (g plant^{-1})	yield (kg ha^{-1})
2016	811.4 (d)	31,516.8 (b)
2013	2067.1 (b)	45,123.7 (a)
2015	1607.7 (c)	34,474.6 (b)
2014	2957.8 (a)	42,123.7 (a)
Duncan (p = 0.05)	<0.000	<0.000

Different letters between years denote significant differences (Duncan test, $p < 0.05$)

DISCUSSION

The first principle for weed management is to keep the weed populations below the economic loss threshold in the production season. Estimation of the weed population dynamics should guide the determination of the control methods to be selected so that products with different life cycles can change the interaction of weed-product positively when they are included in a rotation. It was determined that the weed density was lower for 19 of 25 products included in the rotation, depending on the product, when compared to an area where the same crop was continuously planted. Different planting and harvesting times in rotation provide opportunities for agricultural applications to prevent the reproduction and maturation of weed seeds. In the maize and sunflower rotation, drooping brome (*Bromus tectorum* L.) usually showed up in early spring or autumn, and opportunities to prevent its maturation occurred before planting crops such as maize or sunflower. As a result, a decrease of 20% in the seeds of drooping brome was observed in the first year [Roberts 1981]. In a similar study, after two full rice-maize rotation cycles, *Striga asiatica* seed numbers in the soil (0–10 cm) were lower than conventional farmer practice [Randrianjafizanaka et al. 2018].

It was determined that the density of drooping brome per m^{-2} in the canola and wheat (50 plants m^{-2}) products included in rotation in a 6-year study performed in Canada was reduced by 93% compared to the density in a field, where wheat was planted continuously (740 plants m^{-2}) [Blackshaw 1994]. In a similar study in the United States, it was noted that the density of drooping brome (*B. tectorum*) and jointed goatgrass (*Aegilops cylindrica* Host.) in a sunflower and maize rotation following winter wheat, decreased significantly [Daugovish et al. 1999].

Considering the products examined in our study and to be included in rotation, which is an important element in the struggle with weeds in an organic production system, it is known that the density and biomass of weed populations are reduced as a result of the inclusion of legume products [Anderson 2010)], lentils [Gruber et al. 2012], vegetables cropping systems [Jernigan et al. 2017] and maize-soy-wheat rotation [Schweizer and Zimdahl 1984, Gonzalez et al. 2011, Simic et al. 2016] to feed crops. However, rotation between grain products is known to reduce herbicide use [Schoofs et al. 2005], prevents weed infestation, and guarantees higher product yield in conventional cultivation [Lapinsh et al. 2008]. At the same time, it was determined that the rotation requirement in the fields with herbicide tolerance was sustainable in weed control [Reddy et al. 2006].

As a result of the experiment, it was determined that different crop rotations had significant effect on weed suppression and product yield. In this study, it was determined that the known allelopathic effect of barley in the winter barley + vetch mixed cultivation was both effective [Liu and Lovett 1993, Lovett and Hoult 1995, Zoheir et al. 2007] and the most effective application for reducing the weed coverage area and density of weed compared to all other applications. Similarly, the application of allelopathic broccoli [Zeng et al. 2008, Bilen et al. 2012, Aksoy et al. 2016] also controlled the weed population in a manner comparable to previous studies [Finney et al. 2009, Bajgai et al. 2013]. Although the application of winter spinach seemed to suppress the weed populations compared to the control weeds in the following crops, it remained at a very low level compared to other applications.

The highest yield was obtained from the application of barley + vetch according to the yield results for maize and muskmelon per hectare. This was followed by faba bean and constantly weedless wintery practices. Faba bean as previous crop, determined the highest performance in terms of crops yield [Gresta et al. 2016, Madsen et al. 2016]. Whereas winter broccoli planting had a significant effect on weed density and coverage area, this ratio was not reflected by the yield in the same way. Spinach-planted plots emerged as the least efficient application in terms of yield of subsequent crops. Considering the yield per plant in organic silage maize and muskmelon cultivation in our study, the effectiveness of winter faba bean application followed the application of vetch + barley and broccoli in terms of weed density and coverage area, and positively affected an increase in yield per plant, as in other studies [Song et al. 2007, Jensen et al. 2010, Shahzad et al. 2016]. The reason for this is that it is one of the most effective legume crops for fertilization through increasing the soil nitrogen fixation in the rotation. Additionally, it was shown that significant increase in yields can be achieved by fallowing the exhausted soils and agricultural areas subjected to intensive farming.

Alternative to these production systems include environmentally friendly applications. The systems aim also at restoring the natural balance. In addition, these systems provide products abundant in quality vitamins and proteins [Petr et al. 2004, Langenkämper et al. 2006, Kapoulas et al. 2011].

This study was carried out to investigate the effects of winter crops of spinach, broccoli, faba bean, and vetch + barley, which have been added to crop rotations as a way to control weeds in organic agriculture, on the density and coverage areas of weeds in the summer crops of organic maize and muskmelon, to determine the most suitable rotation for vegetable production in terms of sustainable agriculture.

CONCLUSIONS

The effects of weed density on the coverage area and yield of summer crops of organic maize and muskmelon, grown after the inclusion of winter crops in rotation, were investigated in this study. Winter barley + vetch, broccoli and faba bean and rotations controlled the weed populations and apart from broccoli, barley + vetch and faba bean increased the yield of organic maize and muskmelon at a higher rate compared to other applications. In addition, it was determined that barley + vetch, broccoli and faba bean applications may also be recommended in organic crop rotations. These identified practices will help determine organic and integrated weed management guidelines, leading to sustainable agricultural potential in vegetable production.

REFERENCES

Akobundu. I.O. (1987). Weed science in the tropics: principles and practices. Wiley, Chichester, 522 pp.

Aksoy, E., Arslan, Z. F., Tetik, O., Eymirli, S. (2016). Using the possibilities of some trap, catch and Brassicaceaen crops for controlling crenate broomrape a problem in lentil fields. Int. J. Plant Prod., 10(1), 53–62.

Anderson, R.L. (2010). A rotation design to reduce weed density in organic farming. Renew. Agric. Food Syst., 25(3), 189–195.

Bajgai, Y., Kristiansen, P., Hulugalle, N., McHenry, M. (2013). Comparison of organic and conventional managements on yields, nutrients and weeds in a corn cabbage rotation. Renew. Agric. Food Syst., 30, 132–142. http://dx.doi.org/10.1017/S1742170513000264 [date of access: 12.09.2017].

Bilen, E., Nazik, C.A., Unal, M., Bteich, M.R., Bitar, A.L., Aksoy, U. (2012). Economic performance of pre-crops in a three-year rotation program for organic vegetable production. Acta Hortic., 933, 321–327.

Blackshaw, R. E. (1994). Rotation affects downy brome (*Bromus tectorum*) in winter wheat (*Triticum aestivum*). Weed Technol., 8, 728–732.

Daugovish, O., Lyon, D.J., Baltensperger. D.D. (1999). Cropping systems to control winter annual grasses in winter wheat (*Triticum aestivum*). Weed Technol., 13, 120–126.

Finney, D.M., Creamer, N.G., Schultheis, J.R., Wagger, M.G., Brownie, C. (2009). Sorghum sudangrass as a summer cover and hay crop for organic fall cabbage production. Renew. Agric. Food Syst., 24, 225–233.

Gonzalez-Díaz, L., Van Den Berg, F., Van Den Bosch, F., González-Andújar, J.L., Arévalo, J.R., Fernández, S., López, F., Recasens., J., Sobrino, E. (2011). Crop rotation synchronization at landscape level as a weed management strategy in cereals. Plantas invasoras resistencias a herbicidas y detección de malas hierbas. XIII Congreso de la Sociedad Española de Malherbología, November 2011, La Laguna, 22–24.

Gresta, F., Santonocetoa, C., Avola, G. (2016). Crop rotation as an effective strategy for saffron (*Crocus sativus* L.). Sci. Hortic., 211, 34–39.

Gruber, S., Wahl, E., Zikeli, S., Claupein, W. (2012). Perspectives and limitations of weed control in organic lentils (*Lens culinaris*). J. Kul.pflanzen, 64(10), 365–377.

HRAC (2018). International survey of herbicide resistant weeds. Available: http://weedscience.org/Details/Case.aspx?ResistID=5099 [date of accses: 17.05.2018].

Jernigan, A.B., Caldwell, B.A., Cordeau S., DiTommaso, A. (2017). Weed abundance and community composition following a long-term organic vegetable cropping systems experiment. Weed Sci., 65, 639–649. Available: https://doi.org/10.1017/wsc.2017.33 [date of access: 12.05.2018].

Jensen, E.S., Peoples, M.B., Nielsen, H.H. (2010). Faba bean in cropping systems. Field Crops Res., 115, 203–216.

Kaçan, K., Boz, Ö. (2014). Investigation of alternative weed management methods in organic vineyards of the Aegean region. Turk. J. Agric. Nat. Sci., Special Issue, 2, 1369–1373.

Kapoulas, N., Ilić, Z.S., Đurovka, M., Trajković, Z., Milenković, L. (2011). Effect of organic and conventional production practices on nutritional value and antioxidant activity of tomatoes. Afr. J. Biotechnol., 10(71), 15938–15945.

Khawar, J., Mahajan, G., Sardana, V., Chauhan, B.S. (2015). Allelopathy for weed control in agricultural systems. Crop Prot., 72, 57–65.

Kortekamp, A. (2011). Herbicides and Environment. InTech, Rijeka. Available: https://library.umac.mo/ebooks/b28109740.pdf. [date of access: 10.10.2017].

Langenkämper, G., Zörb, C., Seifert, M., Mäder, P., Fretzdorff, B., Betsche, T. (2006). Nutritional quality of organic and conventional wheat. J. Appl. Bot. Food Quality, 80, 150–154.

Lapinsh, D., Korolova, M., Berzinsh, A. (2008). Crop rotation influence on the weed incidence in cereals. Zemdirbyste (Agriculture), 95(3), 433–439.

Lovett, J.V., Hoult, H.C. (1995). Allelopathy and self-defense in barley. In: Allelopathy: organisms, processes and applications, Inderjit, K.M.M., Dakshini, Einhellig, F.A. (eds.). ACS Symposium Series 582, 170-183. American Chemical Society, Washington, DC.

Madsen, H., Talgrea, L., Eremeeva, V., Alarua, M., Kauera, K., Luikb, A. (2016). Do green manures as winter cover crops impact the weediness and crop yield in an organic crop rotation? Biol. Agric. Hortic., 32(3), 182–191. http://dx.doi.org/10.1080/01448765.2016.1138141 [date of access: 12.05.2018].

Oerke, E.C., Weber, A., Dehne, H.W., Schönbeck, F. (1994). Conclusions and perspectives. In: Crop production and crop protection. Estimated losses in major food and cash crops, Oerke, E.C., Dehne, H.W., Schönbeck, F., Weber, A. (eds.). Elsevier, Amsterdam, 742–770.

Oerke, E.C., Dehne, H.W. (2004). Safeguarding production losses in major crops and the role of crop protection. Crop Prot., 23, 275–285.

Peruzzi, A., Ginanni, M., Raffaelli, M., Borelli., M. (2004). Physical weed control in organic spinach production. Proceedings of the 6th EWRS Workshop on Physical and Cultural Weed Control 8–10 March 2004, Lillehammer, Norway, 5–25.

Peruzzi, A., Ginanni, M., Fontanelli, M., Raffaelli, M., Barberi, P. (2007). Innovative strategies for on-farm weed management in organic carrot. Renew. Agric. Food Syst., 22(4), 246–259.

Petr, J., Kodeš, A., Stehlíková, K., Hubert, D., Svobodová, P. (2004). Feeding quality of wheat from conventional and ecological farming. Sci. Agric. Boh., 35(2), 74–78.

Randrianjafizanaka, M.T., Autfrayb, P., Andrianaivoc, A.P., Ramontaa, I.R., Rodenburg, J. (2018). Combined effects of cover crops, mulch, zero-tillage and resistant varietieson *Striga asiatica* (L.) Kuntze in rice-maize rotation systems. Agric. Ecosyst. Environ., 256, 23–33.

Reddiex, S.J., Wratten, S.D., Hill, G.D., Bourdot, G.W., Frampton, C.M. (2001). Evaluation of mechanical weed management techniques on weed and crop populations. New Zeal. Plant Prot., 54, 174–178

Reddy, K.N., Locke, M.A., Koger, C.H., Zablotowicz, R.M., Krutz, L.J. (2006). Cotton and corn rotation under reduced tillage management: impacts on soil properties, weed control, yield, and net return. Weed Sci., 54(4), 768–774.

Roberts, H.A. (1981). Seed banks in soils. Adv. Appl. Biol., 6, 1–55.

Shahzad, M., Farooq, M., Khawar, J., Mubsbar, H. (2016). Impact of different crop rotations and tillage systems on weed infestation and productivity of bread wheat. Crop Prot., 89, 161–169.

Schoofs, A., Entz, M.H., van Acker, R.C., Martens, J.R.T., Derksen, D.A. (2005). Agronomic performance of pesticide free production under two crop rotations. Renew. Agric. Food Syst., 20(2), 91–100.

Simić, M., Spasojević, I., Kovacević, D., Brankov, M. Dragicević, V. (2016). Crop rotation influence on annual and perennial weed control and maize productivity. Rom. Agric. Res., 33, 125–132.

Song, Y.N, Zhang, F.S., Marschner, P., Fan, F.L., Gao, H.M., Bao, X.G., Sun, J.H., Li, L. (2007). Effect of intercropping on crop yield and chemical and microbiological properties in rhizosphere of wheat (*Triticum aestivum* L.), maize (*Zea mays* L.), and faba bean (*Vicia faba* L.). Biol. Fertil. Soils, 43(5), 565–574.

Steel, R.G.D., Torrie, J.H., Dickey, D.A. (1997). Principles and procedures of statistics. A biometrical approach. Third ed. McGraw Hill Book Co., New York.

Schweizer, E.E., Zimdahl, R.L. (1984). Weed seed decline in irrigated soil after rotation of crops and herbicides. Weed Sci., 32, 84–89.

Tepe, I. (1998). The problems and challenges weeds agriculture and non-agricultural areas in Turkey. Yüzüncü Yıl University Publications No. 32, 237 p. Van.

TURKMETSER (2016). Turkish State Meteorological Service, Menemen Regional Meteorological Station, Menemen, Izmir.

USDA (2018). United States Department of Agriculture, Natural Resources Conservation Service, Introduced, invasive, and noxious plants, Introduced Plants of the Plants Floristic Area. Available: https://plants.usda.gov/java/introduced?startChar=A [date of access:17.05.2018].

Uygur, F.N., Lanini, W.T. (2006). Weed control methods and side effects in organic agriculture. Turkey 3rd Organic Agriculture Symposium 1–4 November 2006, Yalova. Program and abstracts, 173–184.

Weaver, S.E., McWilliams, E.L. (1980). The biology of Canadian weeds *Amaranthus retroflexus* L., *A. powellii* S. Wats. and *A. hybridus* L. Can. J. Plant Sci., 60, 1215–1234.

Yıldız, M., Gürkan, O., Turgut, C., Kaya, Ü., Ünal, G. (2005). Environmental problems caused by pesticides used in agriculture. Turkey Agricultural Engineering Technical Congress, Chamber of Agriculture, Chamber of Engineers, 6, 3–7.

Zeng, R.S., Luo, S.M., Mallik, A.U. (2008). Allelopathy in sustainable agriculture and forestry. Springer, New York. DOI: https://doi.org/10.1007/978-0-387-77337-7.

Zoheir, Y.A., Sadeghi, S., Mashhadi, H.R. (2007). Allelopathic effect of barley (*Hordeum vulgare)*on germination and growth of wild barley (*H. spontaneum*). Pak. J. Weed Sci. Res., 13(1–2), 99–112. Available: http://www.cabi.org/gara/FullTextPDF/2008/20083050754.pdf. [date of access: 10.01.2017].